Friends of Semiahmoo Bay Society

Marine Conservation Initiative

Boundary Bay Intertidal Forage Fish Spawning Habitat Project

Summary of the Project and Findings
July 2006 – October 2007

Funding Provided by:
Vancity EnviroFund & Vancouver Foundation

Prepared for: Friends of Semiahmoo Bay Society
Prepared by: Ramona C. de Graaf, BSc., MSc.,
Emerald Sea Research & Consulting

Table of Contents

Friends of Semiahmoo Bay Society (FoSBS)

FoSBS is a transboundary, project-focused stewardship group working to conserve marine, estuarine and watershed ecosystems in the lower Fraser River Delta and Boundary Bay. Project partners include non-profit groups, First Nations, business, schools and government agencies to share resources to achieve common conservation and educational goals. For further information visit: www.birdsonthebay.ca

Margaret Cuthbert, volunteer Executive Director and past President of FoSBS first became enthused about forage fish and their importance after attending one of Dan Penttila's presentations in 2000.

Acknowledgements

Project Partners and Support

Funding for the Boundary Bay Intertidal Forage Fish Spawning Habitat Project was provided by: Vancouver Foundation and VanCity EnviroFund.

Washington Department of Fish and Wildlife (WDFW), Biologist Dan Penttila has provided training expertise and lab verification of spawned eggs. Dan has worked with the WDFW for 32 years as a fish biologist. He first discovered Pacific sand lance spawning depositions in Puget Sound and has led the research and inventory of surf smelt and sand lance spawning habitats in Washington State. Mr. Penttila has authored numerous papers and coauthored the protocol used for monitoring forage fish habitat. A special thank you to Dan for his dedication to protecting forage fish, valuable workshop instruction, ongoing training and advice to our field leaders and crews.

University of British Columbia, Dr. EB Taylor provided equipment and lab facilities for training interns, processing spawn-bearing sediments and equipment for public workshops.

Fisheries and Oceans Canada, Dr. Tom Therriault provided advice and the authority to proceed with this project.

Community Mapping Network, Brad Mason, Habitat Inventory Biologist, Fisheries and Oceans Canada, and Suzanne Richer provided resources, valuable advice and insight on the CSIM Methodology and expertise for managing the GIS database and the Georgia Basin Habitat Atlas: Boundary Bay.

Emerald Sea Research and Consulting, Ramona C. de Graaf, BSc, MSc, marine biologist, provided training support and field expertise in conducting both the habitat assessment and spawning surveys. A special thank you to Ramona for her crucial contribution to the project and forage fish conservation in Boundary Bay. This report was written by and all photographs taken by Ramona C. de Graaf.

Thank you to the amazing volunteers for their support and valuable contribution: Interns from the University of British Columbia, Wen-Ling Liao, Gigi Lau, Riley Sziklai, Tom Ying, Kelvin, Jimmy, and Yvette Tstete and FoSBS volunteers, Catriona Day, Esther Johnson, Eileen Kaarsemaker, Jennifer Pollard, David Riley, Michelle Scott, Jane Weiss and others.

SECTION ONE:

Background to the Project

Forage fish species are small, schooling fishes (herring, sand lance, surf smelt and capelin) that are important prey for fish (eg. salmon, rockfish, and lingcod), marine mammals (including the endangered humpback whale), and seabirds (eg. Marbled Murrelets, puffins, auklets and others). In turn, forage fish predators like salmon, ling cod and rockfish become prey for larger animals such as seals, sea lions, killer whales and form commercial fisheries important to the economic sustainability of coastal communities. From their eggs, larvae to adults, forage fish fuel our coastal marine food chain and may be important to the recovery of local salmon runs. Thirty five percent of the diet of juvenile salmon and 60% of the diet of Chinook are comprised of Pacific sand lance (*Ammodytes hexapterus)*. Surf smelt (*Hypomesus pretiosus)* make up an important part of the diet of our provincially listed coastal cutthroat trout and bull trout .

Throughout the Strait of Georgia, fish stocks have dramatically declined. Lingcod, rockfish and some Pacific salmon species are only some of the major commercial fish species in decline. Seabird populations throughout British Columbia and Washington State are also decreasing. As well, marine species such as the southern resident killer whale, dependent on salmon runs, have been listed as endangered. Many of these species depend on bait or "forage" fishes as prey. Spawning habitat of forage fishes is located in nearshore marine environments, an environment heavily impacted by human development and recreation.

Documenting and protecting forage fish spawning habitats is a priority for the Friends of Semiahmoo Bay Society. In Boundary Bay, there is little information on the current extent and health of the spawning habitats of herring and no information on the spawning habitat of surf smelt and Pacific sand lance. Surf smelt and sand lance spawn in gravel/sand beach habitats in the upper one third of the intertidal zone (Figure 1). Current spawning habitats of surf smelt and sand lance have been documented throughout the US coasts of the Juan de Fuca Strait, San Juan Islands, and Puget Sound (Penttila 2000, 2001). In Canada, eelgrass beds are protected as critical fish habitat under Fisheries and Oceans Canada "no-net" loss policy (Federal *Fisheries Act).* Protecting forage fish spawning and rearing habitats will have positive benefits by protecting a vital food source for numerous marine predators. Fisheries and Oceans Canada recognizes the need to obtain information on the habitat requirements of forage fishes in Boundary Bay.

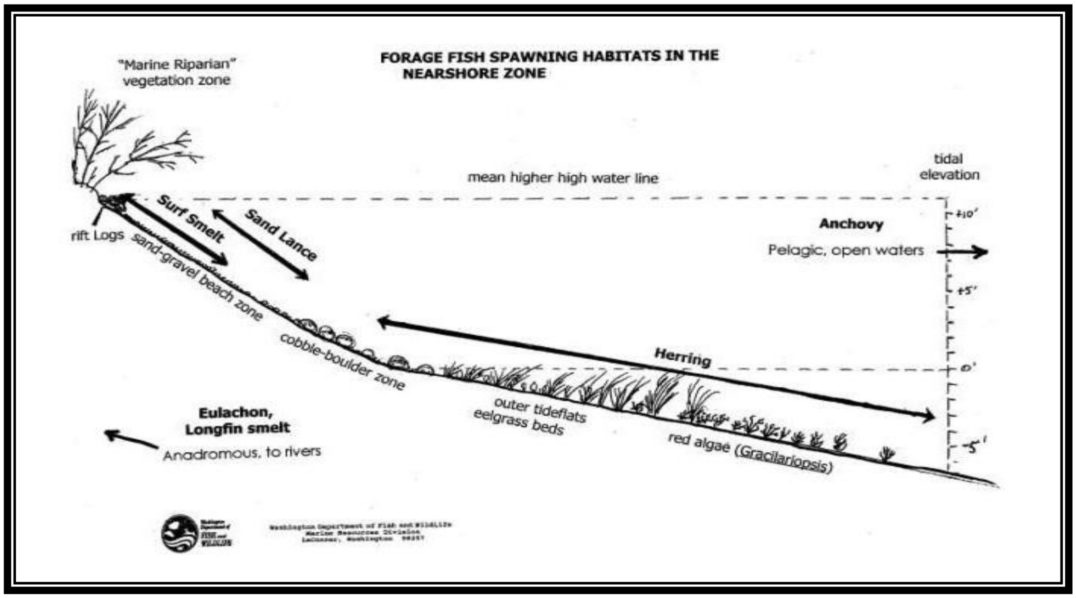


Figure 1: Forage Fish intertidal and subtidal spawning zones (sketch D. Penttila)

Boundary Bay is part of the Fraser River estuary and the Strait of Georgia (Figure 2). It is designated a Site of Hemispheric Importance on the Pacific Flyway for migrating shorebirds, is the top rated Important Bird Area in Canada of 597 designated sites by Birdlife International and is a BC Wildlife Management Area. Important marine habitats found in Boundary Bay include eelgrass beds, sand/mud flats, gravel beaches and five large estuaries. Historically, surf smelt spawned along the shores of White Rock (Hart and McHugh 1944) and were abundant year round in the southern Strait of Georgia (including White Rock) (Therriault *et al* 2002). From 1886 to approximately 1956, significant commercial fisheries for surf smelt were located in White Rock and other areas of the Lower Mainland (Levy 1985, Therriault *et al* 2002). Recreational smelt fisheries continue throughout areas of the Lower Mainland (Therriault *et al* 2002). Over the last 100 years, however, the backshore and intertidal regions throughout Boundary Bay and the Lower Mainland have been extensively modified. Shoreline modifications can negatively impact the nearshore marine food web in numerous ways, but this report will focus on the effects of such modification on the spawning habitat of surf smelt and Pacific sand lance. Shoreline modification is the primary threat to surf smelt and sand lance spawning beaches (Penttila 2005).

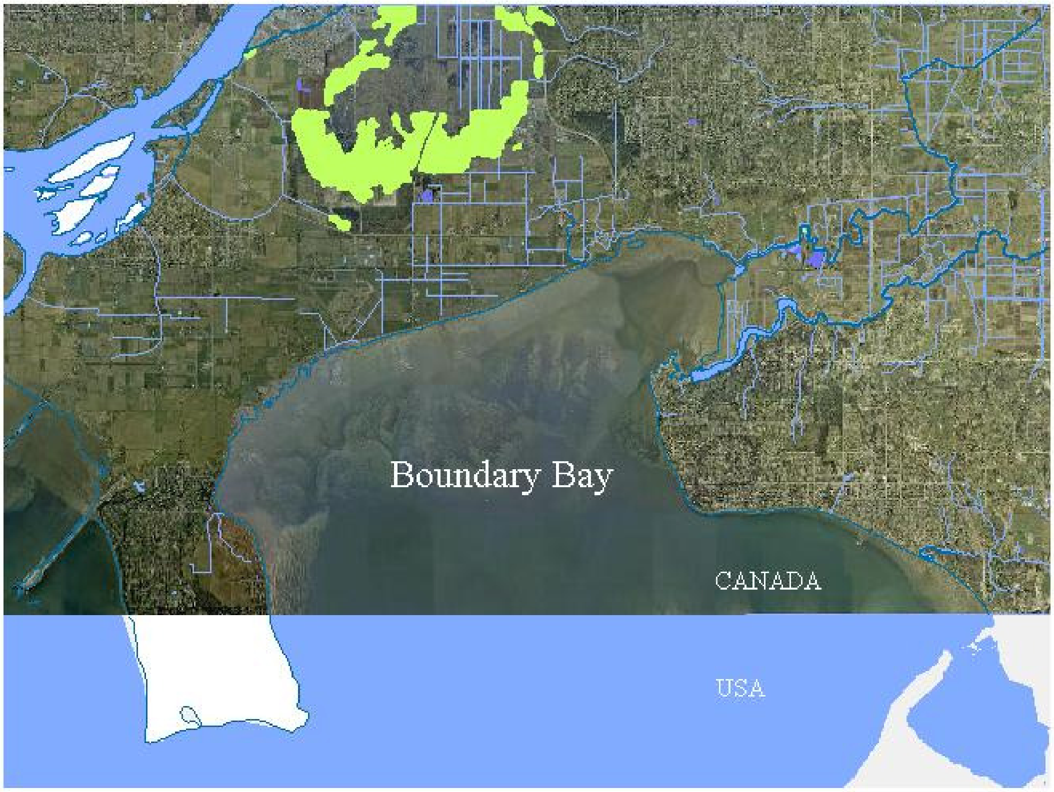


Figure 2: Map of Boundary Bay. Source: Georgia Basin Habitat Atlas: Boundary Bay Website: www.georgiabasin.net

Diversion of sediment-bearing streams through culverts, and the backshore and intertidal placement of railway beds, seawalls, outfall pipes and riprap armouring interrupt natural coastal processes (such as erosion) that supply terrestrially-borne gravel sediments to beaches crucial to spawning surf smelt and Pacific sand lance. Seawalls and railway beds are physical barriers that block the seaward transport of eroding gravels from feeder bluffs. Impediment of the long-shore transport of sediments by groins, outflow pipes, piers, boat ramps and docks have all contributed to the sediment-starved state of some Boundary Bay beach faces.

In general, the placement of seawalls and riprap armouring in the backshore and in the intertidal continues the process of sediment deprivation due to the action of wave scouring. Wave scouring can result in the loss of fine sands and gravels (appropriate for spawning) and the dominance of coarser (larger) gravels and cobble beaches inappropriate for use as spawning gravels for both surf smelt and Pacific sand lance. Seawalls are often placed in the backshore, supralittoral and high intertidal zones (the uppermost portion of the high tide range) which can result in the loss of spawning habitat area, a decrease in beach elevation, an increase in beach slope, interruption of the sediment-transport drift cell, and the loss of sediment retaining logs. Not only are these "hard" approaches to storm protection negatively impacting forage fish populations, but they can fail to deliver the protection intended. Around the world and locally, there are growing incidences of seawalls and other armouring failing to protect land owners.

Modern engineering approaches, or "soft" approaches work with coastal processes to provide safety for human populations and industries as well as maintaining marine ecological functions. While this report will not address this topic in detail, several informative websites and consultants include www.greenshores.ca, www.coastalgeo.com, www.herrarainc.ca and www.sanjuans.org.

The presence of overhanging vegetation in marine riparian zones is important for the ecological function of nearshore marine habitats (Levings and Jamieson 2001; Brennan and Culverwell 2004) including having a positive effect on surf smelt spawn survival (Penttila 2001). The loss of overhanging vegetation (due to shoreline hardening measures) in the marine riparian zone has several ecological implications not only for marine fish and invertebrates, but the loss of shade cover increases the mortality of incubating surf smelt eggs (Penttila 2001, Rice 2006). Summer beach sediment temperatures are moderated by overhanging vegetation.

Surf smelt eggs are typically anchored to surface gravels but are also buried between interstitial spaces within sediments layers (Penttila 2001). Surf smelt eggs deposited in summer months likely encounter high mortalities on the surface but eggs buried deeper in spawning substrates can avoid extreme surface temperatures and drying resulting in an increased survival rate (Penttila 2001). The loss of shading, however, increases thermal stress and desiccation to incubating eggs as temperatures within the sediments rise resulting in increased mortality of even buried eggs (Penttila 2001, Rice 2006). Vegetation buffers the drying effect of winds, and where beaches have lost riparian zones, eggs can also suffer a higher mortality than "natural" due to wind-induced desiccation effects.

This loss of spawning habitat and negative impacts to existing spawning habitat is evident not only in Boundary Bay but also throughout the Fraser River Estuary and Burrard Inlet including Tsawwassen, Roberts and Sturgeon Banks, areas of Wreck Beach, English Bay, Burrard Inlet, West Vancouver and Howe Sound (personal observation). While it is unknown how many unique genetic populations of surf smelt are found from Puget Sound to Howe Sound, it is likely that the dramatic loss of spawning habitat throughout the area has reduced population sizes of both surf smelt and the Pacific sand lance.

A reduced prey base has likely played a role in the reduction of populations of animals that forage on these crucial 'bait fishes". Forage fish expert and Washington Department of Fish and Wildlife fish biologist, Dan Penttila has pioneered methods to research and inventory surf smelt and Pacific sand lance spawning habitats throughout Washington. Upon inspecting the backshore and intertidal zone of White Rock in 2005, Mr. Penttila commented that,

> "shoreline development and the railway causeway have probably impacted the species' uppermost intertidal sand-gravel spawning beaches very heavily, which would make it all the more important to preserve what's left by any regulatory or non-regulatory means possible. Justification could be drawn from the rationale for no-net-loss spawning habitat preservation measures used in US waters for these species, whose ecological value to the food chain is recognized along with its harvest value." (D. Penttila, pers. comm. 2005)

In Washington State, sand lance, surf smelt and other forage fish species such as anchovy are protected due to their importance to upper trophic levels of the food chain to support commercial fisheries (such as salmon, rockfish, ling god) and for ecosystem function (as advocated in WDFW principles of ecosystem management).

In general, surf smelt and Pacific sand lance depend on healthy nearshore and beach habitat, and they are vulnerable to impacts from shoreline development. Beaches with natural erosion processes supplying appropriate sized gravels and extant riparian zones are an optimal state for spawning surf smelt and sand lance. Winter spawning stocks of surf smelt may avoid desiccation stress and may have evolved to exploit beaches lacking overhanging vegetation (D. Penttila, pers. comm. 2007). Of primary importance for spawning is the mixture of gravels with a sand base. Cobbling beaches for heavy equipment operation, bulkheads, seawalls, outflow pipes and structures impeding sediment-transport drift cells are threats to maintaining these crucial spawning beaches.

With Mr. Penttila's assistance and training, Friends of Semiahmoo Bay Society undertook a pilot study to assess and inventory Boundary Bay beaches for spawning of these crucial forage fish species. The content of this report summarizes the data acquired from July 2006 to June 2007 (with mention of spawning results to September 07).

Protocol Development

Using the protocols and training provided by Mr. D. Penttila, WDFW, identification of potential spawning habitat in Boundary Bay was conducted using two methods. The first entailed field surveys of beach areas to find appropriate gravels at the correct tide height. Secondly, some areas, such as Mud Bay, were assessed using shoreline inventory data and photographs available on the Georgia Basin Habitat Atlas: Boundary Bay from a 2004 Coastal Shoreline Inventory Mapping (CSIM) inventory conducted by M. Pepin for Friends of Semiahmoo Bay Society (FoSBS).

While information on the spawning times of both surf smelt and sand lance in British Columbia is sparse, information on spawning times and spawning locations of BC Pacific sand lance were obtained from Blaseckie *et al* (2002), Thuringer (2003), and US spawning information from Penttila (2000). Information on surf smelt spawning populations, spawning times and location were obtained from McHugh and Hart (1944), Levy (1985), Morgan and Levings (1989), Blaseckie *et al* (2002), McPhail, JD (pers. comm.. 2005), Levings, CD (pers. comm. 2007), Williams, J (pers. comm. 2007), and US spawning information from Penttila (2000, 2001) and Friends of the San Juans (2004).

Sampling beaches for spawning activity was concentrated on Boundary Bay beach areas that:

a. had appropriate gravels and were contiguous with beaches identified as spawning habitat by WDFW in the US (Tsawwassen Beach, Delta shores and Peace Arch border beaches);
b. following identification during a beach survey, had appropriate gravels; and
c. were in areas historically described as surf smelt spawning habitat (White Rock).

The beach areas sampled were: Tsawwassen Beach, Tsawwassen; Centennial Park (Boundary Bay Regional Park) and "Delta Shores", Delta; Crescent Beach and Blackie Spit, Surrey; Semiahmoo Bay, White Rock; Little Campbell River Estuary, Semiahmoo First Nation; and Peace Arch Park, Surrey (Figures 3, 4, and 5).

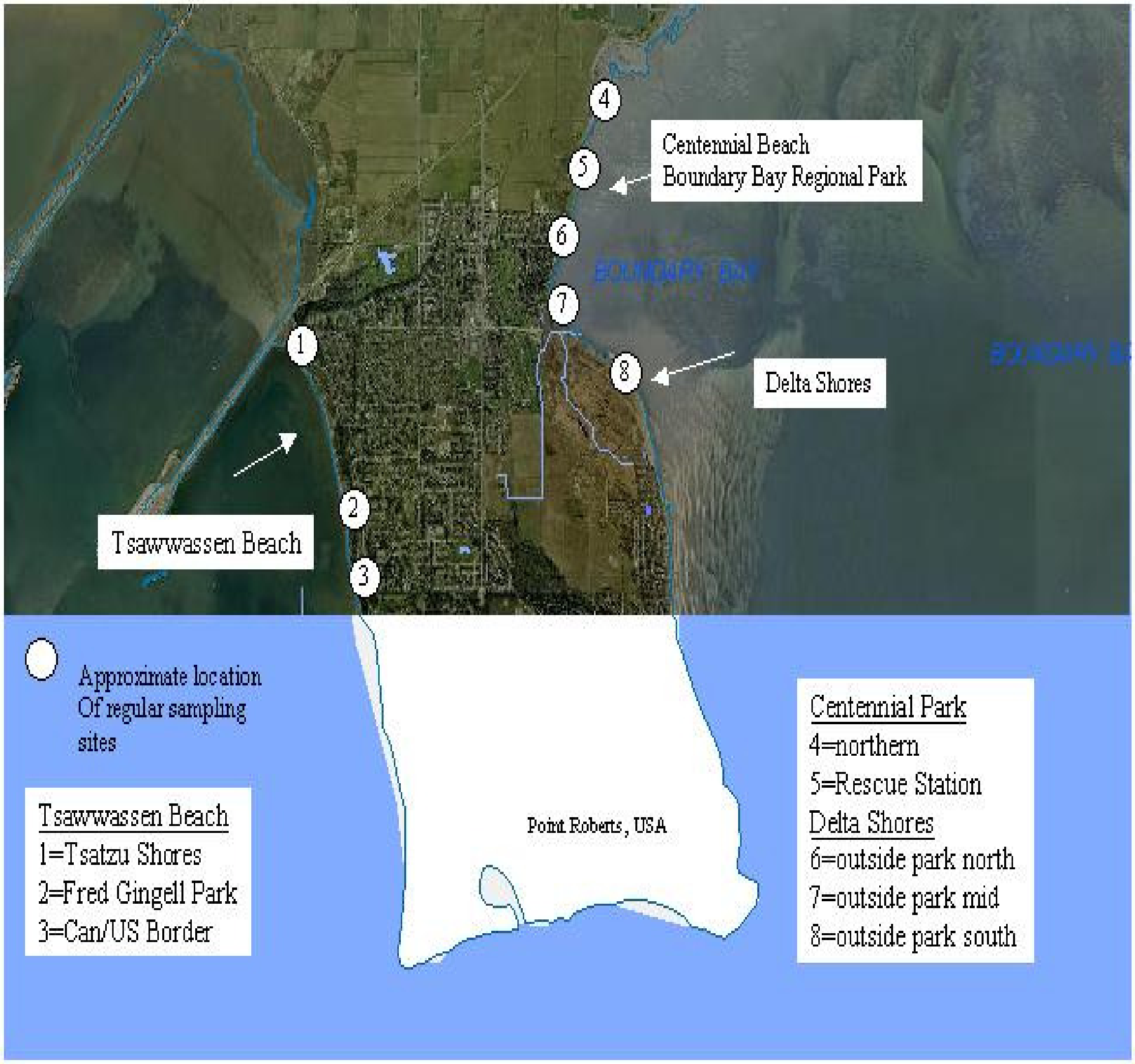


Figure 3: Map of sampling locations along Tsawwassen Beach, Delta Shores, and Boundary Bay Regional Park, British Columbia.
Source: Georgia Basin Habitat Atlas: Boundary Bay

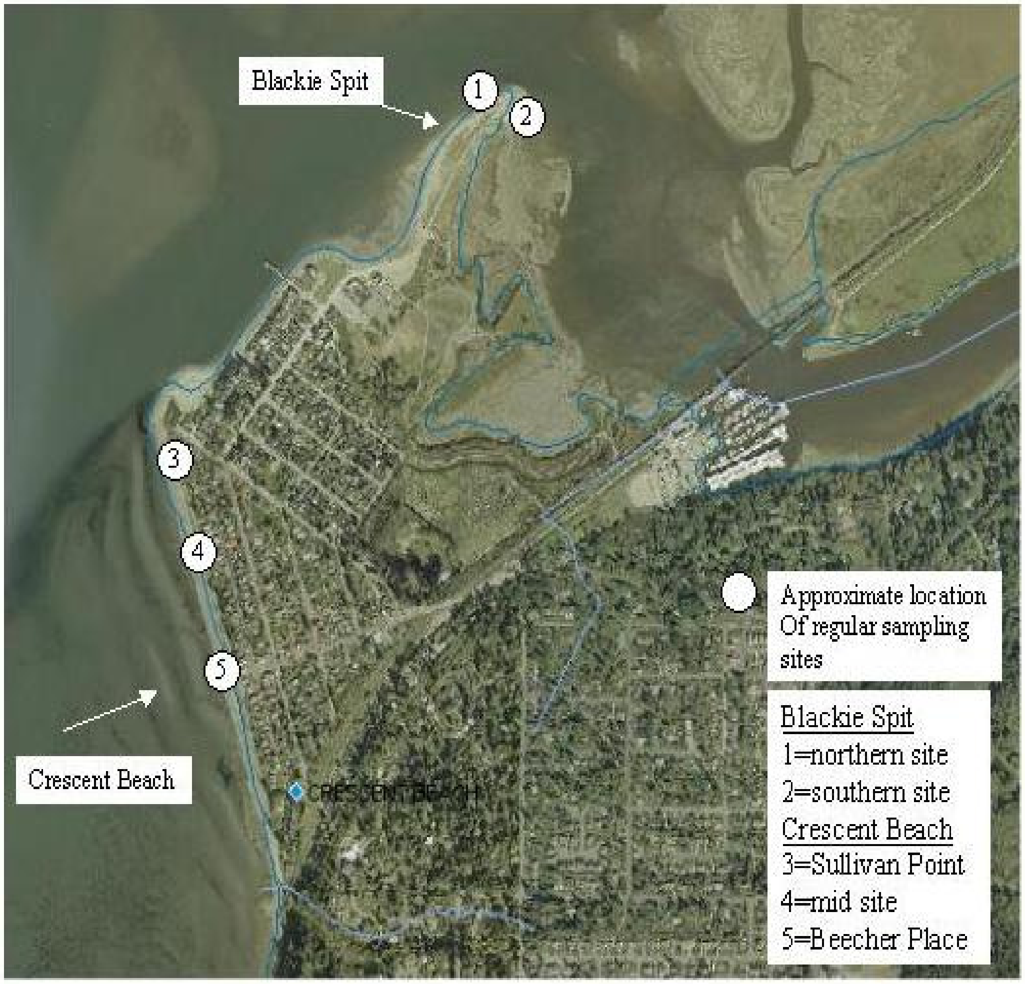


Figure 4: Map of sampling locations along Blackie Spit and Crescent Beach, Surrey shores (British Columbia). Source: Georgia Basin Habitat Atlas: Boundary Bay.

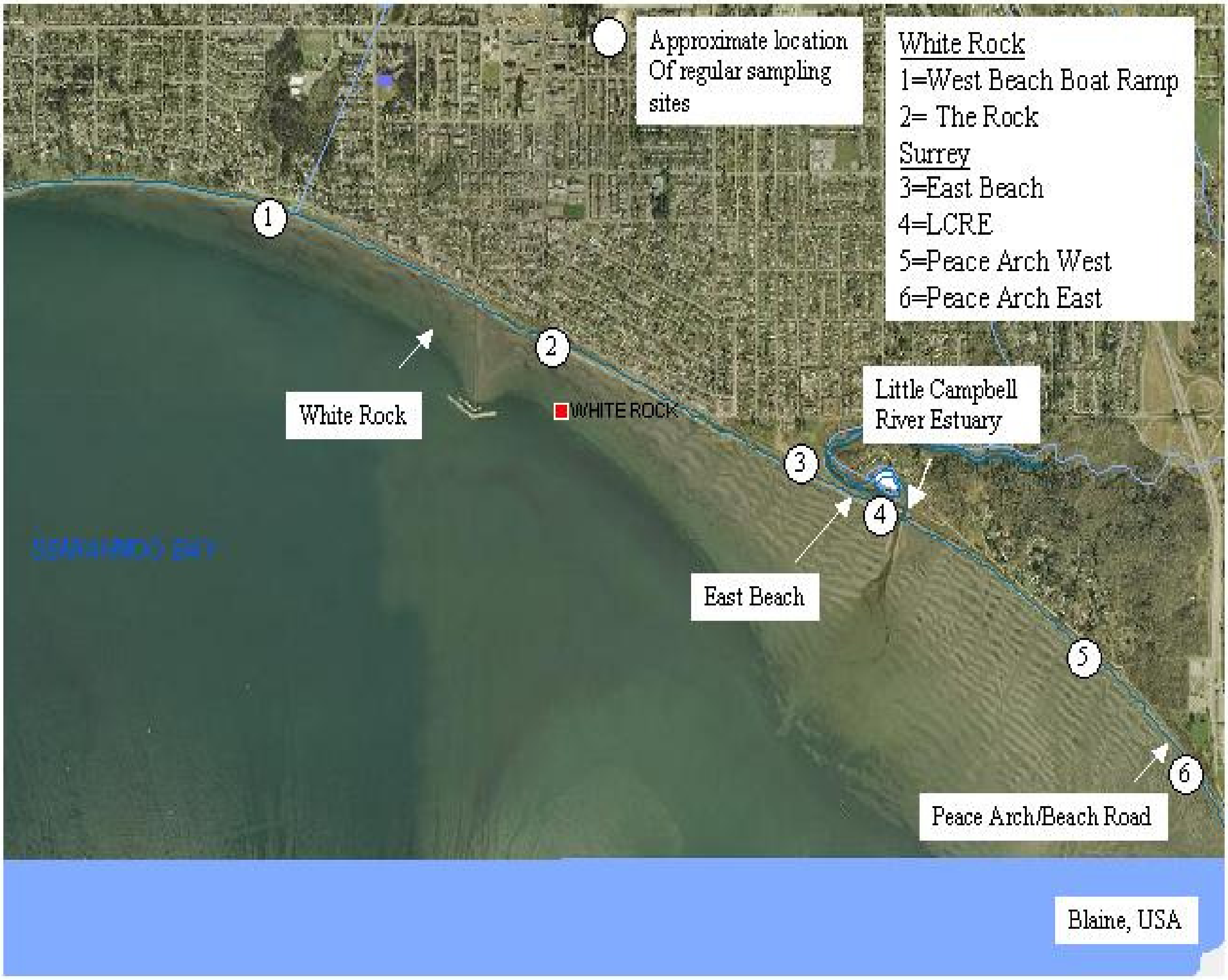


Figure 5: Map of sampling locations along White Rock and Surrey shores (British Columbia). Source: Georgia Basin Habitat Atlas: Boundary Bay.

SECTION TWO:

Results:

<u>Field and Sampling Surveys</u>

From July 2006, to October, 219 bulk samples were collected from eight beach areas. This represents a sampling area of approximately 6.5 kilometres (each sample encompasses 30 metres of beach face). Sampling dates and GPS locations are given in Appendix A. Field surveys were conducted every 2-4 weeks. Along with sediment samples, data were collected of the backshore and intertidal beaches following the WDFW protocols. Across-shore profiles at representative stations of sediment banding (including width and vertical height of intertidal components) were also prepared.

In Puget Sound, Pacific sand lance are known to spawn from November 1 to February 15 (Penttila 2001). Eggs spawned in late December may still be detected in January surveys as the incubation period is approximately four weeks. On December 28, 2006 and January 4, 2007, Pacific sand lance eggs were detected at several sampling stations along Centennial Beach (Figure 5A). The eggs were examined by WDFW for their developmental state to determine spawning time. The approximate spawning dates calculated are December 21, December 23 (December 28, 2006 sample), and December 29, 2006 (January 4, 2007 sample).

At five sampling stations at Crescent Beach, Surrey, surf smelt spawning was detected on June 20 and 24, 2007 (Figure 5A). Eggs were very abundant in the June samples; however, at least 95% of the eggs from these surveys were dead. The viable eggs from the June 20, 2007 sample likely resulted from a spawning event of June 15-17, 2007. The viable eggs from the June 24, 2007 sample were developed to the "1st coiled" stage and were likely 3-5 days old indicating spawning likely took place June 19-21, 2007 (D. Penttila May 30, 2007). At three sampling stations at Crescent Beach, Surrey, surf smelt spawning was detected on August 9, 2007; and at one station on August 17, 2007. Approximate spawning dates, to be confirmed by Mr. Penttila, are August 2 and August 9 (August 9, 2007 sample) and August 11 (August 17, 2007 sample). Unlike the June samples, the majority of the eggs detected in August were viable although the density of eggs (in the winnowed sediment) was considerably less. Surf smelt spawning was found at the Canada/United States Border Station on September 25 and 28, 2007 and at the Fred Gingell Station on September 25, 2007 (Figure 5A). Over 95% of these eggs were viable. Approximate spawning dates, to be confirmed by Mr. D. Penttila, are September 11 and 14, 2007. Sampling at the Fred Gingell station was limited to edges of the area due to the presence of excavating equipment digging up the beach face and eliminating any egg samples present.

<u>Habitat Mapping</u>

The objectives for mapping the shoreline of Boundary Bay were: (1) to access beach habitat as potential for spawning by surf smelt and Pacific sand lance; and, (2), access the level of shoreline alteration and human impact.

(1) Potential Spawning Habitat

Mapping of the shoreline for habitat (sediments) appropriate for sand lance and surf smelt spawning followed Resource Inventory Committee guidelines. An extra element was added to reflect the WDFW grading system for gravel-sand sediment character at representative stations at the surveyed beaches.

Figure 5A: Pacific sand lance and surf smelt Spawning Beaches detected from 2006 to 2007.

Representative stations were profiled by across-shore vertical components. Coding of sediment sizes in the across-shore banding profiles were recorded as follows: when only one sediment size was dominant, only that size was record meaning, for example, "(4)", >75% of the sediment in that band was of a gravel category 4; (3, 2) means 50-75% of gravel category 3 and the rest of gravel size 2; (3, 2, 4) means 25% of each gravel category.

(2) Shoreline Alteration and Human Impact

The shoreline of Boundary Bay was mapped and classified depending on backshore features (such as natural, railway bed, armoured, and others) and human impact.

Potential Spawning Habitat and Spawning Habitat

The distinction between beaches that look suitable for spawning and those that actually show evidence of spawn is an important one. In Puget Sound, it has been found that some beaches appropriate for spawning by surf smelt and sand lance are not used by these fishes, at least at a density of spawn detectable by sampling methods and sampling intervals (Penttila 2005). In Washington State, protection is afforded to beaches where spawn is found underscoring the importance of training individuals in the proper methodologies from field to laboratory screening. Also of importance is characterizing beach sediments in both summer and winter due to the seasonal changes. Some beaches that appear to have finer gravel sizes in summer (suitable for sand lance spawning) coarsen by winter due to storms shifting them from a sediment character suitable for sand lance to one suitable for both sand lance and surf smelt. WDFW protocols and codes were used to access spawning habitat (Appendix B).

Data Management and Storage

The data collected will be incorporated into forage fish GIS layers on the Georgia Basin Habitat Atlas: Boundary Bay. The map and GIS database will allow numerous calculations including the spatial area supporting appropriate sediments, spawning area, riparian vegetation, and shoreline area impacted by alteration of the shoreline by the railway bed, seawalls, private residential development, and others.

Due to the momentum of this project and other community groups on Vancouver Island initiating forage fish spawning projects, Fisheries and Oceans Canada has recently advised the author of their willingness to develop a GIS database for Pacific sand lance and surf smelt spawning projects. Our data and WDFW database management software will be used to assist with the development of this database.

Recommendations:

Sampling:

Results from the first year of sampling are extremely useful to inform further sampling and, in fact, Mr. Penttila recommends that sampling for forage fish spawn encompass at least a 24-month time period to build on information gained as well as the biology of the fish in question. Surf smelt and sand lance may not use beaches every year so sampling for two years usually yields findings of a greater spawning area than can be detected in only one year.

Further sampling for sand lance should be undertaken. In 2006, winter storms and evening tides excluded some sampling. 2006 spawning data indicated possible spawning events from December 21, 23 and 29, 2006. Using the data obtained from the first year of the study is important to inform further sampling. The standard protocol for sand lance surveys suggests sampling in the upper one third of the intertidal zone (+7 feet to 11 feet) (see Moulton and Penttila 2000). However, at locations such as White Rock, much of the upper intertidal zone favourable for spawning is buried under riprap and seawalls. Sand lance may spawn a few feet (or one metre) lower in the intertidal zone on moderate wave-energy sand flats. It is recommended that when sampling for sand lance spawn, survey stations be added to test the hypothesis of sand lance utilizing a slightly lower elevation spawning area and to detect eggs which may have been dispersed due to waves. This was done at Crescent Beach in November 2006 – January 2007. Sampling in November and December at locations such as Sullivan Point (Crescent Beach) to the Blackie Spit pier and White Rock may reveal further locations of sand lance spawning.

Restoration of Spawning Habitat:

As communicated by Dan Penttila, fisheries biologist, Washington Department Fish and Wildlife, any beaches in Boundary Bay found to be supporting spawning, suitable for beach spawners, or able to be restored should be given high priority due to the crucial importance of these forage fishes to the local food chain and the health of our marine waters. In contrast to historical reports of larger spatial areas of spawning habitat in Boundary Bay, currently little spatial area remains that was shown to have detectible levels of spawn or was unimpacted. Acting on opportunities to cooperate for the protection of known spawning areas and restoration of suitable habitat is critical. Recommendations for protection and restoration of beach sites will be categorized by the type of impact to the spawning habitat.

Structures:

Seawalls and Riprap Armouring

In the majority of cases, seawalls and riprap armouring both impede the shoreward movement of terrestrially borne sediments and create a scouring effect due to wave energies. Depending on the direction of the drift cell, groins and outfall pipes can retain sediments limiting distribution of sediments to distal shores. Mr. Penttila states: "Shoreline armouring may be the primary threat to surf smelt and sand lance spawning habitat" (2005, p. 7).

Sediments on gravel beaches used for spawning are either supplied from feeder bluffs located directly behind the beach (Tsawwassen Beach and White Rock) or from sediment-transport drift cells moving sediments from eroding bluffs along shore lines (eg Delta and Centennial Park being fed by the bluffs at Point Roberts). Interruption of the along-shore, sediment-transport drift cell can cause a coarsening of sediments to cobble or a starved sediment condition where sediments are shallow or non-existent. Alteration and shoreline development has led to the loss of some portions of the upper intertidal zone where sediments would accumulate and wave energies dissipated. Waves hitting vertical seawalls tend to scour beaches resulting in large rock/cobble beaches. There are alternatives to these 'hard" approaches to protecting shoreline properties as advocated by

Washington coastal geologist Mr. Jim Johannessen (website www.coastalgeo.com) and Greenshores (www.greenshores.ca).

It should be noted that these are general statements about hard armouring that may not be applicable at the fine-scale due to differences in beach configuration and aspect. There is a need to examine individual situations with care. This was apparent in a localized situation near Boundary Bay Regional Park, Delta. While many areas of beach are indeed scoured due to the presence of seawalls and riprap, a stretch of beach near Boundary Bay Regional Park with riprap has suitable sediments for forage fish spawning. A resident of Delta Shores advised the author that for many years, the beach in front of his seawall was comprised of large cobbles. Recently, due to a failed seawall, he placed riprap in front of the seawall. The sediment type in front of the riprap is now of a character that would support spawning; however, the riprap has narrowed the width of the spawning zone, decreased the beach elevation, and together with the seawall resulted in the loss of the upper spawning zone. However it is interesting to note that in this case, the rip rap created a slope $<90^o$ (rather than the 90^o vertical condition of the seawall) which allowed sediments and eelgrass/seaweed wracks to accumulate. This is an important lesson learned.

Outfall Pipes

Outfall pipes placed along a beach berm and beach face can have considerable effects on the along-shore, sediment-transport drift cell interrupting gravel nourishment to beach areas distal to the cell. For example, at White Rock, near the White Rock Museum and Archives, and near the Peace Arch station, outfall pipes were documented to have finer grained gravels and a beach face with a decreased slope on the western side of the pipe while larger, coarse gravels/cobbles and beach faces with a steeper slope on the eastern side of the pipe. At the Peace Arch station, the outfall pipe is located near the sampling station. It is recommended, especially at the Peace Arch station where the pipe is broken, that these outfall pipes be engineered not to disrupt movement of sediments and interrupt shoreline processes.

Where transport of terrestrial sediments from eroding bluffs/cliffs has been interrupted by bulkheads (eg. seawalls and railway beds), maintaining the sediment-transport drift cell to distal areas is very important to the health and ecological function of gravel beaches as spawning habitat. Structures placed perpendicular to and on top of beaches can compound the severe consequences of seawalls and bulkheads. Where beaches in Boundary Bay have maintained functional gravels for beach spawners, even in the presence of railway beds, seawalls, pier pilings, and groins, the practice of placing structures such as outfall pipes on top of beach faces should be reconsidered.

Other Structures

Pier pilings, jetties, and docks can interrupt natural sediment transport. Placement of these structures should be evaluated with full knowledge of "down beach" effects to shoreline morphology and sediment transport. Changes in sand flat character (slope, elevation, sediment grain size) can impede burrowing by adult sand lance due to reduced oxygen levels in the sand (used by fish for respiration). By reducing the oxygen available for these unique sand dwellers, the usable habitat for adult Pacific sand lance decreases, and by default, the spawning population also decreases.

Along Tsawwassen Beach, a new private pier was constructed this summer/fall. This private development of the shoreline compounded by the almost continuous stretch of seawalls and other shoreline alterations by residents along this beach is a trend detrimental to the health and ecological function of our nearshore waters. Because Tsawwassen Beach is a surf smelt spawning area, the trend toward private piers and docks on top of the beach face is a concern to the productivity of the region. In White Rock, the historic pier/jetty has already changed the elevation of the sand flat in its proximity.

Present Sediment Conditions:

Potential Spawning Habitat

The majority of the shoreline of Boundary Bay has been altered by the railway bed, seawalls and riprap and gravel/sand beaches lost for forage fish spawning. However, the majority of the remaining gravel/sandy shoreline of Boundary Bay present sediments with potential for spawning surf smelt and sand lance—although the majority of even these areas are impacted by human activities and alteration. This is an important distinction. Along a short section of Crescent Beach, although the backshore is heavily altered and groins are present, the appropriate grained sediments still attracts surf smelt to spawn. It is important to remember, however, that 95% of the eggs found at Crescent Beach were dead. The coarse nature of the gravels at Crescent Beach resulted in eggs that were anchored on top of gravels on the sediment surface and in the direct sunlight on a beach lacking the protection of shading vegetation that usually protects eggs from desiccation. In some ideal sediment conditions, smaller "pea gravels" are present which allow anchored eggs to fall between the coarser gravels to incubate in a cooler, humid environment a few centimeters below the sediment surface. Alterations to beach faces (eg removal of vegetation and the lack of eroding sediments) and other disturbances can result in high egg mortality perhaps to the point where few individuals from these spawning events survive to become adult spawners. This can produce "sink" populations (populations with mortality rates higher than survival rates); and these sink populations rely on immigration into the spawning pool from neighbouring "source" populations (populations with survival rates higher than the mortality rate).

Human Impacts and Available Shoreline for Spawning

Only a small percentage of potentially available spawning habitat was used by sand lance and surf smelt in 2006 and 2007 (as detected by our sampling methods and schedule). Other than small stretches of near natural beach as found at Centennial Park (BBRP) and at, Tsawwassen Beach, the Fred Gingell and Canadian/United States border stations, the majority of the shoreline of Boundary Bay has been heavily impacted by human activity. Kilometers of the upper intertidal, at an elevation appropriate for sand lance and surf smelt spawning, has been buried under the railway bed (and its associated armouring) and seawalls (examples include Tsawwassen Beach, Tsawwassen; Beach Grove, Delta; south of Crescent Beach to extensive areas of White Rock). Upper intertidal habitat along the railway bed from Crescent Beach to the West Beach Boat Ramp (Figure 6) and near the Little Campbell River estuary (Figure 7) have been completely buried under the railway bed, cobbling, boulders, and riprap. Other areas, even with an intact supralittoral zone and beach berm have been heavily impacted due to sediment starvation as continuous seawalls and the railway bed completely interrupt the flow of crucial eroding sediments from feeder bluffs to the beaches (such as Tsawwassen Beach and White Rock). In Washington State, beaches have been re-engineered to remedy this loss. In areas of Boundary Bay where sediments were found to be coarse and of a narrow width, beaches could be enhanced by providing appropriate spawning gravels and as often seen in Washington State restoration projects.

Figure 6: Shoreline hardening, Coldicutt Ravine, White Rock, BC
Photo Credit: R.C. de Graaf

Figure 7: Shoreline hardening, near the Little Campbell River Estuary, Surrey, BC.
Photo Credit: R.C. de Graaf

Beach Sediment Enhancement

A few of the areas of Boundary Bay that could be enhanced with addition of sediments include: the historical White Rock Beach surf smelt spawning area of West Beach, Semiahmoo Bay (from the boat ramp area to east of the Pier); The Rock, White Rock; East Beach, Semiahmoo Bay (Finlay Street to the mouth of the Little Campbell River); and from the Peace Arch border west to an area approximately 500 metres east of the little Campbell River. These areas are sediment starved due to the interruption of along-shore sediment transport and diversion of feeder creeks by culverts.

The Crescent Beach area sampled did support surf smelt spawning; however, the sediments are tending toward being coarse and likely are only maintaining a spawning condition due to entrainment of sediments by some of the intertidal groins (Figure 8). Sources of these sediments are unknown due to the sidewalk areas and the loss of sediments in Semiahmoo Bay. Mortality of the eggs may be reduced by enhancing the sediments to provide for finer pea gravels in the gravel mixture and providing shading vegetation. As mentioned previously, pea gravels allow anchored eggs to fall between the coarser gravels providing a cooler, more humid environment in which to incubate rather than on the surface of the large, coarse gravels currently found on Crescent Beach. The position of the riprap armouring and other backshore structures may not be conducive to the long-term persistence of spawning gravels in the long term. Alternatives to armouring such as the placement of and anchoring of logs and maintenance of reduced beach slopes and beach berms are a few of the modern, effective, "soft approaches" to engineering beaches for ecological function and storm protection. The sediment grain sizes present at

Crescent Beach should be monitored to maintain their present condition or even be enhanced. The majority of surf smelt eggs found at Crescent Beach were dead (over 95%), and the mortality may have been due to the lack of shading vegetation along this beach area. In light of the bigger picture of the extreme loss of spawning habitat throughout Boundary Bay, this small area of spawning habitat at Crescent Beach is of crucial importance and should be managed with care. It would be advisable to employ the services of a coastal geologist, such as Mr. Jim Johannessen, and surf smelt expert Mr. Dan Penttila. Mr. Penttila has seen the beach spawning area at Beecher Place, Crescent Beach, Surrey, BC on two occasions. These experts can comment on the location of sediment inputs, how best to maintain and improve the Crescent Beach sediment conditions, and how to provide shading vegetation to maintain the beach for future spawning and reduce the current incidence of high mortality of surf smelt eggs. It is important to note that the deteriorated condition of sediments at Crescent Beach may not be at an end point as coarsening of beaches can be a process taking several decades. Crescent Beach sediment conditions may worsen in the future leading to the loss of this small, isolated area of vital spawning habitat in an otherwise altered landscape that no longer has the capacity to support spawning. In Washington State, beaches once supporting surf smelt spawning have coarsened over several decades resulting in the diminished capacity of the beaches to support spawning (Penttila pers. comm.)

Figure 8: Shoreline hardening, Crescent Beach, Surrey, BC. An example of multiple groins, riprap armouring in the upper intertidal zone and foreshore dyking. Note the southerly flow of the drift cell as sediments accrete on the northern side of the groin. Photo Credit: R.C. de Graaf.

High-value forage fish spawning habitats in Boundary Bay

It is strongly recommended that areas of Boundary Bay and Tsawwassen Beach with the best potential spawning habitat (that scored consistently high by having intact feeder bluffs, overhanging vegetation, wide supralittoral zones, and low human impact) be protected from development and maintained in their present state in accordance with the “precautionary principle”. These beach sections require no restoration only protection from development. Tsawwassen Beach near the Canada/United States border; Fred Gingell Park (English Bluffs); and Tsatsu Shores have many crucial attributes of near “natural” spawning beaches. There are very few areas left for surf smelt to spawn in Boundary Bay and the rest of the Lower Mainland; and indeed, there are few options left to us for the conservation of these species in this critical, and globally significant region of British Columbia.

Pacific sand lance was found to spawn along the shores of Centennial Beach, Boundary Bay Regional Park. This is a popular, year-round destination for beach goers and dog walks. The importance of Centennial Park high intertidal beaches as spawning habitat is significant as sand lance spawn was not detected in other Boundary Bay locations. Every effort should be made to protect the spawning area in Nov-January. It is also recommended that GVRD staff be trained to obtain sediment samples for ongoing monitoring of sand lance spawning in Boundary Bay Regional Park. Interactions with beach goers in the summer of 2006 and 2007 was generally positive. However, some visitors expressed their desire for concrete sidewalks, boat ramps, and more access for wheelchairs along the shoreline. None of these “desires” by the public are compatible with protecting the forage fish link in the nearshore marine food chain of Boundary Bay.

Shade-Providing Vegetation:

Almost all of the surf smelt eggs found at Crescent Beach in June and August 2006 were dead. There are a number of papers supporting the hypothesis that the lack of riparian shade leads to a high mortality of summer-spawned surf smelt eggs (Penttila 2001, Rice 2006). South facing beaches, like Crescent Beach, are exposed to the sun for the entire day. Combined with the longer intertidal duration common in the summer and the lack of shade providing vegetation, the high mortality of the spawned eggs at the Crescent Beach location was not surprising. As so much of the current, potential spawning habitat in Boundary Bay has been impacted by development, the beaches at Crescent Beach are crucial spawning habitat. In contrast to Crescent Beach, spawn bearing samples collected at a west facing, shaded beach at Wreck Beach, Vancouver, in August 2007 were found to contain a high percentage of living eggs (over 90%).

At Semiahmoo Bay, stretches of beach as found at East Beach, Surrey, provide a good opportunity to restore shading vegetation. This stretch of beach is on First Nations land and is part of an area being activity restored by Friends of Semiahmoo Bay Society and numerous concerned partners groups. Also, near the Peace Arch Park, some deciduous trees and shrubs already provide a partially shaded area to the beach, and together with sediment restoration, could provide an opportunity to restore shading vegetation without too much public opposition (relative to the popular beach area of White Rock).

In 1997, a map of Semiahmoo Bay shores was produced providing a sensitivity coding. This map, by Terra, is lacking in several areas but especially with respect to the issue of forage fish beach spawning habitat. Any environmental assessments of the marine habitats and resources of Semiahmoo Bay should take into consideration the present habitat assessments for forage fish as well as those of neighbouring US waters at Drayton Harbor and Semiahmoo Spit.

SECTION THREE:

Site Descriptions

General Overview

Gravel/sand beaches of the natural tidal elevation and appropriate spawning gravels have been impacted throughout Boundary Bay. Where appropriate spawning gravels do exist, many of these shoreline areas are heavily impacted by human activities and alteration of the backshore and intertidal zone. For example, the historical spawning beaches of White Rock area have been significantly impacted or lost to the degree that no spawning activity was detected in this study. Also, the beach area of Crescent Beach has been altered (see section below) or lost due to riprap and the railway bed occupying the backshore and the upper one third of the intertidal zone.

Due to the presence of vegetated eroding bluffs, the three stations at Tsawwassen Beach are the finest examples of natural surf smelt/sand lance spawning habitat in the region. Surf smelt spawn was detected at two of these stations. The next area of natural surf smelt/sand lance spawning habitat is the area of Centennial Beach, Boundary Bay Regional Park, Delta. Sand lance spawn was detected in Centennial Park. The beach area of Crescent Beach was found to support spawning by surf smelt and measures should be taken to enhance and protect this beach as spawning habitat (see section "Recommendations").

Opportunities for enhancement, protection, and restoration of gravel/sand beaches for forage fish spawning in Boundary Bay do exist. Due to the crucial importance of forage fish in the marine nearshore food web, appropriate actions to conserve spawning habitat should be considered in the near future.

Site Descriptions

Latitude and longitude coordinates of all sampled sites are given in Appendix A. Higher high water was calculated using the nearest reference or secondary port according to the Canadian Hydrographic Service calculations for the day.

Shoreline Mapping and Station Classification

Shoreline mapping followed the basic requirements as set out in the British Columbia Resource Inventory Committee and Community Mapping Network Sensitive Habitat Inventory Mapping manuals. For surf smelt and Pacific sand lance, gravel position and sediment grain size within the upper intertidal zone is a primary determinant of spawning habitat suitability. The RIC methodology was adapted to provide for fine-scale, site-specific classification of gravel bands along sand/gravel beaches. Within a beach face, several horizontal gravel bands of different grain size is common. The shoreline component methodology was adapted to allow an inventory method to subdivide the "beach face" shore-line component (B) into smaller units to classify the sediment grain size of gravels and width of spawning habitats.

This allows the researcher to classify potential spawning habitat and the degree of negative impact to the beaches surveyed. Sediment size codes are those used by Mr. D Penttila, WDFW (Moulton Penttila 2000)(Appendix B). Within a beach location, sampling stations were chosen on the criteria of the position of gravels in the upper intertidal and suitability of gravel sizes. Stations classified for beach character were chosen that best represented the general condition (slope, sediment grain size) at each of the eight beaches. Sediment samples were collected in the upper intertidal area below the log line and to one metre below the high tide vegetative drift lines.

Station Classifications and Beach Profiles

Tsawwassen Beach

West of the US Point Roberts surf smelt spawning beach (Penttila 2000, 2001) three sites were routinely sampled along Tsawwassen Beach. The first site was located west of the Canada/US border; the second along the shoreline of Fred Gingell Park, English Bluffs; and the third and most western site at Tsatsu Shores condominiums (Tsawwassen First Nations). On occasion, several sites were sampled in between these targeted areas. The finest gravels occur at the Tsatsu shores location. From July 2006 to June 2007, no stations yielded surf smelt/sand lance spawn. The backshore along the beach is dominated by beach houses and seawalls. Large numbers of private boats are anchored directly on top of the sand/mud flats. This summer, a new private pier was built extending along the beach face with a dock located on the intertidal flat.

Surf smelt spawning activity was detected on September 25 and 28, 2007 at the Canada/US border and Fred Gingell Stations.

Canada/United States border Station

The beach at the Canadian/United States border site is west facing and exposed to the Strait of Georgia. This beach is contiguous with the surf smelt spawning area document by Penttila (2000, 2001). Other than nominal foot traffic, this beach receives little human traffic. The bluffs are largely intact and there is no backshore development and no structures located in the intertidal zone (such as seawalls, piers or groins) impeding the movement of eroded gravels to the beach. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of a station representative of the beach are in Figures 9 and 10 and Table 1. The station is coded as an uplands (1)—natural intertidal (0% impact). A freshwater stream is nearby. While vegetation (short and tall shrubs; deciduous and coniferous trees) is present, little of the vegetative canopy shades the upper intertidal. The beach character to support spawning by surf smelt or Pacific sand lance is excellent and is largely composed of deep, medium gravel (3) with pea gravel (2) and a sand base. This station and the area contiguous (approximately 0.5 km west and 1-2 km east) is exceptional habitat for surf smelt and sand lance spawning. It represents one of the few opportunities in Boundary Bay to preserve spawning habitat in near natural condition.

FoSBS Positive Samples: On September 25 and 28, 2007, surf smelt spawning activity was detected at this station.

Recommendations Summary: Due to the high quality of this habitat, its value as a surf smelt spawning beach, and the rarity of this habitat in Boundary Bay, its natural attributes should be protected. Protection of this area of the beach from the detrimental effects of development is highly recommended.

Table 1: 2007 Across-shore banding profiles Canada/US Border Station, Tsawwassen Beach:

Station Location: Tsawwassen Beach, Canada/US Border
Wave Exposure: Exposed; west facing
Backshore: Primarily forested cliff (eroding); unimpacted shoreline; some residential development and seawalls to the west of the site
Shading: no shade is provided by the cliff face forested canopy to the B2 and B3 components

Zone/ Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
A1	beach berm	Clastic: sand, rock (4)	logs; plants; shrubs;	5.5°	27.1 cm/2.9m	4. 67 m	2.9 m
B1	beach face	Clastic: rock (4), sand	drift seaweed/eelgrass	8°	37cm/2.8m	4.4 m	0 m
B2 (+)	beach face	Clastic: rock (3,2,4) sand	drift seaweed/eelgrass	7.3°	85.5cm/6.7m	4.03 m	5.7 m
B3 (+)	beach face	Clastic: rock (4), sand		7.2°	62.8cm/5.0m	3.18 m	12 m
B4	beach face	Clastic: rock (4,3), gravel (2), cobble	thatched barnacles, *Littorina spp.*	7.8°	44.8cm/3.3m	2.55 m	17 m
B5 top	beach face	Clastic: rock (4), mud	*Ulva sps*, *Enteromorpha sp,* thatched barnacles	5°	17cm/2m	2.1 m	20 m
B5 bottom						1.9 m	22.7 m
B6	tidal flat	Clastic: sand, mud	*Zostera japonica, Zostera marina*	not measured Overall slope is < 1° (+)Spawning habitat at 5.7-12.4 m horizontal			

*measured from band height and width measurements
**using 4.4m as maximum tide height

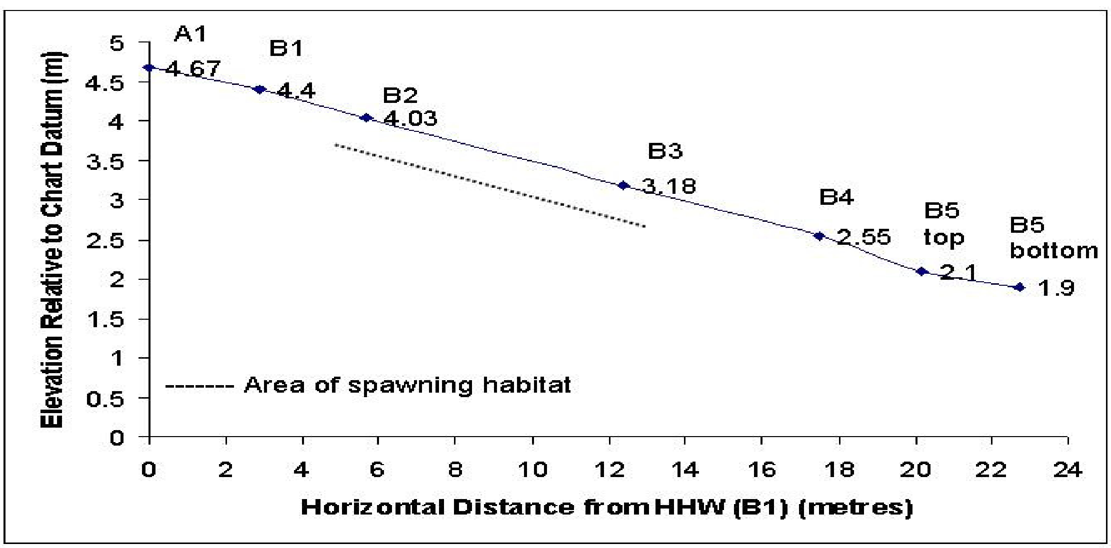


Figure 9: 2007 vertical beach profile of the across-shore transect with elevations, Canada/United States Border Station, Tsawwassen Beach.

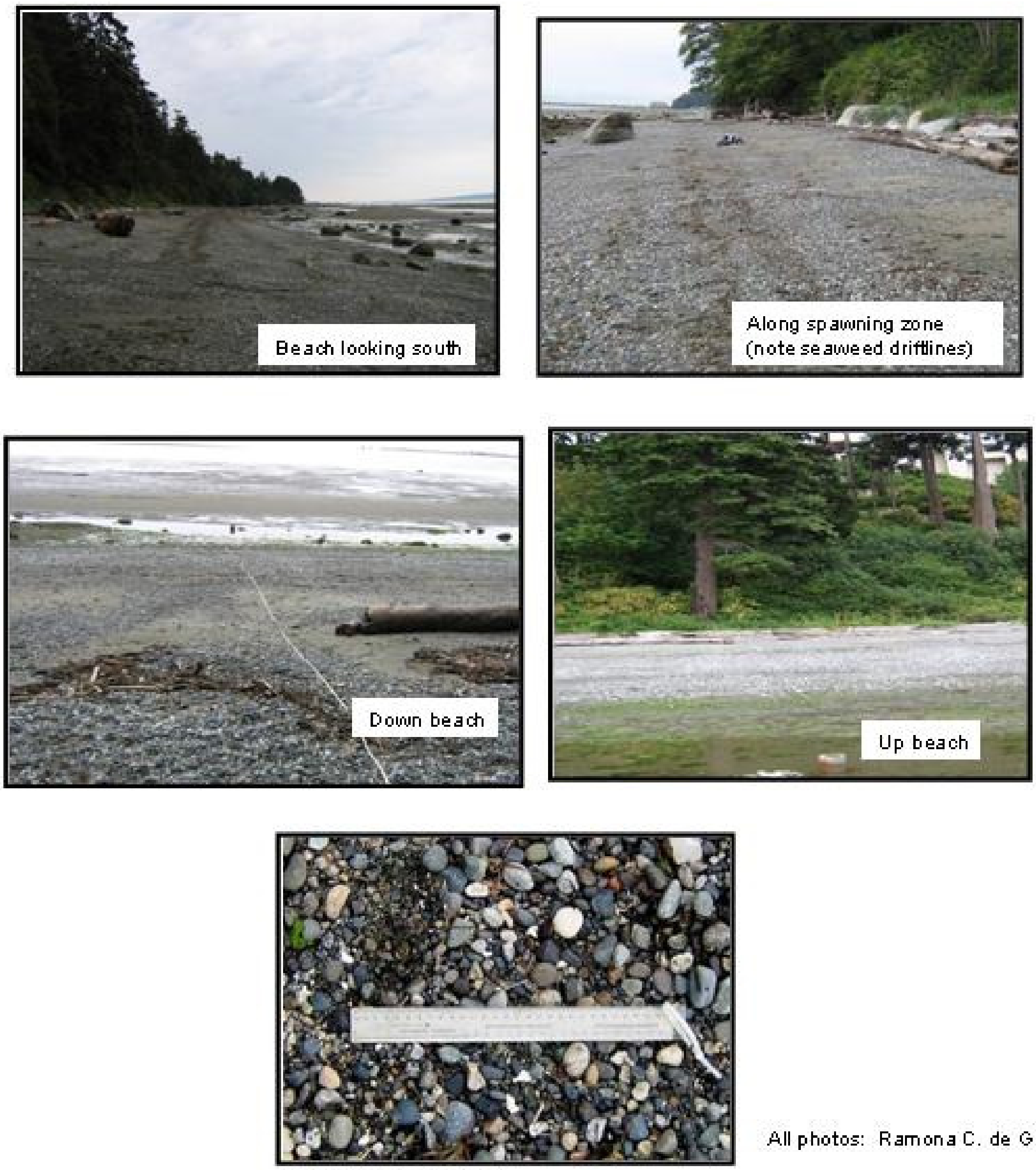


Figure 10: Tsawwassen Beach, Canada/United States Border Station: across-shore transect location and 2007 summer sediment characteristics.

Fred Gingell Park Station

The beach at the Fred Gingell site is south-west facing and exposed to the Strait of Georgia. Located at the base of a public beach access, this beach receives heavy foot traffic and human use relative to other locations. Other than the BC Hydro station and service road, the bluff is intact and there is no backshore development and no structures located in the intertidal zone (such as seawalls, piers or groins) impeding the movement of eroded gravels to the beach. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of a station representative of the beach are in Figures 11 and 12 and Table 2. The station is coded as being an uplands (1)—natural intertidal (0% impact). While vegetation (short and tall shrubs; deciduous and coniferous trees) is present, little of the vegetative canopy shades the upper intertidal. The beach character to support spawning by surf smelt or Pacific sand lance is excellent and is largely composed of deep, medium gravel (3) with pea gravel (2) and a sand base. There are seawalls present at residential properties on both sides of this site. Samples were usually collected in a bulk sampling procedure sometimes exceeding 30 metres in length. Two samples at this location would encompass the entire length of the beach protected by this BC Hydro right-of-way. In September 2007, replacement of submarine power cables will commence resulting in trenching of areas of the beach face. This station and approximately 300 metres of beach is excellent for surf smelt and sand lance spawning and represents one of the few opportunities to preserve a spawning beach in a near natural condition.

FoSBS Positive Results: On September 25, 2007, surf smelt spawning was detected at this station.

Recommendations Summary: As with the border station, the importance of this beach station as surf smelt spawning beach and the existing natural attributes found, protection of this habitat from detrimental development is highly recommended. Planting of marine riparian vegetation to provide shade for incubating surf smelt eggs would improve the habitat.

Table 2: 2007 Across-shore banding profiles of the Fred Gingell Park Station

Location: Fred Gingell Park, Tsawwassen
Wave Exposure: Exposed; west facing
Backshore: Primarily forested cliff (eroding); unimpacted shoreline
residential development and seawalls to the east and west of the site
Shading: no shade provided by the forested, cliff face canopy to the B1/B2 components

Zone/Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
A1	beach berm	Clastic: rock (3), sand	logs; shrubs, salt tolerant plants, maple and alder trees	4.2°	44.1cm/6.0m	4.84 m	6m
B1 (+)	beach face	Clastic: rock (3, 2, 4), sand	drift seaweed/eelgrass; logs	8.9°	109.3cm/8m	4.4 m	0 m
B2 (+)	beach face	Clastic: rock (5, 4), sand	none	8.9°	88cm/6.4m	3.31 m	14 m
B3 top	beach face	Clastic: rock (4), mud	*Ulva sps., Enteromorpha sps,* mussels, thatched barnacles	5.9°	16.5cm/1.6m	2.43 m	20.4m
B3 bottom	beach face					2.27 m	22 m
B4	tidal flat	Clastic: sand, mud	*Zostera japonica, Zostera marina*	not measured			
				(+) Spawning habitat at 6-14 m horizontal			

*measured from band height and width measurements
**using 4.4m as maximum tide height

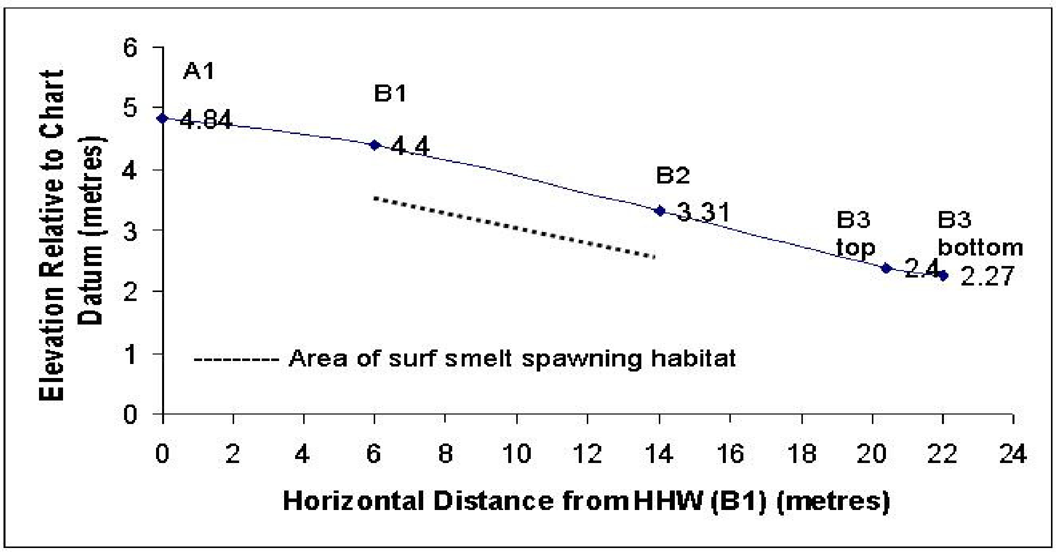
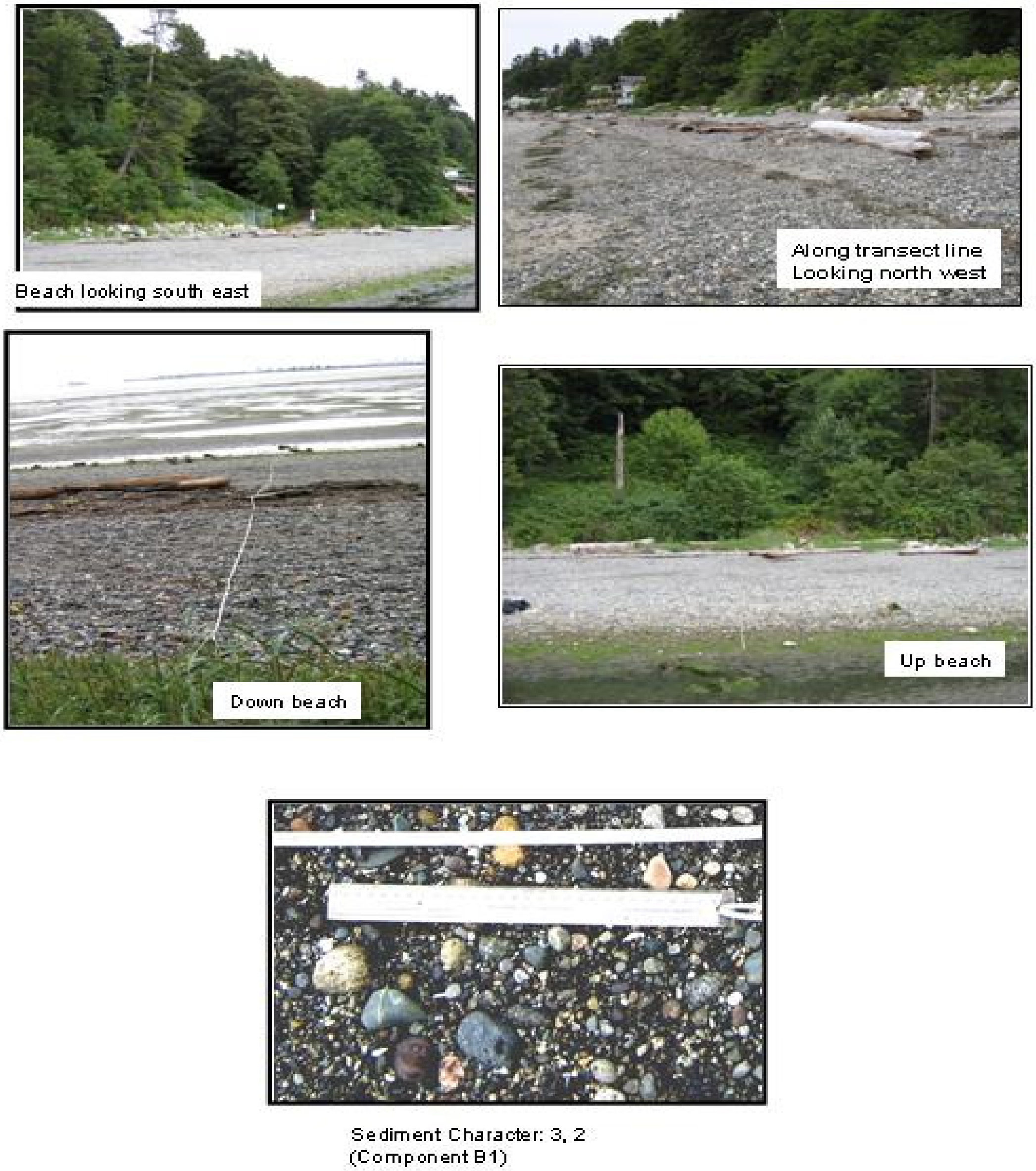


Figure 11: 2007 vertical beach profile of the across-shore transect with elevations, Fred Gingell Station, Tsawwassen Beach.



All photos: Ramona C. de Graaf

Figure 12: Fred Gingell Station, Tsawwassen Beach: across-shore transect location and 2007 summer sediment characteristics.

Tsatsu Shores Condominiums Station

The beach at the Tsatsu Shores site is south facing and exposed to the Strait of Georgia. Sampling stations were at two locations with the first being in the area of the bay directly in front of the condominiums and a second site south of the small, rocky outcrop (Figure 13). At the condominium site, foot traffic is low (relative to the Fred Gingell site). The backshore area has been altered by the condominiums, a paved parking area and roadway which would impede the seaward movement of sediments to the beach area. The intertidal area is not impacted by any structures (such as seawalls, piers or groins) allowing natural transport of sediments. However, the site is bounded on the northern edge by the Tsawwassen ferry causeway and in fall and winter, large amounts of deep, vegetative debris (eelgrass and seaweed) accumulates covering upper beach gravels and creating an anoxic condition. In front of the bay, the backshore area is largely sand, low shrubs, dune plants and logs at the high tide line. Naturally vegetated bluffs are present in the backshore but no vegetation shades the upper intertidal beach gravels. This station is coded as being an uplands (1)—natural (0% impact). The finest gravels along Tsawwassen beach occur at this site likely due to the direction of sediment transport. The beach character to support surf smelt and Pacific sand lance spawning is excellent and consists of deep pea gravel (2) and medium coarse rock (3) with a sand base. Shoreline components were not measured.

At the southern station, natural bluffs continue along the backshore and most of the area is unimpeded by seawalls except at the extreme southern edge of the station where the first beach front properties begin (owned by the Tsawwassen First Nations). Other than the seawalls at the rental properties, there are no structures to impede the movement of eroded gravels to the beach. A dirt tract from the condominiums to the southern edge of the Tsawwassen First Nations rental properties is routed over the upper intertidal gravel beaches and service vehicles have been observed using this dirt tract to the rental homes. The site is coded as uplands (2)—25% impacted--due to the dirt tract and high tide seawall along approximately 25% of the length of this station. While vegetation (short and tall shrubs; deciduous and coniferous trees) is along the backshore, none of the vegetative canopy shades the upper intertidal. The beach character to support spawning by surf smelt or Pacific sand lance is excellent and is largely composed of deep, medium gravel (3) with pea gravel (2) and a sand base. Shoreline components were not measured.

All photos: Ramona C. de Graaf

Figure 13: Condominium and Southern stations showing 2007 summer sediment conditions.

Delta and Boundary Bay Regional Park Beaches

North of the US Point Roberts surf smelt and sand lance spawning beach (Penttila 2001), three stations were routinely sampled along Delta Shores and three-five sites within Centennial Beach, Boundary Bay Regional Park. Both the beaches of Delta Shores and Boundary Bay Centennial Beach are heavily used by the public. The spawning habitat within the park boundaries is heavily impacted by various human activities (digging, sun bathing, beach fires, movement of large woody debris for constructing huts), and spawning attributes are impacted. Along Delta Shores, three sampling stations were located north of the largest, most prominent seawalls near the intertidal waste-water outfall to the park border. The finest gravels/rock occurs in the Centennial Beach location. Three stations within Centennial Park yielded sand lance spawn on December 28, 2006 and January 4, 2007.

Delta Shores Station

The representative station at the Delta shores site is east facing and exposed to Boundary Bay. This beach is used for various human activities including boating, beach combing, dog walking, as a golf driving range, and receives high human impact. Seawalls exist in front of residential properties and there is an engineered wide, sandy storm surge beach berm with dune plants. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of a site representative of the beach are in Figures 14 and 15 and Table 3. There are no structures located in the upper intertidal zone (such as seawalls, piers or groins) impeding the movement of eroded gravels to or along the beach. The site is coded as being an uplands (1)—natural (0% impact). There is no vegetation to shade the upper intertidal beach area. The beach character to support spawning by surf smelt or Pacific sand lance is excellent and is largely composed of deep, medium gravel (3) with pea gravel (2) and a sand base.

Recommendations Summary: Due to the high use of this beach area, backshore seawalls, and pressure to enhance storm water protection, sediment conditions should be monitored to ensure beach character is maintained as potential spawning habitat.

Table 3: 2007 across-shore banding profiles of the Delta Shores Station

Location: Delta Shores, Delta [N49.00.523/W123.02.122]
Wave Exposure: Semi-Protected; east facing
Backshore: wide low lying berm, grasses, plants, sand; unimpacted shoreline; extensive backshore residential development & low seawalls
Shading: no shade

Zone/ Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
A1	beach berm	Clastic: sand	salt tolerant grasses; sand		not measured		> 60 m
A2	beach berm	Clastic: sand	salt tolerant grasses; logs; sand	2.9°	36cm/7m	4.76m	7 m
B1	beach face	Clastic: sand	drift seaweed/eelgrass; logs	8.8°	38cm/2.5 m	4.4 m	0 m
B2 (+)	beach face	Clastic: rock (3,4,2), sand	drift seaweed/eelgrass	6.3°	65.9cm/5.9 m	4.02 m	9.5 m
B3 (+)	beach face	Clastic: rock (3,4,5), sand	thatched barnacles, *Batillaria sps.*	6.5°	29.3 cm/2.6 m	3.36 m	15.4 m
B4 top	beach face	Clastic: rock (4), sand, mud	*Ulva sps, Enteromorpha sps, thatched barnacle, Littorina spp.*	1.8°	94 cm/ 30 m	3.07 m	18 m
B4 bottom						2.13 m	48 m
B5	tidal flat	Clastic: sand, mud	*Zostera japonica, Zostera marina*	not measured			
			Overall slope: 3.1°				
			(+) Potential spawning habitat 9.5-13.6 m horizontal distance				

*measured from band height and width measurements
**using 4.4m as maximum tide height

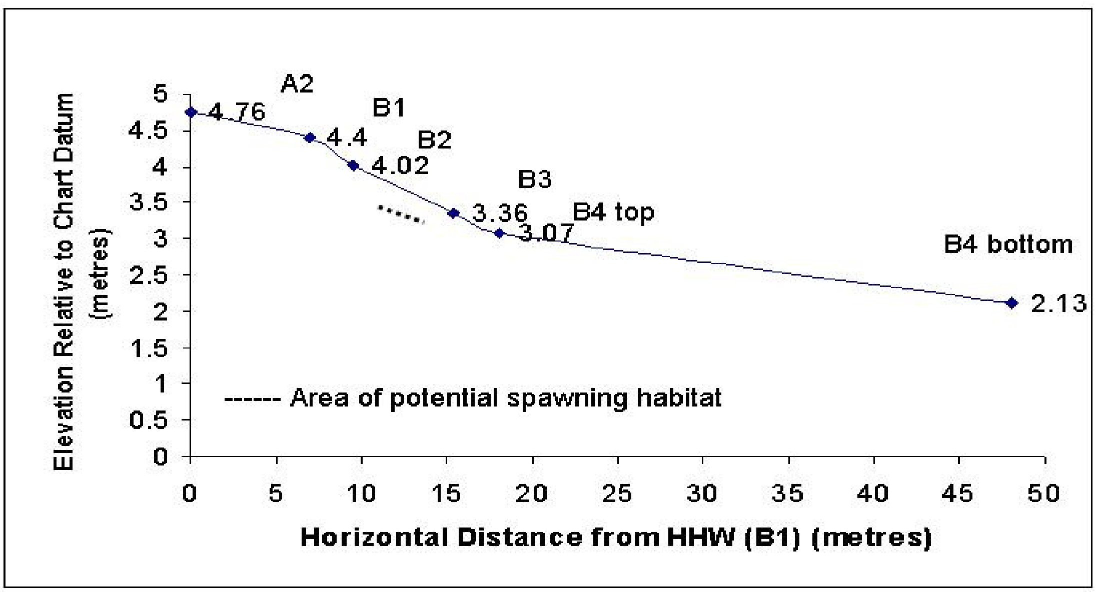


Figure 14: 2007 vertical beach profile of the across-shore transect with elevations, Delta Shores, Delta, BC.


Along shore facing west


Backshore: wide, sandy beach berm


Up beach


Down beach


Sediment Character: 3, 2

All photos: Ramona C. de Graaf

Figure 15: Delta Shores Station, Delta, BC: across-shore transect location and 2007 summer sediment characteristics.

Centennial Beach Stations, Boundary Bay Regional Park

The beach at the Centennial Beach site is east facing and exposed to Boundary Bay. This beach is contiguous with the US surf smelt and sand lance spawning area documented by D. Penttila (2001). The park beaches are used for various human activities including sunbathing, swimming, beach combing, dog walking and receives heavy human impact due to the high numbers of park visitors. The backshore area is a wide, storm-surge beach berm of sand and dune plants. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of a site representative of the beach are in Figures 16 and 17 and Table 4. There is no backshore development and no structures are located in the intertidal zone (such as seawalls, piers or groins) impeding the movement of eroded gravels to or along the beach. The site is coded as being an uplands (1)—natural (0% impact). There is no vegetation to shade the upper intertidal beach area. The beach character to support spawning by surf smelt or Pacific sand lance is excellent and is largely composed of deep, medium gravel (3) and pea gravel (2) with a sand base.

FoSBS Positive Samples: Pacific sand lance spawning was detected at these stations on December 28, 2006, and January 4, 2007.

Recommendations Summary: Due to the high use of this area for recreational activities within the park and its value as crucial spawning habitat, continued monitoring to maintain sediment character is recommended. As well, maintaining the natural values of the park is crucial to overall conservation of local sand lance populations.

Table 4: 2007 across-shore banding profile Centennial Beach Station, Boundary Bay Regional Park, Delta

Location: Boundary Bay Regional Park, Centennial Beach
[N49.00.950/W123.02.365]
Wave Exposure: Semi-Protected; east facing
Backshore: low lying berm, grasses, plants, sand; protected park area
Shading: no shade; unimpacted shoreline

Zone/Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
A1	beach berm	Clastic: sand	salt tolerant grasses; sand	not measured			> 60 m
A2	beach berm	Clastic: sand	salt tolerant grasses; logs; sand	4.9°	51cm/6 m	4.91 m	6 m
B1 (+)	beach face	Clastic: coarse sand	logs; drift seaweeds and eelgrass	6.4°	36.7cm/3.2m	4.4 m	0 m
B2 (+)	beach face	Clastic: rock (3,2,4)	drift seaweeds and eelgrass	7.9°	33cm/2.4m	4.03 m	9.2 m
B3	beach face	Clastic: rock (4,3)	barnacles, snails (*Battilaria)*	1.8°	57.8cm/17.8m	3.7 m	11.6 m
B4top	beach face	Clastic: rock (3)	*Ulva, Enteromorpha*, barnacles, *Littorina scutulata*	2.2°	23cm/5.8m	3.12 m	29.4m
B4bottom	beach face	Clastic: mud	*Ulva, Enteromorpha*, barnacles, *Littorina scutulata*			2.9 m	35.2 m
B5	flat	Clastic: sand/mud	sand flat; tidal ponds with various invertebrates; *Zostera* spp		not measured		
B6	flat	Clastic: sand/mud	*Zostera marina* beds		not measured		
			Overall slope 3.3°				
			(+) Potential Spawning Habitat at 0-5.6 m horizontal distance from B1				

*measured from band height and width measurements
**using 4.4m as maximum tide height

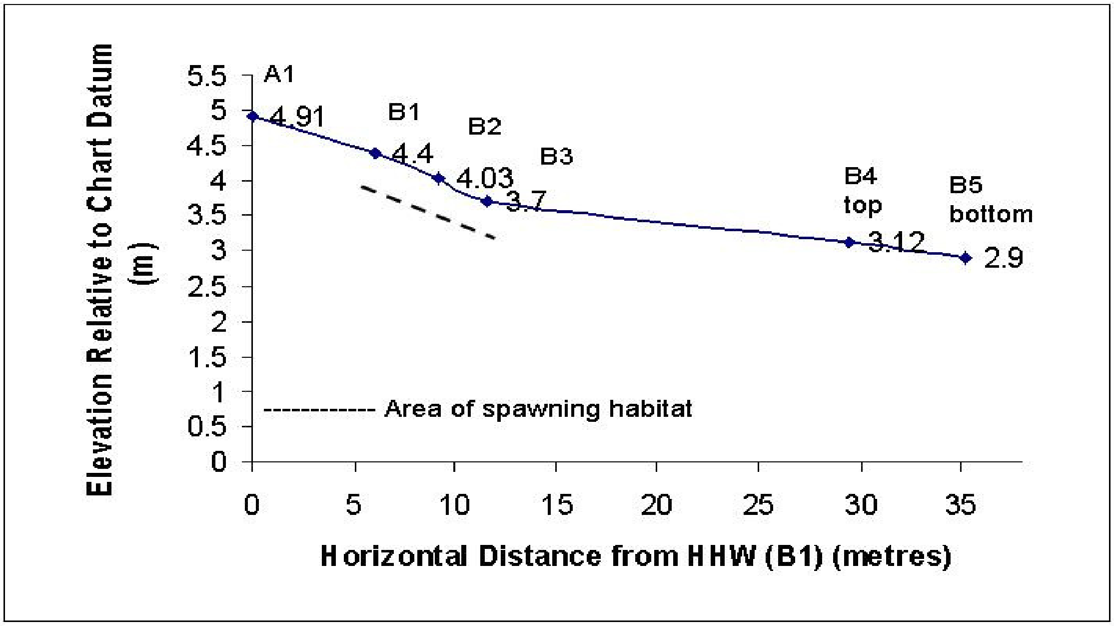


Figure 16: 2007 vertical beach profile of the across-shore transect with elevations, Centennial Beach, Boundary Bay Regional Park, Delta

Along shore facing south west

Along shore facing north

Down beach

Up beach

All photos: Ramona C. de Graaf

Sediment Character: 3, 2

Figure 17: Centennial Beach, Boundary Bay Regional Park, Delta: across-shore transect location and 2007 summer sediment characteristics.

Crescent Beach and Blackie Spit, South Surrey, BC

At Crescent Beach, Surrey, BC two stations were routinely sampled and two stations at Blackie Spit. At Crescent Beach, the first station was located at Beecher Place and the second approximately 300 metres north-west of Beecher Place. At Blackie Spit, two stations were routinely sampled with one station on either side of the Spit.

At Crescent Beach, five sampling stations yielded surf smelt spawn on June 20 and 24, 2007. Surf smelt spawning activity was also detected on August 9 and 17 2007. Surf smelt spawn was found along the south-west facing beach from Sullivan Point to the end of the main foot path east of Beecher Place. The highest spawn density was found near Beecher Place.

Beecher Place Station, Crescent Beach Station, Surrey, BC

Crescent Beach is south-west facing and exposed to the Strait of Georgia. This site is used for various human activities including boating, beach combing, sun bathing, dog walking, and is heavily impacted by human activities. Backshore development includes a side walk, residences and extensive riprap in the area. Groins in the intertidal are evident from Sullivan Point to past Beecher Place. The presence of the backshore structures and intertidal groins will impede the movement of eroded gravels to and along the beach. Slope, sediment characteristics and horizontal distances of shoreline components are in Figures 18 and 19 and Table 5. The Beecher Place station is coded as being an uplands (3)—50% impacted by groins and riprap in the upper intertidal zone as well as highly modified supralittoral zone. There is no vegetation present to shade the gravel beach. The beach character to support spawning by surf smelt or Pacific sand lance is good and is largely composed of deep, coarse (4) and medium gravels (3) with a low amount of pea gravel (2) with a sand base.

FoSBS Positive Samples: Surf smelt spawn was detected on June 20, 24, August 9 and August 17, 2007.

Recommendations Summary: <u>Protecting and enhancing habitat attributes at this surf smelt spawning beach is crucial</u>. Appropriate experts should be consulted to comment on sediment conditions particularly if sediment character is continuing to deteriorate. Shoreline alteration includes intertidal groins, riprap and extensive backshore modification. The current political reality of this area of beach is recognized. However, due to the importance of this spawning beach to the larger area of Boundary Bay, the entire stretch of beach (east and west of Beecher Place to Sullivan Point) should be examined for current sediment transport mechanisms. Also, the City of Surrey should consider re-engineering storm protection measures using modern "soft shore" techniques to provide for the protection required for beach-front property owners as well as maintaining the crucial ecological functioning of this beach. At the minimum, sediments should be enhanced with smaller sediments so that surf smelt egg mortality can be decreased. The possibility of planting marine riparian vegetation should be considered and discussed with relevant interest groups.

Table 5: 2007 across-shore banding profiles, Beecher Place Station, Crescent Beach.

Location: Crescent Beach, Beecher Place
Wave Exposure: exposted; south-west facing
Backshore: grass lawns; gravel side walk; residential housing
Shading: no shade; impacted shoreline

Zone/Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
A1	beach berm	Clastic: sand; rock (4)	salt tolerant plants	6°	117.8cm/11 m	5.8 m	11 m
B1 (+)	beach face	Clastic: rock (4,3)	rock; sand; logs; drift *Zostera* spp	9.7°	50.2cm/3 m	4.6 m	0 m
B2 (+)	beach face	Clastic: rock (4,3,2)	rock	8.0°	80.9cm/6 m	4.1 m	3 m
B3 top	beach face	Clastic: rock (4)	rock; barnacles; *Ulva*	5.0°	43 cm/5 m	3.3 m	9 m
B3 bottom	beach face	Clastic: cobble (5), rock (4)	rock, sand			2.9 m	14 m
B4	sand flat		sand		not measured		
B5	sand flat		sand; *Zostera* spp		not measured		
			Overall slope 6.7°				
			(+) Potential spawning habitat 0-6 m horizontal distance from B1				

*measured from band height and width measurements
**measured against a tide height of approximately 2.9 m at the beach face B3-bottom

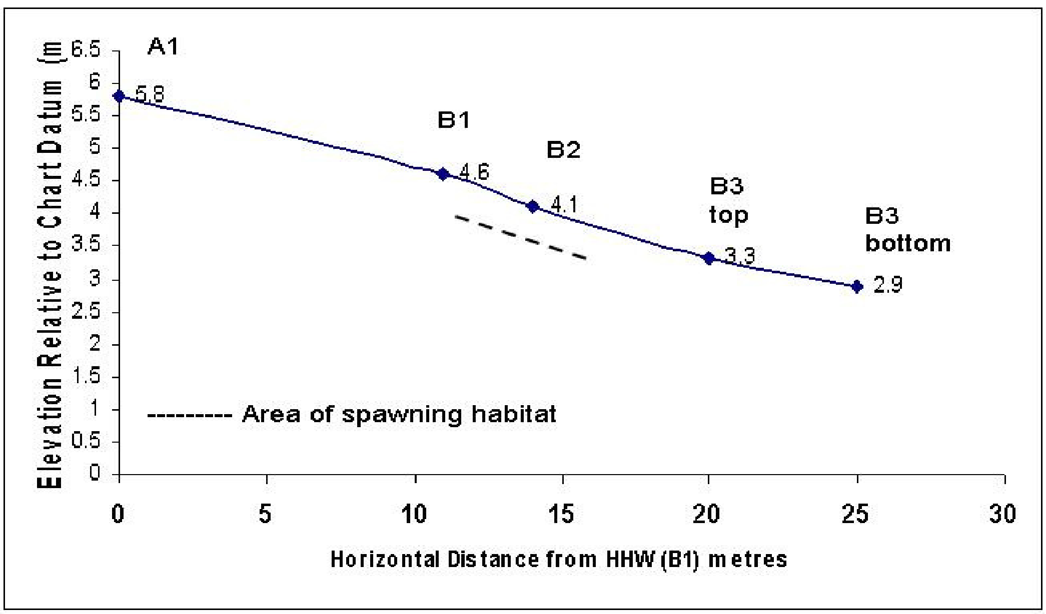


Figure: 18: 2007 Vertical beach profile of the across-shore transect with elevations, Beecher Place Station, Crescent Beach, Surrey, BC.

All photos: Ramona C. de Graaf

Figure 19: Beecher Place Station, Crescent Beach, Surrey, BC: across-shore transect location and 2007 summer sediment characteristics.

Blackie Spit Stations, Surrey, BC

Blackie Spit stations face north-west and south-east and are wave-protected beach faces. The areas sampled were within the bird sanctuary area but are still used by beach and dog walkers. The area is a flat, wide, sandy spit with sediment characteristics being different on either side of the spit. The area has been restored for wildlife values. There are no structures in the backshore or the intertidal to impede the movement of eroded gravels along the beach. These stations are coded as being an upland (1)—natural (0% impact). There is no shading vegetation present. On the north-west face, the beach sediments are very shallow and largely comprised of medium gravel (3) and some pea gravel (2) with shell hash and a sand base and could support spawning surf smelt or Pacific sand lance. Surf smelt in Washington State have been observed to use coarse gravel spit beaches. The sediment condition at this station is poor and sources of gravel input from terrestrial sources is uncertain. On the south-east beach, the gravels are likely deposited from the Nicomekl River outflow and the beach character is mainly coarse sand (1) and shell hash conducive to support sand lance spawning (Figure 20). The minimal wave action in the area is more indicative of an estuarine area. Shoreline components for these stations were not measured.

A. Blackie Spit, south-west station
Along beach looking south-west.

B. Blackie Spit, south-west station
Sediment:shell-hash; coarse sand.

Figure 20: South-west station, Blackie Spit, BC. Spring 2007 sediment conditions.

White Rock and South Surrey, British Columbia

Historically, White Rock beaches were used by surf smelt for spawning (Hart and McHugh (1944), Dr. J.D. McPhail, pers. comm. 2005). Today, from Crescent Beach to the Canadian/United States border, the upper intertidal zone has been heavily impacted by the railway bed/riprap armouring either by placement of these structures within the upper intertidal zone (and the subsequent loss of this zone) or disrupting wave action leading to beach scour and a coarsening of sediments to the size of cobbles.

Few locations in White Rock were suitable for sampling. In White Rock, almost all of the upper intertidal has been lost and much of the sloping, high intertidal beach face replaced with riprap or large cobbles and boulders. Locations sampled or suitable for sampling included West Beach (White Rock Boat Ramp), Museum station (near the White Rock Museum and Archives), The Rock (White Rock), East Beach including two stations west of the Little Campbell River Estuary, and three stations along Beach Road/Peace Arch Park. The coarsest beaches were located in White Rock. Sediments more conducive to surf smelt spawning characteristics occurred on the west side of the Little Campbell River and near the Canadian/United States border (Peace Arch Park). The area of Peace Arch Park is near surf smelt spawning and sand lance spawning beaches in Blaine, WA, near Semiahmoo Spit and Birch Point (Penttila 2000, 2001). The beaches near the Peace Arch Park/Beach Road are heavily impacted by the railway bed. This has resulted in a shallow surface sediment deposit unlikely to be conducive to surf smelt but which may support sand lance spawning.

West Beach Boat Ramp Station, White Rock, BC

The beach is south/south-west facing and exposed to the Strait of Georgia. In the past, a recreational surf smelt fishery occurred at this section of beach, and it was heavily used for spawning. Human activity is high at this beach area and includes boat/kayak launching, beach combing, sun bathing, and other recreational activities (Figure 21). Like other areas in White Rock, the backshore has been developed into parking lots and grassy lawns. The upper intertidal zone was replaced by the railway, promenade, seawalls, riprap, and outfall pipes placed perpendicular to and on top of the beach face. The placement of a concrete boat ramp extending seaward would likely impede sediment movement and degrade the sediment character to the east to the state of a coarseness not useable for forage fish spawning. Some sections of this beach, such as at the museum area, have a beach berm with natural large woody debris (logs). Outfall pipes may impede the movement of eroded gravels along the beach. On inspection beach slope and gravel character on either side of an outfall pipe, is markedly different. On the west side of the pipes, the beach character is that of a coarse (4) and medium gravel (3) with a sand base and a higher beach elevation and slope (indicative of collection of sediments due to the impeding pipe). On the east side of the pipes, the beach character is that of cobble (5) with no smaller gravels and a lower beach elevation (indicative of a sediment starved condition). The West Beach Boat Ramp station is coded as being an uplands (5)—intertidal (100% impact). There is no shading vegetation. The beach character area near the west beach boat ramp is highly degraded with coarse (4) and medium gravel (3) and cobble (5) and the sediment bands are narrow (being less than 1 metre in width). The sediments are shallow and with a minimal fraction of pea gravel. After sieving to 2.0 mm, little gravel sediment remains. Like other areas in White Rock, the beach is likely starved of smaller, eroding terrestrial gravels due to the parking lots, railway bed, promenade, and grass lawns. Shoreline component measurements of this station were not taken.

Recommendations Summary: Shoreline modifications along this stretch of beach are numerous. However, along a beach section from the West Beach Boat Ramp to the White Rock Pier opportunities exist for restoration and enhancement. At the minimum, sediments should be enhanced by adding gravel as well as removing outfall pipes laying on the beach face to promote sediment transport. Planting of marine riparian vegetation would also enhance the spawning potential. Although large areas of the upper intertidal are lost to the extensive riprap and armouring, there are several available lengths of beach that, after restoration, would be long enough to attract surf smelt to spawn, restoring a historical legacy of this area both for ecological function and recreational use. One area is near the first outfall pipe east of the West Beach Boat Ramp and a second is near the outfall pipe just west of the White Rock Museum and Archives. Exact spatial data of these locations can be provided.

Figure 21: West Beach Boat Ramp Station, White Rock, BC. Across-shore transect location and 2007 summer sediment characteristics.

The Rock Station, White Rock, BC

The beach at the Rock is south, south-west facing and exposed to the Strait of Georgia. This beach is heavily used as White Rock attracts a very high number of visitors to the BC Wildlife Management Area. The site is heavily impacted by human activities. Backshore development includes parking lots, grass lawns and the upper intertidal was likely buried or replaced by the railway bed, riprap, grass lawn. At tide heights below maximum high tide, the tide line is at the riprap structures indicating a loss of upper intertidal elevation (being spawning habitat for surf smelt and sand lance). In the intertidal, waste-water pipes, the White Rock Pier and jetty impede the transport of beach sediments along the beach as is evident from the higher elevation of the sand flat behind the jetty/pier structure. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of the Rock Station are in Figures 22 and 23 and Table 6. The station is coded as being an uplands (5)—intertidal 100% impact. There is no shading vegetation. The beach character to support spawning by surf smelt or Pacific sand lance is of a moderate quality with shallow, medium gravel (3) with pea gravel (2) and a sand base. Little gravel sediment is retained after sieving to 2 mm. Much of the habitat to the east of the Rock is of a shallow veneer of pea gravel until the beach face is lost to the riprap piles which continue eastward.

Recommendations Summary: Shoreline modifications along this stretch of beach are numerous. East of the White Rock Pier, few locations along the White Rock beach are suitable for enhancement (although large re-engineering projects would likely be possible). At the Rock station, the sediments should be, at the very least, enhanced with a mixture of smaller gravels to improve the sediment character and increase the width of potential spawning zone. Also, planting of marine riparian vegetation would be advantageous. By improving stretches of beach in this area as well as areas of beach near the West Beach Boat Ramp and near the Little Campbell River Estuary, may provide enough spatial area to attract surf smelt back to their historic White Rock spawning grounds.

Table 6: 2007 across-shore banding profiles, The Rock Station, White Rock, BC.

Location: White Rock, The Rock Station
Wave Exposure: exposed, south south-west facing
Backshore: grassy lawns, promenade
Shading: no shading; heavily impacted/altered intertidal.

Zone/Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height m	Horizontal Distance from HHW m
Backshore			grass lawn; promendade		not measured		
A1	beach berm	Clastic: sand, rock (4)	logs; sand, coarse gravel	4°	74 cm/11.95 m	5.14 m	11.95 m
B1 top (+)	beach face	Clastic: rock (4,3)	logs; coarse gravel	9.5°	118 cm/7.3 m	4.4 m	0 m
B1 bottom (+)	beach face	Clastic: rock (4,3)	logs; coarse gravel			3.2 m	7.3 m
B2	sand flat	Clastic: mud, sand	various invertebrates, *Zostera* spp		not measured		
B3	eelgrass beds	Clastic: sand	*Zostera marina* beds		not measured		
			Overall slope 5.5°				
			(+) Potential spawning habitat at 0-7.3 m from B1				

*measured from band height and width measurements
**using 4.4m as maximum tide height

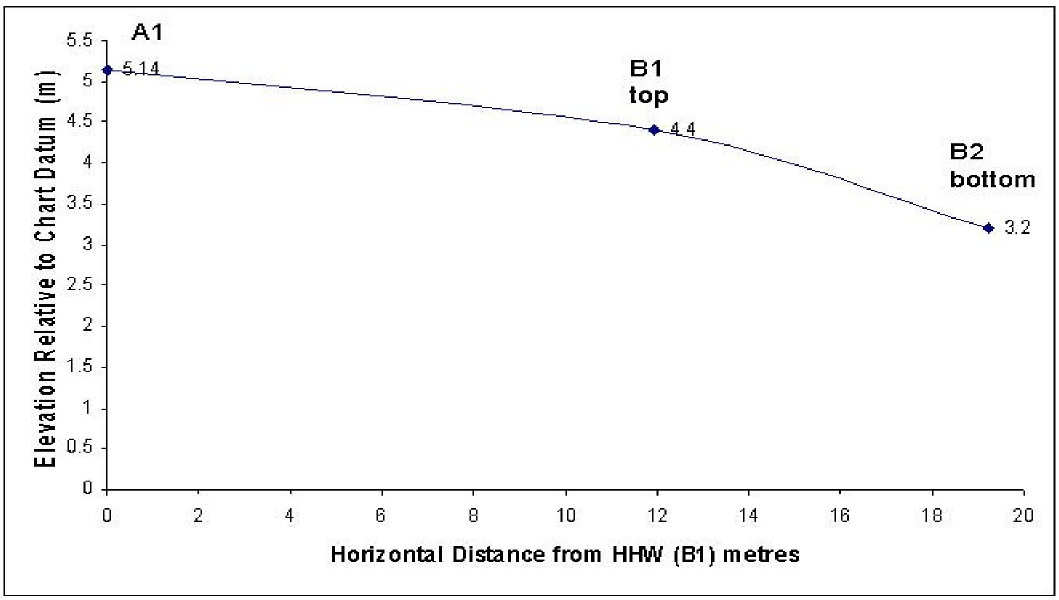


Figure 22: 2007 vertical beach profile of the across-shore transect with elevations, The Rock Station, White Rock, BC.

All photos Ramona C. de Graaf

Figure 23: The Rock Station, White Rock, BC: across-shore transect location and 2007 summer sediment characteristics.

Little Campbell River Estuary Station, East Beach

The beach to the west of the Little Campbell River is south-west facing and exposed to the Strait of Georgia. Throughout the year, large amounts of vegetative debris is present and mainly located in the upper intertidal area. This beach is heavily impacted by human activities similar to other areas in White Rock. Backshore development includes the railway bed which would stop the movement of gravels to the beach. There are no structures located in the intertidal zone (such as seawalls, piers or groins) impeding the movement of eroded gravels along the beach. Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of the LCRE Station are in Figures 24 and 25 and Table 7. The station is coded as being an uplands (2)—25% impact. While vegetation (short and tall shrubs; deciduous trees) is present, none of the vegetative canopy shades the upper intertidal. The beach character to support spawning by surf smelt or Pacific sand lance is moderate and is largely composed of coarse gravel (4). Little medium gravel (3) and small amounts of pea gravel (2) remain after sieving to 2 mm(*). Due to the coarse nature of the sediments and the narrow width of the potential spawning zone, sampling stations along this stretch of beach are limited.

Recommendations Summary: This area of beach has high potential for enhancement due to the wide beach berm and lack of riprap armouring. The sediment character can be improved by supplying a mixture of smaller gravels(*).

Table 7: 2007 across-shore banding profiles, Little Campbell River Estuary Station, Surrey, BC

Location:Little Campbell River Estuary Station
Wave Exposure: exposed, south west facing
Backshore: railway bed
Shading: limited shading; heavily impacted/altered intertidal.

Zone/Com-ponent	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height (m)	Horizontal Distance from HHW m
Backshore							
A1	beach berm	Clastic: sand	shrubs, decidious trees		not measured		
B1(+)	beach face	Clastic: rock (3,4)	logs; no vegetation	~7.1°	95.7cm/7.7m	4.4 m	0 m
B2 top	beach face	Clastic: rock (5)		~4.2°	91.5cm/12.7m	3.44 m	7.7 m
B2 bottom	beach face					2.52 m	20.4m
B3	mud flat	mud/sand			not measured		
			Overall slope ~5.2° (+) Potential spawning habitat at 5.3 - 6.5 m from B1				

*measured from band height and width measurements
**using 4.4m as maximum tide height

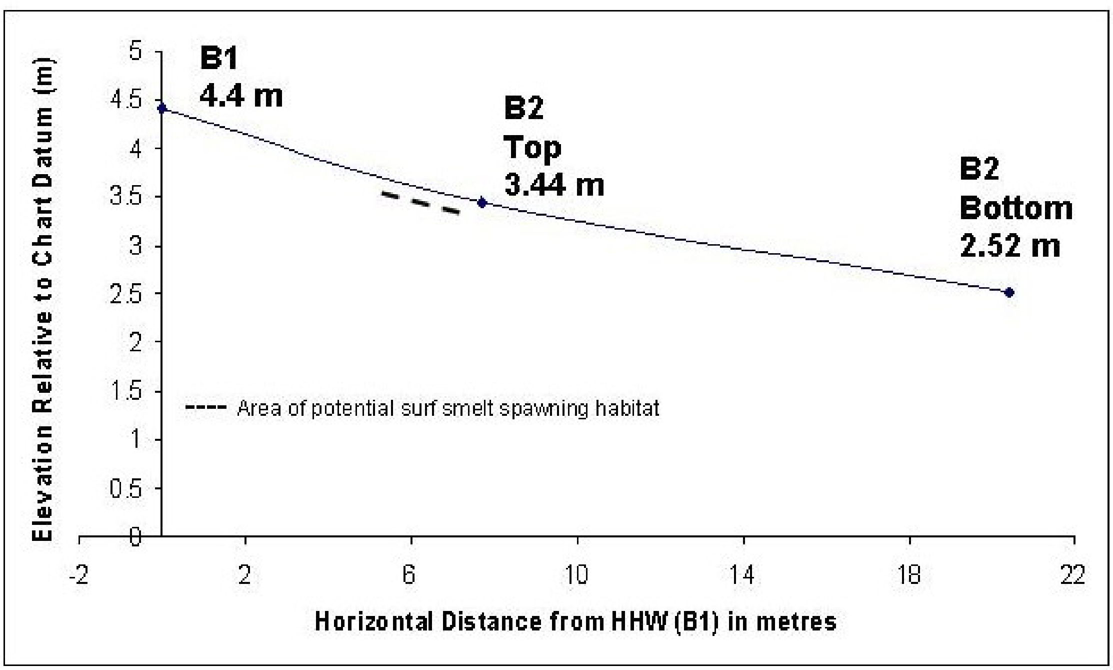
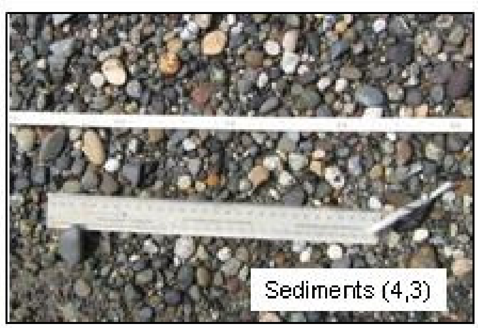


Figure 24: 2007 vertical beach profile of the across-shore transect with elevations, Little Campbell River Estuary Station, Surrey, BC.



All photos Ramona C. de Graaf

Figure 25: Little Campbell River Estuary Station, East Beach: across-shore transect location and 2007 summer sediment characteristics.

Peace Arch Park/Beach Road Stations

The beach at the Peace Arch Park location is west facing and exposed to the Strait of Georgia. This beach has been heavily impacted by development. Other than nominal foot traffic, this site receives little human activity. The backshore and part of the upper intertidal has been impacted by the railway bed and riprap. The upper beach component ("A"-beach berm or supralittoral) and likely some of the uppermost B1 component is buried under the railway bed and riprap. Waste-water outfalls extend into the intertidal and pipes are laid on top of the beach face perpendicular to the shore. These waste-water outfalls impede the shoreward transport of sediments. Backshore development and the outfalls may impede the movement of eroded gravels to and along the beach. The resulting beach is in a starved sediment condition, has an overall decreased beach elevation (and increased slope), and deep eelgrass/seaweed wracks are deposited on top of the narrow spawning zone which remains.

Across-shore banding profiles (including vertical profiles of the across-shore transect with elevations) of the Peace Arch Border Station are in Figures 26 and 27 and Table 8. The station is coded as being an uplands (4)—intertidal (75% impacted) (Figure 27). While vegetation (short and tall shrubs; deciduous trees) are present on the railway bed, little of the vegetative canopy shades the upper intertidal. A few crab apple trees and shrubs are present with a canopy that would shade 25% of the station. In the fall of 2007, it was noted that these shrubs were cut down. The beach character to support spawning by surf smelt or Pacific sand lance is moderate to poor and is largely composed of a narrow spawning width with shallow surface deposit of medium gravels (3) with a sand base and a veneer of pea gravel (2). Little gravel sediment remains after sieving to 2 mm(*). The beaches are suitable for sand lance spawning, but spawning by surf smelt may be limited due to the sediment character, narrow spawning zone width and proximity of the mud flat. This area is close to confirmed sand lance and surf smelt spawning areas located in Blaine, WA at Semiahmoo Spit and Birch Bay (Penttila 2000, 2001).

Recommendations Summary: The beaches at this station are starved of sediments likely due to interruption of along-beach sediment transport and the railway bed blocking the transport of eroding sediments. Removal of outfall pipes lying on top of the beach face may improve movement of sediments to this beach area. Sediments enhanced can be achieved by adding a mixture of smaller gravels(*).

Table 8: 2007 across-shore banding profiles, Peace Arch Border Station, Surrey, BC

Location: Peace Arch Border Station
Wave Exposure: exposed, west facing
Backshore: riprap; railway bed
Shading: limited shading; heavily impacted/altered intertidal.

Zone/Component	Band (form)	Substrate (material)	Vegetation/Invertebrate Species	*Slope	Height/Width	**Tide Height (m)	Horizontal Distance from HHW m
Backshore					not measured		
A1	beach berm	Clastic: sand, rock (3)	Himilayan blackberry, shrubs, sea vetch	~7.7°	48.5cm/3.8m	4.9 m	3.8 m
B1(+)	beach face	Clastic: rock (3), shell fragments		~8.3°	81cm/5.7m	4.4 m	0 m
B2 top	beach face	Clastic: rock (4), no sand base		~6.6°	37cm/3.3m	3.59 m	5.7m
B2 bottom	beach face					3.22 m	9.0 m
B3	mud flat	mud/sand			not measured		
			Overall slope ~7.5°				
			(+) Potential spawning habitat at 3.3-9.0m from B2(bottom)				

*measured from band height and width measurements
**using 4.4m as

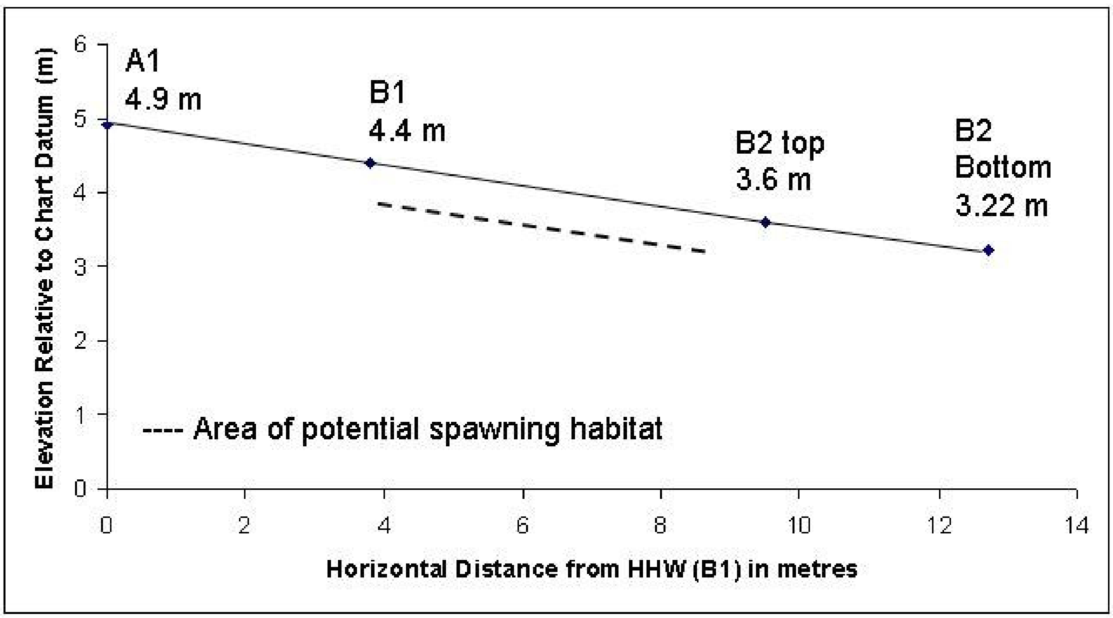
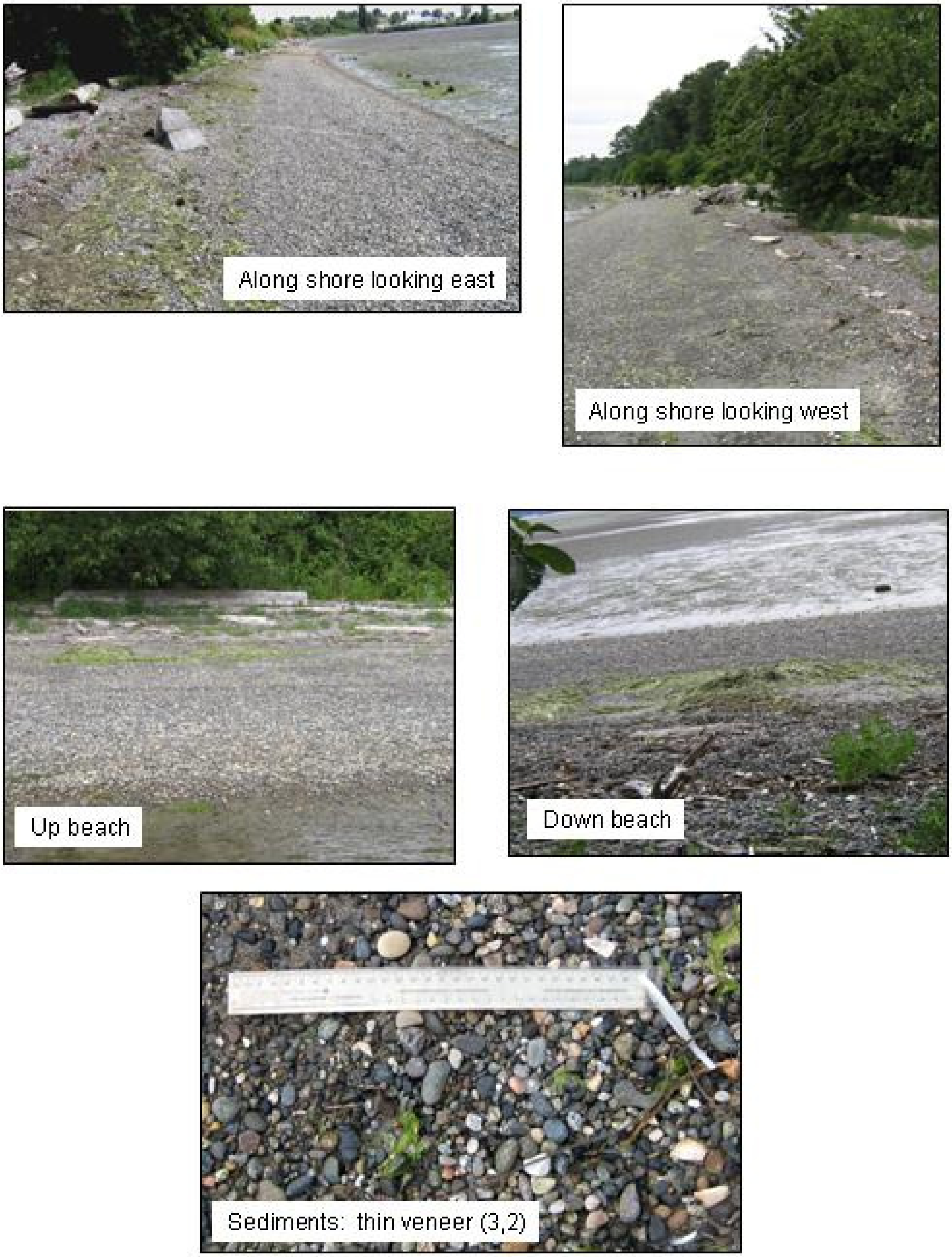


Figure 26: 2007 vertical beach profile of the across-shore transect with elevations, Peace Arch Border Station, Surrey, BC.



All photos Ramona C. de Graaf

Figure 27: Peace Arch border station, East Beach, Surrey, ,BC: across-shore transect location and 2007 summer sediment characteristics.

REFERENCES CITED:

Brennan, JS and H Culverwell (2004) Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Washington Sea Grant Program, Seattle, WA, pp 1-34.

Hart, JL, and JL McHugh (1944) The smelts (Osmeridae) of British Columbia. Bull. Fish. Res. Board Can. No. 64.

Blaseckie, A, Lewis, P, Rach, L, Turk, J. (2002). Pacific Sand Lance *Ammodytes hexapterus*) Spawning Habitat Survey. Prepared for Camosun College Environmental Technology Program submitted June 24, 2002. pp 1-49 with appendices.

Levings, CD, and G. Jamieson (2001) Marine and Estuarine Riparian Habitats and their role in coastal ecosystems, Pacific Region. CSAS Research Document 2001/109. Fisheries and Oceans Canada, Science Board, pp. 1-42.

Levings, CD, personal communications (2007) and documents *in press*.

Levy, DA (1985). Biology and Management of Surf Smelt in Burrard Inlet, Vancouver, BC. Technical Report (Westwater Research Centre) No. 28, UBC, Northburn Printers & Stationers Ltd., pp 1 – 44.

Friends of the San Juans (2004). Documented surf smelt and Pacific sand lance spawning beaches in San Juan County with a summary of protection and restoration priorities for forage fish habitat. http://www.sanjuans.org/pdf_document/foragefishfinalreport.pdf.

McPhail, JD (personal communications 2005).

Morgan, JD and CD Levings (1989) Effects of suspended sediment on eggs and larvae of lingcod (*Ophiodon elongates*), Pacific herring (*Clupea harengus pallasi*), and surf smelt (*Hypomesus pretiosus*). Canadian Technical Report of Fisheries and Aquatic Sciences No. 1729, DFO, pp 1-29.

Penttila, D (2000) Document spawning seasons of populations of the Surf Smelt, *Hypomesus*, in the Puget Sound Basin, WDFW Marine Resources Division, Briefing Report, pp. 32.

Penttila, D (2001) Effects of Shading Upland Vegetation on Egg Survival for Summer-spawning Surf Smelt on Upper Intertidal Beaches in Puget Sound. Proceedings of the Puget Sound Research Conference (2001).

Penttila D 2001 Documented spawning areas of the Pacific Herring, *Clupea*, the Surf Smelt, *Hypomesus*, and the Pacific sand lance, *Ammodytes*, in Whatcom County, Washington. WDFW Marine Resources Division, Manuscript Report, pp. 18.

Penttila D, personal communications 2005 and 2007

Penttila D 2005 Forage Fish Spawning Habitats, Washington Department of Fish and Wildlife Priority Habitat and Species Management Recommendations. June 2005, 1-15.

Rice CA 2006 Effects of Shoreline Modification on a Northern Puget Sound Beach: Microclimate and Embryo Mortality in Surf Smelt (*Hypomesus pretiosus*). Estuaries and Coasts, Vol 29(1) 63-71.

Therriault, TW, McDiarmid AN, and DE Hay (2002) Review of Surf Smelt (*Hypomesus pretiosus*) biology and fisheries with suggested management options for British Columbia. FOA CSAS 2002.

Thuringer, P (2003). Documenting Pacific sand lance (*Ammodytes hexapterus*) spawning habitat in Baynes Sound and the potential interactions with intertidal shellfish aquaculture. Archipelago Marine Research, pp1-32.

Williams, J (personal communications 2007).

Appendix A – Dates and GPS Locations of Bulk Samples

BEACH AND STATION CODES								
BBRP	Boundary Bay Regional Park				BSp	Blackie Spit		
	IN=inside park				CrBe	Cresent Beach		
	OUT=outside park				WR	White Rock		
TSW	Tsawwassen Beach (including Tsatsu shores)					BR=Boat Ramp		
	BR=Border site					R=the Rock		
	FG=Fred Gingell Park				LCRE	Little Campbell Rv Estuary		
	TS=Tsatsu shores				PA	Peace Arch		
Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
070606	PA_1	Can/US border	49	00	439	122	45	899
070606	PA_1				426			879
071306	PA_1	Peace Arch	49	00	056	122	45	412
071306	PA_1		49	00	070	122	45	421
071306	PA_2		49	00	056	122	45	408
071306	PA_2		49	00	070	122	45	419
071306	PA_3		49	00	101	122	45	446
071306	PA_3		49	00	115	122	45	461
071506	WR_1	West Beach	49	01	499	122	49	396
071506	WR_1		49	01	497	122	49	384
071506	WR_2		49	01	497	122	49	384
071506	WR_2		49	01	492	122	49	339
071506	WR_3		49	01	492	122	49	339
071506	WR_3		49	01	490	122	49	309
072806	LCRE_1		49	00	797	122	46	833
072806	LCRE_1		49	00	802	122	46	835
072806	LCRE_2		49	00	797	122	46	833

072806	LCRE_2		49	00	792	122	46	807
072806	LCRE_3		49	00	768	122	46	713
072806	LCRE_3		49	00	777	122	46	751
072806	LCRE_4		49	00	765	122	46	694
080206	CrBe_1		49	02	687	122	53	073
080206	CrBe_1		49	02	704	122	53	066
080206	CrBe_2		49	02	774	122	53	065
080206	CrBe_2		49	02	772	122	53	049

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
080506	TSW_1	FG	49	00	618	123	05	598
080506	TSW_2	FG	49	00	497	123	05	543
080506	TSW_2	FG						
080506	BBRP_1	OUT	49	00	337	123	02	140
080506	BBRP_1		49	00	348	123	02	134
080506	BBRP_2	OUT	49	00	476	123	02	129
08506	BBRP_2		49	00	489	123	02	127
082406	PA_1		49	00	203	122	45	553
082406	PA_1		49	00	214	122	45	566
082406	PA_2		49	00	065	122	45	425
082406	PA_2		49	00	050	122	45	408
082406	PA_3		49	00	186	122	45	528
082406	PA_3		49	00	179	122	45	522
082406	LCRE_1		49	00	789	122	46	801
082406	LCRE_1		49	00	771	122	46	752
082606	BBRP_1	IN	49	01	082	123	02	409
082606	BBRP_1	IN	49	01	099	123	02	424
082606	BBRP_2	IN	49	01	053	123	02	391
082606	BBRP_2	IN	49	01	038	123	02	387
082606	BBRP_3	OUT	49	00	485	123	02	132
082606	BBRP_3	OUT	49	00	504	123	02	127
082606	BBRP_4	OUT	49	00	374	123	02	142
082606	BBRP_4	OUT	49	00	355	123	02	138
092106	BBRP_1	IN	49	01	056	123	02	388
092106	BBRP_1		49	01	067	123	02	397
092106	BBRP_2	IN	49	01	030	123	02	385
092106	BBRP_2		49	01	014	123	02	384
092106	BBRP_3	IN	49	00	917	123	02	350
092106	BBRP_3		49	00	881	123	02	323
092106	BBRP_4	IN	49	00	881	123	02	323
092106	BBRP_4		49	00	809	123	02	293

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
092306	CrBe_1		49	02	679	122	53	069
092306	CrBe_1		49	02	692	122	53	066
092306	CrBe_2		49	02	777	122	53	054
092306	CrBe_2		49	02	713	122	53	068
092306	PA_1		49	00	137	122	45	477
092306	PA_1		49	00	146	122	45	487
092306	PA_2		49	00	161	122	45	501
092306	PA_2		49	00	268	122	45	626
092306	PA_3		49	00	436	122	45	906
092306	PA_3		49	00	364	122	45	780
100706	BBRP_1	IN	49	00	850	123	02	309
100706	BBRP_1	Rescue Station	49	00	868	123	02	313
100706	BBRP_2	IN	49	00	961	123	02	368
100706	BBRP_2		49	00	976	123	02	377
100706	BBRP_3	IN	49	01	094	123	02	341
100706	BBRP_3		49	01	195	123	02	519
100706	TSW_1	TS	49	01	373	123	06	176
100706	TSW_1	TS	49	01	368	123	06	152
100706	TSW_2	TS	49	01	363	123	06	138
100706	TSW_2	TS	49	01	317	123	06	044
102806	PA_1		49	00	155	122	45	499
102806	PA_1		49	00	135	122	45	473
102806	PA_2		49	00	208	122	45	552
102806	PA_2		49	00	221	122	45	570
102806	PA_3		49	00	375	122	45	782
102806	PA_3		49	00	337	122	45	700
102906	BBRP_1		49	00	807	123	02	287
102906	BBRP_1		49	00	802	123	02	292
102906	BBRP_2		49	00	864	123	02	314
102906	BBRP_2		49	00	880	123	02	320
102906	BBRP_3		49	01	059	123	02	390

102906	BBRP_3		49	01	946	123	02	360
Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
092306	CrBe_1		49	02	679	122	53	069
092306	CrBe_1		49	02	692	122	53	066
092306	CrBe_2		49	02	777	122	53	054
092306	CrBe_2		49	02	713	122	53	068
092306	PA_1		49	00	137	122	45	477
092306	PA_1		49	00	146	122	45	487
092306	PA_2		49	00	161	122	45	501
092306	PA_2		49	00	268	122	45	626
092306	PA_3		49	00	436	122	45	906
092306	PA_3		49	00	364	122	45	780
100706	BBRP_1	IN	49	00	850	123	02	309
100706	BBRP_1	Rescue Station	49	00	868	123	02	313
100706	BBRP_2	IN	49	00	961	123	02	368
100706	BBRP_2		49	00	976	123	02	377
100706	BBRP_3	IN	49	01	094	123	02	341
100706	BBRP_3		49	01	195	123	02	519
100706	TSW_1	TS	49	01	373	123	06	176
100706	TSW_1	TS	49	01	368	123	06	152
100706	TSW_2	TS	49	01	363	123	06	138
100706	TSW_2	TS	49	01	317	123	06	044
102806	PA_1		49	00	155	122	45	499
102806	PA_1		49	00	135	122	45	473
102806	PA_2		49	00	208	122	45	552
102806	PA_2		49	00	221	122	45	570
102806	PA_3		49	00	375	122	45	782
102806	PA_3		49	00	337	122	45	700
102906	BBRP_1		49	00	807	123	02	287
102906	BBRP_1		49	00	802	123	02	292
102906	BBRP_2		49	00	864	123	02	314
102906	BBRP_2		49	00	880	123	02	320

102906	BBRP_3		49	01	059	123	02	390
102906	BBRP_3		49	01	946	123	02	360
Date	Site_Sample#	Location	Latitude			Longtitude		
110506	TSW_1	FG	49	00	461	123	05	551
110506	TSW_1	FG	49	00	478	123	05	546
110506	TSW_2	FG	49	00	470	123	05	545
110506	TSW_2	FG	49	00	502	123	05	546
110506	TSW_3	FG	49	00	765	123	05	661
110506	TSW_3	FG	49	00	788	123	05	671
110506	TSW_4	FG	49	01	297	123	06	016
110506	TSW_4	FG	49	01	304	123	06	030
112806	PA_1	Can/US border						
112806	PA_2							
112806	PA_3							
120506	TSW_1	Can/US border	49	00	136	123	05	464
120506	TSW_1		49	00	146	123	05	462
120506	TSW_2	Can/US border	49	00	206	123	05	490
120506	TSW_2		49	00	223	123	05	496
120506	TSW_3		49	00	306	123	05	529
120506	TSW_3		49	00	337	123	05	530
120506	TSW_4	Fred Gingell	49	00	449	123	05	544
120506	TSW_4		49	00	491	123	05	543
120906	PA_1		49	00	385	122	45	814
120906	PA_1		49	00	318	122	45	708
120906	PA_2		49	00	385	122	45	814
120906	PA_2		49	00	436	122	45	902
120906	PA_3		49	00	135	122	45	479
120906	PA_3		49	00	167	122	45	496
120906	PA_4		49	00	167	122	45	496
120906	PA_4		49	00	198	122	45	536
122806	BBRP_1	OUT	49	00	493	123	02	129

122806	BBRP_1	OUT	49	00	525	123	02	123
122806	BBRP_2	OUT	49	00	596	123	02	158
122806	BBRP_2	OUT	49	00	605	123	02	166

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
122806	BBRP_3	IN	49	00	958	123	02	365
122806	BBRP_3	IN	49	00	937	123	02	356
122806	BBRP_4	IN	49	00	835	123	02	312
122806	BBRP_4	IN	49	00	861	123	02	317
123006	PA_1		49	00	80	122	46	855
123006	PA_2		49	00	778	122	46	776
123006	PA_2		49	00	768	122	46	726
123006	PA_3		49	00	138	122	45	481
123006	PA_3		49	00	157	122	45	501
123006	PA_4		49	00	206	122	45	556
123006	PA_4		49	00	230	122	45	581
123006	PA_5		49	00	323	122	45	720
123006	PA_5		49	00	290	122	45	672
010407	BBRP_1	IN	49	01	373	123	02	821
010407	BBRP_1	lagoon	49	01	375	123	02	843
010407	BBRP_2	IN	49	01	369	123	02	822
010407	BBRP_2	lagoon	49	01	367	123	02	822
010407	BBRP_2		49	01	369	123	02	841
010407	BBRP_2		49	01	370	123	02	846
010407	BBRP_3		49	01	227	123	02	556
010407	BBRP_3		49	01	239	123	02	573
010407	BBRP_4					123	02	178
010407	BBRP_4		49	01	061	123	02	388
010407	BBRP_5	IN	49	00	838	123	02	313
010407	BBRP_5	Bag 1	49	00	842	123	02	310
010407	BBRP_5	IN	49	00	849	123	02	317
010407	BBRP_5	Bag 2	49	00	857	123	02	317
012007	TSW_1	Tsatsu	49	01	351	123	06	132
012007	TSW_1		49	01	344	123	06	116

012007	TSW_2	South Site	49	01	299	123	06	025
012007	TSW_2		49	01	281	123	06	017
012007	TSW_3	w of FG	49	00	987	123	05	763
012007	TSW_3		49	00	970	123	05	751

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
012307	TSW_1	Can/US border	49	00	173	123	05	471
012307	TSW_1	Can/US border	49	00	149	123	05	471
012307	TSW_2		49	00	115	123	05	449
012307	TSW_2		49	00	104	123	05	441
012307	TSW_3		49	00	101	123	05	447
012307	TSW_3		49	00	107	123	05	455
012307	TSW_4	FG	49	00	489	123	05	551
012307	TSW_4	FG	49	00	429	123	05	533
012307	TSW_5	FG	49	00	459	123	05	550
012307	TSW_5	FG	49	00	438	123	05	553
012407	WR_1		49	01	155	122	48	019
012407	WR_1	boat ramp						
012407	WR_2							
012407	WR_2	the Rock						
012607	BSp_1		49	03	735	122	52	594
012607	BSp_1		49	03	751	122	52	578
012607	BSp_2		49	03	748	122	52	658
012607	BSp_2		49	03	744	122	52	673
012607	BSp_3		49	03	206	122	53	184
012607	BSp_3		49	03	184	122	53	172
012607	BSp_4		49	03	320	122	53	241
012607	BSp_4		49	03	374	122	53	258
012707	BBRP_1	IN	49	00	801	123	02	297
012707	BBRP_1	IN	49	00	791	123	02	292
012707	BBRP_2	IN	49	00	844	123	02	314
012707	BBRP_2	IN	49	00	831	123	02	305
012707	BBRP_3	OUT	49	00	760	123	02	273
012707	BBRP_3	OUT	49	00	741	123	02	249
012707	BBRP_4	OUT	49	00	626	123	02	194
012707	BBRP_4	OUT	49	00	657	123	02	225
012707	BBRP_5	OUT	49	00	518	123	02	122

012707	BBRP_5	OUT	49	00	496	123	02	125

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
012807	PA_1		49	00	148	122	45	481
012807	PA_1		49	00	177	122	45	534
012807	PA_2		49	00	265	122	45	629
012807	PA_2		49	00	242	122	45	603
012807	PA_3		49	00	265	122	45	629
012807	PA_3		49	00	294	122	45	680
021607	BBRP_1		49	01	142	123	02	458
021607	BBRP_1		49	01	125	123	02	443
021607	BBRP_2		49	01	011	123	02	384
021607	BBRP_2		49	00	991	123	02	381
021607	BBRP_3		49	00	839	123	02	312
021607	BBRP_3		49	00	850	123	02	317
021807	TSW_1		49	00	195	123	05	480
021807	TSW_1		49	00	209	123	05	488
021807	TSW_2		49	00	456	123	05	543
021807	TSW_2		49	00	477	123	05	544
022007	PA_1		49	00	143	122	45	487
022007	PA_1		49	00	161	122	45	505
022007	PA_2		49	00	303	122	45	691
022007	PA_2		49	00	293	122	45	673
022007	CrBe_1		49	03	212	122	53	180
022007	CrBe_1		49	03	237	122	53	195
031007	PA_1							
031007	PA_1							
031007	BSp_1							
031007	BSp_1							
031007	CrBe_1							
03/17/07	BBRP_1	IN	49	00	964	123	02	372
03/17/07	BBRP_1		49	00	944	123	02	359
03/17/07	BBRP_2	IN	49	00	826	123	02	301
03/17/07	BBRP_2		49	00	790	123	02	296

03/17/07	BBRP_3	OUT	49	00	725	123	02	259
03/17/07	BBRP_3		49	00	690	123	02	242
Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
03/14/07	TSW_1		49	01	238	123	05	943
03/14/07	TSW_1		49	01	258	123	05	983
03/14/07	TSW_2	Tsatsu						
03/14/07	TSW_2							
03/14/07	TSW_3							
03/14/07	TSW_3							
031407	TSW_4	Fred Gingell						
031407	TSW_4							
04/06/07	TSW_1	Can/US border	49	00	078	123	05	419
04/06/07	TSW_1		49	00	091	123	05	432
04/06/07	TSW_2	Fred Gingell	49	00	475	123	05	542
04/06/07	TSW_2		49	00	489	123	05	544
04/06/07	TSW_3	Tsatsu	49	01	317	123	06	048
04/06/07	TSW_3		49	01	311	123	06	035
04/06/07	TSW_4	South Site	49	01	256	123	05	975
04/06/07	TSW_4		49	01	236	123	05	948
04/08/07	BBRP_1	OUT	49	00	540	123	02	125
04/08/07		outfall	49	00	553	123	02	132
04/08/07	BBRP_2	OUT	49	00	625	123	02	198
04/08/07		nr border BBRP	49	00	638	123	02	208
04/08/07	BBRP_3	IN	49	01	139	123	02	457
04/08/07		n of parking lot	49	01	109	123	02	429
04/08/07	BBRP_4	IN	49	01	013	123	02	386
04/08/07			49	01	994	123	02	381
04/09/07	CrBe							
04/09/07	BSp_1	South Site	49	03	744	122	52	607
04/09/07	BSp_1		49	03	753	122	52	582
04/09/07	BSp_2	North Site	49	03	709	122	52	726
04/09/07	BSp_2							
04/09/07	PA_1	Can/US border	49	00	126	122	45	465
04/09/07	PA_1		49	00	130	122	45	478

04/09/07	PA_2							
04/09/07	PA_2		49	00	163	122	45	505
04/09/07	PA_2							
Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
04/10/07	LCRE_1		49	00	830	122	46	942
04/10/07	LCRE_1		49	00	814	122	46	886
05/03/07	BBRP_1	OUT	49	00	485	123	02	128
05/03/07		South	49	00	511	123	02	124
05/03/07	BBRP_2	OUT	49	00	614	123	02	173
05/03/07		South	49	00	626	123	02	190
05/03/07	BBRP_3	IN	49	00	842	123	02	315
05/03/07		Rescue St 2						
05/03/07	BBRP_4	IN	49	00	027	123	02	389
05/03/07		n. of headland						
05/04/07	TSW_1		49	01	265	123	05	996
05/04/07	TSW_1							
05/04/07	TSW_2		49	01	278	123	06	005
05/04/07	TSW_2							
05/04/07	TSW_3		49	00	137	123	05	458
05/04/07	TSW_4							
05/04/07	TSW_4		49	00	441	123	05	532
05/09/07	PA_1		49	00	296	122	45	671
05/09/07	PA_1							
05/09/07	PA_2							
05/09/07	PA_2		49	00	185	122	45	534
05/09/07	PA_3							
05/09/07	PA_3							
05/14/07	CrBe_1		49	03	123	122	53	138
05/14/07	CrBe_1		49	03	111	122	53	129
05/14/07	CrBe_2		49	03	071	122	53	116
05/14/07	CrBe_2		49	03	056	122	53	105
05/14/07	LCRE_1		49	00	782	122	46	775
05/14/07	LCRE_1		49	00	774	122	46	742

06/19/07	BBRP_1	IN	49	00	835	123	02	311
06/19/07		IN	49	00	854	123	02	307
06/19/07	BBRP_2	IN	49	00	985	123	02	383
06/19/07		IN	49	01	008	123	02	373
Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
06/19/07	BBRP_3	IN	49	01	209	123	02	539
06/19/07		IN	49	01	229	123	02	558
06/19/07	BBRP_4	OUT	49	00	384	123	02	134
06/19/07		OUT	49	00	361	123	02	139
06/19/07	BBRP_5	OUT	49	00	612	123	02	170
06/19/07	BBRP_5	OUT	49	00	624	123	02	184
06/20/07	CrBe_1		49	03	165	122	53	154
06/20/07	CrBe_1		49	03	194	122	53	170
06/20/07	CrBe_2		49	03	286	122	53	215
06/20/07	CrBe_2		49	03	316	122	53	230
06/20/07	BSp_1		49	03	717	122	52	718
06/20/07	BSp_1							
06/20/07	LCRE_1		49	00	897	122	47	172
06/20/07	LCRE_1		49	00	884	122	47	129
06/20/07	LCRE_2		49	00	838	122	46	979
06/20/07	LCRE_2							
06/24/07	CrBe_1		49	03	350	122	53	247
06/24/07	CrBe_1		49	03	396	122	53	269
06/24/07	CrBe_2		49	03	466	122	53	216
06/24/07	CrBe_2		49	03	454	122	53	240
06/24/07	CrBe_3		49	03	123	122	53	138
06/24/07	CrBe_3		49	03	096	122	53	113
06/24/07	CrBe_4		49	03	071	122	53	113
06/24/07	CrBe_4		49	03	064	122	53	109
06/27/07	TSW_1							
06/27/07	TSW_1		49	00	145	123	05	471
06/27/07	TSW_2		49	00				
06/27/07	TSW_2		49	00	172	123	05	466

06/27/07	TSW_3		49	00	458	123	05	561
06/27/07	TSW_3		49	00	436	123	05	546
06/27/07	TSW_4		49	00	495	123	05	547
06/27/07	TSW_4		49	00	472	123	05	538

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
06/30/07	WR_1		49	01	396	122	48	843
06/30/07	WR_1							
06/30/07	WR_2		49	01	433	122	49	002
06/30/07	WR_2							
06/30/07	WR_3		49	01	189	122	48	182
07/01/07	PA_1		49	00	302	122	45	674
07/01/07	PA_1		49	00		122	45	
07/01/07	PA_2		49	00	165	122	45	494
07/01/07	PA_2		49	00		122	45	
07/13/07	WR_1							
07/13/07	WR_1							
07/14/07	PA_1							
07/14/07	PA_1							
07/14/07	PA_2							
07/14/07	PA_2							
07/14/07	LCRE_1							
07/14/07	LCRE_1							
07/15/07	CrBe_1		49	03	125	122	53	139
07/15/07	CrBe_1		49	03	110	122	53	129
07/15/07	CrBe_2		49	03	094	122	53	118
07/15/07	CrBe_2		49	03	079	122	53	108
07/15/07	CrBe_3		49	03	163	122	53	154
07/15/07	CrBe_3		49	03	149	122	53	145

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
07/17/07	BBRP_1	OUT	49	00	523	123	02	122
07/17/07	BBRP_1							
07/17/07	BBRP_2	IN	49	00	950	123	02	365
07/17/07	BBRP_2		49	00	965	123	02	373
07/17/07	TSW_1	Can/US border	49	00	143	123	05	464
07/17/07	TSW_1	Can/US border	49	00	130	123	05	457
07/17/07	TSW_2	Can/US border	49	00	140	123	05	460
07/17/07	TSW_2	Can/US border	49	00	150	123	05	469
07/17/07	TSW_3	FG	49	00	480	123	05	543
07/17/07	TSW_3	FG	49	00	473	123	05	546
08/09/07	CrBe_1		49	03	122	123	53	129
08/09/07	CrBe_1		49	03	144	123	53	142
08/09/07	CrBe_2		49	03	402	123	53	267
08/09/07	CrBe_2		49	03	355	123	53	248
08/09/07	CrBe_3		49	03	316	123	53	232
08/09/07	CrBe_3							
08/13/07	WR_1	Boat Ramp						
08/13/07	WR_1	Boat Ramp						
08/13/07	WR_2		49	01	370	122	48	773
08/13/07	WR_2							
08/15/07	BBRP_1	IN	49	00	851	123	02	316
08/15/07	BBRP_1		49	00	856	123	02	317
08/15/07	BBRP_2	IN	49	01	007	123	02	385
08/15/07	BBRP_2		49	01	015	123	02	384
08/15/07	BBRP_3	IN	49	01	171	123	02	496
08/15/07	BBRP_3		49	01	178	123	02	506
08/15/07	BBRP_4	OUT	49	00	511	123	02	122
08/15/07	BBRP_4							

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
08/17/07	CrBe_1		49	03	122	122	53	141
08/17/07	CrBe_1		49	03	116	122	53	131
08/17/07	CrBe_2		49	03	113	122	53	126
08/17/07	CrBe_2		49	03	121	122	53	130
08/17/07	WR_1	the Rock	49	01	191	122	48	202
08/17/07	WR_1	the Rock	49	01	228	122	48	275
08/17/07	PA_1		49	00	152	122	45	492
08/17/07	PA_1							
08/17/07	PA_2							
08/17/07	PA_2							
08/18/07	TSW_1	FG	49	00	473	123	05	542
08/18/07	TSW_1	FG	49	00	484	123	05	555
08/18/07	TSW_2		49	00	204	123	05	490
08/18/07	TSW_2		49	00	287	123	05	474
08/18/07	TSW_3	Can/US Border	49	00	143	123	05	460
08/18/07	TSW_3	Can/US Border	49	00	154	123	05	470
08/31/07	CrBe_1	Beecher	49	03	105	122	53	122
08/31/07	CrBe_1	Beecher			123			137
08/31/07	CrBe_2				157			149
08/31/07	CrBe_2				137			139
08/31/07	CrBe_3	Sullivan Pnt						
08/31/07	CrBe_3	Sullivan Pnt						
08/31/07	CrBe_4	Volley ball area						
08/31/07	CrBe_4	Volley ball area						
08/31/07	WR_1	Boat Ramp	49	01	403	122	48	869
08/31/07	WR_1		49	01	409	122	48	896
08/31/07	WR_2	the Rock	49	01	210	122	48	245
08/31/07	WR_2							

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
09/24/07	CreBe_1		49	03	121	122	53	135
09/24/07	CreBe_1							
09/24/07	CrBe_2							
09/24/07	BSp_1		49	03	721	122	52	698
09/24/07	BSp_1		49	03	710	122	52	729
09/25/07	TSW_1		49	00	208	123	05	485
09/25/07	TSW_1				187			491
09/25/07	TSW_2	Can/US Border			135			474
09/25/07	TSW_2				133			457
09/25/07	TSW_3	Can/US Border						
09/25/07	TSW_3							
09/25/07	TSW_3							
09/25/07	TSW_4	FG						
09/25/07	TSW_4							
09/25/07	TSW_5	FG						
09/25/07	TSW_5							
09/28/07	BBRP_1	OUT						
09/28/07	BBRP_1							
09/28/07	BBRP_2	IN						
09/28/07	BBRP_2							
09/28/07	BBRP_3							
09/28/07	BBRP_3							

Date	Site_Sample#	Location	Latitude			Longtitude		
			Degree	min	decmin	Degree	min	decmin
09/28/07	TSW_1		49	00	239	123	05	499
09/28/07	TSW_1							
09/28/07	TSW_2							
09/28/07	TSW_2							
09/28/07	TSW_3	FG	49	00	313	123	05	526
09/28/07	TSW_3	FG						
09/28/07	TSW_4	FG						
09/28/07	TSW_4	FG						
09/28/07	TSW_5							
09/28/07	TSW_5							
09/28/07	TSW_6							
09/28/07	TSW_6							
09/28/07	TSW_7		49	01	295	123	06	019
09/28/07	TSW_7		49	01	303	123	06	029
09/30/07	PA_1							
09/30/07	PA_1							
09/30/07	PA_2							
09/30/07	PA_2							

Appendix B: From Field Protocols of Moulton and Penttila

Field Records and Physical Data:

Data Fields: Environmental characteristics of the sampled location are recorded to help analyze results of sampling. These records are entered on the field data sheet, which is completed at the time of sampling (Figure 14). Personnel involved in sampling need to be listed on the bottom of the sheet in case there are questions regarding the data. The data sheet will be reviewed after the crew has returned from the field. The reviewer will indicate that the sheet has been completed by signing the space labeled "Reviewed by".

The data fields should be filled in as follows:

Last High Tide: Time and elevation of the last high tide - can be obtained from a current tide chart.
Island: Island Sampled
Date of Sampling:
Beach Number: Assigned Number for Beach being sampled.
Sample Number: Sample number from Sample Label.
Time: Time sample label is removed from the beach (0000-2400 hr)
Latitude/Longitude: Latitude and longitude in degrees, minutes, seconds

Beach: Character of the upper beach:

0 = mud,
1 = pure sand,
2 = pea gravel (fine gravel) with sand base,
3 = medium gravel with sand base,
4 = coarse gravel with sand base,
5 = cobble with sand base,
7 = boulder with sand base,
8 = gravel to boulders without sand base,
9 - rock, no habitat

Uplands: Character of the uplands (up to 1,000 ft):
1 = natural, 0% impacted (bulkhead, rip-rap, housing, etc.);
2 = 25% impacted; 3 = 50% impacted; 4 = 75% impacted, 5 = 100% impacted

Sample Zone: Distance of collection parallel from a land mark in feet to the nearest ½ foot. Used to determine the tidal elevation of the spawn deposit

Land Mark: Land mark for sample collection:
1 = down beach from last high tide mark
2 = up beach from last high tide mark
3 = down beach from second to last high tide
4 = down beach from upland toe

5 = up beach from waterline at the time noted

Tidal Elevation: This is determined in the office using the location and time data.

Smelt, Sand Lance, Rock Sole, Herring: subjective field assessment of spawn intensity:

- 0 = no eggs in field,
- 1 = very light, observed in field,
- 2 = light, observed in field
- 3 = light medium, observed in field
- 4 = medium, observed in field
- 5 = medium heavy, observed in field
- 6 = heavy, observed in field
- 7 = very heavy, observed in field
- 8 = eggs observed in the winnow

Width: Width of the potential spawning substrate to the nearest foot

Length: Length of the beach up to 1,000 feet (500 feet on either side of the station) or "C" if continuous.

Shading: Shading of spawning substrate zone, averaging over the 1,000 foot station and best interpretation for the entire day:

- 1 = fully exposed,
- 2 = 25% shaded,
- 3 = 50% shaded,
- 4 = 75% shaded,
- 5 = 100% shaded

Comments: additional information to be entered into the computer, evaluated on a station by station basis.

Samplers: Names of personnel participating in the sample collection

Photo Taken: indicate number and direction of photographs

Prepare a map of each location sampled using a 1:25,000 scale nautical chart. Mark each sample location on the map with appropriate sample number so that the exact site can be re-visited, if needed. Use a GPS to obtain latitude and longitude of each sampled location, but priority should be placed on an accurate map.