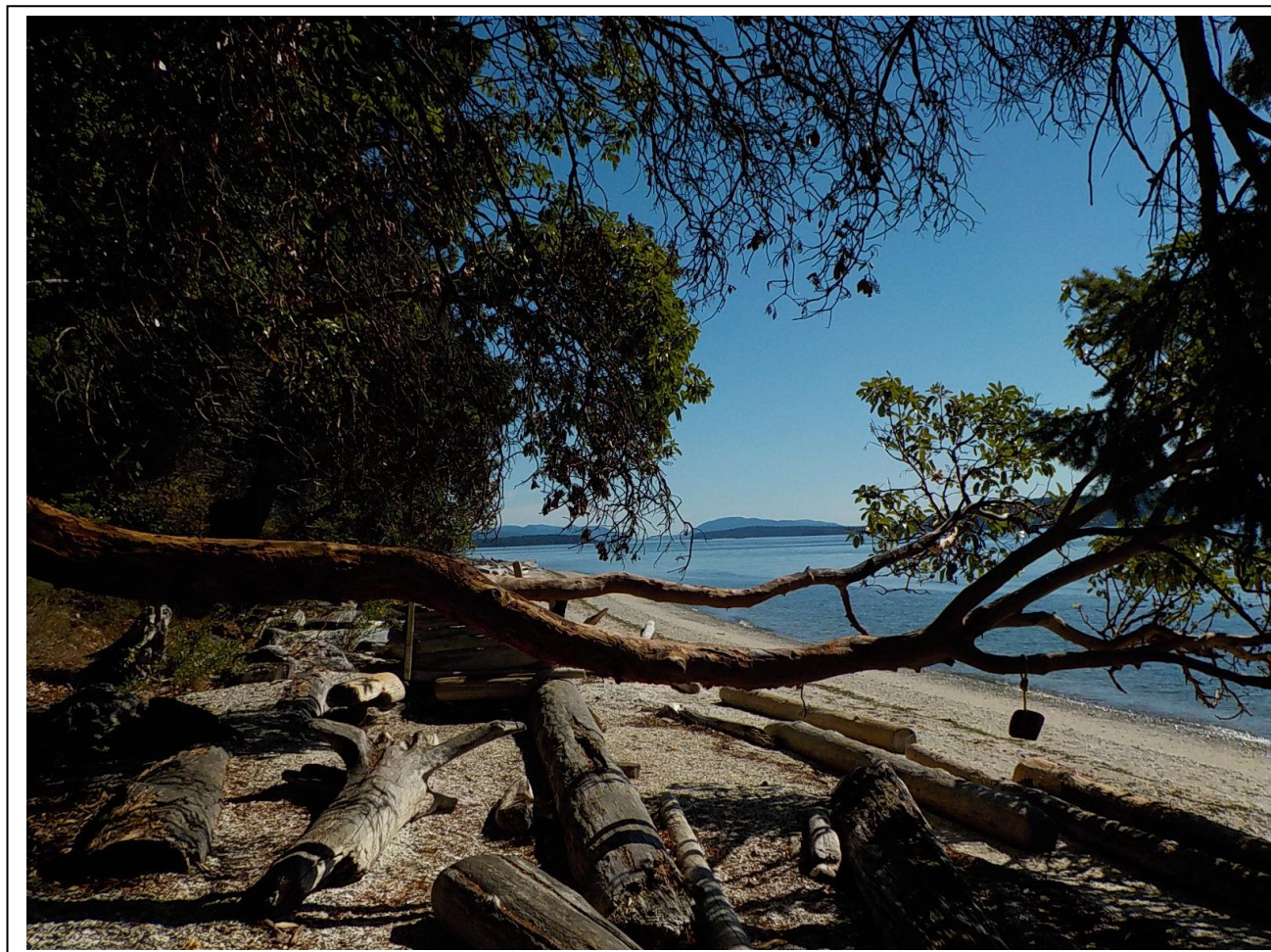


**Valdes Island, British Columbia
Surf smelt and Pacific sand lance
Spawning Habitat Suitability Assessments
September 2015-August 2016**



Valdes Island - Photo: RC de Graaf

Prepared for the Islands Trust and Islands Trust Fund

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1.0 Introduction

The term “forage fish” refers to small schooling fishes that are prey for larger animals. Forage fish, or “feeder fish”, include species such as herring, anchovy, sardines, capelin, smelt and sand lance. This study focusses on beach spawning forage fish: Pacific sand lance and surf smelt.

Beach spawning forage fish are a critical prey source for hundreds of marine predators in the Strait of Georgia. Pacific sand lance are often referred to as the most important fish in the North East Pacific due to this species role as forage for marine fishes, seabirds and marine mammals (Robards 1999). Surf smelt are also important prey for marine predators. Surf smelt are managed by the Department of Fisheries and Oceans under the Surf Smelt Management Plan for commercial and recreational fishers and their population abundance in the Strait of Georgia is declining (Therriault et al 2002). Surf smelt and Pacific sand lance spawning habitats are protected under Section 35 of the Federal *Fisheries Act*.

1.1 Role of forage fish in marine ecosystems

Pacific sand lance and Surf smelt are important to the recovery of marine species at risk (from Humpback and Killer whales to Marbled Murrelets); the marine survival of salmon (such as Chinook and Coho); and the survival of provincially blue-listed coastal cutthroat trout. Both juvenile and adult Chinook and Coho feed on a high percentage of Pacific sand lance.

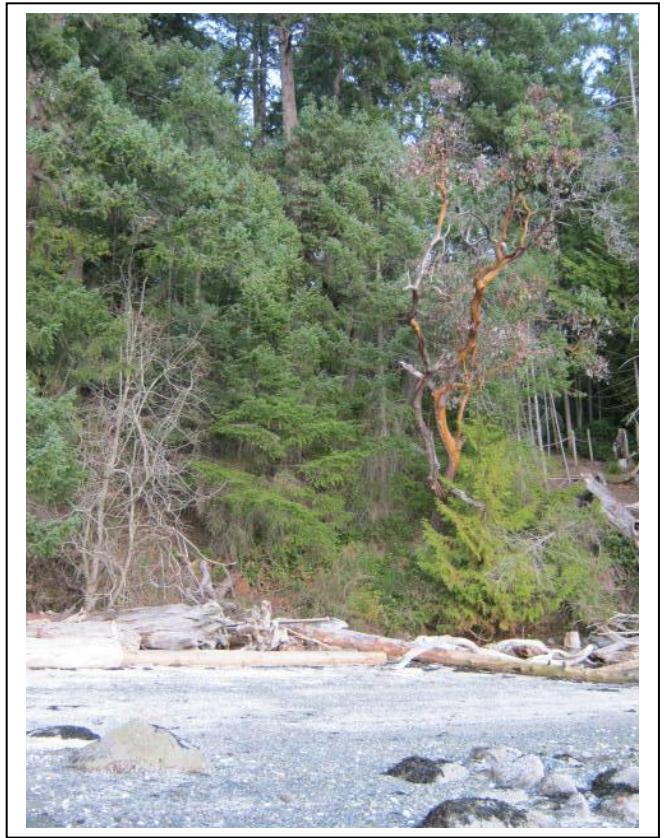
Numerous fish, seabird, and marine mammal populations are in precipitous decline in British Columbia and scientists have started to look at the link between forage fish biomass reduction and these declining populations.

1.2 Connections to other valued ecosystem components

Forage fish depend on nearshore habitats for their survival during several critical life-history stages. Herring spawn on marine vegetation such as eelgrass and seaweeds and Pacific sand lance and surf smelt spawn high up the beach near the log line. Like numerous fish species, Surf smelt and Pacific sand lance also require subtidal areas such as kelp forests for rearing. Backshore components provide sediment sources, marine riparian vegetation and nutrients necessary to create and maintain beach habitats.

1.2.1 Protecting the ecosystem services of Marine Riparian Vegetation

Marine riparian vegetation, gravel/sand beaches and good water-quality are important to the health of these spawning areas. A healthy Surf smelt/Pacific sand lance spawning beach has an intact marine riparian buffer zone, overhanging shade vegetation, a supply of pebble and sand and clean water. Shade from overhanging shoreline vegetation keeps summer Surf smelt eggs moist. Removing shoreline vegetation increases temperatures within the spawning gravels; and on hot summer days, Surf smelt egg mortality is high (Penttila 2001, Rice 2006). Key to maintaining and restoring these shoreline areas will be measures to limit physical structures that negatively affect sediment transport as well as actions that protect marine riparian vegetation and water quality. Land-owner education and expanded biological surveys are all central to protecting these beaches. Careful site planning and guidance can protect shoreline habitats.



Marine Riparian Vegetation - Photo: RC de Graaf

Marine riparian vegetation is a valued ecosystem component that provides benefits for human security and benefits to the ecosystem. Recent studies from Puget Sound and Squamish confirm the use of marine shorelines as rearing habitat for juvenile salmonids, such as Chinook. Dietary analyses show that up to 50% of the stomach contents of juvenile Chinook were composed of insect “windfall”, insects transported by winds from



Overhanging Shade Vegetation
Photo: RC de Graaf

marine shoreline vegetation to the water's surface (Brennan and Culverwell 2004).

Marine riparian vegetation provides ecological benefits as well as a net benefit to property owners as a free “ecosystem service” limiting erosion and stabilizing slope soils. Trees and shrubs absorb large volumes of rain water and filter pollutants. Vegetation removal may cause large sediments loads to enter the ocean limiting light for eelgrass growth and clogging fish gills. A vegetative corridor is an effective, low-cost measure to reduce storm-water runoff and shoreline erosion.

Too often “wave attack” is singled out as causing shoreline banks to erode resulting in falling trees and slumping shoreline slopes. More often, the cause is actually simpler and much easier to control. Marine riparian vegetation loss is often a major contributing factor to or cause of shoreline erosion. Removing trees and shrubs in favour of a lawn near the high water mark can increase land slumping, run off and shoreline bank erosion. Maintaining even a narrow corridor of natural trees and shrubs, even integrated with horticultural landscaping, is an effective way of managing water-run off and mitigating shoreline erosion. Trimming and limbing trees rather than removal adds habitat and absorbs rain-water.

Diverting storm-water through pipes and ditches that empty directly into banks or onto beaches is another cause of erosion. It is easier and less damaging to the environment to re-route storm water into municipal infrastructure or into “rain gardens”. When inspecting shoreline edges, consider the natural protection from nearby islets/islands and rocky headlands that limit winds and reduce wave exposure. Often land owners chose to armour water-front properties when nature has already provided ample protection from most wind and storm events. Soft-sediment (gravel and sand) beaches and logs are an efficient and natural “sea” defence as they dissipate wave energy through their movement, unlike hard, vertical seawalls/riprap that can only displace wave energy causing sediment scour, degradation of beaches. Armouring failure places homes and infrastructure at risk.

Foreshore areas lacking vegetation and overhanging vegetation could benefit by restoring vegetation. Over time, restoration of shrubs and trees (eg alders, arbutus, and maple) along the shoreline edge provides overhanging shade for summer Surf smelt embryos, insect prey for juvenile salmonids and benefits land-owners by stabilizing shoreline sediments. This is particularly important on land forms of eroding cliff/bluff and bank habitats. With careful site planning, shoreline vegetation and other landowner values, such as views, can be maintained.

2.0 Beach Spawning Forage Fish Habitat

Beach spawning forage fish of commercial, recreational and ecological value in the Strait of Georgia are capelin, surf smelt (*Hypomesus pretiosus*) and Pacific sand lance (*Ammodytes hexapterus*). The Washington Department of Fish and Wildlife has conducted extensive surveys in Puget Sound and produced maps of spawning habitat (Penttila, D. 2007). Washington State surveys have been conducted since 1972 (Penttila 2001b). Unfortunately critical spawning habitat of these two forage fishes has not been mapped by government agencies in British Columbia.

Surf smelt and Pacific sand lance depend on a healthy nearshore and beach habitat, and spawning beaches are vulnerable to impacts from shoreline development. Beaches with natural erosion processes supplying appropriate sized sediment and are an optimal state for spawning Surf smelt and sand lance. Of primary importance for spawning is the mixture of gravels and sand. Extant backshore vegetation and marine riparian zones maintain natural soil erosion rates, filter storm water, and overhanging shade increases the survivability of spawned embryos.

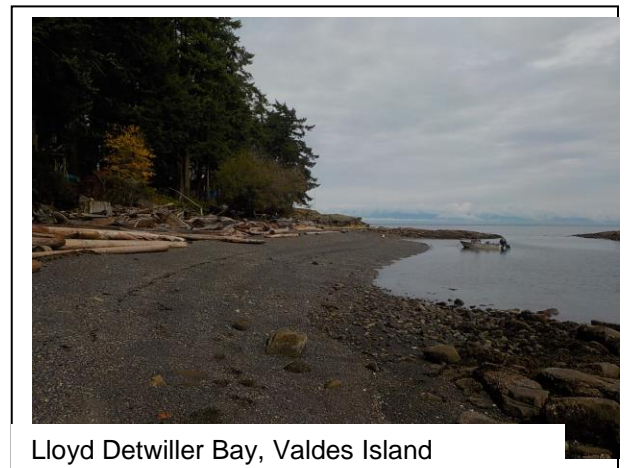


North of Cardale Point, Valdes Island
Photo: RC de Graaf

3.0 Spawning Habitat Characteristics

3.1 Intertidal Elevation

The highest densities of embryos found to date have been in the upper beach slope between the high water seaweed wrack zone and the low high water seaweed wrack zone. Consistently, mixed embryo stages are found in samples taken from +1.5 m to +4.5 m above chart datum and can be found at the highest extent of the maximum high tides. Pacific sand lance spawn may also be found on the sand flat edge near the beach



Lloyd Detwiller Bay, Valdes Island
Photo: RC de Graaf

slope (Penttila 2001b, Penttila 2007, de Graaf unpublished data); however, this area of the intertidal has been sparsely sampled.

3.2 Sediment Characteristics

Both surf smelt and Pacific sand lance embryos can be found on certain beaches in the same beach sediment sample collected along the upper beach slope. Surf smelt are reported to spawn in sediments of fine “pea pebble”/sand to coarse pebble/sand beaches with the bulk of the pooled data set having material of 1-10 mm; although full grain size spectra show numerous sample sets with a wide range of pebble/sand including coarse pebble greater than 2.6 cm (Penttila 2001c). Generally, Surf smelt do not spawn in coarse sand beaches without pebble due to the unique attachment pedestal of the osmerid egg (they are gravel-dependent spawners). Pacific sand lance are reported to spawn in sediments of coarse sand/pebble with the bulk of the pooled data set (67%) having material of a median grain size of 0.2 – 0.4 mm and a portion of the data set (25%) being gravel-coarse sand from 1 – 7mm (Penttila 2001c; 2007). Full analysis of the Penttila data set (2001c) shows a wide range of spawning sediments including coarse pebble/sand beaches greater than 2.6 cm. Recent findings in British Columbia reveal that Pacific sand lance embryos are also found in beaches bearing a high percentage of coarse pebble greater than 2.6 cm (de Graaf unpublished data). Pacific sand lance embryos are found throughout the range of Surf smelt bearing sediments as well as coarse sand. Pacific sand lance do not spawn on fine silt and cobble (Penttila 2007). In British Columbia, both Surf smelt and Pacific sand lance embryos can be found throughout a beach drift cell in the erosion, transport and accretion zones (de Graaf, unpublished data, presented at American Fisheries Society Conference Sept 2011). Over 40 years of government sponsored surveys in Puget Sound carried out by Mr. Penttila has yielded important data on the spawning habitat of these two species. With recent attention to surveys in the Strait of Georgia and the outer coast of Vancouver Island, our understanding of beach spawning habitat types has increased.

3.3 Beach Biophysical Characteristics

Sediments characterizing spawning habitats are typically of fine sediment (sand/pebble) distributed on the beach faces (upper intertidal) of soft-sediment landforms such as pocket coves, bluff-backed beaches and barrier beaches. These finer sediment bands often transition into lower (seaward) bands of cobble zones before the beach face transitions into the lower profile beach terrace (flat), or mid-intertidal zone. The width of the spawning deposition zone (commonly referred to as the B1 component) is variable and can range from 0.5 m to over 10 m in width dependent on geomorphic setting.

4.0 Spawning Seasons

Surf smelt are known to spawn year round in Puget Sound and also have distinct winter and summer spawning stocks (Penttila 2007). In British Columbia, this same pattern has been detected (de Graaf unpublished data). Pacific sand lance spawning is from Nov – January with incubating embryos detected into February (30-45 day fall/winter incubation period). Data compilation for spawning periods for regions of British Columbia has begun due to the effort of the BC Marine Conservation and Research Society. In the Islands Trust Area, communities are presently undertaking spawning surveys with the BCSSA as the Gulf Islands Forage Fish Initiative.

5.0 Threats to Beach Spawning Forage Fish Habitat

Shoreline modifications can negatively impact the nearshore marine food web in numerous ways, but are a primary threat to surf smelt and sand lance spawning beaches (Penttila 2007).

5.1 Shoreline Modification

Many human activities impact and alter marine shorelines either through disruption of the sediment drift cell or by physical alteration of the beach, including: piers, pilings, docks, jetties, groins, breakwaters, riprap, seawalls and others. Marine shellfish aquaculture in foreshore areas can affect beach spawning forage fish habitat. Diversion of sediment-bearing streams through culverts can also starve beaches of spawning sediment. Many of these activities render beaches unusable for spawning. These shoreline modifications can also limit sediment exchange in the shallow subtidal where Pacific sand lance is known to burrow. Vehicles operating directly on top of spawning areas can directly destroy embryos or change habitat by affecting sediment through compaction and reduced motility.

5.2 Marine Riparian Vegetation Habitat Modification

The presence of overhanging vegetation in marine riparian zones is important for the ecological function of nearshore marine habitats providing insect prey for migrating fish (Levings and Jamieson 2001; Brennan and Culverwell 2004) and having a positive effect on summer surf smelt spawn survival (Penttila 2001a, Penttila 2007, Rice 2006). The loss of shade increases thermal stress and desiccation to incubating eggs as sediment temperatures rise resulting in increased mortality of buried eggs (Penttila 2007, Rice 2006). Vegetation buffers the drying effect of winds; and where beaches have lost riparian zones, eggs can also suffer a higher mortality than normal due to wind-induced desiccation effects. Removal of backshore vegetation alters soil natural erosion rates, water absorption, and nutrient flows to marine shorelines.

Other threats to Surf smelt and Pacific sand lance embryos include contamination from acute oil spill events and chronic oiling which can result in 100% mortality of Surf smelt embryos. Oiling from vessel operations near beaches can potentially cause mortality of incubating forage fish embryos (herring, Pacific sand lance, and Surf smelt) (Penttila 2005).

5.3 Sea Level Rise

Of all nearshore habitats, marine shorelines are the most at risk not only to rising sea levels but to how humans respond to this threat (Krueger 2009, Martin 2015, Whitman 2014). Beaches are dynamic shore forms, shifting in response to sediment and water flows. Changing sea levels affect the extent to which beaches retreat landward. Hard revetments (seawalls etc.) at or near the high water line prevent natural retreat of beaches landward. The term “coastal squeeze” applies to marine shoreline habitats that will be diminished or lost as these habitats are blocked from landward retreat due to coastal development and threatened seaward by rising sea levels. Upper beach areas are degraded or lost as increased erosional energy coarsens sediments, and beaches narrow in width (Dethier 2016, Shipman 2009). Most at risk are upper intertidal zones, beach berms and beach faces. As Surf smelt spawn on beach faces, the upper most part of the intertidal zone, their spawn is most at risk of loss. Sixty-six percent (66%) of Surf smelt embryos are deposited in the upper zone of beach faces (Quinn 2012, Whitman 2014). Spawn deposition zones of Pacific sand lance are also on the beach face (Penttila 1995). How management authorities respond to sea level rise has implications not only for forage fish species, but hundreds of predatory species and reliant fisheries.

6.0 Introduction to the Beach Spawning Forage Fish Habitat Assessment

6.1 General Introduction

To refine the study area, sediment maps were produced from the Coastal Resource Information Management System, DataBC (DataBC Catalogue 2013). The data layer used to produce the sediment map was the shoreline biophysical classification by repetitive shore type. All shore-units of unconsolidated sediments were investigated along the entire shoreline length of Valdes Island. Unconsolidated sediments include silt, mud, sand, and gravels. Shore-units of consolidated sediment (rock) were also reviewed to ensure that no suitable habitats were present.

6.2 Area Surveyed

The entire coastline of Valdes Island was surveyed by foot and boat. Unconsolidated sediments consist of gravel (pebble, cobble and boulder), mud and silt areas. Areas of consolidated sediment (rocky shorelines) were surveyed to ensure the absence of any fine sediment accretions. All beach units of unconsolidated sediments were surveyed by foot to ascertain potential sites for detailed assessment. Valdes Island surveys took place on September 11, 25, 28, 29, October 1, 2015; June 21, August 22, 23, and 24, 2016. Surveys were not conducted if there had been major storm activity within seven-ten days of the survey date.

The Lyackson First Nation granted permission to access shorelines under their jurisdiction.

7.0 Methods

Forage Fish Habitat Assessments – Assessing Suitable Forage Fish Spawning Habitat

Actual forage fish spawning beaches are determined after comprehensive embryo surveys (Moulton and Penttila 2001). In the absence of such comprehensive embryo surveys, beaches may be classified as having attributes suitable for Surf smelt/Pacific sand lance spawning habitat following field assessments and model analysis.

7.1 General Methodology

A habitat suitability model is based on the observed response of an animal to specific environmental attributes (Robinson et al 2013). Specific environmental attributes (abiotic or “physical” variables) of the tested habitat patches are assessed as to their similarity to known habitat types. The Forage Fish Habitat Suitability Assessment (FFHSA) entails a survey of habitat attributes for each area of unconsolidated sediments making up the upper component of intertidal beaches (beach berm/beach face and mid intertidal). Measurements are taken of physical variables of the beach units and grain-size samples assessed. These data are used to predict the suitability of beach units relative to beach units observed to be spawning habitat for spawning activity by Surf smelt and Pacific sand lance. Additional variables are measured to assess human activities that may have directly modified the foreshore or adjacent backshore areas and evaluated as to “stressors” on beach habitats. Assessments are conducted by experienced beach spawning forage fish biologists/technicians.

Physical variables from suitable beaches are compared to a database of habitats that were monitored using spawning surveys (over 2 years) for Surf smelt and/or Pacific sand lance in British Columbia and Washington State. The software program PRIMER-E, a multivariate statistical program, set at an 80% similarity threshold, is used to test suitable beaches to this BC/WA database. The PRIMER-E software program is used extensively by ecologists to describe similarities and differences among biological communities, habitat types, or for monitoring biological communities and habitats.

Using statistical analyses, a probability can be assigned to each beach unit measured. Beaches are assigned as being suitable spawning habitat for Surf smelt, Pacific sand lance, or both Surf smelt/Pacific sand lance. Beach units assessed in the field but failing statistical analysis are assigned as “Not Suitable Spawning Habitat”. Beach units not assessed were assigned as “Not Spawning Habitat” in the field and were comprised of mud, silt, rock or shallow pebble layers (veneers) over rock.

For shoreline property owners undertaking works that may impact fish and their habitat, a project review by the Department of Fisheries and Oceans (DFO) may be required. In the absence of a two-year spawning survey, a FFHSA can provide a good indication of suitable surf smelt and sand lance habitat for use by landowners and other agencies responsible for shoreline management.

A description of the survey methodology has been provided to the Islands Trust/Islands Trust Fund.

7.2 GPS/GIS Methodology

7.2.1 Spatial Data Specifications

A Trimble Juno 3B receiver was used to acquire spatial data. GPS data were post-corrected using Path Finder Office software. GPS data were collected according to the GPS Specifications provided by the Islands Trust as part of this contract (Appendix G).

If positional fixes with the Trimble Juno 3B at the desired level of accuracy were not possible due to satellite interference caused by land forms such as sea cliffs, feature data were digitized by the GIS technician from ortho-photographs provided from the Islands Trust and reviewed by the author.

7.2.2 Digitizing Spatial Data and Map Production

Maps of line segments were produced by digitizing spatial data following the protocol in Appendix H.

8.0 Project Limitations

The project was limited to assessing beaches as suitable spawning habitat for two species of beach spawning forage fish, Surf smelt and Pacific sand lance. Data for this study was compiled before major fall/winter storm events. The methods used in a forage fish habitat suitability assessment do not allow one to determine the presence or absence of spawning activity as sediments are not collected for nor screened for the presence of embryos. Spawning surveys are conducted over two spawning seasons (24 months) and follow strict protocols (Moulton and Penttila 2001). The project undertaken grades beaches as having physical variables suitable for spawning, but it does not confirm the presence or absence of spawning activity.

9.0 Valdes Island – Geomorphic Setting and Beach Shoreline Types

Due to the geographic alignment and proximity to Galiano Island, the author has assumed that for Valdes Island, the wave exposure (fetch and energy) regimes are similar and comments are based on the information for Galiano Island as well as the author's field investigations (de Greeff 2011).

As with Galiano Island, wave exposure regimes (fetch and energy) for Valdes Island range from low (sheltered west coast areas) to high (south, east and north coasts). The west coast is more protected from high fetch due to the presence of islands (Vancouver Island, Thetis, Penelakut, Galiano and Salt Spring) having lower wave exposures relative to the east coast which is directly exposed to dominate northwesterly and southeasterly winds and long fetch in the Strait of Georgia. Sections of the south coast are exposed to southwesterly storm winds and Porlier Pass tidal currents. The north coast is mainly exposed to strong tidal forces of Gabriola Pass.

Valdes Island's dominate geomorphic system is rocky shoreline. Valdes Island also has a beach geomorphic system as evidenced by independent drift cells and accretion shorelines. Net sediment drift in the Strait of Georgia is northward and Valdes Island shores showed this same pattern.

Along the majority of Valdes' rocky shorelines, small volumes of sediment are retained between isolated and disjunct rocky headlands in small pocket coves along erosional shores. Pocket coves are present along north, east, south and west shorelines.

Along sections of Valdes' west shore, large volumes of sediment are transported in complex drift cells from eroding land forms (bluffs and banks) creating larger, connected bluff-backed and barrier beaches along accretionary shorelines (Shipman 2008). Several beach units are largely biogenic, composed of shell hash indicative of the high biomass of bivalves in Trincomali Channel. One small, barrier beach system was found on the east coast.

It is useful to consider the geomorphic context of sediment delivery/transport systems when assessing stressors from backshore/foreshore uses that may degrade sediment delivery to the shoreline. For example, due to the limited volume of sediment available along rocky coasts, pocket beaches are particularly sensitive to backshore/foreshore modification. Barrier beaches are sensitive to interruptions in lateral, or littoral drift along shorelines.

10.0 Valdes Island - Results

10.1 Statistical Analyses

In total, thirty-five (35) beach units comprised of unconsolidated sediments were assessed (Table 1). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed thirty-four (34) beach units with 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable spawning habitat” (Figure 1A-E). Twenty-eight (28) of these beach units had continuous habitat and six (6) had discontinuous habitat.

One (1) beach unit failed statistical analyses, the same beach unit with non-conforming grain-sizes, and was classified as “not suitable spawning habitat”.

Eight (8) beach units were comprised of unconsolidated sediments such as mud, silt, or cobble or pebble veneer on rock substrate that are not habitat types that are potential spawning habitat (Table 1). These beach units were assigned as “not habitat” in the field and were not subject to any grain-size or statistical analysis.

Valdes Island had a high number of beach units assessed as suitable. This may be due to high sediment motility along wave-exposed coasts, open-facing pocket coves, and active erosion of bluff systems on the west coast. Of the forage fish habitat suitability assessments of the Gulf Islands conducted to date, this geomorphic condition is unusual. Shorelines where silt, clay and mud can accumulate, such as in inlets and closed pocket coves, are mainly lacking on Valdes Island. On Valdes, Wakes Cove is an example of a closed cove where low sediment motilities resulted in most beach units being comprised of mud and silt. Other examples of such shore forms with limited sediment motility, promoting mud/silt, are Saltery and Whalers Bay (Galiano Island).

10.2 Grain-Size Analyses

Grain-size analyses were used to test for likelihood of beaches to support spawning. All grain-size frequencies curves were classified to Type curves. Thirty-four (34) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix B, Appendix C, Figures 2-7). The grain-size frequencies of one (1) sample did not meet the statistical standards of the analysis.

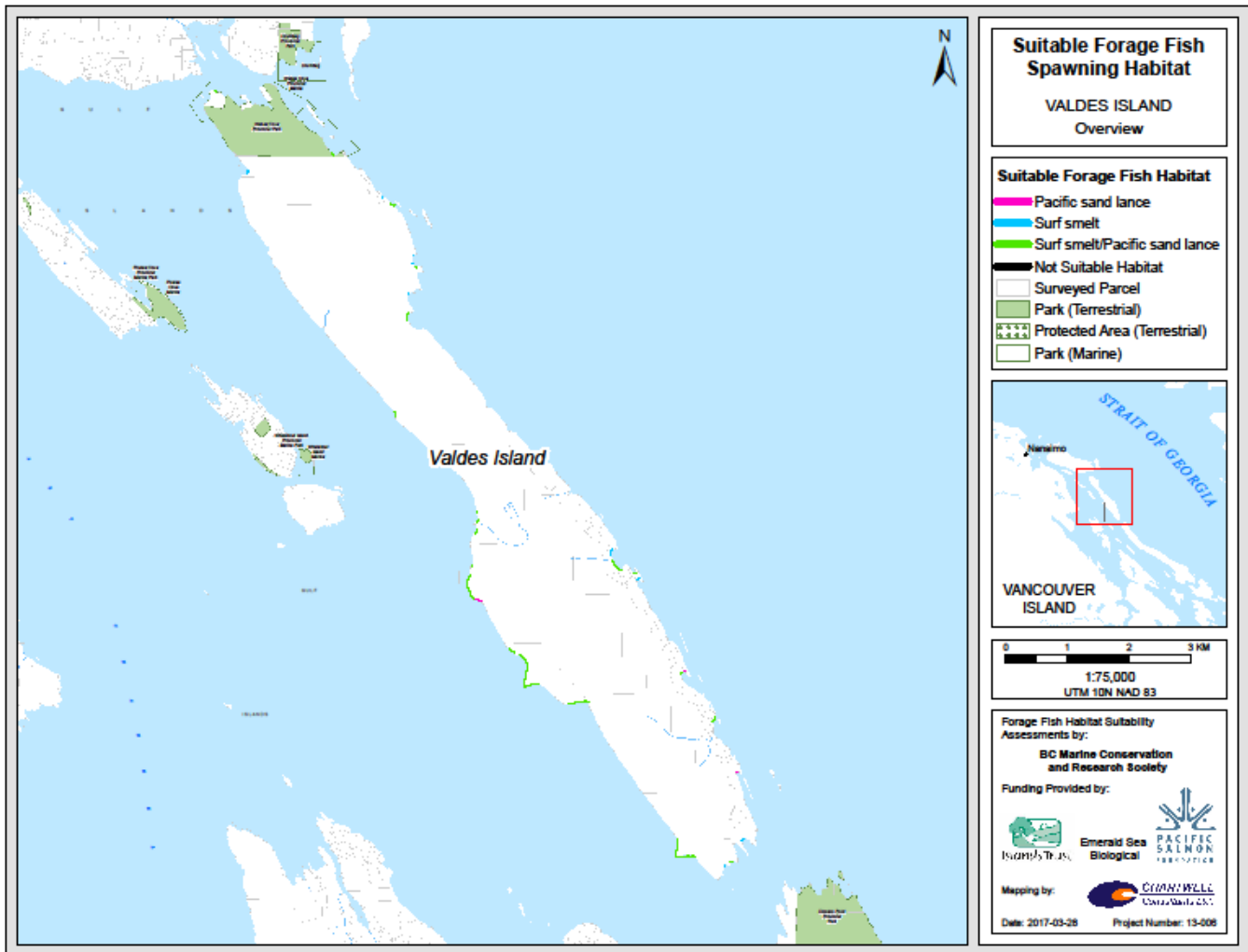


Figure 1A: Suitable Beach Spawning Forage Fish Spawning Habitats – VALDES ISLAND

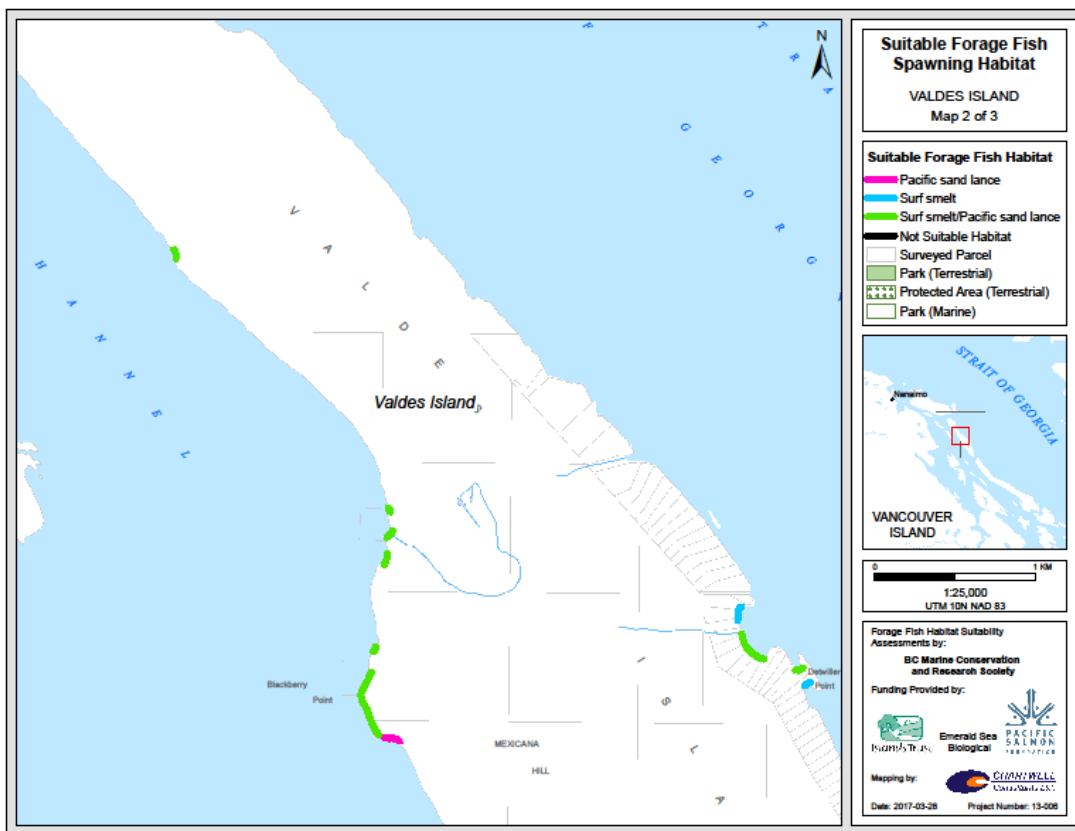
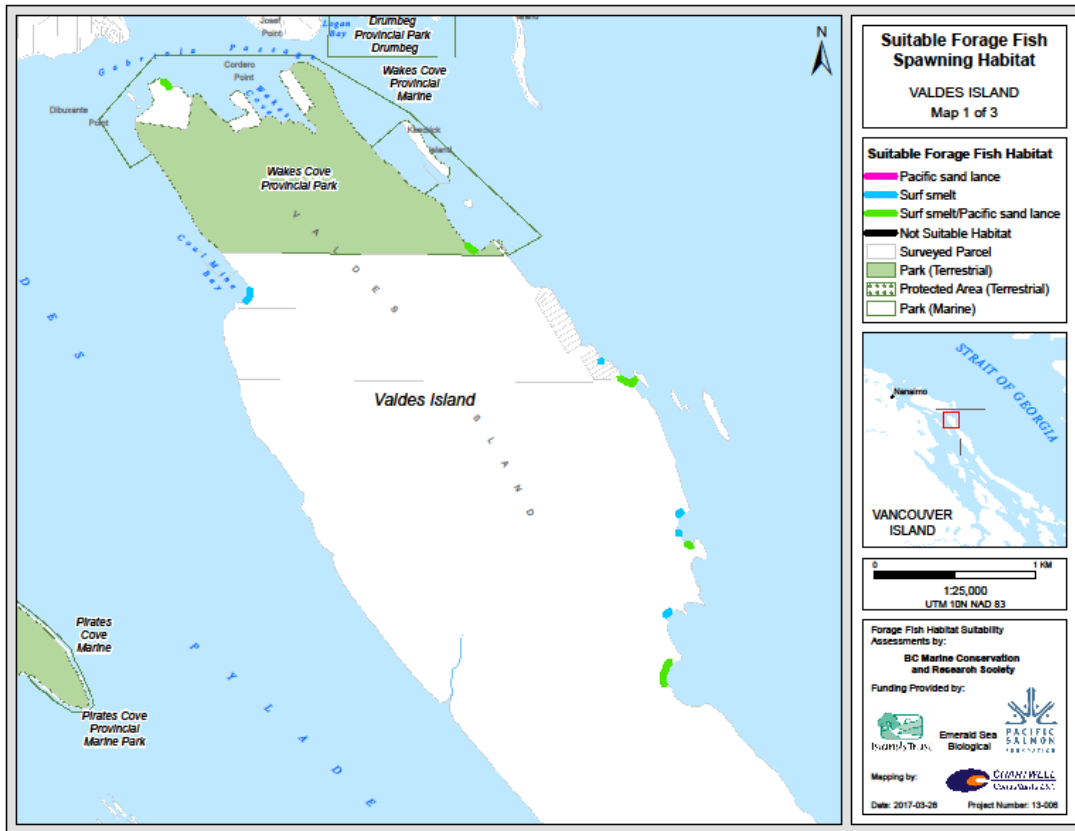


Figure 1B-1C: Suitable Beach Spawning Forage Fish Spawning Habitats – VALDES ISLAND

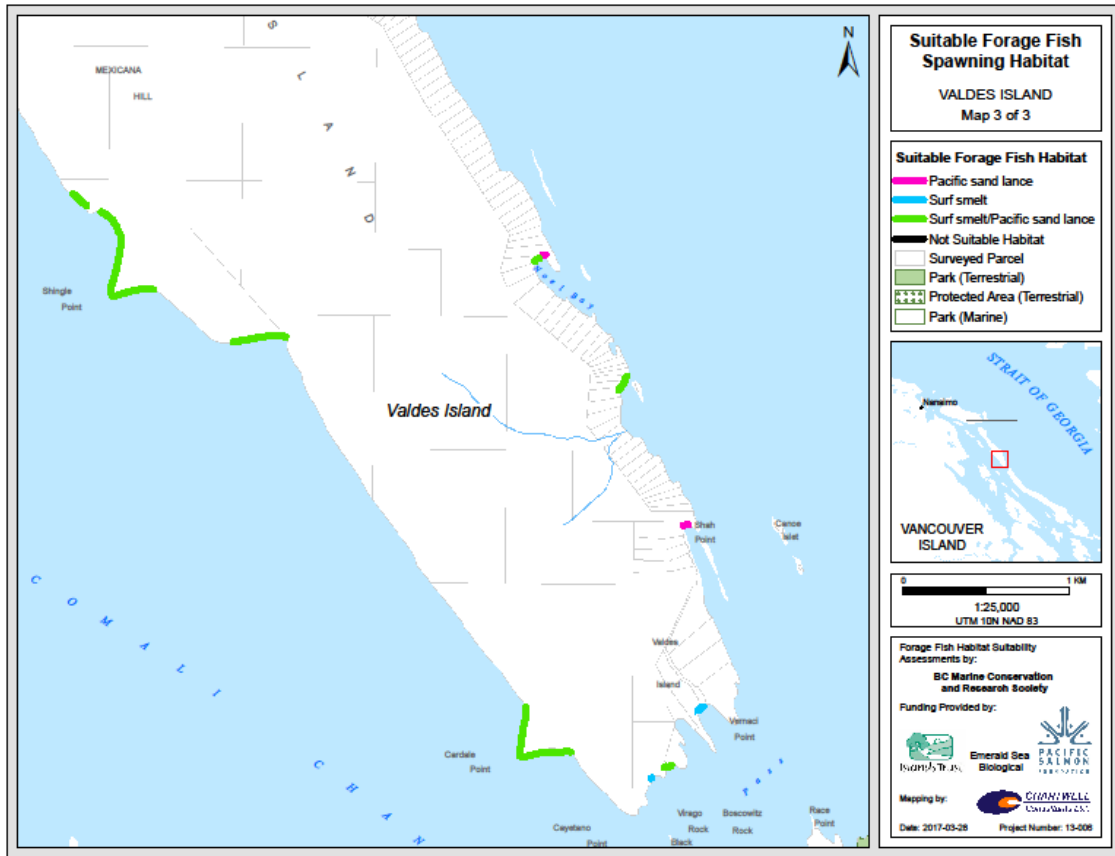


Figure 1D: Suitable Beach Spawning Forage Fish Spawning Habitats – VALDES ISLAND

10.3 Length of Suitable Forage Fish Spawning Habitat

The total shoreline perimeter of Valdes Island is 40.29 kilometers. Suitable forage fish spawning habitat comprised 4.0 kilometers (3,997 m) or 9.90 percent of the Valdes Island shoreline perimeter (Table 1). Of the suitable forage fish spawning habitat, the shoreline perimeter is comprised of 3.75% (150 m) suitable for Pacific sand lance spawning; 9.08% (363 m) suitable for Surf smelt spawning; and 87.17% (3,997 m) as suitable for Surf smelt/Pacific sand lance spawning habitat (Table 2).

Table 1: Valdes Island Beach Units– Suitable Forage Fish Spawning Habitat

	Count	Total	Length (m)	Shoreline Perimeter
Suitable habitat	34		3,997	9.90%
Not Suitable habitat	1		8.7	0.02%
Not Habitat	8			
Total Beach Units		35		
Total Length (meters)			4005.7	9.90%
Habitat Coverage				
Continuous	28		3151	7.80%
Discontinuous	6		846	2.10%
Perimeter Distance of Valdez Island				
			40,290	40.29 km

Table 2: Valdes Island Beach Units– Classification of Suitable Forage Fish Spawning Habitat by Species

	SS	PSL	SS/PSL	Total (m)
Count	9	3	22	34
Length (m)	363	150	3484	3,997
Shoreline Perimeter Percentage	9.08%	3.75%	87.17%	100.00%

SS - Surf smelt

PSL - Pacific sand lance

10.4 Suitable Forage Fish Spawning Habitat Beach Types

Of the thirty-four (34) suitable spawning beaches, three (3) were classified as Pacific sand lance, nine (9) as surf smelt, and twenty-two (22) as mixed Surf smelt/Pacific sand lance spawning habitat (Table 2). Of the Pacific sand lance beaches, grain size analyses assessed three as Type 3 Pacific Sand lance beach (Table 3). Of the surf smelt beaches, grain size analysis assessed five as Type 1, three as Type 2, and one as Type 3 Surf Smelt beaches (Table 3). Of the mixed Surf smelt/Pacific sand lance beaches, grain size analysis assessed three as Type 1; one as Type 2; eight as Type 4, and ten as Type 4 Surf Smelt beaches (Table 3, Appendix C, Figures 2-6).

Two beach units had a high component of shell hash indicative of the high biomass of bivalves in Trincomali Channel and the area. Three beach units had high sand components (grain-size type PSL3), one on the west coast (Blackberry Point) and two on the east coast (Noel Bay).

Similar to Galiano Island, on Valdes Island, the high number of coarser Surf smelt and Surf smelt/Pacific sand lance beaches is reflective of the pocket coves and rocky shorelines (Table 4).

Table 3: Valdes Island Beach Units – Suitable Forage Fish Spawning Habitat by Grain-Size Types

Category	SS	PSL	SS/PSL
PSL TYPE 1			
PSL TYPE 2			
PSL TYPE 3		3	
SS TYPE 1	5		3
SSTYPE 2	3		1
SS TYPE 3	1		8
SS TYPE 4			10
SS TYPE 5			
Totals	9	3	22

10.5 Geographic Position of Suitable Forage Fish Spawning Beaches

10.5.1 Geography

Dividing Valdes Island into north, south, west and east coast lines, 1 suitable beach unit is located on the north coast; 3 on the south coast; 14 on the west coast; and 16 suitable beach units on the east coast (Table 4).

Table 4: Valdes Island - Suitable Forage Fish Spawning Habitat– Geography and Geomorphology of Beach Units

Geographic Divisions	North	South	West	East	Total
Surf smelt		2	1	6	9
Pacific sand lance			1	2	3
Surf smelt/Pacific sand lance	1	1	12	8	22
Geomorphic Habitat Type	North	South	West	East	Total
Pocket Cove	1	3	6	14	24
Barrier beach			2	1	4
Barrier beach - Spit			4		4
Bluff-backed beach			2	1	2
Total	1	3	14	16	34

10.5.2 Geomorphic habitat types

Reflecting the geomorphological systems of Valdes Island, of the 34 suitable beach units, along the wave-exposed shores, pocket coves represented 24 (71%) of the beach units (Table 4). Pockets coves are distributed along the north coast, 1 pocket cove; east coast, 14 pocket coves; south coast, 3 pocket coves; and west coast 6 pocket coves.

Three drift cells were present with feeder bluffs forming bluff-backed and barrier beaches, one on the east coast (Starvation Bay) and two on the west coast (Table 4).

10.6 Foreshore and Backshore Modification

Modification of the foreshore is classified as a percentage of the length of the beach unit that has been altered from a natural state by structures below the high water mark that would impede movement of sediments either to the beach or along the beach. On Valdes, the majority of beach units had no foreshore modifications and shorelines were mainly intact. Thirty-one (31) of the beach units had unmodified shorelines and three (3) were modified (91% and 9% respectively). Of the three (3) modified beach units, two (6%) were 1-25% impacted; one (3%) 26-50% impacted (Table 5). One additional beach unit had creosote pilings on the foreshore, but, while releasing toxins, these do not impeded sediments on the beach face.

Modification of the backshore is classified as structures or significant clearing of the site at or within 30 m of high water mark. On Valdes, twenty-two (22) of the beach units had modified backshores (65%). Eighteen (18) beach units were modified with buildings or other structures and four (4) beach units had no built structures but the lots were cleared of vegetation (Table 5).

As is common, pebble/sand beaches attract private land ownership, and Valdes is no exception. Sixty-five percent (65%) of soft-sediment beaches in this study have been developed and no suitable spawning beaches are protected within a park.

Overall, shoreline development of Valdes Island has been achieved with minimal changes to the natural character and ecological functions of the shoreline at the soft-sediment beach units assessed.

Table 5: Valdes Island - Foreshore and Backshore Modification

Foreshore Modification	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact	Total
Count	31	2	1			34
Percentage	91%	6%	3%			
Foreshore Modification	0% impact	1-50% impact		51-100% impact		
Count	31	3		0		34
Backshore Modification	Yes	No				
Count	22	12				34
Percentage	65%	35%				

10.7 Foreshore and Backshore Structures

Of the three (3) suitable forage fish spawning beach units with modified foreshore zones, the presence of sediment impeding structures were classified and enumerated. In total six (6) structures were classified into five categories (Table 6).

Of the twenty-two (22) suitable spawning beach units with modified backshore zones, all structures present were classified. Buildings were not present on the foreshore. Buildings (cabins, houses, sheds, etc.) are not enumerated but only classified as present or absent. Individual structures were enumerated. The total number of beach units having structures includes buildings. Buildings were present at seventeen (17) beach units. Ten (10) structures were classified into seven (7) categories (Table 6).

On the foreshore, four (4) beach units had 1 foreshore structure each and one (1) beach unit had 2 foreshore structures. On the backshore, three (3) beach units had 1 backshore structure each, one (1) beach unit had two structures, and one (1) beach unit had five backshore structures. One (1) beach unit had six structures, one on the foreshore and five on the backshore.

Hard Armouring

On the foreshore, three beach units had hard armouring (breakwaters, seawalls, and riprap). Seawalls and riprap were present only on the east coast at two separate beach units. On the west

coast, one beach unit has a pair of railway tracks used as a boat ways; the tracks are placed at the level of the beach surface and do not interrupt sediment flow along the beach. At one beach unit on the west coast, there was a breakwater structure and creosote pilings; and this beach unit may be a former industrial site and currently operates as a small local boat basin.

On the backshore, a wooden seawall was present at one beach unit, located on the east coast. At this same beach unit, a total of six structures are present, five on the backshore and one on the foreshore.

Generally, development within the 30 meter backshore zone is moderate and maintenance of natural forest and shorelines evident.

Table 6: Valdes Island Beach Units – Classification of Structures present in Foreshore and Backshore Zones

Category		Foreshore		Backshore		No. Beach Units with Buildings Present
		Count	Percentage	Count	Percentage	
Building						17
Boat Ramp		1	17%	1	10%	
Boat House				2	20%	
Dock/Wooden Pier				1	10%	
Seawall		1	17%	1	10%	
Riprap		1	17%			
Breakwater		1	17%			
Stairs				3	30%	
Platform/Patios				1	10%	
Road to beach				1	10%	
Other		2	32%			
Total Number of Structures		6		10		
Total Number of Beach Units	34					
Number of Beach Units with Structures		4		18		
Percentage Beach Units with Structures			12%	53%	53%	
Beach Units with Structures and Vegetation Cleared				22%	65%	

Other: creosote pilings; railway track

10.8 Overhanging Shade Habitat

Overhanging-shade habitat is classified as the percentage of the length of the beach unit with tree or shrub branches overhanging the spawning zone. Overhanging shade vegetation scores ranging from 0-50% indicates reduced shade habitat.

Marine riparian vegetation may be reduced/absent due to land use/landscaping, structures (ranging from buildings to hard armouring), the type of soils or land form (examples include bluffs and barrier beaches (including spits, lagoons, and beaches with wide berms).



Normal vegetation cover at spits.
Cardale Point, Valdes Island
Photo: RC de Graaf

Generally, trees are present above the high water mark.

During property development, trees are often removed.

Bluffs may lack trees that provide overhanging shade habitat as these land forms are steep sloped and are composed of eroding sediments. Low-lying landforms such as lagoons and spits often have natural vegetation types of low shrub and grasses near the high-water mark and trees more landward or may be devoid of trees. Also, some beaches may have overhanging-shade habitat but the length of the branches do not exceed the width of wide berms.

10.8.1

Of the thirty-four (34) suitable beach units, one (1) of the beach units has no overhanging shade habitat; twelve (12) have 1-25% overhanging shade; two (2) have 26-50% overhanging shade; six (6) have 51-75% overhanging shade; and thirteen (13) have 76-100% overhanging shade habitat (3%, 35%, 6%, 18%, and 38% respectively) (Table 7).

Beach units with overhanging-shade habitat scores of 0-50% represent a reduced habitat condition. Fifteen beach units, 44%, had reduced overhanging shade-habitat (0-50%); and nineteen beach units, 56%, had overhanging shade-habitat of 51-100% (Table 7).

Table 7: Valdes Island - Overhanging Shade Vegetation Habitat Index

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade
Number of Beach Units	1	12	2	6	13
Percentage	3%	35%	6%	18%	38%
Foreshore Modified (Count) %	0	2 (17%)	1 (50%)	0	0
Backshore Modified (Count) %	0	10 (83%)	2 (100%)	1 (17%)	9 (69%)
Landforms Spit/Bluff (Count) %	0	3 (25%)	0	3 (50%)	1 (8%)
	0-50% Shade			51-100% Shade	
Number of Beach Units	15			19	
Percentage	44%			56%	
Foreshore Modified (Count) %	3 (20%)			0	
Backshore Modified (Count) %	12 (80%)			10 (53%)	
Landforms Spit/Bluff (Count) %	3 (20%)			4 (21%)	

10.8.2 Overhanging-Shade Habitat and shoreline modification effects

The relationship between the reduction of overhanging-shade habitat due to modifications below and within 30 meters of the high water mark (foreshore and backshore zones) was assessed.

Of the one (1) suitable beach unit with no overhanging shade, foreshore and backshore zones were not modified; twelve (12) with 1-25% overhead shade, 17% had modified foreshore and 83% modified backshore zones; two (2) beach units with 26-50% overhead shade, 50% modified foreshore and 100% modified backshore zones; six (6) beach units with 51-75% overhead shade had 0% modified foreshore and 17% modified backshore zones; and thirteen (13) beach units with 75-100% overhead shade had 0% modified foreshore and 69% modified back shore zones (Table 7).

Of the 22 beach units with modified backshore zones, twelve (12) had reduced overhanging shade habitat; and ten (10) 51-100% overhanging shade habitat.

In general, modification of the backshore zone (within 30 meters of the high water mark) resulted in reduced overhanging-shade habitat. However, overhanging-shade habitat is still maintained at adequate levels.

10.8.3. Overhanging Shade Habitat and Landform

On Valdes Island, of beach units classified as suitable for forage fish spawning habitat, spits represent four (4) beach units and bluff-backed beaches represented three (3) beach units. Of these seven (7) beach units, none had modified foreshore zones. Three (3) of the spit beach units and one (1) of the bluff-backed beach units had modified backshore zones.

Of the twelve (12) suitable beach units with 1-25% overhanging shade, 3 (25%) had spit/bluff land forms; 51-75% overhanging shade, 3 (50%) had spit/bluff land forms; and 76-100% overhanging shade, 1 (8%) had a spit/bluff land form (Table 7).

Of the fifteen (15) beach units with reduced overhanging-shade habitat, three (3) beach units are spit land forms with no foreshore modifications. Of the nineteen (19) beach units with overhanging-shade habitat scores of 51-100%, four (4) had spit/bluff land forms (Table 7).

In summary, the reduction of overhanging-shade habitat is more closely associated with backshore modifications than land forms such as spits and bluffs.

11.0 Summary

Valdes Island has a shoreline perimeter of 40.29 kilometers with approximately 4.0 kilometers (3,996.49 m) of suitable spawning habitat for Surf smelt and Pacific sand lance. Thirty-four (34) beach units were scored as being suitable spawning habitat (Table 1). Valdes Island presents excellent opportunities to safeguard and protect these critical fish habitats. As well, the majority of Valdes Island represents intact marine riparian zones (extending at least 100 meters landward of the high water mark), protected vital marine shoreline vegetation and prey subsidies for rearing juvenile salmonids.

Valdes Island shorelines are mainly rocky shorelines with numerous pocket coves. This is similar to neighbouring Thetis and Galiano islands. Barrier beaches were also present, representing drift cells, on the east coast (Starvation Bay) and numerous beach units on the west coast. Of the barrier beaches on the west coast, there are two spits which account for four beach units (Shingle Spit and Cardel Spit). Proximal to the spits, the eroding bluffs also account for other barrier beach units. The pocket coves are short in length and have narrow beach faces. Spits, while being longer, also have narrow beach faces. Due to rising sea levels and the form of the east and west coasts of Valdes, persistence of suitable spawning beaches on Valdes will rely on land-use policies such as setbacks and land-owner actions that resist hard armouring and embrace the principles of soft-engineering or “bioengineering”.

Valdes Island had a high number of beach units accessed as suitable. This may be due to high sediment motility along wave-exposed coasts, open-facing pocket coves, and active erosion of bluff systems on the west coast. Of the forage fish habitat suitability assessments of the Gulf Islands conducted to date, this geomorphic condition is unusual. Shorelines where silt, clay and mud can accumulate, such as in inlets and closed pocket coves, are mainly lacking on Valdes Island. On Valdes, Wakes Cove is an example of a closed cove where low sediment motilities resulted in most beach units being comprised of mud and silt. Other examples of such shore forms with limited sediment motility, promoting mud/silt, are Saltery and Whalers Bay (Galiano Island).

Beaches in Trincomali Channel have a very large biomass of bivalves. As with neighbouring Thetis and Valdes Islands, Galiano Island west coast beaches contain a high volume of shell hash, and Blackberry Point is almost a pure “biogenic” beach unit.

On Valdes Island, the percentage of shoreline comprising suitable forage fish spawning habitat was similar to that of neighbouring Galiano Island (6.73%) and Thetis Island (11.9%).

Development at or within 30 meters of the high water mark (backshore zone) was evident at 22 (65%) of suitable beach units. Eighteen (18) beach units had structures and four (4) had no built structures but the lots were significantly cleared of all vegetation. Seventeen (17) of the beach units had buildings (houses or cabins) (Table 6).

Of the thirty-four suitable beach units, 15 (44%) had reduced overhanging-shade habitat (Table 7). Reductions in overhanging-shade habitat were found to be more closely associated with modifications to the backshore zone than to spit or bluff land forms (Table 7).

Generally, development within the backshore zone is moderate and the natural character of the forest and coastline has been maintained. Overall, Valdes Island shoreline development has been achieved with minimal changes to the natural character and ecological functions of the shoreline either where soft-sediment beaches were accessed or the entire island. The marine riparian zone is mainly intact along the majority of Valdes islands coast. Ecological functions such as provision of insect prey for juvenile salmon is intact. Overhanging-shade habitat at soft-sediment beaches is near optimal levels and reductions largely due to land form and minimal clearing by landowners.

The next section of this report provides finer details of certain site-specific stewardship measures to protect ecological functions of spawning habitat and juvenile salmonid rearing habitat. Residents of Valdes Island are to be commended for the excellent condition of the shorelines and marine habitats. These comments are not intended to diminish the excellent approach taken by Valdes' residents to protect their unique and beautiful island home. What follows are mainly ways to increase awareness of specific stewardship measures applicable to marine riparian, spawning beaches and foreshore habitats.

12.0 Mitigating Stressor Impacts and Planning Habitat Enhancement/Restoration

12.1 Marine Shoreline Stewardship

Throughout the islands, good stewardship should be actively encouraged. In the absence of Provincial or Federal marine shoreline management planning initiatives that recognize and protect coastal processes supporting marine riparian and beach habitats, local governance tools can be employed to fill this gap in protecting vital habitats.

12.2 Local Governance:

As coastal resources, marine riparian vegetation and forage fish spawning beaches are sensitive nearshore habitats. Section 3.4.4 of the Islands Trust Policy Statement requires that local trust committees address protection of sensitive coastal areas in official community plans and regulatory bylaws. Section 3.4.5 requires that local trust committees address the planning for and regulation of development in coastal regions to protect natural coastal processes. Coastal planning can assist by

- advocating building setbacks from the high water line as infrastructure protection to avoid armouring
- implementing shoreline buffers and
- Considering drift cell management for contiguous property owners.

Increasingly, regional districts in south coastal British Columbia are including marine shoreline protection measures in Official Community Plans, land-use bylaws and shoreline development permit areas (e.g. Cowichan Valley Regional District, City of Campbell River).

Landowner involvement in habitat protection is vital to any conservation strategy. Marine shoreline habitat protection requires specific management and mitigation measures due to the unique coastal processes forming these habitats and unique threats such as sea level rise and shoreline development. Providing practical tools will encourage effective marine shoreline stewardship as part of an integrated, local conservation strategy.

12.3 Marine Shoreline Protection and Climate Change Adaptation Toolkit for Landowners:

Landowners and local permitting officials are increasingly burdened with environmental protection as more senior governments divest themselves of this responsibility or, as in the case of marine shorelines, lack coherent and effective management policies and standards. Strengthening local governance through policy and bylaw implementation should be accompanied by a tool that property

owners utilize to protect shoreline ecological values while meeting site-development permitting requirements. Such a landowner/stewardship “toolkit” could include:

- GIS-based tools (e.g. Islands Trust MapIT),
- local habitat inventories,
- checklists of local vegetation types,
- information on how to recognize evidence of and causes of erosion,
- available engineering assessments of slope stabilities,
- Site management of storm-water and soil stabilities,
- Islands Trust marine shoreline mapping,
- soft shore/bioengineering options to replace hard armouring (Green Shores for Homes),
- information on “green docks,”
- DFO timing windows of least risk,
- steps to enhance habitat and species biodiversity,
- sea level rise vulnerability information, and
- setback corridors according to emerging Provincial climate change adaptation and municipal sustainability/resiliency options

Utilized by the shoreline property owner to assist with site planning as well as preparing for permits, the toolkit would provide a standardized reporting format for permitting staff and could assist Islands Trust staff to track local targets for sustainable and resilient coastal community planning. A local “Marine Shoreline Protection and Climate Change Adaptation Toolkit” would serve as an incentive for multiple, neighbouring shoreline property owners to work together at the “shoreline drift cell” level to manage backshore processes (eg vegetation, soil and water management) and coastal sediment processes rather than numerous individual site plans. Local, place-based “best management practices” can be developed that will assist neighbouring land owners wishing to mitigate erosion, maintain healthy marine habitats, and adapt to local climate change stressors. As well, incentives for employing “soft” options (bioengineering) rather than hard armouring for shoreline erosion and sea level rise protection should accompany any local bylaw implementation (e.g. Green Shores for Homes). The toolkit can also highlight shoreline areas requiring enhancement and/or restoration.

12.4 Stressors and Enhancement/Restoration

12.4.1 Stressors:

Shoreline modifications can change habitats as well as public access/enjoyment of beaches. Deleterious changes to habitats can be termed “stressors”. A stressor negatively impacts ecological function, poses a threat to future habitat/public values, and decreases public enjoyment/utilization of resources. Stressors can reduce the “ecosystem services” of the environment; for example, seawalls erode pebble/sand beaches reducing beach height, width and the wave- energy dissipating capacity of land-owners frontage, making infrastructure more vulnerable to negative storm impacts. Stressors can also limit the resiliency of coastal habitats to sea level rise. Restoration strategies can lead to effective solutions if grounded in cost-effective, community-supported regulatory tools. The following is a list of stressors applicable to marine shoreline habitats surveyed in this study, including emerging science dealing with rising sea levels and marine shorelines.

Stressors:

A. Shoreline Modifications

1. Hard armouring: seawalls, riprap, lock blocks and others
 - reduces public access to beach
 - removal of spawning habitat
 - interruption of sediment supply
 - increases beach erosion (sediment coarsening, beach profile changes)
 - reduces wave-energy dissipation capacity of high-intertidal beach
 - reduces marine riparian vegetation and overhanging shade habitat
 - Sea Level Rise(SLR) inundation (“coastal squeeze”: habitat narrowing; sediment coarsening; beach profile changes)
2. Pier/Docks; Boat Ramps; Groins; Berms; Breakwaters; clearing foreshore
 - reduces public access to beach
 - blocks sediment supply/littoral drift
 - increases beach erosion (sediment coarsening, beach profile changes)

B. Vegetation Removals

- impairment of soil conditions (slope/shoreline stability, pollution filtering, storm water management)
- loss of overhanging-shade habitat
- loss of nutrient (prey) inputs for juvenile salmonids

Structures placed along shorelines can impede sediment delivery to shorelines either by blocking transport along the beach or blocking sediment transport from eroding land forms. Over time, beaches will lack sediment “nourishment” and will coarsen. Hard structures (seawalls, riprap boulders, retaining walls) have various impacts on the foreshore, but generally these can increase

erosion due to wave-induced scouring. Overtime, fine sediments are scoured from the beach surface, slopes steepen, and sediments coarsen. Foreshore structures may also be placed directly on top of spawning habitat. The cumulative effects of shoreline structures have a detrimental impact on beach spawning forage fish habitat. Clearing cobbles and boulders from the foreshore changes beach profiles and changes sediment supply/delivery leading to altered habitat types.

Forage fish spawning habitat is vulnerable to the impacts of sea level rise. At sites with hard armouring placed below, at or near the high water mark (“natural boundary”) these structures cause a phenomena known as “coastal squeeze”. Hardening of the shoreline prevents the landward transgression of intertidal habitats and wave energy displacement degrades forage fish spawning habitat. As a result, the spatial area of suitable spawning habitats may be reduced or lost completely with increasing sea level rise due to the presence of hard armouring or foreshore infills.

12.4.2 Enhancement/Restoration:

Generally, beach units suitable for forage fish spawning have active sediment inputs (at natural rates of erosion) and intact vegetative corridors (marine riparian vegetation zones). These are priority sites for protection of ecological values through shoreline setbacks (buffer zones), upland site planning, and water quality protection measures. These are also areas of high social and esthetic values. Numerous beach units can be enhanced for juvenile salmonid habitat and forage fish spawning habitat and reducing erosion simply by replanting vegetation, removing or modifying structures that may be blocking sediment drift, and managing storm water and pollution/nutrient inputs into marine habitats. Beach units can also be restored by removal of hard armouring and employing soft bioengineering methods that, depending on the local oceanographic conditions, can be less expensive and more effective in mitigating erosion. The following is a list of enhancement/restoration options relevant to the habitats surveyed.

Enhancement/Restoration:

A. Shoreline Modification

- shoreline development set backs
- soft engineering approaches for shoreline stabilization
- reducing/removal number of foreshore structures present on beach unit
- beach restoration/sediment nourishment

B. Vegetation Removals

- site management/planning
- marine riparian corridors
- trim vegetation for views
- replanting vegetation
- assessing role of invasive plant species

C. Beach Health and Climate Change Resiliency

- Removal of derelict structures
- Removal/replacement of creosote pilings
- Monitoring of upland septic systems
- Monitoring/mitigating oil/fuel fouling sources
- Monitoring storm water effluent
- Minimize docks (size and number) and implement “green dock” guidelines
- Site-management to adapt to rising sea levels

13.0 Recommendations

13.1 Geomorphic Setting

Sea level rise and changing marine conditions are affecting the resiliency of the Salish Sea. Understanding the geomorphic systems and processes forming beach habitat is important for land-use planning and effective conservation measures.

Knowing the coastal processes that built and maintain the beaches of Valdes Island is important. The exposure and length of both the east and west coasts makes Valdes Island beaches highly vulnerable to rising sea levels. The pocket coves are short and narrow beaches. The spits, while having longer lengths, are also narrow. Maintaining natural sediment processes are essential to maintaining beaches in the near and longer future. Development of sites should follow principles of adaptive management to “coastal squeeze” for natural habitats and infrastructure. Persistence of suitable spawning beaches on Valdes will rely on land-use policies such as setbacks and land-owner actions that resist hard armoring and embrace the principles of soft-engineering or “bioengineering”.

Barrier Beaches and bluff-backed beaches

Barrier beaches and bluff-backed beaches are sensitive to interruptions in lateral drift along shorelines and reductions in sediment transport to the drift cell. Bluff-backed beaches generally lack a berm, and barrier beaches exist seaward of storm berms.

The bluff-backed beaches provide extensive sediment inputs to beaches and shallow subtidal zones. These beaches are highly sensitive to clearing of vegetation and soil saturation levels along the bluff and shoreline structures at the base. Management of these fragile land forms should include close monitoring of site development, adequate setbacks from the edge, and prohibit any and all additions of structures at the base. Resisting armoring throughout the beach system will be critical to maintaining these beaches, particularly for future management options against rising sea levels and increasing storm activity.

Along the east coast, Starvation Bay contains a high bank-bluff providing sediments that have formed a unique drift cell on this wave-exposed shore. There is also a creek providing sediments. The mid-intertidal is a gravel flat which is an asset acting to dissipate wave-energy and protect the toe of the shoreline bluff-bank system.

Valdes' west coast eroding bluff systems form and "feed" the beach unit at and proximal to Cardale Point, Shingle Spit, and Blackberry Point.

Pocket Coves

Along all coasts, 24 of the beach units are pocket coves (71%) along eroding, rocky shorelines (Table 4). Sediments at pocket coves generally have high retention times, localized retention features (e.g. headlands) and localized sediment sources rather than reliance on drift cell processes. Pocket coves are generally well protected from wave energy due to the presence of rocky headlands. These beaches are sensitive to changes in sediment supply and/or transport as they have limited sediment inputs. These beach units are highly sensitive to causes of sediment erosion, from vegetation clearing to foreshore structures such as boat ramps and hard revetments (seawalls and riprap boulders). Development affecting sediments within pocket coves should stress setbacks of infrastructure and vegetation management to reduced bank/berm erosion.

East coast pocket coves are highly wave exposed and largely nourished by northward, net sediment movement. East and south coast pocket coves, exposed to seasonal high winds presently maintain a fine balance between sediment transport and limited sediment supply. Development setbacks, vegetation management, and if requested by land owners, utilization of bioengineering, or soft-shore methods for bank erosion mitigation are well-known, effective measures to protect both natural and built environments.

13.2 Public Access

There is no public ferry service to Valdes Island and there are no public utilities. Access is possible by boat and limited logging roads and trails are utilized by residents. Blackberry Point is a popular boating/kayaking destination. Wakes Cove offers some vessel access to the north coast although most of the shoreline is privately owned. On the west coast there is a private boat basin at one beach unit. Wakes Cove is the only park on Valdes Island. There is also a significant amount of land in First Nations Reserve managed by the Lyackson First Nation, a large amount of land along the shoreline owned by Island Timberlands as Private Managed Forest and a portion of the shoreline that remains as Crown land.

Although Valdes Island has a small population, the pebble/sand beaches are mostly developed, either for private or industrial purposes. It is common for pebble/sand beaches to attract private land ownership, and Valdes is no exception, and there were few soft-sediment beaches that did not have development. The majority of beach units surveyed were found to be suitable for spawning, and sixty-five percent (65%) of soft-sediment beaches in this study have buildings/development within the backshore zone. No suitable spawning beaches are protected within any protected zoning categories (e.g. park); however, the natural character of the marine forest, shorelines and beaches has been maintained.

Marine setbacks of 15 m to 30 m have been initiated in a number of municipalities and local trust areas in the Strait of Georgia. Despite their ecological and ecosystem service values, marine shoreline corridors are under-represented in marine planning initiatives. Rarely are these backshore buffer areas implemented to provide wildlife corridors, protect shoreline ecological values, and act as storm berms as part of climate change adaptation measures. On Valdes, undeveloped lands could be protected with marine shoreline setbacks in the near future and form the backbone of a marine conservation strategy for Valdes while providing ecosystem services for islanders. These marine shoreline buffers, linked to the already excellent private-land owner stewardship could assist with protecting the health of the Salish Sea into the future.

13.3 Shoreline structures

Foreshore areas are the property of the Crown unless upland property owners secure a lease for a water lot or have “grandfathered” use of the foreshore through historical zoning (e.g. industrial land sites, commercial, recreational uses). Access to and alterations to the foreshore require permits and approvals at various government levels. Impacts of shoreline structures vary depending on their construction and site-specific factors such as backshore land forms and topography, soils/sediments, wave-exposure, fetch, and tidal currents.

Below the high water mark, two beach units were noted to have short sections of hard armouring (riprap and a stone gabion); and both are east-coast pocket coves. The armouring covered only a small portion of the shoreline (less than 50% of the shoreline length). There was no evidence of erosion of the beach face, impacts to or burial of spawning sediments.

These east coast pocket coves are mainly protected from wave and wind energy by natural features of rocky headlands, proximal reefs, logs, and moderately wide berms (5-10 meters wide). The presence of logs and moderately wide berms provide natural wave-energy dissipation. At both these beach units, cabins/homes are far enough from the high water mark to allow the beaches to transgress landward and survive rising sea levels.

On the west coast, a breakwater divides a section of the shoreline into two separate beach units. This is the only significant shoreline modification on the west coast of Valdes. On the north facing side of one spit, a boat ramp in the form of railway ties traverses the beach face. The boat ramp is mainly level with the beach face and does not impede sediment movement; and, if placed on the beach only temporarily during the summer season, it should not impede lateral movement of sediments.

Within 30 meters of the high water mark, buildings (houses and cabins) were present at 17 of the 34 beach units found to be suitable for spawning by Surf smelt and Pacific sand lance. Structures to access the shoreline were the most common form of modification along Valdes’ shorelines (e.g. stairs to beach, boat houses, and boat ramps) (Table 6).

Often home owners use hard armouring without understanding or knowing site-specific erosion mitigation options. Extensive changes to the backshore can result in accelerated rates of bank erosion independent of marine sources. At both of the east coast pocket coves with hard armouring,

the wide berms, presence of logs, and rocky headlands provide protection from wave-induced bank erosion. Backshore causes of erosion can be reduced and land-owners can enjoy the full potential of their properties. Setting back structures, maintaining and replanting vegetation, as well as storm-water management are effective and low-cost measures to protect shorelines from erosion.

13.3.1 Hard Armouring and Sea Level Rise

Safeguarding backshore and intertidal habitats against “coastal squeeze” builds resiliency during a period of sea level rise. Beaches used for spawning fishes are among the most at risk habitats on the planet due to sea level rise. Eroding backshore land forms and the absence of development, such as seawalls and infrastructure, near the high water mark are both necessary to allow spawning habitat to transgress landward to survive rising sea levels.

Adaptive management for sea level rise involves setbacks as well as professional advice on coastal processes. Neighbouring property owners can achieve better solutions by considering the integrity of the drift-cell or beach as a whole rather than as separate parcels.

On Valdes Island, at all suitable beach units, the present low incidence of armouring and backshore conditions are favourable for landward transgression of spawning beaches.

At present, the low incidence of hard armouring does not preclude the landward transgression of any of the beach units. However, the presence of buildings (cabins/homes) within 5-10 meters of the high water mark will require future solutions to deal with flooding due to rising sea levels. Development on the bluff surface of Starvation Bay will require professional advice to protect land-owners’ investment as well as the natural erosional processes required to maintain the exceptional beach units of this bluff-fed drift cell. Erosion of the bluff at one beach unit at Starvation Bay was noted. Cabins located close enough to the high water mark on low sloping backshore and neighbours would be well-advised to work together with a professional to implement soft-shore techniques to protect and preserve the coastal processes forming banks and beaches. Present infrastructure can be protected by employing soft shore techniques if land owners are provided with this information.

Feeder bluffs sustain barrier beaches and the spits of Valdes Island. Armouring at the feeder bluff toe, groins or breakwaters and seawalls should be rejected as options to assist with protection of these beaches and land forms.

Infrastructure at spits are especially vulnerable as these land forms are likely to be inundated by rising sea levels. Investment in infrastructure at spits should be cautioned and guided by careful site management and planning for the optimal siting of buildings, storm-water management, protection of coastal sediment protection and most importantly, the rejection of hard armouring if sea defences are required.



Low-lying land forms such as spits are highly vulnerable to loss due to rising sea levels.
Cardale Point, Valdes Island Photo: RC de Graaf

13.3.2 Piers and Docks

While piers and docks were not found to span any of the soft-sediment beaches assessed as suitable spawning habitat, these structures are present on Valdes Island.

Overwater structures such as piers and docks have significant negative impacts including loss of public access along shorelines, interruption of sediment transport, shading causing reduction and elimination of submerged aquatic vegetation and creosote. Refitting of aging public dock and park facilities can serve as a “green dock” pilot project by: minimizing the number of and size of docks, removal of creosote pilings and styrofoam floatation, and using light-penetrating panels.

13.4 Vegetation Removal

Backshore zones (area within 30 meters of the high water mark) were modified at 22 (65%) of beach units. 15 beach units (44%) had reduced overhanging-shade habitat (Table 7). Reductions in overhanging-shade habitat were found to be more closely associated with modifications to the backshore zone than to spit or bluff land forms (Table 7). Changes in backshore vegetation include both the character of the vegetation (grasses, trees and shrubs) and the width of the vegetative zone. Areas assessed as being suitable for forage fish spawning may require improved management measures by the logging interests on Valdes.

Erosion

Reductions in marine riparian vegetation can result in shoreline bank erosion due to soil/bank saturation. Losses of trees/shrubs and replacement with lawns within backshore zones (area within 30 meters of the high water mark) can create problems with storm-water management. Evidence of erosion due to storm-water includes slumping surfaces, vegetation scars, talus cones at bluff toes, undercutting of banks, falling trees and exposed roots of trees and shrubs.



Evidence of shoreline bank erosion due to backshore vegetation losses.
Valdes Island - Photo: RC de Graaf

Two beach units showed evidence of bank erosion due to losses of marine riparian vegetation near the high water mark. At both these beach units, protective berms and logs are present, and extensive clearing of marine riparian vegetation has taken place within the backshore zone and lawns have replaced shrubs and trees. On the bluff slope, vegetation scars and talus cones at the base of the bluff were evident. On the low-bank backshore zone, tree roots and undercutting of the bank are evident.

Enhancement and Restoration Measures:

Feeder bluffs and banks erode slowly to provide the sediments necessary to build beaches and protect shorelines from storms. A cost-effective measure to protect shorelines from accelerated-erosion rates is restoring lost vegetation along the bank and even a narrow fringe behind the bank. Natural trees/shrubs can be integrated with more horticultural species. Not only do trees and shrubs absorb large volumes of water, their extensive root systems maintain bank slopes and reduced erosion rates. Rain gardens are drainage ditches enhanced with water-loving plants and are popular in many urban areas adding habitat and assisting with storm-water management and local aquifer renewal.

Vegetation removal along the shoreline should be avoided. To accommodate changes that landowners may require while developing their properties, stewardship practices that encourage alternatives, such as trimming tree branches and shrubs only when needed, rather than vegetation removal, will maintain ecological functions such as insect prey delivery for juvenile salmonids as well as protect shorelines from accelerated rates of erosion. Vegetation replanting is also advised. Native tree and shrub species that provide overhanging-shade habitat can quickly revegetate the shoreline bank.

As stated earlier, overall, shoreline development of Valdes Island has been achieved with minimal changes to the natural character and ecological functions of the shoreline either where soft-sediment beaches were accessed or around the entire island. The marine riparian zone is mainly intact beyond 100 meters from the high water mark and along the vast majority of Valdes Island's shoreline perimeter. Other than minimal reduction in overhanging-shade habitat at some soft-sediment beaches during site development, the marine shoreline forest is near optimal levels.

13.5 Beach Health/Enhancement

The Lyackson First Nation, residents, landowners, the Valdes Island Conservancy and land-use planners continue to ensure that the shorelines of Valdes Island are in excellent condition.

Two beach units present opportunities to improve water quality and overall beach health.

One west-coast beach unit could be improved by removal of metal parts of old machinery on the beach face, likely from former industrial use.

At one beach unit on the west coast, there is a breakwater structure and creosote pilings, likely from former industrial use. The site is currently a small boat basin for residents. The creosote pilings are not of any use. Creosote pilings, particularly older treated logs, present a significant toxic risk as bioaccumulation of these “legacy toxins” move through the food web. Removal of these pilings would improve water quality for fish and shellfish.

14.0 Potential Use of Data Set Provided

This report presents the forage fish spawning habitat maps only. Maps of overhanging shade vegetation, marine riparian vegetation, as well as specific foreshore structures and categories of foreshore/backshore modification can also be generated from the data provided as part of the project deliverables.

A sea level rise risk map can also be generated from these data to show beaches likely to be reduced or lost to rising sea levels due to “coastal squeeze” and changing land forms (lagoons and spits). The term “coastal squeeze” applies to marine shoreline habitats that will be diminished or lost as these habitats are blocked from landward retreat due to coastal development and threatened seaward by rising sea levels.

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Appendix A – Valdes Island – Forage Fish Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Length (m)	Geomorphic Habitat Type	Geographic Position
1	VI_NE13	StarvationByS	Suitable Habitat	Continuous	SS	SST2	52.97	Pocket cove	East
2	VI_SE14	NoelBy1	Suitable Habitat	Continuous	PSL	PSLT3	18.43	Pocket cove	East
3	VI_SE15	NoelBy2	Not Suitable Habitat	Continuous	nil	Cb	8.71	pocket cove	East
4	VI_SE16	NoelBy3	Suitable Habitat	Continuous	SS/PSL	SST3	34.23	Pocket cove	East
5	VI_SE17	LloydDetwillerBy	Suitable Habitat	Continuous	SS/PSL	SST3	104.39	Pocket cove	East
6	VI_SE18	ValdS1	Suitable Habitat	Continuous	PSL	PSLT3	31.75	Pocket cove	East
7	VI_SW22	CardellPntS	Suitable Habitat	Continuous	SS/PSL	SST4	317.65	Barrier beach	West
8	VI_SW23	CardellPntN	Suitable Habitat	Continuous	SS/PSL	SST4	296.54	Barrier beach	West
9	VI_SW24	ShingleS1	Suitable Habitat	Discontinuous	SS/PSL	SST4	335.51	Barrier beach	West
10	VI_SW25	ShingleSpS	Suitable Habitat	Continuous	SS/PSL	SST4	264.16	Barrier beach	West
11	VI_SW26	ShingleSpN	Suitable Habitat	Continuous	SS/PSL	SST4	565.31	Barrier beach	West
12	VI_SW27	ShingleN1	Suitable Habitat	Continuous	SS/PSL	SST1	113.59	Barrier beach	West
13	VI_NW28	BlackBryS1	Suitable Habitat	Continuous	PSL	PSLT3	99.52	Barrier beach	West
14	VI_NW29	BlackbryPnt	Suitable Habitat	Continuous	SS/PSL	SST4	442.35	Barrier beach	West
15	VI_NW30	BlackBryN1	Suitable Habitat	Continuous	SS/PSL	SST3	39.26	Pocket cove	West
16	VI_NW31	BlackBryN2	Suitable Habitat	Discontinuous	SS/PSL	SST3	75.87	Pocket cove	West
17	VI_NW32	BreakwaterBe	Suitable Habitat	Continuous	SS/PSL	SST1	61.48	Pocket cove	West
18	VI_NW33	BlackBryN3	Suitable Habitat	Continuous	SS/PSL	SST4	31.72	Pocket cove	West
19	VI_NW34	DibuxantePtS1	Suitable Habitat	Continuous	SS/PSL	SST4	64.74	Pocket cove	West
20	VI_NW35	CoalMineBy1	Suitable Habitat	Discontinuous	SS	SST1	76.46	Pocket cove	West
21	VI_NE5	ValdNE1	Suitable Habitat	Continuous	SS	SST1	25.41	Pocket cove	East
22	VI_NE6	ValdNE2	Suitable Habitat	Continuous	SS	SST1	12.56	Pocket cove	East
23	VI_NE7	ValdNE3	Suitable Habitat	Continuous	SS/PSL	SST3	31.68	Pocket cove	East
24	VI_NE8	ValdNE4	Suitable Habitat	Continuous	SS	SST1	30.38	Pocket cove	East
25	VI_NE9	ValdNE5	Suitable Habitat	Discontinuous	SS/PSL	SST3	146.88	Pocket cove	East
26	VI_NE3	OysterBy	Suitable Habitat	Continuous	SS	SST3	12.00	Pocket cove	East
27	VI_NE4	ValdN2	Suitable Habitat	Discontinuous	SS/PSL	SST4	114.83	Pocket cove	East
28	VI_NE2	KendrickIs	Suitable Habitat	Continuous	SS/PSL	SST4	60.65	Pocket cove	East
29	VI_S19	Porlier1	Suitable Habitat	Continuous	SS	SST1	48.94	Pocket cove	South
30	VI_S20	Layaksan1	Suitable Habitat	Continuous	SS/PSL	SST1	53.88	Pocket cove	South
31	VI_S21	Layaksan2	Suitable Habitat	Continuous	SS	SST2	7.38	Pocket cove	South
32	VI_N1	DibuxantePtE1	Suitable Habitat	Continuous	SS/PSL	SST2	50.82	Pocket cove	North
33	VI_NE10	StarvationBy1	Suitable Habitat	Discontinuous	SS	SST2	96.52	Barrier beach	East
34	VI_NE11	StarvationBy2	Suitable Habitat	Continuous	SS/PSL	SST3	227.66	Barrier beach	East
35	VI_NE12	StarvationBy3	Suitable Habitat	Continuous	SS/PSL	SST3	50.97	Pocket cove	East

Appendix B – Valdez Island – Forage Fish Habitat Beach Types by Grain Size

Pacific Sand lance - Type 3

Beach Number	Valdez Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
VI_SE14	NoelBy1	PSLT3	PSL	Continuous
VI_SE17	LloydDetwillerby	PSLT3	PSL	Continuous
VI_NW27	BlackBryS1	PSLT3	PSL	Continuous

Surf smelt - Type 1

Beach Number	Valdez Island Beach Unit	Grain Size Type	by Species	Sediment Distribution
VI_SW26	ShingleN1	SST1	SS/PSL	Continuous
VI_NW31	BreakwaterBe	SST1	SS/PSL	Continuous
VI_NW34	CoalMineBy1	SST1	SS	Discontinuous
VI_NE5	ValdNE1	SST1	SS	Continuous
VI_NE6	ValdNE2	SST1	SS	Continuous
VI_NE8	ValdNE4	SST1	SS	Continuous
VI_S18	Porlier1	SST1	SS	Continuous
VI_S19	Layaksan1	SST1	SS,PSL	Continuous

Surf smelt - Type 2

Number	Beach Unit	Type	by	Distribution
VI_NE13	StarvationByS	SST2	SS	Continuous
VI_S20	Layaksan2	SST2	SS	Continuous
VI_N1	DibuxantePtE1	SST2	SS,PSL	Continuous
VI_NE10	StarvationBy1	SST2	SS	Discontinuous

Appendix B – Valdes Island – Forage Fish Habitat Beach Types by Grain Size

Surf smelt - Type 3

Beach Number	Valdes Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
VI_SE15	NoelBy3	SST3	SS/PSL	Continuous
VI_SE16	LloydDetwilerBy	SST3	SS/PSL	Continuous
VI_NW29	BlackBryN1	SST3	SS/PSL	Continuous
VI_NW30	BlackBryN2	SST3	SS/PSL	Discontinuous
VI_NE7	ValdNE3	SST3	SS/PSL	Continuous
VI_NE9	ValdNE5	SST3	SS/PSL	Discontinuous
VI_NE3	OysterBy	SST3	SS	Continuous
VI_NE11	StarvationBy2	SST3	SS,PSL	Continuous
VI_NE12	StarvationBy3	SST3	SS,PSL	Continuous

Surf smelt - Type 4

Beach Number	Valdes Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
VI_SW21	CardellPntS	SST4	SS/PSL	Continuous
VI_SW22	CardellPntN	SST4	SS/PSL	Continuous
VI_SW23	ShingleS1	SST4	SS/PSL	Discontinuous
VI_SW24	ShingleSpS	SST4	SS/PSL	Continuous
VI_SW25	ShingleSpN	SST4	SS/PSL	Continuous
VI_NW28	BlackbryPnt	SST4	SS/PSL	Continuous
VI_NW32	BlackBryN3	SST4	SS/PSL	Continuous
VI_NW33	DibuxantePtS1	SST4	SS/PSL	Continuous
VI_NE4	ValdNE2	SST4	SS/PSL	Discontinuous
VI_NE2	KendrickIs	SST4	SS/PSL	Continuous

Appendix C: Valdes Island – Spawning Beach Habitat Types – Grain-Size Curves

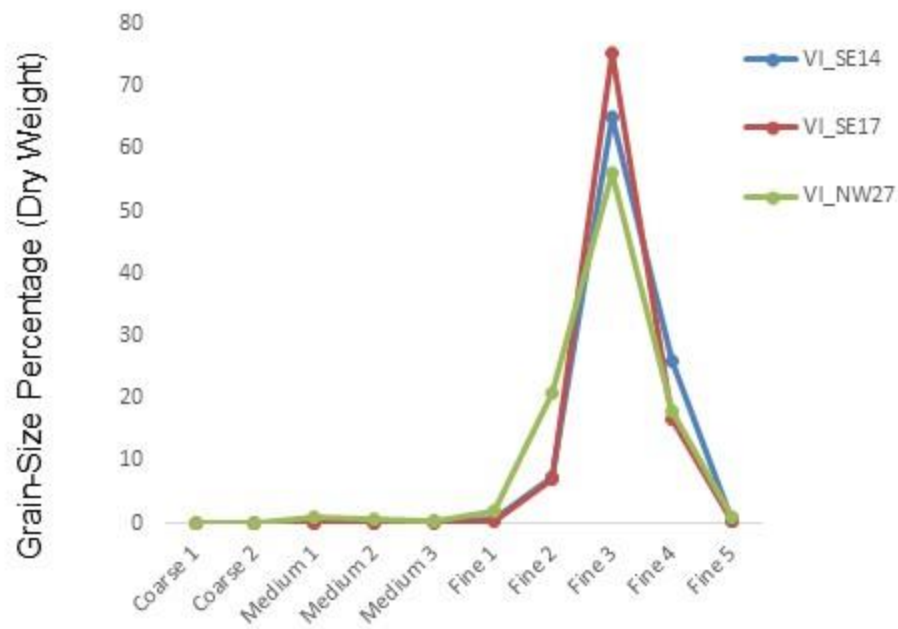


Figure 2– Valdes Island – Pacific sand lance Type 3 Beaches

Appendix C: Valdes Island – Spawning Beach Habitat Types – Grain-Size Curves

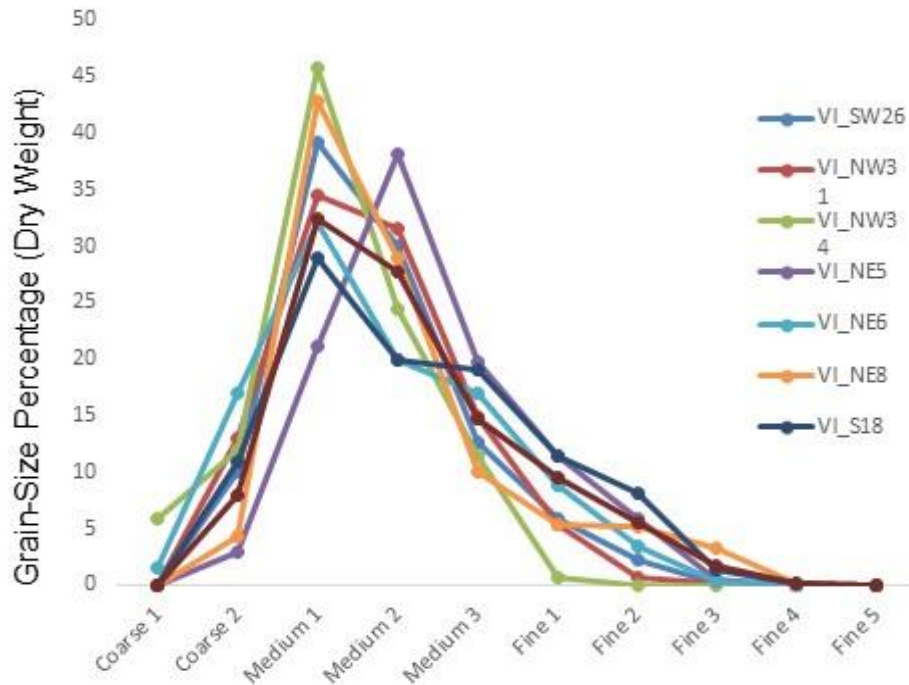


Figure 3 Valdes Island – Surf Smelt Type 1 Beaches

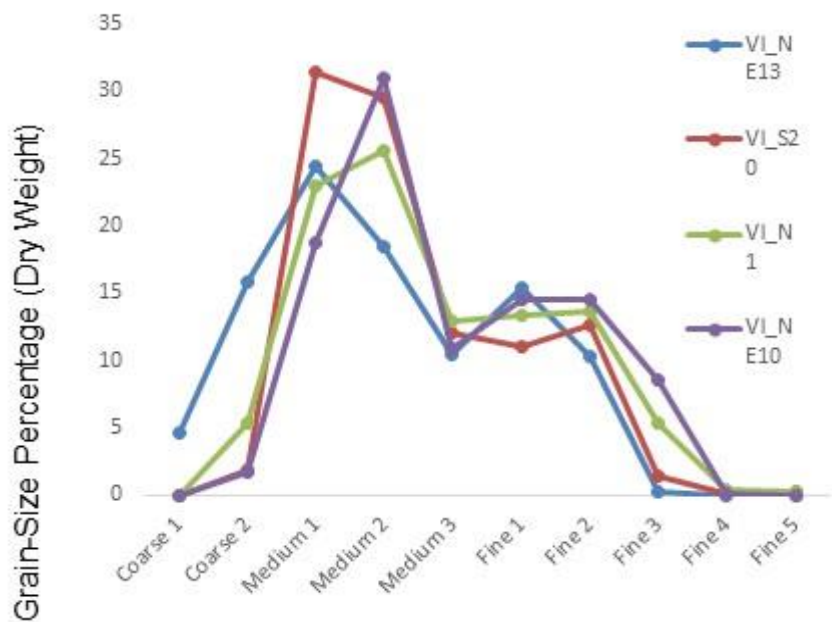


Figure 4 Valdes Island – Surf Smelt Type 2 Beaches

Appendix C: Valdes Island – Spawning Beach Habitat Types – Grain-Size Curves

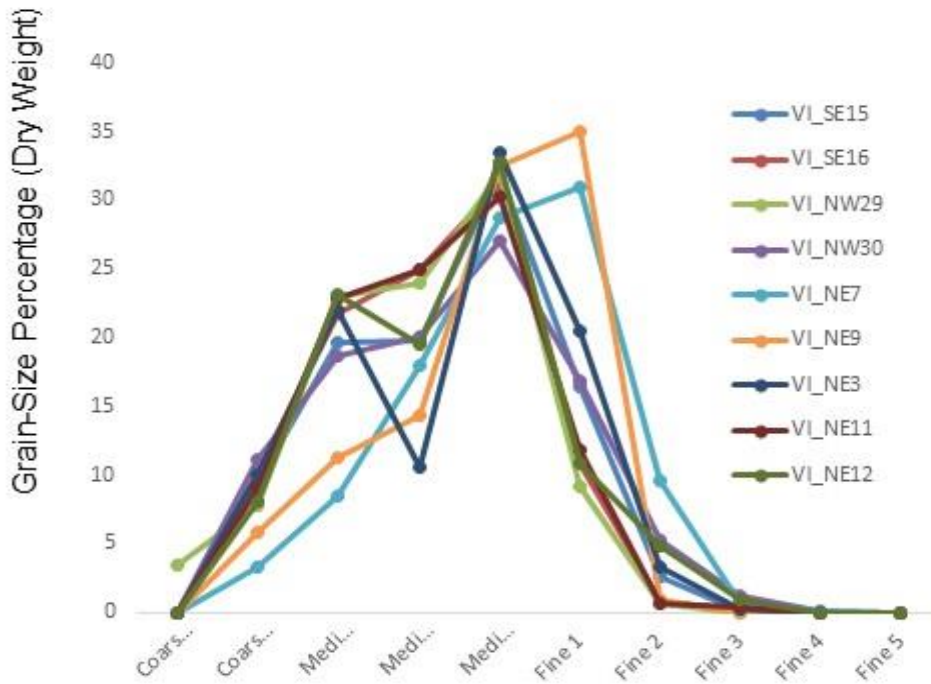


Figure 5 Valdes Island – Surf Smelt Type 3 Beaches

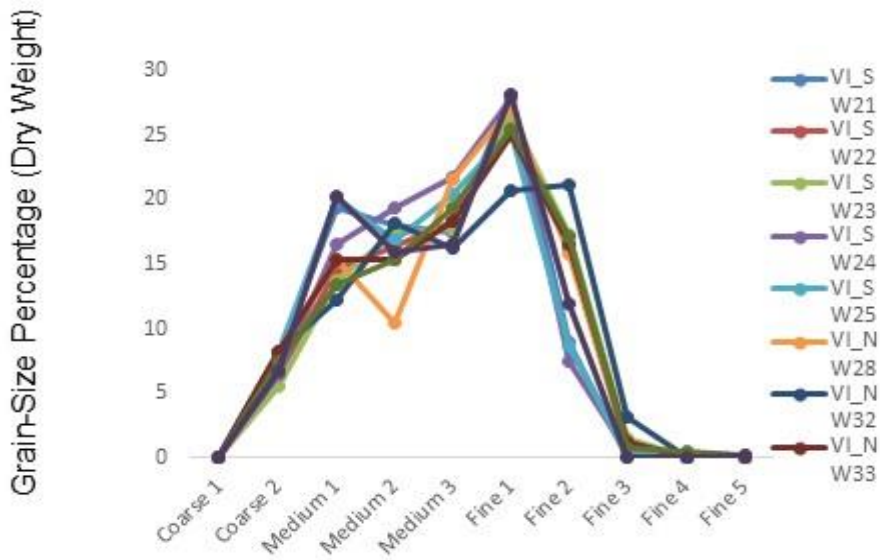


Figure 6 Valdes Island – Surf Smelt Type 4 Beaches

1. General Application

1.01

The target horizontal accuracy is 1 metre. The lowest acceptable horizontal accuracy is 5 metres, at the 95% confidence level. This applies to final map data after averaging (for point features), approximating (for line features), and any editing.

1.02

All GPS receiver systems must be approved for use in stream mapping by Islands Trust GIS staff. Only receiver models which have been tested and proven to be capable of meeting the above accuracy specification in field conditions will be approved.

1.03

At least one person, who is responsible for the quality of the data, must act as a supervisor and have completed GPS-specific training acceptable to Islands Trust GIS staff.

1.04

Field operators must be trained to the satisfaction of the supervisor, including GPS training and other training as required.

2. Field Parameters and Procedures

2.01

All position fixes must use at least four satellites. No height constraints can be applied.

2.02

The minimum elevation angle to satellites is 15 degrees above the horizon.

2.03

The maximum Dilution of Precision (DoP) is:

HDOP 5 (preferred in most cases)

PDOP 8

GDOP 10

VDOP 5 (only if elevations are required)

2.04

For standard static point features, occupation time must be at least 60 seconds AND there must be at least 30 individual position fixes for each feature.

Appendix D: GPS/GIS Methodology

2.05

The maximum distance for point offsets is 25 metres. Directions must be accurate to 2 degrees and distances accurate to 1 metre. If the slope is over 10 percent and over 10 metres long, slope measurements (accurate to 5 percent or 3 degrees) must be made.

2.06

For all line (and polygon) features, all significant deflections and meanders of the feature must be mapped. Dynamic points recorded every 5 metres and static every 50 metres, or significant deflection.

2.07

For line (and polygon) features surveyed in dynamic mode, the majority of the individual position fixes must be no more than 5 metres apart. The maximum distance between successive position fixes is 10 metres.

2.08

The maximum distance for constant line offsets is 5 metres.

2.09

Supplementary traverses (using compass and chain) must begin (Point of Commencement) and end (Point of Termination) on static GPS point features or on survey control monuments of 1 metre or better accuracy.

2.10

Directions for supplementary traverses must be accurate to 2 degrees and distances accurate to 1 metre. If the slope is greater than 10 percent, slope measurements accurate to 5 percent or 2.5 degrees must be made. The maximum length of an individual traverse leg is 50 metres. There is no limit on the total length of a supplementary traverse.

2.11

Static features collected for start and end point of all sampling units. Static features will be collected and accuracy requirements as outlined in section 2.04.

2.12

Sampling unit feature descriptions refer to the centerline of B1 sediment component. Centerline changes of direction will be captured as static points every 50 meters or less. Centerline of features will be described between static points using dynamic mode. Dynamically collected transverses will not be required to meet static feature standards of accuracy.

3. Data Processing and Mapping

3.01

All position fixes must be differentially corrected in real-time or post-processed. If position corrections are used, the same set of satellites must be used at the reference station as at the field receiver.

3.02

Reference stations (real-time or post-processed) must be approved by Islands Trust GIS staff.

3.03

The maximum age of real-time corrections is 20 seconds from the time the observations are made at the reference station to the time the computed corrections are applied at the field receiver.

3.02

All directions from compass observations must be corrected for declination before offset or traverse computations. If applicable, correction for grid convergence must be made.

3.05

Supplemental traverses must close to better than 1 percent (1/100) of the total traverse distance plus 2.5 metres. Traverse misclosures over 2.5 metres total must be adjusted ("balanced") using the standard compass rule method.

3.06

If true NAD 27 coordinates are required, NAD 83 coordinates must be converted using the Canadian National Transformation, version 2 (NT v2).

3.07

If elevations are required, they must be converted from ellipsoidal to orthometric using the CRD Geoid model HT 2.0.

3.08

If data in any other coordinate system (e.g. ground coordinates) are required, procedures acceptable to Islands Trust GIS staff and the owner of the mapping must be used.

3.09

Any discrepancies between the GPS survey and existing mapping used as base maps must be resolved to the satisfaction of Islands Trust GIS staff and the local agency(s) considered responsible for the mapping.

Appendix E: Digitizing Spatial Data and Map Production

Mapping Procedure for Suitable Forage Fish Habitat Beach Segments using Static and Dynamic GPS Features

Pathfinder Office

Export GPS point features and positions-not-in-features as two separate shapefiles using Pathfinder Office.

ArcGIS 10.1

1. Project the two GPS data shapefiles to NAD83 UTM 10N projection..
2. Create an empty polyline shapefile with NAD83 UTM 10N projection for the Forage Fish Habitat beach segments.
3. Connect static GPS features with a common *FILENAME* attribute using the Point to Line tool.
4. Re-shape the centerline between static feature points by snapping to dynamic feature points. Only start and end points with horizontal accuracy less than 5m are used for Forage Fish Segments that are Suitable Habitat.
5. Provide a preliminary *Line_Segmen* classification based on the data sheet provided by Ramona.
6. Finalize beach segment polylines and connect additional attributes.
7. Digitize any remaining 'Not Habitat' segments using ortho-photographs and ArcGIS digitizing tools at a scale of 1:5,000.
8. For segments with GPS end points which don't meet the accuracy standards, the segment end point is digitized using ortho-photographs at 1:5,000 scale. These segments have the attribute *Collection = 'Digitized'*

Appendix F: Forage Fish Habitat Suitability Assessment Methods

Housed with the Islands Trust Fund and the author