Salt Spring Island and Wallace Island
Surf smelt and Pacific sand lance
Spawning Habitat Suitability Assessments
September 2015-September 2016

Isabella Point– Salt Spring 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 for and their population abundance in the Strait of Georgia is declining (Therriault et al 2002, DFO 201). 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.

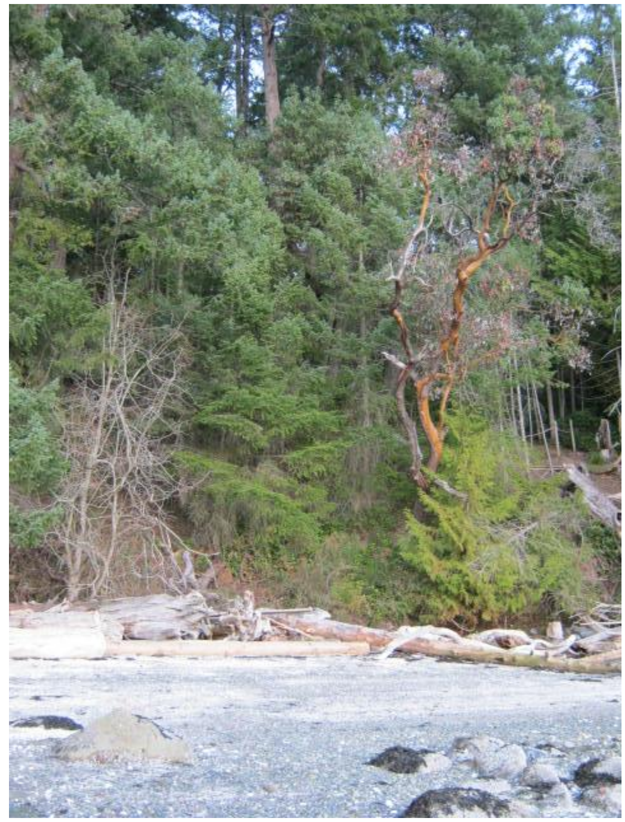
Numerous fish, seabird, and marine mammal populations are in precipitous decline in British Columbia and scientists have started to look at the link between forage fish biomass reduction and these declining populations.

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

Overhanging Shade Vegetation
Photo: RC de Graaf

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. Overtime, 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 gravels 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.

Overhang shade vegetation spanning the spawning zone - 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 slope (Penttila 2001b, Penttila 2007, de Graaf unpublished data); however, this area of the intertidal has been sparsely sampled.

Upper beach face – spawning habitat
Photo: RC de Graaf

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 and 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 Spawning Beaches

Ganges Harbour once supported a commercial fishery for Surf smelt and anchovy. Residents near Southey Point Road reported that locals would collect Surf smelt from this north coast beach (Beach Unit numbers NW1 and NW2). South of Musgrave Landing, residents report shoals of Surf smelt being driven to the beaches due to predation by schools of dog fish shark (Beach Unit number SW143.

On Salt Spring Island, spawning surveys by the British Columbia Marine Conservation and Research Society (Sea Watch Society) have been ongoing since 2011. To date, winter spawning Surf smelt and Pacific sand lance have been detected. All results have been verified by Sea Watch Society and Salish Sea Biological.

A winter-spawning Surf smelt beach was confirmed at Churchill Beach and Pacific sand lance spawning has been confirmed at Walker Hook. A 1-embryo Pacific sand lance beach has been confirmed at Fulford Harbour.

Established survey standards (Washington State and British Columbia) stipulate that results of 1-embryo beaches show evidence of spawning activity but are not conclusive to categorize the beach as a spawning beach until further embryos are detected.

6.0 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).

6.1 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.

6.2 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).

6.3 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.

7.0 Introduction to the Beach Spawning Forage Fish Habitat Assessment

7.1 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 Salt Spring and Wallace Islands. 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.

7.2 Area Surveyed

The entire coastline of Salt Spring Island and Wallace Island were 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. The Tsawout First Nation granted permission to access shorelines under their jurisdiction.

Salt Spring Island was surveyed over 33 days from September 2015 to September 2016 (September 3, 7, 13, 16, 24, 28; October 10, 11, 16, 2015; January 1, 2, 12; May 4, 5, 6, 10, 11, 16, 17, 24, 25; June 23, 29; July 1, 2; August 15, 16, 17, 19, 21; September 3, 4, and 5, 2016.

Wallace Island was surveyed on May 25, June 21, and August 21, 2016.

Surveys were not conducted if there had been major storm activity within seven-ten days of the survey date.

8.0 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.

8.1 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.

8.2 GPS/GIS Methodology

8.2.1 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 E).

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 orthophotographs provided from the Islands Trust and reviewed by the author.

8.2.2 Digitizing Spatial Data and Map Production

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

9.0 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.

10.0. Salt Spring Island - Results

10.1 Statistical Analyses

In total**,** two-hundred and sixteen (216) beach units comprised of unconsolidated sediments were assessed (Table 1). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed one-hundred and ninety-four (194) beach units with 80% similarity to known positive beaches in BC and Washington State and were classified as "suitable spawning habitat" (Figure 1A-N). One hundred and fourty-nine (149) of these beach units had continuous habitat and fourty-five (45) had discontinuous habitat.

Twenty-two (22) beach units failed statistical analyses, had non-conforming grain-sizes, and were classified as "not suitable spawning habitat".

Table 1: Salt Spring Island - Beach Unit Statistical Analysis

	Count	Total	Length (m)	Percentage of Shoreline Perimeter
Habitat	194		15036.84	11.0%
Not Suitable Habitat	22		1297.82	0.9%
Total Beach Units Assessed		216		
Total Length (meters)			16334.00	
Habitat				
Continuous	149		10324.65	
Discontinuous	45		4712.90	
Perimeter Distance of Salt Spring Island			137023.00	

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. One hundred and ninety-four (194) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix B, Appendix C, Figures 2-8). The grain-size frequencies of twenty-two (22) samples did not meet the statistical standards of the analysis.

10.3 Length of Suitable Forage Fish Spawning Habitat

The total shoreline perimeter of Salt Spring Island is 137 kilometers (137,023 m). Suitable forage fish spawning habitat comprised 15 kilometers (15,036.84 m) or 11 percent of the Salt Spring Island shoreline perimeter (Table 1 and 2). The shoreline perimeter is comprised of 0.7%, suitable for Pacific sand lance spawning, 2.7% suitable for Surf smelt spawning, and 7.6% suitable for Surf smelt/Pacific sand lance.

Of the suitable forage fish spawning habitat, 6.1% (917.51 m) is suitable for Pacific sand lance spawning, 24.4 percent (3,667.45) suitable for Surf smelt spawning; and 69.5% (10,451.88) as suitable for Surf smelt/Pacific sand lance spawning habitat (Table 2).

Table 2: Salt Spring Island Beach Units - Suitable Forage Fish Spawning Habitat

Salt Spring Island - Classification of Suitable Forage Fish Spawning Beach Units

	SS	PSL	SS/PSL	Total (m)
Count	54	15	125	
Length (m)	3667.45	917.51	10451.88	15036.84
Length Percentage	24.4%	6.1%	69.5%	100.0%
Shoreline Perimeter Percentage	2.7%	0.7%	7.6%	11.0%

SS - Surf smelt

PSL - Pacific sand lance

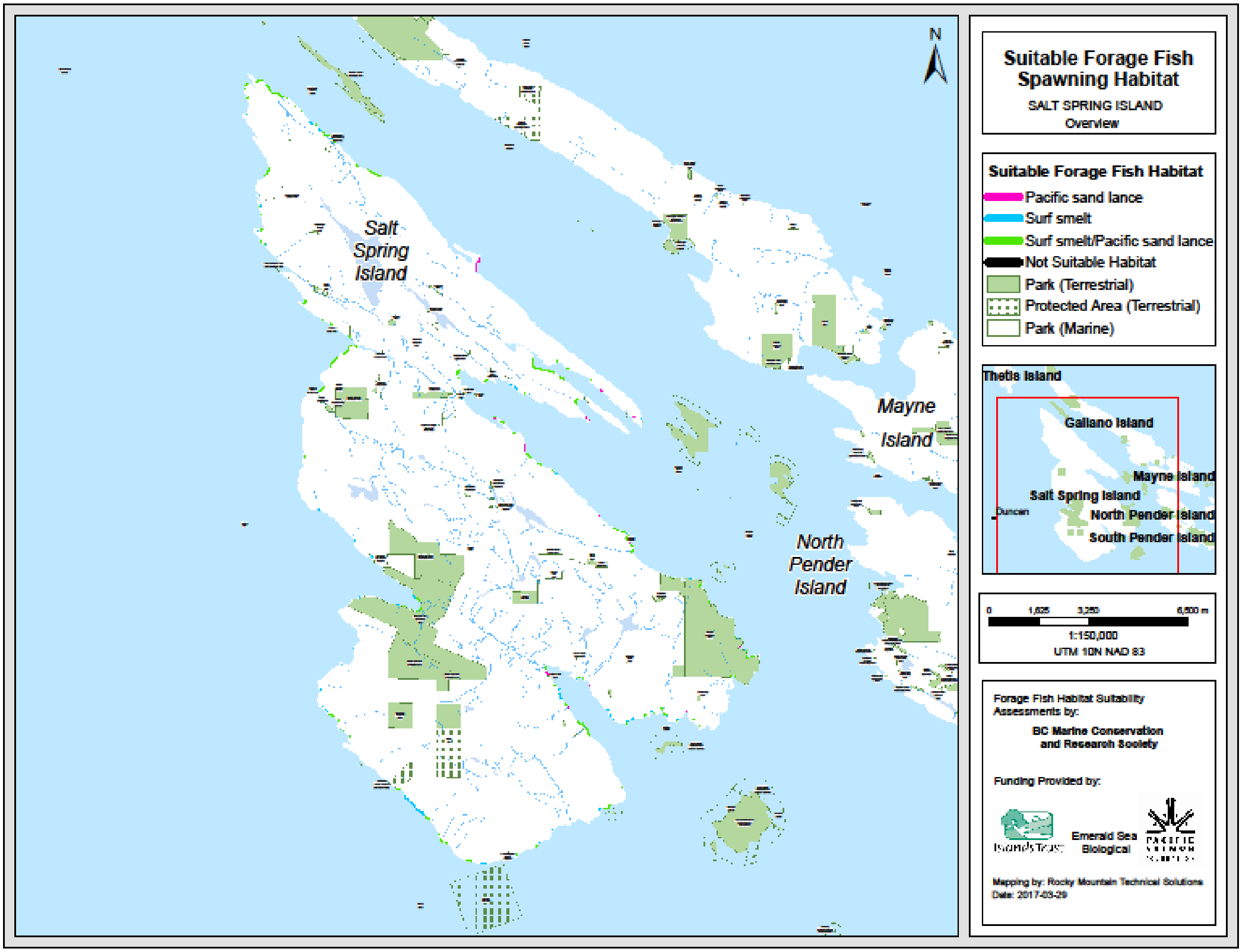
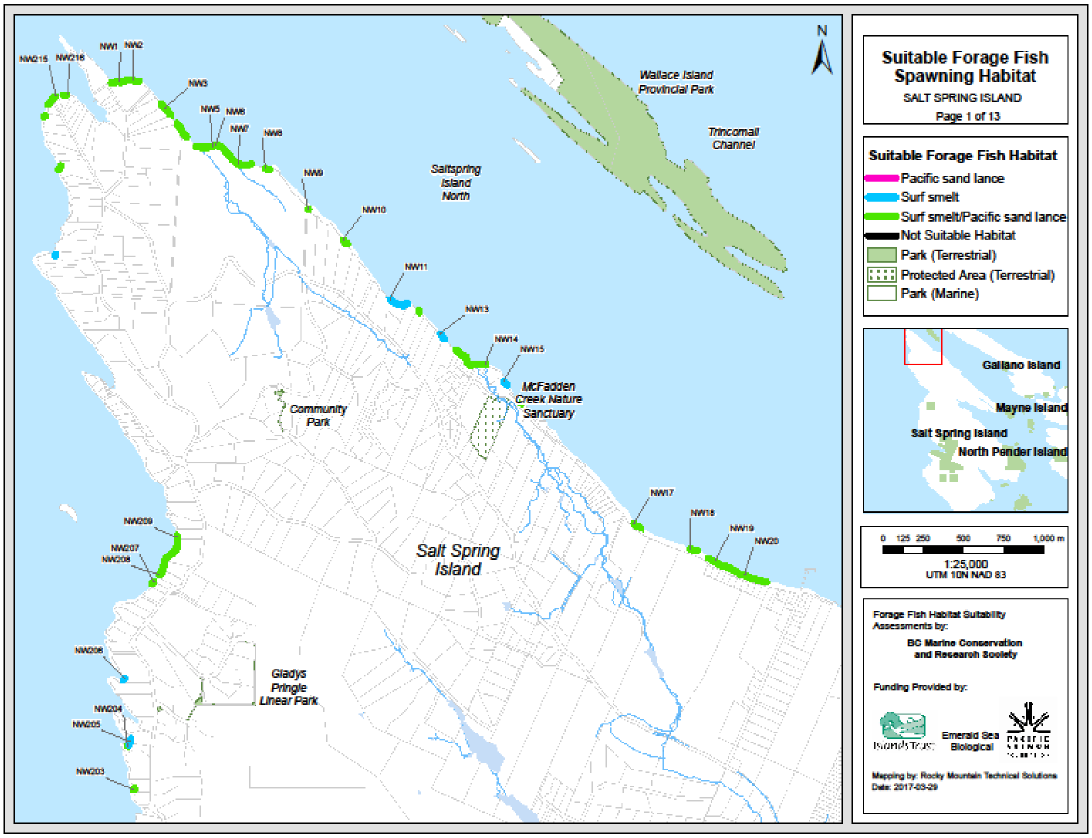


Figure 1A: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats



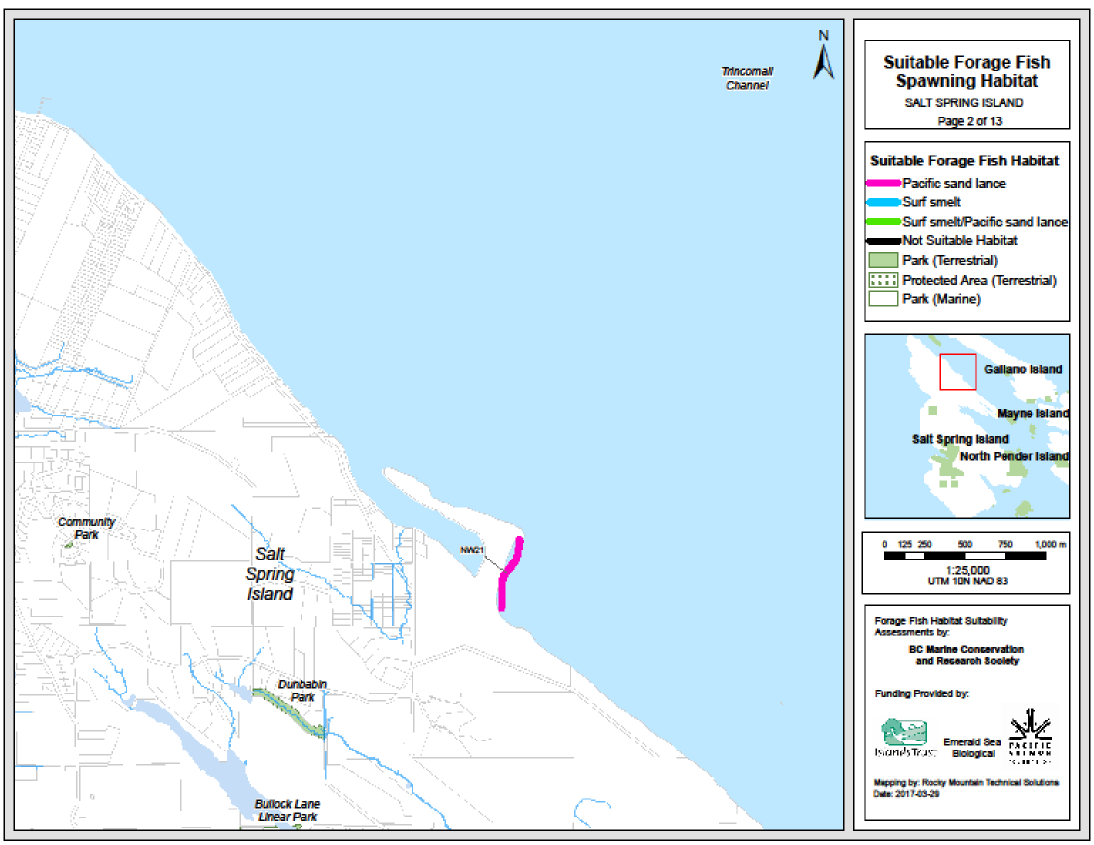
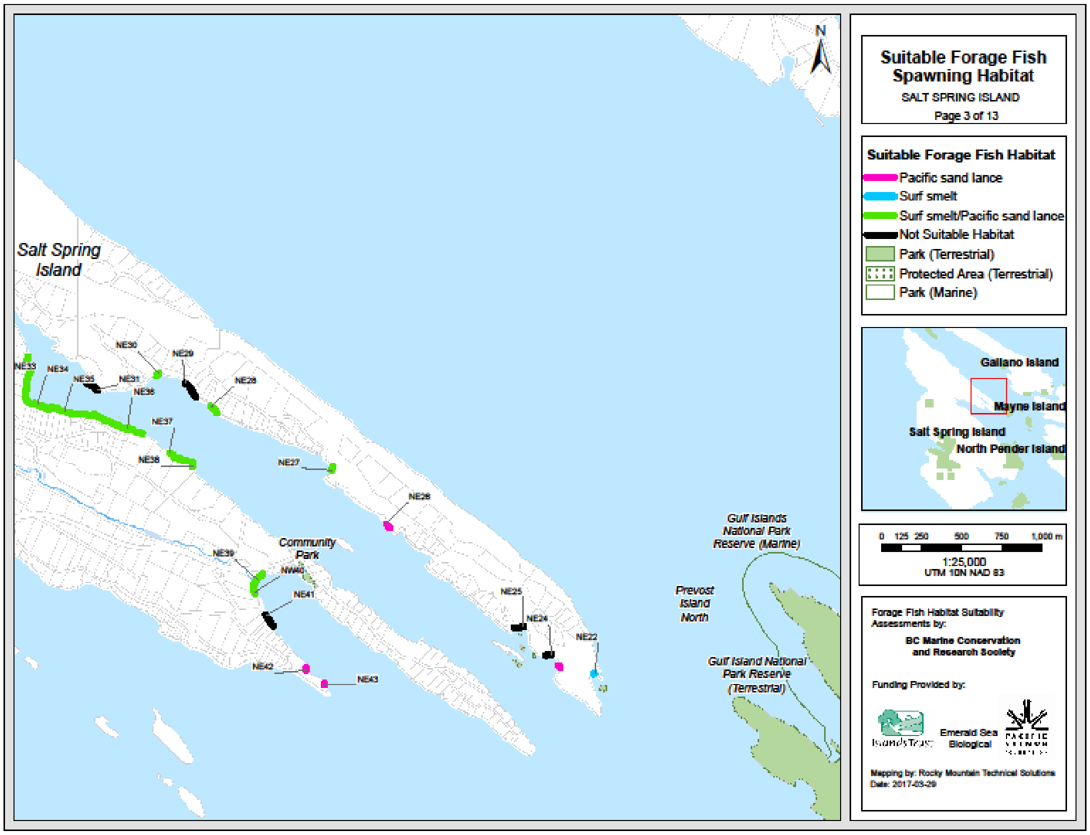


Figure 1B-C: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats



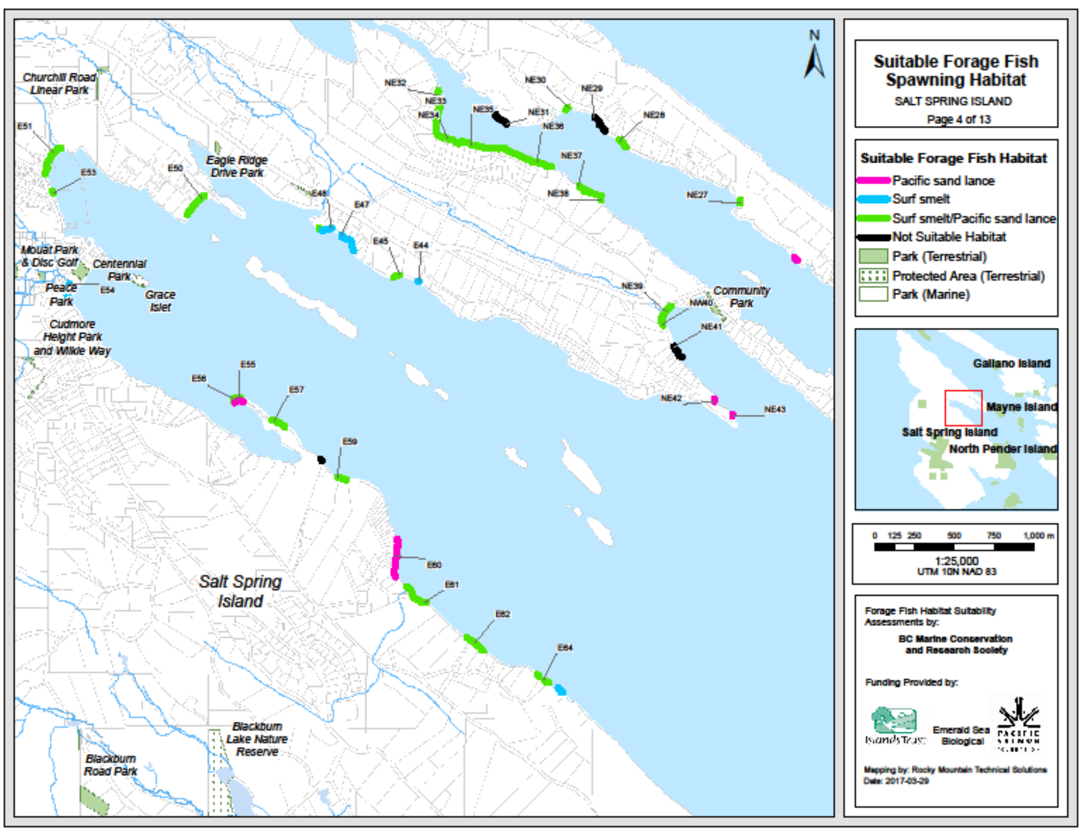
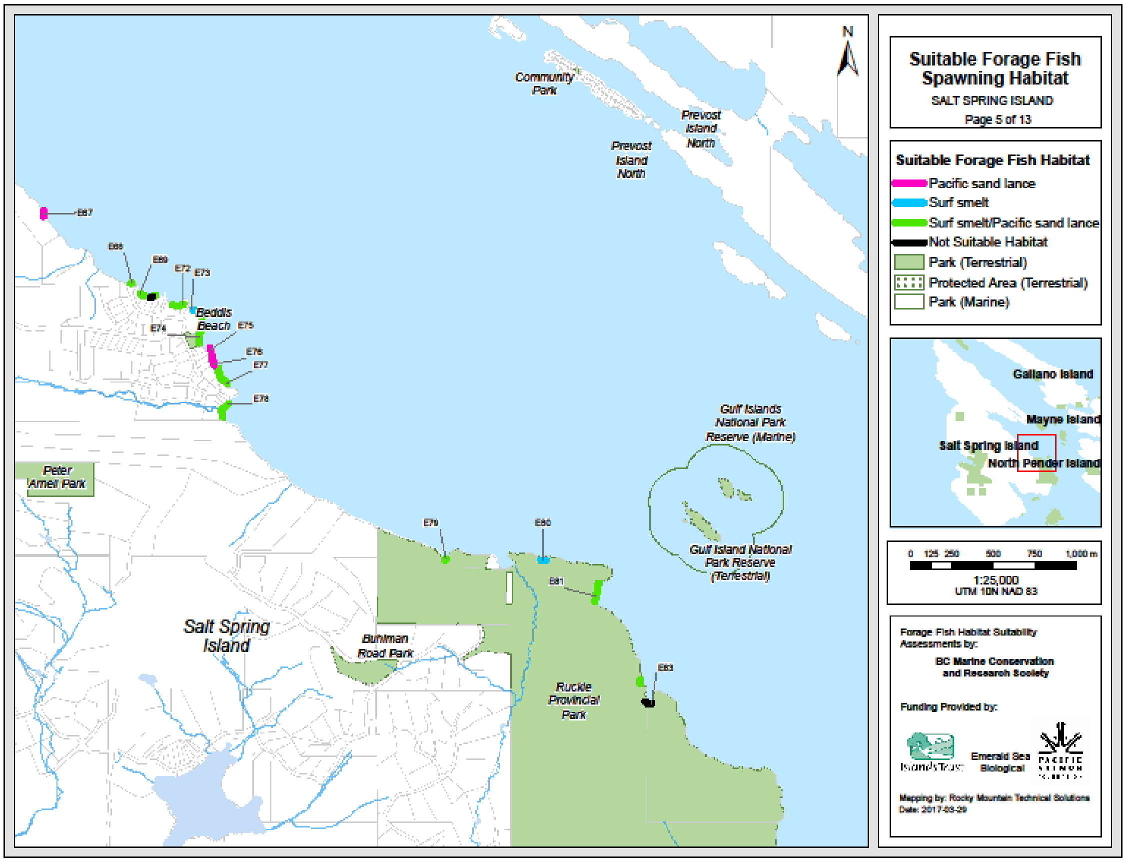


Figure 1D-E: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats



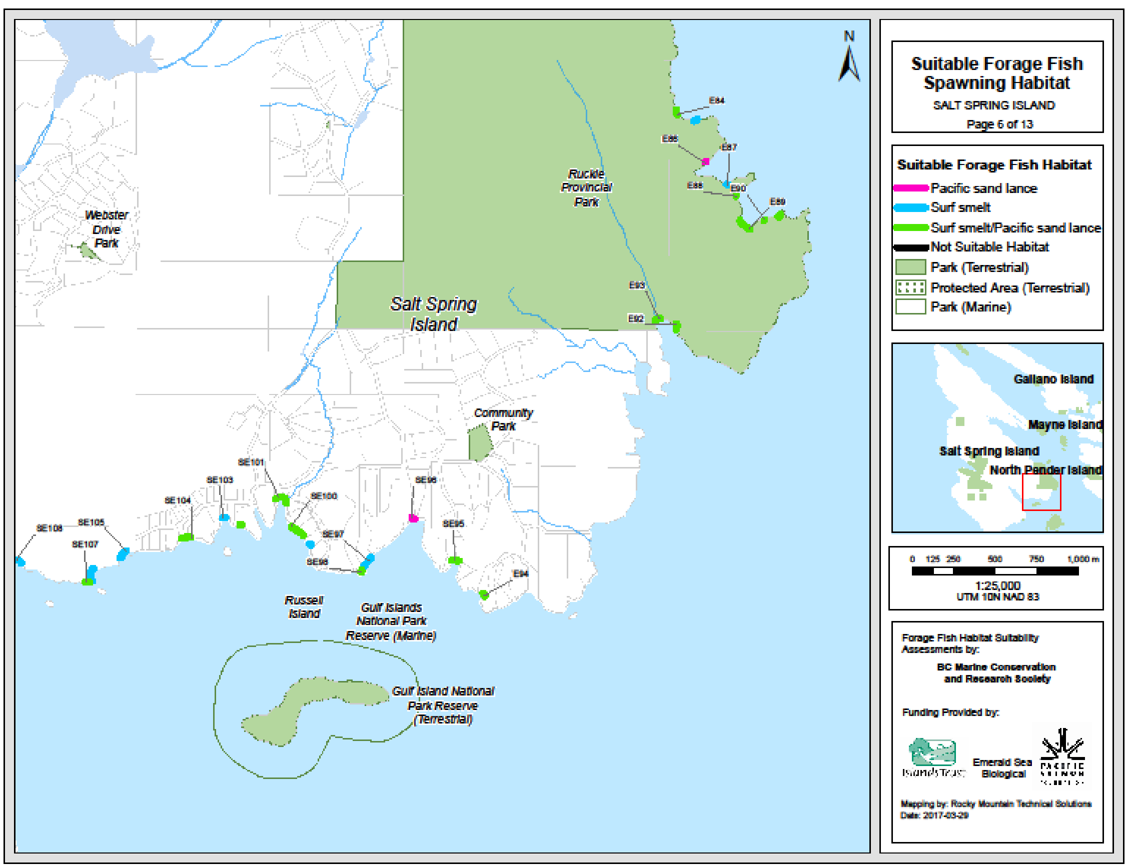
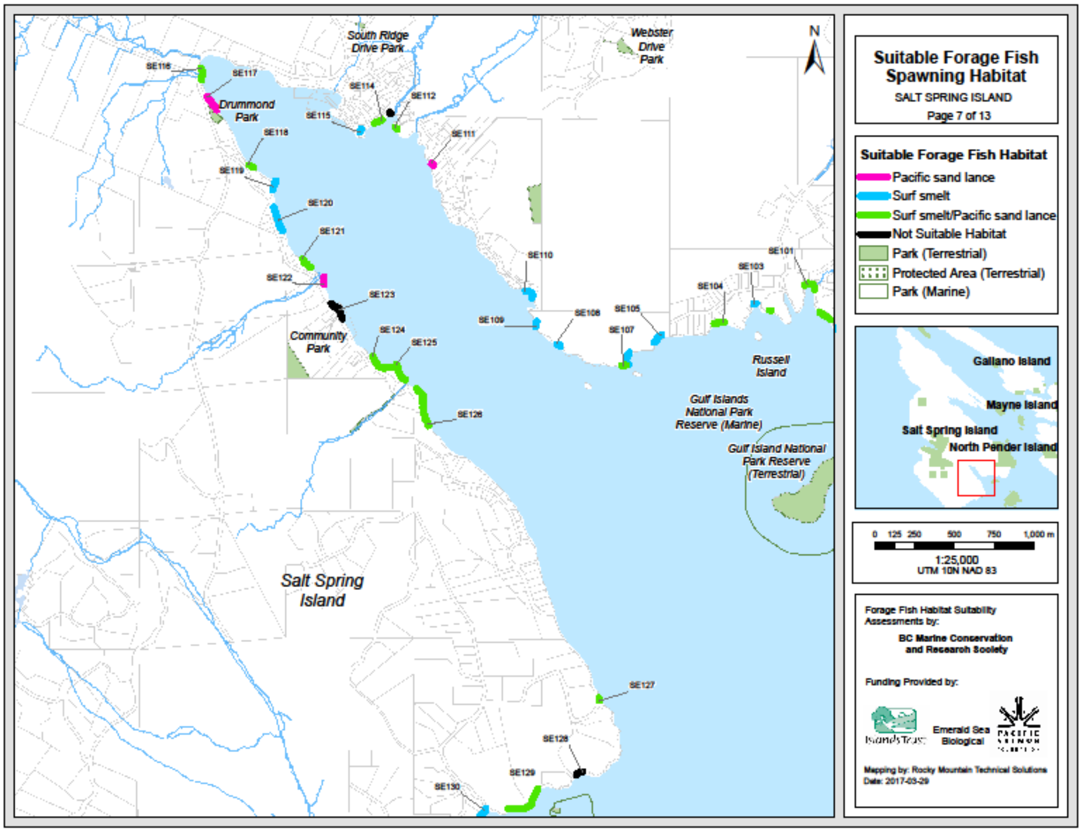


Figure 1F-G: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats



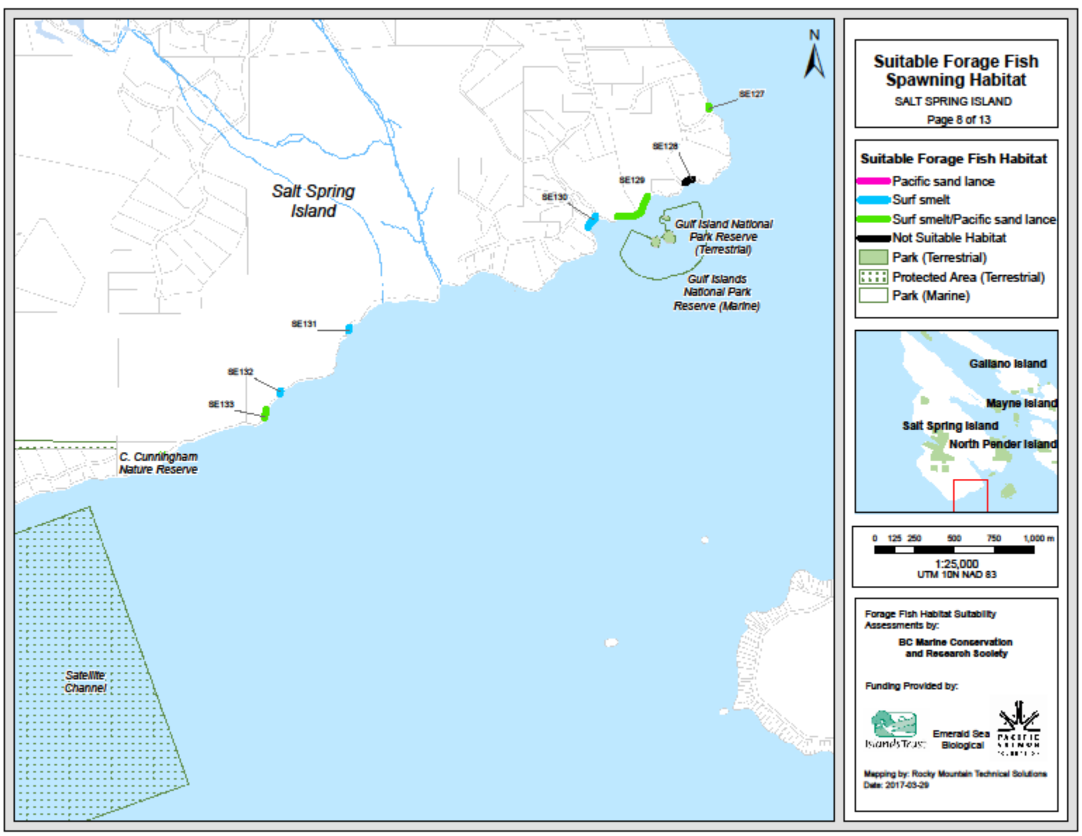


Figure 1H-I: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats

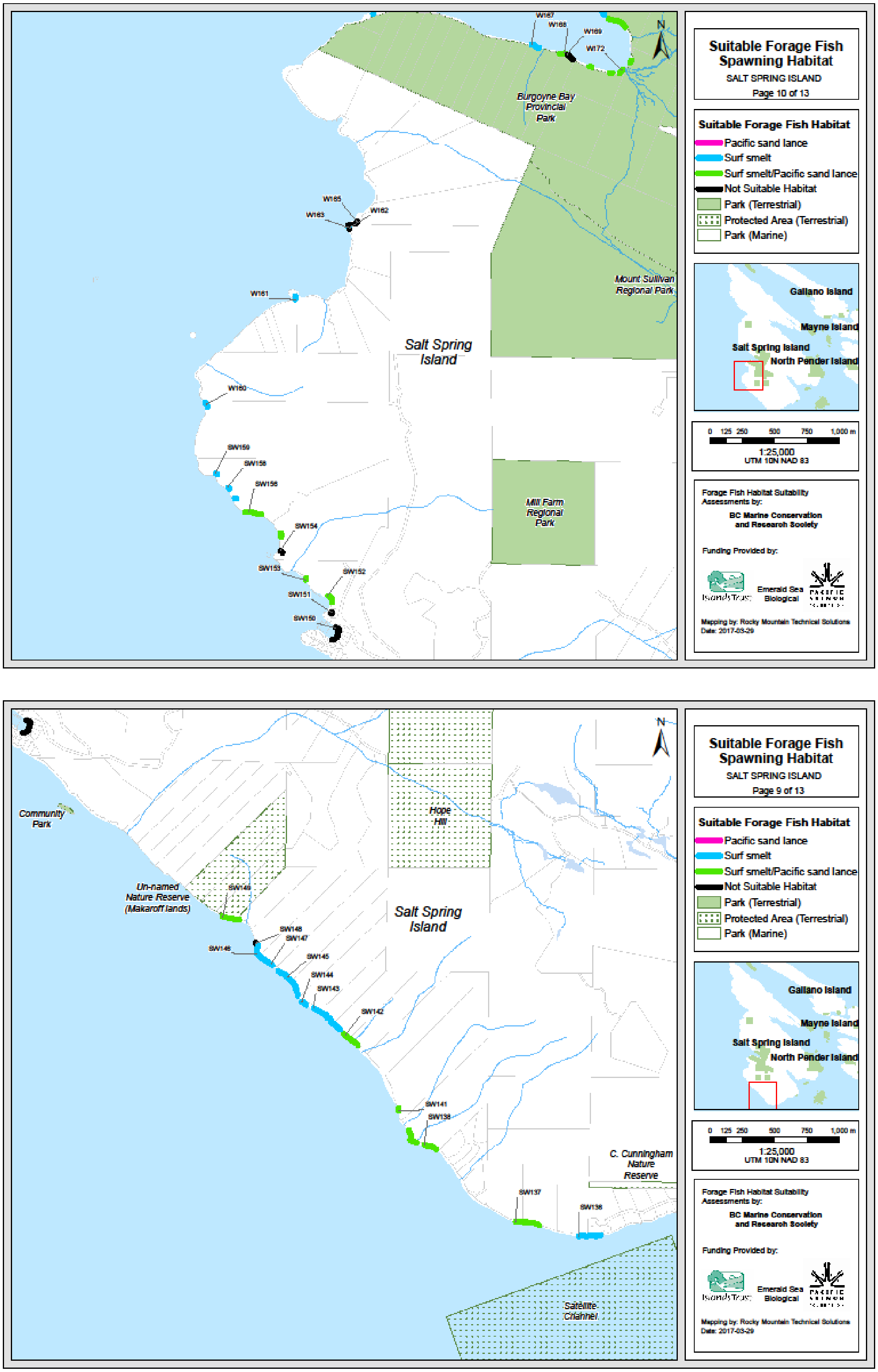
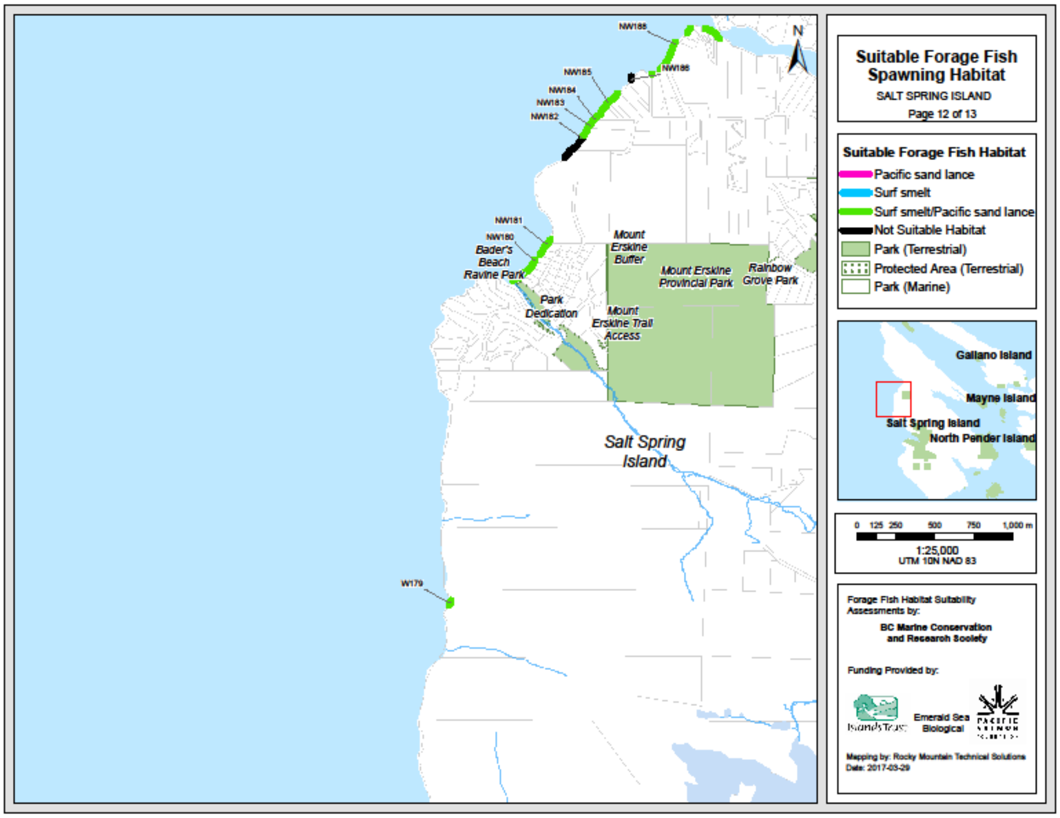


Figure 1J-K: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats



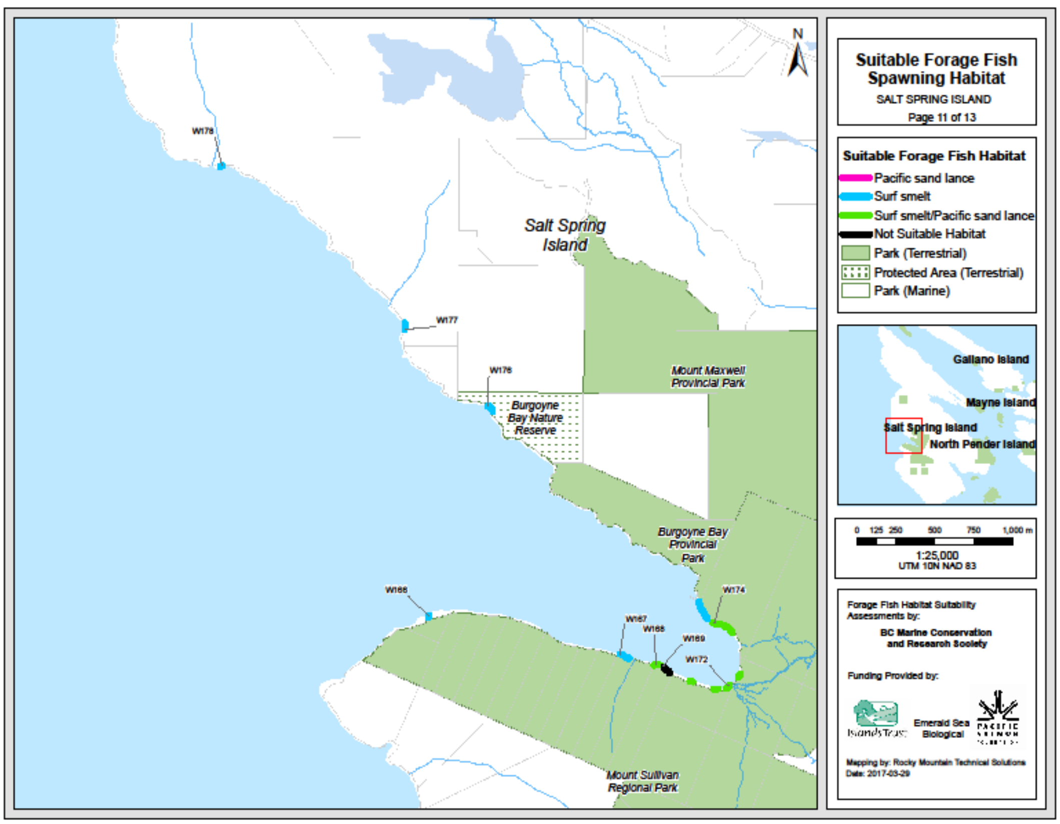


Figure 1L-M: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats

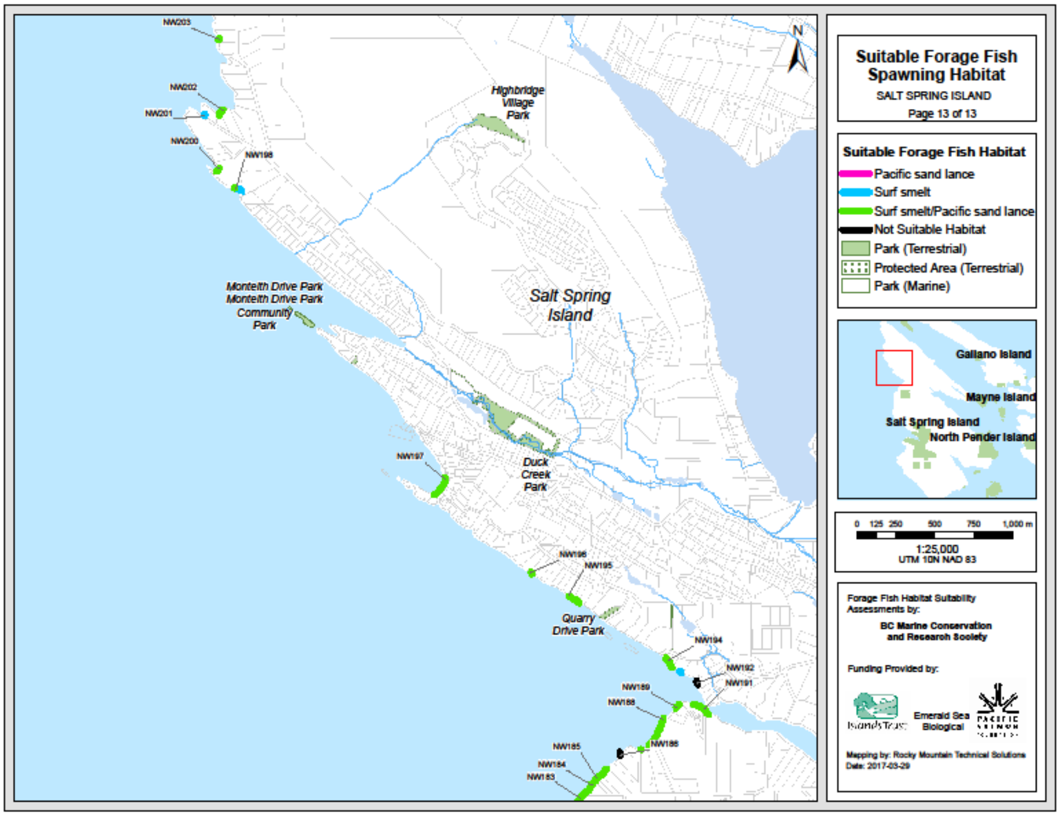


Figure 1N: Salt Spring Island - Suitable Beach Spawning Forage Fish Spawning Habitats

10.4 Suitable Forage Fish Spawning Habitat Beach Types

Of the 194 suitable spawning beaches, 15 (15) were classified as Pacific sand lance, fifty-four (54) as Surf smelt, and one-hundred and twenty-five (125) as mixed Surf smelt/Pacific sand lance spawning habitat (Table 2 and 3). Of the Pacific sand lance beaches, grain size analyses assessed one (1) as Type 1, two (2) as Type 2, and twelve (12) as Type 3 Pacific Sand lance beach. Of the Surf smelt beaches, grain size analysis assessed thirty-six (36) as Type 1, nine (9) as Type 2, seven (7) as Type 3, one (1) as Type 4, and one (1) as Type 5 Surf Smelt beaches. Of the mixed Surf smelt/Pacific sand lance beaches, grain size analysis assessed thirty-six (36) as Type 1; thirty-two (32) as Type 2; twenty-eight (28) as Type 3, and twenty-nine (29) as Type 4 Surf Smelt beach (Table 3, Appendix C, Figures 2-8).

Table 3: Salt Spring Island Beach Units - Habitat by Grain-Size Types

Category	SS Count	PSL Count	SS/PSL Count	Row Totals
PSL TYPE 1		1	1	2
PSL TYPE 2		1		1
PSL TYPE 3		12	1	13
SS TYPE 1	36		36	72
SSTYPE 2	9	32		41
SS TYPE 3	7	1	27	35
SS TYPE 4	1	28		29
SS TYPE 5	1			1
Totals	54	75	65	194

10.5 Geographic Position of Suitable Forage Fish Spawning Beaches

10.5.1 Geography

Dividing Salt Spring Island into north, south, west and east coast lines, sixty-six (66) suitable beach units are located on the north coast, fifty-nine (59) on the south coast, twenty-one (21) on the west coast, and fourty-eight (48) on the east coast (Table 4).

Table 4: Salt Spring Island Beach Units –
Suitable Forage Fish Spawning Habitat by Geographic Position

	SS	PSL	SS/PSL	Total
North	10	5	51	66
South	24	4	31	59
West	8	0	13	21
East	11	7	30	48
Total	54	15	125	194

10.6 Foreshore and Backshore Modification

10.6.1

Modification of the foreshore is classified as a percentage of the beach unit length 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 Salt Spring Island, one-hundred and twenty-nine (129) beach units were unmodified and sixty-five (65) were modified. Of the sixty-five (65) modified beach units, thirty-five (18%) were 1-25% modified, nine (4.6%) were 26-50% modified, eight (4.1%) were 51-75% modified, and thirteen (6.7%) 76-100% modified (Table 5).

Table 5: Salt Spring Island Beach Units - Foreshore Modification

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact	Total
Count	129	35	9	8	13	194
Percentage	66.5%	18.0%	4.6%	4.1%	6.7%	100.0%

Modification of the backshore is classified as structures or significant clearing of the site at or within 30 m of high water mark. On Salt Spring Island, one hundred and thirty-seven (137) beach units had modified backshore zones (71% of total beach units assessed).

10.6.2 Foreshore and Backshore Structures

Of the suitable forage fish spawning beach units with modified foreshore zones (65 beach units) and modified backshore zones (137 beach units), structures were classified and enumerated.

Fourty-five percent (45%) of the suitable forage fish spawning habitat has been modified by foreshore structures (6,769.2 meters) and fourty percent (40%) due to hard armouring (6,023 meters). Seventy-five percent (75%) of the suitable forage fish spawning habitat has backshore zones modified by structures (11,264 meters), seventeen percent (17%) of which is due to hard armouring near the high water mark (2,623.6 m) (Table 6).

Table 6: Salt Spring Island Beach Units - Foreshore and Backshore Structures

	Beach Units		Length	
	Count	Percentage	Meters	Percentage
Total Beach Units	194			
Length of Suitable Spawning Habitat			15036.8	
Foreshore				
Structures Present	65	33.50%	6769.2	45%
Armouring only	63	32.50%	6023.3	40%
Break Waters and Boat Ramps only	8	4.10%	745.9	5%
Backshore				
Structures Present	137		11264.0	75%
Armouring only	28		2623.8	17%
Boat Ramps only	2		78.2	1%

Armouring: seawalls, retaining walls, and stacked boulders (riprap)

10.7 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. In this analysis, overhanging shade vegetation scores ranging from 0-50% indicates reduced shade habitat.

Of the one-hundred and ninety-four (194) suitable forage fish spawning habitat beach units, nineteen (19) of the beach units have no overhanging shade habitat; fourty-one (41) have 1-25% overhanging shade; twenty-eight (28) have 26-50% overhanging shade; thirty-two (32) have 51-75% overhanging shade; and seventy-four (74) have 76-100% overhanging shade habitat (10%, 21%, 14%, 16%, and 38% respectively) (Table 7).

Beach units with overhanging-shade habitat scores of 0-50% represent a reduced habitat condition. Eighty-eight (88) beach units, 45%, had reduced overhanging shade-habitat (0-50%); and one hundred and six (106), 55%, had overhanging shade-habitat of 51-100% (Table 7).

Table 7: Salt Spring Island Beach Units - Overhanging Shade Vegetation Habitat Index

Category	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade
Count	19	41	28	32	74
Percentage	10%	21%	14%	16%	38%

11.0 Results Wallace Island

11.1 Statistical Analysis

The majority of the soft-sediment beaches present on Wallace Island are comprised of mud or cobble over a mud base. Three small coves presented sediments for assessment (Table 8). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed three (3) beach units with 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable spawning habitat” (Figure 9A-B). The three beach units had continuous sediment coverage.

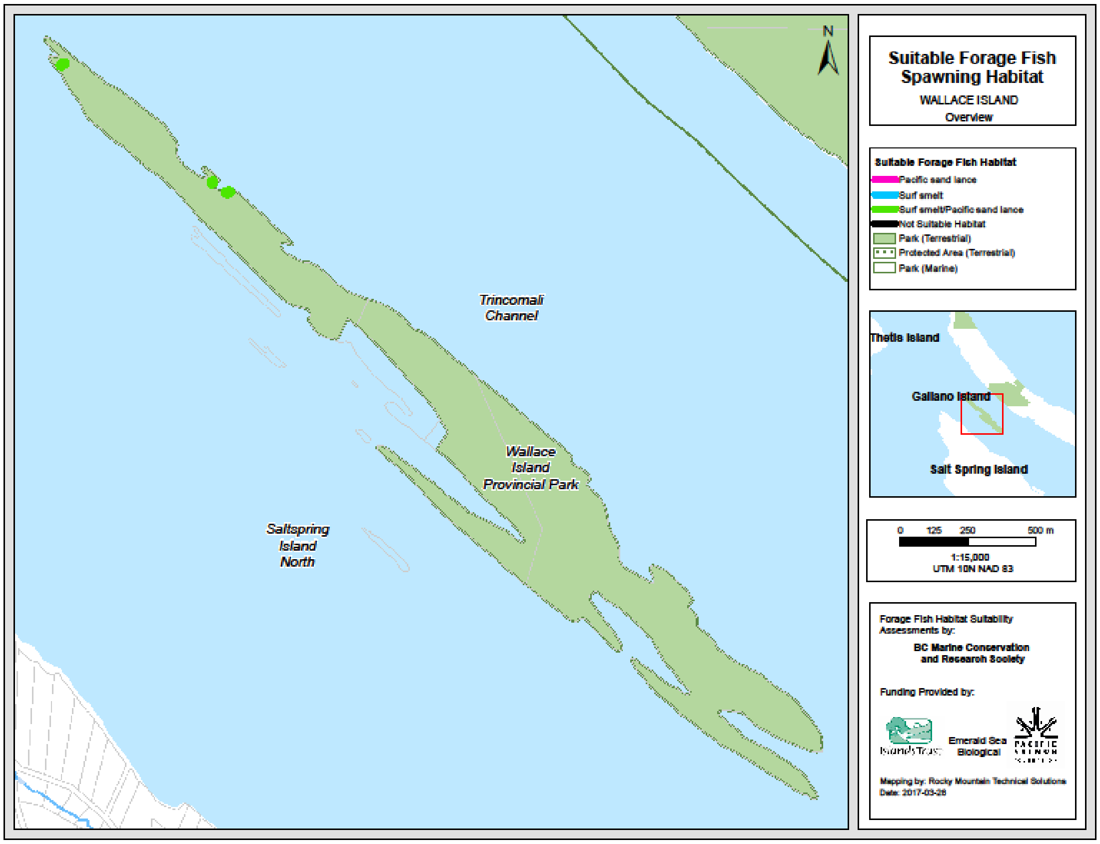
Table 8: Wallace Island Beach Units - Statistical Analysis

	Count	**Total**	**Length (m)**	**Percentage of Shoreline Perimeter**
Habitat (Continuous)	3		29.47	0.24%
Total Beach Units Assessed		3		
Total Length (meters)			29.47	
Perimeter Distance of Wallace Island			12,105 m	

Panther Cove, Conover Cove, Princess Cove, Princess Cove North, and one cove on the south east coast were catalogued during the island survey. The sediments of the upper beach component is comprised of mud and/or cobble. These five (5) coves were classified as “not habitat” in the field.

11.2 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. Three (3) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches.



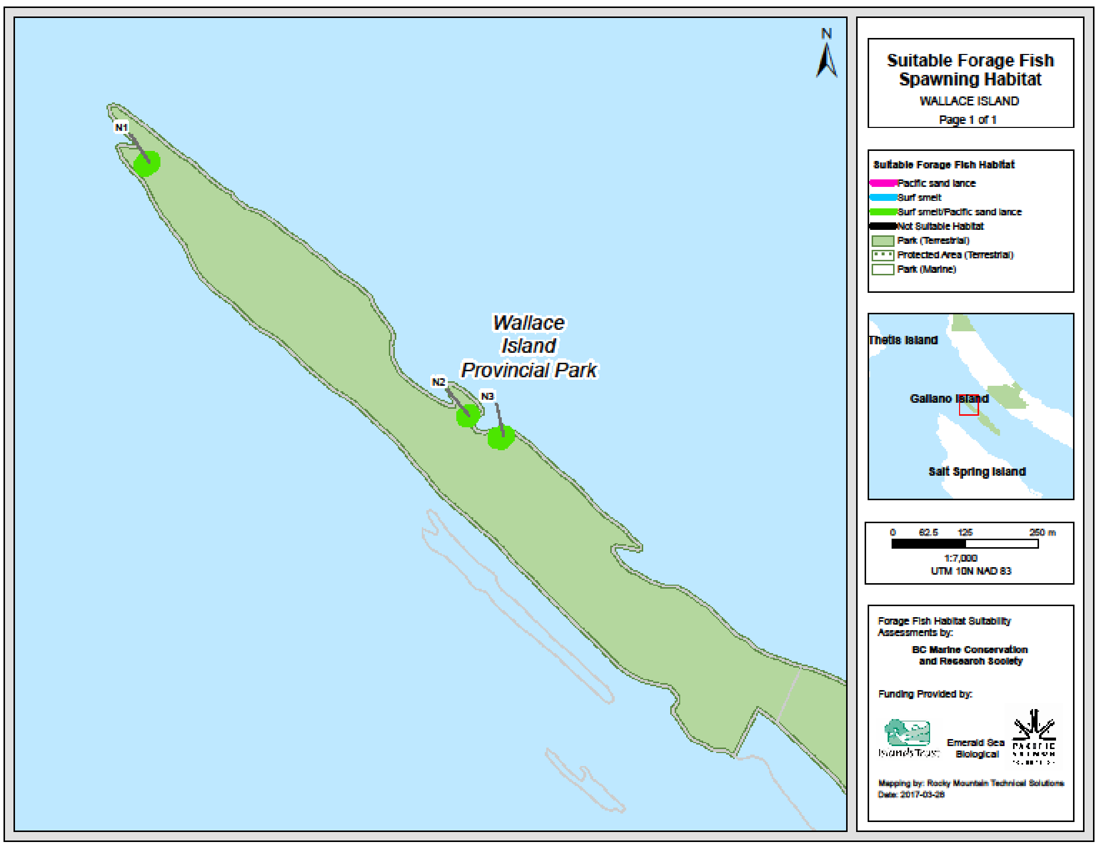


Figure 9A-B: Wallace Island Beach Units –
Suitable Forage Fish Spawning Habitat Types

11.3 Beach Unit Summary Statistics

11.3.1 Length

The total shoreline perimeter of Wallace Island is 12 kilometers. Suitable forage fish spawning habitat comprised 29.47 meters of the shoreline perimeter (0.24%) (Table 7).

11.3.2 Suitable Forage Fish Spawning Habitat Beach Types

The three beach units are suitable spawning habitat for both Surf smelt and Pacific sand lance. The beach units were classified as Type 2 and Type 3 Surf smelt sediment types (Table 8, Appendix D).

11.3.3 Geographic Position

The beach units are located on the northern tip of Wallace (1 beach unit) and the east coast (2 beach units) (Table 8).

11.3.4 Beach Unit Modification and Overhanging Shade Vegetation

The beach units have unmodified foreshore and backshore zones (Table 8). No structures were present on foreshore and backshore zones. Of the suitable beach units, one has 26-50% and two have 76-100% overhanging shade vegetation (Table 8).

Table 9: Wallace Island Beach Units - Summary Statistics

Categories	Count	Percentage	Length
Habitat Type			
Species most likely: SS/PSL	3	100%	29.47
Grain-Size Types			
SST2	2	67%	16.95
SST3	1	33%	12.52
Geographic Position			
North	1	33%	
East	2	67%	
Foreshore Modification			
0% impacted	3	100%	
Backshore Modification			
0% modification	3	100%	
Overhanging Shade Vegetation			
26-50% shaded	1	33%	
76-100% shaded	2	67%	

12.0 Salt Spring Island Summary

The shorelines and shallow subtidal zones around much of Salt Spring Island present excellent quality habitat types, particularly from Walker Hook to Long Harbour, Yeo to Eleanor Point, and Isabella Marine Reserve to Erskin Point. Salt Spring Island's Provincial parks contain a considerable length of marine shorelines. An analysis of the length of beach units suitable for forage fish spawning contained within protected zones was beyond the purview of this analysis.

Of the 216 beach units assessed, 194 were classified as suitable spawning habitat for Surf smelt and Pacific sand lance. The suitable spawning habitat represents 15 kilometers of marine shoreline; 917.5 meters was classified as suitable for Pacific sand lance, 3,667 meters for Surf smelt, and 10,451 meters as mixed Surf smelt and Pacific sand lance. Habitat types by grain-size revealed the full range of sediment types (coarse to fine grained beaches).

Relative to Salt Spring Island's shoreline perimeter, 11% was classified as suitable forage fish spawning habitat. This is similar to the assessment on Thetis Island (11.9%), Valdes Island (9.90%).

Thirty-three percent (33.5%) of beach units classified as suitable forage fish spawning habitat had modified foreshores and seventy-one percent (71%) had modified backshore zones. Hard armouring with seawalls and riprap is present on the foreshore zones of 63 beach units (40%; 6,023 m) and on backshore zones of 28 beach units (17%; 2,624 m). With rising sea levels, armoured beach units are at threat of degradation and loss, including the known Surf smelt spawning beach (Churchill Road) and the putative Pacific sand lance spawning beach at Fulford Harbour.

Long Harbour, Ganges Harbour, Fulford Harbour, Burgoyne Bay and Booth Bay have long been utilized for various resources, from ancient clam gardens (Fulford Harbour) to today's current mixed resource usage. From Vesuvius Point to Southey Point, the majority of pocket coves have been modified with seawalls and backshore development. As part of the shoreline assessments, a catalogue of land use and structures was compiled and could be used to locate opportunities to enhance and restore marine shoreline habitat quality. Derelict structures from historical industrial operations and present operations have been catalogued. Degraded boat ramps and riprap at beach units such as the Surf smelt spawning beach at Churchill road are one such opportunity to enhance spawning habitat, marine riparian vegetation and protection from sea level rise.

13.0 Wallace Island Summary

Wallace Island is a Provincial Marine Park. The marine riparian vegetation is intact around the entire shoreline perimeter. The coastal geomorphology and local oceanographic features has resulted in pocket coves and shallow bays mainly with limited sediment motility.

14.0 Mitigating Stressor Impacts and Planning Habitat Enhancement/Restoration

14.1 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.

14.2 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.

14.3 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.

14.4 Stressors and Enhancement/Restoration

14.4.1 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.

14.4.2 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

15.0 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.

DataBC Catalogue, Copyright 2013, Spatial Analysis Branch, Coastal Resource Information Management System, BC Ministry of Agriculture and Lands, Province of British Columbia. http://geobc.gov.bc.ca

de Graaf, RC and D. Penttila, Emerald Sea Biological (2006). Intertidal Forage Fish Habitat Assessment (Surf Smelt and Pacific Sand Lance). Spawning Survey Field Manual British Columbia, adapted from Moulton and Penttila (2001).

Dethier, M. R. (2016). Multiscale impacts of armoring on Salish Sea shorelines: Evidence for cumulative and threshold effects. Estuarine, Coastal and Shelf Science 175, 106-117.

de Greeff, P (2011) Islands Trust Shoreline Mapping Methodology, pp 19.

Griggs, G.B. 2010 The effects of armoring shorelines—the California Experience, p. 77 in Puget Sound shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S.Geological Survey Scientific Investigations Report 2010-5254, 266 p, Shipman, H, Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010.

Krueger, K. K. (2009). Anticipated Effects of Sea Level Rise in Puget Sound on Two Beach-Spawning Fishes.

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.

Martin, K. (2015). Beach-Spawning Fishes, Reproduction in an Endangered Ecosystem. Boca Raton, FL: CRC Press.

Moulton, L, and D. Penttila (2001) Field Manual for Sampling Forage Fish Spawn in Intertidal Shore Regions. MJM Research and Washington Department of Fish and Wildlife.

Penttila, D. (1995). Documented spawning areas of the Pacific herring (Clupea), Surf smelt (Hypomesus), and Pacific sand lance (Ammodytes) in San Juan County, Washington. Manuscript report. LaConner, WA: Washington Department of Fish and Wildlife, Marine resources Division, 27p.

Penttila, D (2001a). 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 (2001b) 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. 2001(c). Grain-Size analyses of spawning substrates of the surf smelt (Hypomesus) and Pacific sand lance (Ammodytes) on Puget Sound spawning beaches. State of Washington, Department of Fish and Wildlife. Manuscript Report.

Penttila, D 2007. Marine Forage Fishes of Puget Sound. Puget Sound Nearshore Partnership report No. 2007-03. Published by Seattle District, U.W. Army Corps of Engineers, Seattle, Washington

Quinn, T. K. (2012). Patterns of Surf smelt (Hypomesus pretiosus), Intertidal Spawning Habitat Use in Puget Sound, Washington State. Estuaries and Coasts, 35: 1214-1228.

Robards, MD et al 1999. Sand Lance: A review of Biology and predator relations and annotated bibliography. US Department of Agriculture. Portland Oregon. Research Paper PNW-RP-521.

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.

Robinson CLK, D Hrynyk, JV Barrie, J Schweigert (2013) Identifying subtidal burying habitat of Pacific sand lance (Ammodytes hexapterus) in the Strait of Georgia, British Columbia, Canada. Progress in Oceanography, 115, 119-128.

Shipman, H (2008) A Geomorphic Classification of Puget Sound Nearshore Landforms. Puget Sound Nearshore Partnership Report No 2008-001. Published by Seattle District, US Army Corps of Engineers, Seattle, Washington.

Shipman, H, Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S.Geological Survey Scientific Investigations Report 2010-5254, 266 p.

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.

Washington State Department of Ecology, Surface Water and Groundwater on Coastal Bluffs: A Guide for Puget Sound Property Owners. Ecology Publication #95-107; Retrieved March 2014 from http://www.ecy.wa.gov/programs/sea/pubs/95-107/intro.htm

Whitman, T. a. (2014). Healthy Beaches for People and Fish: Protecting shorelines from the impacts of armoring today and rising seas tomorrow. The Impacts of Shoreline Armoring on Beach Spawning Forage Fish Habitat in San Juan County. San Juan Island, WA.

Whitman, T. D. (2014). Tidal elevation of Surf smelt spawn habitat study for San Juan County Washington. San Juan Island, WA: Friends of San Juans, Salish Sea Biological, Washington Department of Fish and Wildlife.

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
1	NW197	VesuviusBe	Suitable Habitat	Continuous	SS/PSL	SST1	140.21	
2	E50	ChurchillBe	Suitable Habitat	Continuous	SS/PSL	SST2	168.56	Surf smelt
3	SW151	MusgravePntN1	Not Suitable Habitat	nill	nill	Pb, Mud	17.79	
4	SW152	MusgravePntN2	Suitable Habitat	Discontinuous	SS;PSL	SST1	72.13	
5	SW156	MusgraveN6	Suitable Habitat	Continuous	SS, PSL	SST1	132.45	
6	W178	BurgByNW1	Suitable Habitat	Continuous	SS	SST1	18.47	
7	W177	BurgByNW2	Suitable Habitat	Discontinuous	SS	SST1	44.73	
8	W176	BurgByNW3	Suitable Habitat	Continuous	SS	SST1	56.80	
9	W166	BoldBl1	Suitable Habitat	Continuous	SS	SST2	10.85	
10	NW196	BoothByNE1	Suitable Habitat	Continuous	SS/PSL	SST3	16.93	
11	W179	ErkinPntN1	Suitable Habitat	Continuous	SS/PSL	SST2	43.35	
12	W165	Sansum6	Not Suitable Habitat	Continuous	nill	Mud	26.45	
13	W160	Sansum1	Suitable Habitat	Continuous	SS	SST3	46.74	
14	SW159	MusgraveN9	Suitable Habitat	Continuous	SS	SST1	16.00	
15	SW158	MusgraveN8	Suitable Habitat	Continuous	SS	SST1	18.79	
16	SW157	MusgraveN7	Suitable Habitat	Continuous	SS	SST1	14.06	
17	W161	Sansum2	Suitable Habitat	Continuous	SS	SST2	25.65	
18	W163	Sansum4	Suitable Habitat	Continuous	SS	SST1	13.33	
19	W164	Sansum5	Not Suitable Habitat	nill	nill	Pb	14.18	
20	W162	Sansum3	Not Suitable Habitat	nill	nill	Cb	6.59	
21	SW155	MusgraveN5	Suitable Habitat	Continuous	SS/PSL	SST1	41.24	
22	SE134	CKeppel14	Suitable Habitat	Continuous	SS/PSL	SST3	30.58	
23	NW216	ArbutusN1	Suitable Habitat	Continuous	SS/PSL	SST1	32.58	
24	NW215	ArbutusN2	Suitable Habitat	Continuous	SS/PSL	SST1	13.61	
25	NW214	ArbutusN3	Suitable Habitat	Continuous	SS/PSL	SST1	13.90	
26	NW212	ArbutusS3	Suitable Habitat	Continuous	SS/PSL	SST1	12.40	
27	NW213	ArbutusS1	Suitable Habitat	Discontinuous	SS/PSL	SST1	21.35	
28	NW1	SoutheyPntN1	Suitable Habitat	Continuous	SS/PSL	SST4	52.01	
29	NW2	SoutheyPntN2	Suitable Habitat	Continuous	SS/PSL	SST2	130.85	
30	NW7	JFostersS1	Suitable Habitat	Continuous	SS/PSL	SST4	82.94	
31	NW6	JFostersS2	Suitable Habitat	Continuous	SS/PSL	SST4	189.24	
32	NW5	JFostersS3	Suitable Habitat	Continous	SS/PSL	SST4	123.96	
33	SE129	IsobPnt1	Suitable Habitat	Continuous	SS/PSL	SST3	260.35	
34	SE127	FulfordE1	Suitable Habitat	Discontinuous	SS/PSL	SST4	21.40	
35	SE128	IsobPntE1	Not Suitable Habitat	nill	nill	Cb	56.51	
36	SE131	CKeppel1	Suitable Habitat	Discontinuous	SS	SST1	21.72	
37	SE133	CKeppel3	Suitable Habitat	Continuous	SS/PSL	SST2	55.95	
38	SE132	CKeppel2	Suitable Habitat	Continuous	SS	SST3	17.13	
39	E81	YeoPnt1	Suitable Habitat	Continuous	SS/PSL	SST1	122.29	
40	E82	YeoPntS2	Suitable Habitat	Continuous	SS/PSL	SST1	22.92	
41	E83	YeoPntS3	Not Suitable Habitat	nill	nill	Cb	52.28	
42	NW207	EagleS1	Suitable Habitat	Continuous	SS/PSL	SST4	21.79	
43	NW208	EagleS2	Suitable Habitat	Discontinuous	SS/PSL	SST4	133.64	

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
44	NW209	EagleN	Suitable Habitat	Continuous	SS/PSL	SST4	144.47	
45	NE39	Wellbury4	Suitable Habitat	Continuous	SS/PSL	SST4	148.34	
46	NW40	LHrbW2	Suitable Habitat	Continuous	SS/PSL	SST4	8.08	
47	NW188	Layard1	Suitable Habitat	Continuous	SS/PSL	SST3	206.18	
48	NW187	Layard2	Suitable Habitat	Continuous	SS/PSL	SST2	8.57	
49	NW182	LayardW1	Not Suitable Habitat	nill	nill	Cb	190.11	
50	NW183	LayardW2	Suitable Habitat	Continuous	SS/PSL	SST1	122.80	
51	NW184	LayardW3	Suitable Habitat	Continuous	SS/PSL	SST1	148.85	
52	NW185	LayardW4	Suitable Habitat	Continuous	SS/PSL	SST3	90.96	
53	NW186	LayardW6	Not Suitable Habitat	nill	nill	Cb	20.56	
54	NE43	Wellbury1	Suitable Habitat	Continuous	PSL	PSLT3	13.43	
55	NE42	Wellbury2	Suitable Habitat	Continuous	PSL	PSLT3	18.38	
56	NE32	BeachDr1B	Suitable Habitat	Continuous	SS/PSL	SST2	26.57	
57	NE33	BeachDr2	Suitable Habitat	Discontinuous	SS/PSL	SST3	277.32	
58	NE38	LHrb1	Suitable Habitat	Continuous	SS/PSL	SST4	29.93	
59	NE37	LHrbS2	Suitable Habitat	Continuous	SS/PSL	SST3	138.68	
60	NE36	LHrbS3	Suitable Habitat	Discontinous	SS/PSL	SST2	341.31	
61	NE35	LHrbS4	Suitable Habitat	Continuous	SS/PSL	SST2	218.49	
62	NE34	LHrbS5	Suitable Habitat	Discontinous	SS/PSL	SST3	162.72	
63	NW193	BoothByN2	Suitable Habitat	Continuous	SS	SST1	18.18	
64	NW194	BoothByN5	Suitable Habitat	Continuous	SS/PSL	SST3	76.59	
65	NW189	BoothByS1	Suitable Habitat	Continuous	SS/PSL	SST2	15.75	
66	NW190	BoothByS2	Suitable Habitat	Continuous	SS/PSL	SST1	14.56	
67	NW191	BoothByS3	Suitable Habitat	Continuous	SS/PSL	SST2	121.31	
68	NW181	BaderBe1	Suitable Habitat	Discontinuous	SS/PSL	SST2	127.51	
69	NW180	BaderBe2	Suitable Habitat	Continuous	SS/PSL	SST2	203.37	
70	SE126	FulfordS1	Suitable Habitat	Continuous	SS/PSL	SST1	257.21	
71	SE125	FulfordS2	Suitable Habitat	Continuous	SS/PSL	SST2	115.74	
72	SE124	FulfordS3	Suitable Habitat	Continuous	SS/PSL	SST4	179.80	
73	SE123	FulfordS4	Not Suitable Habitat	nill	nill	Cb	133.75	
74	SE122	FulfordS5	Suitable Habitat	Continuous	PSL	PSLT3	49.72	
75	SE121	FulfordS6	Suitable Habitat	Discontinuous	SS/PSL	SST1	80.12	
76	SE120	FulfordS7	Suitable Habitat	Discontinuous	SS	SST1	160.19	
77	SE119	FulfordS8	Suitable Habitat	Continuous	SS	SST1	64.82	
78	SE118	FulfordS9	Suitable Habitat	Continuous	SS/PSL	SST4	41.88	
79	SE117	FulfordS10	Suitable Habitat	Continuous	PSL	PSLT3	106.46	PSL,1embryo
80	SE116	FulfordS11	Suitable Habitat	Continuous	SS/PSL	SST1	77.23	
81	NW195	BoothByN1	Suitable Habitat	Discontinuous	SS/PSL	SST4	84.33	
82	NW192	BoothByN3	Not Suitable Habitat	nill	nill	Pb, Mud	28.54	
83	E65	GangesPrS2	Suitable Habitat	Continuous	SS	SST2	13.49	
84	E64	GangesPrS3	Suitable Habitat	Continuous	SS/PSL	SST1	38.46	
85	E63	GangesPrS4	Suitable Habitat	Continuous	SS/PSL	SST3	18.25	

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
86	E62	GangesPrS5	Suitable Habitat	Discontinuous	SS/PSL	SST1	148.39	
87	E61	GangesPrS6	Suitable Habitat	Discontinuous	SS/PSL	SST1	182.98	
88	E60	GangesPrS7	Suitable Habitat	Continuous	PSL	PSLT3	241.52	
89	E74	BeddisBe1	Suitable Habitat	Continuous	SS/PSL	SST4	154.09	
90	E76	BeddisBe2	Suitable Habitat	Continuous	PSL	PSLT3	75.38	
91	E77	BeddisBe3	Suitable Habitat	Continuous	SS/PSL	SST3	114.76	
92	E78	CuLk1	Suitable Habitat	Discontinuous	SS/PSL	SST2	116.93	
93	E75	BeddisBe4	Suitable Habitat	Continuous	PSL	PSLT3	21.41	
94	E54	GasAlley1	Suitable Habitat	Continuous	SS	SST4	119.46	
95	E53	GangesHr1	Suitable Habitat	Continuous	SS/PSL	SST1	16.36	
96	E52	GangesHr2	Suitable Habitat	Continuous	SS/PSL	SST1	41.36	
97	E51	GangesHr3	Suitable Habitat	Discontinuous	SS/PSL	SST1	160.60	
98	E66	GangesPrS1	Suitable Habitat	Continuous	SS	SST5	14.02	
99	NW12	NoRdN2	Suitable Habitat	Continuous	SS/PSL	SST1	14.83	
100	NW13	NoRdN3	Suitable Habitat	Continuous	SS	SST1	41.08	
101	NW14	McFaddenN1	Suitable Habitat	Continuous	SS/PSL	SST4	254.66	
102	NW15	NoRdN5	Suitable Habitat	Continuous	SS	SST1	32.36	
103	NW16	NoRdN6	Suitable Habitat	Continuous	SS/PSL	SST1	14.64	
104	NW17	HudsonN1	Suitable Habitat	Discontinuous	SS/PSL	SST3	57.55	
105	W167	BurgByS1	Suitable Habitat	Continuous	SS	SST1	65.95	
106	W168	BurgByS2	Suitable Habitat	Continuous	SS/PSL	SST3	41.88	
107	W169	BurgByS3	Not Suitable Habitat	nill	SS/PSL	Mud	60.56	
108	W170	BurgByS4	Suitable Habitat	Continuous	SS/PSL	SST3	19.42	
109	W171	BurgByS5	Suitable Habitat	Continuous	SS/PSL	SST1	25.88	
110	W172	BurgByS6	Suitable Habitat	Continuous	SS/PSL	SST1	44.29	
111	W173	BurgByS7	Suitable Habitat	Continuous	SS/PSL	SST1	29.51	
112	W174	BurgByN1	Suitable Habitat	Discontinuous	SS/PSL	SST3	157.35	
113	W175	BurgByN2	Suitable Habitat	Discontinuous	SS	SST2	126.78	
114	NW11	NoRdN1	Suitable Habitat	Discontinuous	SS	SST1	131.48	
115	SE105	Tsawout1	Suitable Habitat	Continuous	SS	SST1	71.33	
116	SE106	Tsawout2	Suitable Habitat	Continuous	SS	SST1	86.50	
117	SE107	Tsawout3	Suitable Habitat	Continuous	SS/PSL	SST2	29.29	
118	SE108	JacksonRf1	Suitable Habitat	Continuous	SS	SST2	35.16	
119	SE109	JacksonRf2	Suitable Habitat	Discontinuous	SS	SST3	33.67	
120	SE110	JacksonRf4	Suitable Habitat	Discontinuous	SS	SST1	75.46	
121	SE115	FulfordL1	Suitable Habitat	Discontinuous	SS	SST1	23.01	
122	SE112	FulfordL2	Suitable Habitat	Continuous	SS/PSL	SST2	25.14	
123	SE114	FulfordL3	Suitable Habitat	Discontinuous	SS/PSL	SST4	53.75	
124	SE113	FulfordL4	Not Suitable Habitat	nill	nill	Md	12.96	
125	SE111	FulfordL5	Suitable Habitat	Continuous	PSL	PSLT1	19.26	
126	NE24	WreckBy	Not Suitable Habitat	nill	nill	Mud, Pb	44.48	
127	NE23	LHrbN2	Suitable Habitat	Discontinuous	PSL	PSLT2	22.03	

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
128	NE25	LHrbN3	Not Suitable Habitat	nill	nill	Cb	58.38	
129	NE26	IsletBe	Suitable Habitat	Continuous	PSL	PSLT3	33.56	
130	SE104	Seabright1	Suitable Habitat	Continuous	SS/PSL	SST2	65.90	
131	SE101	Fraser1	Suitable Habitat	Discontinuous	SS/PSL	SST2	95.62	
132	SE96	King1	Suitable Habitat	Continuous	PSL	PSLT3	26.77	
133	E89	RuckleE1	Suitable Habitat	Discontinuous	SS/PSL	SST3	91.62	
134	E88	RuckleE2	Suitable Habitat	Continuous	SS/PSL	SST3	43.57	
135	E87	RuckleE3	Suitable Habitat	Continuous	SS	SST1	10.91	
136	E86	RuckleE4	Suitable Habitat	Continuous	PSL	PSLT3	11.26	
137	E85	RuckleE5	Suitable Habitat	Continuous	SS	SST2	31.05	
138	E84	RuckleE6	Suitable Habitat	Continuous	SS/PSL	SST3	34.16	
139	SW150	MusgraveN1	Not Suitable Habitat	nill	nill	Mud	151.36	
140	SW153	MusgraveN3	Suitable Habitat	Continuous	SS/PSL	SST1	20.23	
141	SW154	MusgraveN4	Not Suitable Habitat	nill	nill	Cb	22.95	
142	NW198	VesuviusN1	Suitable Habitat	Continuous	SS	SST1	43.90	
143	NW199	VesuviusN2	Suitable Habitat	Continuous	SS/PSL	SST2	13.29	
144	NW200	VesuviusN3	Suitable Habitat	Continuous	SS/PSL	SST3	35.66	
145	NW201	VesuviusN4	Suitable Habitat	Continuous	SS	SST1	11.17	
146	NW202	VesuviusN5	Suitable Habitat	Continuous	SS/PSL	SST2	46.69	
147	NW203	VesuviusN6	Suitable Habitat	Continuous	SS/PSL	SST1	12.81	
148	NW204	VesuviusN7	Suitable Habitat	Discontinuous	SS/PSL	SST1	6.23	
149	NW205	VesuviusN8	Suitable Habitat	Continuous	SS	SST1	41.54	
150	NW210	GrapplerRk1	Suitable Habitat	Continuous	SS	SST1	11.85	
151	NW211	GrapplerRk2	Suitable Habitat	Continuous	SS/PSL	SST3	29.49	
152	NE27	ClamShellBe	Suitable Habitat	Continuous	SS/PSL	SST2	22.44	
153	NE28	KFisherLn1	Suitable Habitat	Continuous	SS/PSL	SST1	65.74	
154	NE29	KFisherLn2	Not Suitable Habitat	nill	nill	Silt/Pb	123.01	
155	NE30	KFisherLn3	Suitable Habitat	Continuous	SS/PSL	SST1	29.56	
156	NE31	Maracaibo	Not Suitable Habitat	nill	nill	nill	109.10	
157	SE103	KFisherRd1	Suitable Habitat	Discontinuous	SS	SST1	20.34	
158	SE102	KFisherRd2	Suitable Habitat	Continuous	SS/PSL	SST2	15.61	
159	SE99	KFisherRd4	Suitable Habitat	Continuous	SS	SST3	14.09	
160	SE100	KFisherRd3	Suitable Habitat	Continuous	SS/PSL	SST4	93.56	
161	SE97	ElPntS1	Suitable Habitat	Discontinuous	SS	SST3	73.69	
162	SE98	ElPntS2	Suitable Habitat	Continuous	SS/PSL	SST3	11.77	
163	SW148	CKeppel17	Not Suitable Habitat	nill	nill	Cb	38.57	
164	SW149	CKeppel18	Suitable Habitat	Continuous	SS/PSL	SST2	135.34	
165	SW146	CKeppel16	Suitable Habitat	Discontinuous	SS	SST2	213.58	
166	SW145	CKeppel15	Suitable Habitat	Discontinuous	SS	SST2	266.30	
167	SW147	CKeppel19	Suitable Habitat	Continuous	SS	SST1	15.18	
168	SW137	CKeppel7	Suitable Habitat	Continuous	SS/PSL	SST3	197.85	
169	SW136	CKeppel6	Suitable Habitat	Discontinuous	SS	SST1	142.48	
170	SW135	CKeppel5	Suitable Habitat	Discontinuous	SS	SST3	40.73	

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
171	SW144	CKeppel14	Suitable Habitat	Continuous	SS	SST1	43.18	
172	SW143	CKeppel13	Suitable Habitat	Discontinuous	SS	SST3	288.55	
173	SW142	CKeppel12	Suitable Habitat	Continuous	SS/PSL	SST4	155.62	
174	SW138	CKeppel18	Suitable Habitat	Continuous	SS/PSL	SST4	102.71	
175	SW139	CKeppel9	Suitable Habitat	Continuous	SS/PSL	SST4	53.87	
176	SW140	CKeppel10	Suitable Habitat	Continuous	SS/PSL	SST4	74.76	
177	SW141	CKeppel11	Suitable Habitat	Continuous	SS/PSL	SST4	21.88	
178	SE130	IsobPntS1	Suitable Habitat	Discontinuous	SS	SST1	89.41	
179	SE95	EleanorPntS1	Suitable Habitat	Discontinuous	SS/PSL	SST2	51.17	
180	E94	EleanorPntS2	Suitable Habitat	Discontinuous	SS/PSL	SST4	21.65	
181	E59	WalterBy7	Suitable Habitat	Continuous	SS/PSL	SST4	60.32	
182	E58	WalterBy6	Not Suitable Habitat	nill	nill	Mud, Pb	22.29	
183	E57	WalterBy5	Suitable Habitat	Continuous	SS/PSL	SST3	100.14	
184	E56	WalterBy3	Suitable Habitat	Continuous	SS/PSL	SST1	63.03	
185	E55	WalterBy1	Suitable Habitat	Continuous	PSL	PSLT3	57.31	
186	NW206	VesuviusN10	Suitable Habitat	Continuous	SS	SST1	19.14	
187	NW4	JFosterN1	Suitable Habitat	Continuous	SS/PSL	SST2	106.73	
188	NW3	JFosterN2	Suitable Habitat	Discontinuous	SS, PSL	SST3	92.38	
189	NW8	JFosterS1	Suitable Habitat	Continuous	SS/PSL	SST2	24.34	
190	NW10	NoEndRdS1	Suitable Habitat	Continuous	SS/PSL	SST3	36.08	
191	NW9	NoEndRdS2	Suitable Habitat	Continuous	SS/PSL	SST3	5.89	
192	NW21	WalkerHook1	Suitable Habitat	Continuous	PSL	PSLT3	453.22	Pacific sand lance
193	NE22	NosePnt1	Suitable Habitat	Continuous	SS	SST1	8.03	
194	E44	GangesE1	Suitable Habitat	Continuous	SS	SST1	7.87	
195	E45	GangesE2	Suitable Habitat	Continuous	SS/PSL	SST2	44.89	
196	E49	GangesNE1	Suitable Habitat	Continuous	SS/PSL	SST1	13.70	
197	E48	GangesNE2	Suitable Habitat	Continuous	SS	SST1	61.76	
198	E46	GangesNE4	Suitable Habitat	Continuous	SS	SST2	3.30	
199	E47	GangesNE3	Suitable Habitat	Continuous	SS	SST1	108.89	
200	NE41	Wellbury3	Not Suitable Habitat	nill	nill	Cb	90.69	
201	E79	CushN1	Suitable Habitat	Continuous	SS/PSL	SST3	16.33	
202	E80	CushS1	Suitable Habitat	Continuous	SS	SST1	31.66	
203	E68	BeddisS2	Suitable Habitat	Continuous	SS/PSL	SST1	13.81	
204	E69	BeddisS3	Suitable Habitat	Continuous	SS/PSL	SST2	27.01	
205	E70	BeddisS4	Suitable Habitat	Discontinuous	SS/PSL	SST2	19.72	
206	E72	BeddisS6	Suitable Habitat	Discontinuous	SS/PSL	SST2	68.81	
207	E73	BeddisS7	Suitable Habitat	Discontinuous	SS	SST1	33.83	
208	E67	BeddisS1	Suitable Habitat	Continuous	PSL	PSL3	29.87	
209	NW20	FernWdN1	Suitable Habitat	Continuous	SS/PSL	SST2	150.35	
210	NW19	FernWdN2	Suitable Habitat	Discontinuous	SS, PSL	SST3	243.90	
211	E92	GrandmaBy1	Suitable Habitat	Continuous	SS/PSL	SST2	46.85	
212	E93	GrandmaBy2	Suitable Habitat	Continuous	SS/PSL	SST3	33.72	

Appendix A – Salt Spring Island – Suitable Forage Fish Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	SPAWN DETECTED
213	NW18	HudsonPnt1	Suitable Habitat	Continuous	SS/PSL	SST4	40.60	
214	E90	RuckleW1	Suitable Habitat	Discontinuous	SS/PSL	SST4	13.73	
215	E91	RuckleWhf1	Suitable Habitat	Continuous	SS/PSL	SST4	21.41	
216	E71	BeddisS5	Not Suitable Habitat	nill	nill	Cb	16.71	

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

Pacific Sand lance - Type 3

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
E55	WalterBy1	PSLT3	PSL	Continuous
E60	GangesPrS7	PSLT3	PSL	Continuous
E67	BeddisS1	PSL3	PSL	Continuous
E76	BeddisBe2	PSLT3	PSL	Continuous
E86	RuckleE4	PSLT3	PSL	Continuous
NE26	IsletBe	PSLT3	PSL	Continuous
NE42	Wellbury2	PSLT3	PSL	Continuous
NE43	Wellbury1	PSLT3	PSL	Continuous
NW21	WalkerHook1	PSLT3	PSL	Continuous
SE117	FulfordS10	PSLT3	PSL	Continuous
SE122	FulfordS5	PSLT3	PSL	Continuous
SE96	King1	PSLT3	PSL	Continuous
E75	BeddisBe4	PSLT3	PSL	Continuous

Pacific Sand Lance - Type 2

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
NE23	LHrbN2	PSLT2	PSL	Discontinuous

Pacific Sand Lance - Type 1

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
SE111	FulfordL5	PSLT1	PSL	Continuous

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

Surf smelt - Type 1

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
E44	GangesE1	SST1	SS	Continuous
E47	GangesNE3	SST1	SS	Continuous
E48	GangesNE2	SST1	SS	Continuous
E49	GangesNE1	SST1	SS/PSL	Continuous
E51	GangesHr3	SST1	SS/PSL	Discontinuous
E52	GangesHr2	SST1	SS/PSL	Continuous
E53	GangesHr1	SST1	SS/PSL	Continuous
E56	WalterBy3	SST1	SS/PSL	Continuous
E61	GangesPrS6	SST1	SS/PSL	Discontinuous
E62	GangesPrS5	SST1	SS/PSL	Discontinuous
E64	GangesPrS3	SST1	SS/PSL	Continuous
E68	BeddisS2	SST1	SS/PSL	Continuous
E73	BeddisS7	SST1	SS	Discontinuous
E80	CushS1	SST1	SS	Continuous
E81	YeoPnt1	SST1	SS/PSL	Continuous
E82	YeoPntS2	SST1	SS/PSL	Continuous
E87	RuckleE3	SST1	SS	Continuous
NE22	NosePnt1	SST1	SS	Continuous
NE28	KFisherLn1	SST1	SS/PSL	Continuous
NE30	KFisherLn3	SST1	SS/PSL	Continuous
NW11	NoRdN1	SST1	SS	Discontinuous

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

Surf smelt - Type 1

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
NW12	NoRdN2	SST1	SS/PSL	Continuous
NW13	NoRdN3	SST1	SS	Continuous
NW15	NoRdN5	SST1	SS	Continuous
NW16	NoRdN6	SST1	SS/PSL	Continuous
NW183	LayardW2	SST1	SS/PSL	Continuous
NW184	LayardW3	SST1	SS/PSL	Continuous
NW190	BoothByS2	SST1	SS/PSL	Continuous
NW193	BoothByN2	SST1	SS	Continuous
NW197	VesuviusBe	SST1	SS/PSL	Continuous
NW198	VesuviusN1	SST1	SS	Continuous
NW201	VesuviusN4	SST1	SS	Continuous
NW203	VesuviusN6	SST1	SS/PSL	Continuous
NW204	VesuviusN7	SST1	SS/PSL	Discontinuous
NW205	VesuviusN8	SST1	SS	Continuous
NW206	VesuviusN10	SST1	SS	Continuous
NW210	GrapplerRk1	SST1	SS	Continuous
NW212	ArbutusS3	SST1	SS/PSL	Continuous
NW213	ArbutusS1	SST1	SS/PSL	Discontinuous
NW214	ArbutusN3	SST1	SS/PSL	Continuous
NW215	ArbutusN2	SST1	SS/PSL	Continuous
NW216	ArbutusN1	SST1	SS/PSL	Continuous
SE103	KFisherRd1	SST1	SS	Discontinuous
SE105	Tsawout1	SST1	SS	Continuous
SE106	Tsawout2	SST1	SS	Continuous
SE110	JacksonRf4	SST1	SS	Discontinuous
SE115	FulfordL1	SST1	SS	Discontinuous
SE116	FulfordS11	SST1	SS/PSL	Continuous
SE119	FulfordS8	SST1	SS	Continuous
SE120	FulfordS7	SST1	SS	Discontinuous
SE121	FulfordS6	SST1	SS/PSL	Discontinuous
SE126	FulfordS1	SST1	SS/PSL	Continuous
SE130	IsobPntS1	SST1	SS	Discontinuous

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

Surf smelt - Type 1

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
SE131	CKeppel1	SST1	SS	Discontinuous
SW136	CKeppel6	SST1	SS	Discontinuous
SW144	CKeppel14	SST1	SS	Continuous
SW147	CKeppel19	SST1	SS	Continuous
SW152	MusgravePntN2	SST1	SS;PSL	Discontinuous
SW153	MusgraveN3	SST1	SS/PSL	Continuous
SW155	MusgraveN5	SST1	SS/PSL	Continuous
SW156	MusgraveN6	SST1	SS, PSL	Continuous
SW157	MusgraveN7	SST1	SS	Continuous
SW158	MusgraveN8	SST1	SS	Continuous
SW159	MusgraveN9	SST1	SS	Continuous
W163	Sansum4	SST1	SS	Continuous
W167	BurgByS1	SST1	SS	Continuous
W171	BurgByS5	SST1	SS/PSL	Continuous
W172	BurgByS6	SST1	SS/PSL	Continuous
W173	BurgByS7	SST1	SS/PSL	Continuous
W176	BurgByNW3	SST1	SS	Continuous
W177	BurgByNW2	SST1	SS	Discontinuous
W178	BurgByNW1	SST1	SS	Continuous

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

Surf smelt - Type 2

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
E45	GangesE2	SST2	SS/PSL	Continuous
E46	GangesNE4	SST2	SS	Continuous
E50	ChurchillBe	SST2	SS/PSL	Continuous
E65	GangesPrS2	SST2	SS	Continuous
E69	BeddisS3	SST2	SS/PSL	Continuous
E70	BeddisS4	SST2	SS/PSL	Discontinuous
E72	BeddisS6	SST2	SS/PSL	Discontinuous
E78	CuLk1	SST2	SS/PSL	Discontinuous
E85	RuckleE5	SST2	SS	Continuous
E92	GrandmaBy1	SST2	SS/PSL	Continuous
NE27	ClamShellBe	SST2	SS/PSL	Continuous
NE32	BeachDr1B	SST2	SS/PSL	Continuous
NE35	LHrbS4	SST2	SS/PSL	Continuous
NE36	LHrbS3	SST2	SS/PSL	Discontinous
NW180	BaderBe2	SST2	SS/PSL	Continuous
NW181	BaderBe1	SST2	SS/PSL	Discontinuous
NW187	Layard2	SST2	SS/PSL	Continuous
NW189	BoothByS1	SST2	SS/PSL	Continuous
NW191	BoothByS3	SST2	SS/PSL	Continuous
NW199	VesuviusN2	SST2	SS/PSL	Continuous
NW2	SoutheyPntN2	SST2	SS/PSL	Continuous
NW20	FernWdN1	SST2	SS/PSL	Continuous
NW202	VesuviusN5	SST2	SS/PSL	Continuous
NW4	JFosterN1	SST2	SS/PSL	Continuous
NW8	JFosterS1	SST2	SS/PSL	Continuous

Surf smelt - Type 2

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
SE101	Fraser1	SST2	SS/PSL	Discontinuous
SE102	KFisherRd2	SST2	SS/PSL	Continuous
SE104	Seabright1	SST2	SS/PSL	Continuous
SE107	Tsawout3	SST2	SS/PSL	Continuous
SE108	JacksonRf1	SST2	SS	Continuous
SE112	FulfordL2	SST2	SS/PSL	Continuous
SE125	FulfordS2	SST2	SS/PSL	Continuous
SE133	CKeppel3	SST2	SS/PSL	Continuous
SE95	EleanorPntS1	SST2	SS/PSL	Discontinuous
SW145	CKeppel15	SST2	SS	Discontinuous
SW146	CKeppel16	SST2	SS	Discontinuous
SW149	CKeppel18	SST2	SS/PSL	Continuous
W161	Sansum2	SST2	SS	Continuous
W166	BoldBl1	SST2	SS	Continuous
W175	BurgByN2	SST2	SS	Discontinuous
W179	ErkinPntN1	SST2	SS/PSL	Continuous

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

Surf smelt - Type 3

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
E57	WalterBy5	SST3	SS/PSL	Continuous
E63	GangesPrS4	SST3	SS/PSL	Continuous
E89	RuckleE1	SST3	SS/PSL	Discontinuous
E77	BeddisBe3	SST3	SS/PSL	Continuous
E79	CushN1	SST3	SS/PSL	Continuous
E84	RuckleE6	SST3	SS/PSL	Continuous
E93	GrandmaBy2	SST3	SS/PSL	Continuous
NE33	BeachDr2	SST3	SS/PSL	Discontinuous
NE34	LHrbS5	SST3	SS/PSL	Discontinous
NE37	LHrbS2	SST3	SS/PSL	Continuous
NW10	NoEndRdS1	SST3	SS/PSL	Continuous
NW17	HudsonN1	SST3	SS/PSL	Discontinuous
NW185	LayardW4	SST3	SS/PSL	Continuous
NW188	Layard1	SST3	SS/PSL	Continuous
NW19	FernWdN2	SST3	SS, PSL	Discontinuous
NW194	BoothByN5	SST3	SS/PSL	Continuous
NW196	BoothByNE1	SST3	SS/PSL	Continuous
NW200	VesuviusN3	SST3	SS/PSL	Continuous
NW211	GrapplerRk2	SST3	SS/PSL	Continuous
NW3	JFosterN2	SST3	SS, PSL	Discontinuous
NW9	NoEndRdS2	SST3	SS/PSL	Continuous

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

Surf smelt - Type 3

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
SE109	JacksonRf2	SST3	SS	Discontinuous
SE129	IsobPnt1	SST3	SS/PSL	Continuous
SE132	CKeppel2	SST3	SS	Continuous
SE134	CKeppel14	SST3	SS/PSL	Continuous
SE97	ElPntS1	SST3	SS	Discontinuous
SE98	ElPntS2	SST3	SS/PSL	Continuous
SE99	KFisherRd4	SST3	SS	Continuous
SW135	CKeppel5	SST3	SS	Discontinuous
SW137	CKeppel7	SST3	SS/PSL	Continuous
SW143	CKeppel13	SST3	SS	Discontinuous
W160	Sansum1	SST3	SS	Continuous
W168	BurgByS2	SST3	SS/PSL	Continuous
W170	BurgByS4	SST3	SS/PSL	Continuous
W174	BurgByN1	SST3	SS/PSL	Discontinuous
E88	RuckleE2	SST3	SS/PSL	Continuous

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

Surf smelt - Type 4

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Sediment Distribution
E54	GasAlley1	SST4	SS	Continuous
E59	WalterBy7	SST4	SS/PSL	Continuous
E74	BeddisBe1	SST4	SS/PSL	Continuous
E90	RuckleW1	SST4	SS/PSL	Discontinuous
E91	RuckleWhf1	SST4	SS/PSL	Continuous
E94	EleanorPntS2	SST4	SS/PSL	Discontinuous
NE38	LHrb1	SST4	SS/PSL	Continuous
NE39	Wellbury4	SST4	SS/PSL	Continuous
NW1	SoutheyPntN1	SST4	SS/PSL	Continuous
NW14	McFaddenN1	SST4	SS/PSL	Continuous
NW18	HudsonPnt1	SST4	SS/PSL	Continuous
NW195	BoothByN1	SST4	SS/PSL	Discontinuous
NW207	EagleS1	SST4	SS/PSL	Continuous
NW208	EagleS2	SST4	SS/PSL	Discontinuous
NW209	EagleN	SST4	SS/PSL	Continuous
NW40	LHrbW2	SST4	SS/PSL	Continuous
NW5	JFostersS3	SST4	SS/PSL	Continous
NW6	JFostersS2	SST4	SS/PSL	Continuous
NW7	JFostersS1	SST4	SS/PSL	Continuous
SE100	KFisherRd3	SST4	SS/PSL	Continuous
SE114	FulfordL3	SST4	SS/PSL	Discontinuous
SE118	FulfordS9	SST4	SS/PSL	Continuous
SE124	FulfordS3	SST4	SS/PSL	Continuous
SE127	FulfordE1	SST4	SS/PSL	Discontinuous
SW138	CKeppel18	SST4	SS/PSL	Continuous
SW139	CKeppel9	SST4	SS/PSL	Continuous
SW140	CKeppel10	SST4	SS/PSL	Continuous
SW141	CKeppel11	SST4	SS/PSL	Continuous
SW142	CKeppel12	SST4	SS/PSL	Continuous

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

Surf smelt - Type 3

Beach Number	Salt Spring Island Beach Unit	Grain Size Type	Suitable by Species	Spawning Beach	Sediment Distribution
E66	GangesPrS1	SST5	SS		Continuous

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

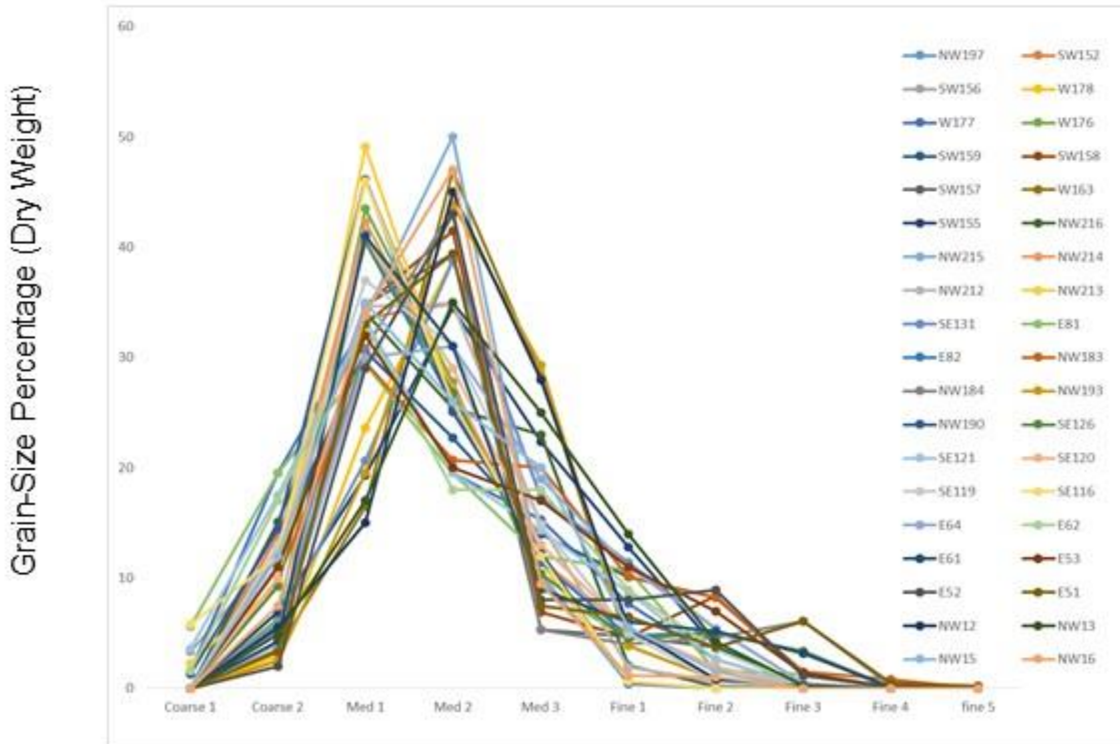


Figure 2 Salt Spring Island – Surf Smelt Type 1 Beaches

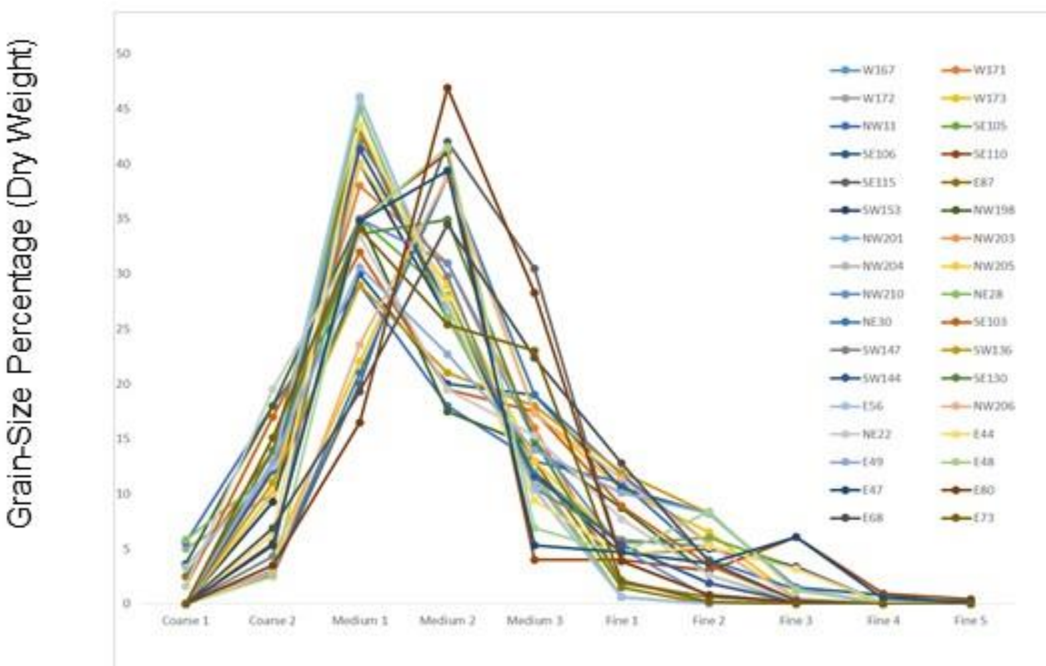


Figure 3 Salt Spring Island – Surf Smelt Type 1 Beaches

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

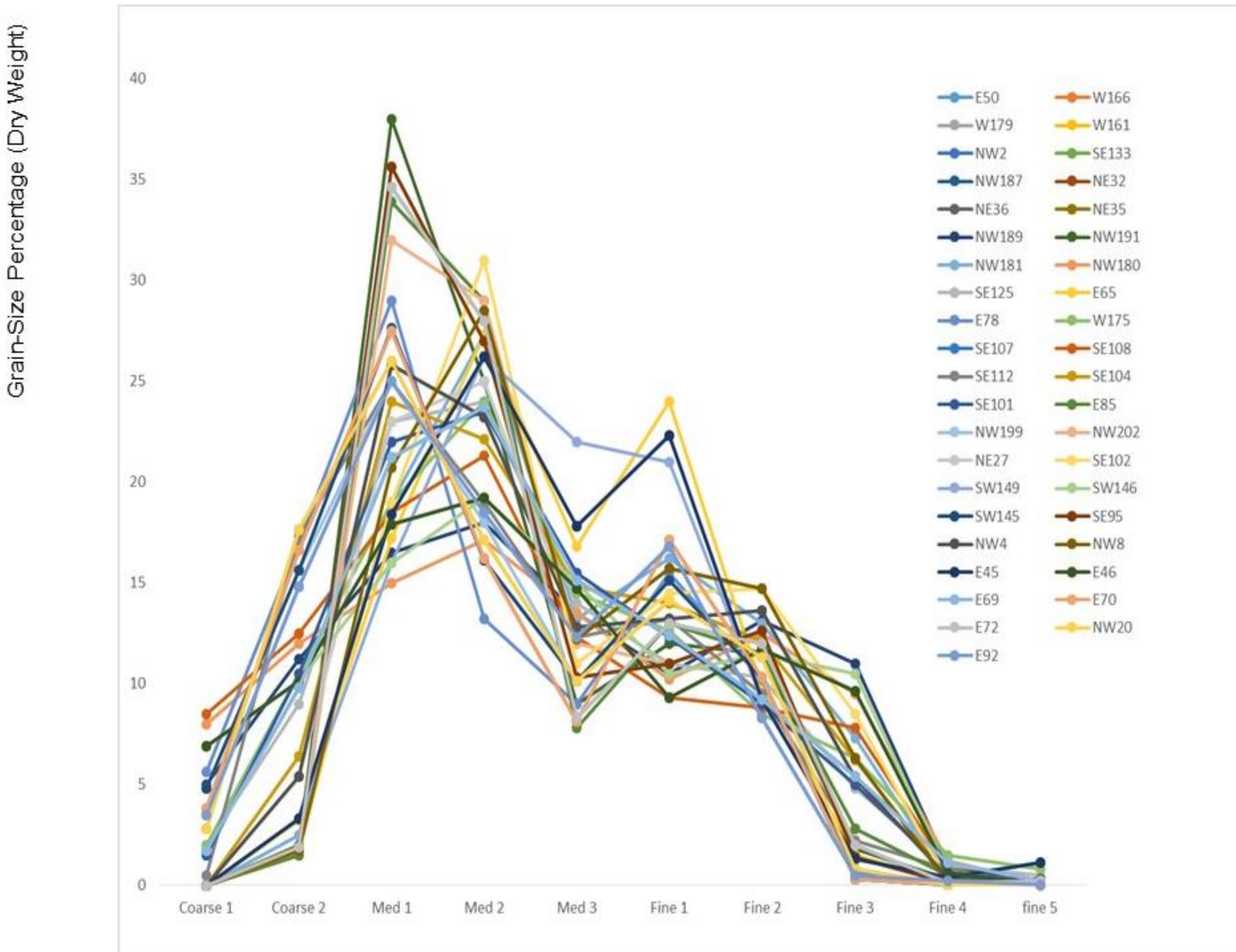


Figure 4 Salt Spring Island – Surf Smelt Type 2 Beaches

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

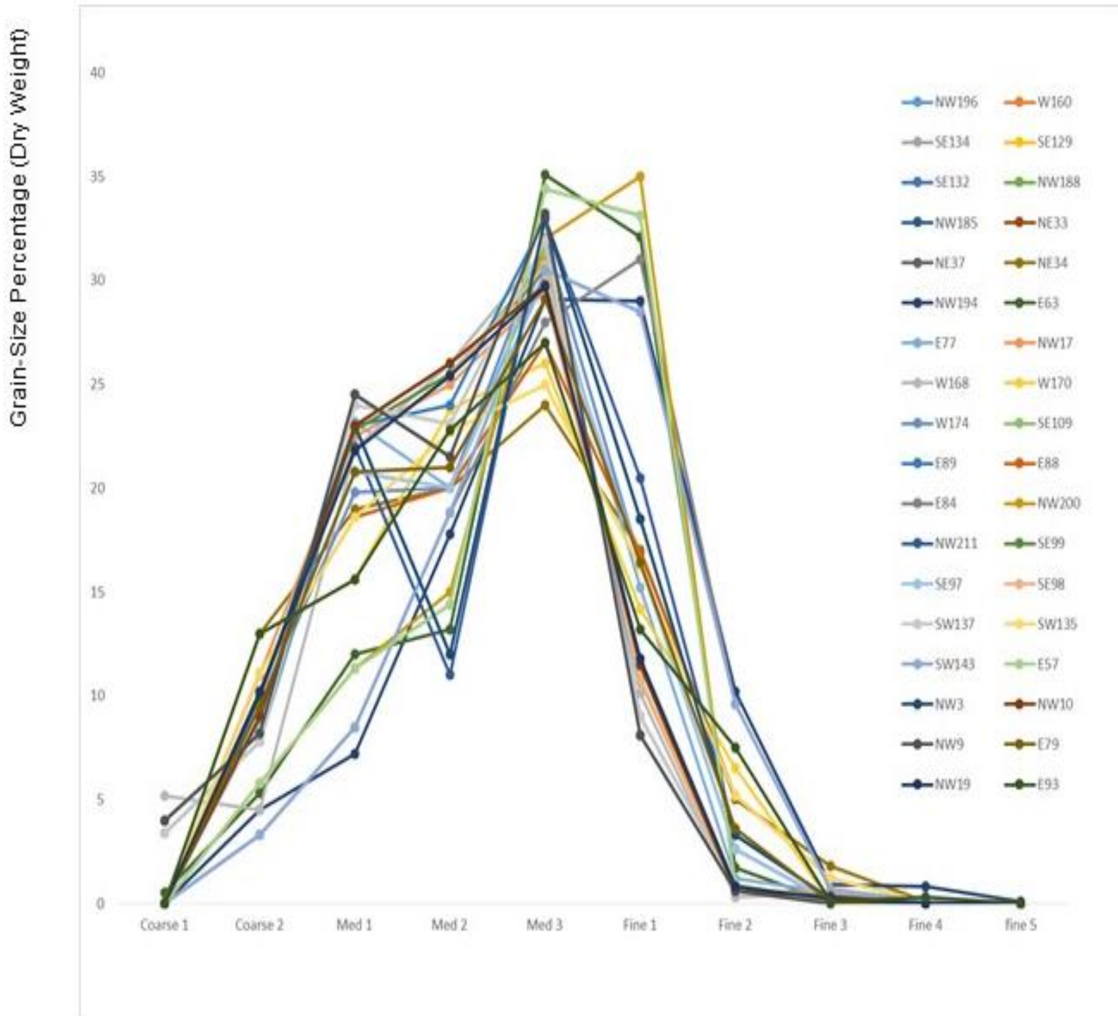


Figure 5 Salt Spring Island – Surf Smelt Type 3 Beaches

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

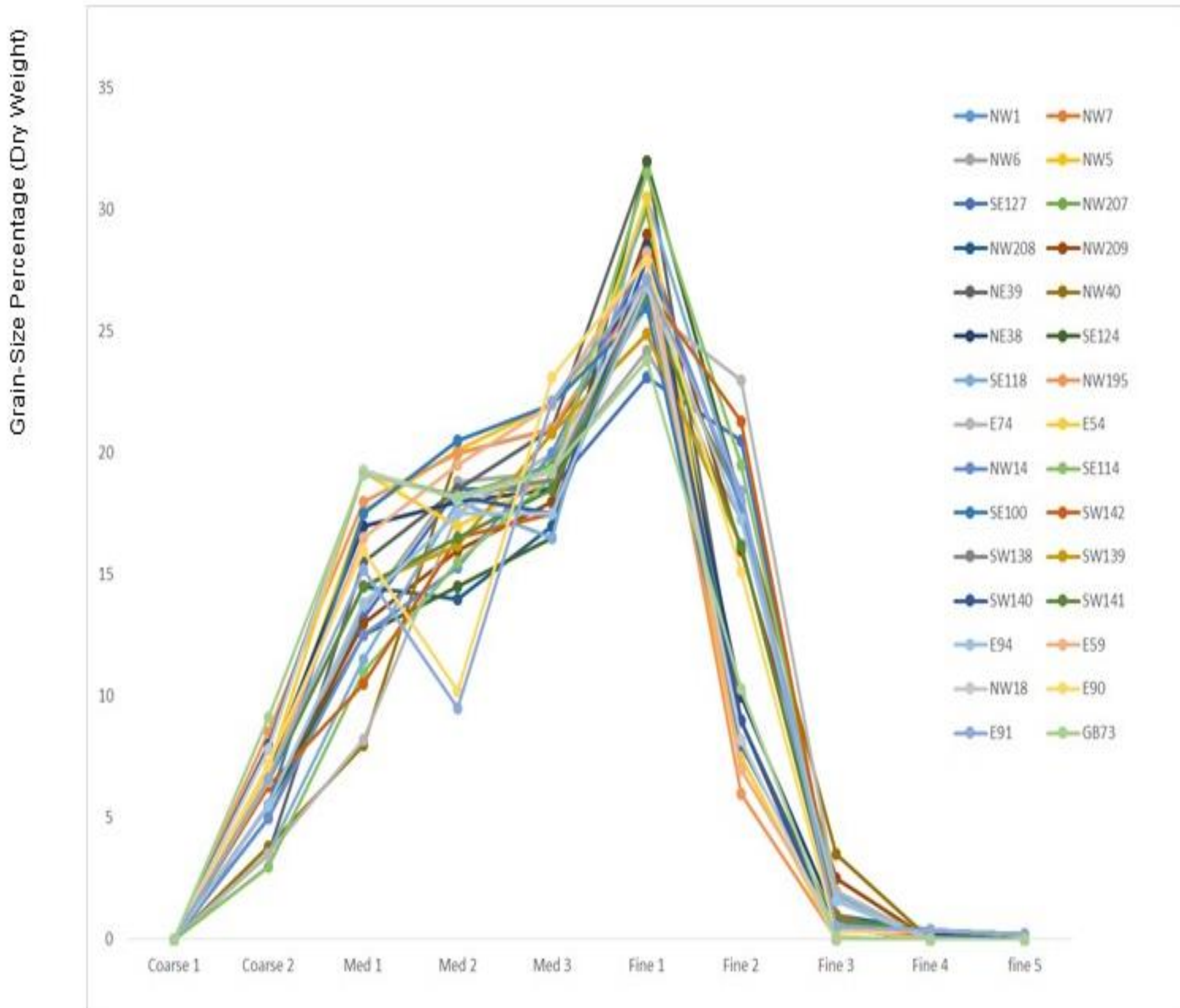


Figure 6 Salt Spring Island – Surf Smelt Type 4 Beaches

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

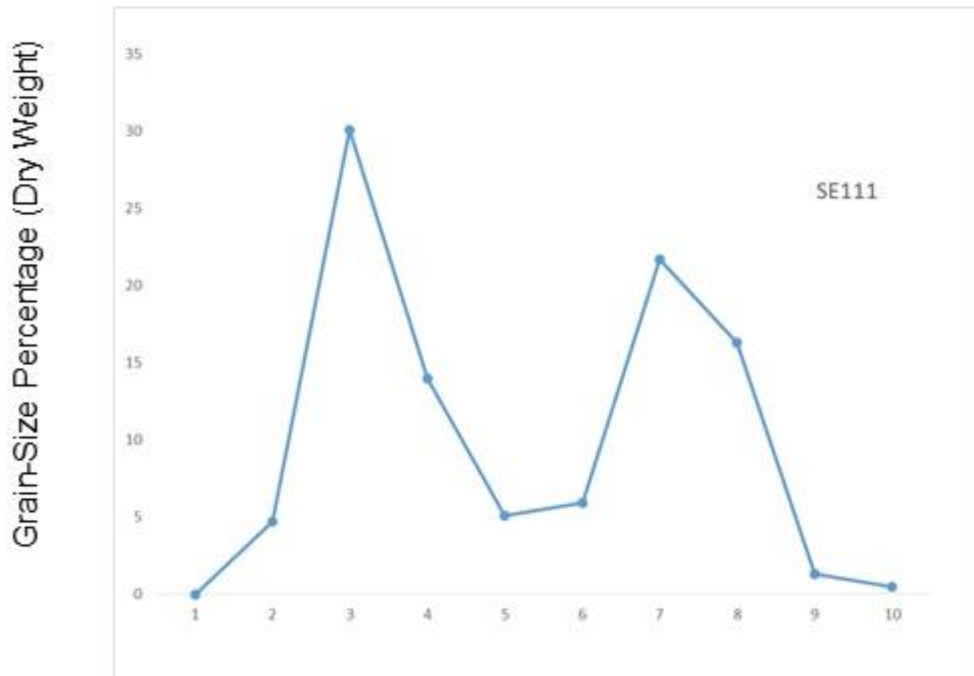


Figure 7 Salt Spring Island – Pacific sand lance Type 1 Beaches

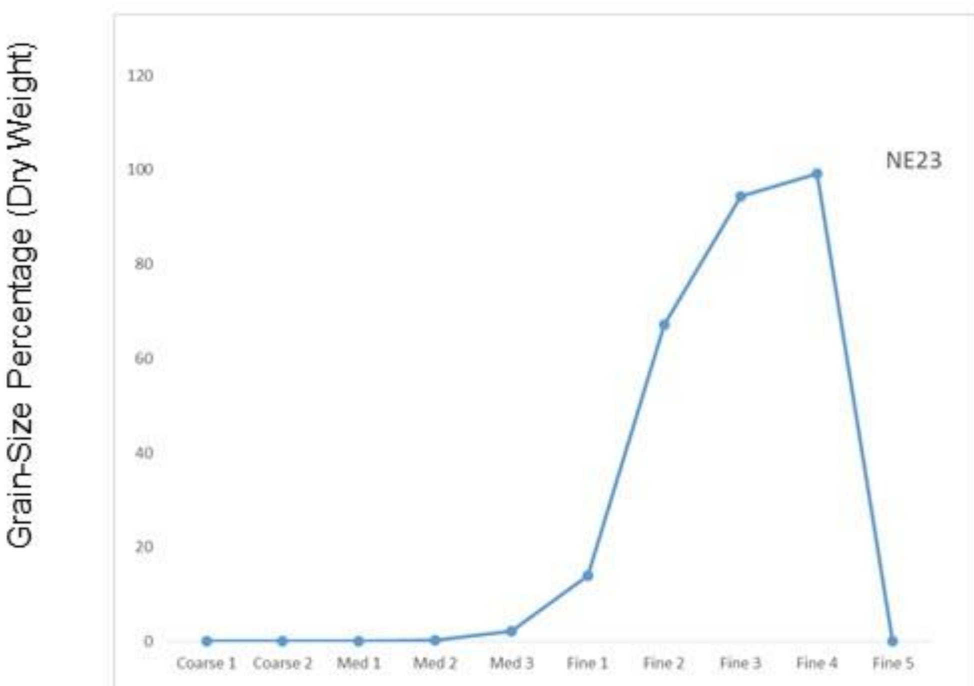


Figure 8 Salt Spring Island – Pacific sand lance Type 2 Beaches

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

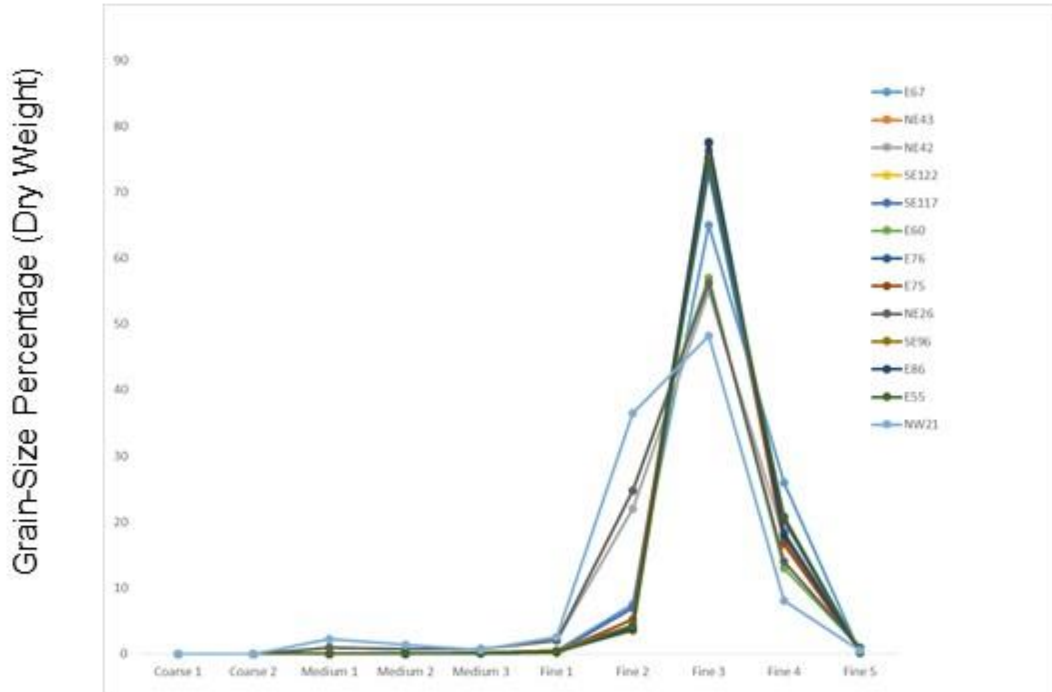


Figure 9 Salt Spring Island – Pacific sand lance Type 3 Beaches

Appendix D: Wallace Island – Suitable Forage Fish Spawning Habitat Beach Unit Classifications

GIS ID	Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species most likely	Grain Size Type	Beach Unit Length (m)	Geomorphic Habitat Type
1	N1	ChiversPnt	Suitable Habitat	Continuous	SS/PSL	SST2	12.26	Pocket Cove
2	N2	NEast2	Suitable Habitat	Continuous	SS/PSL	SST2	4.69	Pocket Cove
3	N3	NEast3	Suitable Habitat	Continuous	SS/PSL	SST3	12.52	Pocket Cove

Appendix E: GPS/GIS Methodology

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 positions 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 E: 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 meet
collection 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 F: 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 G: Forage Fish Habitat Suitability Assessment Methods

Housed with the Islands Trust Fund and the author