Bowen Island
Surf smelt and Pacific sand lance
Spawning Habitat Suitability Assessments

Tunstall Bay
Photo: RC deGraaf

Prepared for the Bowen Island Municipality and the Islands Trust,
Bowen Island Local Trust Committee

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Bowen Island September 25 – October 1, 2014

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Pocket Cove – Bowen Island
Photo: RC de Graaf

1. Introduction

The term “forage fish” refers to small schooling fishes that are prey for larger animals. Forage 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 Chinook and Coho feed on sand lance both as juveniles and as adults.

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 habitat for their survival. 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.

2. Beach Spawning Forage Fish Habitat

Beach spawning forage fish of commercial, recreational and ecological value in the Strait of Georgia are the 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). Approximately 10% of Puget Sound beaches are used by surf smelt for spawning and 10% are used by Pacific sand lance (Penttila 2007). Unfortunately critical spawning habitat of these two forage fishes has not been mapped in British Columbia.

Surf smelt and Pacific sand lance depend on a healthy nearshore and beach habitat, and they are vulnerable to impacts from shoreline development. Beaches with natural erosion processes supplying appropriate sized gravels and extant marine riparian zones are an optimal state for spawning surf smelt and sand lance. Of primary importance for spawning is the mixture of gravels and sand.

Bowen Island – West coast
Intact shoreline with suitable forage fish spawning habitat.
Photo: RC de Graaf

3. 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. 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.

3.2 Sediment Characteristics

Both surf smelt and 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). 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). 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). Recent findings in British Columbia reveal that sand lance embryos are also found in beaches bearing a high percentage of coarse pebble greater than 2.6 cm (de Graaf unpublished data). 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 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

Beaches in British Columbia bearing surf smelt and Pacific sand lance spawning sites are typically of sand/pebble in the upper component of the beach slope, a cobble component seaward, followed by a sand or mud flat toward the low tide zone. The width of the sand/pebble component (commonly referred to as the B1 component) is variable and can range from 0.5 m to over 10 m in width.

4. 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, summer and year round spawning beaches have been detected (de Graaf unpublished data). 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 extraordinary effort of 30+ communities working with the author through the BC Shore Spawners Alliance (BCSSA), a project 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. 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).

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 sand lance is known to burrow.

Left: Riprap (stacked boulders)
Above: Pier with floats
Photos: RC de Graaf

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.

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

6. 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 Bowen 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.

Bowen Island surveys took place on September 25 to October 1, 2014. From September to October 2014, no major storm activity was noted for the Strait of Georgia.

6.2 Area Surveyed

The entire coastline of Bowen Island was surveyed by foot with the exception of some areas of consolidated sediment (rocky beaches, rock terraces etc.). Vessel surveys were also conducted using a 15 foot boat equipped with a depth sounder. Areas with consolidated sediment types interspersed with unconsolidated sediment types were mapped to provide an estimate of total shoreline area surveyed. Contiguous shoreline areas of consolidated sediments were surveyed by kayak and boat to ensure the absence of pocket coves.

Areas surveyed included areas with drift cell attributes of erosional faces that graded into beach areas. These are areas with unconsolidated sediments of gravel/sand as well as mud/silt areas. Gravel is defined as pebble, cobble and boulder.

Beach units of pebble and sand were assessed for spawning habitat suitability. Areas of mud/silt were assessed for the presence of upper bands of pebble and sand.

7. Methods

Forage Fish Habitat Assessments – Assessing Suitable Forage Fish Spawning Habitat

Actual forage fish spawning beaches are determined after a two-year embryo survey and the presence of two or more embryos in a sample (Moulton and Penttila 2001). In the absence of such comprehensive surveys, beaches may be classified as suitable surf smelt/Pacific sand lance spawning habitat following a habitat assessment. The habitat assessment protocol used in this project, the Forage Fish Habitat Assessment, has been developed through a collaboration of forage fish biologists from British Columbia and Washington State. Due to the current transition of the Department of Fisheries and Oceans Habitat Program to the Fisheries Protection Program and numerous staff reassignments, the FFHA protocol vetting process has been stalled.

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). The Forage Fish Habitat Assessment (FFHA) 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. Additional variables are measured to assess human activities that may have directly modified the foreshore or adjacent backshore areas. Assessments are conducted by experienced beach spawning forage fish biologists/technicians. 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.

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 statistical 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 assigned as “Not Spawning Habitat" are those consisting 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 FFHA 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 detailed description of the survey methodology has been provided to the Islands Trust/Islands Trust Fund and is available upon request for the purposes of verifying the validity of the data collection and analysis.

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 X).

GPS specifications were adjusted in two circumstances. Firstly, during vessel-based surveys, at beach units scored in the field as “not habitat” due to the dominance of cobble and boulder substrates and access to the shoreline was difficult, positional data (latitude and longitude) was collected following the Islands Trust eelgrass methodology. Feature data were taken by collecting 3 fixes at 1 second intervals each. The vessel was used and placed on the lower tide limit while recording positional data, uncorrected water depth (by depth sounder) and the time.
Secondly, 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.

7.2.2 Digitizing Spatial Data and Map Production

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

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 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 being “suitable” spawning beaches, but it does not confirm the presence or absence of spawning activity.

9. Results

9.1 BOWEN ISLAND

9.1.1 Statistical Analyses

In total, fourty-five (45) beach units comprised of unconsolidated sediments were assessed (Table 1). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed fourty (40) beach units with 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable spawning habitat” (Table 1, Figure 1A-1E). Twenty-three (23) of these beach units had continuous habitat and seventeen (17) had discontinuous habitat.

Five (5) beach units failed statistical analyses, the same beach units with non-conforming grain-sizes, and were classified as “not suitable spawning habitat”. Two (2) of the beach units classified as “not suitable spawning habitat”, encompassing 182 meters, may have been degraded due to shoreline modifications resulting in increased erosion. A list of the beach units identified in map Figures 1A-1E is provided as Appendix A.

Suitable Spawning Habitat
Tunstall Bay (Sealy Beach)
Photo: RC de Graaf

Thirty (30) beach units were comprised of unconsolidated sediments such as mud, silt, cobble that are not habitat types that are potential spawning habitat (Table 1, Figure 1A-AE: Bowen Island Map of Assessed Suitable Forage Fish Spawning Beaches). Six (6) of these beach units, encompassing 686 meters, had significant shoreline modifications and/or localized erosion factors (wakes of local vessel traffic and from BC ferries) that may have contributed to lack of fine spawning sediments and the current beach condition of cobble and/or cobble/boulder.

Table 1: Bowen Island - Beach Unit Statistical Analyses				
	Count	**Total**	**Length (m)**	**Percentage of Shoreline Perimeter**
Habitat	40	40	3390.1	8%
Not Suitable (due to modifications/erosion effects)	3(2)	5	282.1	1%
Not Habitat-Modification/Erosion Effects	24(6)	30	2052.1	5%
Total Beach Units		75		
Total Length (meters)			5724.3	14%
Habitat				
Continuous	23		1496.1	4%
Discontinuous	17		1894	5%

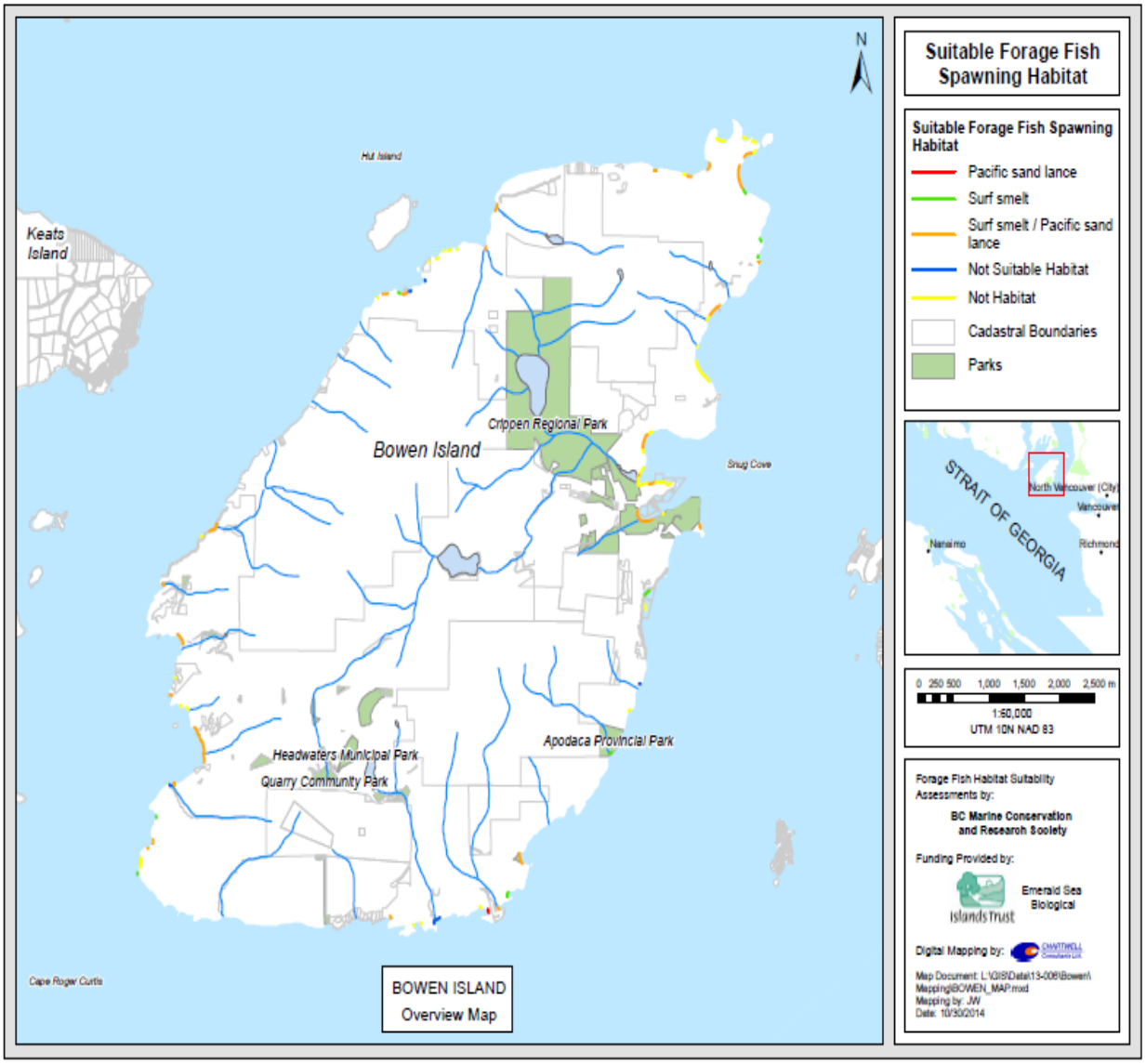
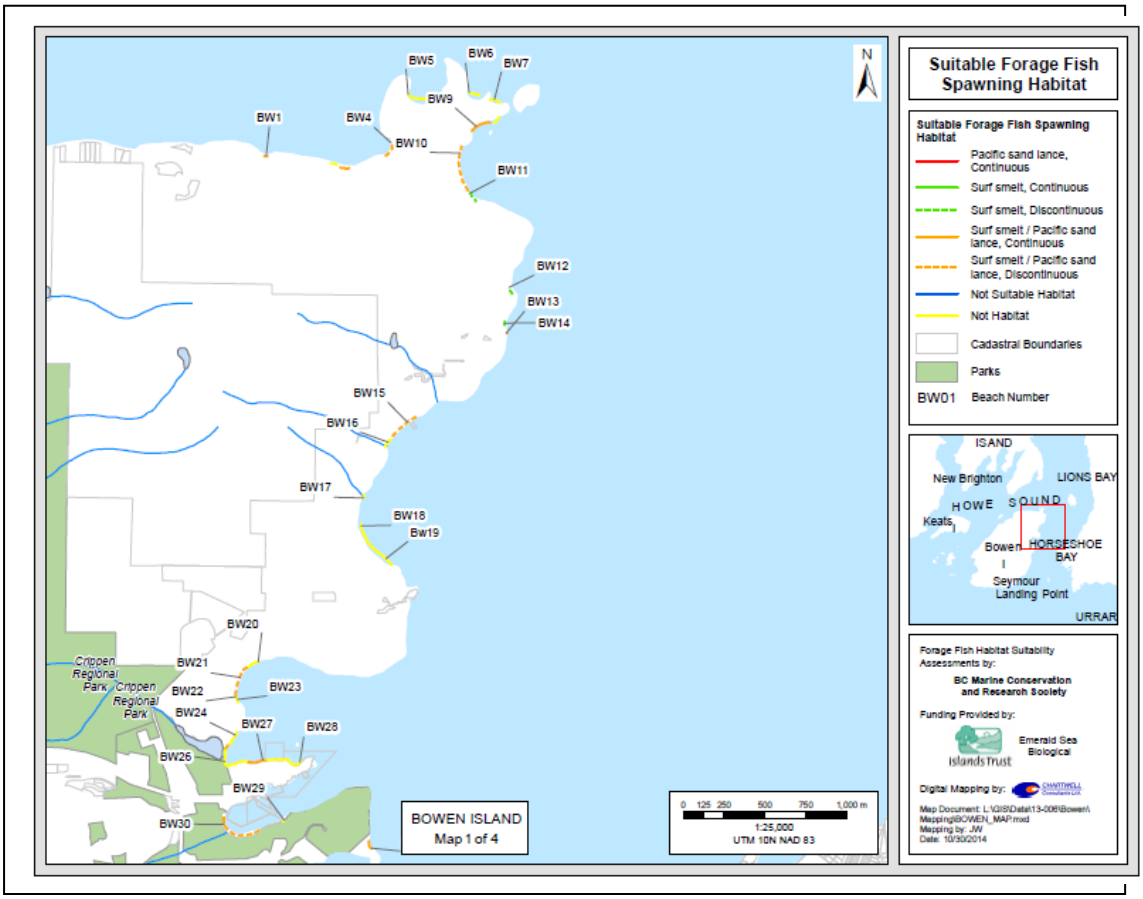


Figure 1A: Suitable Beach Spawning Forage Fish Spawning Habitats – BOWEN ISLAND



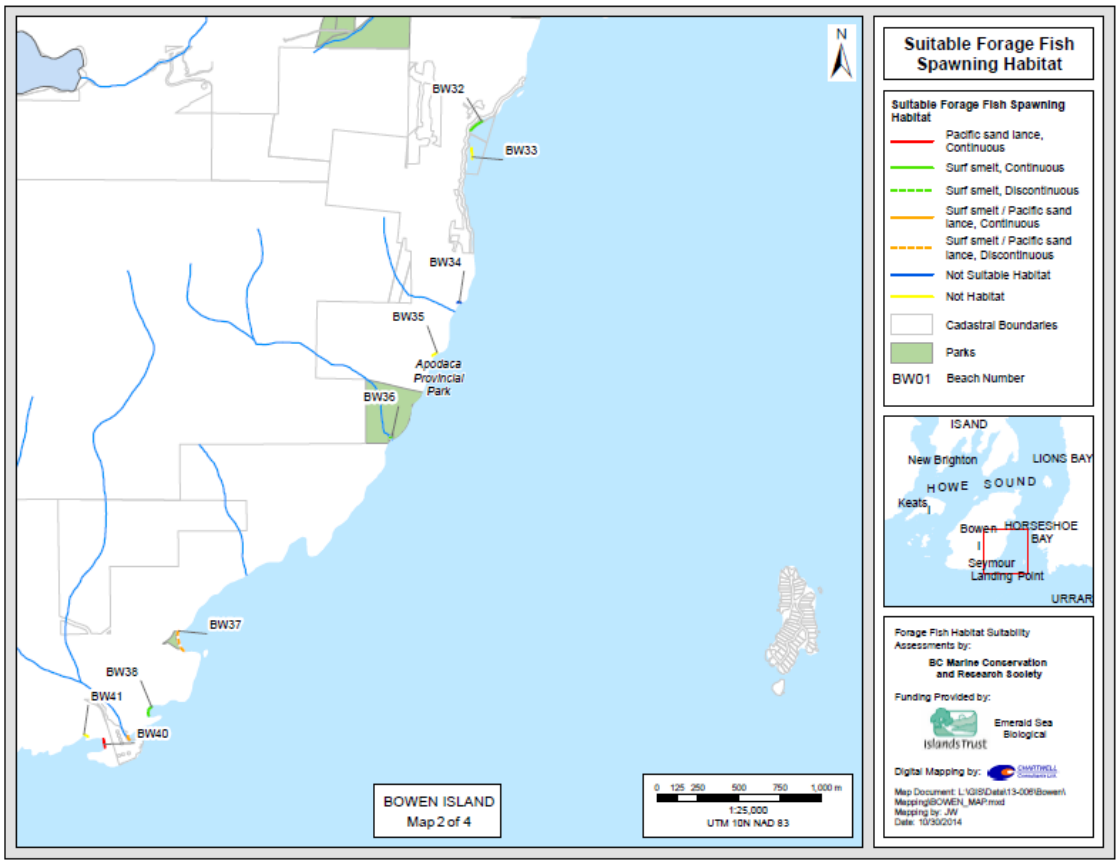
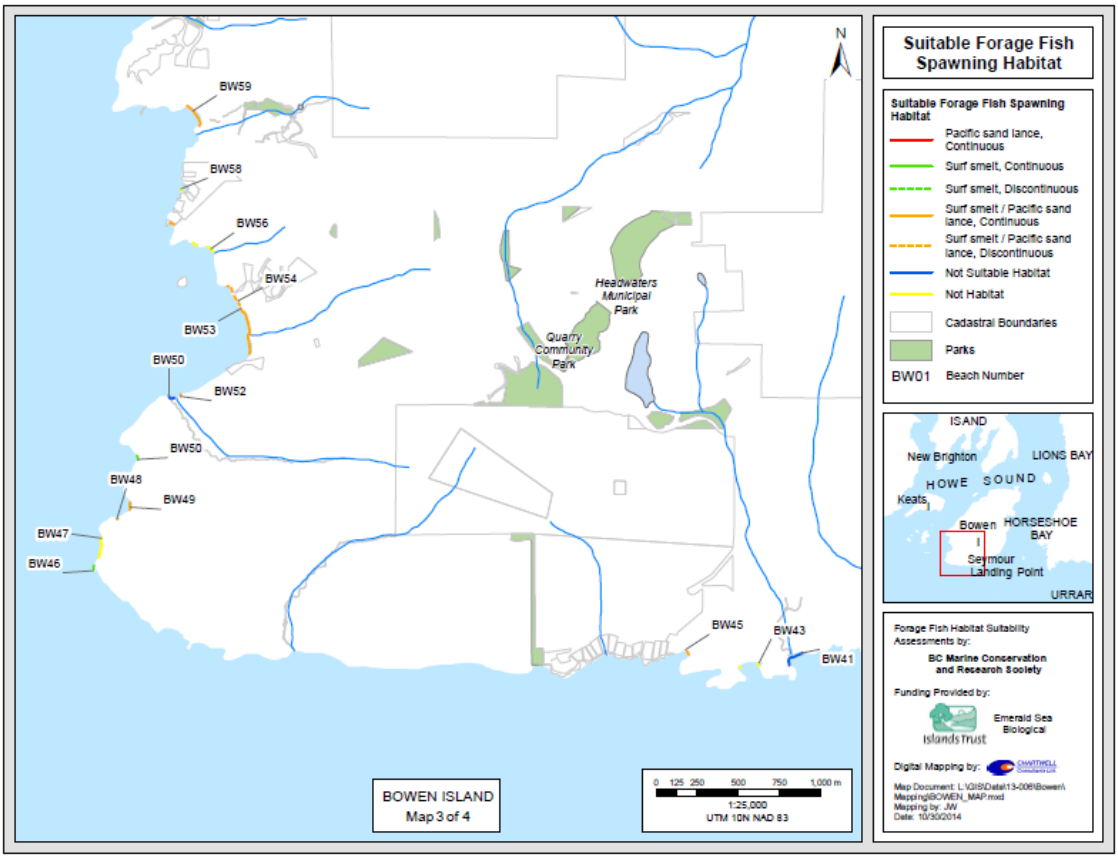


Figure 1B-1C: Suitable Beach Spawning Forage Fish Spawning Habitats – BOWEN ISLAND



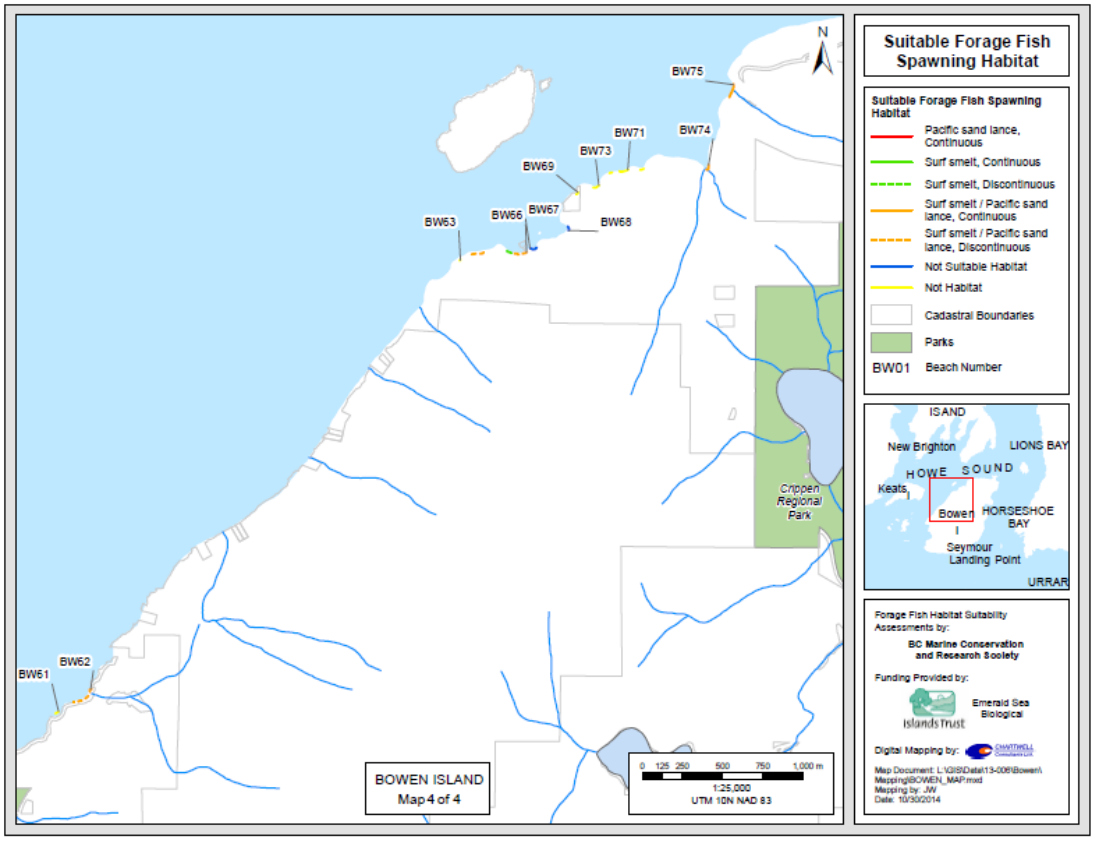


Figure 1D-1E: Suitable Beach Spawning Forage Fish Spawning Habitats – BOWEN ISLAND

9.1.2 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. Fourty (40) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix C, Figures 2-5). The grain-size frequencies of five (5) beach units did not meet the statistical standards of the analysis.

9.1.3 Length of Suitable Forage Fish Spawning Habitat

The total shoreline perimeter of Bowen Island is 41.8 kilometers. Suitable forage fish spawning habitat comprised 3.4 kilometers (3,390.1 meters) or 8% of the Bowen Island shoreline perimeter. The shoreline perimeter is comprised of 1.0% (413.6 m) classified as suitable for surf smelt; 0.1% (56 m) as suitable for Pacific sand lance; and 7.0% (2,920.5 m) as suitable for surf smelt/Pacific sand lance (Table 2).

Table 2: Bowen Island – Classification of Suitable Forage Fish Spawning Beach Units

	SS	PSL	SS/PSL	Total (m)
Count				
Length (m)	413.6	56	2920.5	3390.1
Length Percentage	12	2	86	100
Shoreline Perimeter Percentage	1.0	0.1	7.0	8.0

SS - Surf smelt
PSL - Pacific sand lance

9.1.4 Suitable Forage Fish Spawning Habitat Types

Of the 40 suitable spawning beach units, one (1) was classified as Pacific sand lance, nine (9) as surf smelt, and thirty (30) as mixed surf smelt/Pacific sand lance spawning habitat (Table 3). Of the Pacific sand lance beaches, grain size analyses assessed one as a Type 3 Pacific sand lance beaches. Of the surf smelt beaches, grain size analysis assessed eight as Type 1 and one as Type 2 surf smelt beaches. Of the mixed surf smelt/Pacific sand lance beaches, grain size analysis assessed seven as Type 1; ten as Type 2; seven as Type 3, and five as Type 4 surf smelt beaches (Appendix B, Appendix C Figures 2-5).

Overall, grain-size types were coarser than surveyed on Denman, Hornby and Thetis Islands. This is likely due to the prevailing oceanographic and weather conditions dominating Howe Sound.

Table 3: Bowen Island Grain-Size Types

Category	SS	PSL	SS/PSL
PSL TYPE 1			
PSL TYPE 2			
PSL TYPE 3		1	
SS TYPE 1	8		7
SSTYPE 2	1		10
SS TYPE 3			7
SS TYPE 4			5
SS TYPE 5			
Totals	9	1	29

9.1.5 Geographic Position of Suitable Forage Fish Spawning Beaches

Dividing Bowen Island into north, south, west and east coast lines, six (6) suitable beach units are located on the north coast; twelve (12) suitable beach units are located on the south coast; seven (7) suitable beach units on the west coast; and fifteen (15) suitable beach units on the east coast (Table 4).

Table 4: Bowen Island Coast Lines - Suitable Forage Fish Spawning Beach Units

	SS	PSL	SS/PSL	Total
North	1		5	6
South	2	1	9	12
West	1		6	7
East	5		10	15
Total	9	1	30	40

9.1.6 Foreshore 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 that would impede movement of sediments either to the beach or along the beach. Twenty-four (24) of the beach units had unmodified shorelines (60%) and sixteen (16) were modified (40%). Of the 16 (40%) modified beach units, 7 (18%) were 1-25% impacted; 7 (18%) were 1-25% impacted; 3 (8%) were 26-50% impacted; 2 (5%) were 51-75% impacted; and 4 (10%) were 75-100% impacted (Table 5).

Table 5: Bowen Island - Foreshore Modification

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	24	7	3	2	4
Percentage	60	18	8	5	10

Foreshore Modification
Structure: Hard Armouring
Riprap ("stacked boulders) intruding into the foreshore.
Photo: RC de Graaf

9.1.7 Foreshore and Backshore Structures

Of the sixteen (16) suitable forage fish spawning beach units with modified foreshore zones, the presence of sediment impeding structures were classified and enumerated. In total twenty-six (26) structures were classified into twelve categories over 16 beach units (Table 6).

Seven (7) beach units had 1 foreshore structure each, four (4) beach units had 2 foreshore structures each, three (3) beach units had 3foreshore structures each, and one (1) beach unit had 7 foreshore structures.

Of the fourty (40) suitable spawning beach units, eighteen (18) had modified backshore zones. In total thirty-one (31) structure types were classified into nine (9) categories. The majority of structures (14) were stairways to the beach. Buildings (cabins, houses, sheds, etc.) are not enumerated but only classified as present or absent. All other Individual structures were numerated. Buildings were present at twenty-eight (28) beach units (Table 6).

Riprap (stacked boulder) at or below the natural boundary
Photo: RC de Graaf

Table 6: Bowen Island - Foreshore and Backshore Structures

	Foreshore		Backshore		
Category	Count	Percentage	Count	Percentage	No. Beach Units Buildings Present
Building					28
Boat Ramp	2	8	2	6	
Boat House			1	3	
Dock/Wooden Pier	6	23			
Seawall	7	27	1	3	
Riprap	6	23	2	6	
Groin	1	4			
Breakwater	1	4			
Infill/bulkhead	1	4	1	3	
Storm Water Outfall	1	4	1	3	
Stairs			14	45	
Platforms/Patios			4	13	
Road to beach	1	4	5	16	
Total Number of Structures	26		31	100	
Beach Units with Structures	16		18		

9.1.8 Overhanging Shade Vegetation

Marine riparian overhanging shade is classified into percentage of the length of the beach unit with tree branches overhanging the spawning zone. Trees are, generally, located above the high water mark and subject to removal by property owners. Of the beach units assessed as suitable forage fish spawning habitat,30% of the beach units had no overhanging shade; 28% had 1-25% overhead shade; 28% had 26-50% overhanging shade; 5% had 51-75% overhanging shade; 10% had 76-100% overhanging shade (12, 11, 11, 2, and 4 respectively)(Table 7).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the beach units assessed as suitable forage fish spawning habitat with no overhanging shade, 25% had modified foreshore and 92% modified backshore zones; beach units with 1-25% overhead shade had 64% had modified foreshore and 100% modified backshore zones; beach units with 26-50% overhead shade had 55% modified foreshore and 82% modified backshore zones; beach units with 51-75% overhead shade had 0% modified foreshore and 100% modified backshore zones; and beach units with 76-100% overhead shade had 0% modified foreshore and 50% modified back shore zones (Table 7). In general, modification of foreshore areas resulted in significant losses of overhead shade bearing trees.

Table 7: Bowen Island - Overhead Shade Vegetation

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade
Count	12	11	11	2	4
Percentage	30	28	28	5	10
Foreshore Modified %	25%	64%	55%	0%	0%
Backshore Modified %	92%	100%	82%	100%	50%

10.0 Summary and Recommendations

10.1 General

The shoreline of Bowen Island relative to those surveyed in 2013-2014 on Denman, Hornby and Thetis, were notably different in the small percentage of pure sand beaches and overall, beaches comprised of coarser beach types. However, with approximately 3.4 kilometers of suitable spawning Bowen Island provides excellent opportunities to safeguard and protect these critical fish habitats.

As stated in the introduction, particular marine shorelines are critical fish habitat for spawning surf smelt and Pacific sand lance, and also provide rearing grounds for juvenile salmonids. Forage Fish Habitat Assessments (FFHAs) can grade beaches as to their spawning suitability only. Where resources permit, the Islands Trust and the Island Trust Fund should support further forage fish habitat spawning surveys and community involvement in marine habitat stewardship.

Recommendations from this study have been evaluated with the goal of balancing changing oceanographic conditions (sea level rise), ecological values, public access/enjoyment of beaches, and shoreline property values. Recommendations should also promote local governance tools and community discussions that incorporate emerging engineering, biological and policy advances for shoreline protection and ecological/resource benefits.

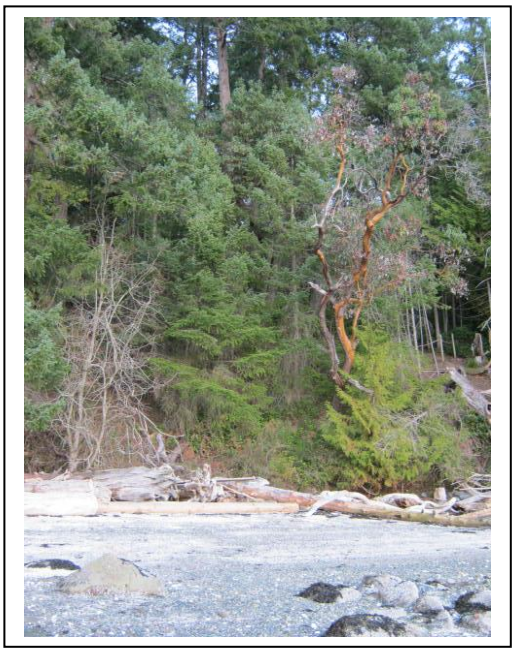
Shoreline structures:

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. Overtime, beaches lack sediment “nourishment” and will coarsen. Some structures, such as hard structures (seawalls, riprap boulders, retaining walls) have various impacts on the foreshore, but generally these structures can increase erosion due to wave-induced scouring on the face of these structures. 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. The majority of piers/docks on Bowen Island had footings on hard, rock substrate which is preferable to footings on soft sediment beaches.

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

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 spawning surveys are all central to protecting these beaches.



Marine Riparian Vegetation
Thetis Island - 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).

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. Managing storm water by maintaining vegetation is an effective and low-cost measure.

Foreshore areas lacking vegetation and overhanging vegetation could benefit by restoring vegetation. Overtime, restoration of shrubs, alders, arbutus, maples and other trees in some areas would also provide overhanging shade for summer surf smelt embryos and insect prey for juvenile salmonids. Replanting vegetation benefits property owners by stabilizing shoreline sediments. This is particularly important on high bank and bluff habitats. With careful site planning, shoreline vegetation and other landowner values, such as views, can be maintained.

Overhanging Shade Vegetation

Photo: RC de Graaf

Stressors/Restoration:

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. Restoration strategies can lead to effective solutions if grounded in cost-effective, community-supported regulatory tools. The following is a list of stressors and restoration options relevant to the shoreline survey completed.

Stressors:

A. Shoreline Modifications

1. Hard armouring
    - reduces public access to beach
    - removal of spawning habitat
    - interruption of sediment supply
    - increases beach erosion (sediment coarsening, beach profile changes)
    - Sea Level Rise(SLR) inundation (habitat narrowing; sediment coarsening; beach profile changes)
    -
2. Pier/Docks; Boat Ramps; Groynes; 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 overhead shade vegetation
- loss of nutrient (prey) inputs for juvenile salmonids

Enhancement/Restoration:

A. Shoreline Modification

- shoreline 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 set backs
- trim vegetation for views
- replanting
- assessing role of invasive plant species

C. Beach Health

- Removal of derelict structures
- Removal/replacement of creosote pilings
- Monitoring of upland septic systems
- Monitoring/mitigating oil/fuel fouling sources

Shoreline Management Goals/Policies

Land-Owner Stewardship

Throughout the islands, good stewardship should be actively encouraged and formalized in regulation where appropriate. 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 reducing the need for sea defences by advocating building setbacks from the water line, implementing shoreline buffers and considering drift cell management for contiguous property owners. As a coastal resource, forage fish spawning beaches are a sensitive nearshore habitat and protection measures for these beaches could be included in Official Community Plans, Land Use Bylaws and shoreline development permit areas.

Marine shoreline management policies, bylaws and shoreline development permit areas are increasing in popularity among jurisdictions bounding south coastal British Columbia. Forage fish spawning habitat protection requires specific management and mitigation measures.

Land owners and local permitting officials are becoming increasingly burdened with environmental protection as more senior governments divest themselves of this responsibility or lack effective management regimes. Implementing changes to new bylaws should be accompanied by tools to assist property owners in meeting permit requirements. Bowen Island, like other municipalities, would benefit from developing a common “toolkit” for property owners to protect shoreline ecological values while planning development of their properties. These could include checklists of Bowen Island vegetation types, timing windows of least risk for marine species, and local government funded engineering assessments of slope stabilities. These could work as incentives for multiple shoreline property owners to work at the “shoreline drift cell” level to manage sediment processes rather than individual site planes. As well as incentives for employing “soft” options (bioengineering) rather than hard armouring for shoreline erosion and sea level rise protection should accompany any local bylaw implementation. Local “best management practices” can be developed that will assist land owners wishing to develop and steward their properties.

Measures to protect beach habitats

Generally, beach units suitable for forage fish spawning that are have sediment inputs, intact natural shorelines and riparian vegetation zones with overhanging shade trees. 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 by replanting vegetation, 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.

Public Access

Properly managed public access points to marine shorelines can be an asset for residents and visitors as they promote opportunities to connect with nature and protect shoreline ecological values. Shoreline modifications can hinder public access to beaches either due to overwater structures (piers/dock structures) or seawalls/rock revetments physically limiting access (Griggs 2010, Shipman et al 2010).

Public access to marine shorelines on Bowen Island is limited. It was common to encounter beaches fronting private properties with little to no public access being utilized by a select few; and in some instances with significant levels of shoreline modifications. Some of the public access points also are challenging for residents/visitors to launch a kayak or canoe.

The lack of public access both by road or foot to marine shorelines can result in changes such as multiple access stairs along single beach units, a common occurrence on Bowen and elsewhere. Public access points may reduce the need for multiple access stairs and improve enjoyment for both residents and visitors.

Water Quality

On Bowen Island, the majority of beach units are pocket coves. Beach units representing longer “beaches” are uncommon on Bowen Island and include the long beach unit bounded by the park and the Union Steamship marina in Snug Cove. The presence of residual fuel/oil on surface waters is common on beaches in close proximity to marinas. Petroleum/oil fouling of beach sediment results in mortality of incubating embryos. It is recommended that the use of oil/fuel absorbent pads be

encouraged in boat bilges and that a permanent oil/fuel absorbent boom is placed along the Snug Cove beach. These protective measures would also benefit the productivity of the creek.

Storm water and soil management are essential to controlling deleterious materials entering marine receiving waters as well as maintaining upland slope stability. Stormwater management for receiving marine waters is a critical issue for beach health and fish. High banks, bluffs and cliffs may erode faster than the normal background rate due to inadequate water and soil management of upland properties. In many cases, solutions to these stressors can be simply implemented by reviewing site management plans and improving infrastructure planning.

During field surveys, heavy rains allowed the author to observe the high bank and water outfall pipe at one beach unit. Due to clearing of vegetation both within the marine riparian zone and the uplands, soil saturation monitoring of the upland area is recommended, as is re-vegetating the cleared bank slope, relocation of the road to the new housing development farther inland, and reducing the volume of storm water runoff and potential siltation of fish bearing marine waters. The close proximity of the new housing development and road to the shoreline may create a future stressor on the beach habitat if erosion protection measures for the high bank/sea cliff are requested. This can be mitigated almost entirely by creating a shoreline buffer that will both protect road infrastructure, property values and reduce harmful impacts to the beach area and marine receiving waters. A shoreline buffer also absorbs nutrients and pollutants; provides esthetic values such as a natural viewscape and maintains wildlife values for both property owners and marine recreational users.

<u>Shoreline structures</u>

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.

Shoreline Erosion Mitigation

On Bowen Island, 40% (16) of beach units suitable as forage fish spawning habits were impacted by foreshore structures that impeded the delivery of sediments to the beaches or the transport of sediments along the drift cell. Ten percent (4) of beach units suitable as forage fish spawning habitats had hard armouring (seawalls, riprap, infills) at the natural boundary (backshore); some of these may

have resulted in habitat losses due to accelerated erosion. In light of future sea level change predictions, as well as shoreline development, threats/pressures to harden shorelines will increase. Alternative “soft bioengineering” methods to mitigate shoreline erosion, such as elevated foreshore/beach nourishment methods as well as replanting shoreline vegetation are techniques preferable to seawall, riprap, and infills at or below the natural boundary.

On Bowen Island, eight (8) beach units (total of 868 meters) with shoreline modifications had significantly coarsened sediments resulting in classification as “not spawning habitat” or “not suitable” spawning habitat. It is possible that sediments at these beach units were degraded over time from fine sediments (pebbles and sand) to coarse sediments (cobbles/boulders) due to these shoreline modifications and local wave/swell conditions. Three beach units presented foreshore structures such as infills/seawalls, resulting in losses of suitable forage fish spawning habitat.

Hard armouring intruding into the foreshore.
Left: Riprap boulders
Above: Seawall with infill
Photos: RC de Graaf

Four beach units in Mannion Bay have been significantly altered as a result of historical and present shoreline alterations. Pebbly Beach and Sandy Beach present excellent habitat and local stewards are currently monitoring these for forage fish spawning activity. Mannion Bay has significant values for property owners and recreational users. A shoreline restoration project including protection for

shoreline property owners utilizing an elevated foreshore design with beach nourishment and ecological restoration of vegetation (juvenile salmonid recruitment) and forage fish beach spawning habitat is highly recommended.

Mannion Bay
Degraded beach units
Photos: RC de Graaf

BC ferry operations produce significant waves/swell that may affect some beach units, as may other large displacement vessels. At beach units with particular aspects and water depth contours, the wave energy of ferries and other vessel wakes was observed to be significant (personal observation). It is noted that this observation was made in the field and further investigation and review of this comment is needed. Some of the shoreline erosion protection measures taken by individual shoreline property owners may be due to this continuous wave energy occurrence. Statements from some land owners provided the author with important history/reasoning for their construction of “ferry wake dampeners” (e.g. berms, groins, breakwaters). Further study and scientific review of this issue is recommended to determine the significance of this stressor on forage fish spawning beaches and for shoreline property values.

Piers and Docks

Proliferation of piers and docks can reduce public access to the foreshore as well as negatively impact marine habitats. Coastal planning by the Bowen Municipality should evaluate the cumulative impacts to social and ecological values and consider the placement of and maximum number of piers/docks per beach should be re-evaluated. Investigation of "green docks", minimizing float sizes, shared pier/dock facilities, community moorage facilities is recommended. Shoreline property owners along the Millers Landing1 (BW 15) beach unit have a seasonal (summer) dock that is shared by a number of residents and meets the needs of these families as well as reducing harm to marine habitats.

The majority of piers/docks on Bowen Island had footings on hard, rock substrate which is preferable to footings on soft sediment portions of beach units. However, some piers were also located on soft sediment beach units.

At a large bay and well used recreational beach, a situation presented where a large volume of boulders/riprap was placed at the base of a high bank property to allow for the construction of pier footings. These boulders/riprap have significantly blocked transport of sediments along the beach (littoral drift) as well as creating a significant barrier to the public at higher tides and a pedestrian safety hazard. This particular infrastructure effectively blocks the sediment supply in the bay into two drift cells. Disruption of sediment flows along shorelines is a significant stressor to the long term sustainability of beach habitats. It is recommended that this pier footing and associated boulder/riprap obstruction be removed. Immediately adjacent to this property is a pier with footings on hard substrates. Sharing of a common causeway over the intertidal zone and perhaps sharing complete pier/dock structures by these two adjacent property owners would be of benefit to the public to access the shoreline as well as long-term stability of the beach and spawning habitat.

Shoreline sediment processes interrupted by riprap/boulders
Photo: RC de Graaf

Vegetation Losses:

Marine Riparian Vegetation and Overhanging Shade Vegetation:

On Bowen Island, 85% of beach units (34 beach units) had only 1-50% cover of overhanging shade vegetation. These differences may be due to land forms, soils, and landscaping or a result of placement of shoreline and backshore structures. Encouraging stewardship practices that involve trimming tree branches and shrubs, rather than vegetation removal, will maintain the benefits of marine shoreline vegetation (from shade to nutrient subsidies) to marine ecosystem as well as protect shorelines from accelerated rates of erosion. Vegetation replanting is also advised.

Beach Health/Enhancement

Several beach units presented opportunities to remove derelict structures and improve water quality (storm water and fuel/oil contamination). Some derelict structures may be the result of past (historical) uses of the beaches. When repairing old piers/dock structures, minimizing the number of pilings, removal/elimination of creosote pilings, and following green dock guidelines provide a positive benefit to marine habitats.

While historical commercial/industrial land/beach uses may have left structures such as bulkheads and infills, these should not be encouraged for present or future residential/recreational development if they negatively affect shoreline areas.

Future uses of data provided

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

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Appendix A – Bowen Island Beach Units

Bowen Island - Beach Units						
Beach Number	Beach Unit Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Beach Unit Length (m)
BW1	SmugglersCvRd1	Habitat	Continuous	Surf smelt/Pacific sand lance	T1	22.32
BW2	SmugglersCvRd2	Not Habitat				42.34
BW3	SmugglersCvRd3	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	60.72
BW4	SmugglersCove	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T1	107.58
BW5	ColumbineCv	Not Habitat				127.79
BW6	HoodPntW	Not Habitat				67.24
BW7	HoodPntE	Not Habitat				70.85
BW8	CatesBayN	Not Habitat				47.80
BW9	CatesBay1	Habitat	Continuous	Surf smelt/Pacific sand lance	T1	131.93
BW10	CatesBay2	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T3	283.83
BW11	CatesBay3	Habitat	Discontinuous	Surf smelt	T1	66.25
BW12	EagleCliffe1	Habitat	Discontinuous	Surf smelt	T1	46.12
BW13	EagleCliffe2	Habitat	Continuous	Surf smelt/Pacific sand lance	T3	5.19
BW14	EagleCliffe3	Habitat	Continuous	Surf smelt	T1	25.54
BW15	MillersLanding1	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T3	209.58
BW16	MillersLanding2	Not Habitat				60.86
BW17	MillersLanding3	Not Habitat				21.74
BW18	Millerslanding4	Not Habitat				184.39
Bw19	MillersLanding5	Not Habitat				129.35
BW20	Pebbly1	Not Habitat				73.82
BW21	Pebbly2	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T2	154.92
BW22	Pebbly3	Habitat	Continuous	Surf smelt/Pacific sand lance	T4	37.98
BW23	Pebbly4	Not Habitat				40.48
BW24	Sandy1	Not Habitat				105.57
BW25	Sandy2	Habitat	Continuous	Surf smelt/Pacific sand lance	T4	30.96
BW26	Sandy3	Not Habitat				229.84
BW27	Sandy3	Habitat	Continuous	Surf smelt/Pacific sand lance	T3	120.66
BW28	Sandy4	Not Habitat				236.43
BW29	SnugCove1	Not Habitat				15.62

Appendix A – Bowen Island Beach Units

Beach Number	Beach Unit Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Beach Unit Length (m)
BW30	SnugCove2	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T2	309.87
BW31	DormanPnt	Habitat	Continuous	Surf smelt/Pacific sand lance	T3	54.40
BW32	SeptemberMorning	Habitat	Continuous	Surf smelt	T2	94.07
BW33	SeptemberMorning2	Not Habitat				69.70
BW34	NApodoca1	Not Suitable				23.83
BW35	NApodaca2	Not Habitat				37.98
BW36	ApodocaMrnPark	Habitat	Discontinuous	Surf smelt	T1	14.76
BW37	SeymourBay	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T2	134.19
BW38	Trinity	Habitat	Continuous	Surf smelt	T1	65.97
BW39	Union	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	26.40
BW40	Alder Bay	Habitat	Continuous	Pacific sand lance	T3	55.76
BW41	N AlderBay	Not Habitat				30.21
BW42	ArbutusBay	Not Suitable				133.80
BW43	EchoCove1	Not Habitat				22.28
BW44	EchoCove2	Not Habitat				12.75
BW45	Fairweather Bay	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T1	40.41
BW46	CapeRogerCurtis1	Habitat	Discontinuous	Surf smelt	T1	33.36
BW47	CapeRogerCurtis2	Not Habitat				132.33
BW48	CapeRogerCurtis3	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T1	7.61
BW49	CRogerCurtisBeach	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	49.80
BW50	CapeRogerCurtis5	Habitat	Discontinuous	Surf smelt	T1	35.75
BW51	CollingwoodPnt1	Not Suitable				48.37
BW52	CollingwoodPnt2	Habitat	Continuous	Surf smelt/Pacific sand lance	T4	14.52
BW53	TunstallBay1	Habitat	Continuous	Surf smelt/Pacific sand lance	T4	298.53
BW54	Sealy Beach	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T3	124.72
BW55	TunstallBay2	Habitat	Continuous	Surf smelt/Pacific sand lance	T3	14.32
BW56	TunstallN1Sections	Not Habitat				83.30
BW57	BowenBayS1	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	30.37
BW58	BowenBayS2	Not Habitat				15.95
BW59	BowenBay	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	155.70

Appendix A – Bowen Island Beach Units

Bowen Island - Beach Units						
Beach Number	Beach Unit Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Beach Unit Length (m)
BW60	KingEdwardBay	Habitat	Continuous	Surf smelt/Pacific sand lance	T4	35.59
BW61	ClipperPl	Not Habitat				25.69
BW62	IslandView	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T2	159.39
BW63	GalbraithBayS1	Not Habitat				7.10
BW64	GalbraithBayS2	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T1	81.49
BW65	GalbraithBay1	Habitat	Continuous	Surf smelt	T1	31.75
BW66	GalbraithBay2	Habitat	Discontinuous	Surf smelt/Pacific sand lance	T1	83.92
BW67	GalbraithBay3	Not Suitable				48.38
BW68	GalbraithBay4	Not Suitable				27.72
BW69	Huckleberry1	Not Habitat				18.30
BW70	Huckleberry5	Not Habitat				41.81
BW71	Huckleberry4	Not Habitat				17.28
BW72	Huckleberry3	Not Habitat				59.05
BW73	Huckleberry2	Not Habitat				24.12
BW74	GraftonCreek	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	42.21
BW75	HoneymoonCreek	Habitat	Continuous	Surf smelt/Pacific sand lance	T2	91.37

Appendix B - Beach Grain-Size Types – Bowen island

Beach type Classifications - Bowen Island				
Pacific sand lance - Type 3				
Beach Number	Bowen Island Beach Unit	Grain Size Type	Species	Sediment Distribution
BW40	Alder Bay	T3	Pacific sand lance	Continuous

Beach type Classifications - Bowen Island				
Surf smelt - Type 1				
Beach Number	Bowen Island Beach Unit	Grain Size Type	Species	Sediment Distribution
BW36	ApodocaMrnPark	T1	Surf smelt	Discontinuous
BW38	Trinity	T1	Surf smelt	Continuous
BW50	CapeRogerCurtis5	T1	Surf smelt	Discontinuous
BW46	CapeRogerCurtis1	T1	Surf smelt	Discontinuous
BW14	EagleCliffe3	T1	Surf smelt	Continuous
BW12	EagleCliffe1	T1	Surf smelt	Discontinuous
BW65	GalbraithBay1	T1	Surf smelt	Continuous
BW11	CatesBay3	T1	Surf smelt	Discontinuous
BW48	CapeRogerCurtis3	T1	Surf smelt/Pacific sand lance	Discontinuous
BW45	Fairweather Bay	T1	Surf smelt/Pacific sand lance	Discontinuous
BW9	CatesBay1	T1	Surf smelt/Pacific sand lance	Continuous
BW66	GalbraithBay2	T1	Surf smelt/Pacific sand lance	Discontinuous
BW64	GalbraithBayS2	T1	Surf smelt/Pacific sand lance	Discontinuous
BW4	SmugglersCove	T1	Surf smelt/Pacific sand lance	Discontinuous
BW1	SmugglersCvRd1	T1	Surf smelt/Pacific sand lance	Continuous

Appendix B - Beach Grain-Size Types – Bowen island

Beach type Classifications - Bowen Island				
Surf smelt - Type 2				
Beach Number	Bowen Island Beach Unit	Grain Size Type	Species	Sediment Distribution
BW32	SeptemberMorning	T2	Surf smelt	Continuous
BW39	Union	T2	Surf smelt/Pacific sand lance	Continuous
BW49	CRogerCurtisBeach	T2	Surf smelt/Pacific sand lance	Continuous
BW59	BowenBay	T2	Surf smelt/Pacific sand lance	Continuous
BW37	SeymourBay	T2	Surf smelt/Pacific sand lance	Discontinuous
BW75	HoneymoonCreek	T2	Surf smelt/Pacific sand lance	Continuous
BW74	GraftonCreek	T2	Surf smelt/Pacific sand lance	Continuous
BW62	IslandView	T2	Surf smelt/Pacific sand lance	Discontinuous
BW21	Pebbly2	T2	Surf smelt/Pacific sand lance	Discontinuous
BW3	SmugglersCvRd3	T2	Surf smelt/Pacific sand lance	Continuous
BW30	SnugCove2	T2	Surf smelt/Pacific sand lance	Discontinuous

Beach type Classifications - Bowen Island				
Surf smelt - Type 3				
Beach Number	Bowen Island Beach Unit	Grain Size Type	Species	Sediment Distribution
BW31	DormanPnt	T3	Surf smelt/Pacific sand lance	Continuous
BW13	EagleCliffe2	T3	Surf smelt/Pacific sand lance	Continuous
BW15	MillersLanding1	T3	Surf smelt/Pacific sand lance	Discontinuous
BW54	Sealy Beach	T3	Surf smelt/Pacific sand lance	Discontinuous
BW55	TunstallBay2	T3	Surf smelt/Pacific sand lance	Continuous
BW27	Sandy3	T3	Surf smelt/Pacific sand lance	Continuous
BW10	CatesBay2	T3	Surf smelt/Pacific sand lance	Discontinuous

Beach type Classifications - Bowen Island				
Surf smelt - Type 4				
Beach Number	Bowen Island Beach Unit	Grain Size Type	Species	Sediment Distribution
BW53	TunstallBay1	T4	Surf smelt/Pacific sand lance	Continuous
BW60	KingEdwardBay	T4	Surf smelt/Pacific sand lance	Continuous
BW22	Pebbly3	T4	Surf smelt/Pacific sand lance	Continuous
BW25	Sandy2	T4	Surf smelt/Pacific sand lance	Continuous
BW52	CollingwoodPnt2	T4	Surf smelt/Pacific sand lance	Continuous

Appendix C

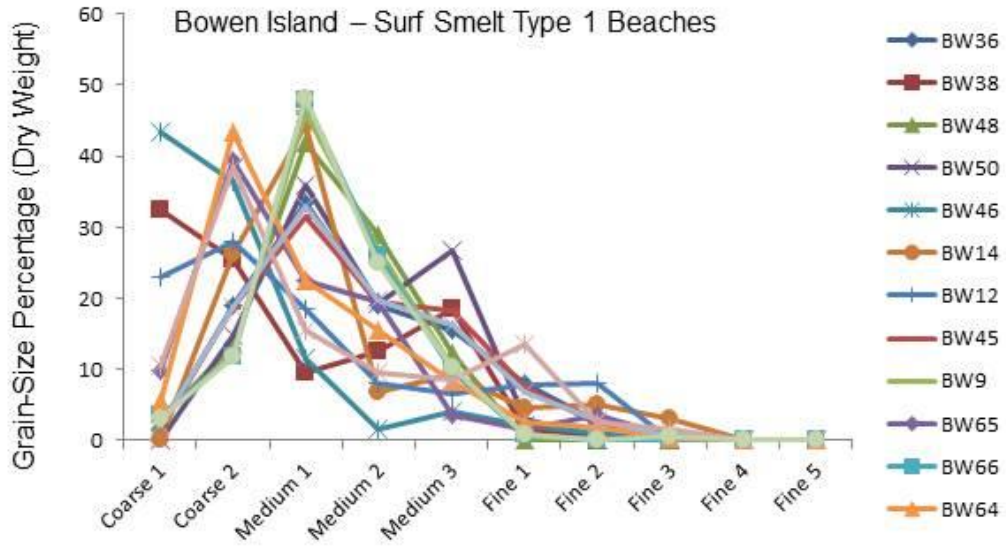

Figure 2 Bowen Island – Surf Smelt Type 1 Beaches

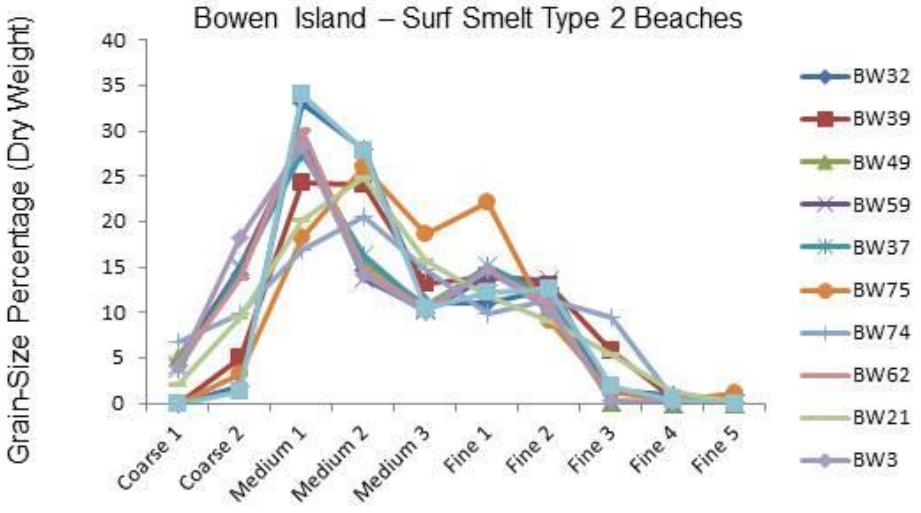

Figure **3** Bowen Island – Surf Smelt Type 2 Beaches

Appendix C

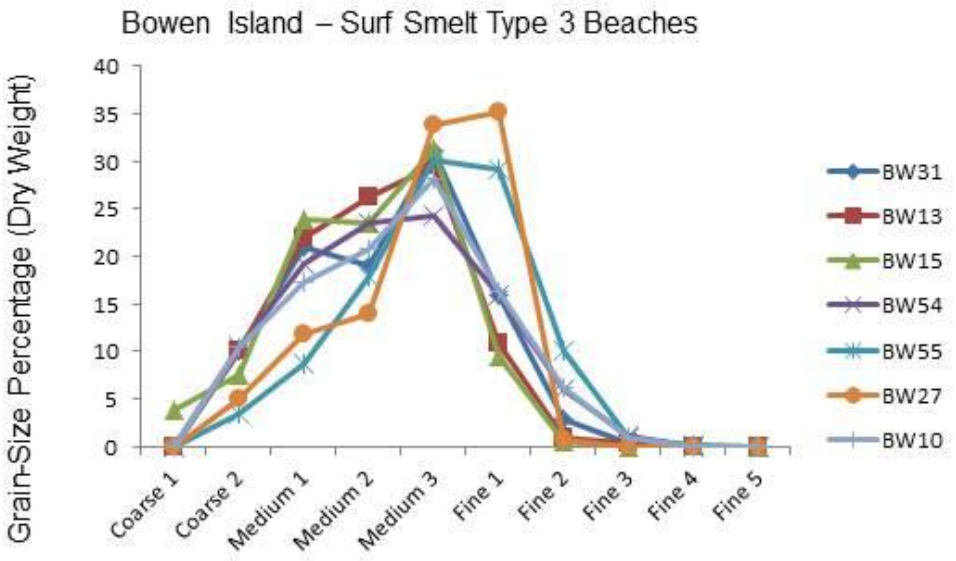

Figure **4** Bowen Island – Surf Smelt Type 3 Beaches

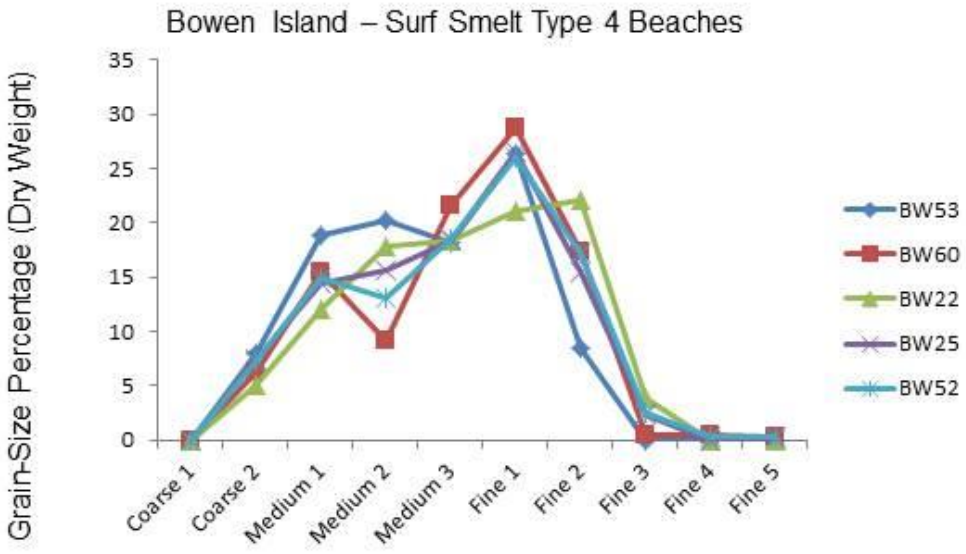

Figure **5** Bowen Island – Surf Smelt Type 4 Beaches

Appendix C

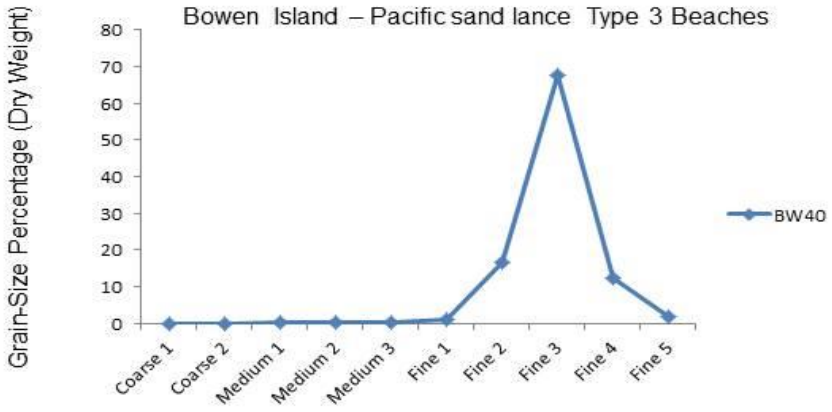

Figure **6**– Bowen Island – Pacific sand lance Type 3 Beaches

Appendix D: GPS/GIS Methodology

Global Positioning System Specifications

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.

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.

4. Deliverables and Archiving

4.01
The following digital files must be archived and delivered to Islands Trust GIS staff and other appropriate agency(s) in the following formats:

Deliverable	**Digital Format**
Uncorrected GPS data	GPS manufacturer's proprietary
Reference station data	downloaded format
Originally corrected GPS • Including complete metadata report for all dynamic and static point features, including but not limited to Max HDOP, Max PDOP, and Horizontal Precision	ESRI Shapfile
Final map	ESRI ArcGIS MXD

Appendix E: Digitizing Spatial Data and Map Production

Mapping Procedure for 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 based on the *Point_Type* field which describes whether the features is a start, mid or end point on a beach segment. Only start and end points with horizontal accuracy less than 5m are used.
4. Re-shape the centerline between static feature points by snapping to dynamic feature points.
5. Provide a preliminary *Habitat* designation (Yes/No) and *Species* classification based on the data sheet provided by Ramona.

Forage Fish Segments Attributes

FID – Unique identifier assigned to each segment by ArcGIS software.
Habitat – Declared Potential Habitat (Yes) or Not Habitat (No) while in the field. This is based on the observed shore type. For example, cobble shoreline is Not Habitat.
Species – Declared Surfsmelt (SS)/ Pacific Sandlance (PSL), Surf Smelt and Pacific Sandlance (SS/PSL) or Not Suitable Habitat (NSH)**.**
Length - Length of the segment.

Appendix F: Forage Fish Habitat Suitability Assessment Methods

Housed with the Islands Trust Fund and the author