Thetis, Hornby and Denman Islands
Beach Spawning
Forage Fish Habitat Suitability Assessments

Henry Bay, Denman Island
Photo: D. Woodward

Prepared for the Islands Trust and Islands Trust Fund

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Beach Spawning Forage Fish Habitat Suitability Assessments Thetis, Hornby, and Denman Island Sept 2013 – Feb 2014

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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.

Komas Feeder Bluff, Denman Is.
Photo: D.Woodward

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.

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 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, a 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 Thetis, Hornby and

Denman 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.

Thetis Island surveys took place on September 14-16, 2013, November 8, 2013, and February 5, 7, and 9, 2014. Hornby Island surveys took place on October 17-21, 2013. Denman Island surveys took place on September 19-22, 2013, November 19-24, 2013, and February 17-21, 2014.

From October to November, 2013, no major storm activity was noted for the Strait of Georgia. During February 2014 surveys, weather events did not appear to change the beach sediment character as comparisons with data sets from 2009-2012 showed similar beach sediment attribute scores.

Data acquired by the author and by BC Shore Spawners Alliance community groups (Thetis Island Friends of Forage Fish, Conservancy Hornby Island, and Association for Denman Island Marine Stewards) have been incorporated into this report.

6.2 Area Surveyed

The entire coastlines of Thetis, Hornby, and Denman Islands were surveyed by foot with the exception of some areas of consolidated sediment (rocky beaches, rock terraces etc.). 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 Confirmed Spawning Habitats

On Denman Island, the Association of Denman Island Marine Stewards has been working as part of the BC Shore Spawners Alliance Project since 2009. Surf smelt and Pacific sand lance spawning activity on Denman Island beaches has been detected. These data are to be produced separate report.

On Hornby Island, Conservancy Hornby Island has been working as part of the BC Shore Spawners Alliance Project since 2009. Pacific sand lance spawning activity on Hornby Island beaches has been detected. These data are to be provided in a separate report.

7.3 GPS/GIS Methodology

7.3.1 Spatial Data Specifications

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

7.3.2 Digitizing Spatial Data and Map Production

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

8.0 Project Limitations

The project was limited to assessing beaches as suitable spawning habitat for two species of beach spawning forage fish, surf smelt and Pacific sand lance. Data for this study was compiled before major fall/winter storm events. The methods used in a forage fish habitat 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.

The degree to which aquaculture structures located on the mid-lower portions of the foreshore affect sediment delivery to upper spawning areas is uncertain and would require further research to assess.

9. Results

9.1 Thetis Island

9.1.1 Grain-Size and Statistical Analyses

In total, 65 beach units were assessed during field assessments or using statistical analyses. In the field, 12 beach units were classified as “not spawning habitat” being composed of either consolidated sediment types (boulder or rock ramp habitats) or unconsolidated sediments unfavourable for spawning (mud, silt, cobble, or shallow pebble veneer layers). Fifty-three (53) beach units were composed of unconsolidated sediments representing potential forage fish spawning habitat.

Grain-size analyses were used to test for likelihood of beaches to support spawning. All grain-size frequencies curves were classified to Type curves. All of the 53 beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix B).

Principal Component Analysis of beach metrics, including grain-size analyses, clustered all 53 beaches within 80% similarity to known positive beaches in BC and Washington State. Forty-eight (48) of these beaches had continuous habitat and five (5) had discontinuous habitat. Nine (9) beaches were comprised of unconsolidated sediments such as mud, silt, cobble that are not suitable as spawning habitat (Figure 1).

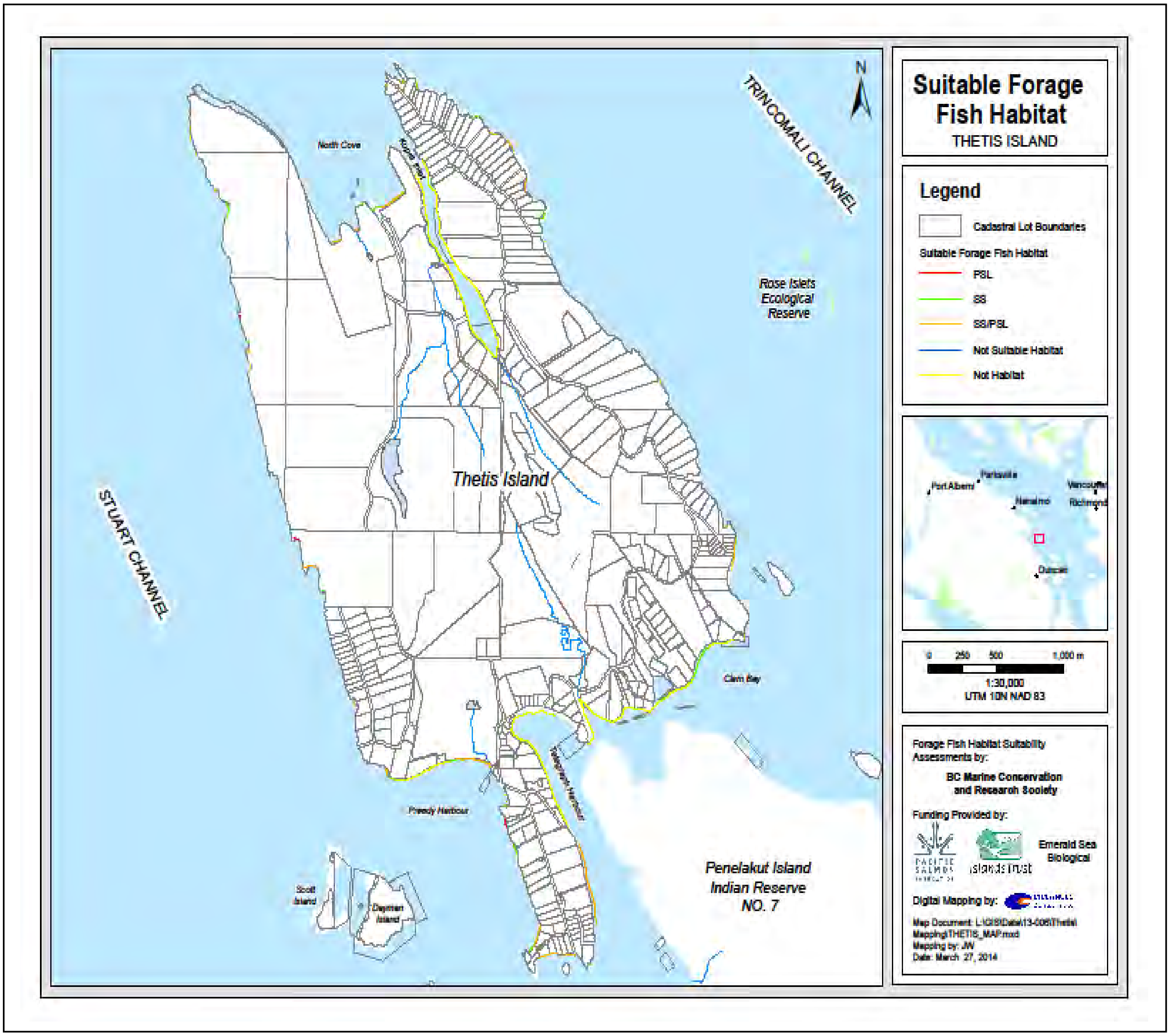


Figure 1: Thetis Island:
Suitable surf smelt and Pacific sand lance Spawning Habitats

9.1.2 Length of Suitable Forage Fish Spawning Habitat

A total of 9,096 m of shoreline was assessed. The total length of suitable spawning habitat is 3,180 meters and classified as 825 m specific to surf smelt (26%), 94 m specific to Pacific sand lance (3%), and 2,261 meters as mixed surf smelt/Pacific sand lance spawning habitat (71%) (Table1). Beach units assessed as “not spawning habitat” encompassed 5,916 m.

The shoreline perimeter distance (length) of Thetis Island is 26.6 kilometers (26,651.1 m). Suitable forage fish spawning beaches are distributed along approximately 11.9% of the Thetis Island shoreline length with 3.1% as surf smelt, 0.4% as Pacific sand lance, and 8.5% as mixed surf smelt/Pacific sand lance spawning habitats (Table 1).

Table 1: Classification of Thetis Island Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
Length (m)	825	94	2261	3,180
Length Percentage (%)	26%	3%	71%	
Percentage of Thetis Shoreline	3.10%	0.35%	8.50%	11.90%

SS - Surf smelt
PSL - Pacific sand lance

9.1.3 Suitable Forage Fish Spawning Habitat Types

Of the 53 suitable spawning beaches, 21 were classified as surf smelt, 3 as Pacific sand lance, and 29 as mixed surf smelt/Pacific sand lance spawning habitat (Table 2). Of the surf smelt beaches, grain size analyses assessed 15 as Type 1; 4 as Type 2; and 2 as Type 3 Surf Smelt beaches. Of the Pacific sand lance beaches, grain size analyses assessed 1 as Type 1 and 2 as Type 3 Pacific Sand lance beaches. Of the mixed surf smelt/Pacific sand lance beaches, grain size analyses assessed 2 as Type 1, 18 as Type 2, 7 as Type 3, and 2 as Type 4 Surf Smelt beaches (Appendix A).

Table 2: Thetis Island Grain-Size Types

	SS	PSL	SS/PSL
PSL TYPE 1		1	
PSL TYPE 2			
PSL TYPE 3		2	
SS TYPE 1	15		2
SSTYPE 2	4		18
SS TYPE 3	2		7
SS TYPE 4			2
SS TYPE 5			

9.1.4 Geographic Distribution of Suitable Forage Fish Spawning Beaches

Dividing Thetis Island into north, south, west and east coast lines, 5 beach units are located on the north coast (2 SS, 3, SS/PSL); 21 beach units are located on the south coast (11 SS, 1 PSL, 9 SS/PSL); 16 beach units on the west coast (4 SS, 2 PSL, 10 SS/PSL); and 11 on the east coast (4 SS and 7 SS/PSL) (Table 3).

Table 3: Thetis Island Geographic Distribution of Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
North	2	0	3	5
South	11	1	9	21
West	4	2	10	16
East	4	0	7	11

9.1.5 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. Of the 53 beach units suitable for forage fish spawning, 62% (33) had unmodified shorelines ; 19% (10) were 1-25% impacted; 7.5% (4) were 26-50% impacted; 4% (2) were 51-75% impacted; and 7.5% (4) were 75-100% impacted(Table 4).

Table 4: Foreshore Modification - Thetis Island

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	33	10	4	2	4
Percentage	62	19	7.5	4	7.5

9.1.6 Foreshore and Backshore Structures

Of the 53 suitable forage fish spawning beach units, 20 were classified as having modified foreshore zones. Within the foreshore, the presence of sediment impeding structures were classified and enumerated. In total 28 structures were classified into 10 categories (Table 5).

Three beach units had 1 foreshore structure each, 5 beach units had 2 different foreshore structures, and 2 beach units had 3 foreshore structures.

Of the suitable spawning beach units, 47 (89%) had modified backshore zones. Buildings (cabins, houses, sheds, etc.) are not enumerated but only classified as present or absent. All other individual structures were counted. The 59 backshore structures were classified into seven categories (Table 5).

Table 5: Foreshore and Backshore Structures - Thetis Island

	Foreshore Count	Percentage	Backshore Count	Percentage
Building			42	71
Boat Ramp	4	14	2	3
Break Water	2	7		0
Boat House		0		0
Concrete Posts	1	4		0
Dock/Wooden Pier	2	7	1	2
Patio Deck	1	4		0
Railway ties	1	4		0
Road	1	4	4	7
Riprap	9	32	1	2
Seawall	4	14	4	7
Stairs to Beach	3	11	5	8
Total	28	100%	59	100%

9.1.7 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 and shrubs located above the high water mark are generally subject to removal by property owners. Of the 53 suitable forage fish spawning habitat beach units, 26% of the beach units had no overhanging shade; 25% had 1-25% overhanging shade; 13% had 26-50% overhanging shade; 6% had 51-75% overhanging shade; 30% had 76-100% overhanging shade)(Table 6).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the beach units suitable for forage fish spawning there were: 14 beach units with 0% overhanging shade, 29% had modified foreshore and 93% modified backshore zones; 13 beach units with 1-25% overhanging shade, 54% had modified foreshore and 92% modified backshore zones; 7 beach units with 26-50% overhanging shade had 29% modified foreshore and 100% modified backshore zones; 3 beach units with 51-75% overhanging shade had 0% modified foreshore and 76% modified backshore zones; and 16 beach units with 75-100% overhanging shade had 44% modified foreshore and 81% modified back shore zones (Table 6). In general, foreshore and backshore areas had significant losses of overhanging shade vegetation with 64% (34) of beach units having only 1-50% overhanging shade cover.

Table 6: Overhanging Shade Vegetation and Shoreline Modification - Thetis Island

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade	Total
Count	14	13	7	3	16	53
Percentage	26	25	13	6	30	
Foreshore Modification Percentage	29%	54%	29%	0%	44%	
Backshore Modification Percentage	93%	92%	100%	67%	81%	

9.2 Hornby Island

9.2.1 Grain-Size and Statistical Analyses

In total, 59 beach units were assessed during field assessments or using statistical analyses. In the field, 17 beach units were classified as “not spawning habitat” being composed of either consolidated sediment types (boulder or rock ramp habitats) or unconsolidated sediments unfavourable for spawning (mud, silt, cobble, or shallow pebble veneer layers).

Of the beach units classified as “not spawning habitat”, there was habitat degradation due to compaction or alteration of sediments for industrial roads by shellfish aquaculture in the upper intertidal at one beach unit.

Grain-size analyses were used to test for likelihood of beaches to support spawning. All grain-size frequencies curves were classified to Type curves. All of the 34 beaches showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix D). The grain-size frequencies of 8 beaches did not meet the statistical standards of the analysis.

Principal Component Analysis of beach metrics, including grain-size analyses assessed 34 beach units within 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable habitat”(Figure 2). Eight (8) beach units failed statistical analyses, the same beach units with non-conforming grain-sizes, and were classified as “not suitable habitat”. Of the 34 beach units comprising “suitable habitat” 26 beach units these beach units had continuous habitat and 8 had discontinuous habitat.

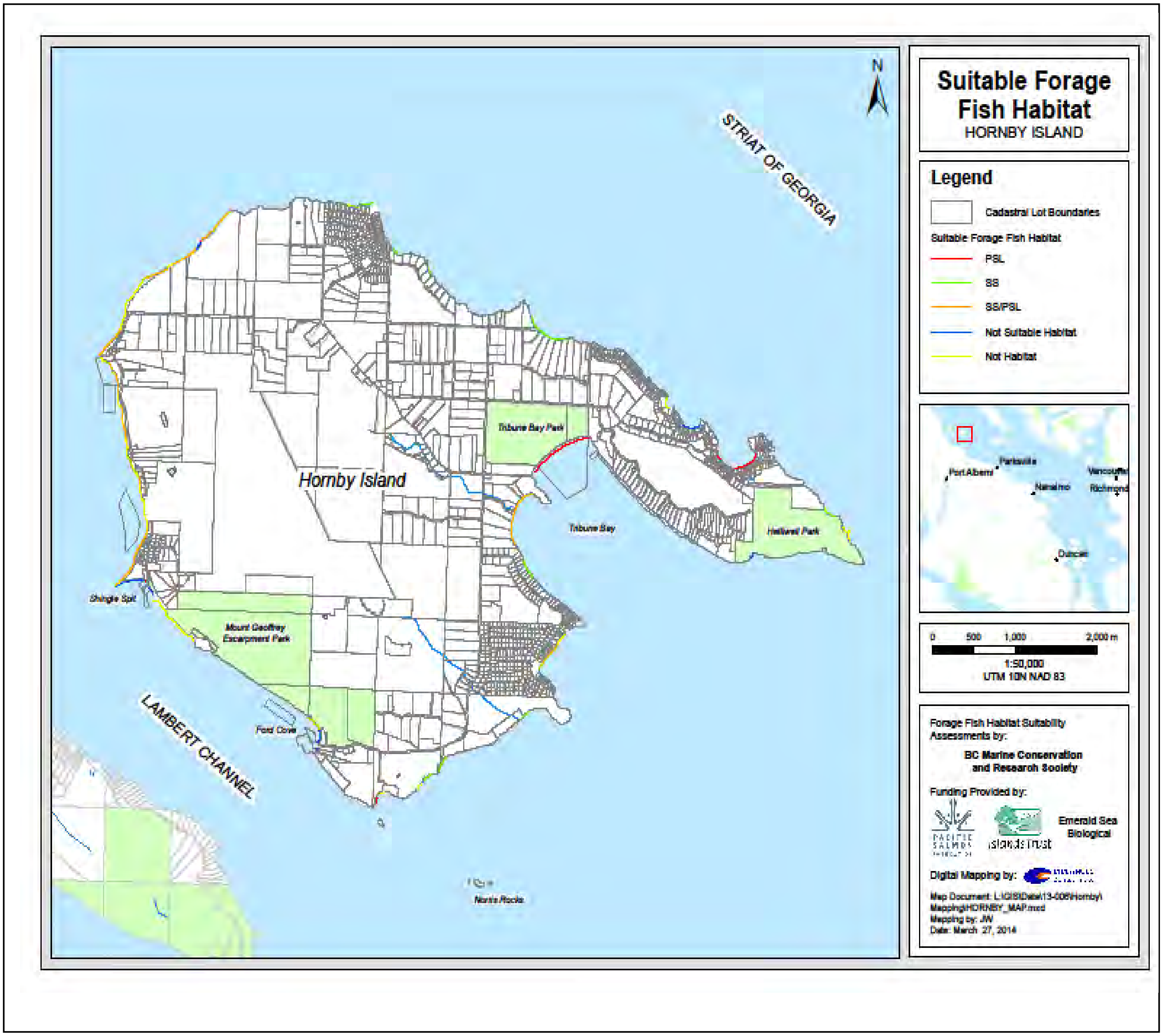


Figure 2: Hornby Island
Suitable surf smelt and Pacific sand lance Spawning Habitats

9.2.2 Length of Potential Forage Fish Spawning Habitat

A total of 11,317.5 m of shoreline were assessed. The total length of suitable spawning habitat on Hornby Island is 7,252.5 meters and classified as 1,607 m specific to surf smelt (22%), 1,293.6 m Pacific sand lance (18 %), and 4,351.9 meters as mixed surf smelt/Pacific sand lance spawning habitat (60%) (Table 7). 1,014.8 m of habitat was assessed as “not suitable spawning habitat” (Section 9.2.1) and 3,049.7 m as “not spawning habitat” (Section 9.2.1).

The shoreline perimeter distance of Hornby Island is 26.6 kilometers (26,651 m). Suitable forage fish spawning beaches are distributed along approximately 21.7% of the Hornby Island shoreline length with 4.8% as surf smelt, 3.9% as Pacific sand lance, and 13.0% as mixed surf smelt/Pacific sand lance spawning habitats.

Table 7: Classification of Hornby Island Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
Length (m)	1607	1294	4352	7,253
Length Percentage (%)	22%	18%	60%	
Percentage of Hornby Shoreline	4.8%	3.9%	13.0%	21.70%

SS - Surf smelt
PSL - Pacific sand lance

9.2.3 Suitable Forage Fish Spawning Habitat Types

Of the 34 suitable spawning beach units, 10 were classified as surf smelt, 6 were classified as Pacific sand lance, and 18 as mixed surf smelt/Pacific sand lance spawning habitat (Table 8). Of the beach units, grain size analyses assessed 6 as Type 1, 1 as Type 2, 3 as Type 5 surf smelt habitats. Of the beach units, grain size analyses assessed 6 as Pacific sand lance Type 3 habitats. Of the mixed surf smelt/Pacific sand lance beaches, grain size analysis assessed 1 as Type 1; 5 as Type 2; 8 as Type 3, and 4 as Type 4 Surf Smelt beaches (Appendix C).

Table 8: Hornby Island Grain-Size Types

	SS	PSL	SS/PSL
PSL TYPE 1			
PSL TYPE 2			
PSL TYPE 3		6	
SS TYPE 1	6		1
SSTYPE 2	1		5
SS TYPE 3			8
SS TYPE 4			4
SS TYPE 5	3		
Totals	10	6	18

9.2.4 Geographic Distribution of Suitable Forage Fish Spawning Beaches

Dividing Hornby Island into north, south, west and east coast lines, 5 beach units are located on the north coast (3SS, 2PSL); 5 beach units are located on the south coast (3 SS, 1 PSL, 1 SS/PSL); 15 beach units on the west coast (2 PSL, 13 SS/PSL); and 9 on the east coast (5 SS and 4 SS/PSL) (Table 9).

Table 9: Hornby Island Geographic Distribution
Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
North	3	2		5
South	3	1	1	5
West		2	13	15
East	5		4	9

9.2.5 Foreshore Modification

Foreshore modification was assessed for beach units scored as suitable habitat. 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. Of the 34 beach units suitable for forage fish spawning, 28 (82%) of the beach units had unmodified shorelines and 6 (18%) were modified (15% were 1-25% impacted; and 1 (3%) was 75-100% impacted) (Table 10).

Table 10: Foreshore Modification - Hornby Island

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	28	5			1
Percentage	82	15			3

9.2.6 Foreshore and Backshore Structures

Of the 34 suitable forage fish spawning beach units, 9 beach units had modified foreshore zones, the presence of sediment impeding structures was classified and counted. Aquaculture structures were not enumerated but classified as present or absent. Twelve (12) structures were classified into 8 categories (Table 11). Six (6) beach units had 1 foreshore structure each and 3 beach units had 2 foreshore structures each.

Of the beach units suitable for forage fish spawning, 91% (31) had modified backshore zones. Buildings (cabins, houses, sheds, etc.) are not enumerated but only classified as present or absent.

All other structures were counted. Forty-six (46) backshore structures were classified into 5 categories. 31 beach units had backshore structures (Table 11).

Table 11: Foreshore and Backshore Structures - Hornby Island

	Foreshore		Backshore	
	Count	Percentage	Count	Percentage
Building			31	67
Boat Ramp			1	2
Break Water				
Boat House				
Concrete Posts				
Dock/Wooden Pier	1	8		
Jetty (ferry, other)	2	17		
Pilings	1	8		
Pier, concrete	1	8		
Road			6	13
Riprap	1	8	1	2
Seawall				
Stairs to Beach			7	15
Aquaculture berming (bivalve)	4	33		
Aquaculture Groins	1	8		
Aquaculture Roads	1	8		
Aquaculture Driving				
Total	12		46	

9.2.7 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 and shrubs are, generally, located above the high water mark and subject to removal by property owners. Of the suitable forage fish spawning beach units, 57% of the beach units had no overhanging shade; 29% had 1-25% overhanging shade; 9% had 26-50% overhanging shade; and 6% had 51-75% overhanging shade; 0% had 76-100% overhanging shade (Table 12).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the suitable forage fish spawning beach units with no overhanging shade, 10.5% had modified foreshore and 100% modified backshore zones; beaches with 1-25% overhanging shade had 1% modified foreshore and 80% modified backshore zones; beaches with 26-50% overhanging shade had 67% modified foreshore and 100% modified backshore zones; beaches with 51-75% overhanging shade had 50% modified foreshore and 50% modified backshore zones (Table 12). In general, the absence of overhanging shade vegetation within the beach units (foreshore and backshore zones) was apparent. Ninety-four percent (94%) of the beach units had 1-50% overhanging shade vegetation, 6% had 51-75% overhanging shade vegetation, and no beach units had 76-100% overhanding shade vegetation.

Table 12: Overhanging Shade Vegetation - Hornby Island

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade	Total
Count	19	10	3	2	0	34
Percentage	56	29	9	6		
Foreshore Modification Percentage	11%	1%	67%	50%	0%	
Backshore Modification Percentage	100%	80%	100%	50%		

9.3 Denman Island

9.3.1 Grain-Size and Statistical Analyses

In total, 152 beach units were assessed. In the field, 26 beach units were classified as "not habitat" being composed of either consolidated sediment types (boulder or rock ramp habitats) or unconsolidated sediments unfavourable for spawning (mud, silt, cobble, or shallow pebble veneer layers). It is possible that some of these beach units classified as cobble and boulder lack fine sediments due to blockage of sediment movement by aquaculture structures in the mid and lower foreshore zones but determination of this is beyond the scope of this survey.

An additional 14 beach units were determined not to be habitat due to modifications of the upper shoreline area. Residential riprap armouring completely buried habitat at one (1) beach unit. There was habitat degradation due to complete intrusion of *Spartina* spp. at one (1) beach unit. There was habitat degradation due to compaction or alteration of sediments for industrial roads by shellfish aquaculture in the upper intertidal together with co-occurrence of *Spartina* spp. at twelve (12) beach units. These particular modifications accounted for approximately 2,678.9 meters of habitat modification not accounted for in foreshore modification scores of suitable spawning habitats (Figure 3).

One hundred and twelve (112) beach units were composed of unconsolidated sediments. 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 nine (109) of the beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches. The grain-size frequencies of three (3) samples did not meet the statistical standards of the analysis due to high mud/silt contents (Appendix F).

Principal Component Analysis of beach metrics, including grain-size analyses, assessed 109 beach units within 80% similarity to known positive beaches in British Columbia and Washington State and were classified as "suitable spawning habitat" (Figure 3). Three (3) of the beach units failed statistical analyses, the same beach units with non-conforming grain-sizes, and were classified as "not suitable spawning habitat". Of the 109 beach units classified as suitable forage fish spawning habitat, 88 had continuous habitat and 21 had discontinuous habitat (Figure 3).

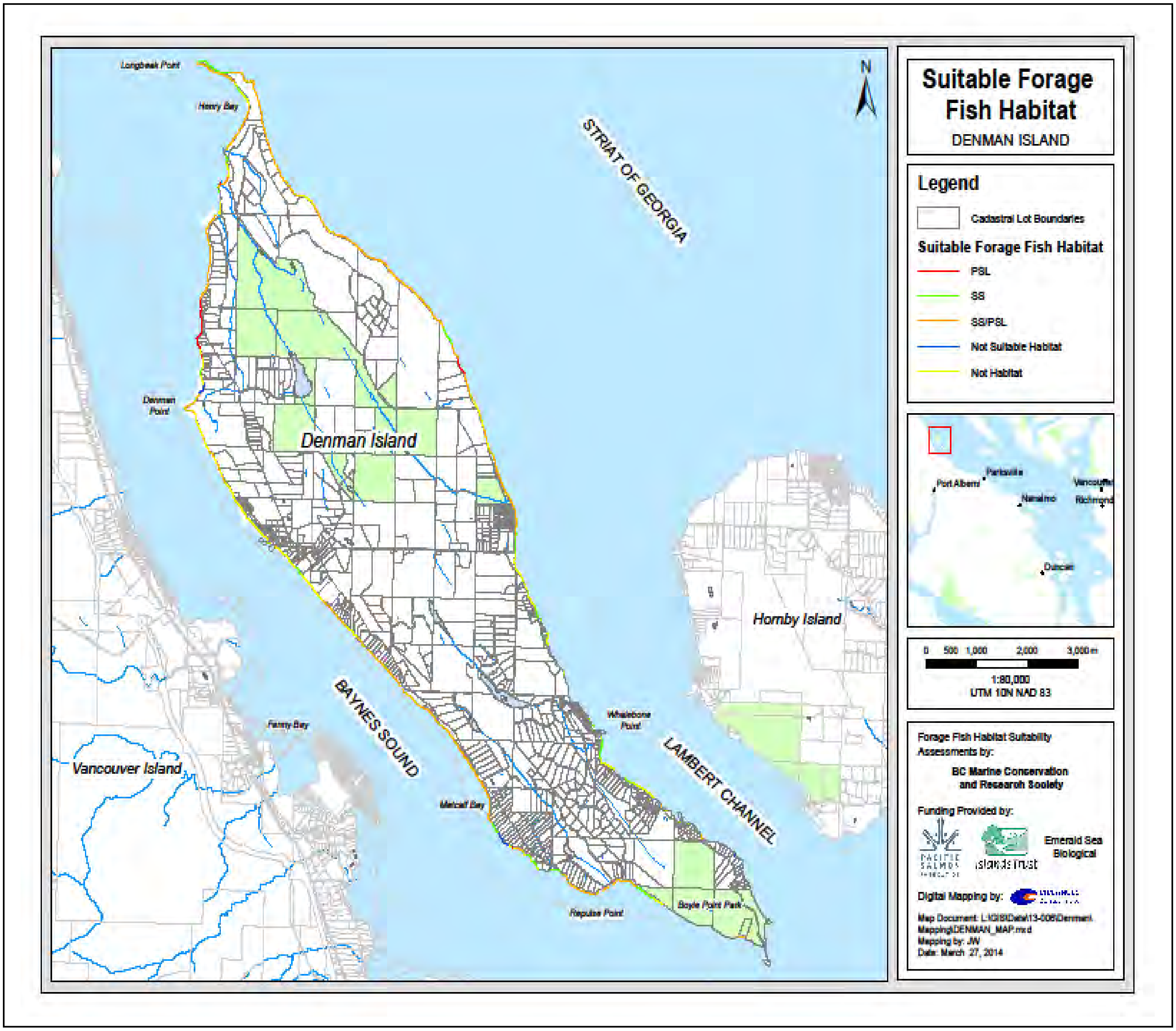


Figure 3: Denman Island
Suitable surf smelt and Pacific sand lance Spawning Habitats

9.3.2 Length of Suitable Forage Fish Spawning Habitat

The total length of suitable spawning habitat on Denman Island is 26,341 m and was classified as 4,102 m specific to surf smelt (15.6%), 1,410.1 m Pacific sand lance (5.4%), and 20,828.1 meters as mixed surf smelt/Pacific sand lance spawning habitat (79.0%) (Table 13). 563.5 m of habitat was assessed as “not suitable spawning habitat” (Section 9.3.1) and 8,228.6 m as “not spawning habitat” (section 9.3.1).

The shoreline perimeter distance of Denman Island is 44 kilometers (44,092.7 m). Suitable forage fish spawning beach units are distributed along approximately 59.7% of the Denman Island shoreline length with 9.3% as surf smelt, 3.2% as Pacific sand lance, and 47.2% as mixed surf smelt/Pacific sand lance habitats.

Table 13: Classification of Denman Island Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
Length (m)	4102	1410.1	20,828	26,341
Length Percentage (%)	15.6%	5.4%	79.0%	
Percentage of Denman Shoreline	9.3%	3.2%	47.2%	59.7

SS - Surf smelt
PSL - Pacific sand lance

9.3.3 Suitable Forage Fish Spawning Habitat Types

Of the 109 suitable spawning beaches, 30 were classified as surf smelt, 8 as Pacific sand lance, and 71 as mixed surf smelt/Pacific sand lance spawning habitat (Table 14). Of the surf smelt beaches, grain size analysis assessed 17 as Type 1, 6 as Type 2, 1 as Type 3, 1 as Type 4, and 5 as Type 5. Of the Pacific sand lance beaches, grain size analysis assessed 6 as Type 1 and 2 as Type 3 Pacific sand lance beaches. Of the mixed surf smelt/Pacific sand lance beaches, grain size analysis assessed 11 as Type 1; 18 as Type 2; 26 as Type 3; and 16 as Type 4 surf smelt beaches (Appendix E). Denman Island surf smelt beaches show the complete range of heterogeneous surf smelt grain-size types which is an uncommon result.

Table 14: Denman Island Grain-Size Types

	SS	PSL	SS/PSL
PSL TYPE 1		6	
PSL TYPE 2			
PSL TYPE 3		2	
SS TYPE 1	17		11
SSTYPE 2	6		18
SS TYPE 3	1		26
SS TYPE 4	1		16
SS TYPE 5	5		
Totals	30	8	71

9.3.4 Geographic Distribution of Suitable Forage Fish Spawning Beaches

Dividing Denman Island into north, south, west and east coast lines, 10 beach units are located on the north coast (4 SS, 6 SS/PSL); 6 beach units are located on the south coast (1SS, 5SS/PSL);

50 beach units on the west coast (10SS, 7 PSL, 33 SS/PSL); and 45 beach units on the east coast (15 SS, 1 PSL, and 27SS/PSL) (Table 15).

Table15: Denman Island - Geographic Distribution of Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
North	4		6	10
South	1		5	6
West	10	7	33	50
East	15	1	27	45
Totals	30	8	71	109

9.3.5 Foreshore Modification

Beach units scored as suitable habitat were assessed for modifications. Modified beach units were classified by percentage of the length of the beach that has been altered from a natural state by structures that would impede movement of sediments either to the beach or along the beach foreshore, including the beach berm, beach slope, and beach flat (to chart datum).

The majority of intertidal (foreshore) shellfish aquaculture and subsequent infrastructure on Denman Island is found on the West and South coast lines, with the exception of the northern extent of Henry Bay (along Longbeak Point). Applications for subtidal aquaculture leases for geoduck cultivation within Henry Bay and areas of Lambert Channel (east coast) are under review.

Although structures such as boulder groins are known to impede sediment delivery throughout the foreshore (upper to lower zones), the effect on sediment delivery of other structures such as aquaculture berms (bivalve culture) and anti-predator nets is unclear. Due to the unknown effect on sediment delivery by shellfish aquaculture structures/activities in the mid and lower foreshore components, the criteria of percent foreshore modification across the beach foreshore on Denman Island was amended to include only foreshore structures located within the distribution of the beach berm and beach face, the upper beach spawning area.

Eighty-five, 85, (78%) of the beach units had unmodified shorelines and 24 (22%) were modified. Of the 24 beach units, 78% were in a natural state; 15% were 1-25% impacted; 4% were 26-50% impacted; 1.5% were 51-75% impacted; and 1.5% were 75-100% impacted (Table 16).

Table 16: Foreshore Modification of beach slope (B1) - Suitable Spawning Beach Units Denman Island

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	85	16	4	2	2
Percentage	78%	15%	4%	1.50%	1.50%

Within the upper intertidal zone (B1), the number of beach units with modifications due to residential land use was 16, including some boulder groins. The number of beach units with modifications due to shellfish aquaculture tenure usage was 15. Two beach units were modified by ferry terminals.

As noted in Section 9.3.1, 2,606.4 meters of upper beach habitat (B1 component) has been lost to aquaculture roads and the co-occurrence of aquaculture roads with invasion of *Spartina* spp. over 13 beach units. Of these, 11 beach units accounting for 1,852.6 meters were contiguous with suitable spawning areas and would likely have been scored as suitable forage fish spawning habitats. Aquaculture industrial roads are also present in the mid and lower foreshore components.

9.3.6 Foreshore and Backshore Structures

Of the 24 suitable forage fish spawning beach units with modified upper foreshore zones, the presence of sediment impeding structures was classified and enumerated. Aquaculture structures were not enumerated but classified as present or absent. Evidence of aquaculture driving was also noted in areas not compacted but where tire treads were evident. In total 45 structures/activities were classified into 16 categories (Table 17). Including structures from beach units classified as “not habitat”, 58 structures/activities were classified in 16 categories. 14 beach units had 1 foreshore structure each; and 10 beach units had 2 foreshore structures.

Of the suitable spawning beach units, 76 (70%) had modified backshore zones and 11 beach units at the toe of high bluffs were unable to be assessed for presence of structures or modifications. Buildings (cabins, houses, sheds, etc.) are not enumerated but only classified as present or absent. All other structures were numerated. Eight-two (82) backshore structures were enumerated and classified into 7 categories (Table 17).

Four (4) beach units had three backshore structures and 25 beach units had two backshore structures. The most common combination of three structures was building, seawall and riprap armouring. The most common combination of two structures was buildings and stairways to beaches and buildings with roadways.

Table 17: Upper Foreshore Structures/Activities and Backshore Structures - Denman Island

	Upper Foreshore		Backshore	
	Count Suitable Habitats (Count Not Habitat)	Percentage Suitable Habitats	Count	Percentage
Boulder Berms	2	4.4%		
Building	1	2.2%	45	54.9%
Boat Ramp				
Break Water	2	4.4%		
Boat House			2	2.4%
Concrete Posts				
Dock/Wooden Pier				
Groins (Residential)	5	11.1%		
Jetty (ferry, other)	2	4.4%		
Other	2	4.4%	4	4.9%
Pilings	2	4.4%		
Pier, concrete				
Road	1	2.2%	19	23.2%
Riprap	11(1)	24.4%	2	2.4%
Seawall	3	6.7%	2	2.4%
Spartina	1	2.2%		
Stairs to Beach	1	2.2%	8	9.8%
Aquaculture berming (bivalve)	1	2.2%		
Aquaculture Groins	2	4.4%		
Aquaculture Roads	1(12)	2.2%		
Aquaculture Driving	8	17.8%		
Total	45(58)		82	

9.3.7 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 and shrubs are generally located above the high water mark and subject to removal by property owners. Of the 109 suitable beach units, 37% of the beach units had no overhanging shade; 25 had 1-25% overhead shade; 16 had 26-50% overhanging shade; 7 had 51-75% overhanging shade; 16 had 76-100% overhanging (Table 18).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the 40 suitable beach units with no overhanging shade vegetation, 18% had modified foreshore and 70% had modified backshore zones; of the 27 beach units with 1-25% overhanging shade, 33% had modified foreshore and 74% modified backshore zones; of the 17 beach units with 26-50% overhanging shade 18% had modified foreshore and 53% had modified backshore zones; of the 8 beach units with 51-75% overhanging shade 25% had modified foreshore and 75% had modified backshore zones; and of the 17 beach units with 75-100% overhanging shade 18% had modified foreshore and 47% had modified backshore zones (Table 18). In general, foreshore and backshore areas had significant losses of shade bearing trees with 84 beach units (77%) having only 1-50% overhanging shade.

Table 18: Overhanging Shade Vegetation - Denman Island

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade	Total
Count	40	27	17	8	17	109
Percentage	37%	25%	16%	7%	16%	
Foreshore Modification Percentage	18%	33%	18%	25%	18%	
Backshore Modification Percentage	70%	74%	53%	75%	47%	

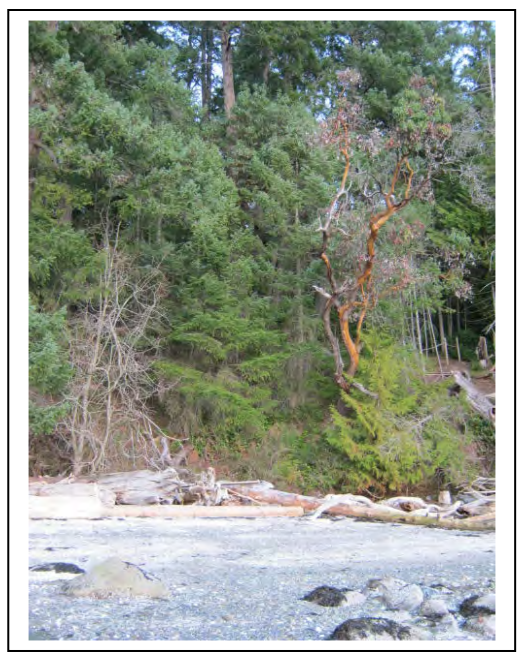
10. Summary and Recommendations

10.1 General

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.

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 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
Thetis Island - Photo: RC de Graaf

10.2 Specific Recommendations

With approximately 37 kilometers of suitable spawning habitat Thetis, Hornby and Denman Islands provide excellent opportunities to safeguard and protect these critical fish habitats.

Overhanging Shade Vegetation:

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
North Pender
Photo: RC de Graaf

The islands had different percentages of remaining marine riparian vegetation along the foreshore with reduced overhanging shade habitat. On Thetis, 64% of beach units had only 1-50% cover of overhanging shade, Hornby 94% of beach units had only 1-50% cover of overhanging shade, and on Denman 77% of beach units had only 1-50% cover of overhanging shade. These differences may be due to land forms, soils, and landscaping. Encouraging stewardship practices that involve trimming tree branches and shrubs, rather than vegetation removal, will maintain nutrient subsidies to marine ecosystem as well as protect shorelines from accelerated rates of erosion.

Shoreline structures:

Thetis, Hornby Island, and Denman Islands have a low number of modified shorelines supporting suitable forage fish spawning habitats (38%, 18%, and 22% respectively). While the number of concrete/wooden seawalls and riprap revetments affecting potential forage fish beaches was not high, there were some shoreline properties that had significant hardening. In light of future sea level change predictions, as well as shoreline development, pressures to harden shorelines will increase.

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.

On Thetis Island, 38% of beach units suitable as forage fish spawning habits were impacted by structures that impeded the delivery of sediments to the beaches or the transport of sediments along the drift cell. On Hornby 18% were impacted by these structures, and on Denman 22% were impacted by these structures. Denman had significant areas of foreshore severely degraded on the upper beach slope resulting in the loss of approximately 2.6 km of habitat likely suitable as spawning habitat.

Only potential forage fish beaches were inventoried for foreshore structures such as seawalls and private docks. There are a significant number of shoreline properties without unconsolidated sediment beaches that have private docks and seawalls as well as areas of mud flats with un-elevated docks and boat ramps. On Thetis Island, numerous un-elevated dock structures are encountered within Telegraph Harbour and “The Cut”.

Observations of the presence of suitable forage fish habitat along shoreline areas within shellfish aquaculture tenures are hopefully informative to tenure operators. The information presented is to aid in efforts to better manage these tenures and protect critical fish habitats pursuant to the Federal *Fisheries Act*.

Shoreline Management – Drift Cells and Land forms:

More generally, it was noted that high banks and bluffs are a common land form on Hornby and Denman Islands. Thetis also has some bluffs at the mouth of Telegraph Harbour.

Protecting soils and vegetation on bluff tops is critical to managing erosion. A common perception is that wave forces are largely responsible for eroding bluffs. However, human activity on bluff tops and high-bank land forms often contributes more significantly to slumping bluffs and damage to residential properties (Washington State Department of Ecology 2014). Denman has a large number of properties located on bluff tops along southern, eastern and western coast lines. Maintaining shoreline vegetation in these areas is important.

Landowner response to bluff slumping sometimes includes addition of riprap or seawalls at the high water mark along property lines. The riprap and seawalls can encroach on the foreshore and forage fish spawning areas. Public educational materials about managing surface water runoff are a major recommendation of this report. Modification of bluff top activities would reduce the need for erosion protection at bluff toes, preventing damage to spawning habitat. Managing storm water, setting structures back from the edge, maintaining vegetation and using pervious gravels in driveways are all common ways of protecting bluff top properties. Controlling storm water runoff and reducing impervious surfaces is not just for the shoreline property owner but is part of good management throughout a watershed. Excellent resource materials for managing building on many land forms, including bluffs, are available on the Washington State, Department of Ecology website and through the BC Coastal Stewardship series available at Washington Department of Ecology (www. http://www.ecy.wa.gov) and Green Shores (www.stewardshipcentrebc.ca/greenshores).

Stairways to the beach down bluff faces are a common occurrence on Thetis, Hornby and Denman. The majority of stairways that were constructed down bluffs and high-banks were excellent and appeared to maintain vegetation within the stair footprint. There were some exceptions where vegetation within the construction footprint had been completely removed (Repulse Bay, Denman Island). Along some of these high bank and bluff shores, stairways, gazebo and landings co-occurred with significant areas of vegetation removal (East Road, Denman Island). In some communities, providing better signage and frequency of public beach accesses helps to reduce development of private accesses.

Land-Owner Stewardship

Throughout the islands, continued good stewardship of shoreline vegetation 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. Suitable 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. In creating regulatory protection mechanisms, there should also be consideration of bylaw enforcement.

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Appendix A Beach Type Classifications Thetis Island

Beach Type Classifications - Thetis Island

Surf Smelt Type 1			Surf Smelt Type 2		
Beach Number	Thetis Island Beach Name	Beach Type	Beach Number	Thetis Island Beach Name	Beach Type
3	PIONEERCAMP	SS1	9	CLAMBAYEAST	SS2
6	HBERRYCLAMBAY	SS1	27	THETISTHECUT	SS2
7	CLAMBAY1	SS1	41	OVERBURYFARM2SOUTH	SS2
12	BH_HB3POSITIVE	SS1	50	ENDOFFORBESRD	SS2
20	BELLAVISTARD1	SS1	2	NORTHCOVE2	SS2
23	PREDDYHRSECT2NORTH	SS1	4	PIONEERCAMP2	SS2
26	FAIRVIEWRDEND	SS1	14	TEHRS	SS2
30	COMMDOCKCOVE2	SS1	15	TEHRS2	SS2
31	COMMDOCKCOVE3	SS1	18	FOSTERPNTRDSE1	SS2
32	FOSTERSOUTHEAST	SS1	19	FOSTERPNTRDSE2	SS2
48	NORTH2NOFIRES	SS1	21	BELLAVISTARD2	SS2
54	THETIS-COVENE1	SS1	22	PREDDYHARBSOUTH1	SS2
58	TRINCOLMIRDEND	SS1	29	COMMDOCKCOVE1	SS2
59	PORLIERRDSOUTH1	SS1	34	NR373LUPIN	SS2
62	PORLIERRDNORTH1	SS1	35	SOUTH373LUPIN	SS2
45	THETISNWEST4	SS1	39	CAMPCOLUMBIASOUTH	SS2
47	N1NOFIRES	SS1	46	THETISNWEST5	SS2
			49	RUPERTRD1	SS2
			51	LAWRENCE RD	SS2
			53	SUNRISEPNTRD2	SS2
			56	TRINCOLMIRDCOVE2	SS2
			60	SUNRISENORTHEAST1	SS2

Beach Type Classifications - Thetis Island

Surf Smelt Type 3			Surf Smelt Type 4		
Beach Number	Thetis Island Beach Name	Beach Type	Beach Number	Thetis Island Beach Name	Beach Type
1	NOCOVE1	SS3	10	BH_HB1	SS4
37	BELOWYURT373LUPIN	SS3	55	THETISNECOVE2	SS4
5	PIONEERCAMP3	SS3			
28	FAIRVIEWNORTH1	SS3			
40	OVERBURY FARM	SS3			
42	THETISCOVENW1	SS3			
43	NWESTTHETISIS1	SS3			
57	TRINCOLMIRDCOVE1	SS3			
61	LOT167SOUTH	SS3			
Pacific sand lance Type 1			Pacific sand lance Type 3		
33	373LUPIN	PSL1	38	CAMPCOLUMBIANORTH	PSL3
			25	CUNNINGHAMRD1	PSL3

Appendix B: Beach Type Grain-Size Curves Thetis Island

Appendix B

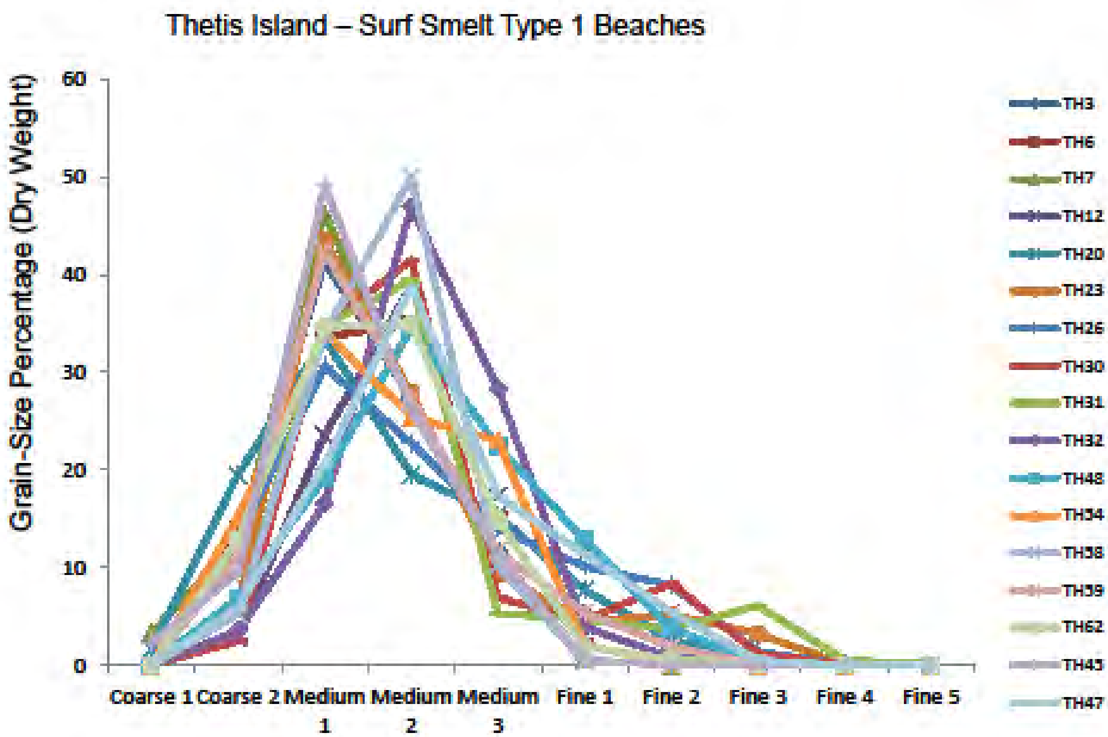

Figure 4: Thetis Island – Surf Smelt Type 1 Beaches

Appendix B

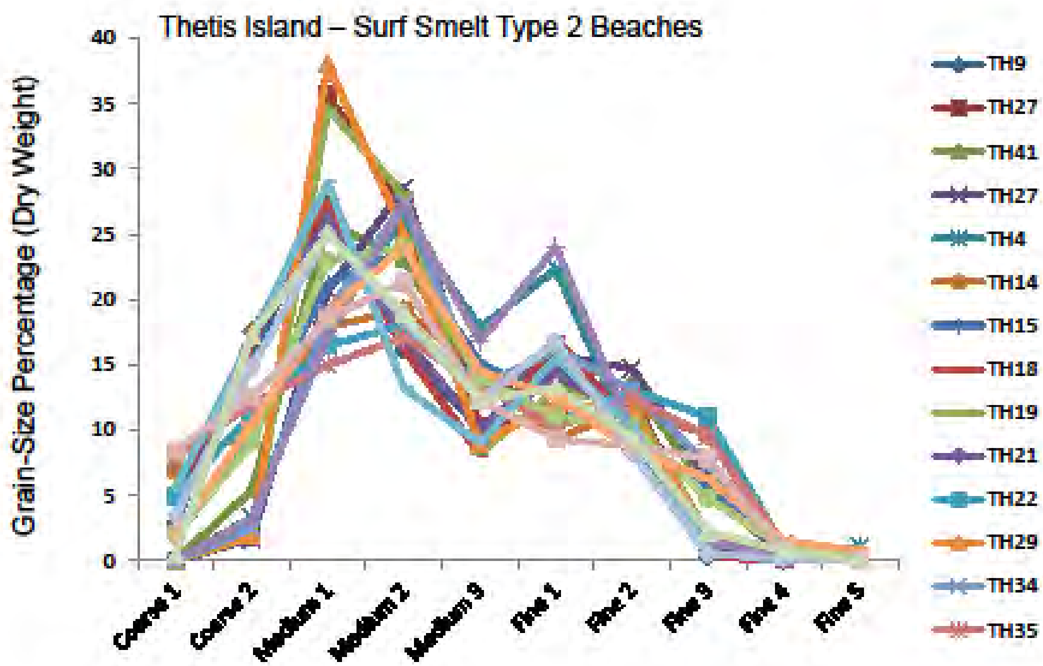

Figure 5: Thetis Island – Surf Smelt Type 2 Beaches

Appendix B

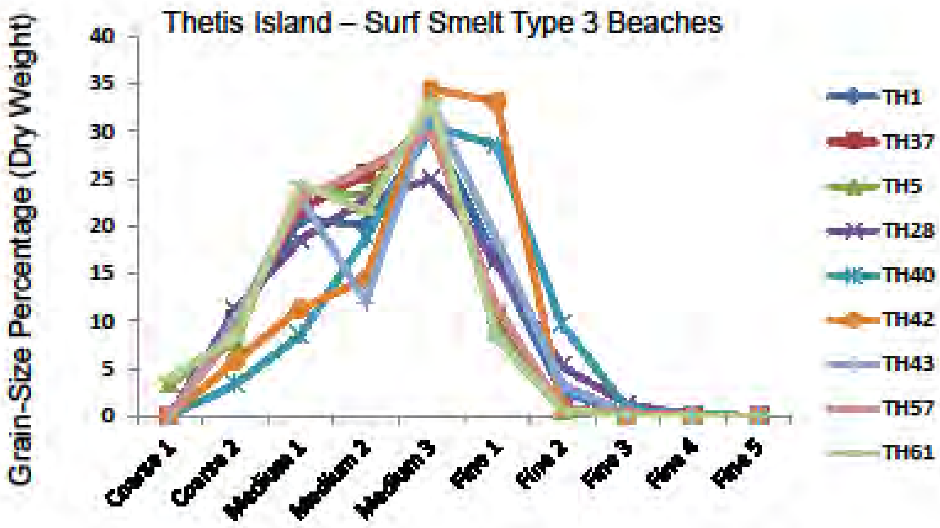

Figure 6: Thetis Island – Surf Smelt Type 3 Beaches

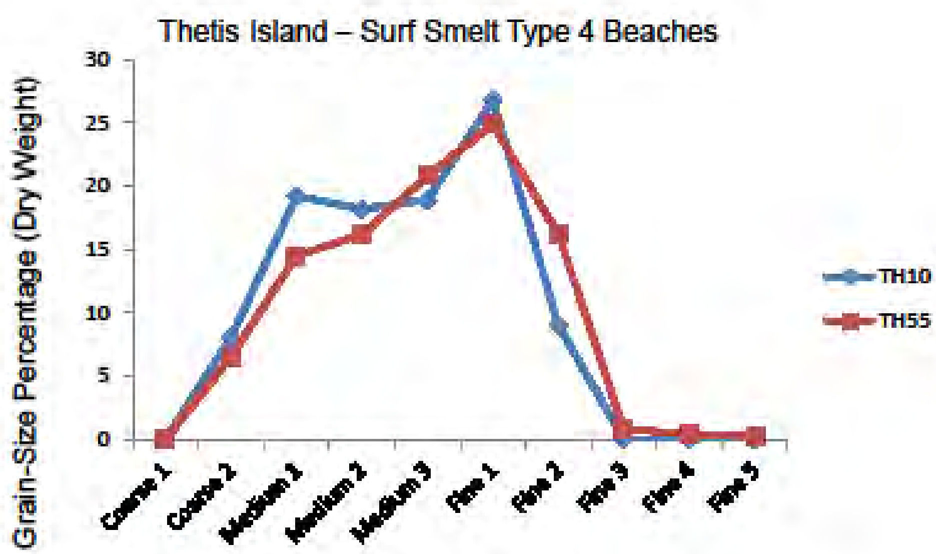

Figure 7: Thetis Island – Surf Smelt Type 4 Beaches

Appendix B

Thetis Island – Pacific sand lance Type 1 Beaches

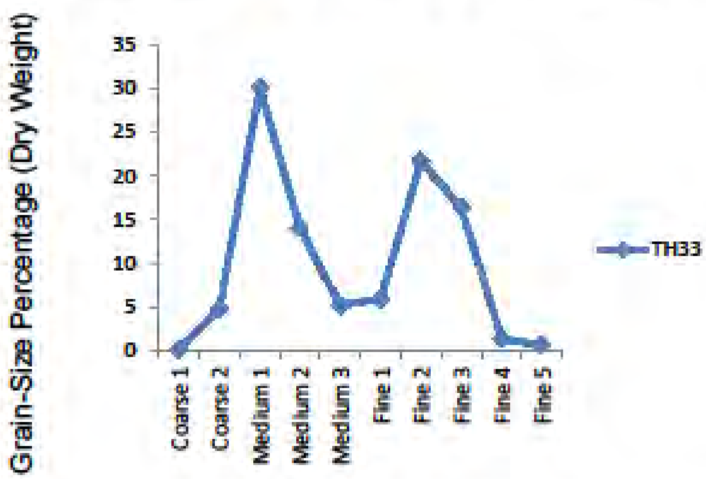

Figure 8: Thetis Island – Pacific sand lance Type 1 Beaches

Thetis Island – Pacific sand lance Type 3 Beaches

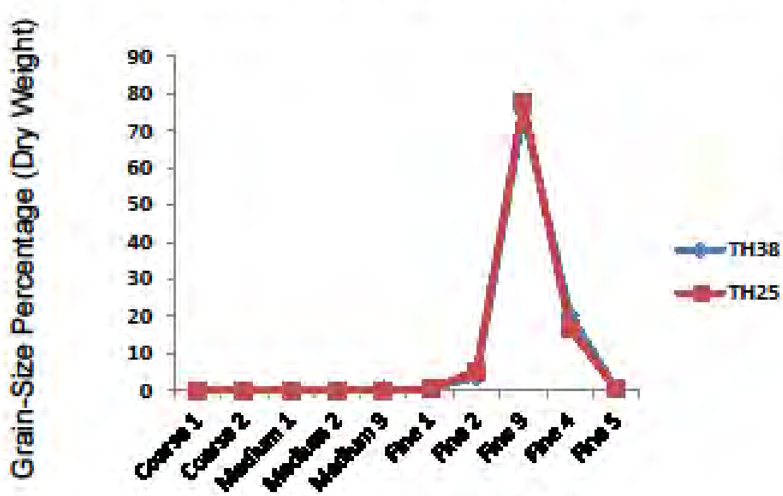

Figure 9: Thetis Island – Pacific sand lance Type 3 Beaches

Appendix C Beach Type Classifications Hornby Island

Appendix C

Beach Type Classifications - Hornby Island

Surf Smelt Type 1			Surf Smelt Type 2		
Beach Number	Hornby Island Beach Name	Beach Type	Beach Number	Hornby Island Beach Name	Beach Type
H15	.THESPIT.	SS1	H22	.SHINGLERDPOSITIVE4.	SS2
H40	.WESTGRASSYPNTPOSITIVE.	SS1	H24	.SHINGLRD3POSTITVE.	SS2
H41	.GRASSYPNTPARK.	SS1	H55	.LITTLETRIB.	SS2
H43	.GALLEONSOUTH_HIDDEN	SS1	H56	.SEAWRIGHTRDPOSITIVES.	SS2
H44	.SSOFGALLEOON.	SS1	H58	.SANDPIPER1.	SS2
H49	.HELLIWELLNORTH.	SS1	H59	.SANDPIPER2.	SS2
H6	.DOWNESPNT.	SS1			

Surf Smelt Type 3			Surf Smelt Type 4		
Beach Number	Hornby Island Beach Name	Beach Type	Beach Number	Hornby Island Beach Name	Beach Type
H16	.SHINGLEPOS7.	SS3	H29	PHIPPSPOS1	SS4
H18	.SHINGLEPOS6.	SS3	H34	SAVOIERDPOST2	SS4
H20	.SHINGLPOST5.	SS3	H35	SAVOIERDPOS1	SS4
H26	SHINGLERDNSECTION2	SS3	H54	.LITTLETRIB2.	SS4
H28	SHINGLERDSECTION1	SS3			
H32	SAVRDP3	SS3			
H38	NSAVOIERD1	SS3			
H9	.FORDCOVENORTH.	SS3			

Appendix C

Beach Type Classifications - Hornby Island

Surf Smelt Type 5

Beach Number	Hornby Island Beach Name	Beach Type
H1	.NORTHSANDDOLLAR1.	SS5
H2	.NORTHSANDDOLLAR2.	SS5
H42	.TRALEEPNTPOSITIVE.	SS5

Pacific sand lance Type 1

Beach Number	Hornby Island Beach Name	Beach Type
H13	.PUB.	PSL3
H37	GEORGEFARM	PSL3
H4	.SANDDOLLARPOSITIVE.	PSL3
H47	.WHALINGSTATIONNORTH.	PSL3
H48	.WHALINGSTSOUTH.	PSL3
H53	.BIGTRIB.	PSL3

Appendix D: Beach Type Grain-Size Curves _- Hornby Island

Appendix D

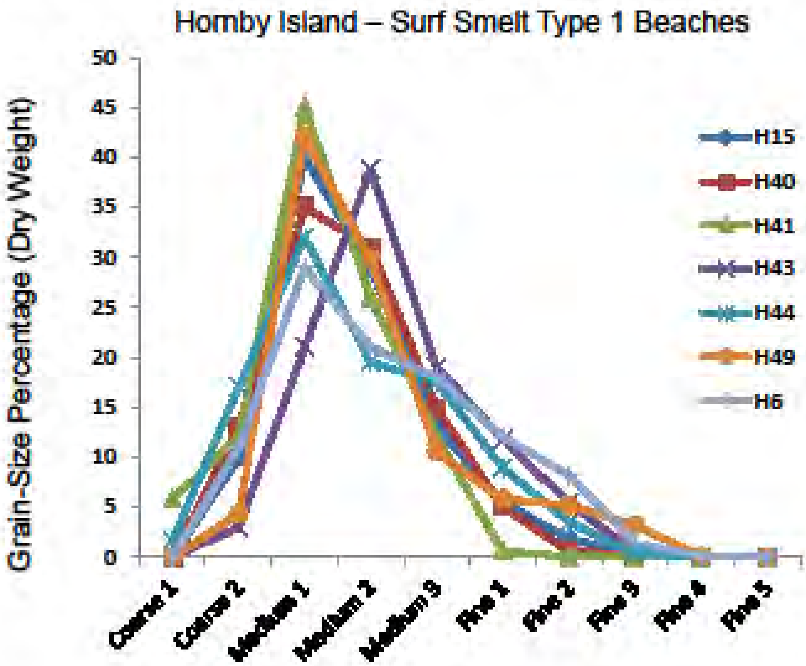

Figure 10: Hornby Island – Surf Smelt Type 1 Beaches

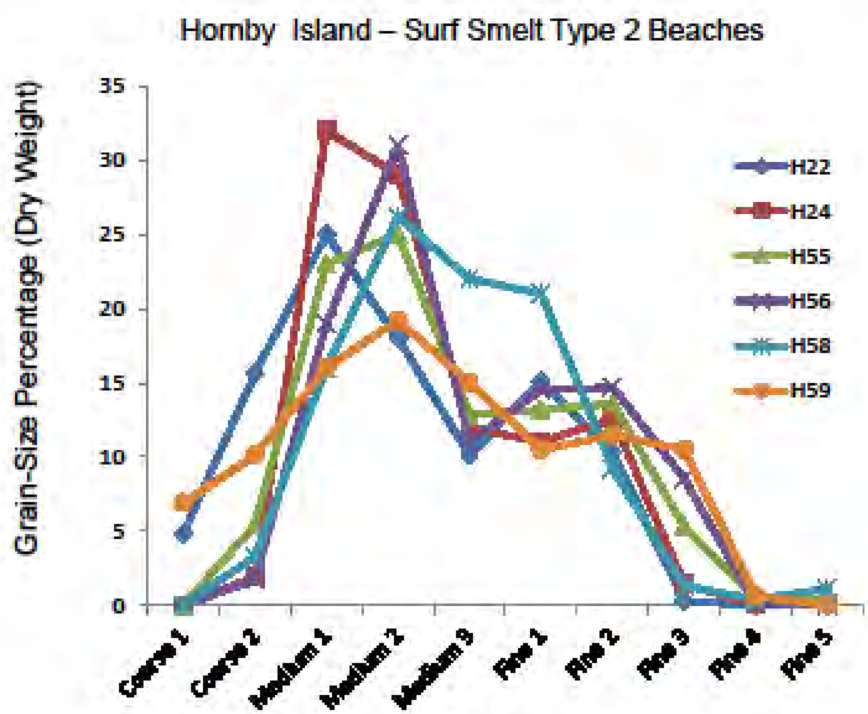

Figure 11: Hornby Island – Surf Smelt Type 2 Beaches

Appendix D

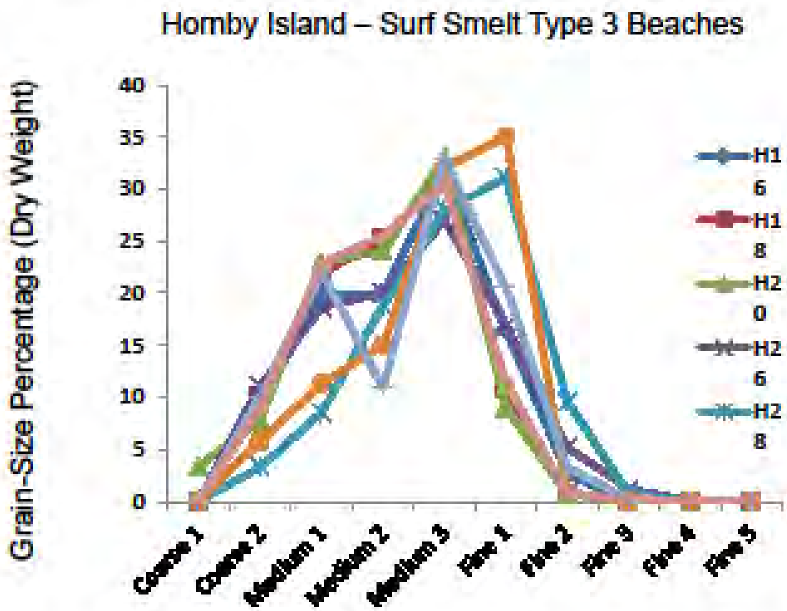

Figure 12: Hornby Island – Surf Smelt Type 3 Beaches

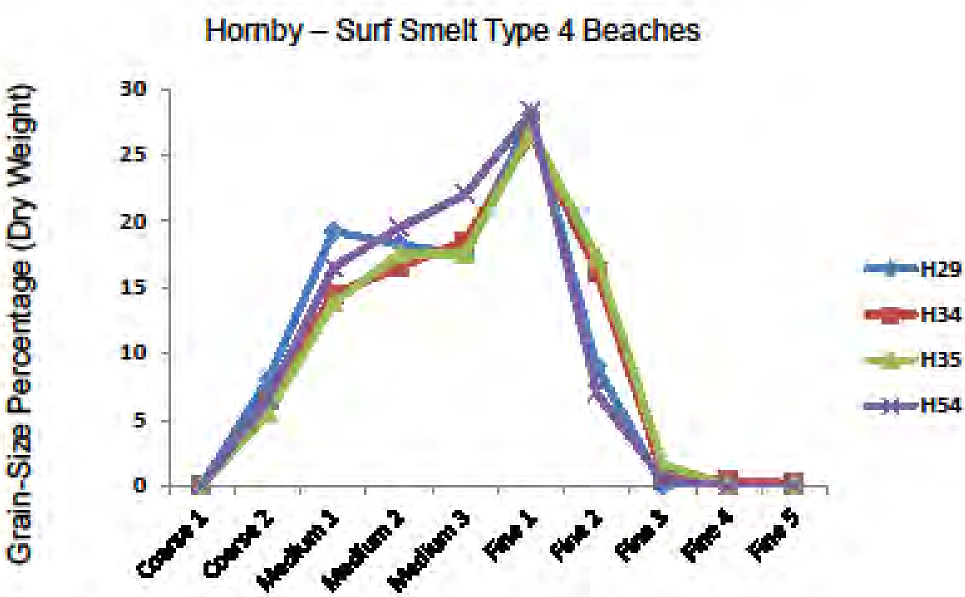

Figure 13: Hornby Island – Surf Smelt Type 4 Beaches

Appendix D

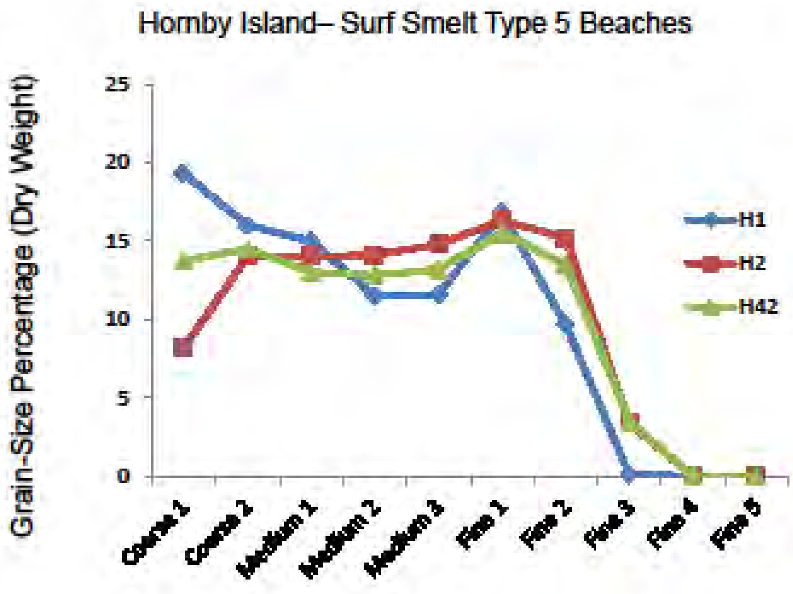

Figure :14 Hornby Island – Surf Smelt Type 5 Beaches

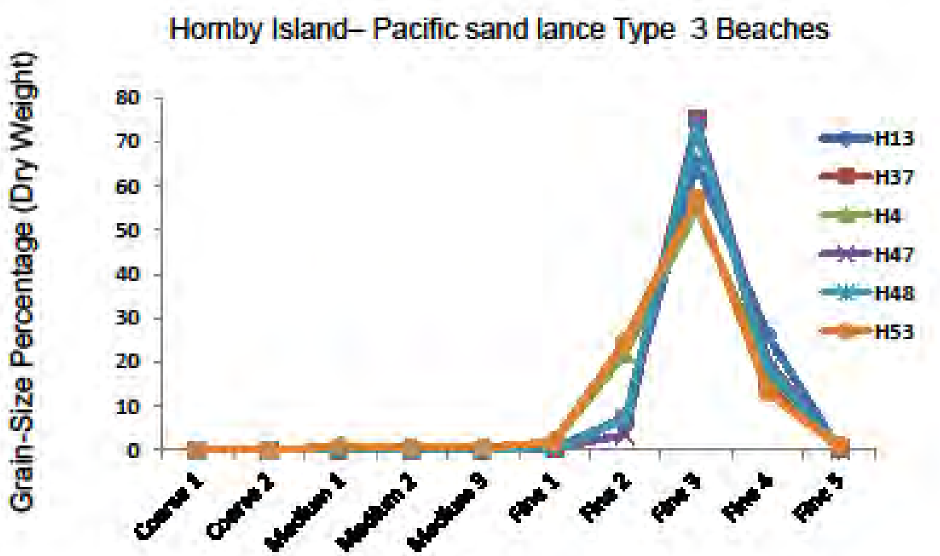

Figure :15 Hornby Island – Pacific sand lance Type 3 Beaches

Appendix E: Beach-Type Classifications - Denman Island

Appendix E

Beach Type Classifications - Denman Island

Surf Smelt Type 1

Beach Number	Denman Island Beach Name	Beach Type
DI50	DENMAN- LONEPINEFARM1	SS1
DI9	DENMFERRYDOCK	SS1
DI10	DENM-FERRYSOUTH	SS1
DI11	DENM-HINTONRDS2B	SS1
DI12	HENRYBAYSOUTH1	SS1
DI62	HENRYBAYSOUTH3	SS1
DI13	HENRYBAYSOUTH6	SS1
DI65	METCALFEBAYS1	SS1
DI16	METCALFEBAYSOUTH2	SS1
DI76	BEADNELLCRNORTH3	SS1
DI19	CABLEBEACHMID	SS1
DI21	DENMKAYAKACCESS	SS1
DI82	DENM-NE2	SS1
DI38	ELLABAY3	SS1
DI90	ELLASBAY2	SS1
DI92	FILONGLEYCREEK	SS1
DI25	GRAVELBAYN2	SS1
DI26	GRAVELYBAYN1	SS1
DI27	GRAVELYBAYS1	SS1
DI28	LINDSEYDIXONMID	SS1
DI29	LITTLEBURNABYS1	SS1
DI99	BETTYSBEACH	SS1
DI100	REPULSEBAY2POSITIVE	SS1
DI108	HENRYBAYNORTH3	SS1
DI35	HENRYBAYNORTH7	SS1
DI36	LONGBEAKPNTNE1	SS1
DI37	LONGBEAKPNTNE2	SS1
DI109	LONGBEAKPNTNE3	SS1

Appendix E

Beach Type Classifications - Denman Island

Surf Smelt Type 2

Beach Number	Denman Island Beach Name	Beach Type
DI39	CHRISMANGLADSONESOUTH1	SS2
DI40	CHRISMANGLADSTONEMIDDLE1	SS2
DI43	METCALFEBAYN1	SS2
DI47	MILLARDRDS4.	SS2
DI56	DENMFERRYNORTH3	SS2
DI57	DENM-LONEPINEFARM3	SS2
DI61	HENRYBAY2	SS2
DI15	HINTONRDSOUTH3-REDO	SS2
DI69	MILLARDRDNORTH1	SS2
DI17	SCOTTRD1	SS2
DI71	SCOTTRDSOUTH3	SS2
DI72	DENMNE6	SS2
DI20	CABLEBEACHSOUTH1	SS2
DI79	DENMNE1	SS2
DI83	DENMNE3	SS2
DI84	DENMNE4	SS2
DI91	FILLONGLEY_KIOSK	SS2
DI24	GLENSHN2	SS2
DI96	GRAVELYBAYN3	SS2
DI101	REPULSEBAY 3P	SS2
DI33	REPULSEBAY1POSITIVE	SS2
DI106	DENMHENRYBAYNORTH1	SS2
DI107	HENRYBAYNORTH2	SS2
DI34	HENRYBAYNORTH5	SS2

Appendix E

Beach Type Classifications - Denman Island

Surf Smelt Type 3		
Beach Number	Denman Island Beach Name	Beach Type
DI41	CHRISMANGLADSTONENORTH1	SS3
DI42	CHRISMANRDNORTH1	SS3
DI45	MILLARDRDS2	SS3
DI46	MIIIARDRDS3	SS3
DI48	CHRISMANSCOTTRD3	SS3
DI49	CHRISMANSCOTTRD4	SS3
DI51	DENMANFERRYNORTH5	SS3
DI52	DENMANHINTONRDS1B	SS3
DI55	DENM-FERRYNORTH1	SS3
DI60	HENRYBAY1	SS3
DI63	HENRYBAYSOUTH5PATS	SS3
DI66	METCALFEBY2	SS3
DI67	MILLARDRDN2	SS3
DI68	MILLARDRDN3	SS3
DI70	MILLARDRDNORTH4	SS3
DI18	SCOTTRD3	SS3
DI73	BEADNELLCREEKN1	SS3
DI74	BEADNELLCREEKN5	SS3
DI75	BEADNELLCRN7	SS3
DI77	CABLEBESOUTH2	SS3
DI88	ELLABAYNORTH1	SS3
DI89	ELLABAYNORTH2NEGATIVE	SS3
DI93	FILONGLEYSOUTH1	SS3
DI94	FILONGLEYSOUTH2	SS3
DI95	FORSYTHBEACH	SS3
DI102	REPULSEBAY 4P	SS3
DI013	REPULSEBAY5P	SS3

Appendix E

Beach Type Classifications - Denman Island

Surf Smelt Type 4		
Beach Number	Denman Island Beach Name	Beach Type
DI44	MILLARDRDS1	SS4
DI53	DENMANWESTCLIFFE1	SS4
DI54	DENMANWESTCLIFFENORTH2	SS4
DI58	DENMWESTCLIFFENORTH1	SS4
DI59	FERRYSOUTH3	SS4
DI64	HINTONRDN2	SS4
DI78	CRITCHLEYSOUTH1	SS4
DI80	DENMNE11	SS4
DI81	DENMNE12	SS4
DI85	DENMNE5	SS4
DI86	DENMNE8	SS4
DI87	DENMNE9	SS4
DI23	GLENSHN1	SS4
DI97	MORNINGBEACHN1	SS4
DI98	MORNINGBEACHSOUTH1	SS4
DI104	DENMANISLANDNORTH1	SS4
DI105	DENMANISLNORTH2	SS4

Surf Smelt Type 5		
Beach Number	Denman Island Beach Name	Beach Type
DI14	HINTONRDNORTH3	SS5
DI22	EASTRDMID2	SS5
DI30	MCFARLENEBEACHN1	SS5
DI31	MCFARLENEBEACHNORTH2	SS5
DI32	McFarlenes Beach	SS5

Appendix E

Beach Type Classifications - Denman Island

Pacific sand lance Type 1

Beach Number	Denman Island Beach Name	Beach Type
DI1	CHRISMANSCOTT1	PSL1
DI2	CHRISMANSCOTT2	PSL1
DI3	DENMSCOTTRDNORTH1	PSL1
DI4	HENRYBAYSOUTH4	PSL1
DI6	SCOTTRD5	PSL1
DI7	SCOTTRDNORTH2	PSL1

Pacific sand lance Type 3

Beach Number	Denman Island Beach Name	Beach Type
DI8	ELLASBAY	PSL3
DI5	HINTONRDNORtH1	PSL3

Appendix F: Beach Type Grain-Size Curves Denman Island

Appendix F

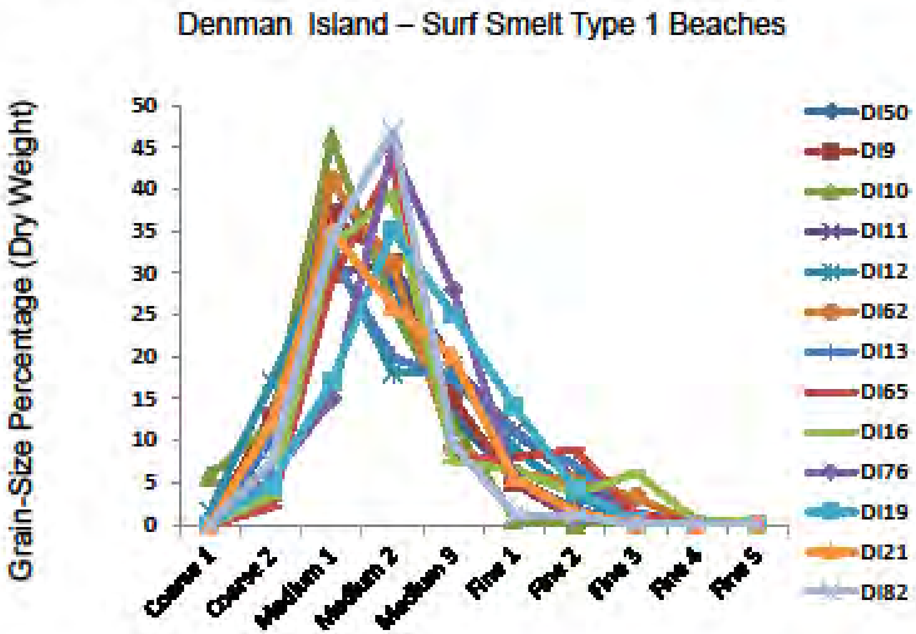

Figure 16: Denman Island – Surf Smelt Type 1 Beaches

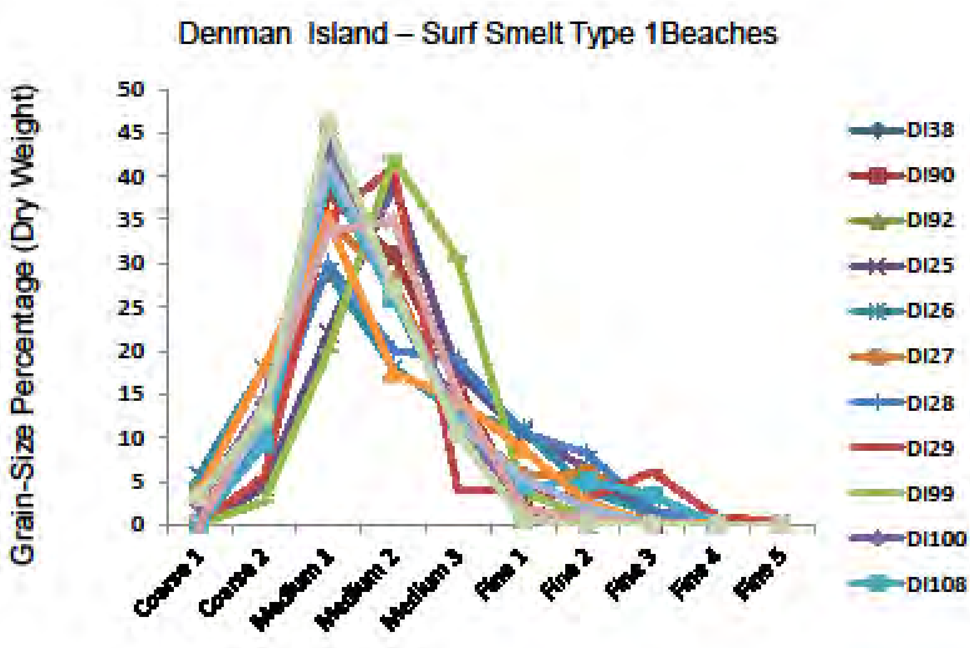

Figure 17: Denman Island – Surf Smelt Type 1 Beaches

Appendix F

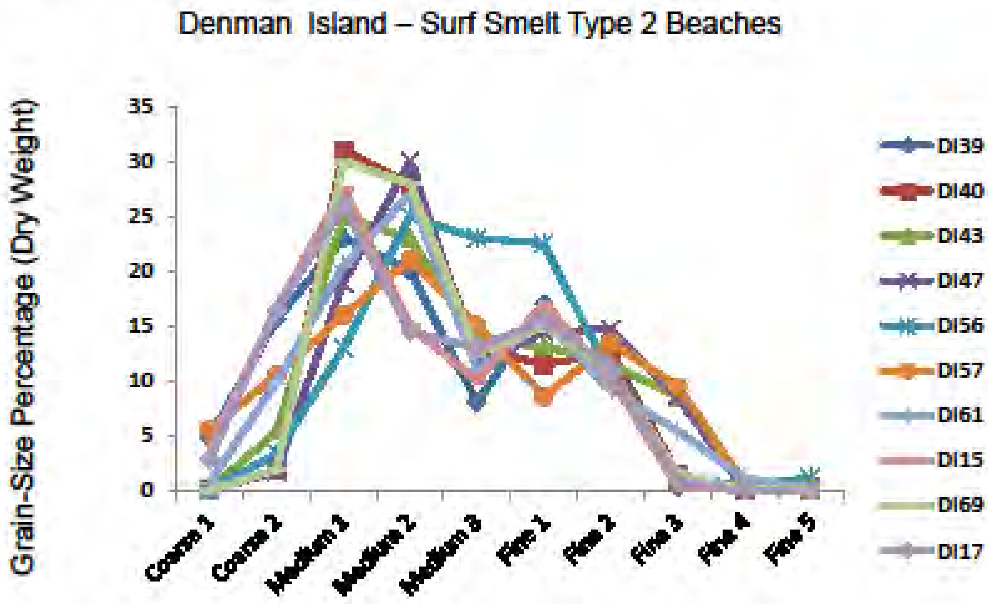

Figure 18 Denman Island – Surf Smelt Type 2 Beaches

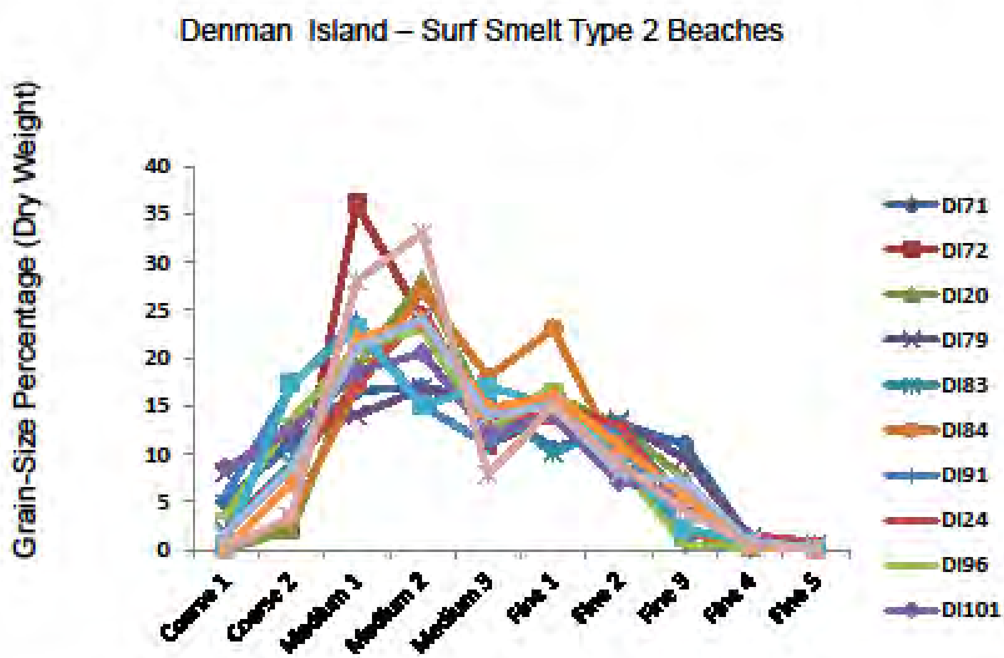

Figure 19 Denman Island – Surf Smelt Type 2 Beaches

Appendix F

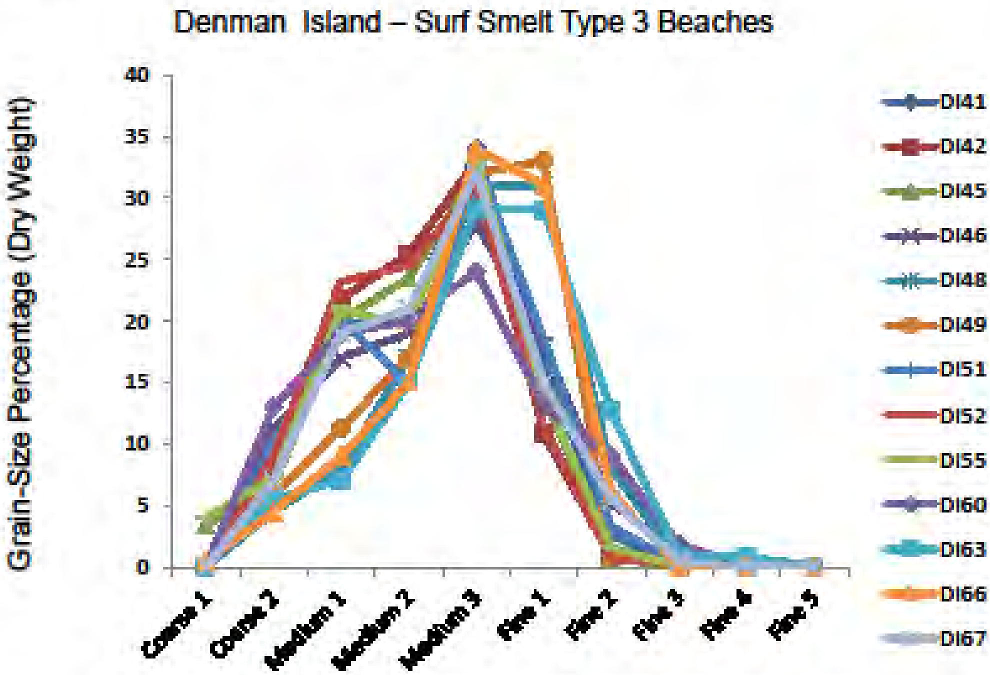

Figure 20 Denman Island – Surf Smelt Type 3 Beaches

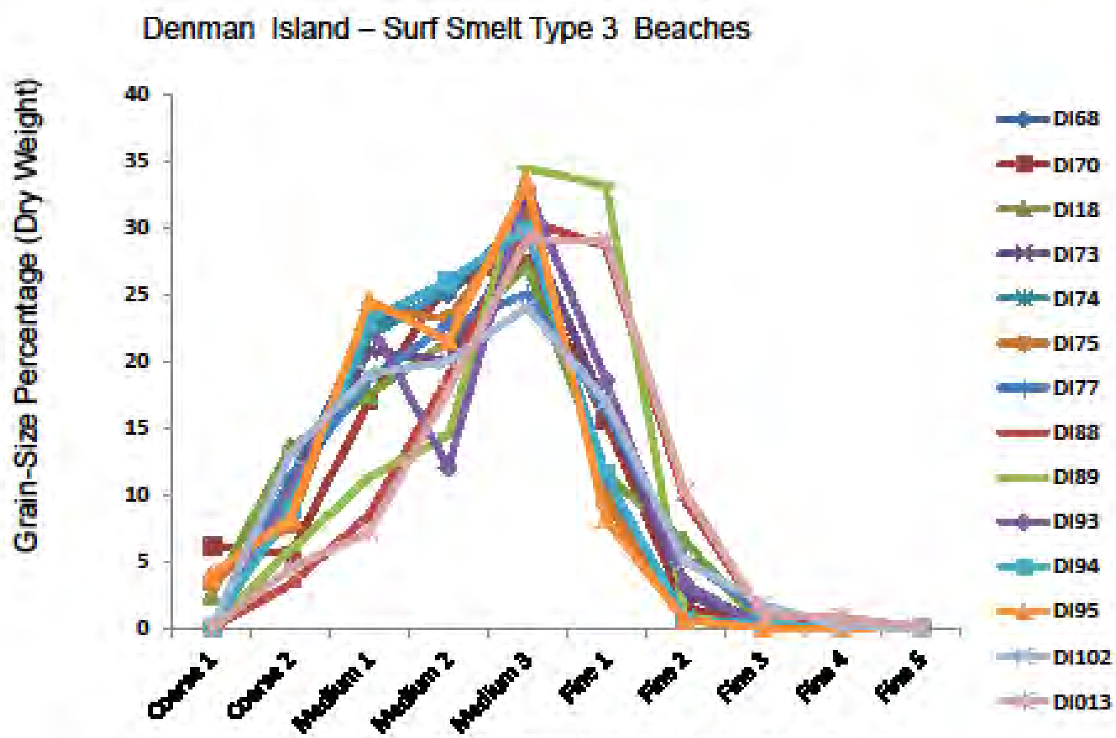

Figure 21 Denman Island – Surf Smelt Type 3 Beaches

Appendix F

Denman Island – Surf Smelt Type 4 Beaches

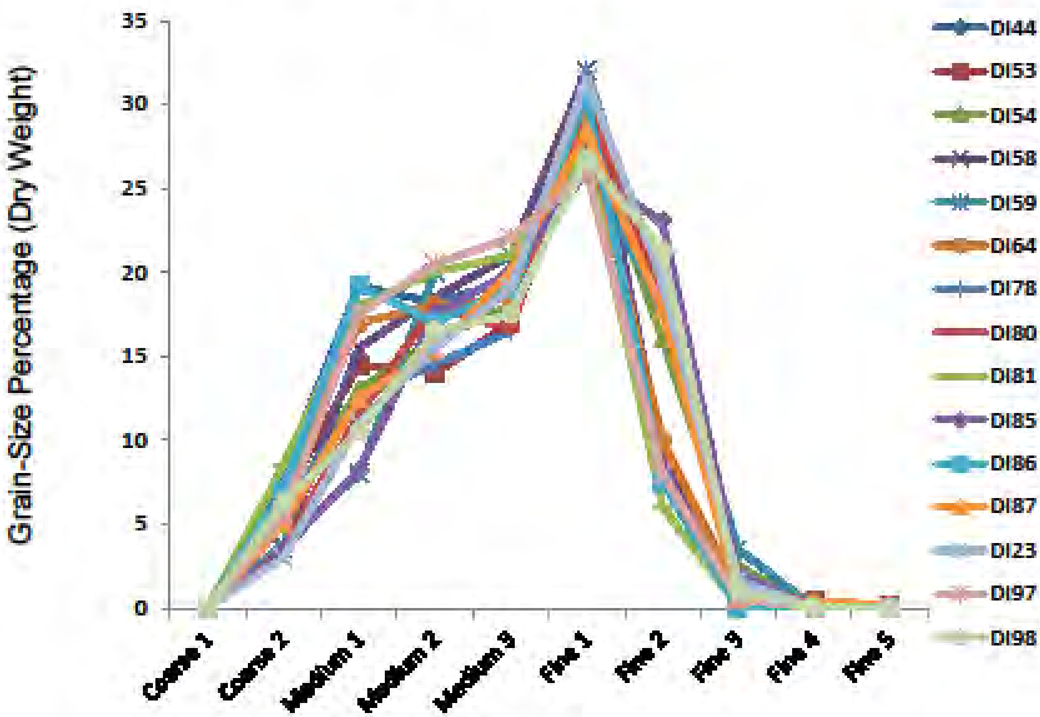

Figure 22 Denman Island – Surf Smelt Type 4 Beaches

Denman Island – Surf Smelt Type 5 Beaches

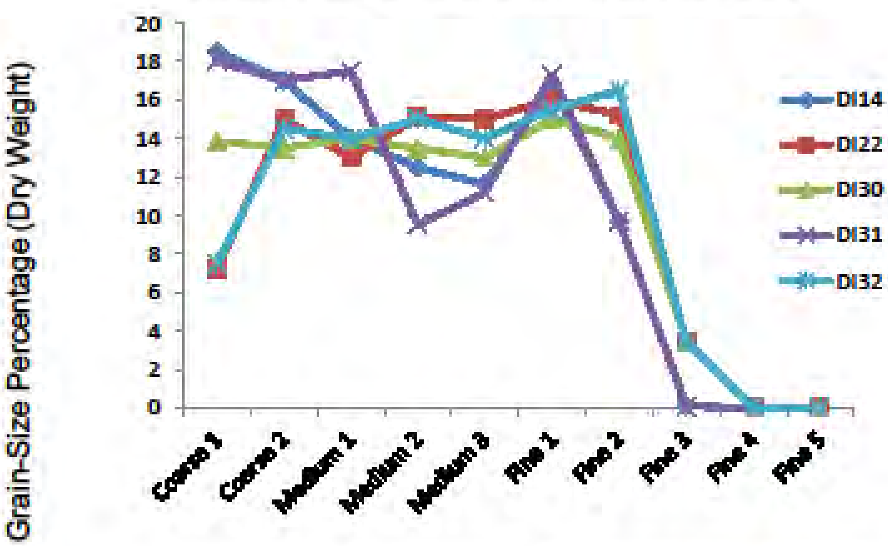

Figure 23 Denman Island – Surf Smelt Type 5 Beaches

Appendix F

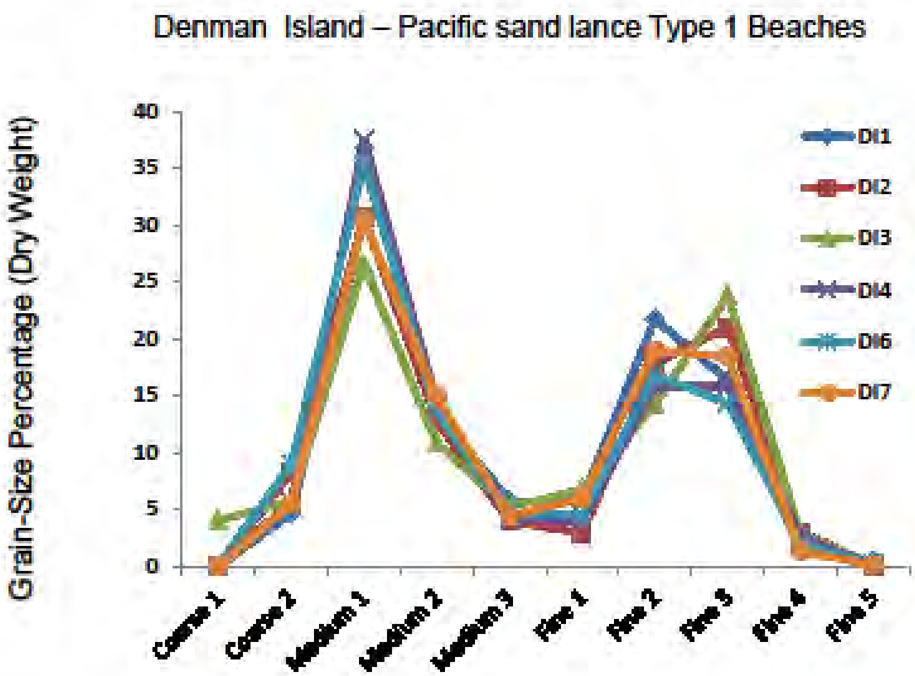

Figure 24 Denman Island – Pacific sand lance Type 1 Beaches

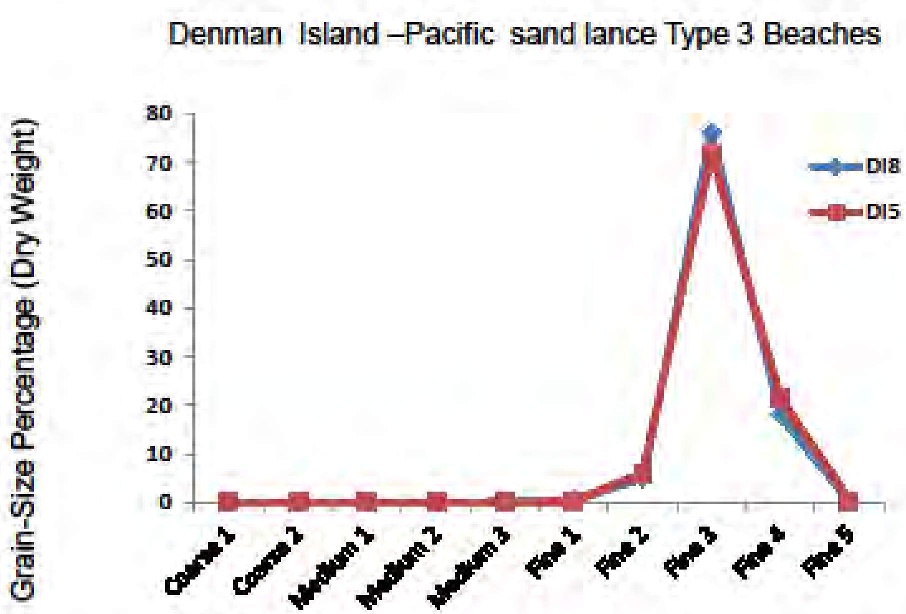

Figure 25 Denman Island – Pacific sand lance Type 3 Beaches

Appendix G: 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 H: 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 I: Forage Fish Habitat Suitability Assessment Methods

Housed with the Islands Trust Fund and the author