

Gambier and Keats Islands Surf smelt and Pacific sand lance Spawning Habitat Suitability Assessments



Pebble Beach – Keats Island
Photo: RC de Graaf

Prepared for the Islands Trust and Islands Trust Fund

Prepared by:
Ramona C. de Graaf, BSc, MSc
Marine Biologist
Forage Fish Specialist

British Columbia Marine Conservation and Research Society
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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.



Halkett Bay Marine Park.
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.



Mannion Creek West
Photo: RC de Graaf

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 over 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, 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 Gambier and Keats 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.

Gambier Island surveys took place on September 6-11, 2014. Keats Island surveys took place on September 11, 12, and October 2, 2014.

From September to October 2014, no major storm activity was noted for the Strait of Georgia.

6.2 Area Surveyed

The entire coastlines of Gambier and Keats Island 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 GPS/GIS Methodology

7.2.1 Spatial Data Specifications

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

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 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.

9. Results

9.1 GAMBIER ISLAND

9.1.1 Statistical Analyses

In total, 78 beach units comprised of unconsolidated sediments were assessed (Table 1). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed forty (40) beach units with 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable spawning habitat” (Figure 1A-E). Twenty-eight (28) of these beach units had continuous habitat and twelve (12) had discontinuous habitat.

Four (4) beach units failed statistical analyses, the same beach units with non-conforming grain-sizes, and were classified as “not suitable spawning habitat”. Thirty-four (34) beach units were comprised of unconsolidated sediments such as mud, silt, cobble that are not habitat types that are potential spawning habitat (Figure 1A-E).

Seven (7) of these beach units had significant shoreline modifications and/or localized erosion factors (vessel wakes) that may have contributed to lack of fine spawning sediments and the current beach condition of cobble and/or cobble/boulder. A list of beach units identified in the map Figures 1A-E is provided in Appendix A.

Table 1: Gambier Island - Beach Unit Statistical Analyses

	Count	Total	Length (m)	Percentage of Shoreline Perimeter
Habitat	40	40	2122.8	3%
Not Suitable	4	4	265.6	0.4%
Not habitat (Modification/Erosion Effects)	27(7)	34	4638.8	6%
Total Beach Units		78		
Total Length			7027.2	
Habitat	Count		Length	
Continuous	28		1235.2	2%
Discontinuous	12		887.6	1%

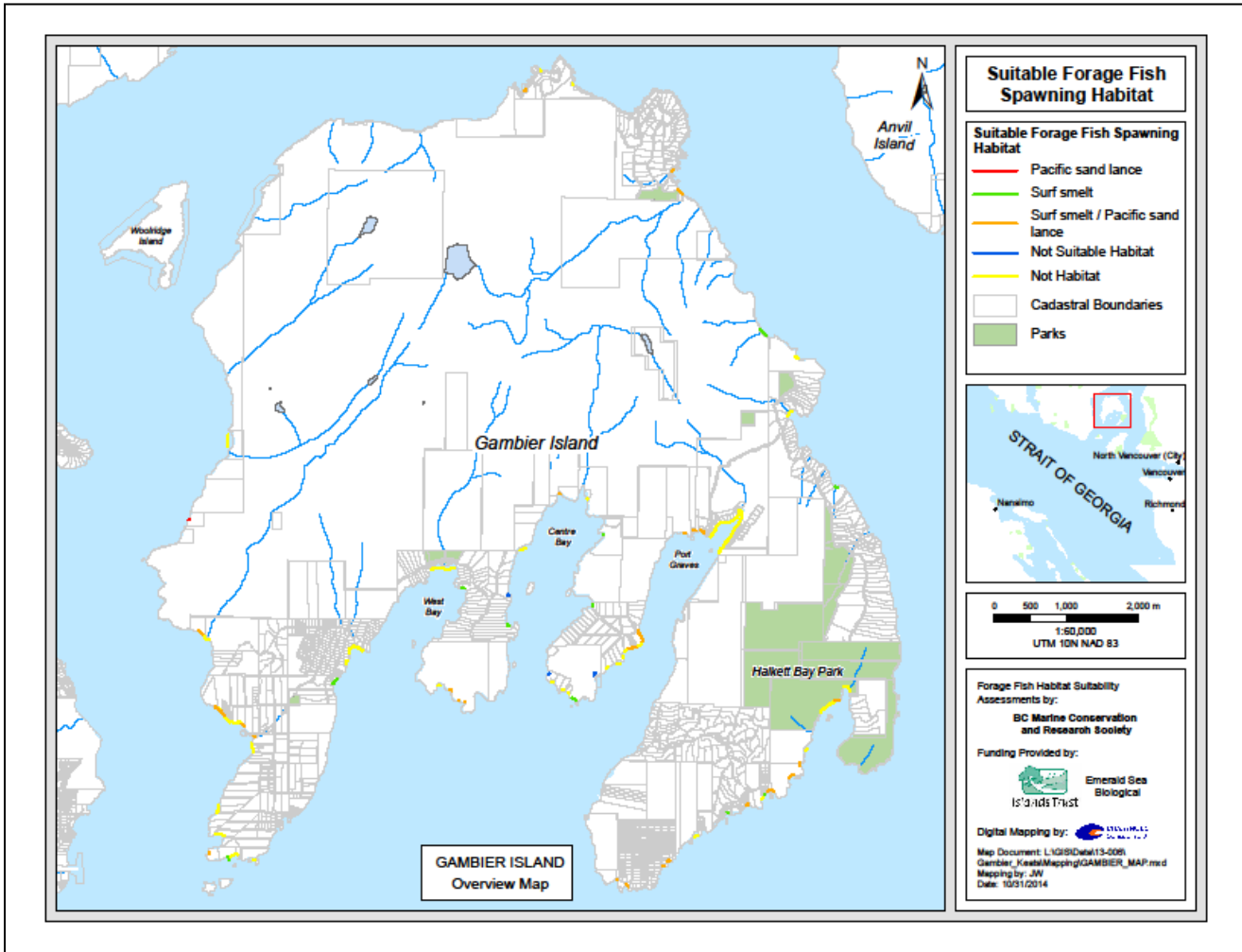


Figure 1A: Suitable Beach Spawning Forage Fish Spawning Habitats – GAMBIER ISLAND

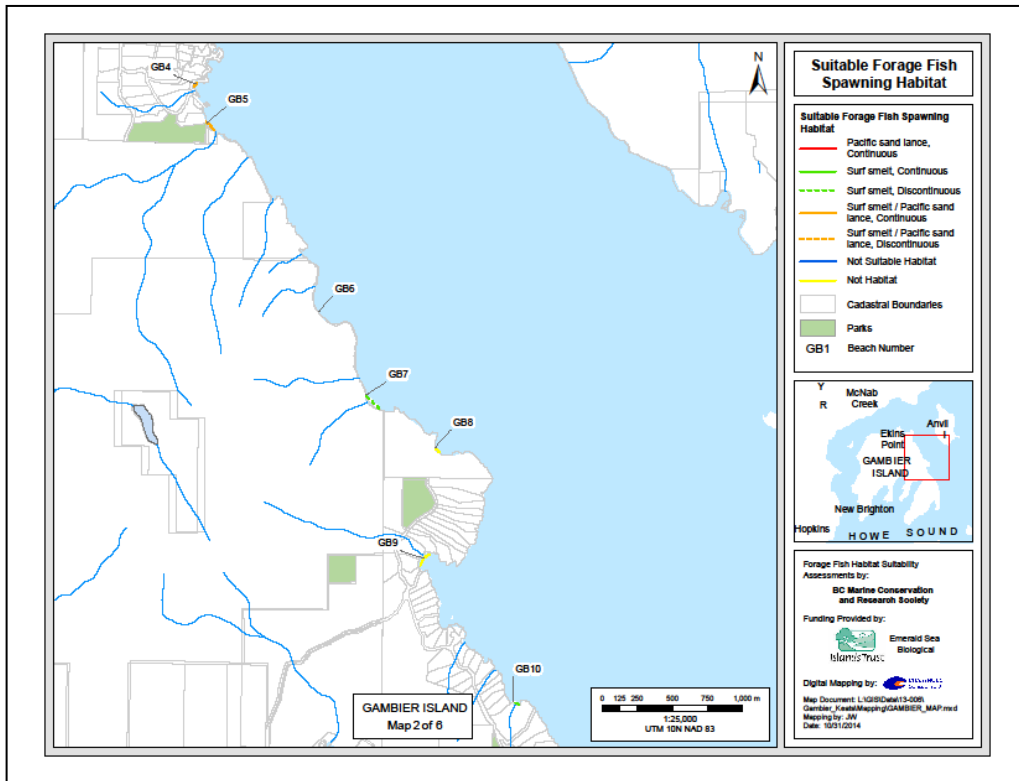
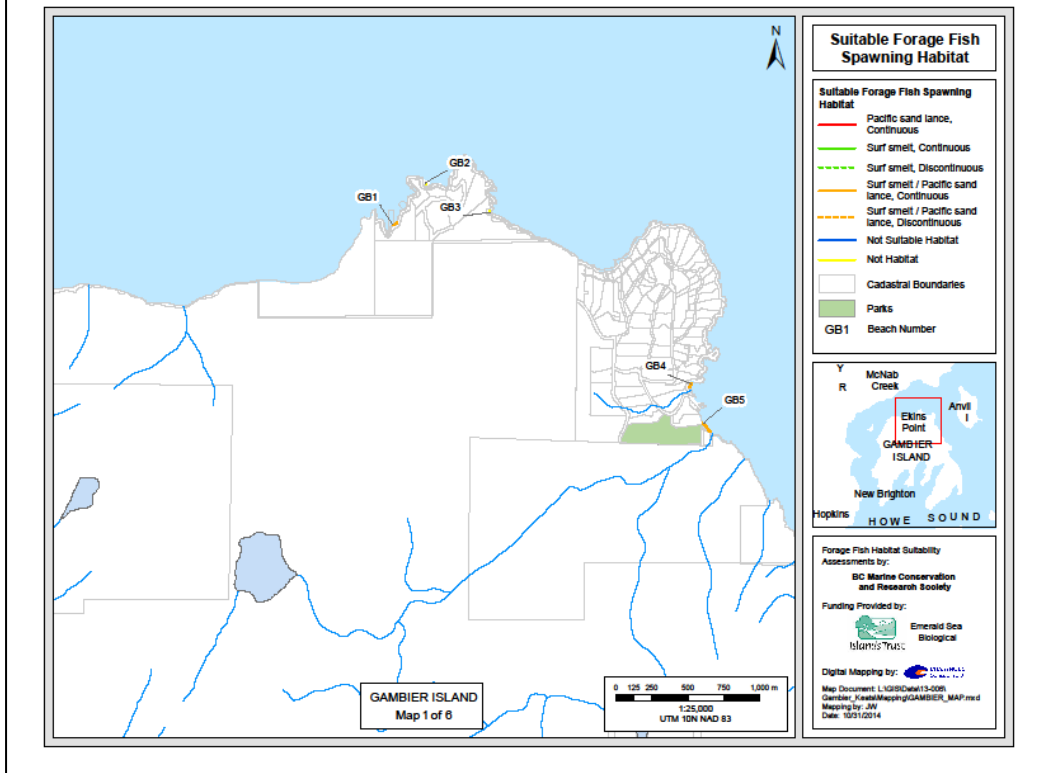


Figure 1B-1C: Suitable Beach Spawning Forage Fish Spawning Habitats – GAMBIER ISLAND

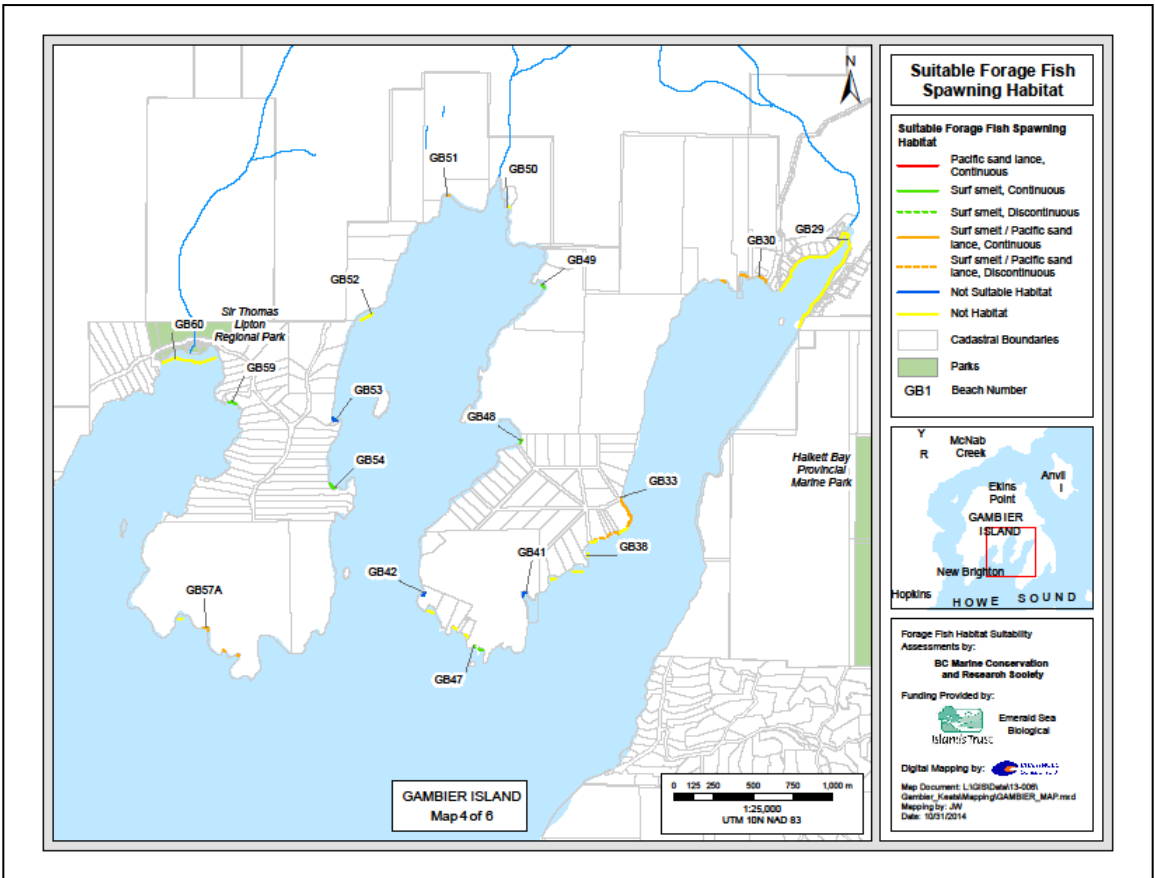
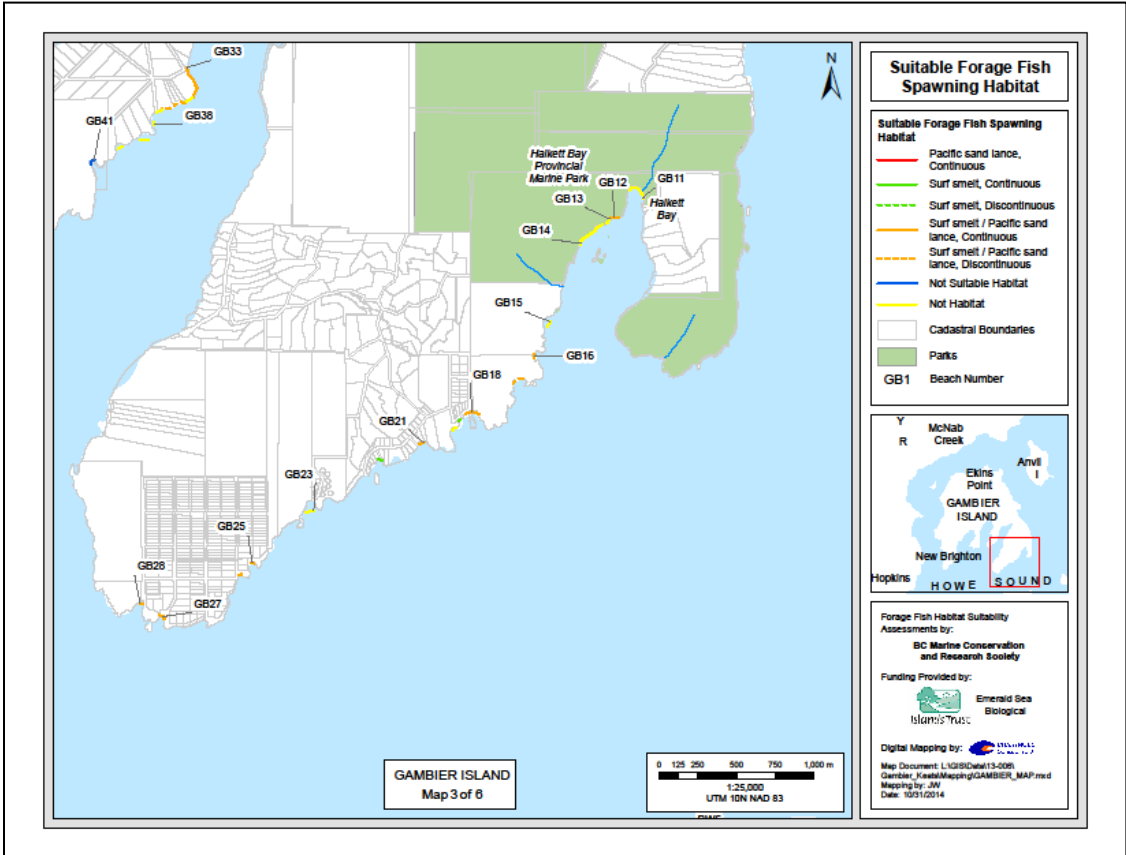


Figure 1D-1E: Suitable Beach Spawning Forage Fish Spawning Habitats – GAMBIER ISLAND

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. Forty (40) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix B, Appendix C, Figures 2-7). The grain-size frequencies of four (4) samples did not meet the statistical standards of the analysis.

9.1.3 Length of Suitable Forage Fish Spawning Habitat

The total shoreline perimeter of Gambier Island is 74.1 kilometers. Suitable forage fish spawning habitat comprised 2.1 kilometers (2,123 m) or three percent (3%) of the Gambier Island shoreline perimeter (Table 1). Of the suitable forage fish spawning habitat, the shoreline perimeter is comprised of 1% (20 m) suitable for Pacific sand lance spawning; 27.7% (587.5 m) suitable for surf smelt spawning; and 71.3% (1,515.5 m) as suitable for surf smelt/Pacific sand lance spawning habitat (Table 2).

Table 2: Gambier Island - Classification of
Suitable Forage Fish Beaches

	SS	PSL	SS/PSL	Total
Count	11	1	28	40
Length (m)	587.5	20	1515.5	2123
Length Percentage	27.70%	1%	71.30%	

SS - Surf smelt

PSL - Pacific sand lance

9.1.4 Suitable Forage Fish Spawning Habitat Beach Types

Of the 40 suitable spawning beaches, 1 was classified as Pacific sand lance, 11 as surf smelt, and 28 as mixed surf smelt/Pacific sand lance spawning habitat (Table 2). Of the Pacific sand lance beaches, grain size analyses assessed 1 as Type 3 Pacific Sand lance beach. Of the surf smelt beaches, grain size analysis assessed 10 as Type 1 and 1 as Type 4 Surf Smelt beaches. Of the mixed surf smelt/Pacific sand lance beaches, grain size analysis assessed 15 as Type 1; 7 as Type 2; 3 as Type 4, and 1 as Type 5 Surf Smelt beaches (Appendix C, Figures 2-7). There were few pure sand beach types; and overall, grain size types are coarser than those surveyed on Denman, Hornby and Thetis Islands.

Table 3: Gambier Island Grain-Size Types

Category	SS	PSL	SS/PSL
PSL TYPE 1			
PSL TYPE 2			
PSL TYPE 3		1	
SS TYPE 1	10		15
SSTYPE 2			7
SS TYPE 3			2
SS TYPE 4	1		3
SS TYPE 5			1
Totals	11	1	28

9.1.5 Geographic Position of Suitable Forage Fish Spawning Beaches

Dividing Gambier Island into north, south, west and east coast lines, 1 suitable beach unit is located on the north coast; 28 suitable beach units are located on the south coast; 7 suitable beach units on the west coast; and 4 suitable beach units on the east coast (Table 4).

Table 4: Gambier Island Gambier Island Coast Lines
Suitable Forage Fish Beach Units

	SS	PSL	SS/PSL	Total
North			1	1
South	9		19	28
West		1	6	7
East	2		2	4

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 (20) of the beach units had unmodified shorelines and twenty (20) were modified. Of the twenty (20) modified beach units, 8 (20%) were 1-25% impacted; 3 (7.5%) were 51-75% impacted; and 9 (22.5%) were 75-100% impacted (respectively) (Table 5).

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	20	8	0	3	9
Percentage	50	20	0	7.5	22.5

9.1.7 Foreshore and Backshore Structures

Of the twenty-one (21) suitable forage fish spawning beach units with modified foreshore zones, the presence of sediment impeding structures were classified and enumerated. In total twenty-nine (29) structures were classified into nine categories (Table 6).

Of the suitable spawning beach units, 11, 27.5% had modified backshore zones. In total twelve (12) structures were classified into seven categories. 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 24 beach units (Table 6).

Ten (10) beach units had 1 foreshore structure each, seven (7) beach units had 2 foreshore structures each, two (2) beach units had 3 foreshore structures each, and two (2) beach units had 4 foreshore structures.

Table 6: Foreshore and Backshore Structures - Gambier Island

Category	Foreshore		Backshore		No. Beach Units Buildings Present
	Count	Percentage	Count	Percentage	
Building					24
Boat Ramp	2	5.1			
Boat					
Boat House	1	2.6	1	8.3	
Dock/Wooden Pier	14	35.9	1	8.3	
Seawall	6	15.4			
Riprap	8	20.5	1	8.3	
Groin	4	10.3			
Break Water	1	2.6			
Infill	2	5.1			
Storm Water Outfall	1	2.6			
Stairs			1	8.3	
Platforms/Patios					
Derelict floats					
Derelict Boats					
Road to beach			6	50.0	
Boardwalks			2	16.7	
Total Number of Structures	39	100	12	100	24
Beach Units with Structures	21	52.5	11	27.5	

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 suitable beach units, 25% of the beach units had no overhanging shade; 37.5% had 1-25% overhead shade; 15% had 26-50% overhanging shade; 2.5% had 51-75% overhanging shade; 20% had 76-100% overhanging shade (10, 15, 6, 1, and 8 beach units respectively)(Table 7).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the suitable beach units with no overhanging shade, 25% had modified foreshore and 30% modified backshore zones; beach units with 1-25% overhead shade, 45% had modified foreshore and 43% modified backshore zones; beach units with 26-50% overhead shade had 15% modified foreshore and 15% modified backshore zones; beach units with 51-75% overhead shade had 0% modified foreshore and 0% modified backshore zones; and beach units with 75-100% overhead shade had 15% modified foreshore and 12% modified back shore zones (Table 7). In general, modification of foreshore and backshore areas resulted in significant losses of shade bearing trees.

Table 7: Overhead Shade Vegetation - Gambier Island

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade
Count	10	15	6	1	8
Percentage	25	37.5	15	2.5	20
Foreshore Modified %	25%	45%	15%	0%	15%
Backshore Modified %	30%	43%	15%	0%	12%

9.2 Keats Island

9.2.1 Statistical Analyses

In total, twenty-seven (28) beach units comprised of unconsolidated sediments were assessed (Table 1). Principal Component Analysis using PRIMER-E and beach metrics, including grain-size analyses, assessed twenty-one (21) beach units within 80% similarity to known positive beaches in BC and Washington State and were classified as “suitable spawning habitat” (Figure 8A-C)(Table 8). Fourteen (14) of these beach units had continuous habitat and seven (7) had discontinuous habitat.

Six (6) beach units were comprised of unconsolidated sediments such as mud, silt, cobble that are not habitat types that are potential spawning habitat (Table 8; Figure 8A-C). Three (3) of these beach units had significant shoreline modifications and/or localized erosion facts (wakes from BC ferries) that may have contributed to lack of fine spawning sediments and the current beach condition of cobble and/or cobble/boulder. A list of beach units identified in the map Figures 8A-C is provided in Appendix D.

Table 8: Keats Island - Beach Unit Statistical Analyses

	Count	Total	Length (m)	Percentage of Shoreline Perimeter
Habitat	21	21	2036.2	14.4%
Not Suitable	0			
Not habitat (Modification/Erosion Effects)	3(3)	6	390	2.8%
Total Beach Units		27		
Total Length			2426.2	
Habitat	Count		Length	
Continuous	14		1090.1	7.7%
Discontinuous	7		946.2	6.7%

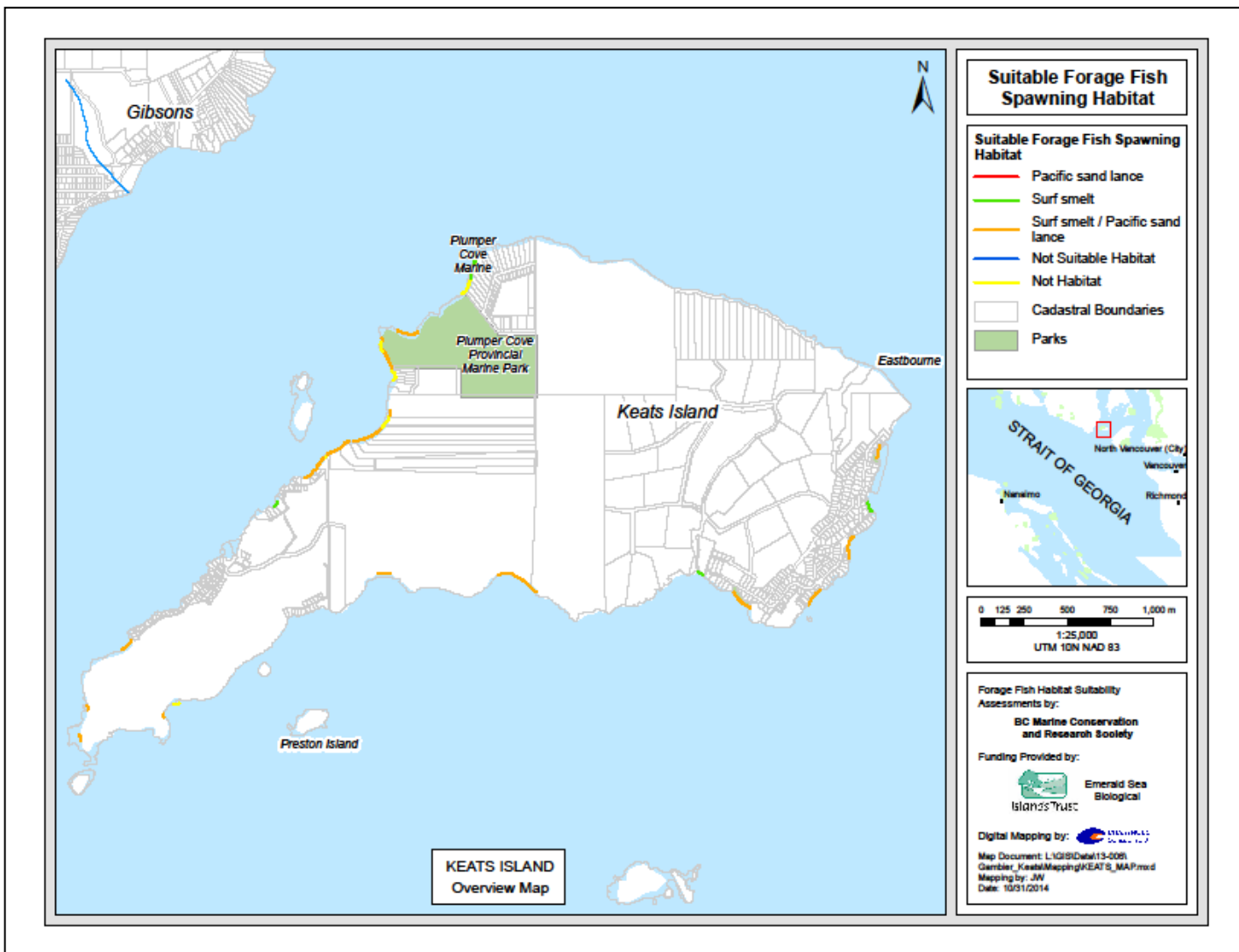


Figure 8A: Suitable Beach Spawning Forage Fish Spawning Habitats – Keats Island

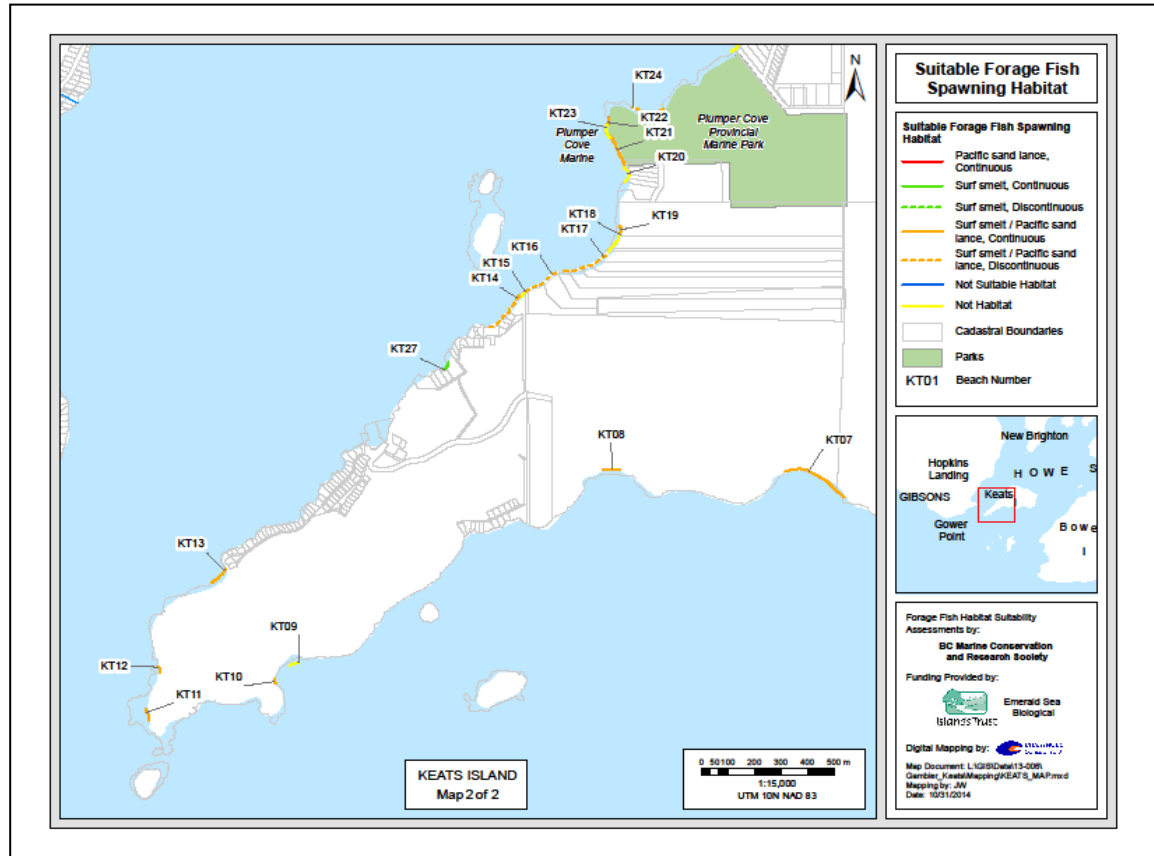
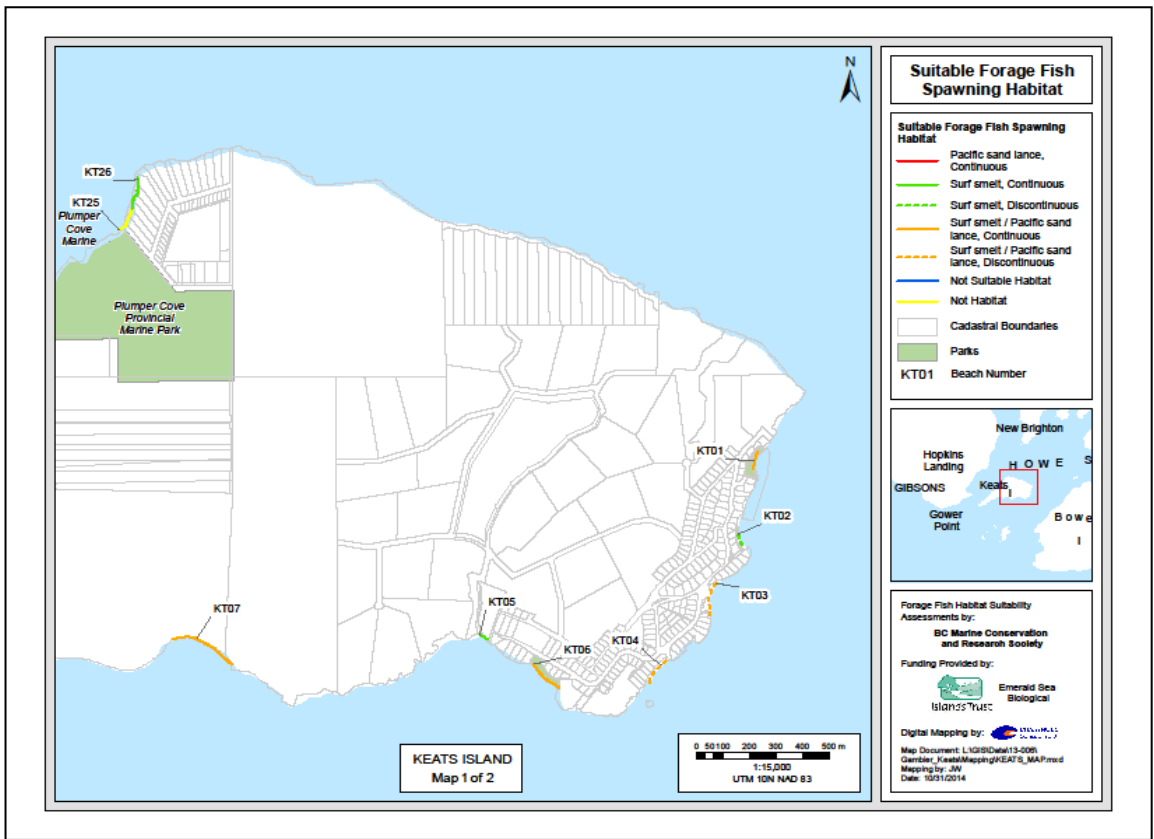


Figure 8B-C: Suitable Beach Spawning Forage Fish Spawning Habitats – Keats Island

9.2.2 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. Twenty-one (21) beach units showed grain-size frequencies curves that were within 80% and higher similarity to known positive spawning beaches (Appendix E; Appendix F, Figures 9-12).

9.2.3 Length of Suitable Forage Fish Spawning Habitat

The total shoreline perimeter of Keats Island is 14.2 kilometers (14,149 m). Suitable forage fish spawning habitat comprised 14.4% (2,036 meters) of the Keats Island shoreline perimeter (Table 8, Table 9). Of the suitable forage fish spawning habitat, the shoreline perimeter is comprised of 12.6% (258 m) suitable for surf smelt spawning, and 87.4% (1,778 meters) as mixed surf smelt/Pacific sand lance spawning habitat (Table 9).

Table 9: Classification of Keats Island
Suitable Forage Fish Beaches

	SS	PSL	SS/PSL	Total
Count	4	0	17	21
Length (m)	257.8		1778.4	2036.2
Length Percentage	12.60%		87.40%	

SS - Surf smelt

PSL - Pacific sand lance

9.2.4 Suitable Forage Fish Spawning Habitat Types

Of the twenty-one (21) suitable spawning beaches, four (4) were classified as surf smelt and seventeen (17) as mixed surf smelt/Pacific sand lance spawning habitat (Table 10). Of the surf smelt beaches, grain size analysis assessed two as Type 1, one as Type 3 and one as Type 4 surf smelt beaches. Of the mixed surf smelt/Pacific sand lance beaches, grain size analysis assessed ten as Type 2; two as Type 2; two as Type 3; and 3 as Type 4 Surf Smelt beaches (Appendix E). There were few pure sand grain-size types and overall, grain-size types are coarser than those found on Denman, Hornby and Thetis islands.

Table 10: Keats Island Grain-Size Types

	SS	SS/PSL
SS TYPE 1	2	10
SSTYPE 2		2
SS TYPE 3	1	2
SS TYPE 4	1	3
SS TYPE 5		

9.2.5 Geographic Position of Suitable Forage Fish Spawning Beaches

Dividing Keats Island into north, south, west and east coast lines, one (1) beach units was located on the south coast; eleven (11) beach units on the west coast; and nine (9) beach units the east coast.

Table 11: Keats Island Coast Lines
Suitable Forage Fish Beach Units

	SS	SS/PSL	Total
North	0	0	0
South	0	1	1
West	2	9	11
East	2	7	9

9.2.6 Foreshore Modification

Modification of the foreshore is classified as a 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. Twelve (12) of the beach units had unmodified shorelines and nine (9) were modified. Of the twenty one (21) beach units, 57% were in a natural state; 14% were 1-25% impacted; 10% were 26-50% impacted; 10% were 51-75% impacted; and 10% were 75-100% impacted (12, 3, 2, 2, and 2, respectively)(Table 12).

Table 12:: Foreshore Modification - Keats Island

	0% impact	1-25% Impact	26-50% Impact	51-75% Impact	76-100% Impact
Count	12	3	2	2	2
Percentage	57	14	10	10	10

9.2.7 Foreshore and Backshore Structures

Of the nine (9) suitable forage fish spawning beach units with modified foreshore zones, the presence of sediment impeding structures were classified and enumerated. In total, 24 (24) structures were classified into ten categories (Table 13).

Of the suitable spawning beach units, nine (9) (41%) had modified backshore zones. In total nine (9) structures were classified into six categories. 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 12 beach units (Table 13).

Of the suitable spawning beach units, three (3) beach units had 1 foreshore structure each, four (4) beach units had 2 foreshore structures each, one (1) beach unit had 3 foreshore structures, one (1) beach unit had 4 foreshore structures; and one (1) beach unit had 5 foreshore structures.

Table 13: Foreshore and Backshore Structures - Keats Island

Category	Foreshore		Backshore		
	Count	Percentage	Count	Percentage	No Beach Units Buildings Present
Building					12
Boat Ramp	1	4			
Boat					
Boat House					
Dock/Wooden Pier	6+	25	1	11	
Seawall	4	17	4	44	
Riprap	5	21	1	11	
Groins	3	13			
Infill	1	4			
Stairs	1	4	1	11	
Platforms/Patios	1	4	1	11	
Derelict floats	1	4			
Derelict Boats	1	4			
Road to beach			1	11	
Total Number of Structures	24	100	9	100	
Beach Units with Structures	10	45	9	41	

9.2.8 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 suitable beach units, 14% of the beach units had no overhanging shade; 32% had 1-25% overhead shade; 14% had 26-50% overhanging shade; 18% had 51-75% overhanging shade; 23% had 76-100% overhanging shade (3, 7, 3, 4 and 5 respectively)(Table 14).

Marine riparian vegetation may be absent due to soil conditions, the type of land form, or due to landscaping. Of the suitable beach units with no overhanging shade, 33% had modified foreshore and 100% modified backshore zones; beaches with 1-25% overhead shade, 57% had modified foreshore and 71% modified backshore zones; beaches with 26-50% overhead shade had 67% modified foreshore and 100% modified backshore zones; beaches with 51-75% overhead shade had 50% modified foreshore and 25% modified backshore zones; and beaches with 75-100% overhead shade had 20% modified foreshore and 40% modified back shore zones (Table 14). In general, an increase in backshore modification resulted in significant losses of shade bearing trees.

Table 14: Overhead Shade Vegetation - Keats Island

	Fully exposed	1-25% Shade	26-50% Shade	51-75% Shade	76-100% Shade
Count	3	7	2	4	5
Percentage	14	32	14	18	23
Foreshore Modified %	33%	57%	50%	50%	20%
Backshore Modified %	100%	71%	100%	25%	40%

10.0 Summary and Recommendations

10.1 General

The shorelines of Howe Sound islands, Gambier, Keats and Bowen Islands 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 2.1 kilometers of suitable spawning habitat on Gambier Island and 2.04 kilometers on Keats Island, there are excellent opportunities to safeguard and protect these critical fish habitats. Gambier and Keats Island had the same length of suitable forage fish spawning habitat, although Gambier has a shoreline perimeter of 74.1 kilometers and Keats a shoreline perimeter of 14.1 kilometers.

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:

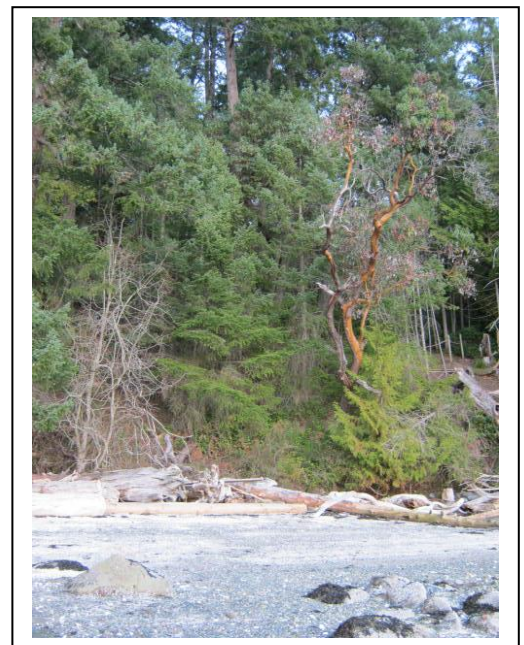
Structures placed along shorelines can impede sediment delivery to shorelines either by blocking transport along the beach or blocking sediment transport from eroding land forms. Over time, beaches lack sediment “nourishment” and will coarsen. Some structures, such as hard structures (seawalls, riprap 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. Clearing cobbles and boulders from the foreshore changes beach profiles and changes sediment supply/delivery leading to altered habitat types.

Forage fish spawning habitat is vulnerable to the impacts of sea level rise. At sites with hard armouring placed 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.

Marine Riparian Vegetation
Thetis Island - Photo: RC de Graaf

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 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; Groins; Berms; Breakwaters; clearing foreshore
 - reduces public access to beach
 - blocks sediment supply/littoral drift
 - increases beach erosion (sediment coarsening, beach profile changes)
 -

B. Vegetation Removals

- impairment of soil conditions (slope/shoreline stability, pollution filtering, storm water management)
- loss of 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

10.2.0 Specific Recommendations

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. Gambier/Keats Islands, 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 Gambier/Keats islands 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.

Beach units suitable for forage fish spawning that are generally, intact with natural shorelines and riparian vegetation zones (e.g. Gambier: east coast beach units, Halkett Bay and Mannion Creek) are priority sites for protection of ecological values through shoreline setbacks and site management planning. Suitable forage fish spawning beach units in Halkett Bay are unique on Gambier Island as the mid-intertidal and shallow subtidal zones are comprised of soft sediments suitable for Pacific sand lance burrowing. Throughout other areas of Gambier Island, these zones are comprised of cobble/boulder substrate or eelgrass beds which are not conducive to burrowing by Pacific sand lance. Protection of nearshore and subtidal forage fish habitats of Halkett Bay is a high priority. Another exceptional habitat area is Mannion Creek.

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 Gambier and Keats is limited. The lack of public access both by road or foot to marine shorelines can result in significant shoreline modification of beach units. It is common to encounter beaches fronting properties with little to no public access becoming utilized by a select few; and in some instances with significant levels of shoreline modifications. Examples can be commonly found where modifications are initiated on shorelines isolated by geography or zoning and are not monitored. In some communities, providing better signage and frequency of public beach accesses helps to reduce changes such as multiple access stairs along single beach units. Public access points may reduce the need for multiple access stairs and improve enjoyment for both residents and visitors.

Shoreline structures:

Foreshore areas are the property of the Crown unless upland property owners secure a lease for a water lot or have “grandfathered” use of the foreshore through historical zoning (e.g. industrial land

sites, commercial, recreational uses). Access to and alterations to the foreshore require permits and approvals at various government levels.

Shoreline Erosion Mitigation

Gambier Island

Gambier Island had a significant proportion of suitable spawning habitat classified as having modified shorelines. Gambier Island, 52.5% (21) 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. In light of future sea level change predictions, as well as shoreline development, threats/pressures to harden shorelines will increase. Seawall, riprap, and infills below the natural boundary should be removed or elevated foreshore/beach nourishment methods employed to re-establish and enhance forage fish spawning habitat.

On Gambier Island, seven and possibly ten beach units had significantly coarsened sediments resulting in classification as “not habitat” but 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 shoreline modifications and local wave/swell conditions. On Gambier Island, these beach units measure a total of 786 m and may represent habitat losses.



Foreshore structure impeding sediment flow.
Photo: RC de Graaf

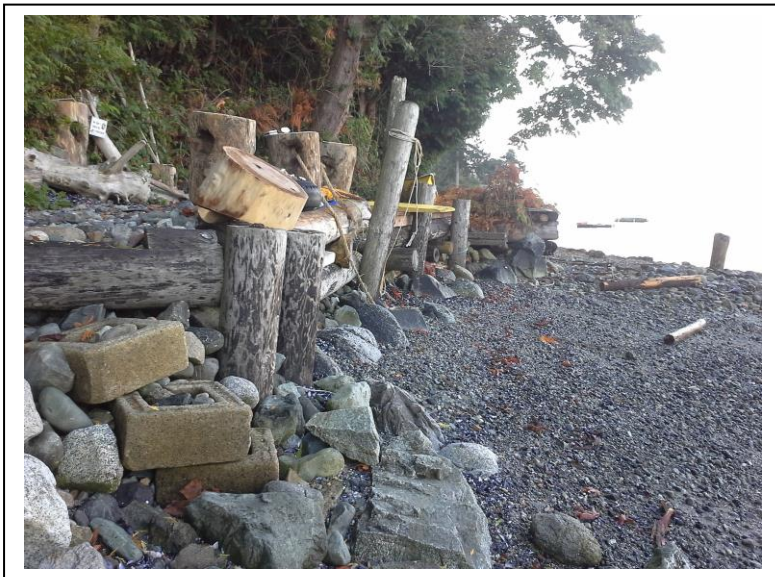
Keats Island

On Keats Island, 43% of beach units (9 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. In light of future sea level change predictions, as well as shoreline development, threats/pressures to harden shorelines will increase. Seawall, riprap, and infills below

the natural boundary should be removed or elevated foreshore/beach nourishment methods employed to re-establish and enhance forage fish spawning habitat.

On Keats Island, three (3) beach units had significantly coarsened sediments resulting in classification as “not habitat” and measured 231 meters in length. 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 significant shoreline modifications, the number and type of shoreline structures, vegetation removals and local wave/swell conditions.

Three beach units classified as suitable forage fish spawning habitat had significant shoreline modifications near, at or below the natural boundary impairing ecological function and shoreline processes: including seawalls, foreshore infills, riprap armouring, piers/docks,



Foreshore structures impeding sediment delivery and flow along beach surface.
Photo: RC de Graaf

Piers and Docks

Gambier Island

Proliferation of piers and docks can reduce public access to the foreshore as well as negatively impact marine habitats. Coastal planning 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. Aging public dock facilities can serve as a “green dock” pilot project to educate other residents.

A number of beach units located in Port Graves, Centre Bay, West Bay, and Thornbrough Bay have significant shoreline modification and vegetation removals. The majority of beach units in these bays were modified with hard armouring, piers/docks. The high number of piers/docks is a concern due to cumulative impacts on multiple valuable habitats. The majority of beach units on Gambier constitute pocket coves. Multiple piers/docks within a single pocket cove are not uncommon. Due to the loss of public access to these beaches and cumulative effects on spawning habitat, placement of and maximum number of piers/docks per beach should be re-evaluated.

A number of beach units in Thornbrough Bay also had areas of the foreshore where cobbles/boulders were cleared and either displaced or used for building mid-intertidal berms. Stressors related to this activity are alteration of sediment/littoral drift and changes of beach profiles including degradation and loss of spawning habitat. As foreshore areas are not to be altered or disturbed without application to the Province, educating land owners on foreshore matters is strongly encouraged.



Clearing of cobbles and boulders resulting in changes to beach profiles and sediment types.
Photo: RC de Graaf

Keats Island

A large number of piers/docks on Keats Island span soft sediment beaches and their construction should be evaluated to mitigate any sediment flow disruptions. Unelevated piers/floats are not permitted by present best management practices and two such structures are present at one beach unit in Plumper Cove south, although not comprising suitable forage fish spawning habitat, unelevated docks deny public access to the foreshore and can be significantly block sediment transport.

Three beach units in Plumper Cove South and Plumper Cove North had areas of the foreshore where cobbles/boulders were cleared and either displaced or used for building mid-intertidal berms. Stressors related to this activity are alteration of sediment/littoral drift and changes of beach profiles including degradation and loss of spawning habitat. This is particularly true at one beach unit where this activity (combined with a seawall below the natural boundary) has resulted in extreme changes in

beach elevation and littoral drift resulting in a loss of spawning habitat. These cobble groins/berms span the upper and mid foreshore and under pier footings should be removed to restore forage fish spawning habitat.



Cobbles at pier footings blocking sediment flow.

Photo: RC de Graaf



Foreshore moving/clearing of cobble and boulder resulting in beach profile changes.

Photo: RC de Graaf

Vegetation Losses:

Marine Riparian Vegetation and Overhanging Shade Vegetation:

Gambier Island

On Gambier Island, 77.5% of beach units (31 beach units) had only 1-50% cover of overhanging shade vegetation. 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. Vegetation replanting is also advised.

Keats Island

On Keats Island, 57% of beach units (12 beach units) had only 1-50% cover of overhanging shade vegetation. 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.

Beach Health/Enhancement

Several beach units presented opportunities to remove derelict structures/vessels which will improve water quality and overall beach health. Within Plumper Cove BC Marine Park (Keats Island), two medium size derelict vessel hulls are present and should be removed. 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. Vegetation losses can be offset by replanting.

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 - Beach Units Gambier Island

Gambier Island - Beach Units

Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Length (m)
GB1	ThunderbirdYC	Habitat	Continuous	SS/PSL	T2	41
GB2	EkinsPnt1	Not Habitat			nil	10
GB3	EkinsPnt2	Not Habitat			nil	13
GB4	Douglas Bay 1	Habitat	Continuous	SS/PSL	T1	39
GB5	Douglas Bay 2	Habitat	Continuous	SS/PSL	T1	82
GB6	BrigadeBay5	Not Suitable	Continuous		T1	164
GB7	BrigadeBay4	Habitat	Discontinuous	SS	T1	141
GB8	BrigadeBay3	Not Habitat			nil	50
GB9	BrigadeBay2	Not Habitat			nil	107
GB10	BrigadeBay1	Habitat	Discontinuous	SS	T1	46
GB11	HalketBayN	Not Habitat			nil	144
GB12	HalkettBayMrnP3	Habitat	Continuous	SS/PSL	T1	57
GB13	HalkettBayMrnP2	Not Habitat			nil	42
GB14	HalkettBayMrnP1	Not Habitat			nil	210
GB15	HalkettBayWestw	Not Habitat			nil	39
GB16	HalkettBayWest1	Habitat	Continuous	SS/PSL	T1	33
GB17	Camp Fircom	Habitat	discontinuous	SS/PSL	T1	93
GB18	Camp Fircom1	Habitat	Continuous	SS/PSL	T2	99
GB19	Camp Fircom2	Habitat	Discontinuous	SS	T1	21
GB20	Camp Fircom3	Not Habitat			nil	34
GB21	HopePntN6	Habitat	Continuous	SS/PSL	T5	38
GB22	HopePntN5	Habitat	Discontinuous	SS	T4	27
GB23	HopePntN4	Not Habitat			nil	57
GB25	HopePntN2	Habitat	Discontinuous	SS/PSL	T1	43
GB26	HopePntN1	Habitat	Continuous	SS/PSL	T4	27
GB27	HopePnt2	Habitat	Continuous	SS/PSL	T1	48
GB28	HopePnt1	Habitat	Continuous	SS/PSL	T1	17
GB29	PtGraves Estuary	Not Habitat			nil	1324
GB30	CampArtaban1	Habitat	Continuous	SS/PSL	T1	55
GB31	PtGravesPier	Habitat	Continuous	SS/PSL	T1	44
GB32	PtGraves1	Habitat	Discontinuous	SS/PSL	T2	25
GB33	PottsPnt1	Habitat	Continuous	SS/PSL	T2	156
GB34	PottsPnt2	Habitat	Continuous	SS/PSL	T1	62
GB35	PottsPnt3	Not Habitat			nil	52

Appendix A - Beach Units Gambier Island

Gambier Island - Beach Units						
Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Length (m)
GB36	MitchellCove5	Habitat	Discontinuous	SS/PSL	T1	164
GB37	MitchellCove6	Not Habitat			nil	42
GB38	MitchellCove4	Not Habitat			nil	21
GB39	MitchellCove3	Not Habitat			nil	57
GB40	MitchellCove1	Not Habitat			nil	35
GB41	East Bay	Not Suitable			nil	44
GB42	GambierPnt1	Not Suitable			nil	25
GB43	GambierPntS1	Not Habitat			nil	41
GB44	GambierPntS2	Not Habitat			nil	23
GB45	GambierPntS3	Not Habitat			nil	26
GB47	GambierPntS5	Habitat	Discontinuous	SS	T1	64
GB48	MacKenzieCove	Habitat	Discontinuous	SS	T1	18
GB49	WVYachtClub	Habitat	Continuous	SS	T1	27
GB50	CentreBay6	Not Habitat			nil	328
GB51	CentreBayYachtStation	Habitat	Continuous	SS/PSL	T3	19
GB52	CentreBayS1	Not Habitat			nil	89
GB53	Cecil's Landing1	Not Suitable			nil	33
GB54	Cecil's Landing2	Habitat	Continuous	SS	T1	47
GB55	Carmelo4	Habitat	Continuous	SS/PSL	T3	11
GB56	Carmelo3	Habitat	Continuous	SS/PSL	T2	12
GB57A	Carmelo5	Habitat	Continuous	SS/PSL	T1	11
GB58	Carmelo1	Not Habitat			nil	24
GB59	WestBayN5	Habitat	Continuous	SS	T1	58
GB60	WestBayN4	Not Habitat			nil	362
GB61	WestBayN3	Not Habitat			nil	278
GB62	WEstBayN2	Not Habitat			nil	45
GB63	WEstBayN1	Habitat	Discontinuous	SS	T1	89
GB64	HebbPnt4	Not Habitat			nil	28
GB66	Druid Bay	Not Habitat			nil	125
GB67	HebbPnt1	Habitat	Continuous	SS	T1	52
GB68	AvalonByS1	Habitat	Continuous	SS/PSL	T1	23
GB69	Avalon Bay	Not Habitat			nil	134
GB70	Burgess Cove	NotHabitat			nil	131

Appendix A - Beach Units Gambier Island

Gambier Island - Beach Units						
Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Length (m)
GB71	NewBrS2	Not Habitat			nil	136
GB72	NewBrS1	Habitat	Continuous	SS/PSL	T4	21
GB73	NewBrN1	Habitat	Discontinuous	SS/PSL	T4	75
GB74	NewBrN2	Not Habitat			nil	289
GB75	NewBrN3	Habitat	Discontinuous	SS/PSL	T1	82
GB76	NewBrN4	Not Habitat			nil	33
GB77	NewBrN5	Habitat	Continuous	SS/PSL	T2	57
GB78	MannionCk1	Not Habitat			nil	145
GB79	Andys1	Not Habitat			nil	166
GB79	MannionCk2	Habitat	Continuous	SS/PSL	T2	82
GB80	Andys2	Habitat	Continuous	PSL	T3	20

Beach Type Classifications - Gambier Island

Surf smelt Type 1

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB7	BrigadeBay4	T1	SS	140.6
GB10	BrigadeBay1	T1	SS	45.9
GB19	Camp Fircom2	T1	SS	20.8
GB47	GambierPntS5	T1	SS	64.2
GB48	MacKenzieCove	T1	SS	17.8
GB49	WVYachtClub	T1	SS	27.0
GB54	Cecil's Landing2	T1	SS	46.6
GB59	WestBayN5	T1	SS	57.6
GB63	WEstBayN1	T1	SS	89.1
GB67	HebbPnt1	T1	SS	51.5
GB4	Douglas Bay 1	T1	SS/PSL	38.8
GB5	Douglas Bay 2	T1	SS/PSL	81.6
GB12	HalkettBayMrnP3	T1	SS/PSL	56.7
GB16	HalkettBayWest1	T1	SS/PSL	33.4
GB17	Camp Fircom	T1	SS/PSL	93.1
GB25	HopePntN2	T1	SS/PSL	43.3
GB27	HopePnt2	T1	SS/PSL	48.1
GB28	HopePnt1	T1	SS/PSL	16.7
GB30	CampArtaban1	T1	SS/PSL	55.1
GB31	PtGravesPier	T1	SS/PSL	43.5
GB34	PottsPnt2	T1	SS/PSL	62.2
GB36	MitchellCove5	T1	SS/PSL	163.7
GB57A	Carmelo5	T1	SS/PSL	10.7
GB68	AvalonByS1	T1	SS/PSL	22.7
GB75	NewBrN3	T1	SS/PSL	82.4

Appendix B – Beach Types Gambier

Appendix B – Beach Types Gambier Island

Beach Type Classifications - Gambier Island

Surf smelt Type 2

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB1	ThunderbirdYC	T2	SS/PSL	41.0
GB18	Camp Fircom1	T2	SS/PSL	98.6
GB32	PtGraves1	T2	SS/PSL	25.4
GB33	PottsPnt1	T2	SS/PSL	155.6
GB56	Carmelo3	T2	SS/PSL	12.1
GB77	NewBrN5	T2	SS/PSL	57.3
GB79	MannionCk2	T2	SS/PSL	81.8

Surf smelt Type 3

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB51	CentreBayYachtStation	T3	SS/PSL	19.3
GB55	Carmelo4	T3	SS/PSL	11.2

Surf smelt Type 4

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB22	HopePntN5	T4	SS	26.5
GB26	HopePntN1	T4	SS/PSL	27.4
GB72	NewBrS1	T4	SS/PSL	21.4
GB73	NewBrN1	T4	SS/PSL	75.0

Surf smelt Type 5

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB21	HopePntN6	T5	SS/PSL	37.6

Pacific sand lance Type 3

Beach Unit Number	Beach Unit Name	Beach Type	Species	Length (m)
GB80	Andys2	T3	PSL	19.9

Appendix C: Beach Type Grain-Size Curves Gambier Island

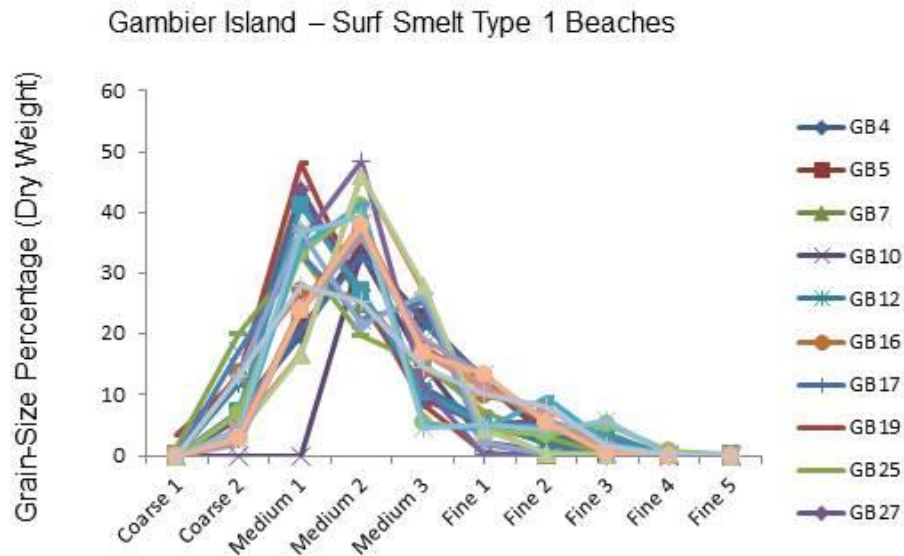


Figure 2 Gambier Island – Surf Smelt Type 1 Beaches

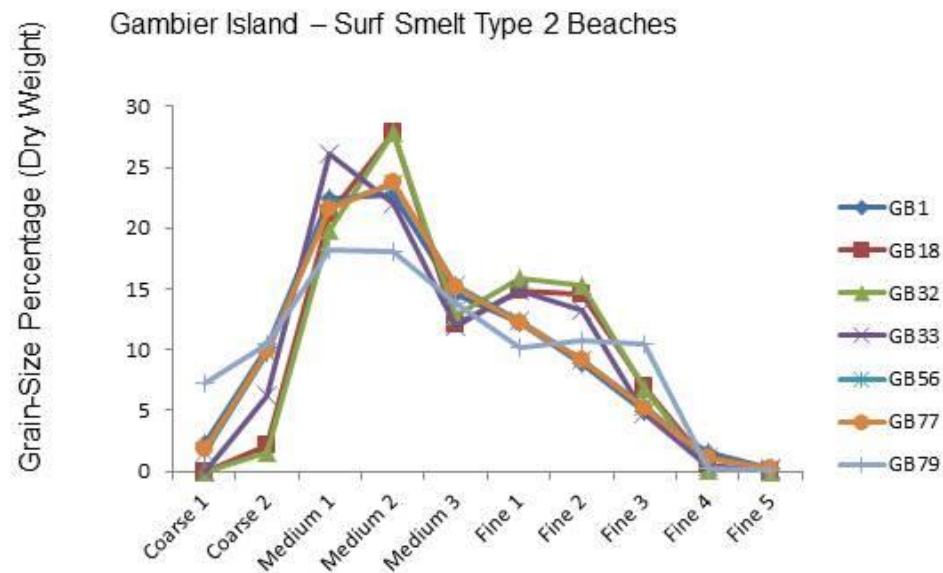


Figure 3: Gambier Island – Surf Smelt Type 2 Beaches

Appendix C: Beach Type Grain-Size Curves Gambier Island

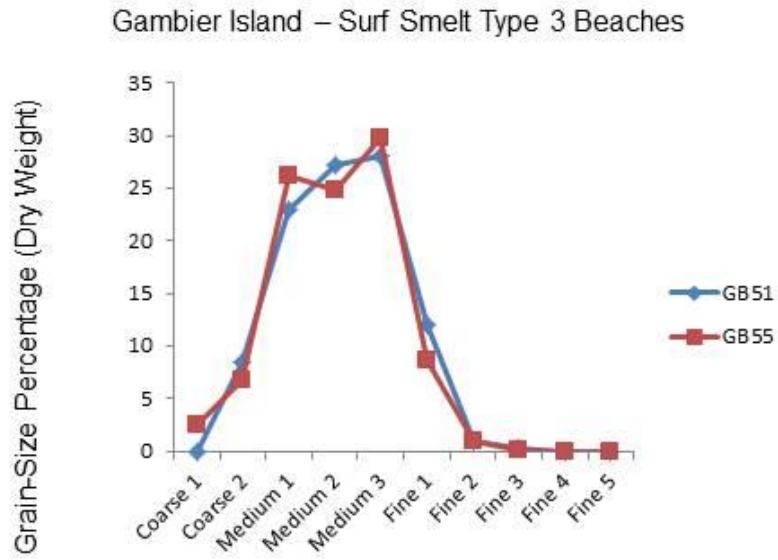


Figure 4: Gambier Island – Surf Smelt Type 3 Beaches

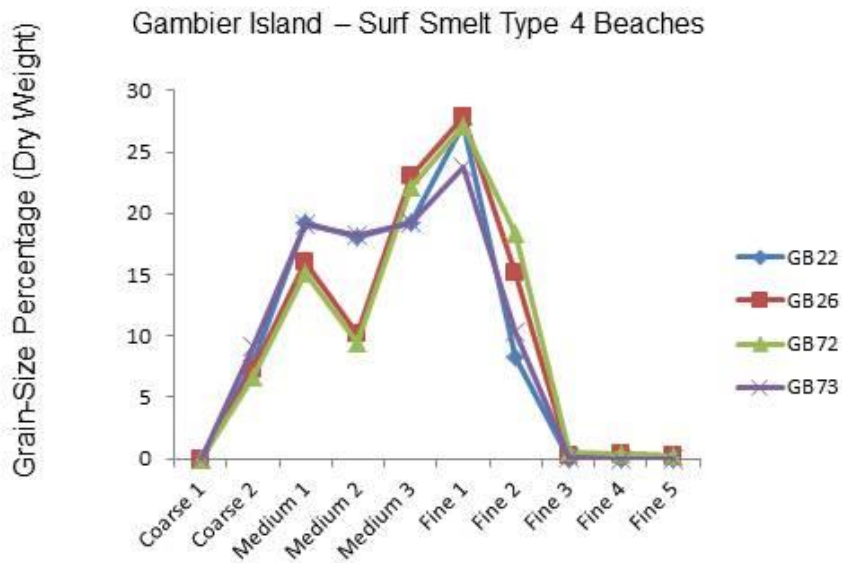


Figure 5: Gambier Island – Surf Smelt Type 4 Beaches

Appendix C: Beach Type Grain-Size Curves Gambier Island

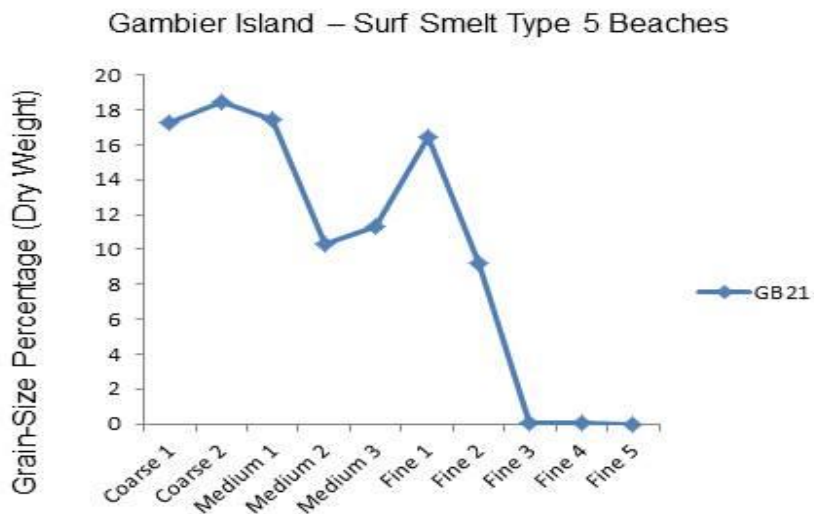


Figure 6: Gambier Island – Surf Smelt Type 5 Beaches

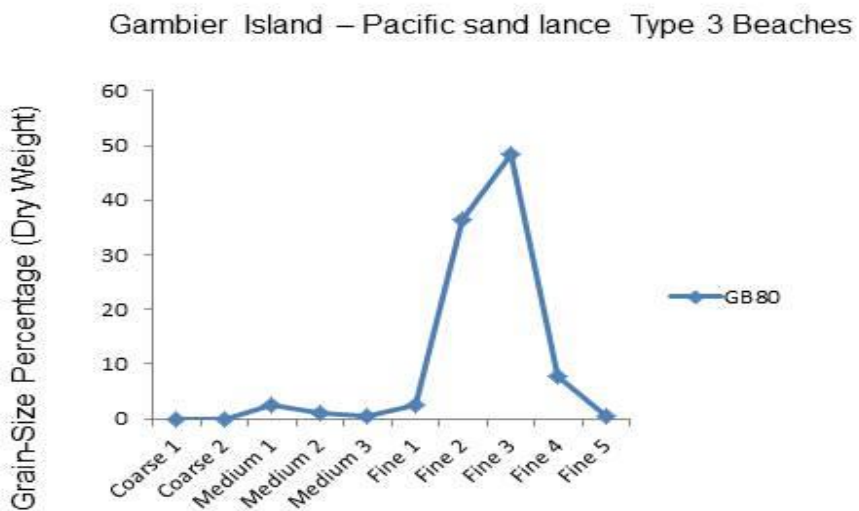


Figure 7: Gambier Island – Pacific sand lance Type 3 Beaches

Appendix D: Beach Units Keats Island

Keats Island - Beach Units

Beach Number	Beach Name	Habitat Class	Sediment Distribution	Species Most Likely	Grain Size Type	Length (m)
KT01	Wreck	Habitat	Continuous	SS/PSL	T3	69.3
KT02	East	Habitat	Discontinuous	SS	T4	60.4
KT03	Maple	Habitat	Discontinuous	SS/PSL	T2	134.4
KT04	Laurels	Habitat	Discontinuous	SS/PSL	T1	113.4
KT05	Andys	Habitat	Continuous	SS	T1	31.4
KT06	West	Habitat	Continuous	SS/PSL	T4	137.9
KT07	Pebble	Habitat	Continuous	SS/PSL	T1	262.0
KT08	HardToComeByCove	Habitat	Continuous	SS/PSL	t1	64.8
KT09	BeachcomerPnt2	Not Habitat	Nil	nil	nil	34.6
KT10	BeachcomerPnt	Habitat	Continuous	SS/PSL	T1	19.9
KT11	Salmon Rock	Habitat	Continuous	SS/PSL	T1	47.7
KT12	SandyS1	Habitat	Continuous	SS/PSL	T1	27.5
KT13	Sandy	Habitat	Continuous	SS/PSL	T4	76.9
KT14	PlumperS1	Habitat	Discontinuous	SS/PSL	T1	173.1
KT15	PlumperS2	Not Habitat	Nil	nil	nil	42.4
KT16	PlumperS3	Habitat	Discontinuous	SS/PSL	T1	148.6
KT17	PlumperS4	Habitat	Discontinuous	SS/PSL	T1	186.0
KT18	PlumperS5	Not Habitat	Nil	nil	nil	88.9
KT19	PlumperS6	Habitat	Continuous	SS/PSL	T4	30.6
KT20	PlumperS7	Not Habitat	Nil	nil		70.6
KT21	PlumperCove3	Habitat	Continuous	SS/PSL	T2	125.2
KT22	PlumperCove2	Habitat	Continuous	SS/PSL	T1	31.0
KT23	PlumperCoveNeg	Not Habitat	Nil	nil	NIL	53.6
KT24	PlumperCove1	Habitat	Discontinuous	SS/PSL	T3	130.3
KT25	PlumperN1	Not Habitat	Nil	nil	NIL	99.7
KT26	PlumperN2	Habitat	Continuous	SS	T3	132.5
KT27	Plumper10	Habitat	Continuous	SS	T1	33.6

Beach Type Classifications - Keats Island

Surf smelt Type 1

Beach Number	Beach name	Grain Size Type	Species	Length (m)
KT05	Andys	T1	SS	31.4
KT27	Plumper10	T1	SS	33.6
KT08	HardToComeByCove	t1	SS/PSL	64.8
KT11	Salmon Rock	T1	SS/PSL	47.7
KT16	PlumperS3	T1	SS/PSL	148.6
KT17	PlumperS4	T1	SS/PSL	186.0
KT04	Laurels	T1	SS/PSL	113.4
KT07	Pebble	T1	SS/PSL	262.0
KT10	BeachcomerPnt	T1	SS/PSL	19.9
KT14	PlumperS1	T1	SS/PSL	173.1
KT12	SandyS1	T1	SS/PSL	27.5
KT22	PlumperCove2	T1	SS/PSL	31.0

Surf smelt Type 2

Beach Number	Beach name	Grain Size Type	Species	Length (m)
KT03	Maple	T2	SS/PSL	134.4
KT21	PlumperCove3	T2	SS/PSL	125.2

Surf smelt Type 3

Beach Number	Beach name	Grain Size Type	Species	Length (m)
KT26	PlumperN2	T3	SS	132.5
KT24	PlumperCove1	T3	SS/PSL	130.3
KT01	Wreck	T3	SS/PSL	69.3

Surf smelt Type 4

Beach Number	Beach name	Grain Size Type	Species	Length (m)
KT02	East	T4	SS	60.4
KT06	West	T4	SS/PSL	137.9
KT19	PlumperS6	T4	SS/PSL	30.6
KT13	Sandy	T4	SS/PSL	76.9

Appendix F: Beach Type Grain-Size Curves Keats Island

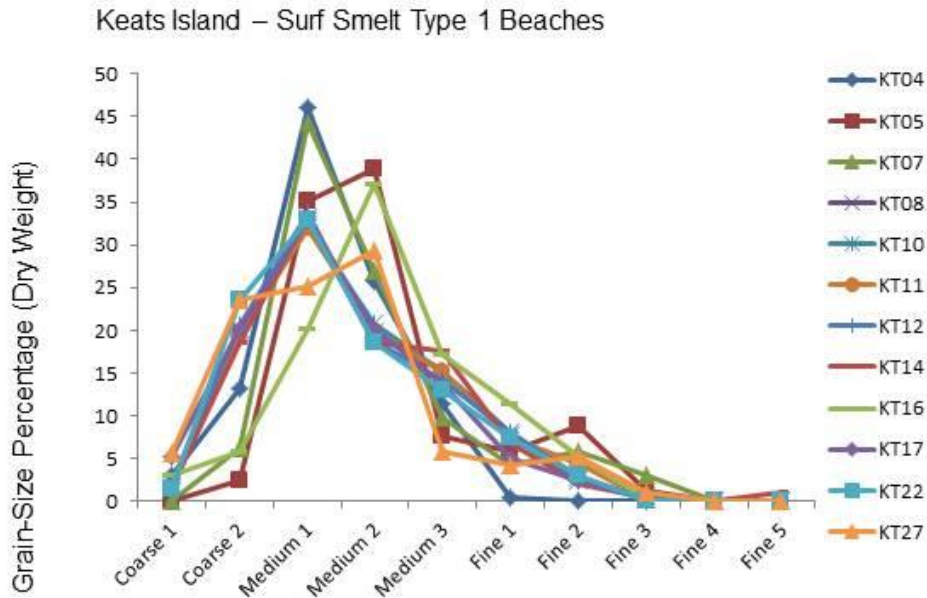


Figure 9 Gambier Island – Surf Smelt Type 1 Beaches

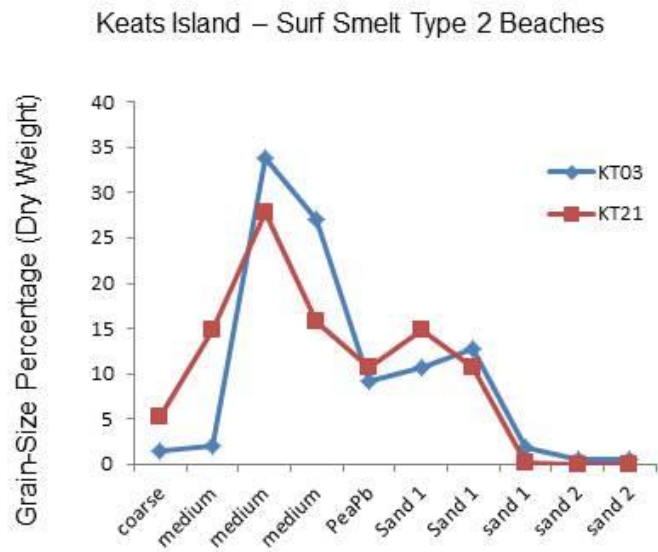


Figure 10: Keats Island – Surf Smelt Type 2 Beaches

Appendix F: Beach Type Grain-Size Curves Keats Island

Keats Island – Surf Smelt Type 3 Beaches

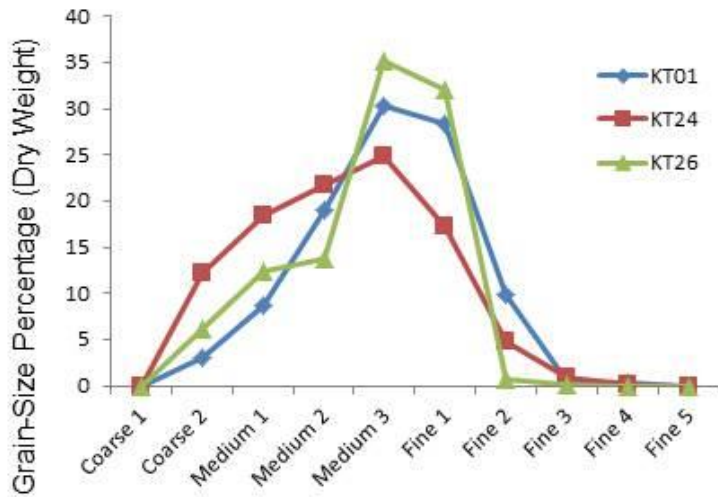


Figure 11: Keats Island – Surf Smelt Type 3 Beaches

Keats Island – Surf Smelt Type 4 Beaches

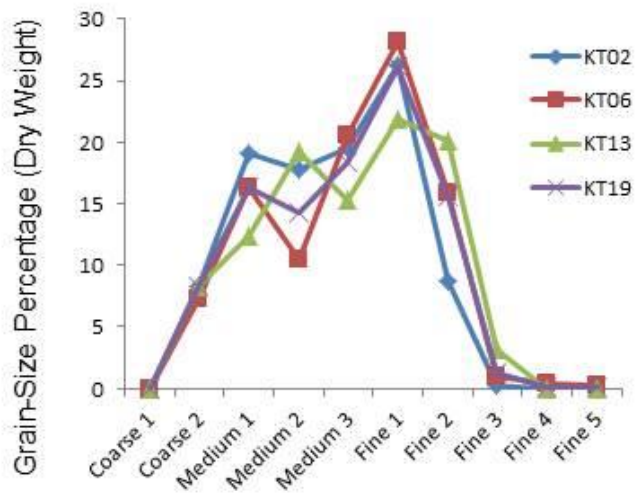


Figure 12: Keats Island – Surf Smelt Type 4 Beaches

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 <ul style="list-style-type: none">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.

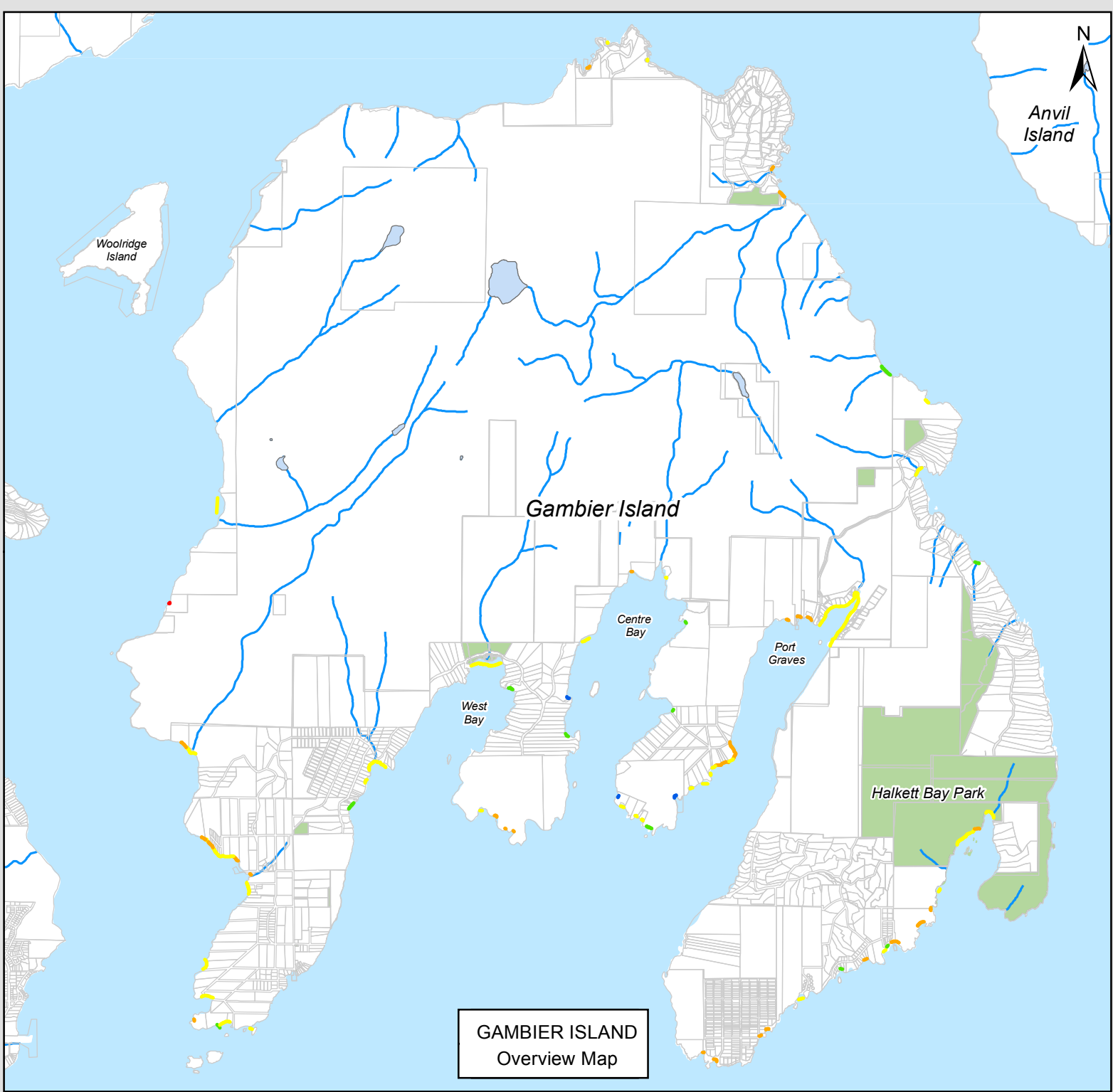
Habitat – Declared Potential Habitat (Yes) or Not Habitat (No) while in the field. This is based on the observed shore type. For example, cobble shoreline is Not Habitat.

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

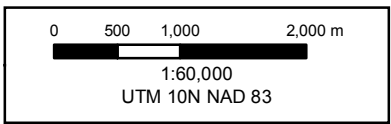
Housed with the Islands Trust Fund and the author



Suitable Forage Fish Spawning Habitat

Suitable Forage Fish Spawning Habitat

- Pacific sand lance
- Surf smelt
- Surf smelt / Pacific sand lance
- Not Suitable Habitat
- Not Habitat
- Cadastral Boundaries
- Parks



Forage Fish Habitat Suitability Assessments by:

BC Marine Conservation and Research Society

Funding Provided by:



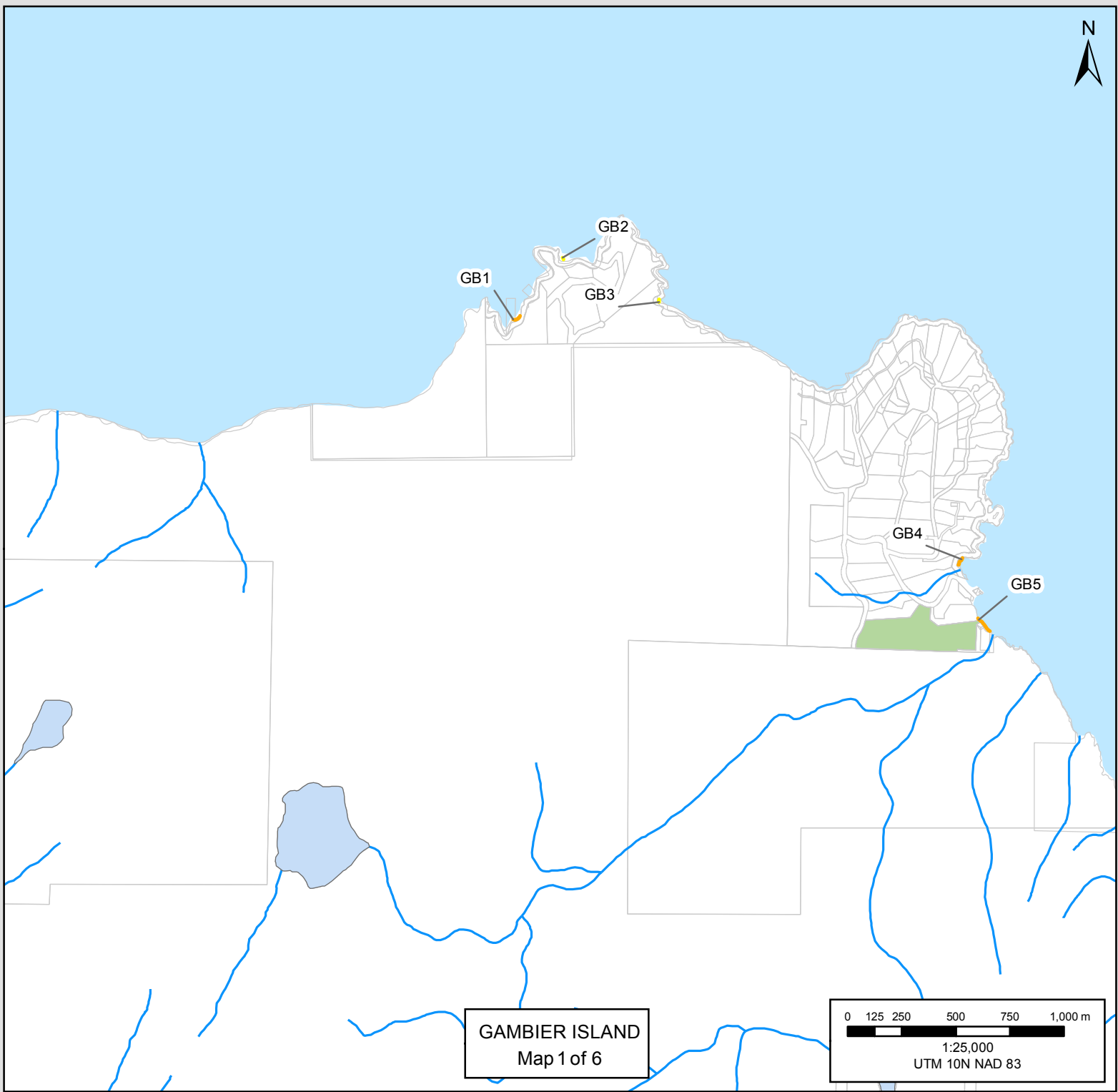
Emerald Sea Biological

Islands Trust

Digital Mapping by: **CHARTWELL Consultants Ltd.**

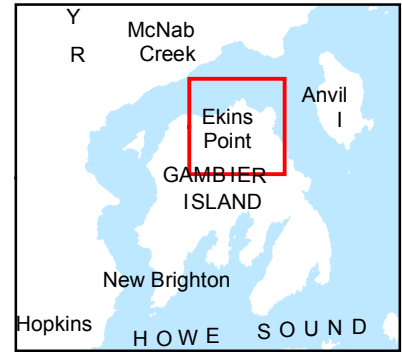
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 Mapping by: JW
 Date: 10/31/2014

GAMBIER ISLAND Overview Map

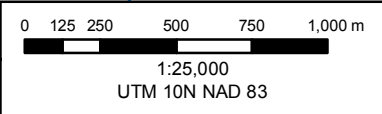


Suitable Forage Fish Spawning Habitat

- Suitable Forage Fish Spawning Habitat**
- Pacific sand lance, Continuous
 - Surf smelt, Continuous
 - - - Surf smelt, Discontinuous
 - Surf smelt / Pacific sand lance, Continuous
 - - - Surf smelt / Pacific sand lance, Discontinuous
 - Not Suitable Habitat
 - Not Habitat
 - Cadastral Boundaries
 - Parks
 - GB1 Beach Number



GAMBIER ISLAND
Map 1 of 6



Forage Fish Habitat Suitability Assessments by:

BC Marine Conservation and Research Society

Funding Provided by:

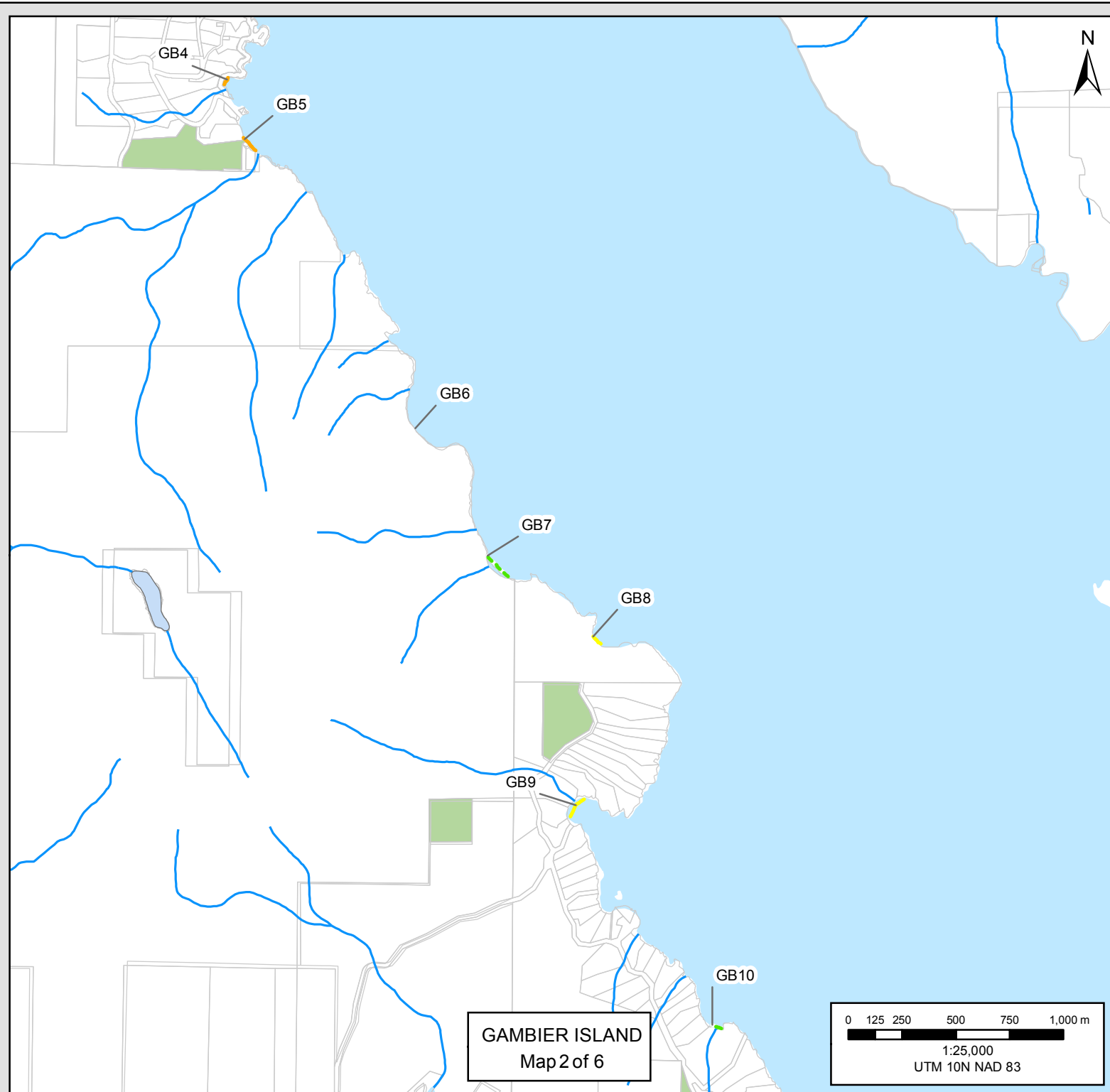


Emerald Sea Biological
Islands Trust

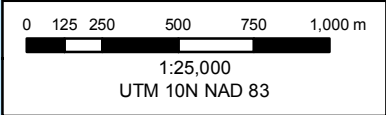
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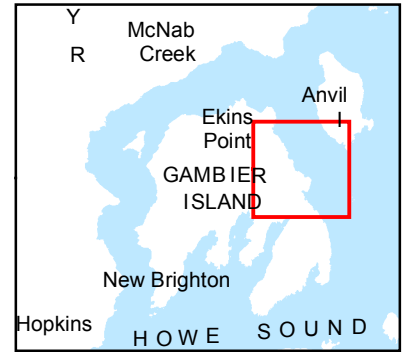


GAMBIER ISLAND
Map 2 of 6






Suitable Forage Fish Spawning Habitat

- Suitable Forage Fish Spawning Habitat**
- Pacific sand lance, Continuous
 - Surf smelt, Continuous
 - - - Surf smelt, Discontinuous
 - Surf smelt / Pacific sand lance, Continuous
 - - - Surf smelt / Pacific sand lance, Discontinuous
 - Not Suitable Habitat
 - Not Habitat
 - Cadastral Boundaries
 - Parks
 - GB1** Beach Number

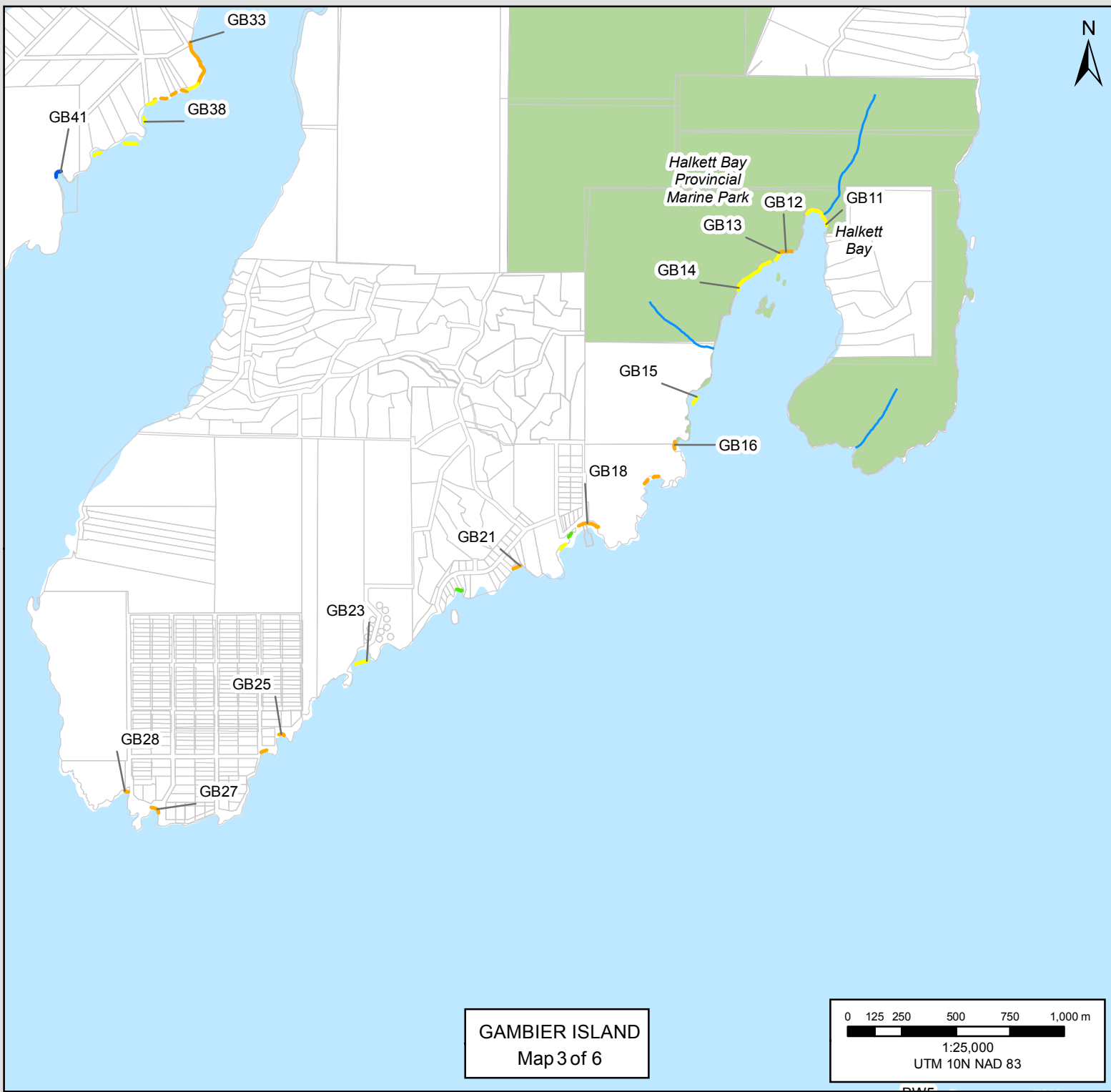


Forage Fish Habitat Suitability Assessments by:
BC Marine Conservation and Research Society

Funding Provided by:
 Emerald Sea Biological
 Islands Trust

Digital Mapping by:
 CHARTWELL Consultants Ltd.

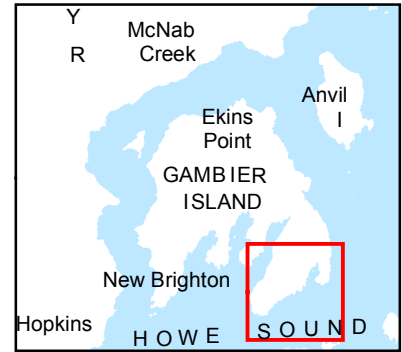
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 Mapping by: JW
 Date: 10/31/2014



GAMBIER ISLAND
Map 3 of 6

Suitable Forage Fish Spawning Habitat

- Suitable Forage Fish Spawning Habitat**
- Pacific sand lance, Continuous
 - Surf smelt, Continuous
 - - - Surf smelt, Discontinuous
 - Surf smelt / Pacific sand lance, Continuous
 - - - Surf smelt / Pacific sand lance, Discontinuous
 - Not Suitable Habitat
 - Not Habitat
 - Cadastral Boundaries
 - Parks
 - GB1 Beach Number



Forage Fish Habitat Suitability Assessments by:

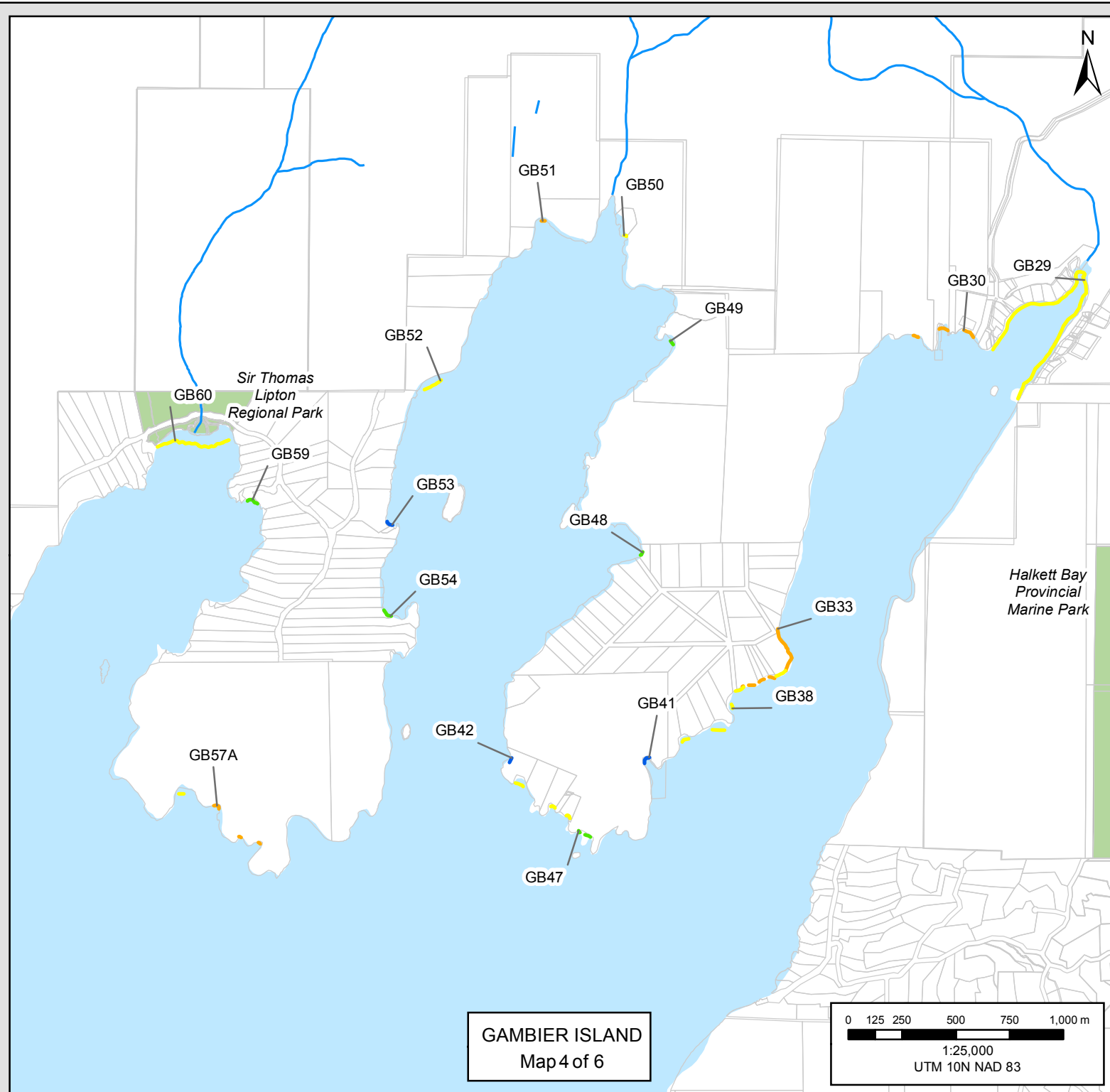
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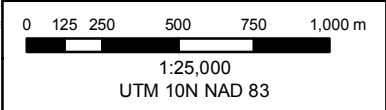


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Date: 10/31/2014



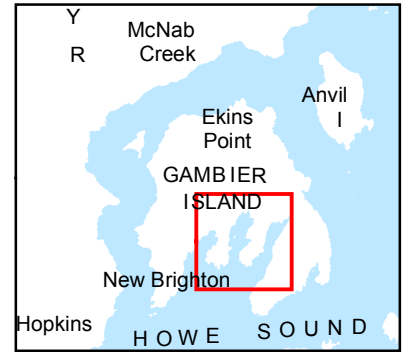
GAMBIER ISLAND
Map 4 of 6



Suitable Forage Fish Spawning Habitat

Suitable Forage Fish Spawning Habitat

- Pacific sand lance, Continuous
- Surf smelt, Continuous
- - - Surf smelt, Discontinuous
- Surf smelt / Pacific sand lance, Continuous
- - - Surf smelt / Pacific sand lance, Discontinuous
- Not Suitable Habitat
- Not Habitat
- Cadastral Boundaries
- Parks
- GB1 Beach Number



Forage Fish Habitat Suitability Assessments by:

BC Marine Conservation and Research Society

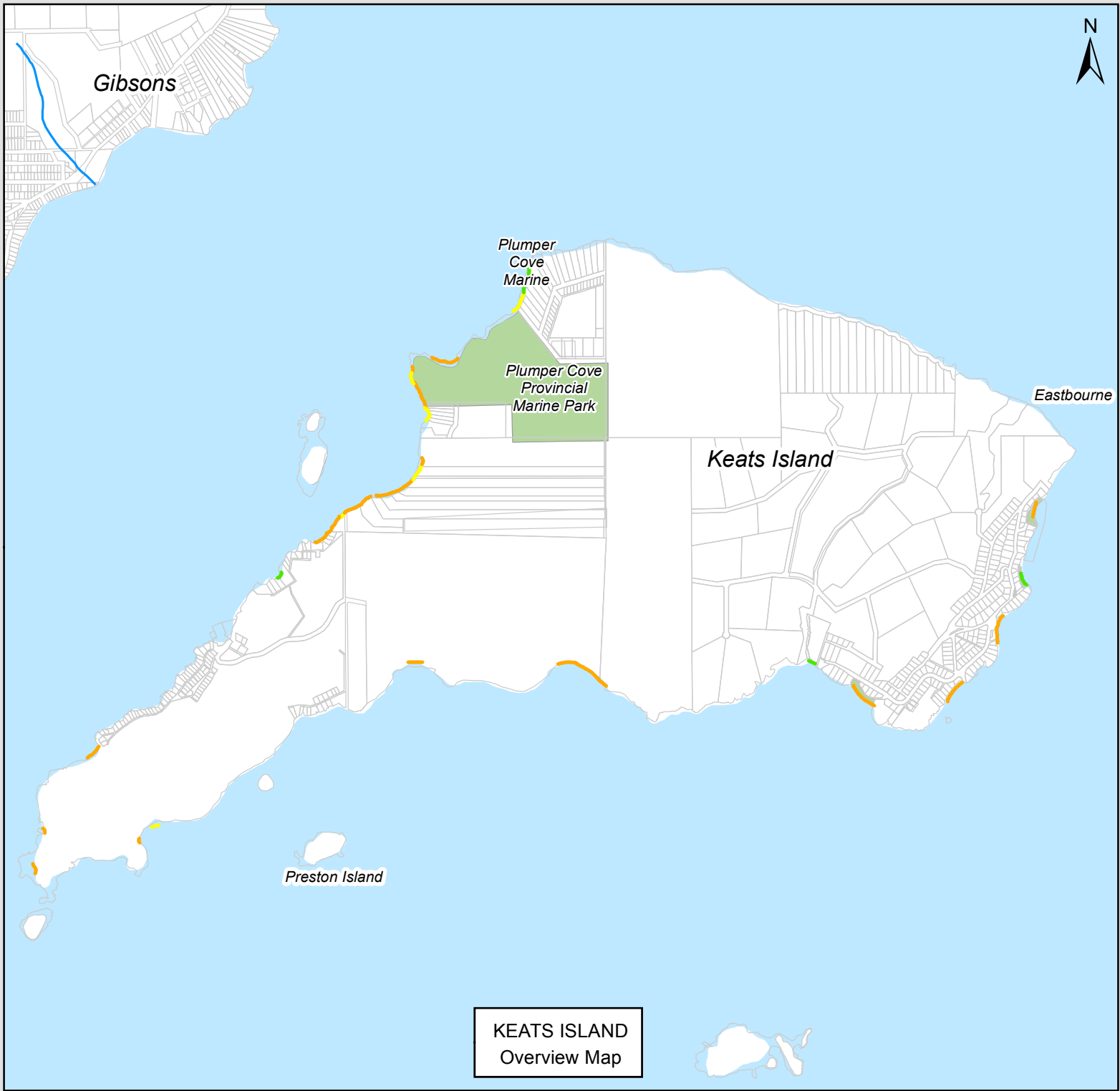
Funding Provided by:

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Islands Trust

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 Mapping by: JW
 Date: 10/31/2014

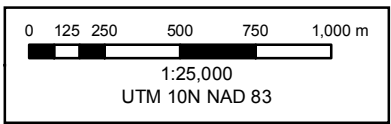


**KEATS ISLAND
Overview Map**



Suitable Forage Fish Spawning Habitat

- Suitable Forage Fish Spawning Habitat**
- Pacific sand lance
 - Surf smelt
 - Surf smelt / Pacific sand lance
 - Not Suitable Habitat
 - Not Habitat
 - Cadastral Boundaries
 - Parks



Forage Fish Habitat Suitability Assessments by:

BC Marine Conservation and Research Society

Funding Provided by:

Emerald Sea Biological

Islands Trust

Digital Mapping by:

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 Date: 10/31/2014



Suitable Forage Fish Spawning Habitat

Suitable Forage Fish Spawning Habitat

- Pacific sand lance, Continuous
- Surf smelt, Continuous
- Surf smelt, Discontinuous
- Surf smelt / Pacific sand lance, Continuous
- Surf smelt / Pacific sand lance, Discontinuous
- Not Suitable Habitat
- Not Habitat
- Cadastral Boundaries
- Parks
- KT01 Beach Number



Forage Fish Habitat Suitability Assessments by:


BC Marine Conservation and Research Society

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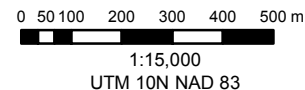
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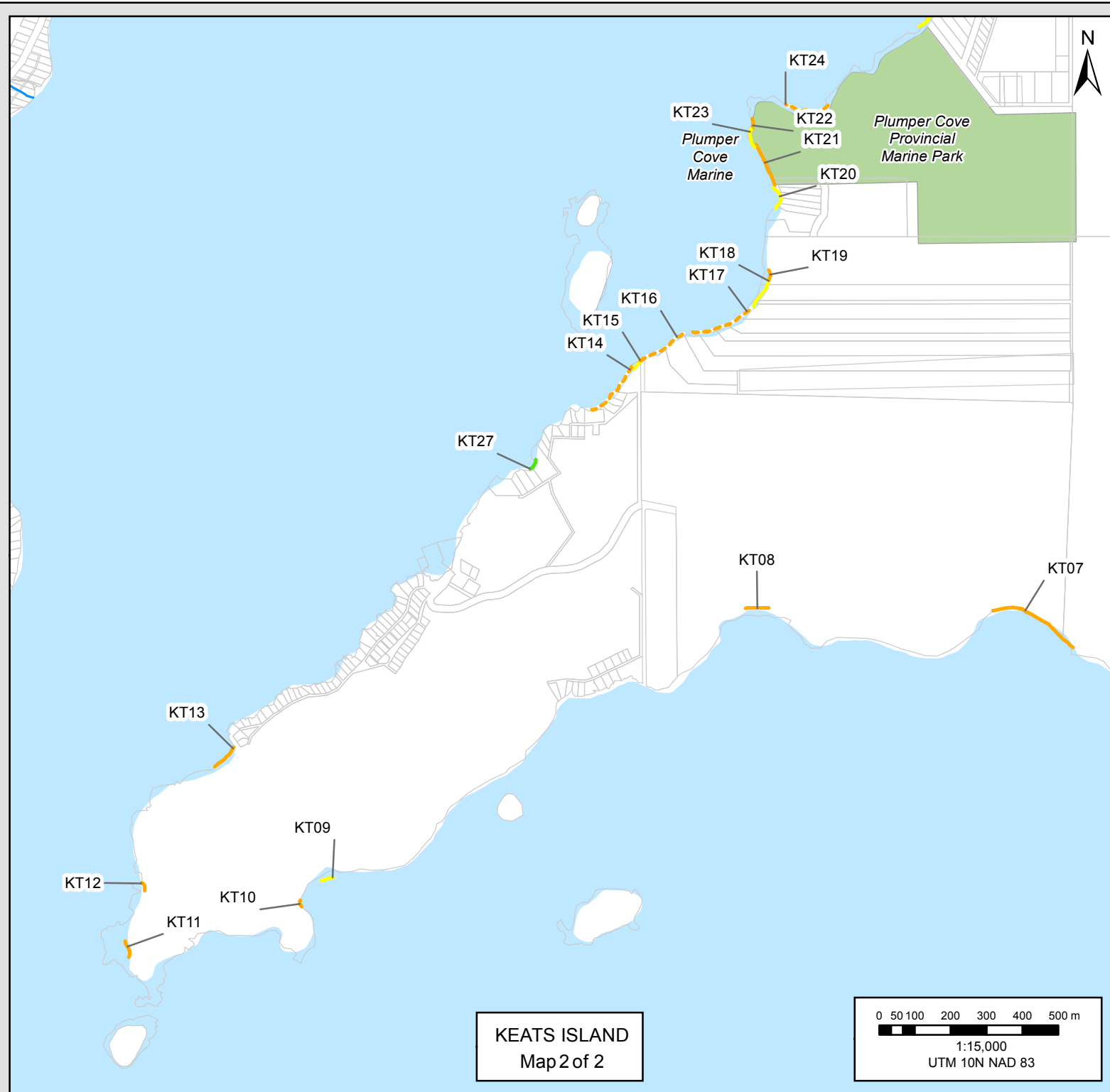
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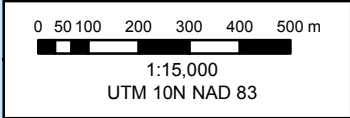
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KEATS ISLAND
Map 1 of 2





KEATS ISLAND
Map 2 of 2





Suitable Forage Fish Spawning Habitat


Suitable Forage Fish Spawning Habitat

- Pacific sand lance, Continuous
- Surf smelt, Continuous
- - - Surf smelt, Discontinuous
- Surf smelt / Pacific sand lance, Continuous
- - - Surf smelt / Pacific sand lance, Discontinuous
- Not Suitable Habitat
- Not Habitat
- Cadastral Boundaries
- Parks
- KT01 Beach Number



Forage Fish Habitat Suitability Assessments by:
BC Marine Conservation and Research Society

Funding Provided by:
 Emerald Sea Biological
 Islands Trust

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