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MCORI Project: 21BCSC0004 **November 2021**

Analysis of Current and Historic Conditions in Roberts Bay, BC

Mermaid Creek Estuary, Roberts Bay

Prepared for:
SeaChange Marine Conservation Society
and
Peninsula Streams Society

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The suggested citation for this report is:
Cook, S. and L. McCormick. 2021. Analysis of Current and Historic Conditions in Roberts Bay, BC. Prepared by Coastal and Ocean Resources, Victoria, B.C. 53 p.

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TABLE OF CONTENTS

SECTION	TITLE	PAGE
	TABLE OF CONTENTS	ii
	LIST OF FIGURES AND TABLES	iii
1	INTRODUCTION AND METHODS	1
2	GROUND SURVEY RESULTS	4
2.1	Site BC21-RB-01	6
2.2	Site BC21-RB-02	11
2.3	Site BC21-RB-03	15
2.4	Site BC21-RB-04	19
2.5	Site BC21-RB-05	23
2.6	Site BC21-RB-06	27
2.7	Drone Imagery Survey	31
2.8	Roberts Bay Substrate Map	32
3	HISTORIC COMMUNITY IMAGERY AND INFORMATION SUMMARY	36
4	HISTORIC AERIAL IMAGERY ANALYSIS	40
5	REFERENCES	52

LIST OF FIGURES AND TABLES

FIGURE	DESCRIPTION	PAGE
1	Map of the Shoal Harbour Migratory Bird Sanctuary boundaries	1
2	Locations of ground survey transects in Roberts Bay	5
3	Location of Site BC21-RB-01 from drone imagery	6
4	Example photos from BC21-RB-01	7
5	Elevation profile for Site BC21-RB-01	8
6	Location of Site BC21-RB-02 from drone imagery	11
7	Example photos from BC21-RB-02	12
8	Elevation profile for Site BC21-RB-02	13
9	Location of Site BC21-RB-03 from drone imagery	15
10	Example photos from BC21-RB-03	16
11	Elevation profile for Site BC21-RB-03	17
12	Location of Site BC21-RB-04 from drone imagery	19
13	Example photos from BC21-RB-04	20
14	Elevation profile for Site BC21-RB-04	21
15	Location of Site BC21-RB-05 from drone imagery	23
16	Example photos from BC21-RB-05	24
17	Elevation profile for Site BC21-RB-05	25
18	Location of Site BC21-RB-06 from drone imagery	27
19	Example photos from BC21-RB-06	28
20	Elevation profile for Site BC21-RB-06	29
21	Examples of drone aerial imagery taken at 300 ft altitude in Roberts Bay	31
22	Map of the substrate types in Roberts Bay	32
23	Map of the substrate types in the north end of Roberts Bay	33
24	Map of the substrate types near the Ardwell Avenue access in Roberts Bay	33
25	Map of the substrate types in Roberts Bay near the mouth of Mermaid Creek	34
26	Map of the substrate types in the south end of Roberts Bay	34
27	Images of seawalls and large boulders placed in Roberts Bay near Ardwell Avenue beach access	36
28	Image of Mermaid Creek salt marsh in front of Roberts Bay residence	36
29	Images of mud shrimp and infaunal holes in Roberts Bay	37
30	Images of other impacts to Roberts Bay as documented by community members	38
31	Examples of wildlife photos taken by residents of Roberts Bay	39
32	Photos from the Mermaid Creek estuary salt marsh taken February 2021	40
33	Mermaid Creek salt marsh polygon from 1964 orthophoto	41
34	Mermaid Creek salt marsh polygon from 1972 orthophoto	42
35	Mermaid Creek salt marsh polygon from 1975 orthophoto	42
36	Mermaid Creek salt marsh polygon from 1980 orthophoto	43
37	Mermaid Creek salt marsh polygon from 1986 orthophoto	43
38	Mermaid Creek salt marsh polygon from 1992 orthophoto	44
39	Mermaid Creek salt marsh polygon from 1999 orthophoto	44
40	Mermaid Creek salt marsh polygon from 2005 orthophoto	45

FIGURE	DESCRIPTION	PAGE
41	Mermaid Creek salt marsh polygon from 2007 orthophoto	45
42	Mermaid Creek salt marsh polygon from 2011 orthophoto	46
43	Mermaid Creek salt marsh polygon from 2013 orthophoto	46
44	Mermaid Creek salt marsh polygon from 2015 satellite image	47
45	Mermaid Creek salt marsh polygon from 2016 satellite image	47
46	Mermaid Creek salt marsh polygon from 2017 orthophoto	48
47	Mermaid Creek salt marsh polygon from 2019 orthophoto	48
48	Mermaid Creek salt marsh polygon from 2021 drone imagery	49
49	Calculated area of the Mermaid Creek salt marsh by year	50
50	A comparison of the extent of the Mermaid Creek salt marsh in 1964 versus 2021	51

TABLE	DESCRIPTION	PAGE
1	Ground station information for the Roberts Bay survey	4
2	General biota observed for biobands at site BC21-RB-01	9
3	General biota observed for biobands at site BC21-RB-02	14
4	General biota observed for biobands at site BC21-RB-03	18
5	General biota observed for biobands at site BC21-RB-04	22
6	General biota observed for biobands at site BC21-RB-05	26
7	General biota observed for biobands at site BC21-RB-06	30
8	Area of the Mermaid Creek estuary salt marsh as measured from the polygons created from the orthophotos and satellite images with calculated carbon storage and sequestration using values from Chastain et al., 2021	49

1 INTRODUCTION AND METHODS

Roberts Bay is located on the east side of the Saanich Peninsula, in the city of Sidney, BC. It is a protected bay surrounded by an urban, residential neighbourhood that has seen significant development over the past 50 years. Roberts Bay is part of the Shoal Harbour Migratory Bird Sanctuary in recognition of the importance of the area to migratory marine bird populations as well as other wildlife (Figure 1). More than 40 species of marine birds are regularly reported in the area including Pacific Great Blue Herons, which are listed as a species at risk in BC (ECCC, 2021). Mermaid Creek empties onto the southern end of the Bay. This small estuary supports a salt marsh consisting mainly of *Sarcocornia pacifica* (American glasswort or pickleweed) at its mouth. An eelgrass bed is growing offshore, the extent and current condition of which is still being assessed. The bay is also known to support spawning of forage fish in the upper intertidal beach sediment on the northern portion of the bay (personal communication, Ian Bruce). Development pressure, contaminants from runoff, riparian habitat removal, shoreline hardening, and long-term boat anchoring are some of the pressures facing Roberts Bay.

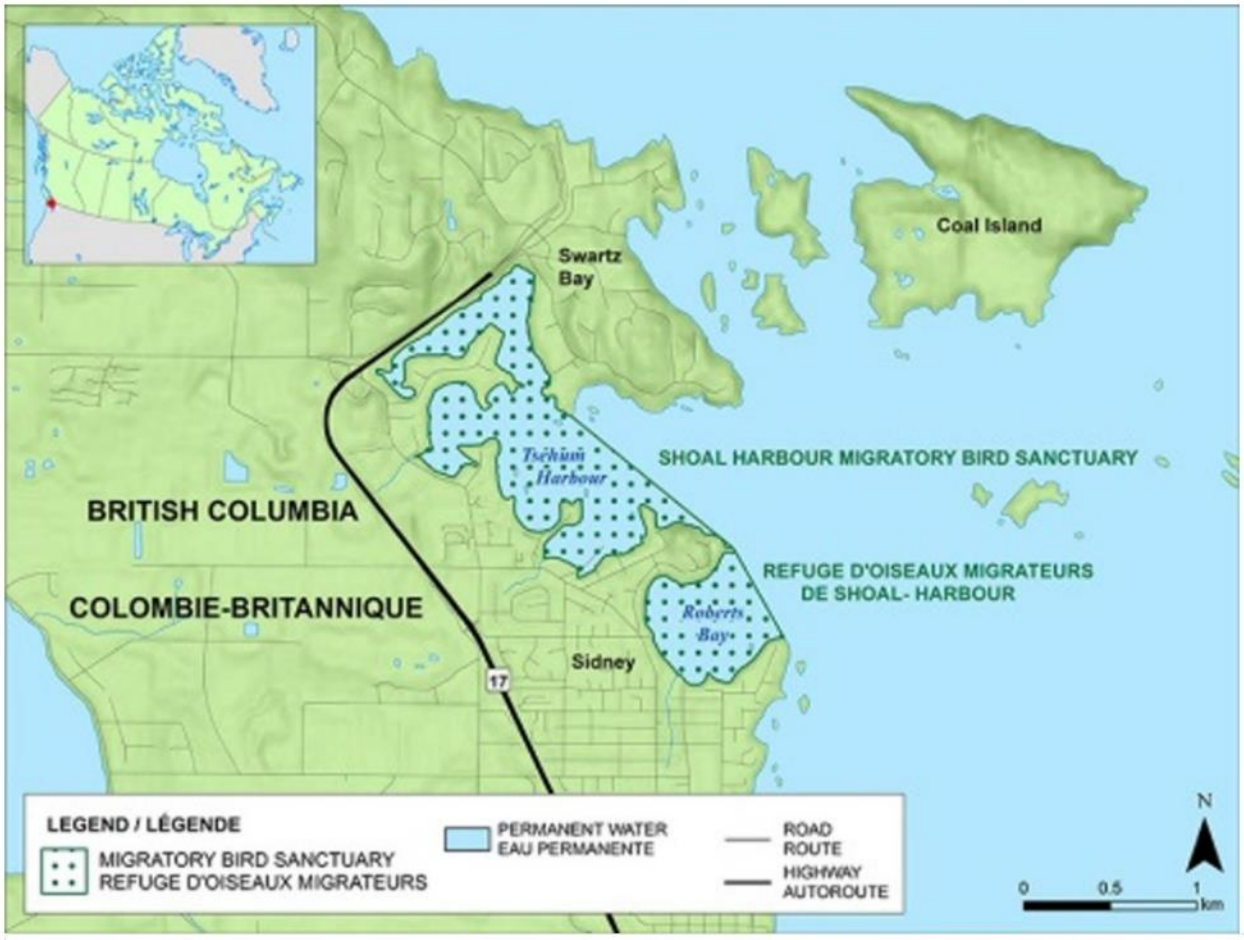

Figure 1. Map of the Shoal Harbour Migratory Bird Sanctuary boundaries, including Roberts Bay (ECCC, 2021).

This project aims to describe the current conditions in Roberts Bay and to assess historic changes that have occurred to the extent that is possible, with particular focus on the salt marsh at the Mermaid Creek estuary. This report is meant to inform decision making regarding restoration efforts in the Bay. These efforts could focus on the salt marsh, the eelgrass bed and the beach sediments. Restoration efforts will likely include both restoring and maintaining ecosystem function as well as the carbon sequestration capacity of the salt marsh and eelgrass bed. The carbon sequestration capacity of coastal ecosystems (including salt marshes, seagrass beds and mangrove forests) is termed 'blue carbon' and despite the relatively small global extent of these habitats, they are disproportionately important in terms of the overall rate of carbon sequestration compared to terrestrial ecosystems (McLeod *et al*., 2011; Duarte *et al*., 2013). Restoration of impacted blue carbon ecosystems have been shown to expand and enhance carbon storage and sequestration for both eelgrass (*Zostera marina*) beds (Greiner *et al*., 2013; Hodgson and Spooner, 2016) and salt marsh habitats (Poppe and Rybczyk, 2021; Crooks *et al*., 2014; Campbell, 2010).

A shore station survey was conducted to detail current conditions in Roberts Bay. A brief description and schematic of the geomorphic and biological characteristics of the ground station were recorded for each site. This information included habitat type, exposure, major features or uniqueness of the site (e.g., adjacent freshwater influx), and the relative placement of substrates, features, and dominant biota within each tidal zone. Representative site photographs were taken from the upper beach towards the waterline and from the lower beach towards the upland habitat to show the across-shore habitat and relative locations of biobands. Site photographs included alongshore and across-shore views to show relative positions and patchiness of substrate and biota and to place the shore station in the context of nearby habitats. Additional site photos focused on individual biobands, species assemblages, or individual species.

A physical transect was placed within each site from the estimated mean high-water line (MHWL) to the waterline at the time we arrive at the station. It was placed to best reflect the overall shoreline habitat observed at that site. The GPS position was recorded at the top of the transect. Profile breaks were established based on changes in biota (e.g., bioband divisions) and/or major substrate or slope changes (e.g., shift from a vertical rock wall to a rock platform or shift from a cobble beach face to a boulder field). Measurements of slope were taken for each unique zone of the beach and were used to calculate vertical elevation compared to the waterline (waterline = 0 m elevation), although the actual elevation of the waterline was later calculated using observed water levels using the nearest Fisheries and Oceans Canada tide station and the date and time the transect was placed. Horizontal measurements were made with a surveyor's measuring tape. Physical and biological characteristics were recorded for each unique zone. The amount of the intertidal zone exposed at each site varied depending on when in the tide cycle it was sampled and where the site was located so caution should be used when comparing data directly between sites. We also assessed a qualitative measure of relative abundance for each taxa which was based on the approximate number of individuals, or percent cover of sessile or attached taxa, within 5 meters either side of each transect, and size of the organism.

Bioband boundaries in the intertidal and supratidal zones were delineated and labeled on the profile sketch such that their relative position along the profile was reflected (vertically and horizontally), with the potential for bands to overlap. The biobands that were defined at each site follow the definitions found in Tables 25, 26 and 27 of the 2017 ShoreZone protocol (Cook *et al*., 2017). The ShoreZone framework was used as it provides a convenient and consistent way to organize the biota at each site. Detailed photographs were taken of each bioband to document species assemblages. Within each intertidal bioband, observed species were identified to the lowest taxonomic level along a 10 m swath

on either side of the measuring tape with an estimate of relative abundance. The relative abundance categories used were:

- Abundant: the organism occurs in large numbers throughout most of a band.
- Frequent: the organism is present in moderate numbers throughout most of a band.
- Occasional: the organism occurs sporadically or in small patches within a band.
- Rare: only a few isolated individuals of the organism occur in a band.
- Present: the species was noted but relative abundance was not assessed.

These abundance estimates were scaled to the size of individual organisms and their ecology. For example, a dozen Sunflower Stars (*Pycnopodia helianthoides*) in the swath would be considered abundant, whereas it would take many thousands of the Acorn Barnacle (*Balanus glandula*) in the same area to be considered abundant. Quadrat data was not collected during these surveys as the marsh and mud flat habitat types that dominated the survey area are not described well using quadrat methodology.

All data was entered in an updated version of the MS Access BC ShoreZone ground station database (kindly provided by Archipelago Marine Research Ltd.) with some modifications made to attach links to all the photo files and to accommodate quadrat data if it is collected. All data were reviewed following data entry for accuracy and completeness.

A drone survey to collect aerial imagery of Roberts Bay was conducted during the May 28th low tide window as well. This survey was to provide a broad assessment of sediment distribution on the beach and was meant to be used in conjunction with the ground survey data. The drone took images at 300ft, which would make it comparable to ShoreZone aerial imagery taken of the Bay in 2004, and also at 100ft to provide higher resolution images for mapping purposes.

The assessment of current conditions in Roberts Bay, including results from the ground survey and interpretation of the drone imagery, is presented in Section 2.

To assess historic conditions and details changes that have occurred over time in the bay, Peninsula Stream Society and Coastal & Ocean Resources engaged with the Roberts Bay Resident Association and the Friends of Shoal Harbour to ask community members for historic photos of Roberts Bay or qualitative observations of change over time. This information was compiled and assessed by CORI staff and is summarized in Section 3 of this report.

In order to assess change to the Mermaid Creek salt marsh, CORI sourced historic orthophotos and satellite images, georeferenced them and created polygons of the areal extent of the salt marsh. The salt marsh was identified by texture and colour, where the images were in colour. The area of each polygon was calculated in ArcMap. The results of this analysis is presented in Section 4.

The eelgrass bed offshore in Roberts Bay was surveyed by SeaChange Conservaton Society to support a potential restoration project. That data was not included in this summary report but should be considered as an addendum once it is available.

2 GROUND SURVEY RESULTS

The CORI team surveyed 6 transects in Roberts Bay during the low tide window on May 28th, 2021. Ground station site information is provided in Table 1 with locations shown in Figure 2.

Table 1. Ground station information for the Roberts Bay survey.

Station Name	Date	Time at Station	Tide Height (m)	Latitude	Longitude	Site Description
BC21-RB-01	28-May-21	12:38	0.50	48.66539	123.40075	Rock and gravel ramp
BC21-RB-02	28-May-21	12:45	0.55	48.66547	123.40343	Rocky platform with sand and gravel tide flat
BC21-RB-03	28-May-21	11:38	0.09	48.66375	123.40392	Sand and gravel beach with tidal flat
BC21-RB-04	28-May-21	12:00	0.25	48.66265	123.40318	Sand and gravel beach with tidal flat
BC21-RB-05	28-May-21	10:35	-0.16	48.66082	123.40134	Marsh with delta and sand/gravel tide flat
BC21-RB-06	28-May-21	10:29	-0.16	48.660278	123.39789	Sand and gravel beach with tidal flat

During the survey we observed 74 unique taxa, including aquatic or terrestrial vascular plants, algae, invertebrates and fish. We identified all to the lowest taxonomic level possible.

Detailed descriptions of the geomorphological and biological attributes observed in-situ for each shore station are presented in the following sections. These descriptions include satellite images with shore station locations, aerial ShoreZone images showing the surveyed beaches, photos highlighting geomorphology, biobands, algae, and invertebrates, and a beach profile showing distribution of substrates and biobands. The relative abundance of the taxa observed in each bioband are also presented in a table in each section. Note that a 'Bare' bioband in the ground survey does not mean that there were no species present. This designation reflects an area devoid of a distinct algal or invertebrate bioband which may still have scattered individuals present. This area typically occurs in the high intertidal and/or low supratidal zone or on sediments which are too mobile to have attached fauna. There is no Bare Bioband for the ShoreZone habitat mapping protocol so those bands have no equivalent in the classification database.

Figure 2. Locations of ground survey transects in Roberts Bay.

2.1 Site BC21-RB-01

Site BC21-RB-01 was located on the north end of Roberts Bay. The intertidal portion of the site consisted of a rock ramp with a veneer of boulder and cobble. The supratidal part of the beach was an eroding diamicton cliff consisting of clay/mud/sand with cobble and what appeared to be chunks of concrete vegetated with terrestrial trees and shrubs. It seems likely the cliff is actually eroding fill that was used to extend the yards of the residential properties along this part of the beach. Figure 3 is an aerial drone photo of the site with the transect location marked. Figure 4 shows example photos from the site survey and Figure 5 shows an elevation profile of the site with substrate types and biobands indicated. The weather during the survey was overcast warm and sunny.

Figure 3. Location of ground survey site BC21-RB-01 in Roberts Bay. See Table 1 for exact coordinates and Figure 2 for the general location of the site in Roberts Bay.

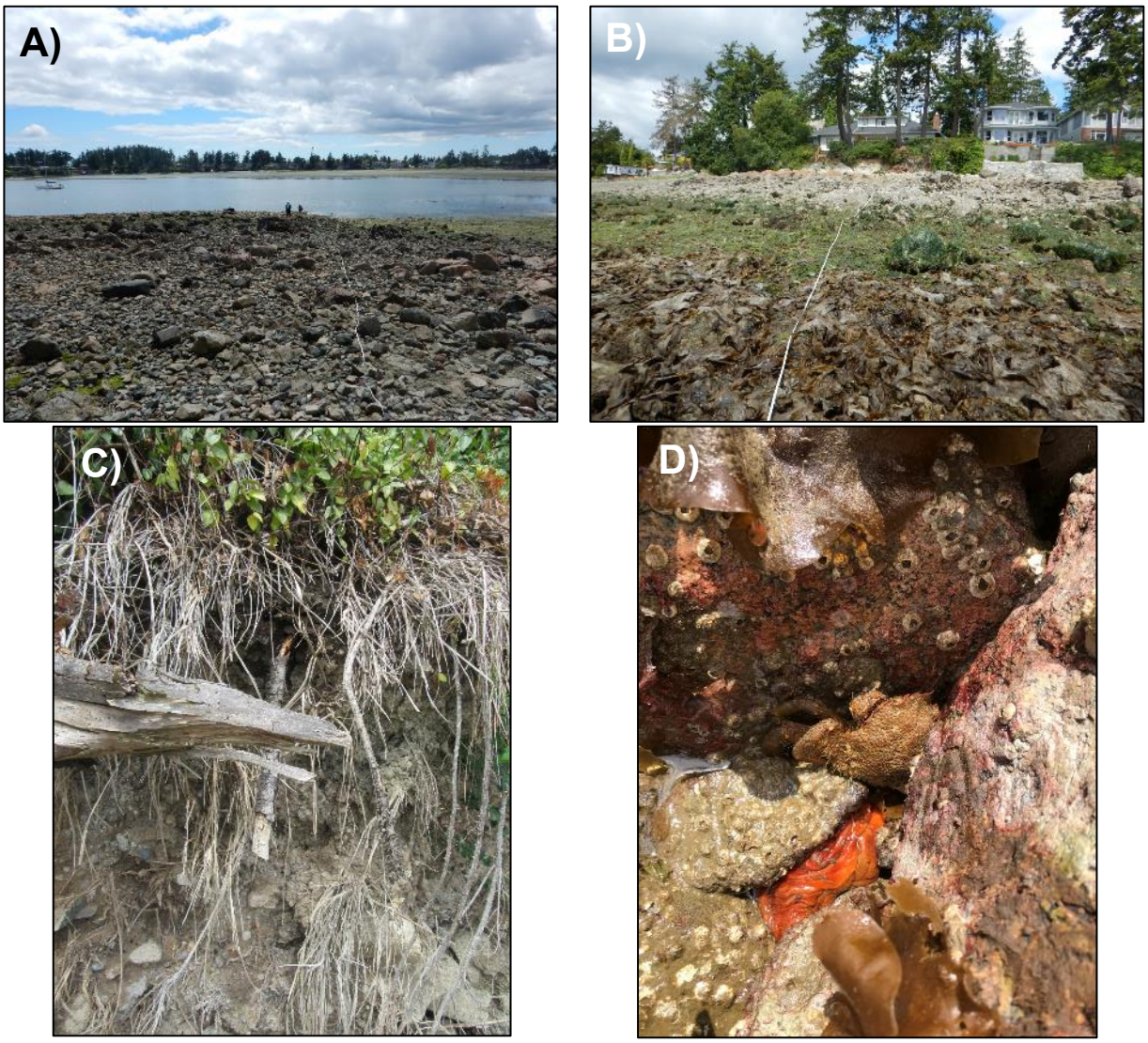

Figure 4. A) View of Site BC21-RB-01 looking from the top of the transect to the waterline, B) Looking from the waterline to the top of the transect, C) The eroding diamicton/fill cliff in the supratidal, and D) Close-up of some boulders in the lower intertidal including a Helmet Crab (*Telmessus cheiragonus*), Plumose anemone (*Metridum senile*), encrusting coralline algae and acorn barnacles (*Balanus* sp.).

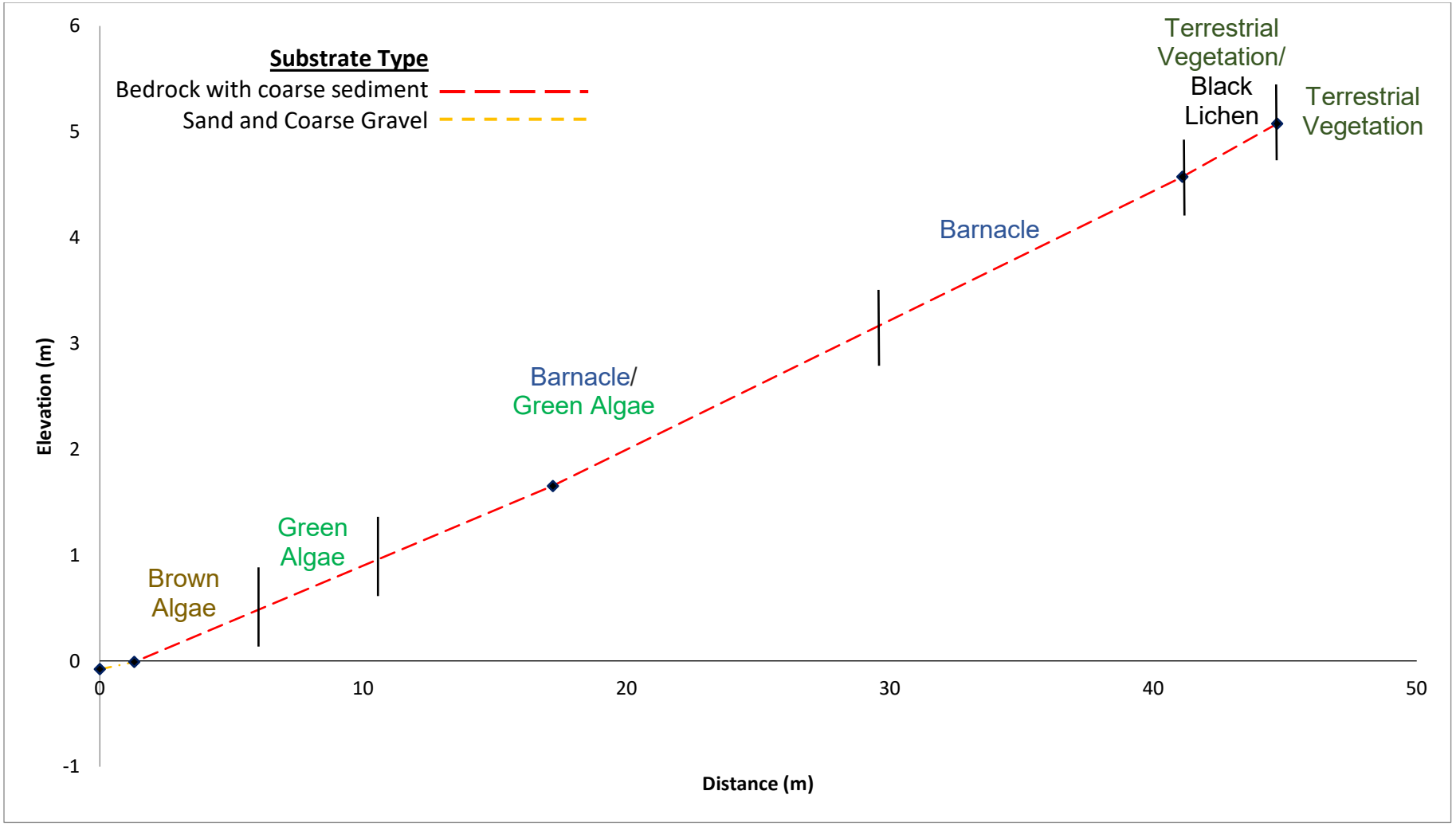

Figure 5. Elevation profile of Site BC21-RB-01 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada.

The biota observed in the general assessment of the biobands at Site BC21-RB-01 is presented in Table 2 along with an estimation of relative abundance within each band. The species found at this site were fairly typical of a protected rocky shoreline, although there was a skim of fine sediment on some of the boulder and rock surfaces that may have inhibited more attachment of sessile organisms. It should be noted that two introduced species were recorded at this site: Japanese Wireweed (*Sargassum muticum*) and Japanese Oyster (*Crassotrea gigas*). While neither were very abundant, the Wireweed in particular is concerning as it is has been expanding its range over the southern coast of BC (Coastal and Ocean Resources, 2021) and is considered invasive in neighboring Washington State (although it is not listed as such here in BC). There is significant literature available on the impacts of introduced Japanese Wireweed with somewhat conflicting conclusions, as some studies find negative impacts on native species (DeWreede and Vandermeulen, 1988; Britton-Simmons, 2004) and some finding little to no impacts (Sanchez and Fernandez, 2005; Olabarria *et al*., 2009). White (2003) studied the effects of *S. muticum* on macroalgal communities and grazing invertebrates in BC and found that the effects of introduction were both density and time dependent and were mediated through competition for light and also that the effects went in both positive and negative directions depending on the species being studied.

Table 2. General biota observed for the biobands at Site BC21-RB-01 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A	Terrestrial Vegetation	ATRIPA	*Atriplex patula*	Orache	Patchy
A	Terrestrial Vegetation	POTEAN	*Potentilla anserina* ssp. *pacifica*	Silverweed	Patchy
A	Terrestrial Vegetation/Black Lichen	VERRUC	*Verrucaria* sp.	Black Crust	Patchy
B1	Barnacle	HILDSP	*Hildenbrandia* sp.	Thalloid red algae	
B1	Barnacle	LITTSP	*Littorina* sp.	Periwinkle snail	Occasional
B1	Barnacle	LOTTSP	*Lottidae sp.*	Unidentified limpet	Rare
B1	Barnacle	ENTESP	*Enteromorpha* sp.	Wrinkled green tube seaweed	
B1	Barnacle	FUCUDI	*Fucus distichus*	Rockweed	
B1	Barnacle	MASTPA	*Mastocarpus papillatus*	Small papillate straps	
B1	Barnacle	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Frequent
B2	Barnacle/Green Algae	HEMISP	*Hemigrapsus* sp.	Shore crab	Rare
B2	Barnacle/Green Algae	CRASGI	*Crassostrea gigas*	Japanese Oyster	Frequent
B2	Barnacle/Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Abundant
B2	Barnacle/Green Algae	MASTPA	*Mastocarpus papillatus*	Small papillate straps	
B2	Barnacle/Green Algae	ENDOMU	*Endocladia muricata*	Thin dark spiny wires	
B2	Barnacle/Green Algae	LOTTSP	*Lottidae*	Unidentified limpet	Frequent
B2	Barnacle/Green Algae	LITTSP	*Littorina* sp.	Periwinkle snail	Frequent
B2	Barnacle/Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Barnacle/Green Algae	LEATDI	*Leathesia difformis*	Convoluted yellow sac	Rare
B2	Barnacle/Green Algae	FUCUDI	*Fucus distichus*	Rockweed	
B2	Barnacle/Green Algae	MYTITR	*Mytilus trossulus*	Blue Mussels	Rare
B2	Barnacle/Green Algae	ISOPOD	*Isopod* sp.	Unidentified isopod	Rare

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
B2	Barnacle/Green Algae	PAGUSP	*Pagurus* sp.	Unidentified hermit crab	Rare
B2	Barnacle/Green Algae	SERPUL	*Serpulidae*	Tube worms	Rare
B2	Barnacle/Green Algae	SNAILS	Snail sp.	Unidentified snail	Occasional
B2	Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Occasional
B2	Green Algae	LITTSP	*Littorina* sp.	Periwinkle snail	Occasional
B2	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Green Algae	AGARCL	*Agarum clathratum*	Sieve Kelp	
B2	Green Algae	BOSSSP	*Bossiella* sp.	Coralline algae	
B2	Green Algae	SARGMU	*Sargassum muticum*	Japanese wireweed	
B2	Green Algae	LOTTSP	*Lottidae*	Unidentified limpet	Occasional
B2	Green Algae	SCYPHO	*Scyphozoa sp.*	Unidentified jellyfish	Occasional
B2	Green Algae	ANEMSP	unidentified anemone sp.	Unidentified anemone	Rare
B2	Green Algae	FUCUDI	*Fucus distichus*	Rockweed	
B2	Green Algae	EPIAPR	*Epiactis prolifera*	Brooding anemone	Rare
B2	Green Algae	PODOCE	*Pododesmus macrochisma*	Jingle shell	Rare
B2	Green Algae	LEATDI	*Leathesia difformis*	Convoluted yellow sac	Rare
B2	Green Algae	CHITSP	unidentified chiton sp.	Unidentified chiton	Frequent
B2	Green Algae	FUCUSP	*Fucus* sp.	Rockweed	
B2	Green Algae	FOLRED	unidentified foliose red sp.	Unidentified foliose reds	
B3	Brown Algae	LEATDI	*Leathesia difformis*	Convoluted yellow sac	Rare
B3	Brown Algae	FOLRED	unidentified foliose red sp.	Unidentified foliose reds	
B3	Brown Algae	CHITSP	unidentified chiton sp.	Unidentified chiton	Abundant
B3	Brown Algae	AGARCL	*Agarum clathratum*	Sieve kelp	
B3	Brown Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B3	Brown Algae	SARGMU	*Sargassum muticum*	Japanese wireweed	
B3	Brown Algae	BOSSSP	*Bossiella* sp.	Coralline algae	
B3	Brown Algae	EPIAPR	*Epiactis prolifera*	Brooding anemone	Rare
B3	Brown Algae	EVASTR	*Evasterias troschelii*	Mottled star	Rare
B3	Brown Algae	PODOCE	*Pododesmus cepio*	Jingle shell	Occasional
B3	Brown Algae	SERPUL	*Serpulidae*	Unidentified calcareous Tube worms	Occasional
B3	Brown Algae	HEMISP	*Hemigrapsus* sp.	Shore crab	Rare
B3	Brown Algae	PAGUSP	*Pagurus* sp.	Unidentified hermit crab	Rare
B3	Brown Algae	PUGESP	*Pugettia* sp.	Kelp crab	Rare
B3	Brown Algae	TELMCH	*Telmessus cheiragonus*	Helmet Crab	Rare
B3	Brown Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Frequent

2.2 Site BC21-RB-02

Site BC21-RB-02 was located at the north end of Roberts Bay, in an area with an exposed rock platform at the top of the beach and a large sand/gravel/fines tide flat below that. Figure 6 is an aerial drone photo of the site with the transect location marked. Figure 7 shows example photos from the site survey and Figure 8 shows an elevation profile of the site with substrate types and biobands indicated.

Figure 6. Location of ground survey site BC21-RB-02, in Roberts Bay. See Table 1 for exact coordinates and Figure 2 for the general location of the site in Roberts Bay.

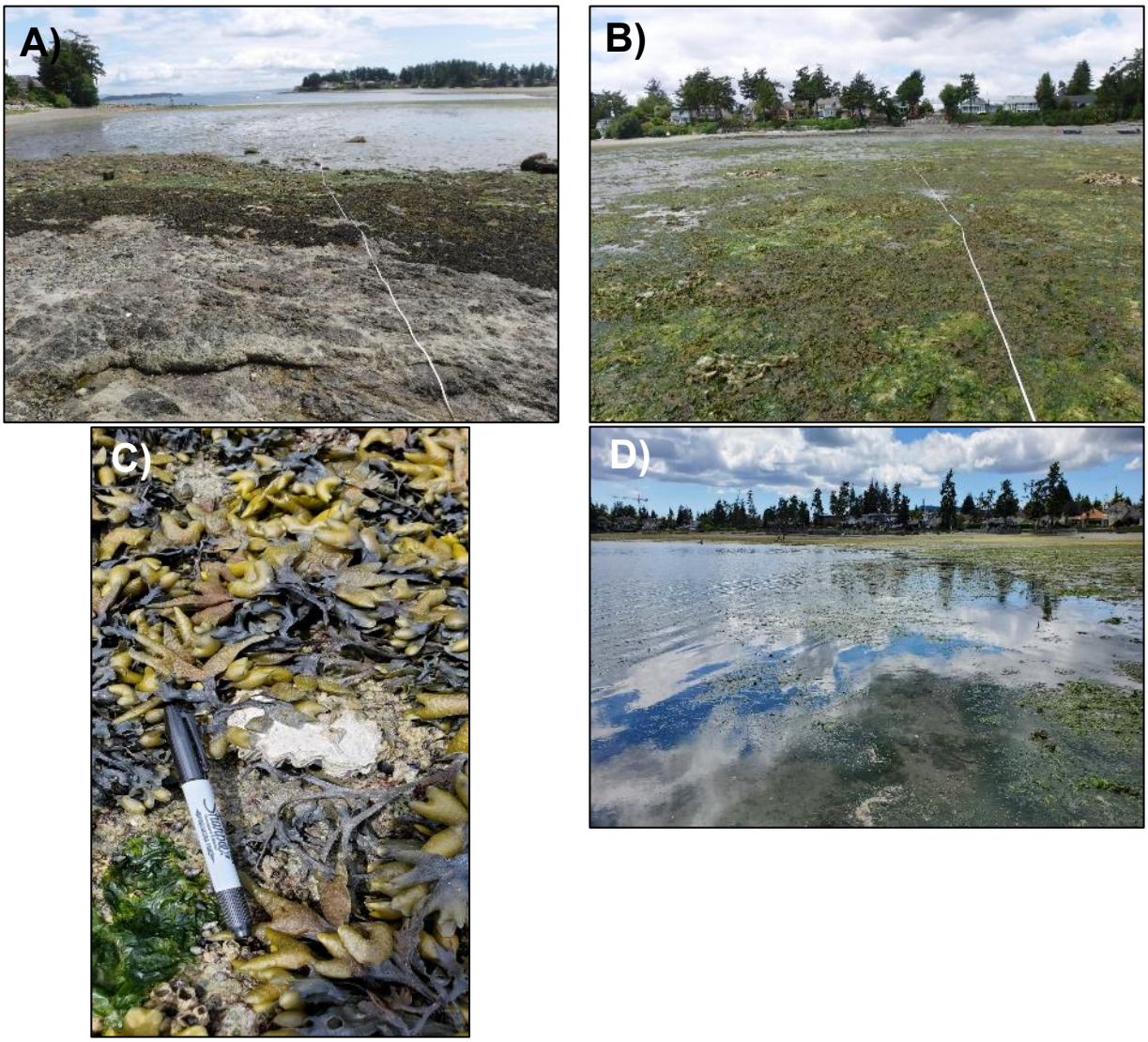

Figure 7. A) View of Site BC21-RB-02 from the top of the transect looking to the waterline, B) From the waterline looking to the top of the transect, C) Close-up of the Rockweed (*Fucus* sp.) and Japanese Oyser (*Crassotrea gigas*) on the upper rock platform, and D) The Eelgrass (*Zostera marina*) patch in the subtidal.

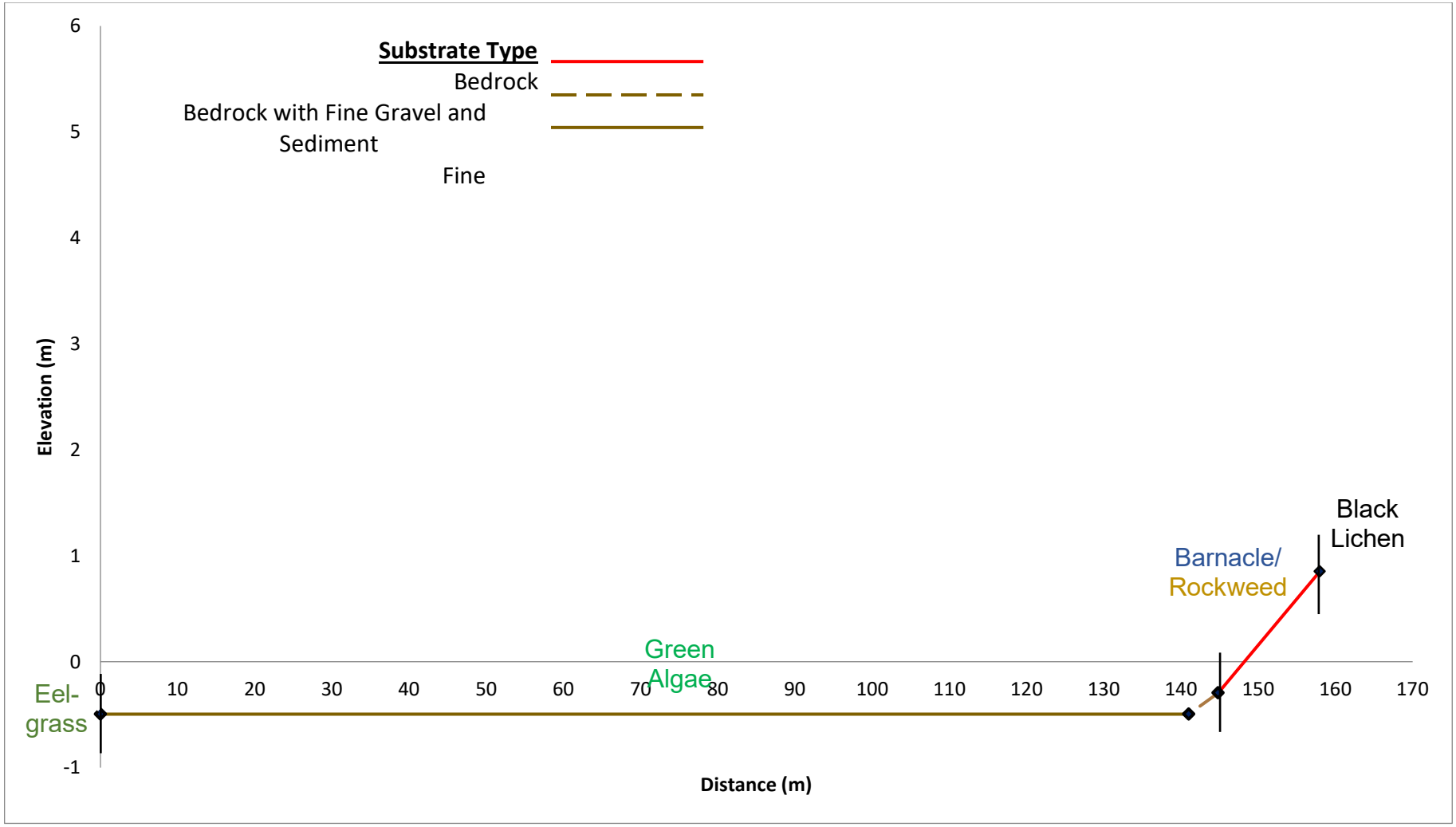

Figure 8. Elevation profile of Site BC-21-RB-02 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada.

The biota observed in the general assessment of the biobands at site BC21-RB-02 is presented in Table 3 along with an estimation of relative abundance within each band. European Wall Lizards (*Podarcis muralis*) were noted in the supratidal at this site. These are an invasive species in BC and are abundant around Victoria, although the potential effects on native species remain relatively unknown in BC. Himalayan Blackberry (*Rubus armenicus*) was also noted in the supratidal at this site and is also a well-established invasive species in BC.

Table 3. General biota observed for the biobands at Site BC21-RB-02 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A	Black Lichen	LICHEN	Unidentified lichen sp.	Unidentified lichen	Present
A	Black Lichen	YELLLI	yellow lichen	yellow lichen	Present
A	Black Lichen	GRINSP	*Grindelia integrifolia*	Gumweed	Present
A	Black Lichen	TARAOF	*Taraxacum officinale*	Common Dandelion	Present
A	Black Lichen	HEDEHE	*Hedera helix*	English Ivy	Present
A	Black Lichen	RUBUBI	*Rubus armeniacus*	Himalayan Blackberry	Present
A	Black Lichen	PODMUR	*Podarcis muralis*	European wall lizard	Present
A	Black Lichen	SYMPAL	*Symphoricarpos albus var. albus*	Common Snowberry	Present
A	Black Lichen	AMYGDA	Subfamily Amygdaloideae	Stone fruit trees	Present
B1	Barnacle/Rockweed	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B1	Barnacle/Rockweed	FUCUDI	*Fucus distichus*	Rockweed	
B1	Barnacle/Rockweed	HILDSP	*Hildenbrandia* sp.	Thalloid red algae	
B1	Barnacle/Rockweed	MASTPA	*Mastocarpus papillatus*	Small papillate straps	
B1	Barnacle/Rockweed	LEATDI	*Leathesia difformis*	Convoluted yellow sac	Rare
B1	Barnacle/Rockweed	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Abundant
B1	Barnacle/Rockweed	MYTITR	*Mytilus trossulus*	Blue mussel	Frequent
B1	Barnacle/Rockweed	LOTTSP	*Lottidae*	Unidentified limpet	Frequent
B1	Barnacle/Rockweed	HEMISP	*Hemigrapsus* sp.	Shore crab	Occasional
B1	Barnacle/Rockweed	NUCESP	*Nucella* sp.	*Nucella* snail	Rare
B1	Barnacle/Rockweed	REDALG	unident red algae	Unidentified red algae	
B1	Barnacle/Rockweed	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Green Algae	DIATOM	Diatoms	Diatoms	
B2	Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B2	Green Algae	HEMISP	*Hemigrapsus* sp.	Shore crab	Rare
B2	Green Algae	ENTEMO	*Enteromorpha intestinalis*	Sea lettuce	
B2	Green Algae	SCYPHO	*Scyphozoa* sp.	Unidentified Jellyfish	Rare
B2	Green Algae	REDALG	Unidentified red algae	Unidentified red algae	
C1	Eelgrass	CHLOPL	Unidentified green algae	Unidentified green algae	Present
C1	Eelgrass	ZOSTMA	*Zostera marina*	Eelgrass	Present

2.3 Site BC21-RB-03

Site BC21-RB-03 was located in the middle of the northern end of Roberts Bay and has a sand and gravel beach up high and sand/gravel/fines tide flat below. Figure 9 is an aerial drone photo of the site with the transect location marked. Figure 10 shows example photos from the site survey and Figure 11 shows an elevation profile of the site with substrate types and biobands indicated.

Figure 9. Location of ground survey site BC21-RB-03, in Roberts Bay. See Table 1 for exact coordinates and Figure 2 for the general location of the site in Roberts Bay.

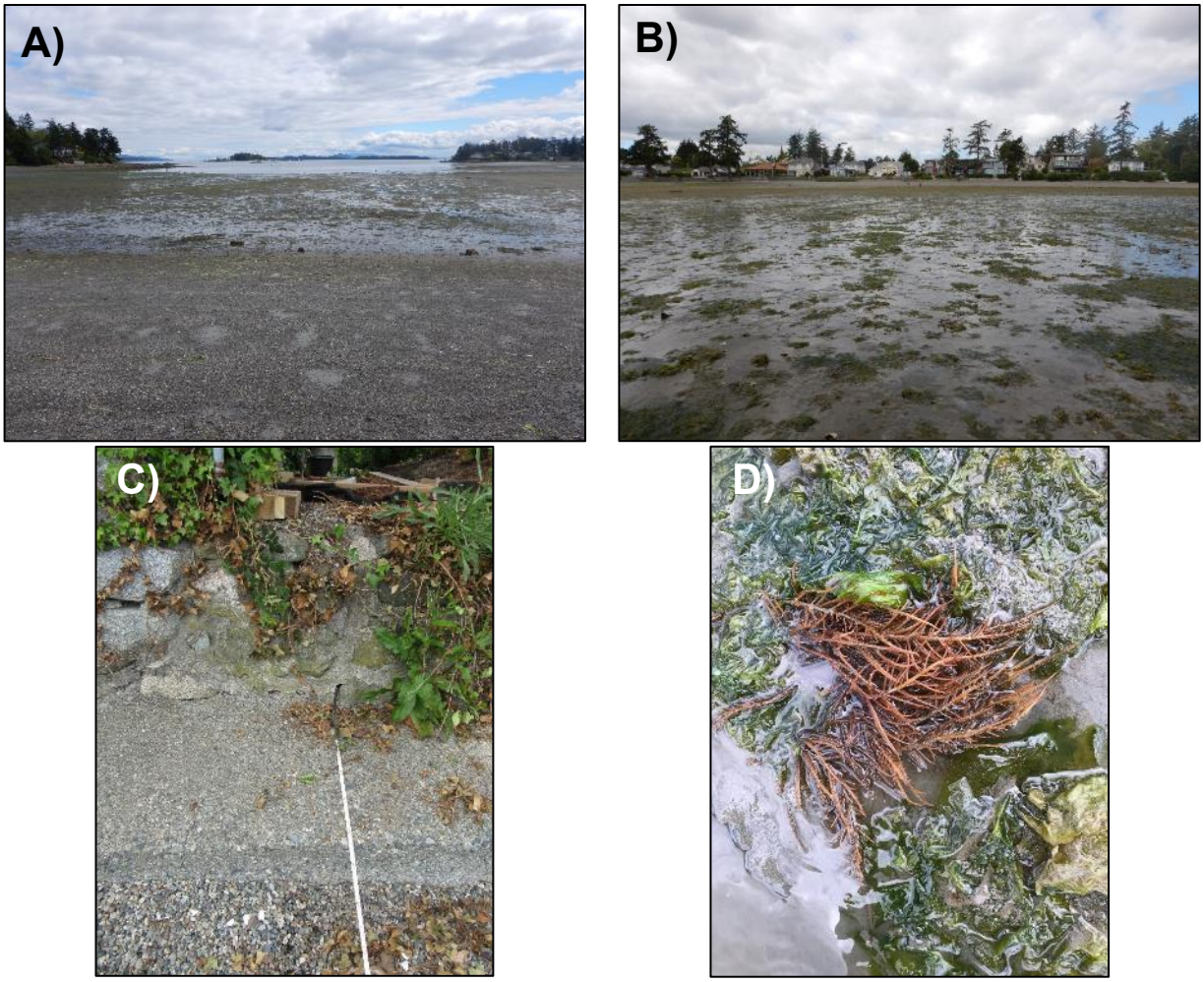

Figure 10. A) View of Site BC21-RB-03 from the top of the transect looking to the waterline, B) From the waterline looking to the top of the transect, C) Rock wall in the surpratidal, and D) Filamentous red algae mixed with foliose green algae on the tidal flat.

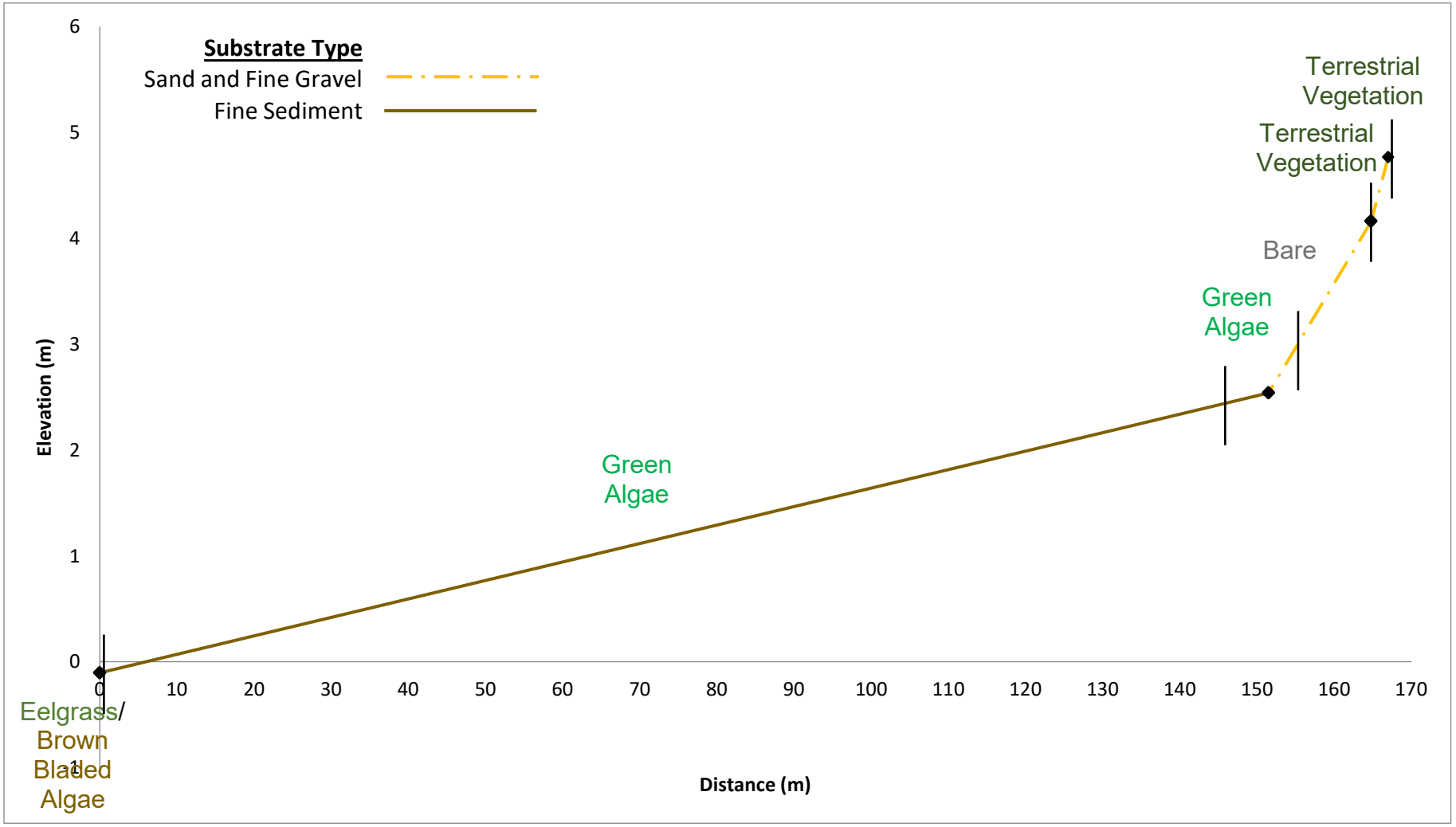

Figure 11. Elevation profile of Site BC21-RB-03 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada

The biota observed in the general assessment of the biobands at site BC21-RB-03 is presented in Table 4 along with an estimation of relative abundance within the band. The supratidal at this site was a seawall at the base of a residential lot. Shoreline hardening such as this was common along the shoreline of Roberts Bay and would dramatically decrease erosion of sediment on to the beach. Native eelgrass (*Zostera marina*) was noted in the subtidal. Small patches of Dune Grass (*Leymus mollis*) were noted adjacent to this transect.

Table 4. General biota observed for the biobands at Site BC21-RB-03 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A1	Terrestrial Vegetation	ASTEUN	Family Asteraceae	Unidentified Aster	Present
A1	Terrestrial Vegetation	HEDEHE	*Hedera helix*	English Ivy	Present
A2	Terrestrial Vegetation	RUMESP	*Rumex* sp.	Docks and sorrels	Present
A2	Terrestrial Vegetation	ATRIPA	*Atriplex patula*	Orache	Present
B1	Bare	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B2	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Unidentified sea lettuce	
B2	Green Algae	ENTEMO	*Enteromorpha intestinalis*	Stringy sea lettuce	
B2	Green Algae	DIATOM	Diatoms	Diatoms	
B2	Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B2	Green Algae	MYTITR	*Mytilus trossulus*	Blue mussel	Rare
B2	Green Algae	PHAESP	Unidentified brown algae	Unidentified brown algae	
B3	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Unidentified sea lettuce	
B3	Green Algae	ENTEMO	*Enteromorpha intestinalis*	Stringy sea lettuce	
B3	Green Algae	DIATOM	Diatoms	Diatoms	
B3	Green Algae	FILRED	Unidentified filamentous red algae	Unidentified filamentous red algae	
B3	Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B3	Green Algae	HAMIVE	*Haminoea vescicula*	Bubble shell	Frequent
B3	Green Algae	HAMIVE	*Haminoea vescicula*	Bubble shell egg mass	Frequent
B3	Green Algae	SCULSP	Sculpinidae, other	Unidentified sculpin	Occasional
B3	Green Algae	SNAILS	Unidentified snail	Unidentified snail	Rare
B3	Green Algae	PHAESP	Unidentified brown algae	Unidentified brown algae	
B3	Green Algae	CLINSP	*Clinocardium* sp.	Unidentified heart cockle	Rare
C1	Eelgrass/Brown Bladed Algae	ULVASP	*Ulva/Ulvaria* sp.	Unidentified sea lettuce	
C1	Eelgrass/Brown Bladed Algae	DIATOM	Diatoms	Diatoms	
C1	Eelgrass/Brown Bladed Algae	ZOSTMA	*Zostera marina*	Eelgrass	Abundant
C1	Eelgrass/Brown Bladed Algae	LAMISA	*Saccharina latissima*	Sugar kelp	
C1	Eelgrass/Brown Bladed Algae	FISHSP	Unidentified fish species	Unidentified fish species	Rare
C1	Eelgrass/Brown Bladed Algae	PHAESP	Unidentified brown algae	Unidentified brown algae	

2.4 Site BC21-RB-04

Site BC21-RB-04 was located at the beach access at the end of Ardwell Avenue. This site appears to be in a relict delta feature indicating it is likely a creek used to empty on to the beach here. A culverted storm drain empties on to the beach currently and it is possible this is the remnant of a stream system. It is also a minor source of sediment to the beach. Figure 12 is an aerial drone photo of the site with the transect location marked. Figure 13 shows example photos from the site survey and Figure 14 shows an elevation profile of the site with substrate types and biobands indicated.

Figure 12. Location of ground survey site BC21-RB-04 in Roberts Bay. See Table 1 for exact coordinates and Figure 2 for the general location of the site in Roberts Bay.

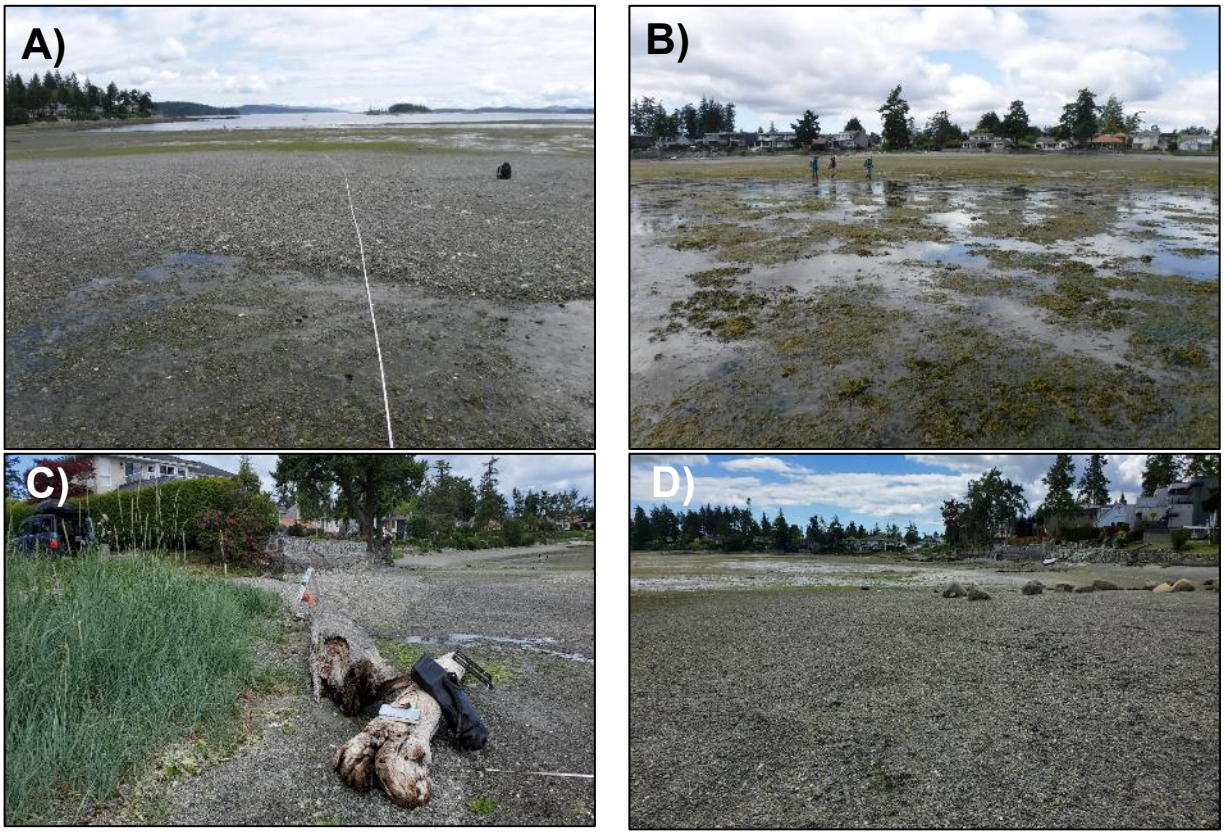

Figure 13. A) View of Site BC21-RB-04 from the top of the transect looking to the waterline, B) From the waterline looking to the top of the transect C) The Dune Grass and logs at the beach access in the supratidal, and D) Looking to the right of the beach access where large boulders can be noted. These boulders were added to the beach by a local resident in order to prevent sediment transport down the beach.

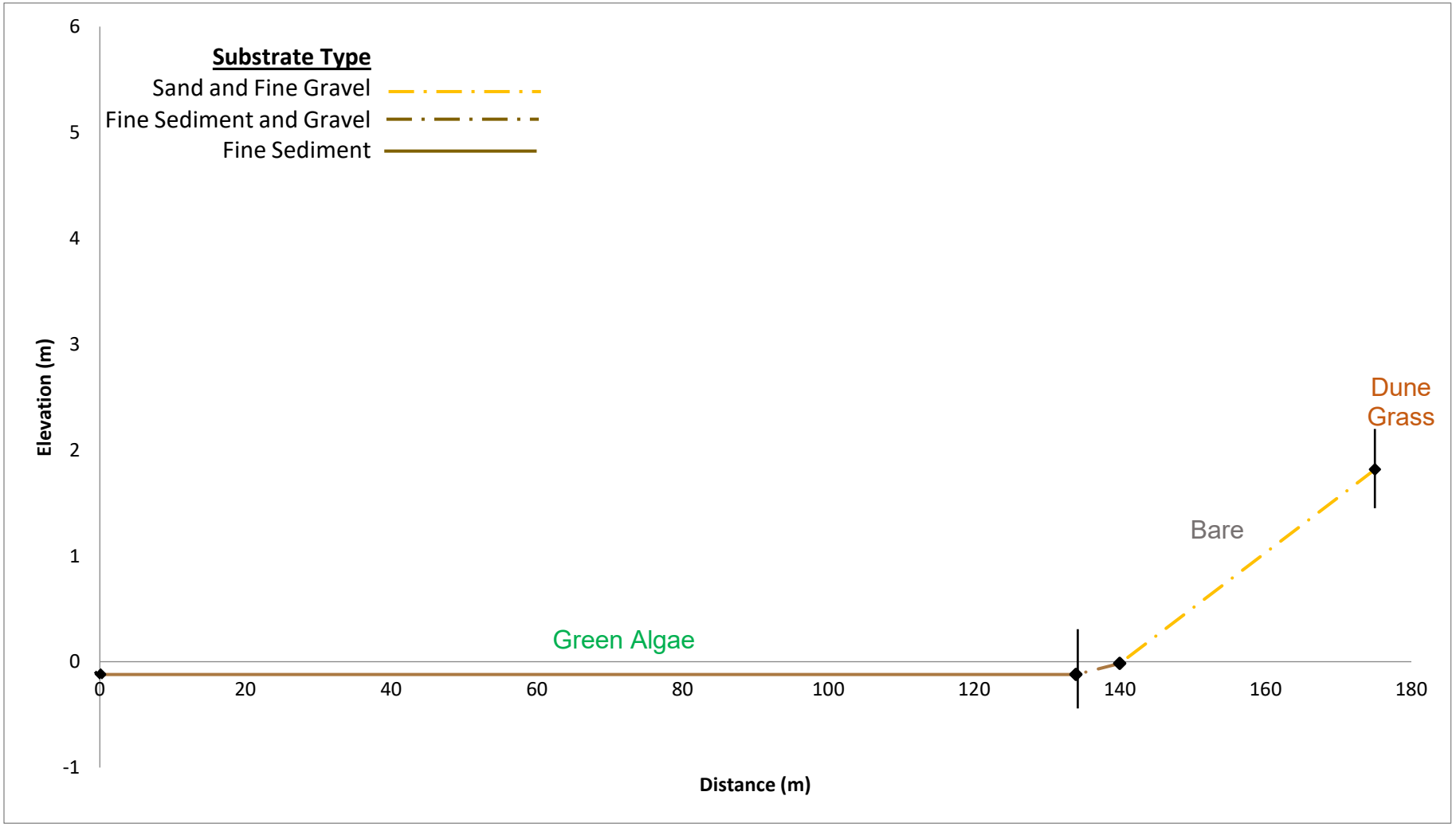

Figure 14. Elevation profile of Site BC21-RB-04 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada.

The biota observed in the general assessment of the biobands at site BC21-RB-04 is presented in Table 5 along with an estimation of relative abundance within the band. There was little attached vegetation along this transect. It is a fairly disturbed site due to the beach access.

Table 5. General biota observed for the biobands at Site BC21-RB-04 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A	Dune Grass	ELYMMO	*Leymus mollis*	Dune Grass	Present
A	Dune Grass	ATRIPA	*Atriplex patula*	Orache	Present
A	Dune Grass	GRASSP	Unidentified grasses/rushes	Unidentified grasses/rushes	Present
A	Dune Grass	PODMUR	*Podarcis muralis*	Common wall lizard	Present
A	Dune Grass	CONVOL	Family Convolvulaceae	Morning glory	Present
A	Dune Grass	TARAOF	*Taraxacum officinale*	Common Dandelion	Present
A	Dune Grass	SALIPA	*Sarcocornia pacifica*	American glasswort	Present
A	Dune Grass	BRASSP	Family Brassicaceae	Unidentified mustard family	Present
A	Dune Grass	APIACE	Family Apiaceae	Celery, carrot or parsley family	Present
A	Dune Grass	RUMECR	*Rumex crispus*	Curly Dock	Present
A	Dune Grass	RUMESP	*Rumex* sp.	Unidentified dock	Present
B1	Bare	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B1	Bare	HEMISP	*Hemigrapsus* sp.	Shore crab	Rare
B1	Bare	LITTSP	*Littorina* sp.	Periwinkle snail	Rare
B1	Bare	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B1	Bare	PLANMA	*Plantago maritima*	Maritime plantain	
B1	Bare	GRASSP	Unidentified grasses/rushes	Unidentified grasses/rushes	
B2	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Green Algae	DIATOM	Diatoms	Diatoms	
B2	Green Algae	ZOSTMA	*Zostera marina*	Eelgrass	Rare
B2	Green Algae	GRACSP	*Gracilaria* sp.	Branching filamentous red algae	
B2	Green Algae	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B2	Green Algae	SCULSP	Sculpinidae, other	Unidentified sculpin	Rare
B2	Green Algae	FISHSP	Unidentified fish species	Unidentified fish species	Rare
B2	Green Algae	DESMSP	*Desmarestia* sp.	Acid kelp	Present
B2	Green Algae	SACCSP	*Saccharina* sp.	Large bladed brown algae	Present

2.5 Site BC21-RB-05

Site BC21-RB-05 was located in the marsh and delta complex where Mermaid Creek empties into Roberts Bay. Figure 15 is a ShoreZone aerial photo of the site with the transect location marked. Figure 16 shows example photos from the site survey and Figure 17 shows an elevation profile of the site with substrate types and biobands indicated.

Figure 15. Location of ground survey site BC21-RB-05 in Roberts Bay. See Table 1 for exact coordinates and Figure 2 for the general location of the site in Roberts Bay.

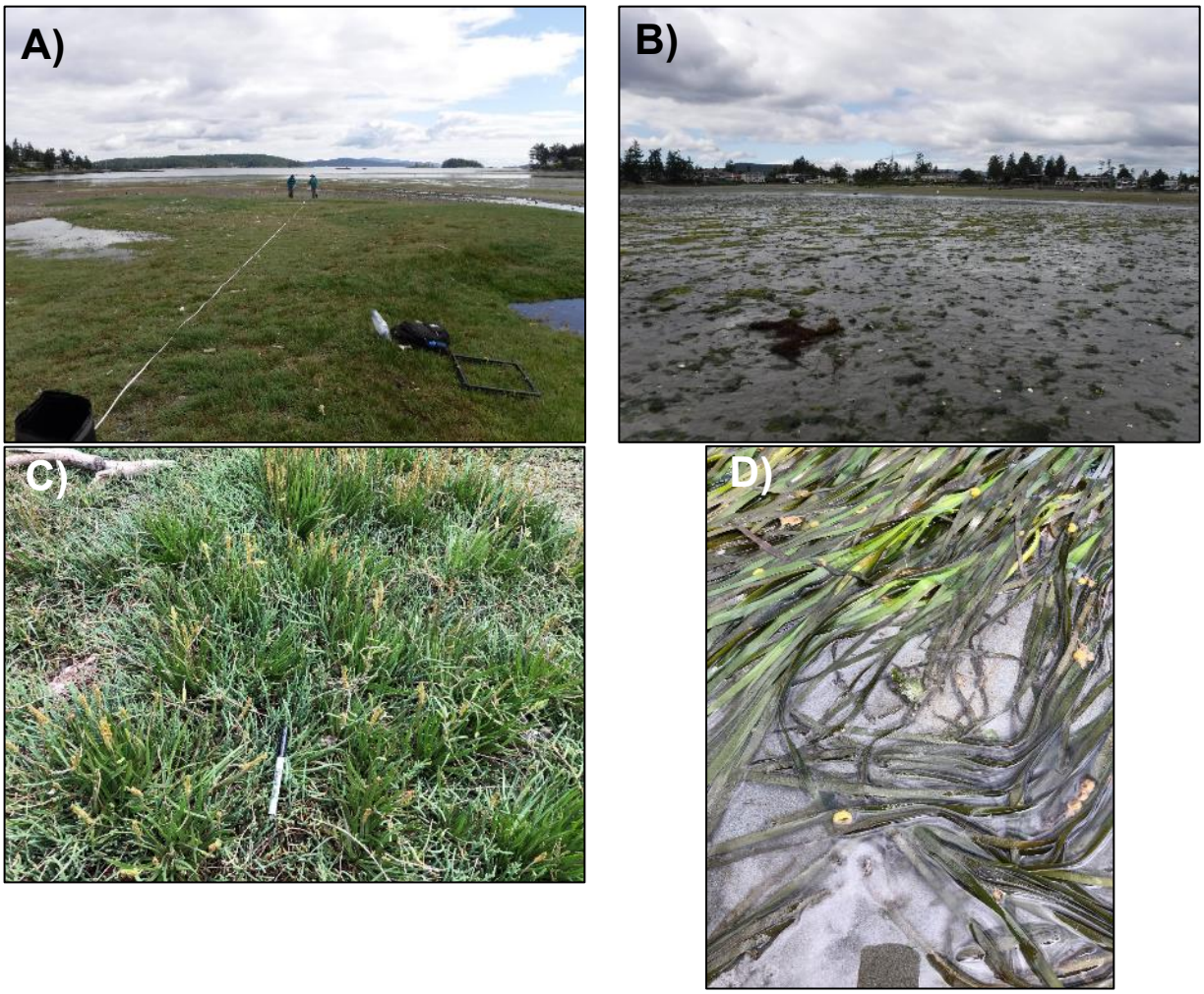

Figure 16. A) View of Site BC21-RB-05 from the top of the transect looking to the waterline, B) From the waterline looking to the top of the transect C) Close-up of American Glasswort (*Sarcocornia pacifica*) and Maritime Plaintain (*Plantago maritima*) in the high part of the marsh, and D) Close-up of Eelgrass (*Zostera marina*) with attached bubble shell (*Haminoea vesicula*) egg masses (yellow).

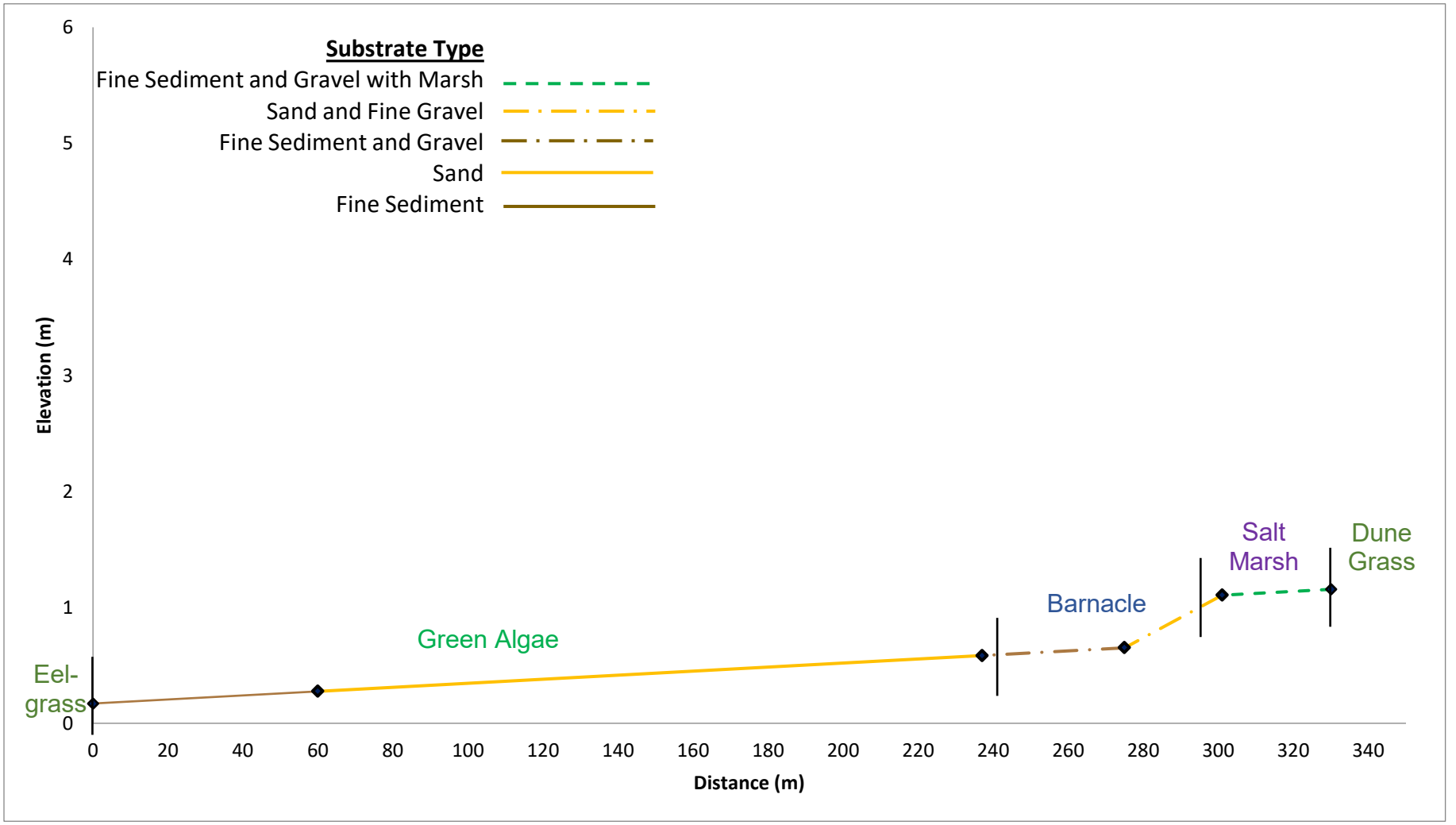

Figure 17. Elevation profile of Site BC21-RB-05 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada.

The biota observed in the general assessment of the biobands at site BC21-RB-05 is presented in Table 6 along with an estimation of relative abundance within the band. This site was dominated by the delta of Mermaid Creek including an American Glasswort (*Sarcocornia pacifica*) salt marsh in the upper intertidal/lower supratidal. This marsh showed clear signs of erosion along the seaward edge and is the potential focus of the restoration effort in Roberts Bay.

Table 6. General biota observed for the biobands at Site BC21-RB-05 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A	Dune Grass	ELYMMO	*Leymus mollis* (formerly *Elymus*)	Dune Grass	Present
A	Dune Grass	PLANMA	*Plantago maritima*	Maritime plantain	Present
A	Dune Grass	GRINSP	*Grindelia integrifolia*	Gumweed	Present
A	Dune Grass	GRASSP	Unidentified grasses/rushes	Unidentified grasses/rushes	Present
A	Dune Grass	SALIPA	*Sarcocornia pacifica*	American glasswort	Present
A	Dune Grass	RUMESP	*Rumex* sp.	Docks and sorrels	Present
A	Dune Grass	RUBUBI	*Rubus armeniacus*	Himalayan Blackberry	Present
A	Dune Grass	ROSANU	*Rosa nutkana*	Nootka Rose	Present
A	Dune Grass	POTEAN	*Potentilla anserina* ssp. *pacifica*	Silverweed	Present
A	Dune Grass	RANUSP	*Ranunculus* sp.	Unidentified buttercup	Present
A	Dune Grass	HERASP	*Heracleum maximum*	Cow-Parsnip	Present
A	Dune Grass	APIACE	Family Apiaceae	Celery, carrot or parsley family	Present
B1	Salt Marsh	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	Present
B1	Salt Marsh	PLANMA	*Plantago maritima*	Maritime plantain	Rare
B1	Salt Marsh	GRASSP	Unidentified grasses/rushes	Unidentified grasses/rushes	Rare
B1	Salt Marsh	GLAUMA	*Glaux maritima*	Sea milk-wort	Present
B1	Salt Marsh	SALIPA	*Sarcocornia pacifica*	American glasswort	Abundant
B2	Barnacle	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Barnacle	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Occasional
B2	Barnacle	MYTITR	*Mytilus trossulus*	Blue mussel	Rare
B2	Barnacle	MASTPA	*Mastocarpus papillatus*	Small papillate straps	
B2	Barnacle	LITTSP	*Littorina* sp.	Periwinkle snail	Occasional
B2	Barnacle	HEMISP	*Hemigrapsus* sp.	Shore crab	Rare
B3	Green algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B3	Green algae	GRACSP	*Gracilaria* sp.	Gelatinous filamentous red algae	
B3	Green algae	SARCGA	*Sarcodiotheca gaudichaudii*	Large one-plane pink branching algae	
B3	Green algae	TRESSP	*Tresus* sp.	Unidentified horse clam	Rare
B3	Green algae	DESMSP	*Desmarestia* sp.	Acid weed	Present
C1	Eelgrass	ZOSTMA	*Zostera marina*	Eelgrass	Present
C1	Eelgrass	FISHSP	Unidentified fish species	Unidentified fish species	Present
C1	Eelgrass	CAPRSP	Unidentified caprellid species	Unidentified skeleton shrimp	Present
C1	Eelgrass	PUGESP	*Pugettia* sp.	Kelp crab	Present

2.6 Site BC21-RB-06

Site BC21-RB-06 was located on the south end of Roberts Bay near a short wharf. Figure 18 is an aerial drone photo of the site with the transect location marked. Figure 19 shows example photos from the site survey and Figure 20 shows an elevation profile of the site with substrate types and biobands indicated.

Figure 18. Location of ground survey site BC21-RB-06 in Roberts Bay. See Table 1 for exact coordinates and Figure 1 for the general location of the site in Roberts Bay.

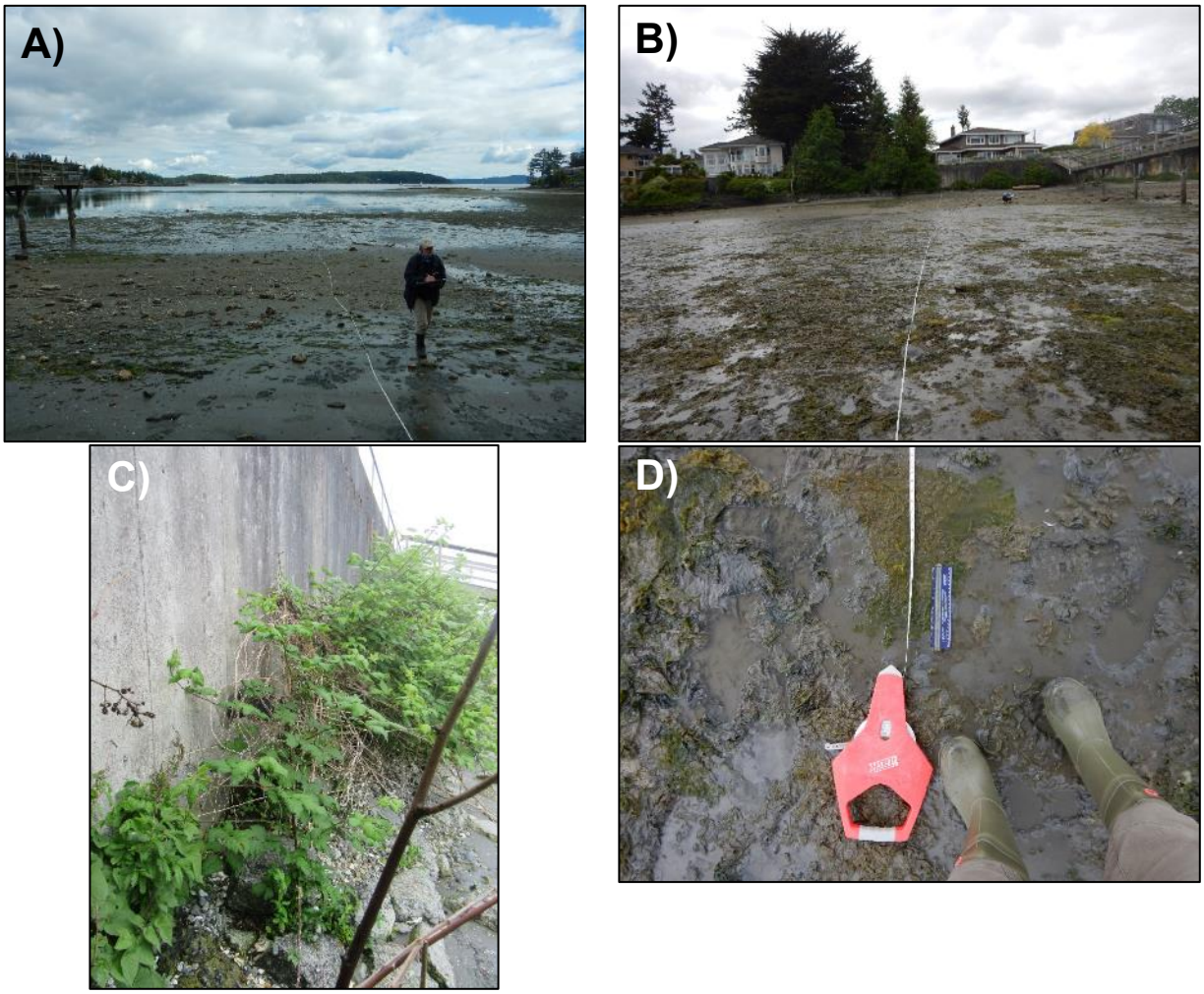

Figure 19. A) View of Site BC21-RB-06 from the top of the transect looking to the waterline, B) From the waterline looking to the top of the transect, C) High seawall at the bottom of a residential lot in the supratidal, and D) Mudflat at the end of the transect with Sea Lettuce (*Ulva/Ulvaria* sp.).

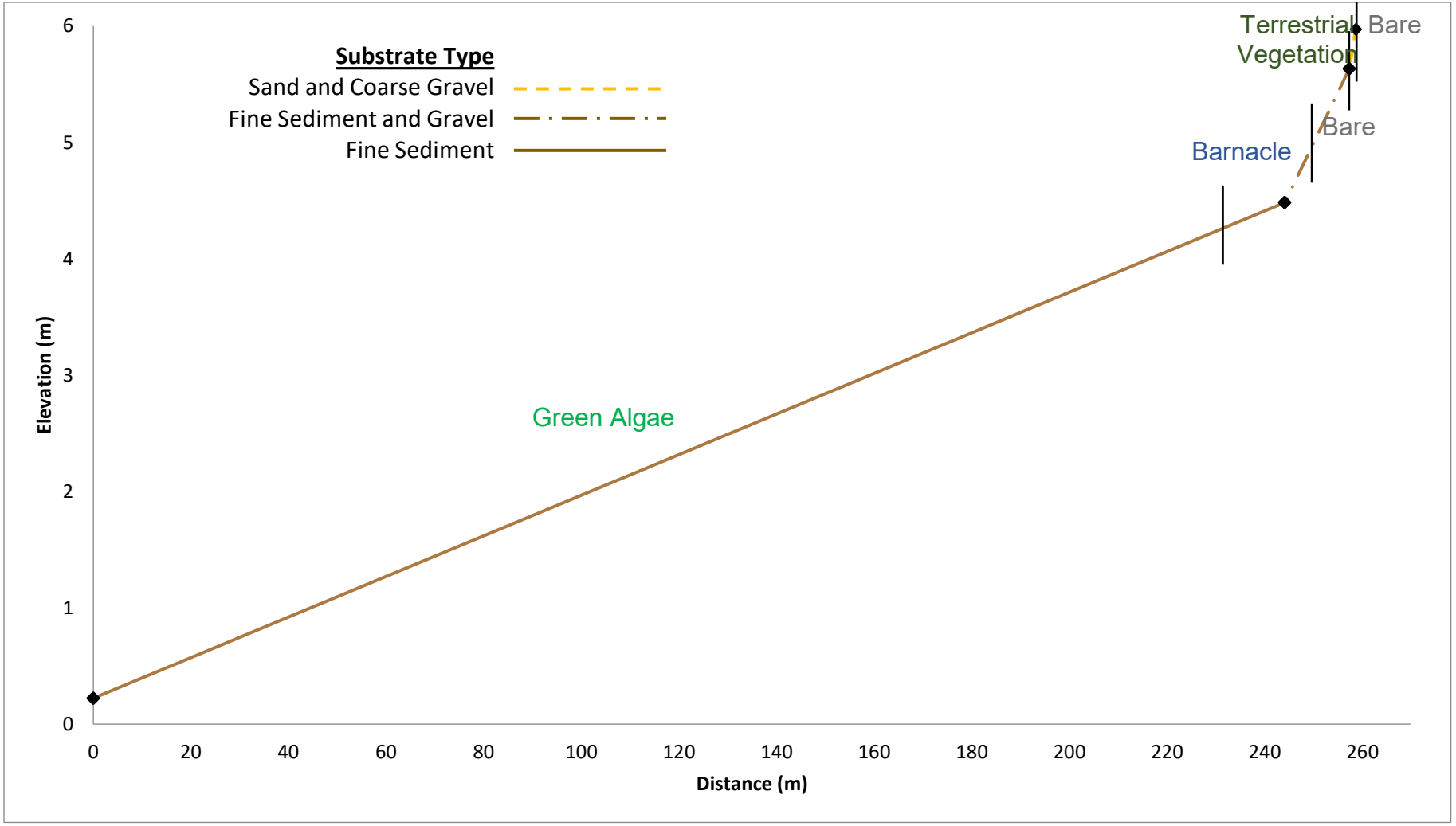

Figure 20. Elevation profile of Site BC21-RB-06 with Substrate Type (indicated by line colour and style) and Biobands (indicated by black vertical lines and coloured text). The elevation of the waterline at the date and time of the survey was taken using the observed tide levels from the Victoria, BC tide station maintained by Fisheries and Oceans Canada.

The biota observed in the general assessment of the biobands at site BC21-RB-06 is presented in Table 7 along with an estimation of relative abundance within the band. The lower beach had fine sediment and the team was unable to make it all the way to the waterline without getting stuck so were unable to assess the subtidal zone.

Table 7. General biota observed for the biobands at Site BC21-RB-06 with an estimation of relative abundance. The A Zone is the supratidal, the B Zone is the intertidal and the C Zone is the subtidal.

Zone	Bioband	Code	Taxonomic Name	Common Name	Relative Abundance
A2	Terrestrial Vegetation	RUBUBI	*Rubus armeniacus*	Himalayan Blackberry	Present
A2	Terrestrial Vegetation	CONVOL	Family convolvulaceae	Morning glory	Present
A2	Terrestrial Vegetation	POTEAN	*Potentilla anserina* ssp. *pacifica*	Silverweed	Present
A2	Terrestrial Vegetation	ROSACE	Family Rosaceae	Roses	Present
B1	Bare	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Occasional
B2	Barnacle	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B2	Barnacle	ENTEMO	*Enteromorpha intestinalis*	Stringy sea lettuce	
B2	Barnacle	MASTPA	*Mastocarpus papillatus*	Small papillate straps	
B2	Barnacle	FOLRED	*Gracilaria* sp.	Gelatinous filamentous red algae	
B2	Barnacle	BALAGL	*Balanus glandula*	Common pacific acorn barnacle	Rare
B2	Barnacle	LITTSP	*Littorina* sp.	Periwinkle snail	Rare
B2	Barnacle	MYTITR	*Mytilus trossulus*	Blue mussel	Rare
B2	Barnacle	CRASGI	*Crassostrea gigas*	Japanese oyster	Rare
B2	Barnacle	PAGUSP	*Pagurus* sp.	Unidentified hermit crab	Rare
B2	Barnacle	ANTHXA	*Anthopleura xanthogrammica*	Solitary green anemone	Rare
B3	Green Algae	ULVASP	*Ulva/Ulvaria* sp.	Sea lettuce	
B3	Green Algae	ENTEMO	*Enteromorpha intestinalis*	Stringy sea lettuce	
B3	Green Algae	HAMISP	*Haminoea vesicula*	Bubble shell	Frequent
B3	Green Algae	HAMISP	*Haminoea veiscula* egg masses	Bubble shell egg masses	Abundant
B3	Green Algae	DIATOM	Diatoms	Diatoms	
B3	Green Algae	SACCSP	Large bladed brown algae	Large bladed brown algae	
B3	Green Algae	CLINCA	*Clinocardium californiense*	Heart cockle	

2.7 Drone Imagery Survey

Drone imagery was taken by Victoria Air Photos and Survey on May 28th, 2021 at the same time as the ground survey conducted by CORI staff. The drone operator took images at 300 ft altitude to be comparable to the ShoreZone images taken in 2004. He also took additional images at 100 ft altitude to provide additional details. Examples of these images are shown in Figure 21.

Figure 21. Examples of the drone aerial imagery taken at 300 ft altitude in Roberts Bay. The drone panned from Roberts Point at the south end of the Bay to Armstrong Point at the north end of the Bay.

2.8 Roberts Bay Substrate Map

The ground survey observations were combined with the drone aerial imagery to interpret the best available satellite image of the study area to create a generalized areal map of the substrate types in Roberts Bay. This map is shown in Figure 22. Close-ups of some sections of the Bay are found in Figures 23 through 26.

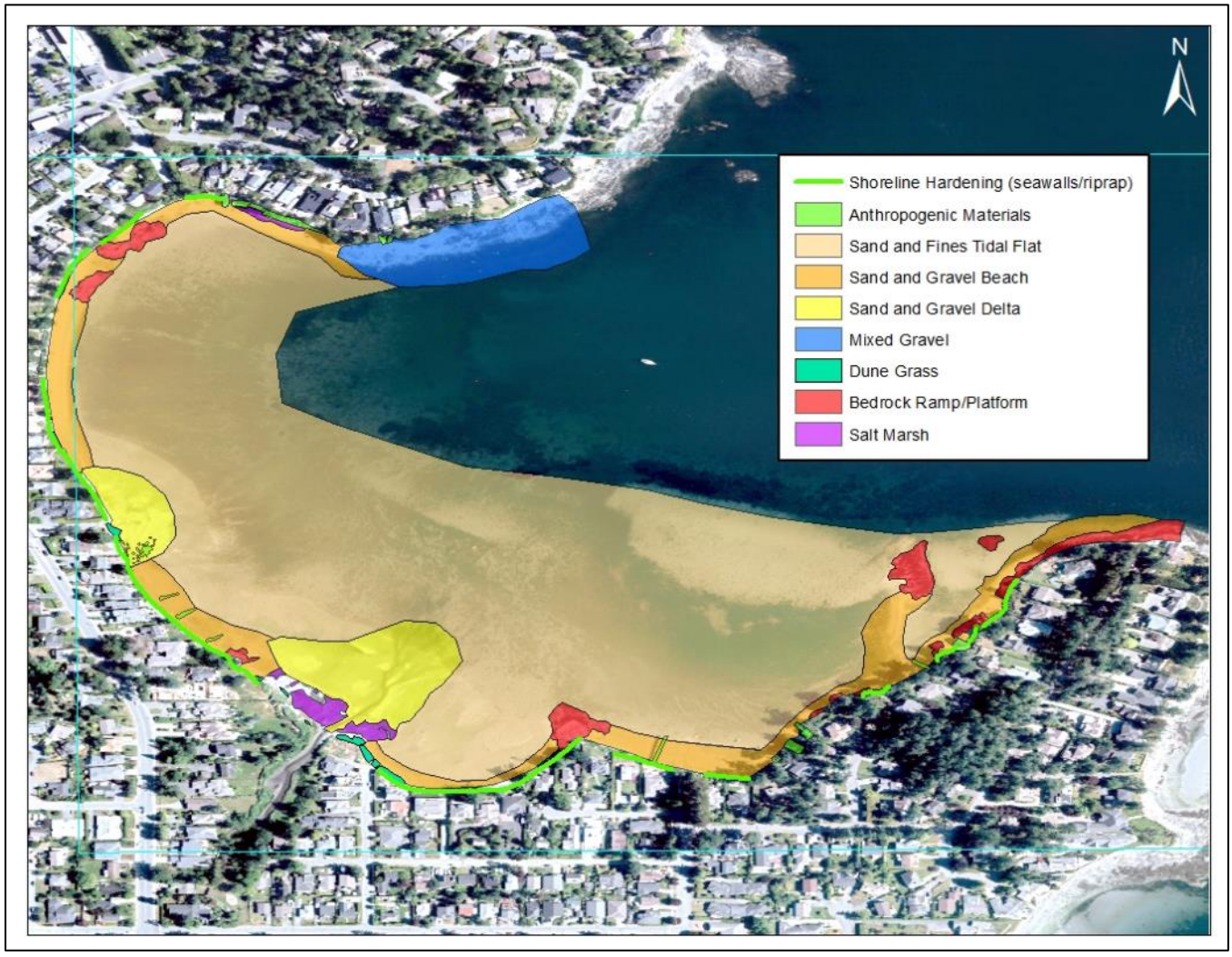

Figure 22. Map of the substrate types in Roberts Bay as interpreted from ground survey observations and drone aerial imagery.

Figure 23. Map of the substrate types in the north part of Roberts Bay as interpreted from ground survey observations and drone aerial imagery.

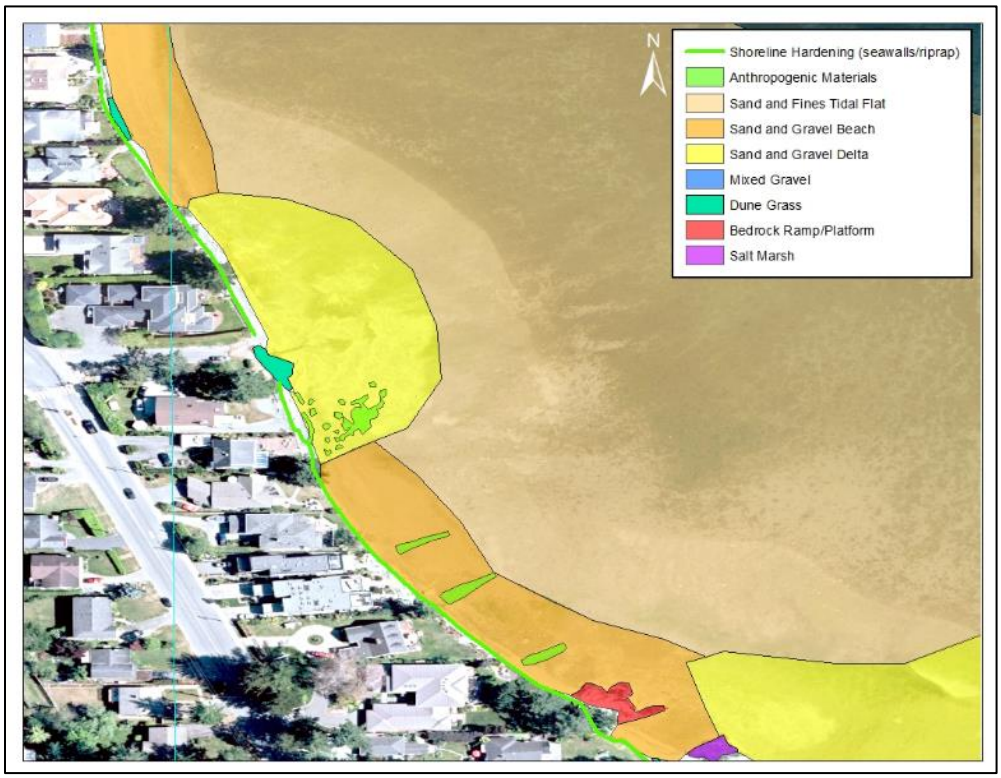

Figure 24. Map of the substrate types in near the Ardwell Avenue beach access in Roberts Bay as interpreted from ground survey observations and drone aerial imagery.

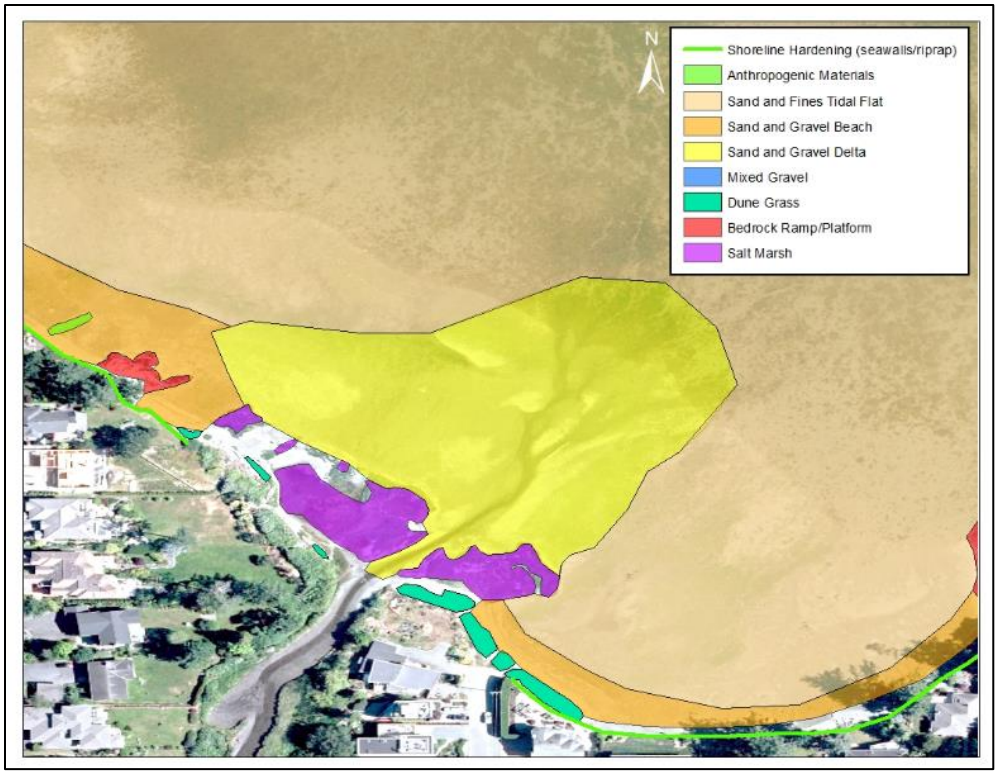

Figure 25. Map of the substrate types in Roberts Bay near the mouth of Mermaid Creek as interpreted from ground survey observations and drone aerial imagery.

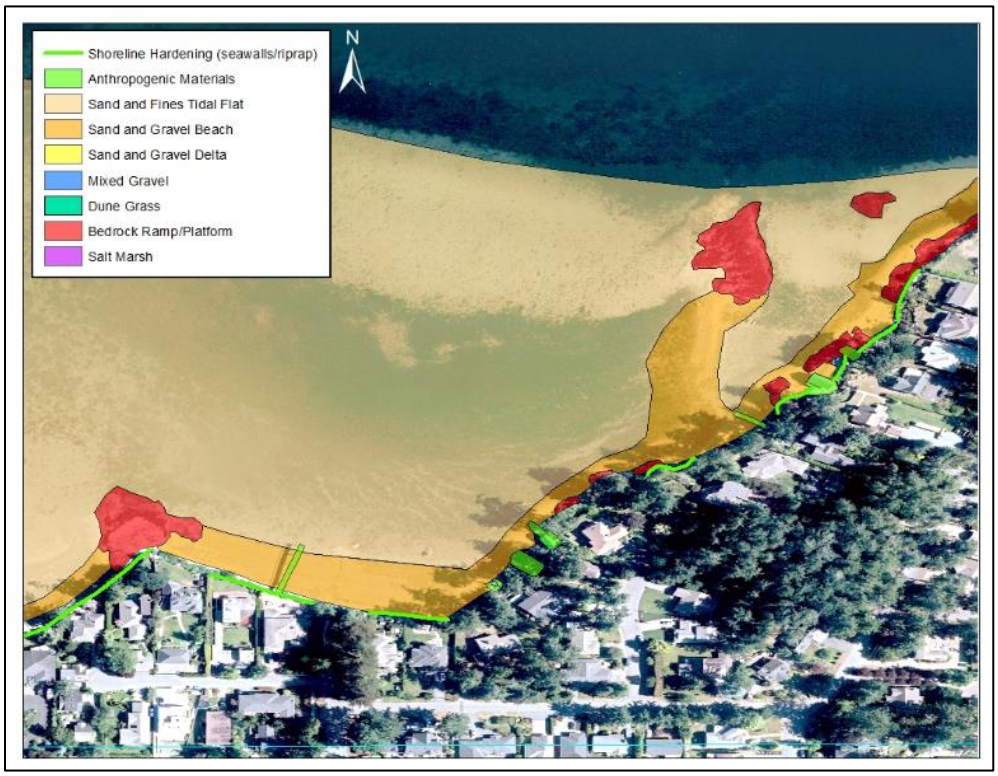

Figure 26. Map of the substrate types in the south end of Roberts Bay as interpreted from ground survey observations and drone aerial imagery.

As seen in the substrate map, Roberts Bay is dominated by a sand/fines tidal flat in the lower intertidal, with a sand/gravel beach face hugging the shoreline. A few scattered rock ramps/platforms are scattered around the bay, providing some hard substrate for attachment of sessile biota. There is also a sand/fine gravel delta spreading down the beach from the outlet of Mermaid Creek as well as what appears to be a relict delta at the beach access off Ardwell Avenue. The salt marsh at Mermaid Creek is discussed in more detail in the next section but it should be noted there is also a small, fringing salt marsh on the north end of the bay. This marsh has had some direct alterations due to development. A few small patches of Dune Grass are spread along the bay.

The backshore around the bay has been extensively modified through residential development. Seawalls have been built to prevent erosion of residential lots and there are several docks, houses and other structures that extend into the intertidal, including over the fringing marsh on the north end of the bay. These anthropogenic modifications have undoubtedly altered the flow of sediment onto the beach, likely in an uneven fashion as development has progressed through the years. Some of the modifications, such as the groins and the large boulders in the middle portion of the bay, appear to have been placed to prevent sediment transport along the beach.

3 HISTORIC COMMUNITY IMAGERY AND INFORMATION SUMMARY

Part of this project was to engage the residents of the Roberts Bay area and ask if they had information or historic photos that could help illustrate the changes that have occurred over time. The respondents all indicated they had noted long-term changes in the sediment texture and distribution across the bay as well as fluctuations in the depth of sediment at the top of the beach. The increase in the amount of shoreline hardened by seawalls has also been noted as increasing (Figure 27).

Figure 27. Image of seawalls in the supratidal zone of Roberts Bay, as well as some large boulders that were placed on the beach near the Ardwell Avenue public access point (image courtesy of Adrian Rowland, year unknown).

They also noted the marsh at the mouth of Mermaid Creek had shrunk over time (Figure 28).

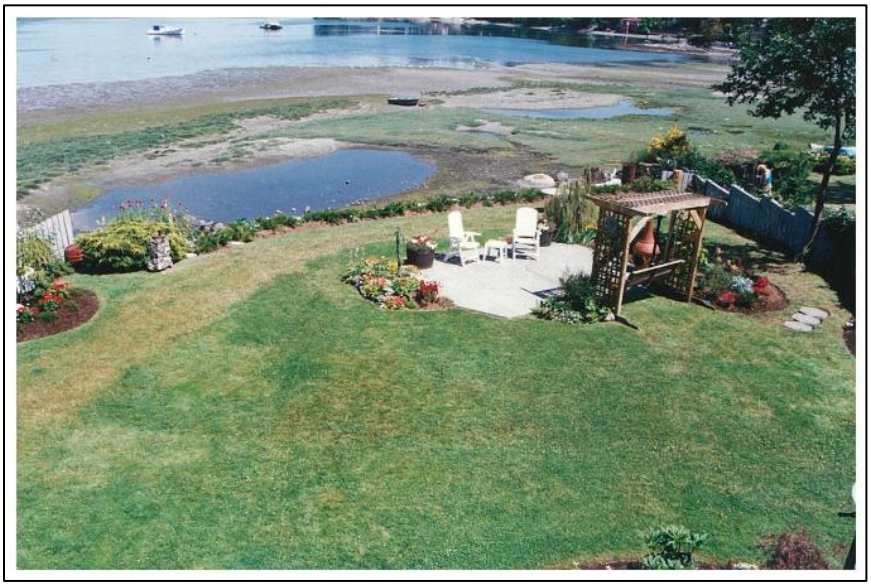

Figure 28. Image of salt marsh in front of residence near Mermaid Creek, showing the marsh extended further than it does at present (image courtesy of Mickey McGee, between 1991-1993).

KJ Finley, who is a biologist that has lived on the bay for numerous years, also made mention of the loss of the mud shrimp (*Upogebia pugettensis*) community (Figure 29) and he blames the introduction of a parasitic isopod that has been affecting mud shrimp populations in the Pacific Northwest (Griffen, 2009; Dumbauld *et al*., 2011; Whalen *et al*., 2020). Unfortunately, the consequences to the physical characteristics of the beach or to the biological communities of those beaches have not yet been well-studied. We did not observe the presence of this isopod during the ground survey but we did not assess the infaunal community. No mud shrimp were observed and there was little evidence of infaunal holes caused by *Upogebia*.

Figure 29. *Upogebia pugettensis* in Roberts Bay and infaunal holes caused by *Upogebia* (courtesy of KJ Finley, 1995).

Other impacts community members have documented through photographs in Roberts Bay are shown in Figure 30.

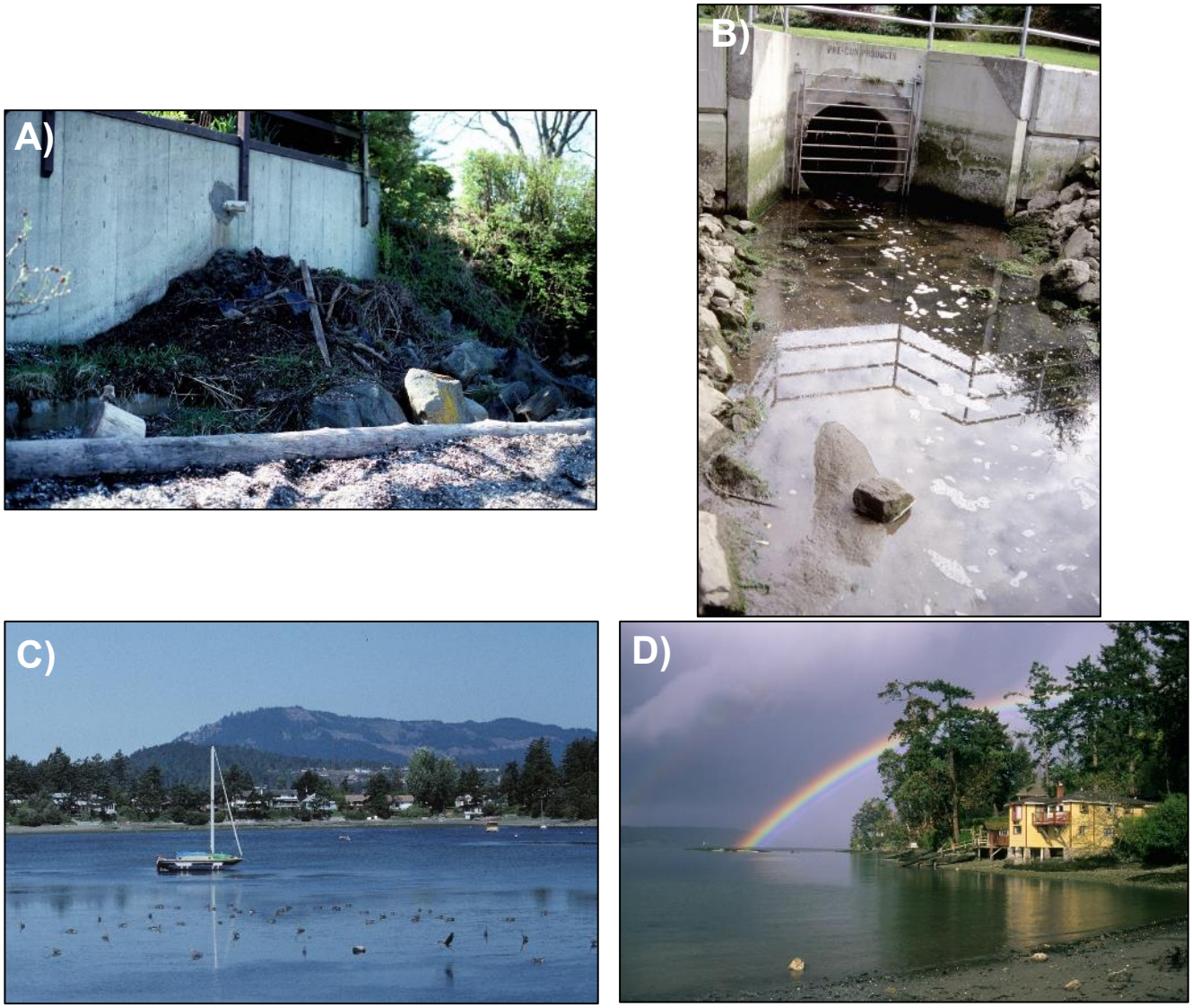

Figure 30. Other impacts to Roberts Bay documented by community members: A) Fill and debris accumulation at the foot of the seawall near Third Street (courtesy of KJ Finley, 2005), B) Mermaid Creek storm drain (courtesy of KJ Finley, 2005), C) Catamaran anchored in eelgrass bed (courtesy of KJ Finley, 2005), D) Encroachment of houses or other structure into the intertidal zone. This image shows the historic 'Ramona' house on the south end of the bay (courtesy of KJ Finley, 2003).

The most common observations from community members were regarding the diversity and abundance of wildlife in Roberts Bay (Figure 31), which is unsurprising considering it is part of the Shoal Harbour Migratory Bird Sanctuary.

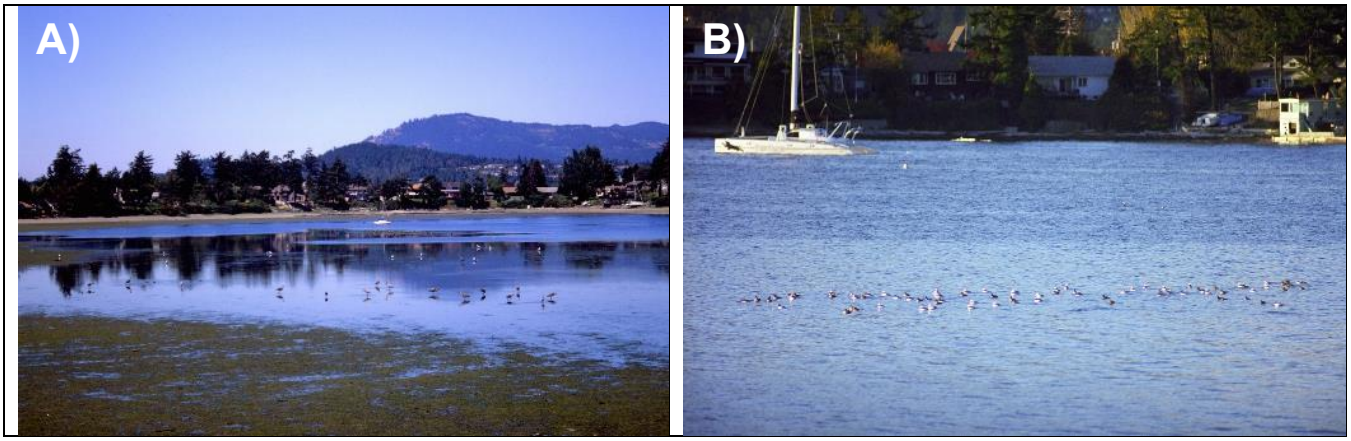

Figure 31. Examples of the wildlife photos taken by residents of Roberts Bay over the years: A) a gathering of Great Blue Herons (*Ardea herodias*) in Roberts Bay (courtesy of KJ Finley, 2010), B) Buffleheads (*Bucephala albeola*) gathering during the spring migration in Roberts Bay (courtesy of KJ Finley, year unknown).

4 HISTORIC AERIAL IMAGERY ANALYSIS

The Mermaid Creek estuary is one focus of the potential restoration efforts in Roberts Bay. It was clear from observations on the ground survey that the salt marsh at the mouth of the creek was actively eroding (Figure 32) and the team saw evidence of buried peat on the beach below the marsh that indicated the marsh had at one point extended further. The historic photos and observations from community members also supported that observation.

Figure 32. Photos from the Mermaid Creek estuary salt marsh taken by Sarah Cook on February 17th, 2021: A) the seaward edge of the marsh clear signs of erosion, B) sand and pebble overlaying the salt marsh that had appeared to have been deposited during a recent storm, and C) large clumps of American Glasswort (*Sarcocornia pacifica*) in the wrack line that appeared to be recently torn from the marsh.

Understanding how the marsh has changed over time is of paramount importance to any restoration effort as it will help to understand the pressures facing the marsh. The historic photos and observations from community members provided qualitative data but we wished to determine if more quantitative data could be gleaned. CORI staff therefore sourced historic orthophotos and satellite imagery where the estuary was visible. The May 2021 drone imagery provided evidence of current conditions. 16 images, ranging from 1964 to 2021, were georeferenced (using landmarks around Roberts Bay that were visible in each image) and analyzed. For each image, a georeferenced polygon was created to represent the extent and location of the salt marsh. The texture and colour (where the images were in colour) were used to determine areas that represented salt marsh versus bare sediment. This interpretation was informed by the ground observations during the May 2021 ground survey. Those polygons are presented in Figures 33 through 48. All figures are presented at the same scale for comparative purposes. The areal extent of each polygon was calculated using tools in ESRI ArcMap and those results are presented in Table 8 and Figure 49.

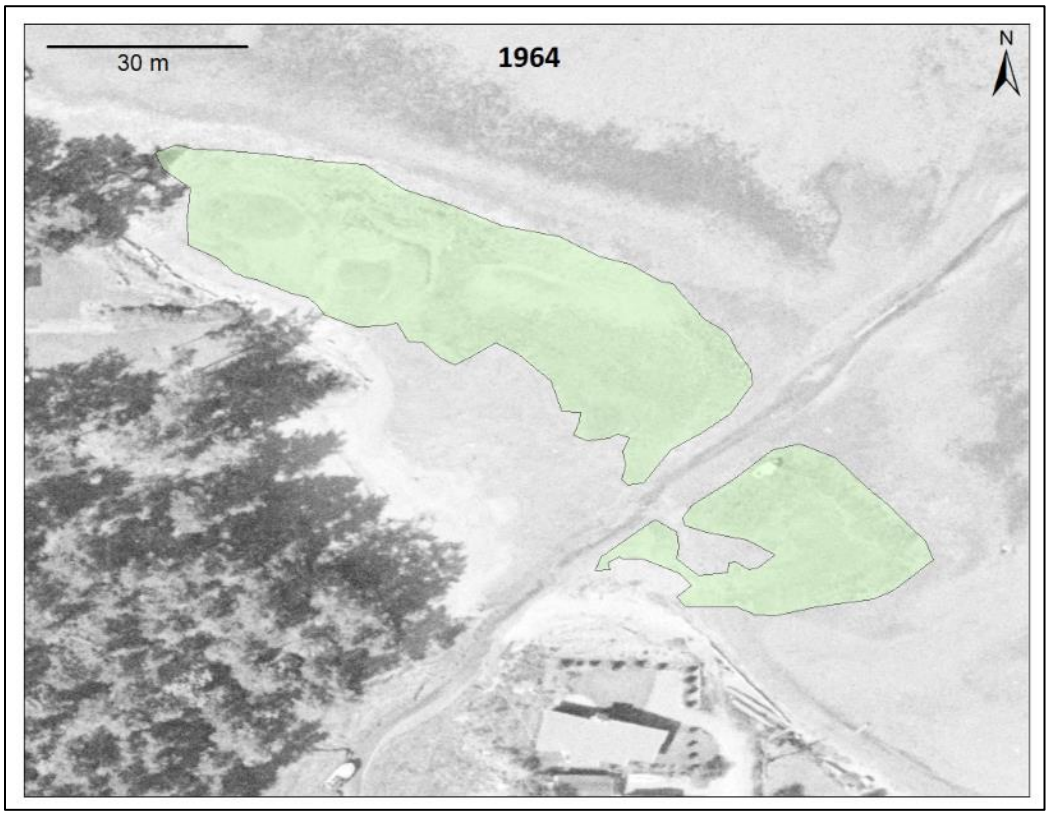

Figure 33. Mermaid Creek salt marsh polygon overlaying 1964 orthophoto of Roberts Bay area.

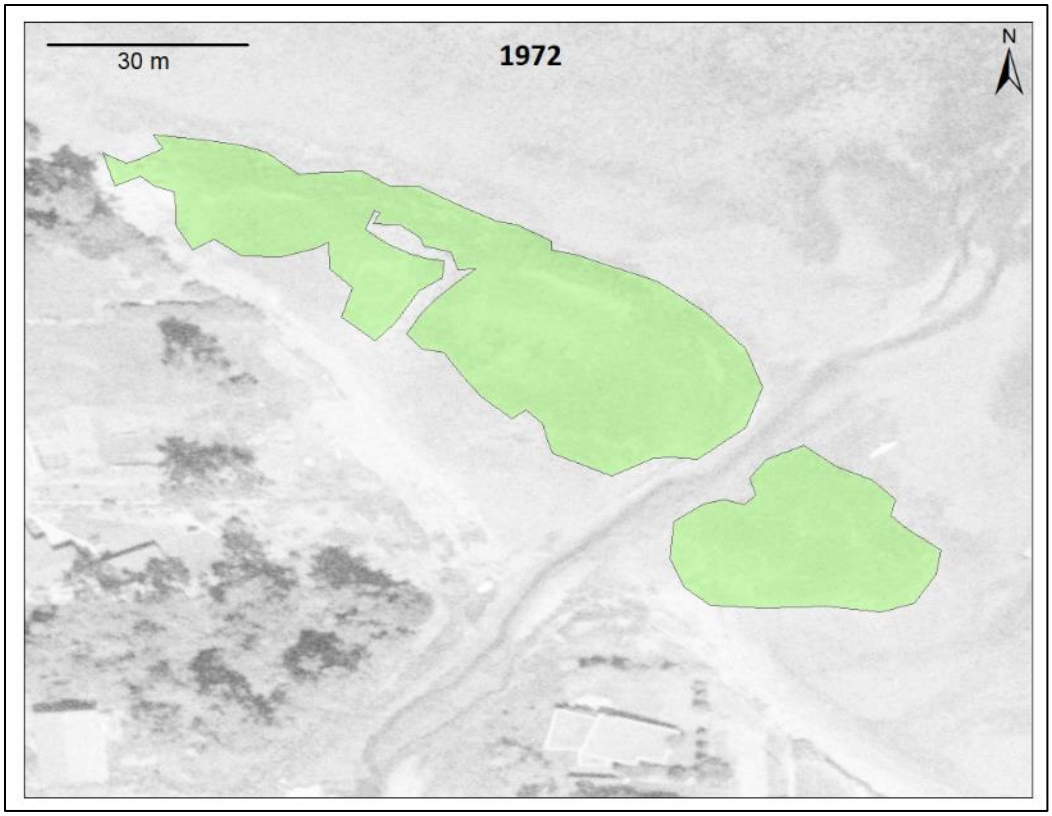

Figure 34. Mermaid Creek salt marsh polygon overlaying 1972 orthophoto of Roberts Bay area.

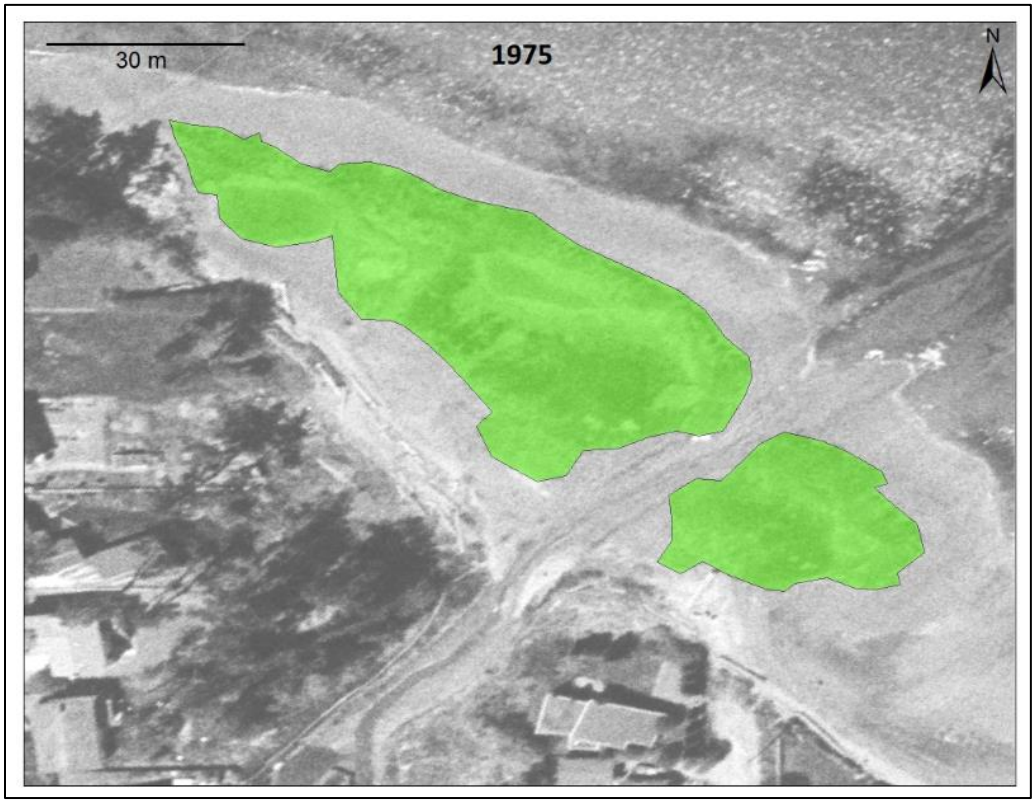

Figure 35. Mermaid Creek salt marsh polygon overlaying 1975 orthophoto of Roberts Bay area.

Figure 36. Mermaid Creek salt marsh polygon overlaying 1980 orthophoto of Roberts Bay area.

Figure 37. Mermaid Creek salt marsh polygon overlaying 1986 orthophoto of Roberts Bay area.

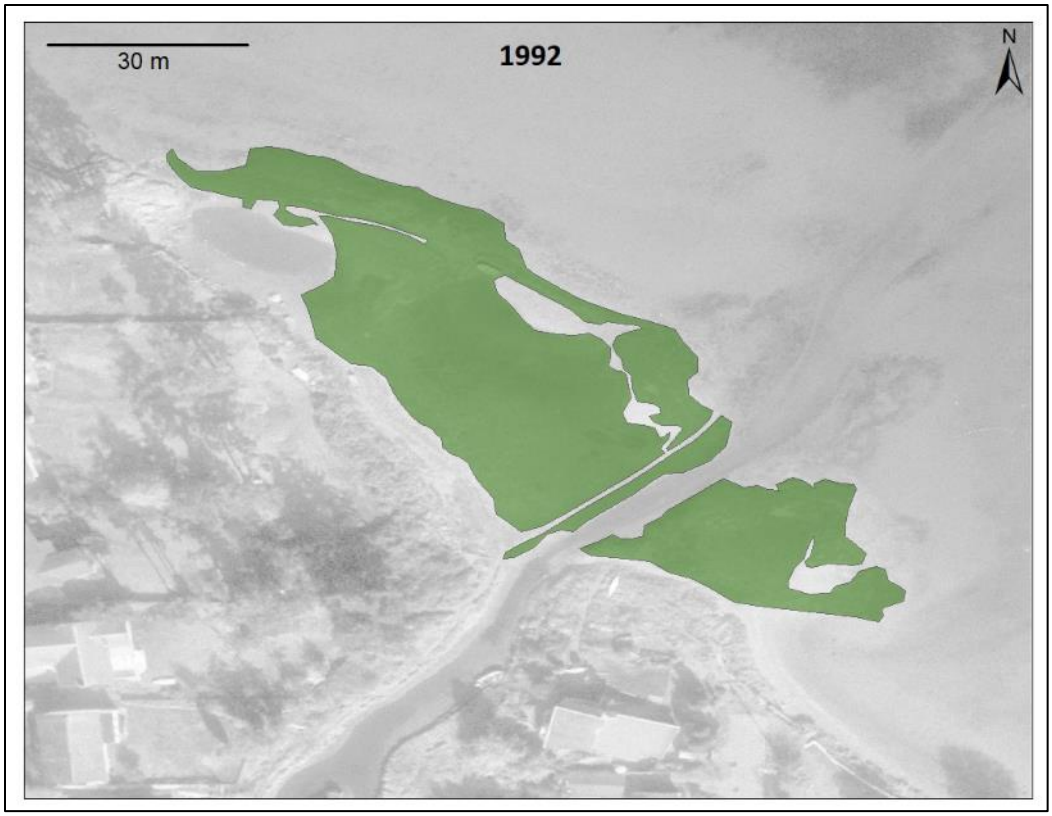

Figure 38. Mermaid Creek salt marsh polygon overlaying 1992 orthophoto of Roberts Bay area.

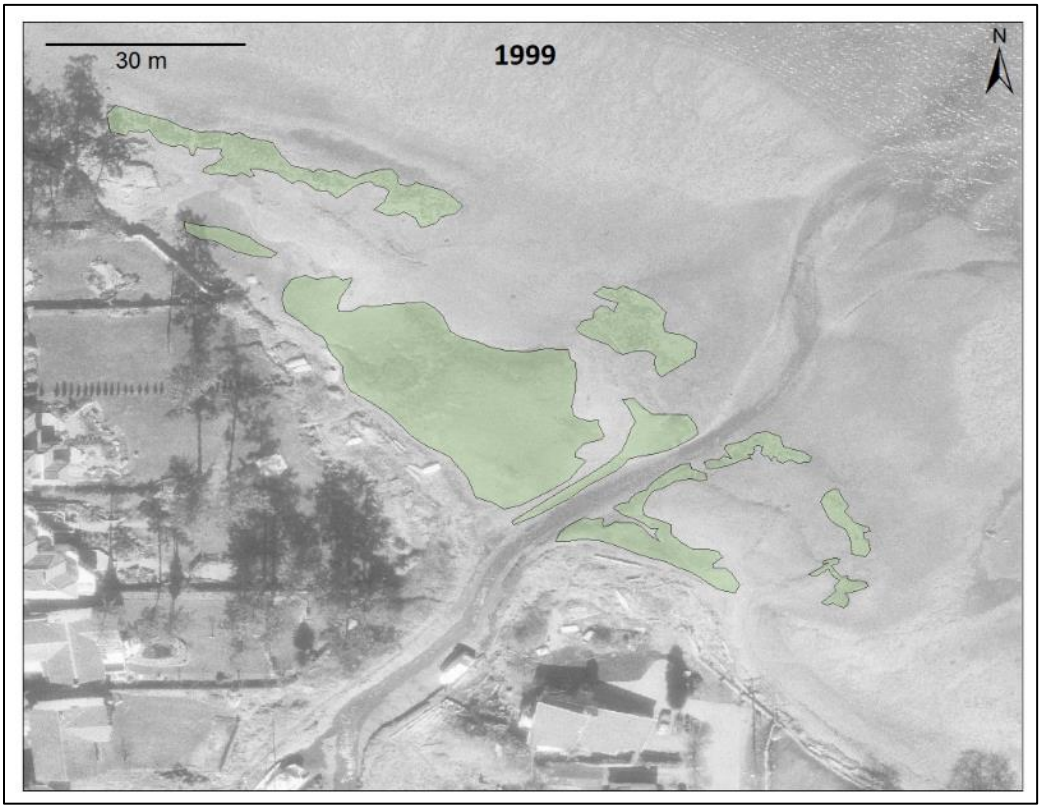

Figure 39. Mermaid Creek salt marsh polygon overlaying 1999 orthophoto of Roberts Bay area.

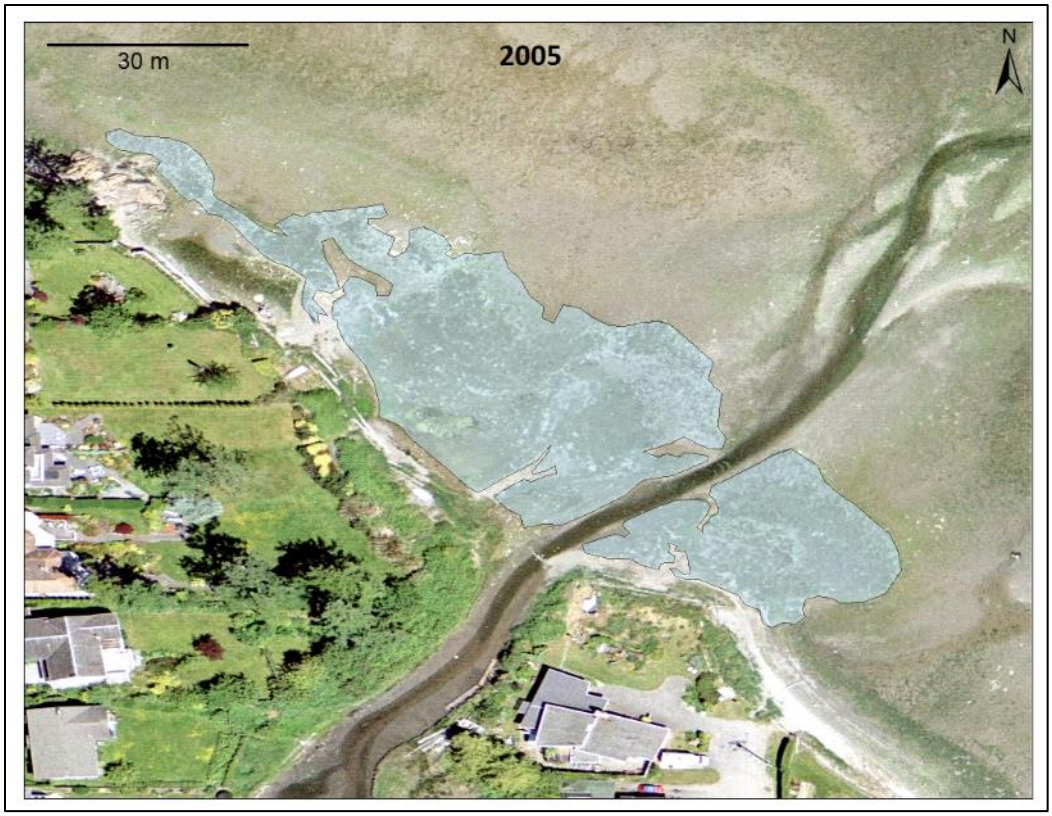

Figure 40. Mermaid Creek salt marsh polygon overlaying 2005 orthophoto of Roberts Bay area.

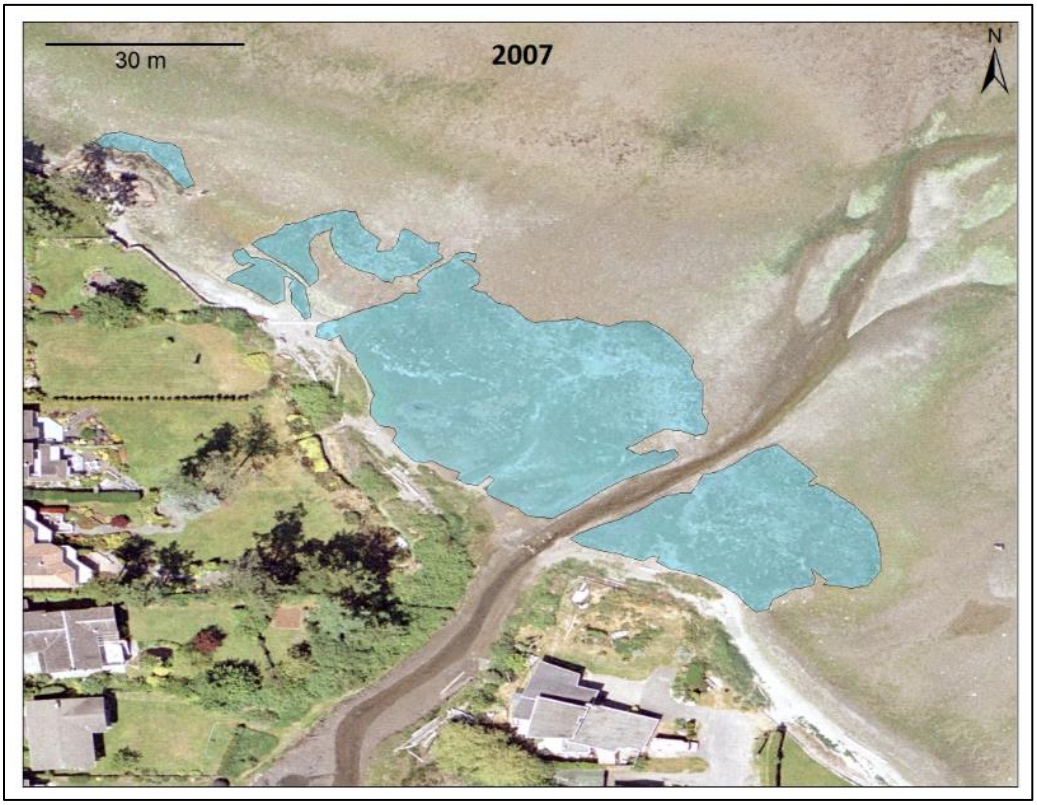

Figure 41. Mermaid Creek salt marsh polygon overlaying 2007 orthophoto of Roberts Bay area.

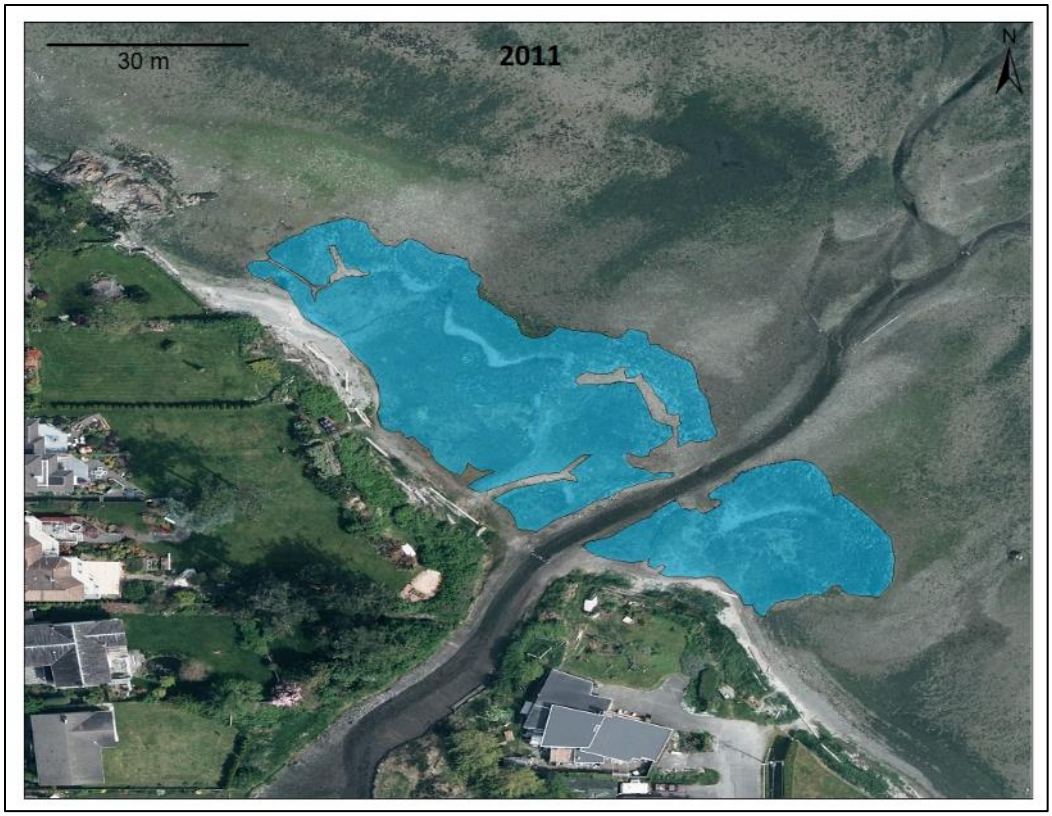

Figure 42. Mermaid Creek salt marsh polygon overlaying 2011 orthophoto of Roberts Bay area.

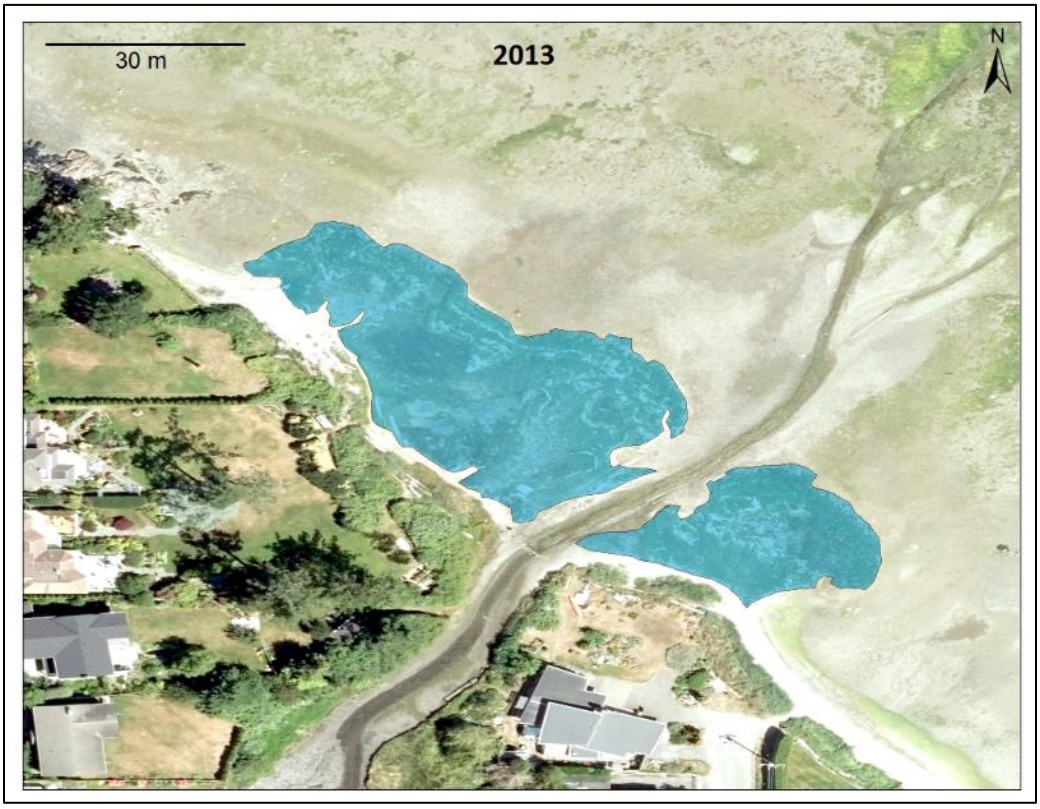

Figure 43. Mermaid Creek salt marsh polygon overlaying 2013 orthophoto of Roberts Bay area.

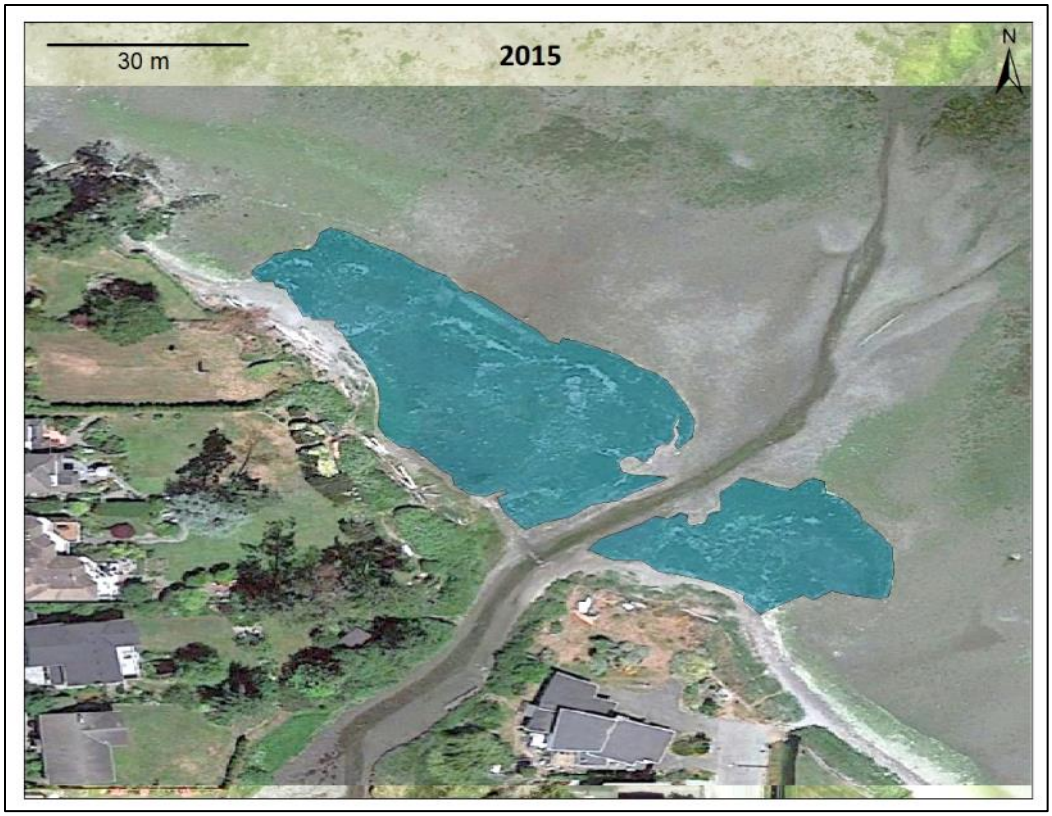

Figure 44. Mermaid Creek salt marsh polygon overlaying 2015 satellite image of Roberts Bay area.

Figure 45. Mermaid Creek salt marsh polygon overlaying 2016 satellite image of Roberts Bay area.

Figure 46. Mermaid Creek salt marsh polygon overlaying 2017 orthophoto of Roberts Bay area.

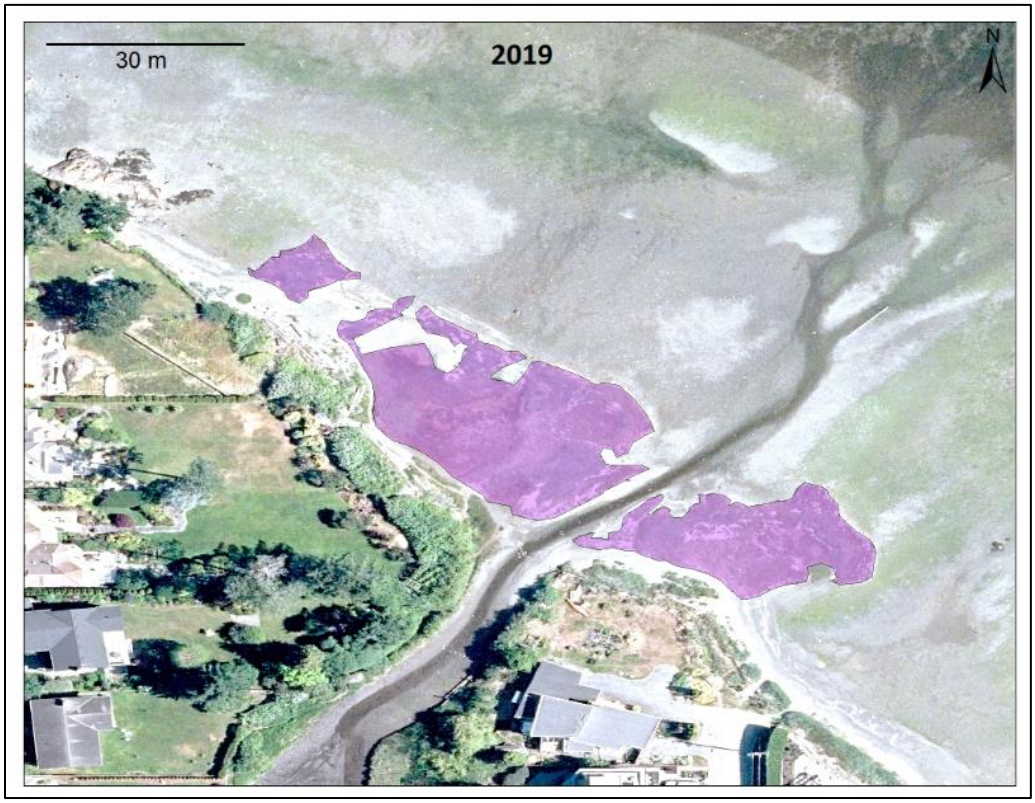

Figure 47. Mermaid Creek salt marsh polygon overlaying 2019 orthophoto of Roberts Bay area.

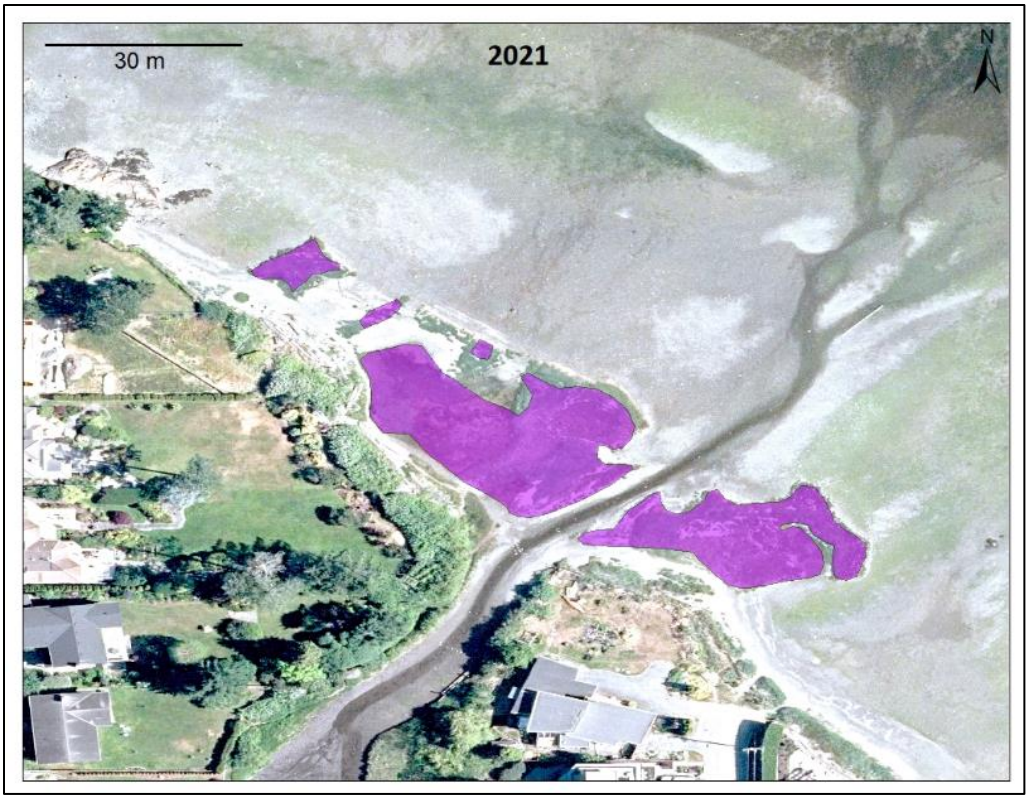

Figure 48. Mermaid Creek salt marsh polygon created using 2021 aerial drone imagery. It is overlaying the 2019 orthophoto of Roberts Bay area, as no more current orthophoto was available.

Table 8. Area of the Mermaid Creek estuary salt marsh as measured from the polygons created from the orthophotos and satellite images. Carbon storage and carbon sequestration capacity were calculated using values from Chastain *et al*., 2021.

Year	Area (m2)	Area (ha)	Carbon Storage (assuming 80.6 tonnes/ha)	Carbon Sequestration (assuming 146 g C/m^2/yr)
1964	3600.9	0.36	29.02	525,731.40
1972	3714.4	0.37	29.94	542,302.40
1975	3811.4	0.38	30.72	556,464.40
1980	3548.4	0.35	28.60	518,066.40
1986	3552.0	0.36	28.63	518,592.00
1992	3433.6	0.34	27.67	501,305.60
1999	2081.1	0.21	16.77	303,840.60
2005	3440.7	0.34	27.73	502,342.20
2007	3131.6	0.31	25.24	457,213.60
2011	2901.4	0.29	23.39	423,604.40
2013	2738.2	0.27	22.07	399,777.20
2015	2692.7	0.27	21.70	393,134.20
2016	2606.5	0.26	21.01	380,549.00
2017	2185.7	0.22	17.62	319,112.20
2019	1873.6	0.19	15.10	273,545.60
2021	1494.1	0.15	12.04	218,138.60

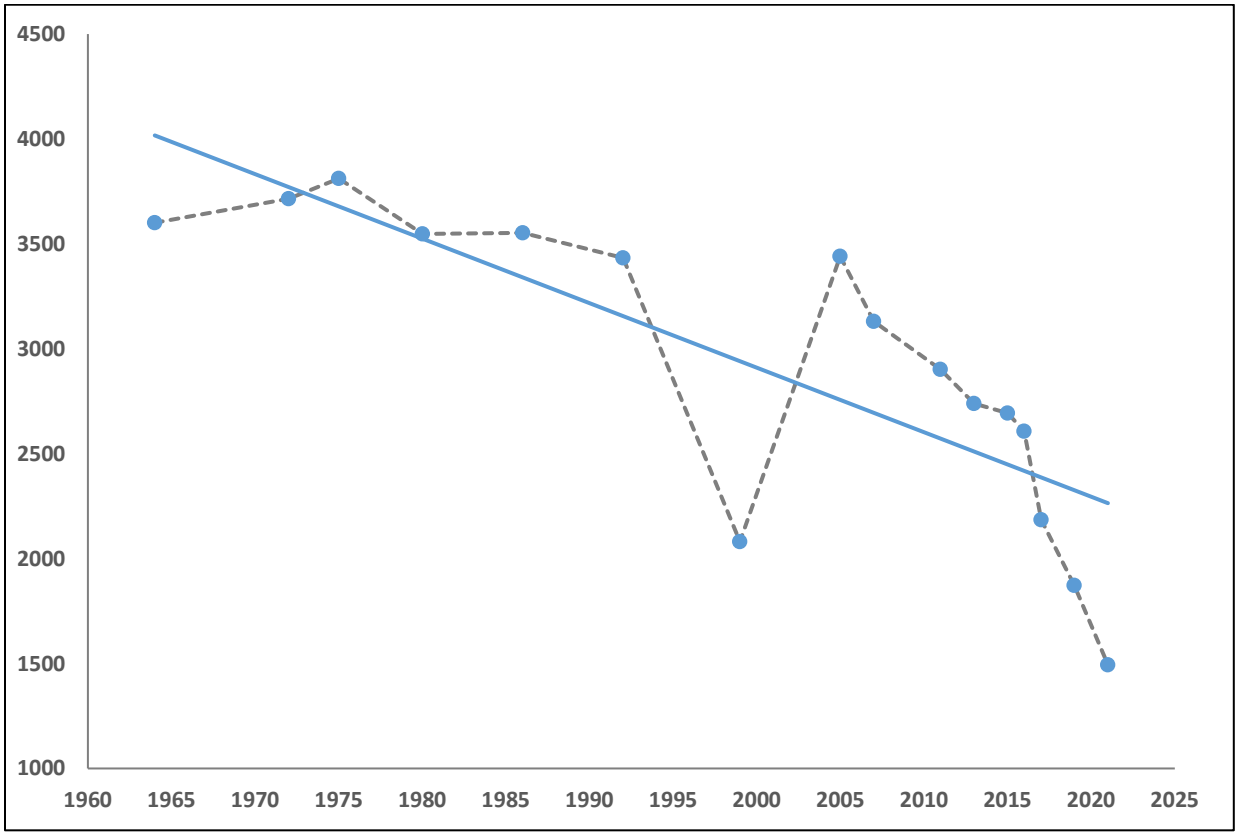

Figure 49. Calculated area of the Mermaid Creek salt marsh (in m^2) by year.

The salt marsh at the mouth of Mermaid Creek has shrunk significantly in the past 57 years and the pace of shrinkage has accelerated since 2005. This also means that the carbon stored in the marsh has decreased and carbon sequestration capacity has diminished. With the amount of area being lost annually, the marsh has effectively turned from a carbon sink into a carbon source. It should also be noted that the upper marsh edge on the north side of the mouth of Mermaid Creek has been retreating up the beach (Figure 50) as the front edge has been eroding. The fact the marsh had room to retreat was likely what kept the areal extent more stable until 2005 when the marsh began to experience coastal squeeze in addition to erosion of the seaward edge. The extreme drop in areal marsh extent in 1999 appears to have been due to a large amount of sediment being deposited on top of the marsh, likely due to a storm event. The marsh appeared to recover from this event before 2005 showing that the marsh is capable of recovery from extreme events; however, with global sea level rise and shifts in weather patterns due to climate change, storm events like these likely will become more common. These events will likely have greater impact in the future due to the other pressures experienced by the marsh and the lack of room for retreat.

This analysis provides insights into potential restoration efforts. It is clear the estuary can support a much larger marsh which is a good basis for restoration and provides a reasonable expectation of success. The active erosion of the front edge, the sediment deposits on the marsh during storm events, and the coastal squeeze the marsh is currently experiencing make it clear that simply adding sediment to the beach below the marsh and replanting (or allowing colonization) will fail if measures are not put in place to mitigate wave action and prevent erosion.

Figure 50. A comparison of the extent of the salt marsh in 1964 versus 2021. The marsh has shrunk by approximately 2,000 m^2 and retreated up the beach over 20m in some sections.

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