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Mud Bay Eelgrass Mapping and Monitoring

Report to City of Surrey

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FRIENDS OF SEMIAHMOO BAY SOCIETY

Acknowledgements

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We gratefully acknowledge the financial support of the Province of British Columbia.

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1. Introduction

The City of Surrey is leading a project funded by the Federation of Canadian Municipalities to prioritize infrastructure and ecosystem risk in Mud Bay. The City has partnered with Ducks Unlimited Canada (DUC), Friends of Semiahmoo Bay Society (FOSBS), and ecologists at University of British Columbia (UBC), each of which has expertise in the ecological components of Mud Bay. Between Summer 2016 and Summer 2018 FOSBS worked with UBC and SeaChange to carry out eelgrass mapping and monitoring on eelgrass beds in Mud Bay.

Eelgrass beds are present in the lower tidal and subtidal areas of Boundary and Mud Bay (Kellerhals and Murray 1969, Bird and Cleugh 1979, Baldwin and Lovvorn 1994, City of Surrey 2008, BirdLife International 2018). These beds have been noted as the richest sites in terms of biomass of invertebrates in the Bays, providing very important feeding grounds for waterfowl (Kellerhals and Murray 1969, Baldwin and Lovvorn 1992, 1994). Eelgrass beds in the bay include both native eelgrass species and introduced dwarf eelgrass (Harrison and Dunn 2004). Introduced dwarf eelgrass has increased the total eelgrass coverage in the Bay (Harrison and Dunn 2004). This is expected to have a beneficial effect on species such as mallard, American wigeon, and brant goose, which eat the leaves, but could have a negative effect on shorebirds (e.g. sandpiper spp.) which feed on un-vegetated mudflats (Harrison and Dunn 2004).

This project builds on eelgrass mapping efforts to date. Boat based eelgrass mapping was completed using an underwater camera and mapping software to interpolate data points, informing the total extent and relative abundance of eelgrass in Mud Bay and Boundary Bay. Foot-based sampling was conducted to quantify abundance and eelgrass bed health.

2. Methods

1.1. Field Methods

1.1.1. Foot-based Sampling

Sites

All surveys and experiments occurred in two eelgrass beds in Boundary Bay (Figure 1). The first is in Mud Bay at the outflow of the Nicomekl and Serpentine rivers, and the second at Crescent Beach for comparison.

Sampling

Plots were staked with 1 piece of rebar in center, down approximately 1.5 m into the sediment. Eight plots at each site were sampled 3 of times with a 50 cm equilateral triangle oriented by compass bearing. Mud Bay was sampled in May, June, and August 2018 and Crescent Beach was sampled in May, June, and July. Shoot density, leaf length and leaf width were measured during each sampling interval for each plot.

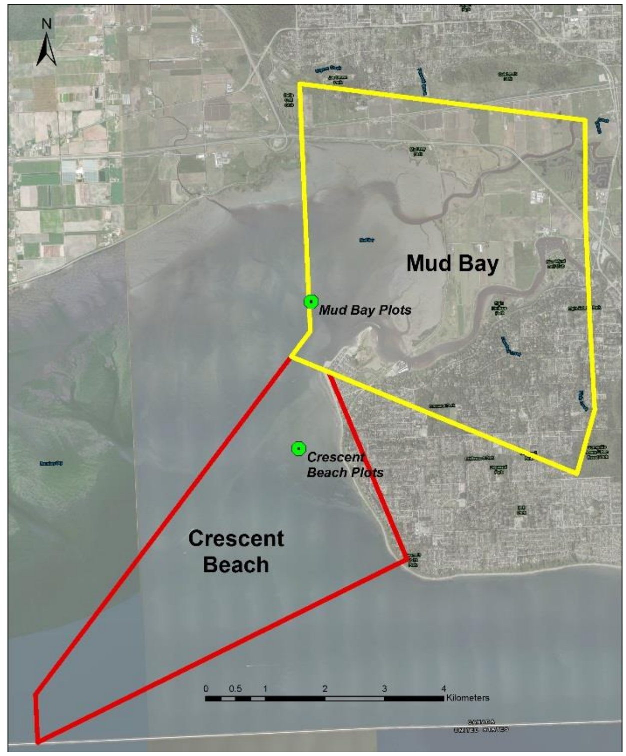

Figure 1. Study sites and plots locations for eelgrass mapping

1.1.2. Boat-based Mapping

Surveys were done by boat equipped with a depth sounder, Trimble and/or garmin gps. An underwater camera was towed behind the boat and connect to a live video monitor on board the boat. The boat ran transects perpendicular to shore approximately 200 m apart. Points were collected along the transects and visual observations at each point were recorded on field data sheets. Attributes recorded include:

Table 1. Boat based eelgrass data collected

Attribute	Description
Waypoint	*The number or name of the waypoint*
Depth	*Depth reading from depth sounder*
Presence	*Edge of Bed, Inside of Bed or None*
Form	*Flat or Fringing*
Distribution	*Continuous or Patchy*
Substrate Type	*Primary, Secondary and/or Tertiary*
Percent Cover	*Visual Estimate of % cover*
Tide	*Slack Tide or Running Tide*
Visibility	*Low, medium or high*
Comments	*Any notes or comments*

Form can be either fringing or flat. Fringing beds are those that occur as relatively narrow bands usually on gentle slopes and Flat beds are more expansive beds covering large areas such as tidal flats. Distribution can be either patchy or continuous. Patchy beds are those that contain isolated groups or patches of plants. Beds that are not patchy, were classified as continuous; a bed that had a few bare patches was classified as continuous.

1.2. Analysis

Two approaches to mapping were used, distance-based aggregation of like (same attributes) data points to generate polygons and a spatial analysis of points using kriging to interpolate points to a raster. Both methods required the creation of point feature classes from field data sheets be entered into an excel spreadsheet and then joined to the spatial data files from the GPS/GNSS device used during field data collection. Sites are classified as either Mud Bay or Crescent Beach (Figure 1).

1.2.1. Foot-based

Shoot Density

Eelgrass shoot densities useful indicators of environmental change responding to environmental change over time (Phillips et al. 1983, Olesen et al. 1994). The number of shoots in the sampling unit was multiplied by the number of sampling units to make one metre squared to determine shoot density. All plots were averaged together to get mean shoot density for each site.

Leaf Area Index

Leaf area indices are often used to estimate the productivity of eelgrass and the amount of habitat available for colonization by epifauna. The LAI is calculated according to the following formula:

LAI = mean shoot length x mean shoot width x mean density of shoot /m2

LAI is potentially more sensitive to environmental stress than is a parameter such as leaf width since it integrates both density and area (Neckles, 1994). Five measures of leaf width and five measures of leaf length were averaged to get mean leaf width and mean leaf width for each plot.

1.2.2. Boat-based

Distance-based Aggregation

Attribute fields, specifically Presence, Bed Type and Percent Cover, were each used to group points into polygons. See Table 2 for a list of eelgrass attribute fields and associated attribute combinations. In effect, all points with the “Bed Type” attribute as “Continuous, Flat” were grouped together.

Table 2. Attribute fields used for eelgrass bed analysis

Field	Description
Transects	*All points*
Presence	*Detected (inside & edge) or not detected*
Bed Type	*1 of 4 combinations of Form and Distribution: "Continuous, Flat", "Continuous, Fringing", "Patchy, Flat", or "Patchy, Fringing"*
Percent Cover	*If present, then 1 of 3 percent cover categories : "<25", "26-75", or ">75"*

To generate polygons based on point data, points were buffered radially 30 meters and point feature class were split by attributes to separate feature classes (ie. All 25_75 % cover class buffered points as one independent attribute feature class). Each attribute feature class was spatially aggregated based 250 m distance to create polygons for each attribute class. Barriers of alternate attribute options for the same attribute type were included in the buffer analysis to prevent the aggregation from overlapping alternate attribute point observations that were within 250 meters of two like attributes points. Manual edits were completed as a part of a visual inspection of the data aggregation. The polygons of spatially aggregated attribute types were merged to create one feature class for all polygons of each attribute type (ie. Percent Cover, Bed Type).

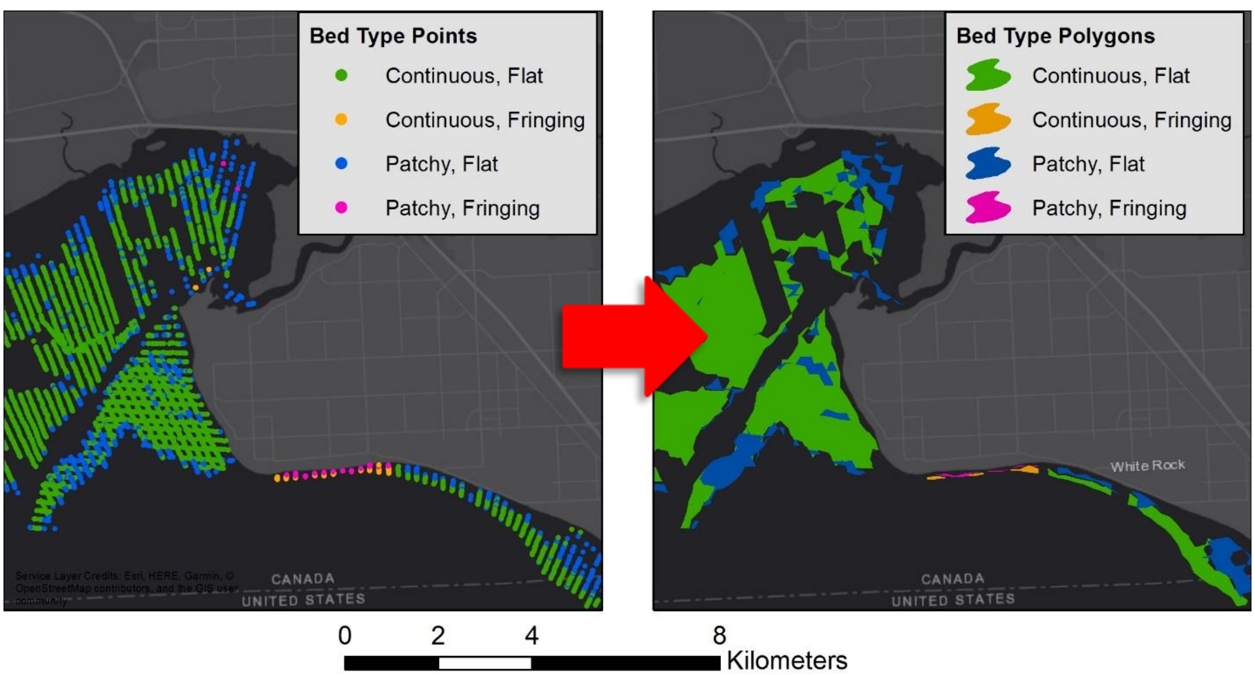

Figure 2. Example of attribute and distance-based point aggregation to polygons

Interpolation

Kriging was used to generate the best unbiased prediction of intermediate values (the spaces between points in a transect and between transects). Kriging is a geostatistical approach to interpolate points for which the interpolated values are modeled by a Gaussian process using determined prior covariances.

Table 3. Bed characteristic values assigned for interpolation

Bed Characteristics					
Form	**Value**	**Distribution**	**Value**	**Cover**	**Value**
NULL	000	NULL	000	NULL	000
None	001	None	010	0%	100
Patchy	002	Fringing	020	<25%	200
Continuous	003	Flat	030	25-75%	300
				>75%	400

All point data was merged into one feature class and each attribute type was assigned a unique number value (Table 3). Form and distribution were combined to create one unique value for each combination (Table 4). R was used to fit the data to a model and determine its covariances for kriging as shown in Figure 3 (R Core Team, 2018).

Table 4 Value for form and distributions combinations

Form, Distribution	Form + Distribution Value
Null, Null	0
None, None	11
Patchy, Fringing	22
Continuous, Flat	33
Patchy, Flat	32
Continuous, Fringing	23

Then using ArcGIS 10.4, in the Spatial Analyst toolbox, the kriging tool was used. Ordinary kriging was selected and spherical semivariogram model was selected based on the results shown in Figure 2. A surface raster is generated as well as a variance raster which is the predicted variance of the modelled surface raster.

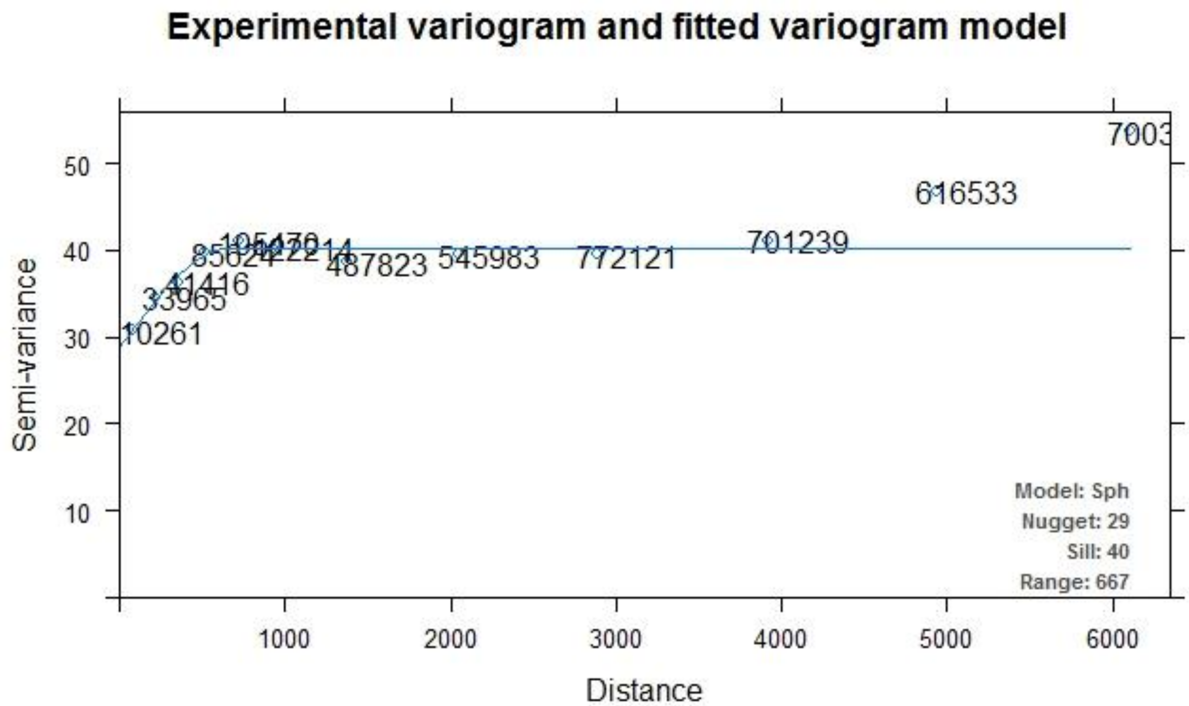

Figure 3. Semivariogram model for bed type with best fit for interpolation.

3. Results & Discussion

3.1.1. Foot-based sampling

Shoot Density

Zostera marina (Figure 4) shoot density (Shoots/ m^2) at Crescent Beach (>350 shoots/m^2) was double that of Mud Bay (~200 shoots/m^2).

Leaf Width, Shoot Length and LAI

Leaf width was higher in all three months at Mud Bay compared to Crescent Beach. Shoots were longer on average for all three months in Mud Bay compared to Crescent Beach. Mean LAI was higher in Mud Bay than at Crescent Beach for the first two sampling intervals and only lower in the third sampling interval, although there was no significant difference in the LAI between sites for any sampling period. LAI is supposed to reflect changes in available seagrass

Figure 4. *Zostera marina* shoots in Mud Bay

habitat and thus diversity and abundance of species. This should be verified Mud Bay and Crescent Beach. As well, this is a snapshot in time of eelgrass bed health in Mud Bay and Boundary Bay and does not indicate what stressors may or may not be impacting each area and whether each bed is near a stressor threshold.

Table 5. Summary statistics for foot-based sampling

		Crescent Beach			Mud Bay		
		May n = 9	June n = 8	July n = 8	May n= 9	June n = 8	August n = 8
Shoot Density	Minimum	128.0000	157.0393	208.0000	128.0000	129.3265	144.0000
	Maximum	368.0000	628.1571	736.0000	544.0000	332.5538	240.0000
	Mean ± Standard Deviation	280.89 ± 85.08	381.05 ± 148.60	460.00 ± 193.47	236.44 ± 130.91	205.54 ± 62.21	182.00 ± 38.19
	95% Confidence Intervals (Lower, Upper)	(225.30, 336.48)	(278.08, 484.03)	(325.93, 594.07)	(150.92, 321.97)	(162.43, 248.65)	(155.54, 208.46)
Shoot Length	Minimum	23.96	32.20	37.00	32.84	58.08	37.92
	Maximum	39.60	47.70	55.70	60.96	102.52	156.04
	Mean ± Standard Deviation	30.76 ± 5.16	37.60 ± 4.74	45.25 ± 5.92	51.02 ± 8.85	75.49 ± 16.79	82.45 ± 39.40
	95% Confidence Intervals (Lower, Upper)	(27.38, 34.13)	(34.32, 40.88)	(41.15, 49.35)	(45.23, 56.80)	(63.86, 87.12)	(55.14, 109.75)
Leaf Width	Minimum	0.32	0.36	0.28	0.34	0.48	0.40
	Maximum	0.44	0.46	0.44	0.56	0.62	0.56
	Mean ± Standard Deviation	0.38 ± 0.05	0.41 ± 0.04	0.38 ± 0.05	0.44 ± 0.06	0.55 ± 0.05	0.47 ± 0.07
	95% Confidence Intervals (Lower, Upper)	(0.35, 0.41)	(0.38, 0.43)	(0.34, 0.41)	(0.40, 0.48)	(0.51, 0.59)	(0.42, 0.52)
LAI	Minimum	1594.778	2139.500	3076.740	1786.496	3606.656	3026.304
	Maximum	5296.896	10083.430	13429.500	14373.786	13972.313	15379.302
	Mean ± Standard Deviation	3,248.46 ± 1,147.48	5,887.29 ± 2,539.68	7,930.00 ± 3,841.64	5,641.91 ± 3,928.03	8,819.86 ± 3,711.54	7,535.59 ± 4,840.75
	95% Confidence Intervals (Lower, Upper)	(2,498.79, 3,998.14)	(4,127.41, 7,647.17)	(5,267.93, 10,592.08)	(3,075.64, 8,208.17)	(6,247.94, 11,391.78)	(4,181.18, 10,890.00)

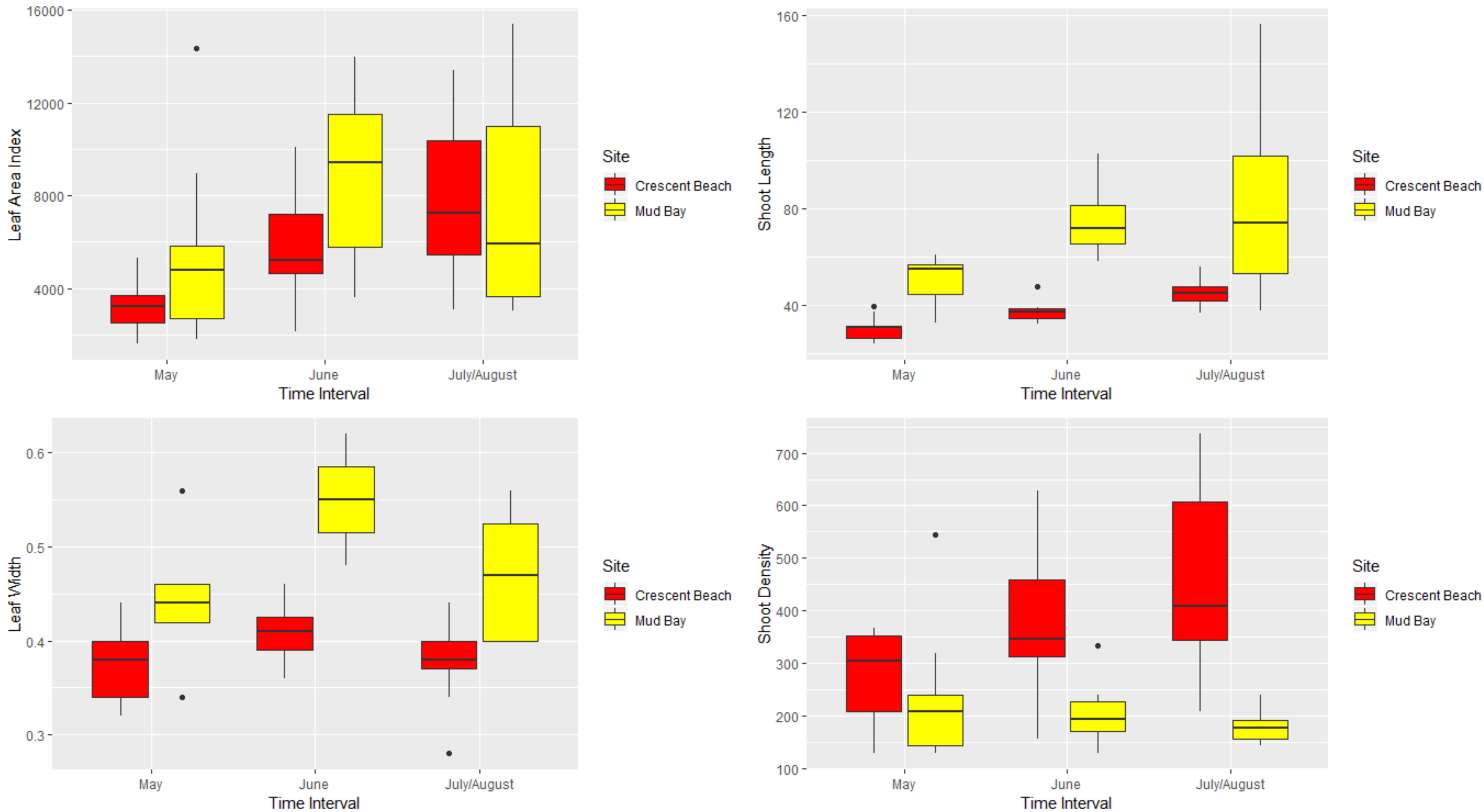

Figure 5. Foot-based sampling boxplots for Leaf Area Index (LAI), Shoot Length, Leaf Width and Shoot Density at Crescent Beach and Mud Bay for 2018

3.1.2. Boat-based Mapping

Distance-based Aggregation

Although this method is less scientific it does produce a representative and useful dataset of eelgrass bed extent and attributes. Repeating this analysis is likely to yield slightly different results each time. Polygons are easy to visually manipulate and to quantify bed type areal extent. Boundary Bay and Mud Bay are both dominated by Continuous, Flat beds. Change in area between years in each of Table 6 and Table 7 does not necessarily reflect a shift in the system and is likely a result of a shift in the surveyed extent. Further analysis to detect inter-annual change would require areas that were surveyed in both years be compared under the same or similar conditions (light, season, visibility).

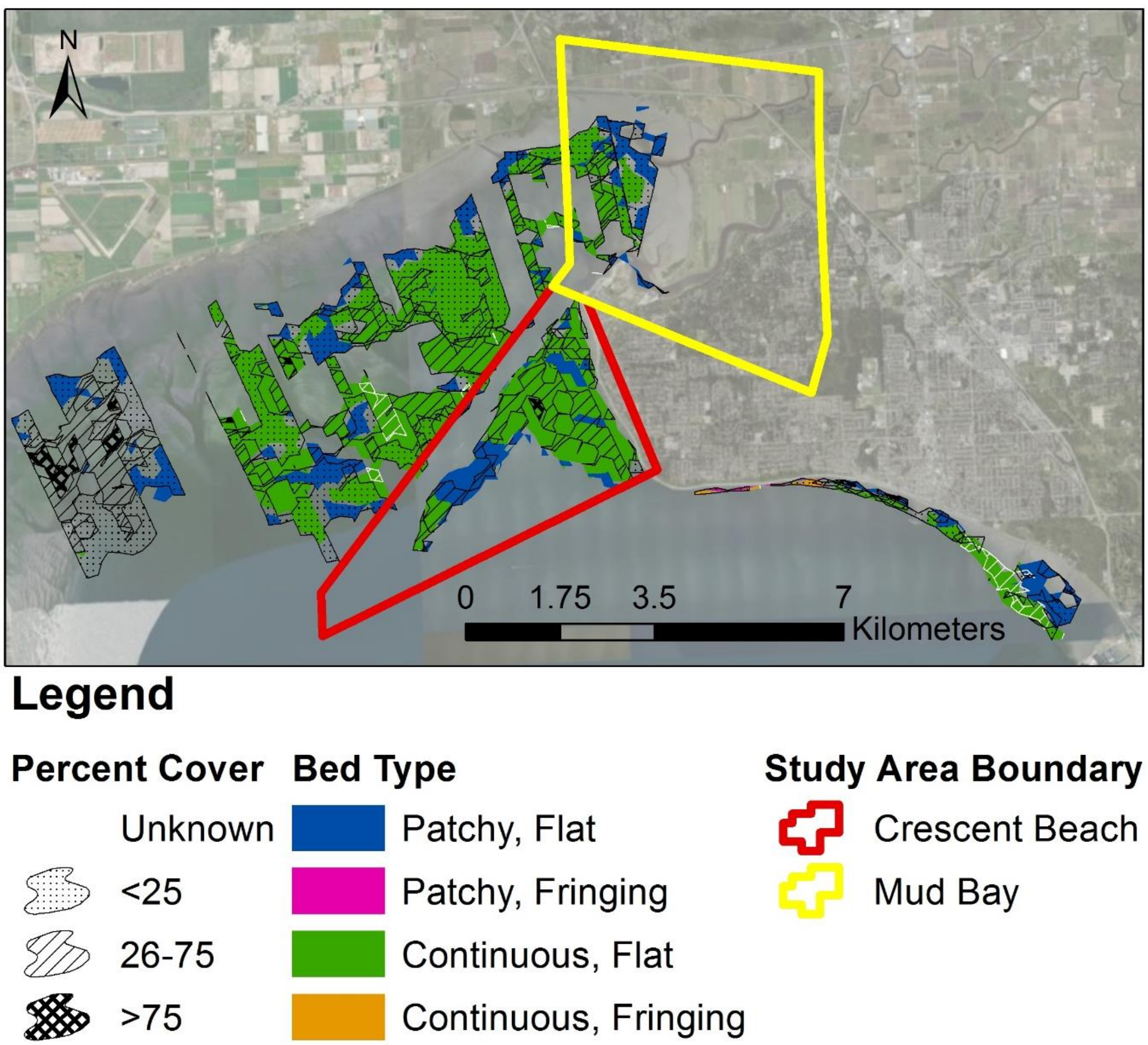

Figure 6. Map of distance-based aggregation of like attributes

Table 6. Area of eelgrass bed attributes in Mud Bay

Bed Type	Area (ha)		Percent Cover	Area (ha)	
	2016	2017		2016	2017
Continuous, Flat	116.76	39.23	0 %	93.25	12.33
Continuous, Fringing	0.00	0.00	< 25%	177.39	54.96
Patchy, Flat	93.70	8.96	25 - 75%	48.51	1.51
Patchy, Fringing	0.00	0.00	> 75%	0	0.00

Table 7. Area of eelgrass bed attributes at Crescent Beach

Bed Type	Area (ha)		Percent Cover	Area (ha)	
	2016	2017		2016	2017
Continuous, Flat	510.39	328.3	0 %	20.59	44.55
Continuous, Fringing	0.00	0.00	< 25%	65.69	0.73
Patchy, Flat	36.13	118.8	25 - 75%	71.65	205.11
Patchy, Fringing	0.00	0.00	> 75%	0.01	5.81

Interpolation

Interpolation appears to be the most robust method for analyzing the boat-based field mapping of eelgrass. The methods and results are repeatable and provide predicted variance of the interpolated dataset. The output is a raster dataset that can be used in statistical comparison to future mapping of similar data type collection. A power analysis could be performed to determine the sample size required for an area to produce a large and accurate enough raster for comparison at one to several sites in Boundary Bay, including Mud Bay, to monitor eelgrass beds. As with distance-based aggregation, interpolation determined Continuous, Flat beds to be dominant in Boundary Bay and Mud Bay. Mud Bay has more Patchy, Flat beds in the upper intertidal. Quantification of bed attribute areal extent is not as straightforward as the polygons from distance-based aggregation. Interpolation results in a gradient of attribute values; classifying the range for each attribute type will require further analysis. Bed type interpolation is shown with the confidence in Figure 7; lower predicted variance equals higher confidence. Figure 9 shows what the interpolation looks like compared to the sample point data.

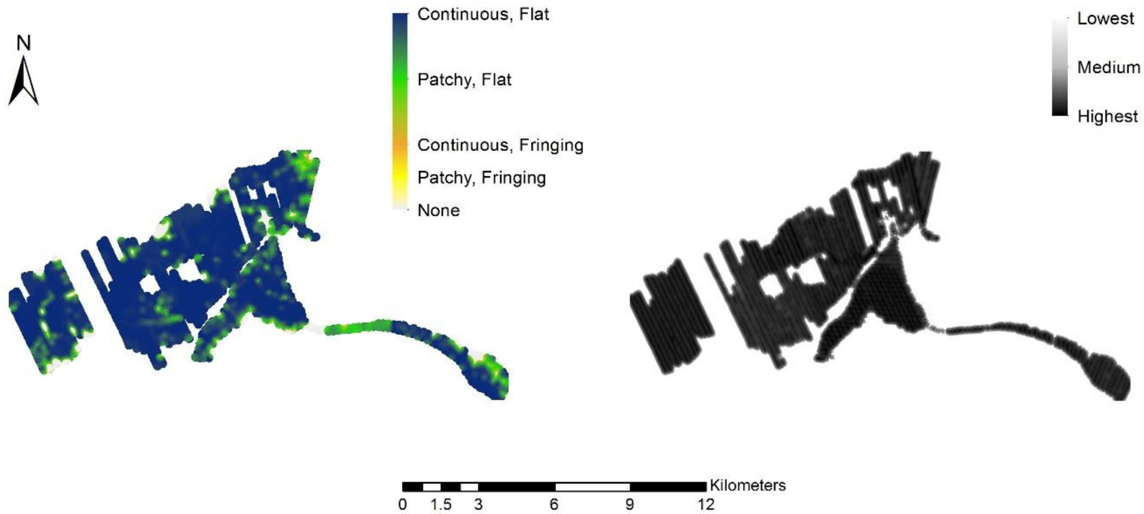

Figure 7. Interpolated sample points (left) and confidence of interpolation (right) for bed type

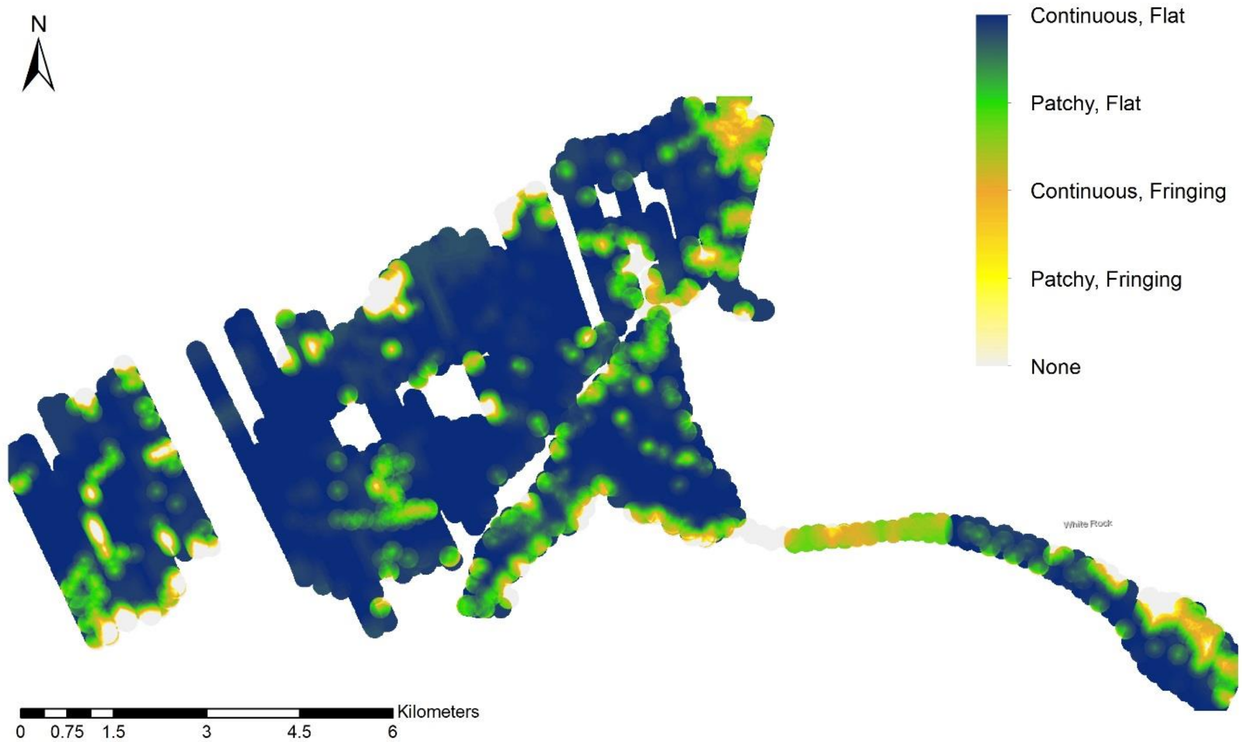

Figure 8. Interpolation map for bed type attribute points

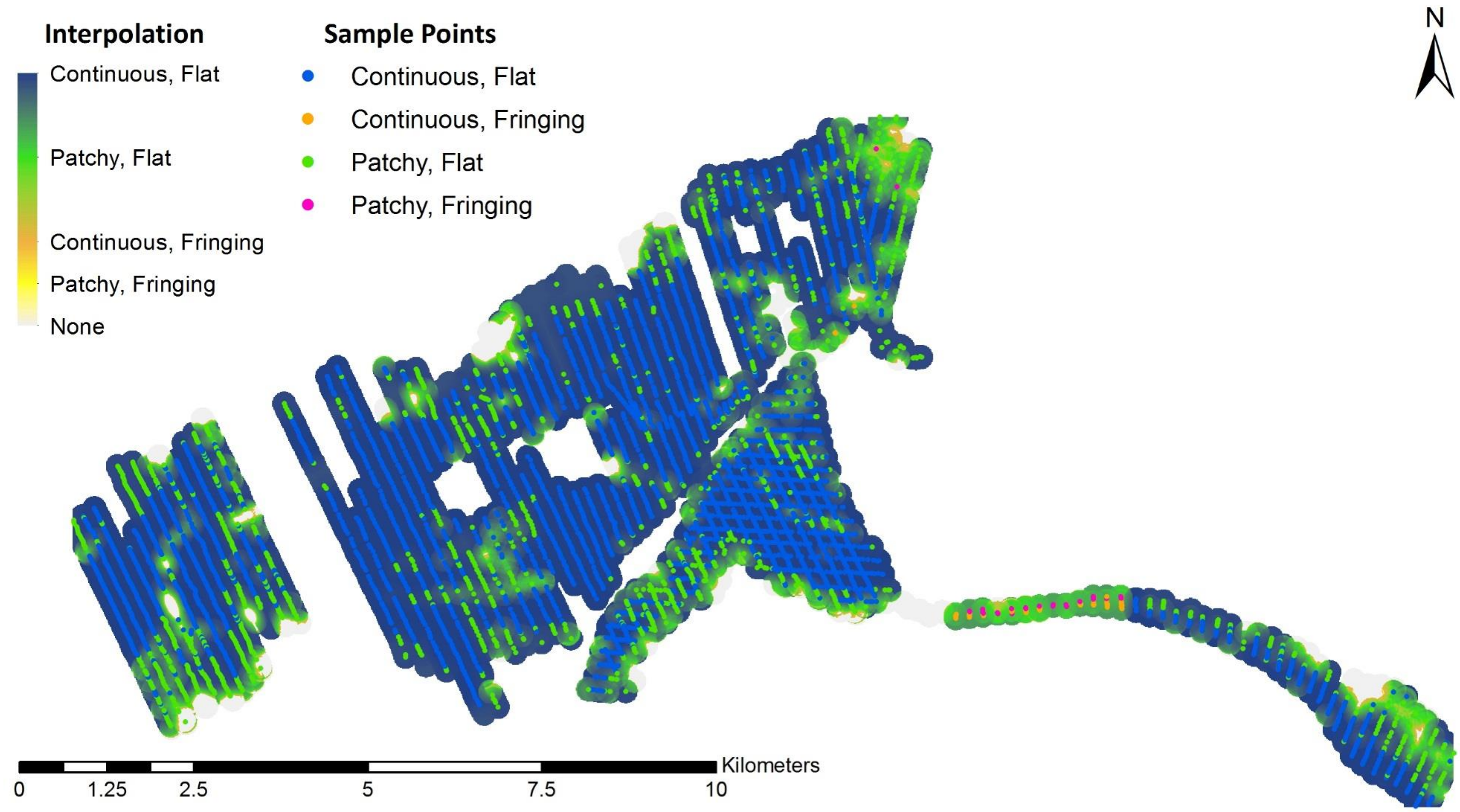

Figure 9. Sample points shown over interpolation

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5. Appendix – A : Maps of Mud Bay

5.1. Distance-based aggregation

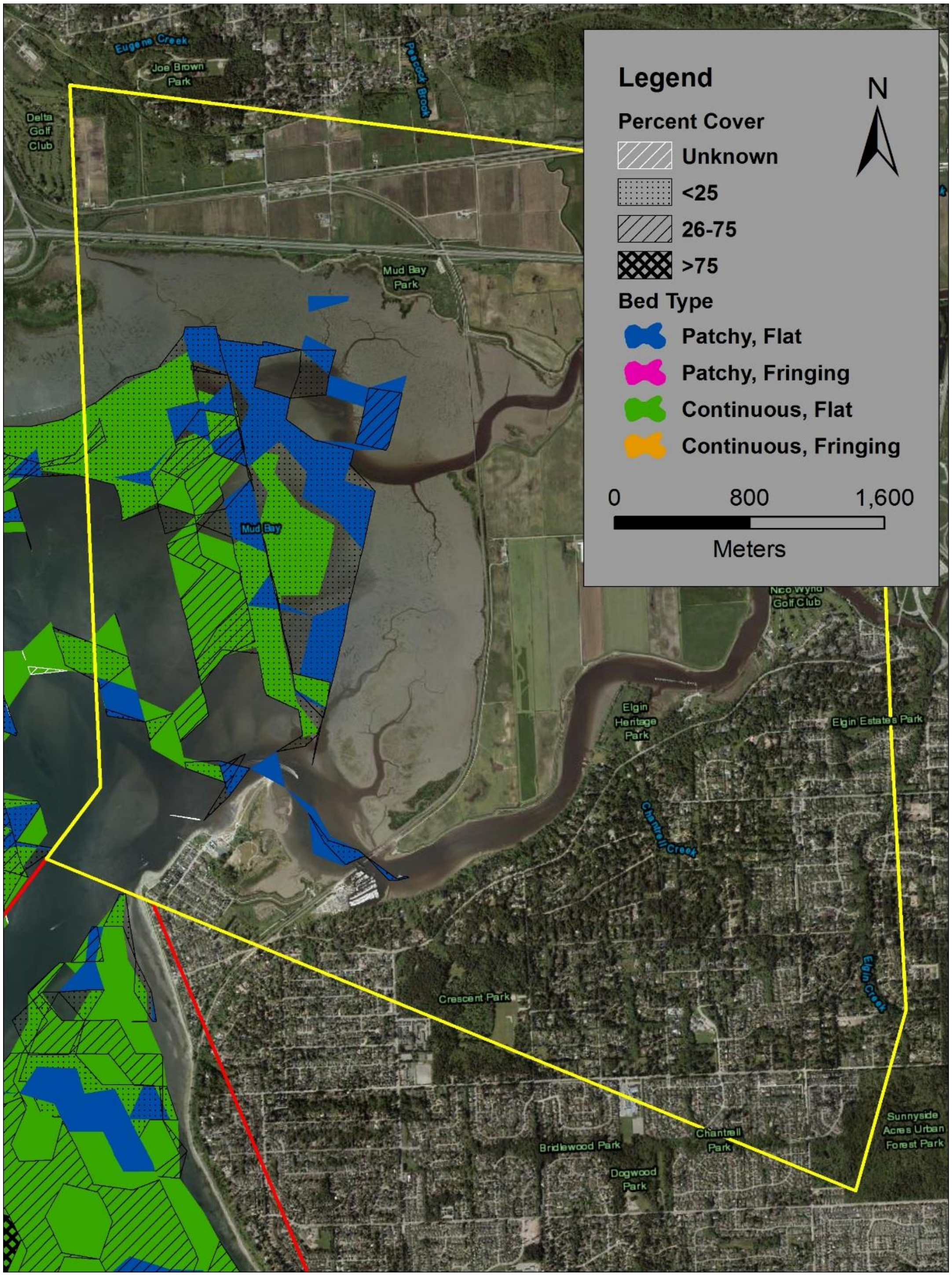

Figure 10. Map of mud bay eelgrass beds

5.2. Interpolation

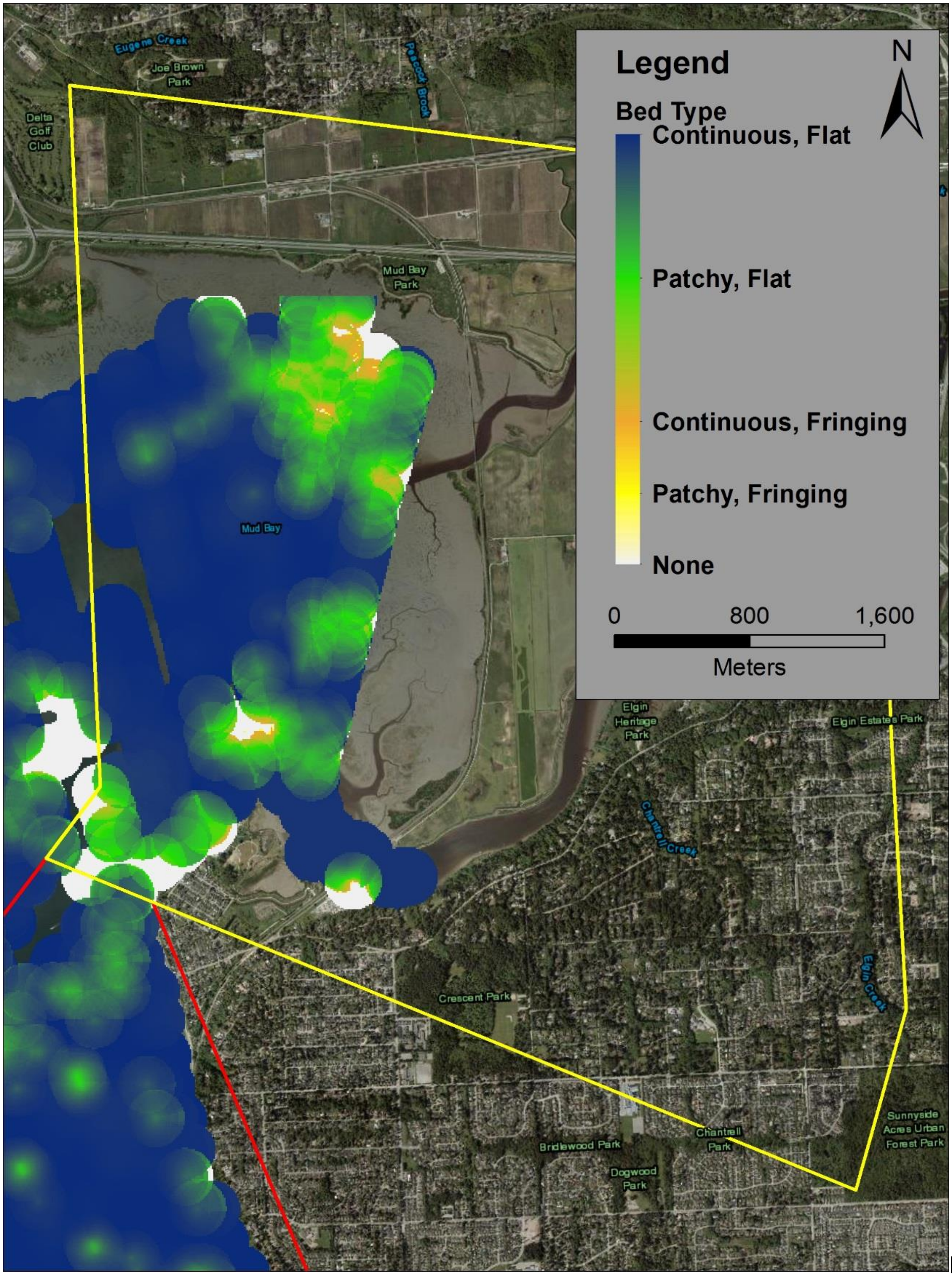

Figure 11. Bed type interpolation map for Mud Bay

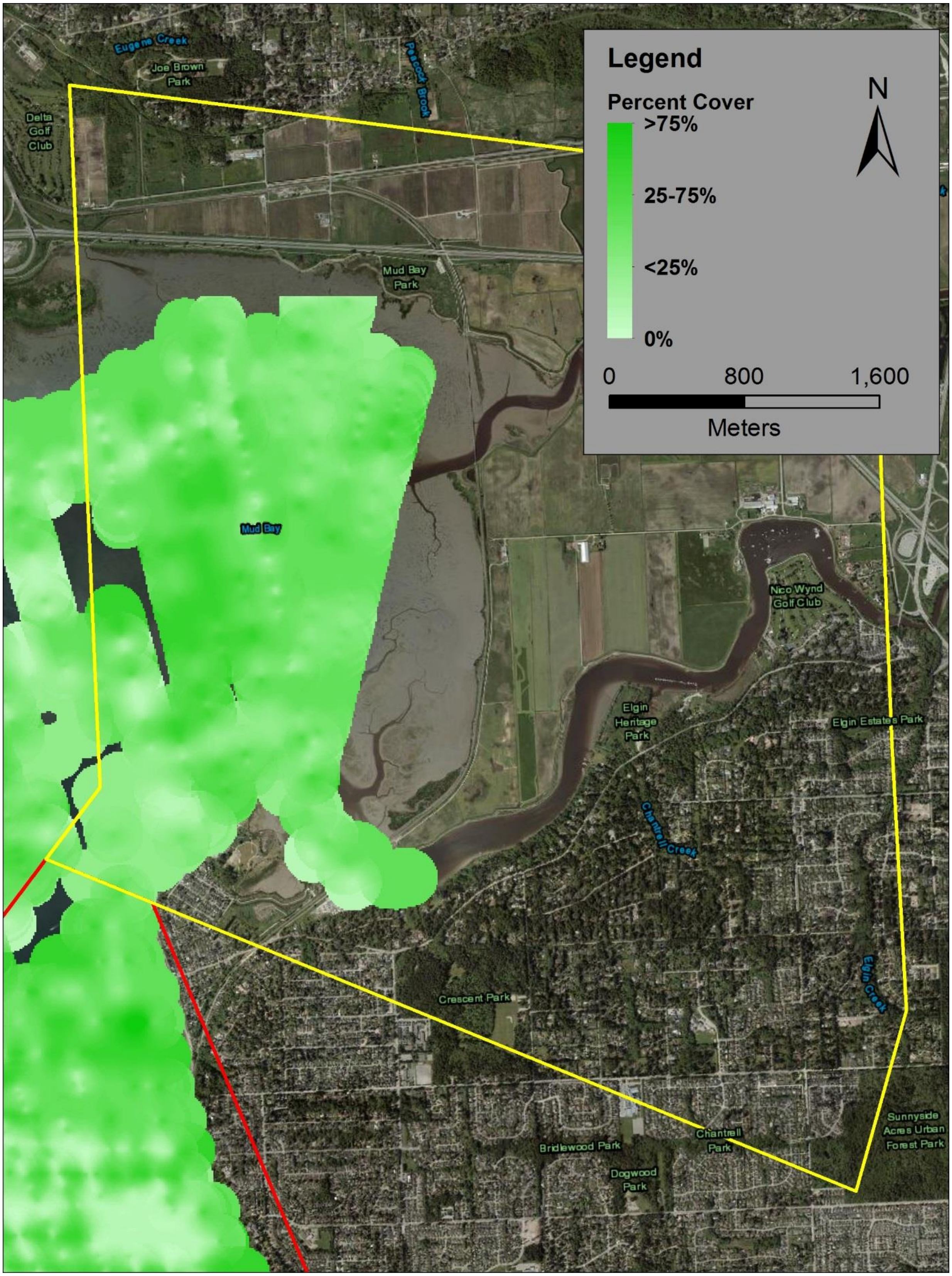

Figure 12. Percent cover interpolation map for Mud Bay