Mapping of Aquaculture Bays in the Gulf Region for Marine Spatial Planning

Prepared by

Applied Geomatics Research Group
NSCC, Middleton
Tel. 902 825 5475
email: tim.webster@nscc.ca

Submitted to

Monique M. Niles
Biologist – Aquaculture and Coastal Ecosystems
DFO – Gulf, Moncton NB
March 28, 2017

How to cite this work and report:

Webster, T., Gemmel, M., Vallis, A. 2017. Mapping of Aquaculture Bays in the Gulf Region for Marine Spatial Planning. Technical report, Applied Geomatics Research Group, NSCC Middleton, NS.

Table of Contents

Table of Figures

List of Tables

1 Introduction

1.1 Project Background

Four Nova Scotia study areas were surveyed in 2016 using topo-bathymetric lidar for the Department of Fisheries and Oceans Canada (DFO). The bays are shallow, protected inlets vegetated with eelgrass that host aquaculture, recreational users, and seasonal residents. The sensor used was AGRG's Chiroptera II integrated topo-bathymetric lidar sensor, equipped with a 60 megapixel multispectral camera.

The objective of this project was to assist DFO with marine spatial planning in four bays along the Northumberland Strait. This report is presented as part of an ongoing project and includes the results of the lidar survey and derived data products, including the seamless depth and contour maps of the four bays and intertidal zone, derived from the lidar point cloud. This report presents the high-resolution imagery, processed using the aircraft trajectory and direct georeferencing. This report also highlights the results of the ground truth survey such as bottom type, underwater photos and water clarity. Eelgrass maps derived from the lidar and orthophotos are presented along with a depth distribution analysis of eelgrass.

1.2 Study Area

Out of six study areas, two are located on the New Brunswick shoreline and the other four are located on the Nova Scotia shoreline of the Northumberland Strait (Figure 1-1). The most westerly study area is Pugwash-River Philip (PWRP). This survey included River Philip, Pugwash River, and the Pugwash Harbour. The next two study areas, located in Pictou County, are Boat Harbour and Merigomish. The fourth area, Mabou, is located in western Cape Breton and has a very narrow mouth to an inlet that has two major rivers draining into it.

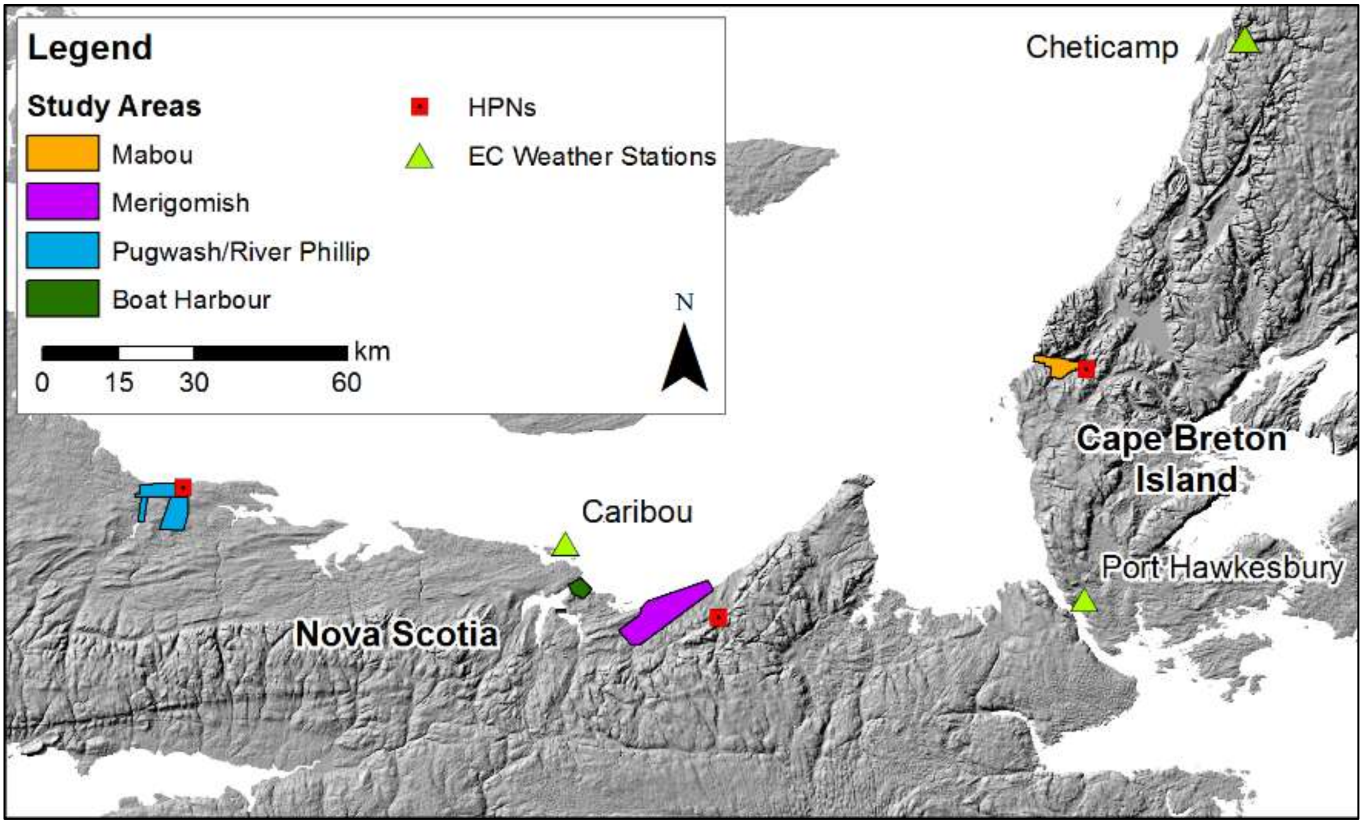


Figure 1-1: The topo-bathymetric lidar study areas in the Southern Gulf of St. Lawrence surveyed in July 2016 showing NS High Precision Network (HPN) stations (orange squares) and Environment Canada (EC) Weather Stations (green triangles).

2 Methods

2.1 Lidar Survey Details

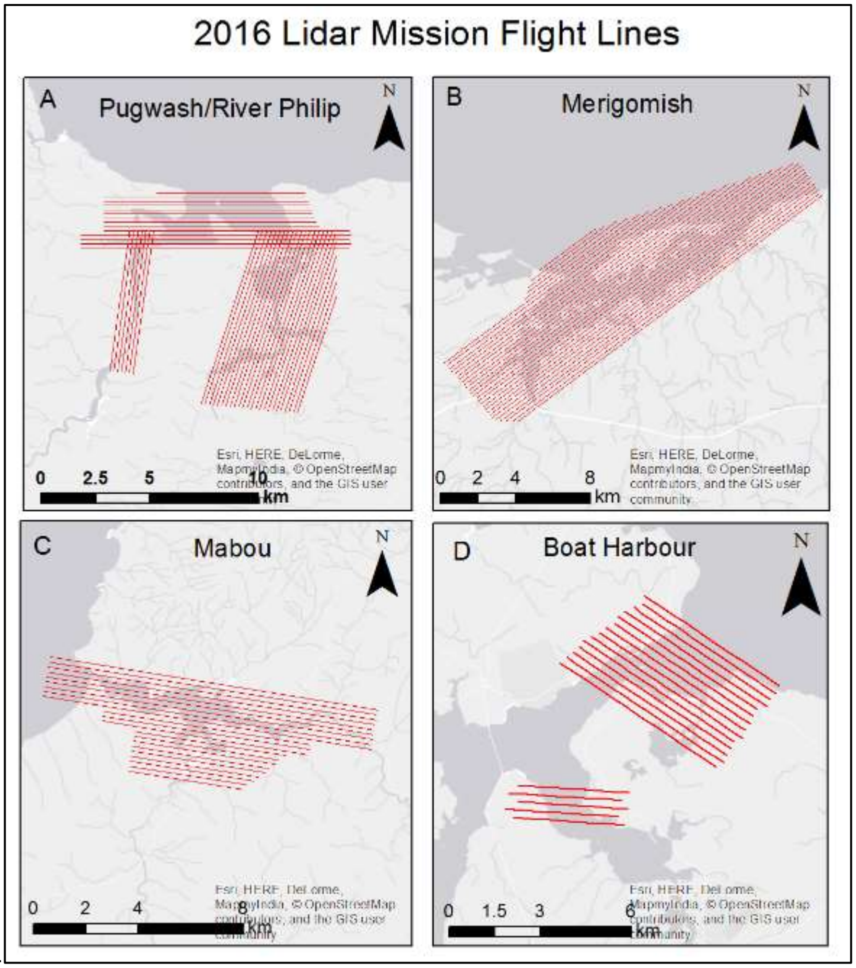
The lidar surveys were conducted in July and September 2016 (Table 2.1). The surveys were planned using Mission Pro software. The planned flight lines for each study area are shown in Figure 2-1. The aircraft required ground-based high precision GPS data to be collected during the lidar survey in order to provide accurate positional data for the aircraft trajectory. A Leica GS14 RTK GPS system was used to set up a base station set to log observations at 1 second intervals over a Nova Scotia High Precision Network (HPN) (Figure 1-1).

The PWRP survey began on July 7 and was approximately two thirds completed when light rain forced the survey to be aborted and postponed until July 11, when it was completed in good weather conditions. The Merigomish survey was started on July 12 but the survey was postponed after one flight line had been completed because the aircraft had reached its maximum daily flight time; the survey was completed on July 13. The Merigomish study area was the largest (87 km^2) and took 5.5 hours to complete. The Mabou survey was also attempted on July 12 and although the weather was suitable for lidar the water clarity conditions were poor and the survey was aborted with no good data collected.

Suitable weather and water clarity conditions were present on July 19 at Mabou and the survey was completed. Boat Harbour was the smallest study area (12 km^2) and was surveyed on September 7.

Study Area	Abbreviated Name	Survey Date	Survey Time (UTC)	Survey Duration (hrs)	Number of Flight Lines	Area (km^2)
Neguac	NEG	July 11	1030 – 1430	4	33	60
Shediac	SHED	July 12	1140 – 1500	3.25	27	40
Pugwash/River Philip	PWRP	July 7	1245 - 1630, 1730 -1845	6	45	57
		July 11	2000 - 2100			
Merigomish	MERI	July 12	1930 - 2030	5.5	31	87
		July 13	1130 - 1400, 1630 - 1830			
Mabou	MAB	July 12 Aborted, no good data	1745 -1815	2.5	21	25
		July 19	1715 - 1945			
Pictou	BH	Sept 7	1315 – 1450	1.5	19	12

Table 2.1: 2016 lidar survey dates, durations, areas, and flight lines.



4

Figure 2-1: Flight lines for the 2016 study areas (A) Pugwash/River Philip, (B) Merigomish, (C) Mabou, and (D) Pictou.

2.2 Ground Truth Data Collection

Ground truth data collection is an important aspect of topo-bathymetric lidar data collection. In 2016 AGRG researchers conducted ground truth data collection including hard surface validation and depth measurements to validate the lidar, Secchi depth measurements for information on water clarity, and underwater photographs to obtain information on bottom type and vegetation (Table 2.2). The seabed elevation was measured directly using a large pole onto which the RTK GPS was threaded, in addition to manual measurements using a lead ball on a graduated rope, and a commercial-grade single beam echo sounder. By threading the RTK GPS antenna on the pole and measuring the elevation of the seabed directly errors introduced into depth measurements obtained from a boat were eliminated, such as those caused by wave action, tidal variation, and angle of rope for lead ball drop measurements. Table 2.2 summarizes the ground truth measurements.

Fieldwork for this project extended beyond the time of flight ground truth measurements to include current meters, depth profiling instruments, and turbidity buoys. A Teledyne RDI Sentinel V20 1000 kHz Acoustic Doppler Current Profiler (ADCP) was deployed at first at PWRP and then at Mabou to measure current speed and direction for minimum 35 days (Table

2.2). A 600 kHz RiverRay ADCP, which measures currents from a moving vessel, was used in PWRP and Mabou to measure flow across different sections of River Phillip, Pugwash River, and at each of the rivers entering Mabou Harbour.

A Seabird 25plus Conductivity Temperature Depth (CTD) sensor was used during the lidar survey on July 7 at PWRP and in Mabou on July 13 and 21 to measure changes in salinity, temperature, turbidity and chlorophyll through the water column across each study area. The CTD data provide insight into the structure of the water column, e.g. whether it is well-mixed or stratified; this information was valuable in evaluating lidar penetration. The data also provided an additional depth validation method. A 1 m x 1 m steel cube was deployed at PWRP on July 7 to assess the lidar's ability to detect such a shape. A Nexsens Technology CB-50 Turbidity buoy equipped with a cell modem was deployed at Mabou on July 13 in order to remotely monitor water clarity. The buoy monitored turbidity at 0.75 m below the water surface every 15 minutes and uploaded the data to a web server three times a day.

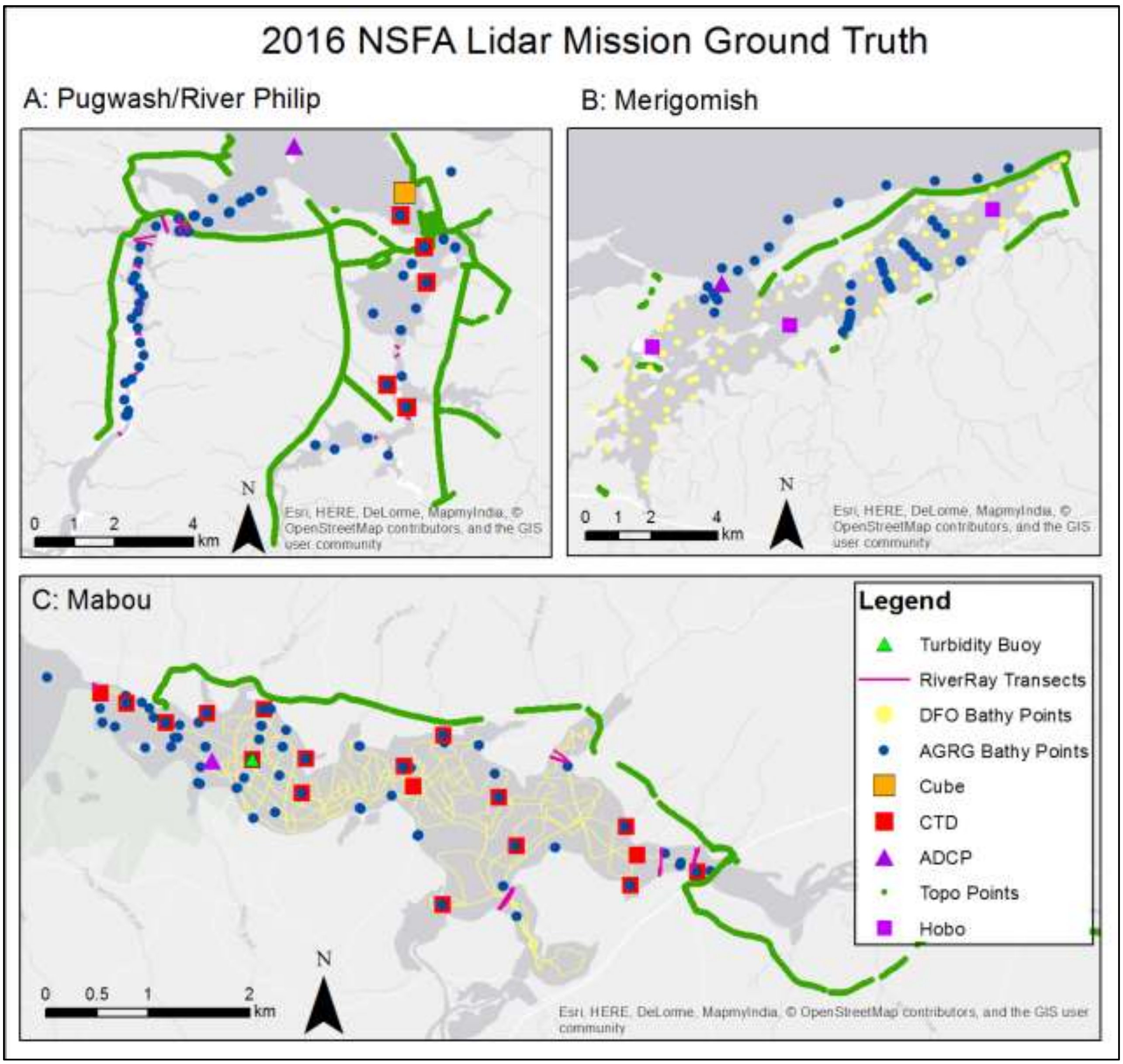


Figure 2-2: Location of hard surface GPS validation points, AGRG and DFO boat-based ground truth waypoints at (A) Pugwash/River Philip, (B) Merigomish and (C) Mabou. The location of the ADCP deployed in Merigomish by DFO is unknown at this time, no CTD measurements were obtained in Merigomish, and a cube was deployed in Pugwash only.

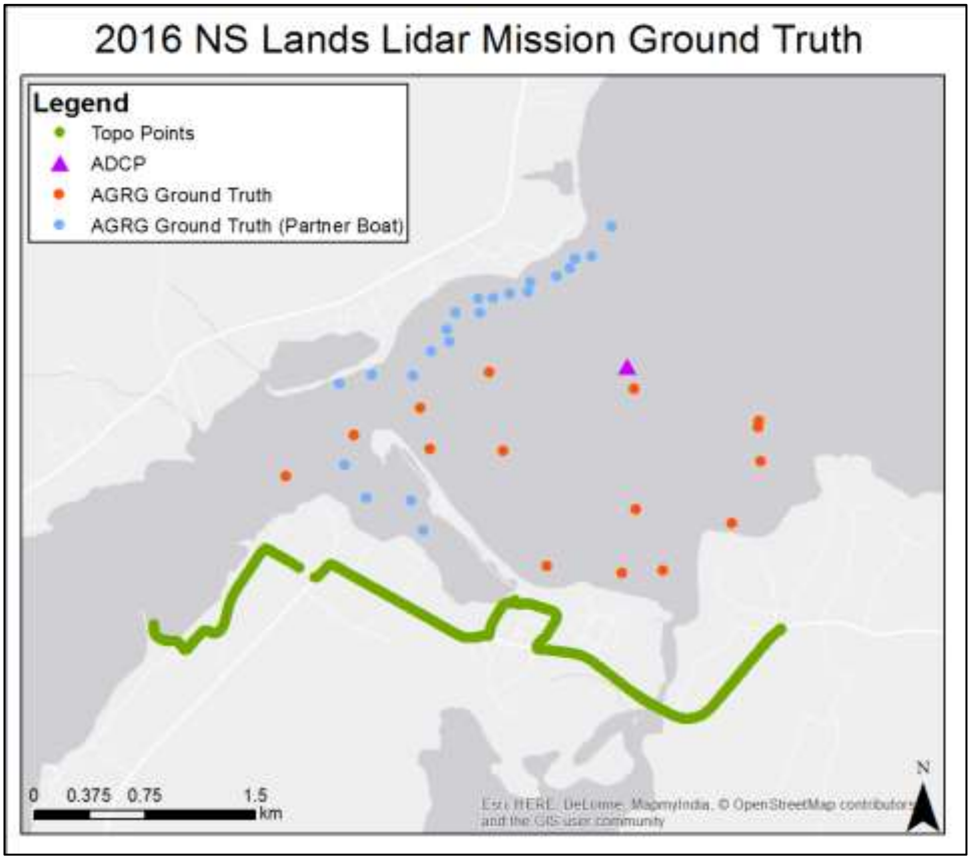


Figure 2-3: Location of hard surface GPS validation points, AGRG and partner boat-based ground truth points, and ADCP deployment at Boat Harbour.

Location	Date	Base station	GPS System	Secchi	Depth	ADCP	Underwater Photos	Hard Surface GPS	CTD	Turbidity Buoy	Cube	Partner Participation
PWRP	July 7*	13698	GS14, 1200	Y	P, M, ES	RR	P, Q_{50}	Y	Y	-	Dep. & Rec.	NSFA
	July 14	13698	GS14, 1200	-	ES	RR	P, Q_{50}	-	-	-	-	NSFA
	Aug 5		GS14	-	-	Sentinel Dep.	-	-	-	-	-	
	Sept 9	-	-	-	-	Sentinel Rec.	-	-	-	-	-	
MERI	July 13*	21949	GS14, Garmin	Y	M	-	P,Q_{50}	Y	-	-	-	NSFA
	July 18				M							DFO ONLY
	Aug 10				BioSon.							DFO ONLY
MAB	July 13	-	Garmin	Y	ES	-	-	-	Y	Deployed	-	-
	July 21	214131	GS14, 1200, Garmin	Y	P,M	RR	P,Q_{50}	Y	Y	Recovered	-	NSFA
	Aug 30				BioSon.							DFO ONLY
	Sept 15	-		-	-	Sentinel Dep.	-	-	-	-		
	Oct 27	-	-	-	-	Sentinel Rec.	-	-	-	-		
PICTOU	Aug 11	206392	GS14,1200	Y	P, M, DM	Dep.	Q_{50}	Y	-	-	-	Pictou Landing First Nation
	Aug 30	-	GS14	-	-	-	-	-	-	-	-	Y
	Sept 13	-	-	-	-	Rec.	-	-	-	-	-	-

Table 2.2: Ground truth summary. * Indicates that the ground truth survey was occurring with the lidar survey. GPS Column: Two Leica GPS systems were used: the GS14 and the 530; a handheld Garmin GPS unit was also employed. Depth Column: P=GPS antenna threaded onto the large pole for direct bottom elevation measurement; M=manual depth measurement using lead ball or weighted Secchi disk; DM=handheld single beam DepthMate echo sounder; ES=Single beam commercial grade Humminbird Echo Sounder; BioSon.=BioSonics brand echo sounder. Underwater Photos: P=GoPro camera secured to pole for underwater still photos; Q_{50}=0.25 m^2 quadrat with downward-looking GoPro camera. ADCP- Sentinel Deployed or Recovered (Sent. Dep./Sent. Rec.), or RiverRay (RR).

2.3 Time of Flight Conditions: Weather, Tide and Turbidity

Meteorological conditions during and prior to topo-bathy lidar data collection are an important factor in successful data collection. As the lidar sensor is limited by water clarity, windy weather has the potential to stir up any fine sediment in the water and prevent good laser penetration. Rainy weather is not suitable for lidar collection, and the glare of the sun must be factored in for the collection of aerial photography. Before each lidar survey we primarily monitored weather forecasts using four tools: the Environment Canada (EC) public forecast (http://weather.gc.ca/) for Caribou and Port Hawkesbury (Figure 1-1); EC's Marine Forecast (https://weather.gc.ca/marine/index_e.html); SpotWx (www.spotwx.com), which allows the user to enter a precise location and choose from several forecasting models of varying model resolution and forecast length; and a customized EC forecast for the lidar study areas provided to AGRG every eight hours. Each of these tools had benefits and shortcomings, and it was through monitoring all four that a successful lidar mission was achieved. For example, the customized EC forecast was the only tool that provided a fog prediction, on an hourly basis. However, the SpotWx graphical interface proved superior for wind monitoring. Only the EC public forecast alerted us to Weather Warnings that were broadcast in real-time, such as thunderstorms, and the marine forecast provided the only information for offshore conditions. The tide is another important consideration in a bathymetric lidar survey, and ideally each survey would be flown as close to low tide as possible to extend the area of laser penetration.

Although the summer of 2016 was particularly hot and dry, the lidar mission was not without its metrological challenges. As mentioned in Section 2.1 the PWRP survey was completed during two separate flights after the first flight was aborted due to light rain, which started late in the day on July 7 (Figure 2-4). Wind was between 10 and 20 km/hr blowing from the North during the survey and the tide began and low tide but was near high tide by the end of the survey. Wind in the days prior to the survey was low, staying mostly below 20 km/hr after July 3; it is not expected that wind at PWRP had an impact on water clarity on July 7. The survey was completed on July 11 in the sheltered River Philip arm of the study area during a high tide. Although wind is reported to have been ~25 km/hr at Caribou there were no issues with wind during the flight and lidar penetration was good.

The Merigomish survey on July 12 was flown under low wind conditions (~5 km/hr), clear skies, and a high tide (Figure 2-4). The survey was restarted on July 13 on a falling tide to maximize the amount of survey time near low tide. Wind was between 5 and 15 km/hr during the survey and no rain was reported.

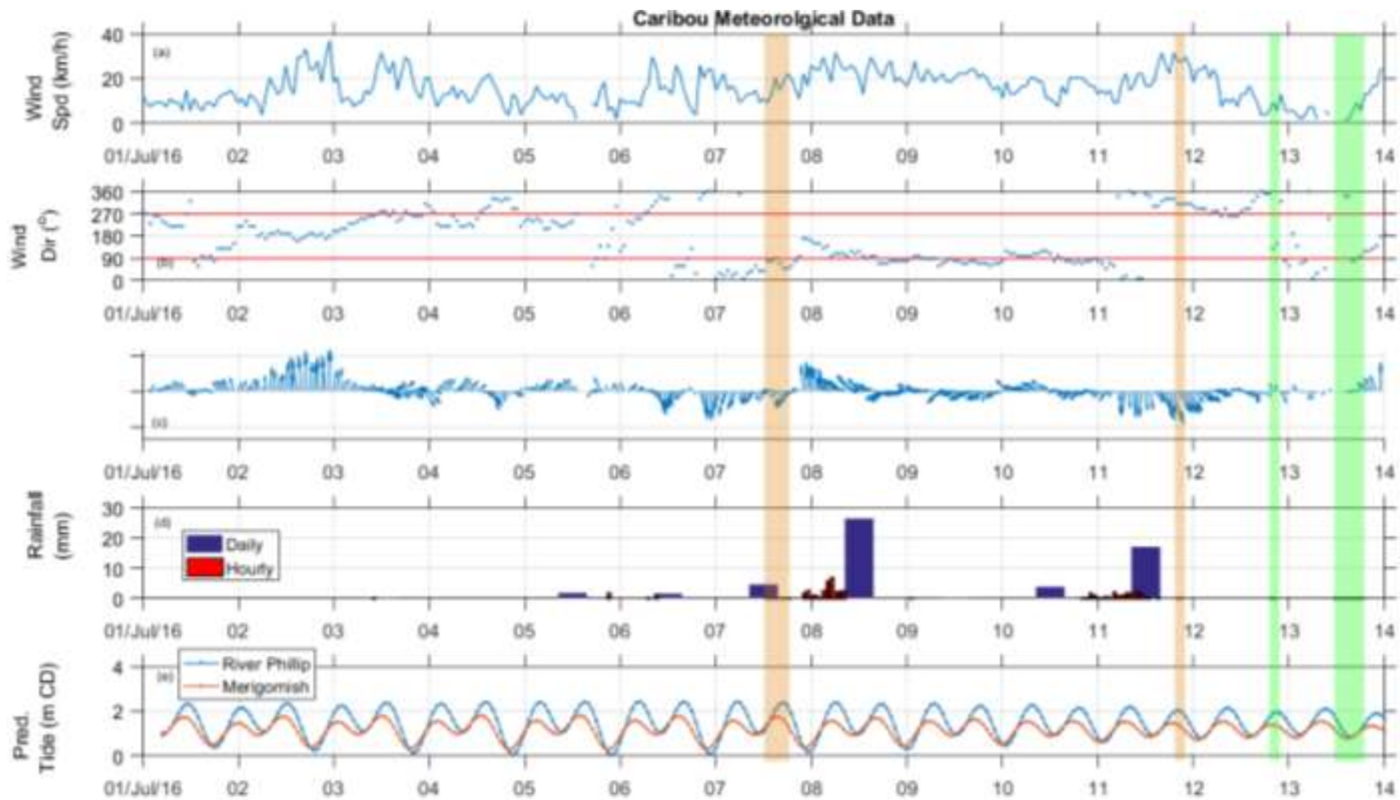


Figure 2-4: Caribou meteorological data (a) wind speed; (b) wind direction; (c) wind vectors indicating speed and direction wind is blowing towards; (d) daily rainfall; (e) predicted tide at River Phillip and Merigomish in Chart Datum. Lidar surveys at PWRP and MERI are highlighted in orange and green, respectively. Time axis is in UTC time zone.

The first survey at Mabou was attempted on July 12 in <20 km/hr northerly wind on a rising tide but was aborted due to poor lidar penetration. The lidar operator reported that the water appeared cloudy and red. There were several small rainfall events during the week prior to that survey, including July 11 where 11.2 mm of rain fell at Cheticamp (there is no rainfall record at Port Hawkesbury) (Figure 2-5). This rainfall event, combined with 30 km/hr north wind on the same day, could have flushed sediment from the river systems into Mabou Harbour, or stirred up suspended sediments from the sandstone cliffs. A field team was deployed to Mabou July 13 to deploy a turbidity buoy to monitor water clarity conditions at Mabou in real-time (Figure 2-7a) and local NSFA contacts were also enlisted to visually assess water clarity. The area was re-surveyed on July 19 when the water was reported to be clear of the red suspended sediment by the local contact, and the turbidity buoy indicated that water clarity had improved (Figure 2-5f). The survey was completed during a low tide with blowing from the north at ~15 km/hr. During ground truth surveys on July 21 turbidity varied from clear near the mouth of the harbour to reduced clarity farther up the inlet. In between lidar surveys there was an event on July 15 where ~14 mm of rain was recorded at Cheticamp and the wind reached 30 km/hr blowing from the south; this event correlates with a small increase in turbidity that quickly decreased, and remained low until the buoy was removed on July 21 following the lidar survey. A correlation between high tide and high turbidity is apparent (Figure 2-7).

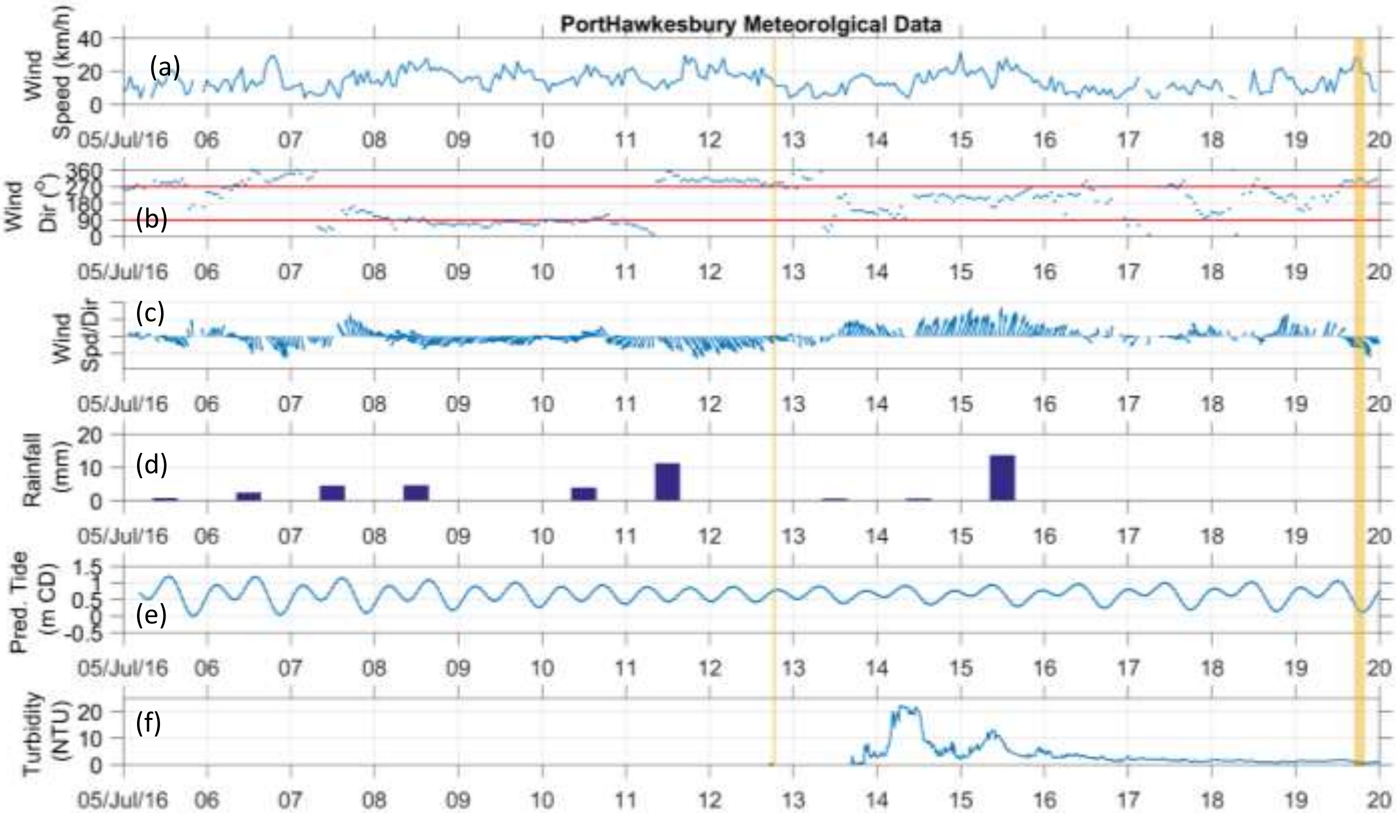


Figure 2-5: (a- c): Wind speed and direction data recorded at Port Hawkesbury; (d) daily rainfall recorded at Cheticamp; (e) predicted tide at Port Hood in Chart Datum; (f) turbidity measured by AGRG buoy. The attempted and completed lidar surveys are highlighted in orange. Time axis is in UTC time zone.

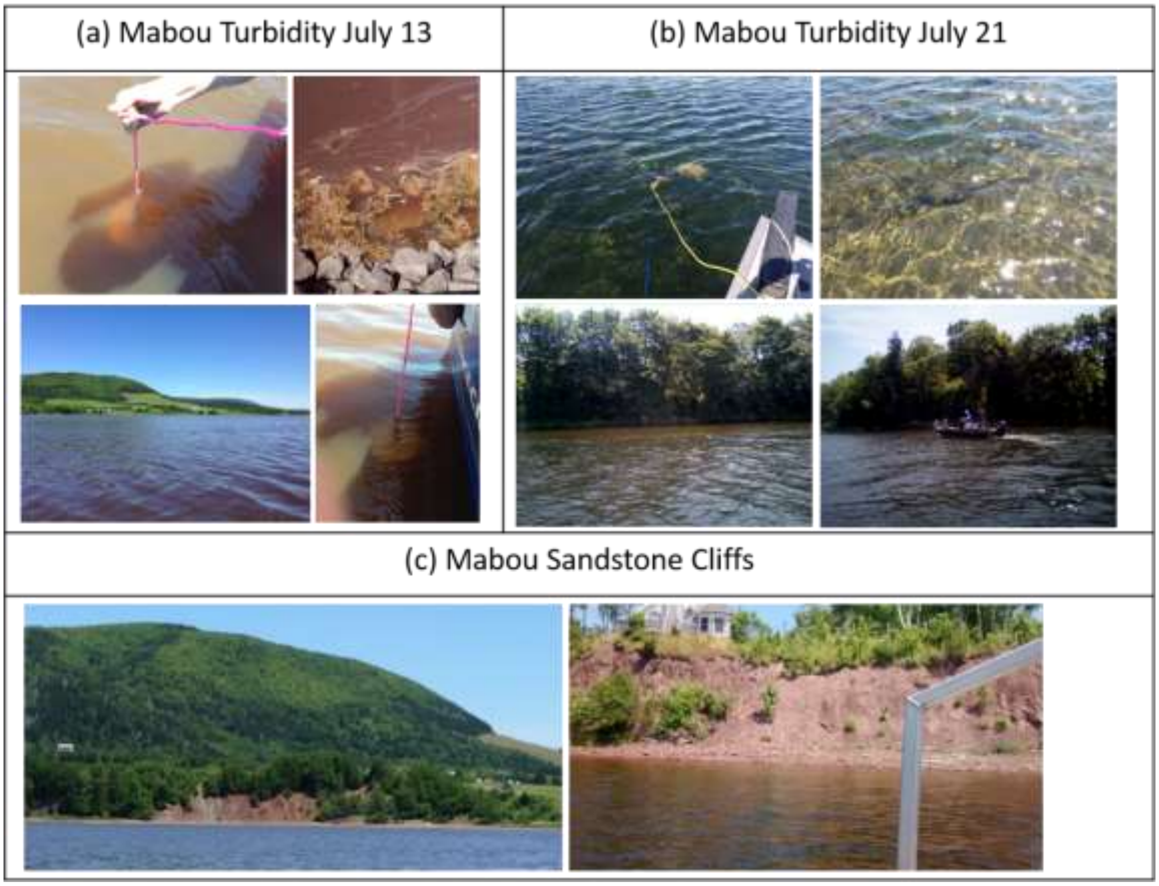


Figure 2-6: (a) High turbidity at Mabou on July 13; (b) varying turbidity during ground truth on July 21; (c) red sandstone cliffs that could contribute easily suspended sediment as they are eroded.

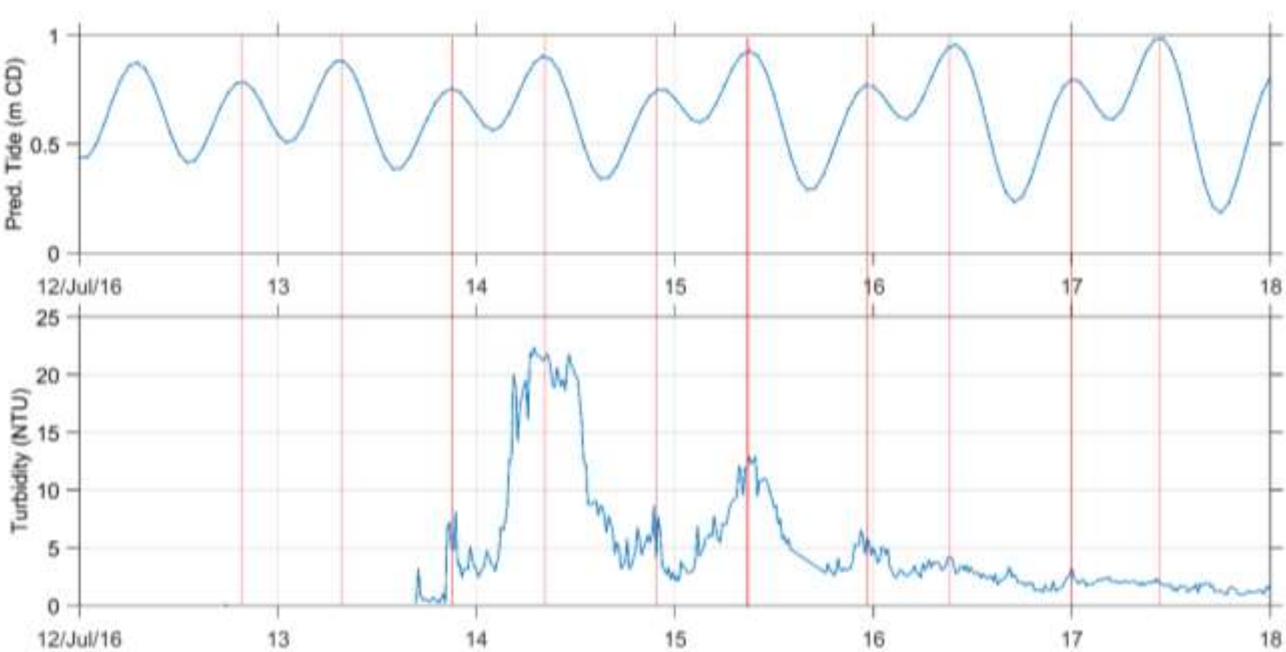


Figure 2-7: Mabou predicted tide and turbidity measured by the AGRG buoy, July 12 – 18. Peaks in turbidity line up with high tides.

3 Results

3.1 Bottom Imagery

The underwater photographs taken using a GoPro camera are useful indicators of bottom type throughout the study areas. The following sections present some of the images obtained during the field season displayed on the RCD30 5 cm resolution orthophoto mosaics.

3.1.1 Pugwash-River Philip

The bottom type at the mouths of the Pugwash River and River Philip was a combination of sand and thick, healthy eelgrass, and the water appears clear (Figure 3-1, Figure 3-2). Farther upstream in River Philip the water colour is darker and the bottom type appears to be composed mainly of mud and sand (Figure 3-3).

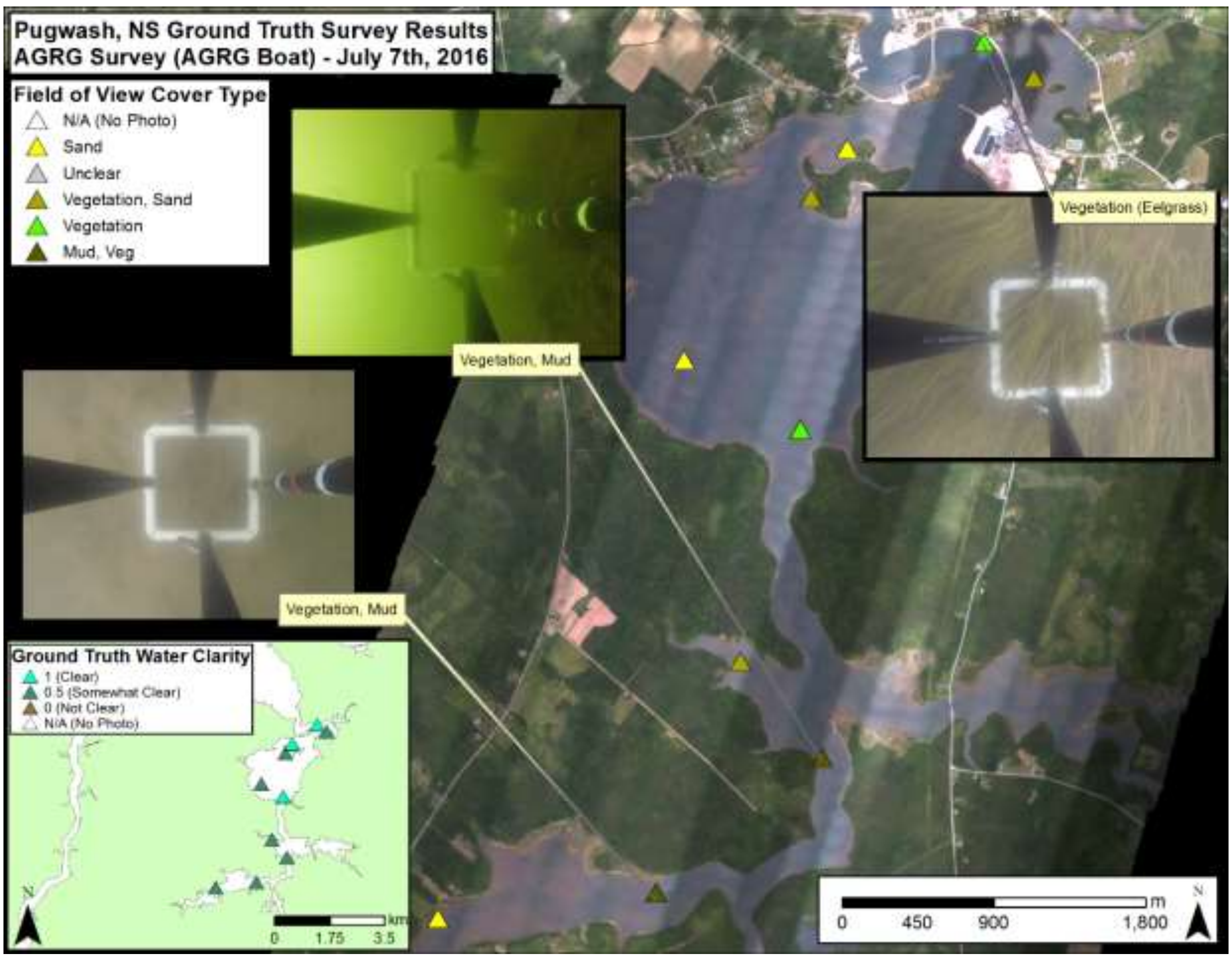


Figure 3-1: PWRP underwater photo ground truth for the July 7 survey (AGRG Boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

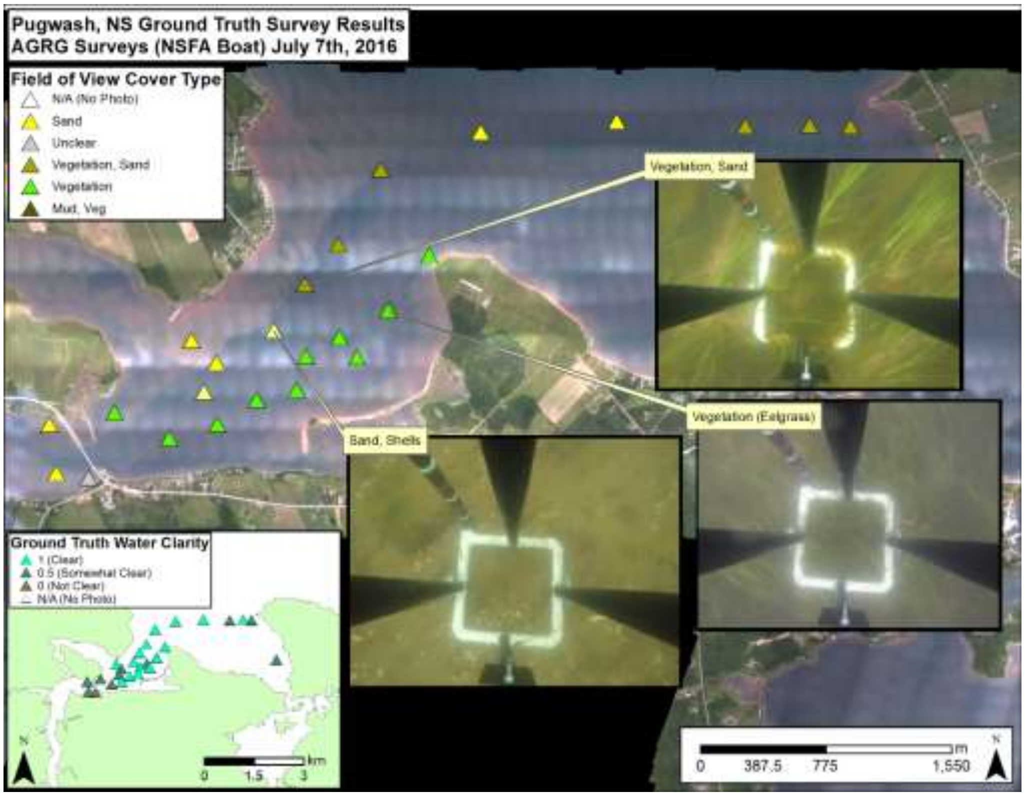


Figure 3-2: PWRP underwater photo ground truth for the July 7 survey (NSFA Boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

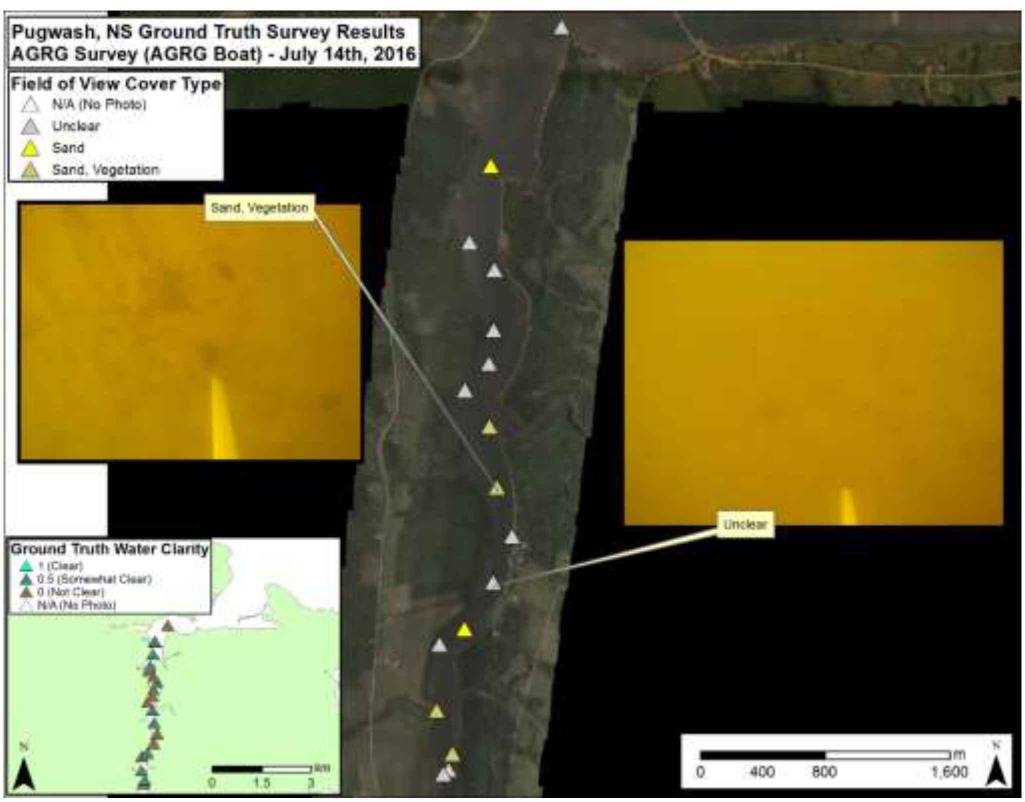


Figure 3-3: PWRP underwater photo ground truth for the July 14 survey (AGRG Boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

3.1.2 Boat Harbour

The bottom type at Boat Harbour was a combination of sand, mud, fucus and eelgrass. The water appears mainly clear in the inner bay, North West of Pictou (Figure 3-4) Towards Pictou Landing, on the Eastern side of the study area, the water is darker and the bottom appears to be composed mainly of mud and sand with a small amount of fucus present.

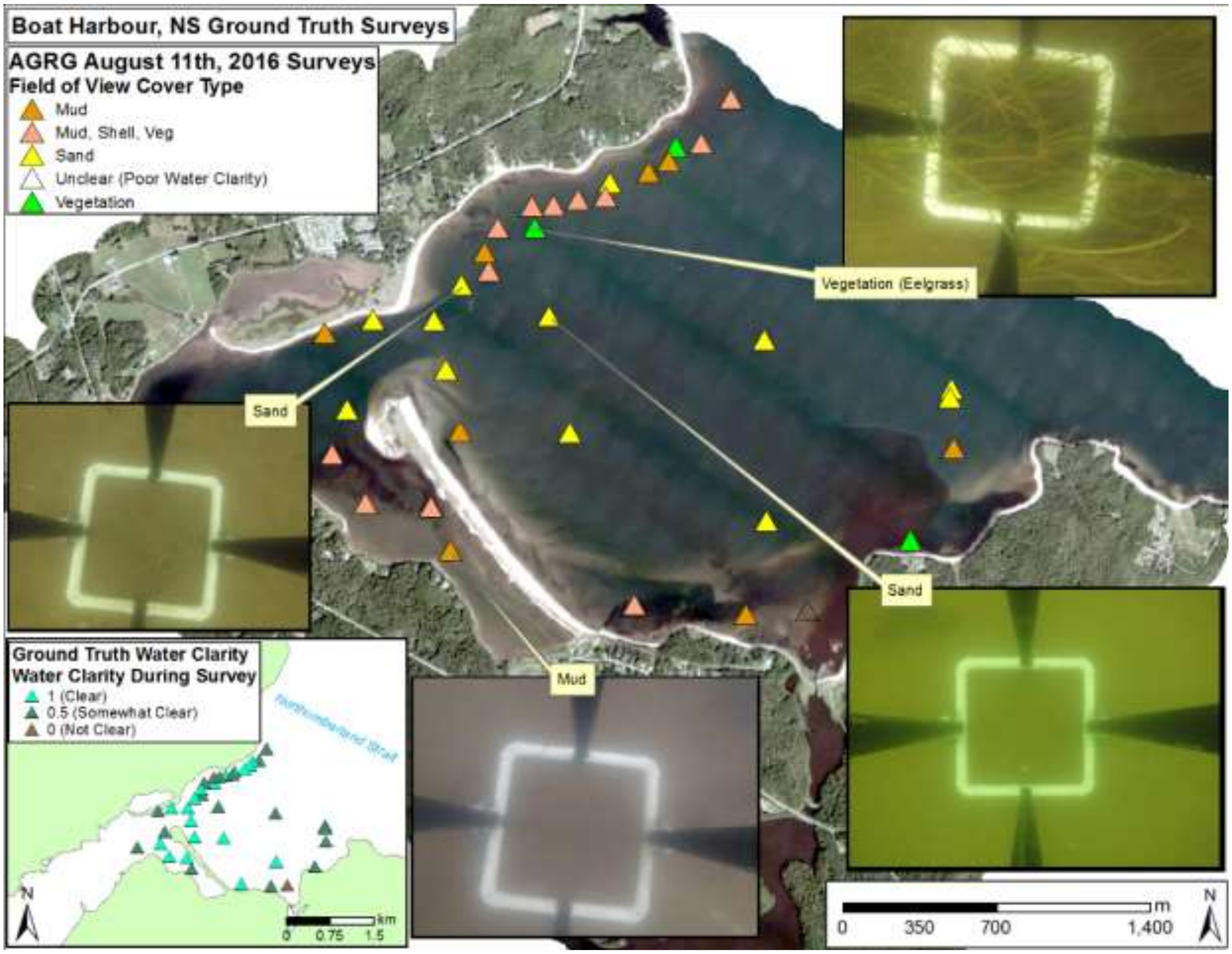


Figure 3-4: Boat Harbour underwater photo ground truth for the Aug 11 surveys (AGRG Boat and partner boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

3.1.3 Merigomish

The seaward side of Merigomish Harbour appears to be characterized by a sandy bottom with focus or rockweed (Figure 3-5), whereas the inner harbour appears to contain thick, healthy eelgrass growing on a sandy bottom. Water clarity appears good both inside and outside the harbour.

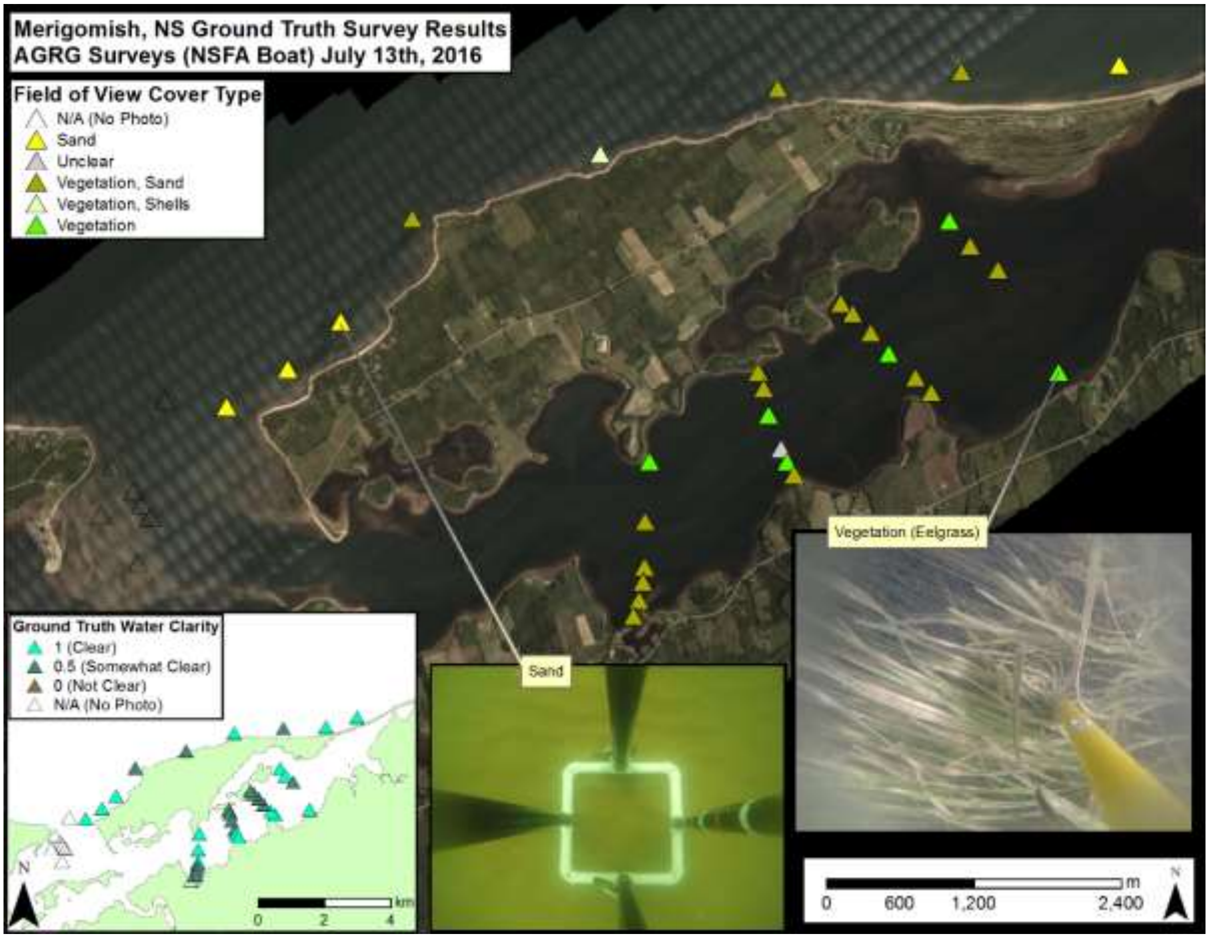


Figure 3-5: Merigomish underwater photo ground truth for the July 13 surveys (NSFA Boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

3.1.4 Mabou

The bottom at Mabou contains patches of eelgrass throughout the length of the inlet, and sediment such as mud, sand, and other vegetation (Figure 3-6). The eelgrass appears thicker and healthier in the clearer water near the harbour mouth, and becomes sparser and browner nearer the mouth of the rivers where the water clarity is moderately reduced.

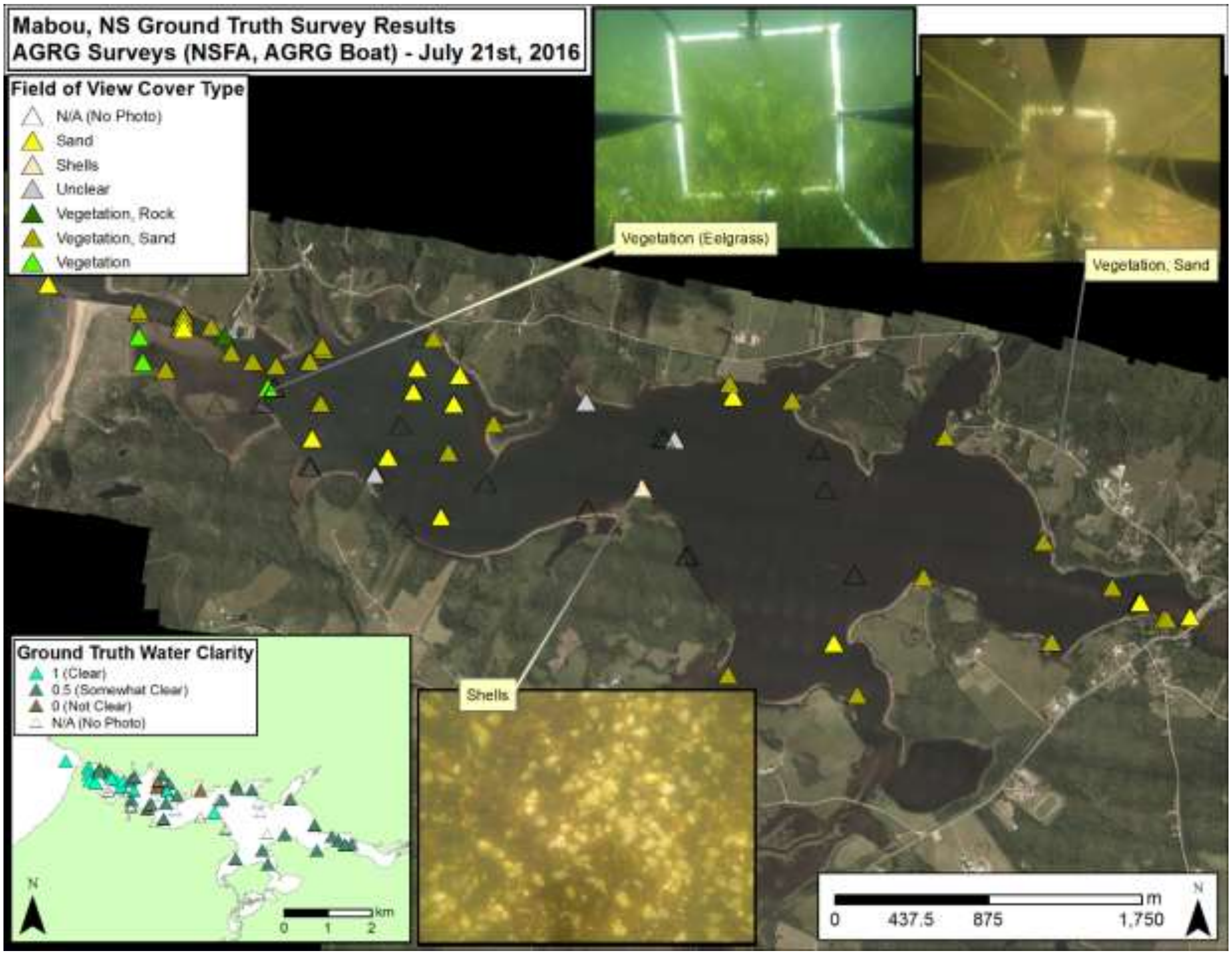


Figure 3-6: Mabou underwater photo ground truth for the July 21 surveys (AGRG Boat, NSFA Boat) symbolized to show cover type. Background image is RCD30 orthophoto RGB mosaic.

3.2 SAV Maps and Validation using Bottom Imagery and BioSonics

Submerged Aquatic Vegetation (SAV) maps were derived from the lidar and orthophotos and included the water depth raster, derived from the DEM, lidar bottom reflectance intensity, and the true-color aerial photograph orthomosaic. The approach used the red and green imagery bands, which were extracted from the true-color aerial photograph orthomosaic. Ratios of their differences and of their sums were added together and weighted by the interlaced lidar intensity data. The result was then normalized by the effects of depth. The resulting raster represents vegetation presence index, and was subject to a threshold procedure to result in a final shapefile of vegetation presence or absence. The procedure to produce the final SAV map involved manual editing of the shapefile using the RGB photos for interpretation, and included removing shadows created by overlapping trees in the imagery and clipping of the dataset to the relevant area.

Depth contour maps were generated using ArcMAP built-in tools. Maps are presented that show the overlap of eelgrass and depth.

3.2.1 Eelgrass Area by Depth Interval

3.2.1.1 Pugwash-River Philip

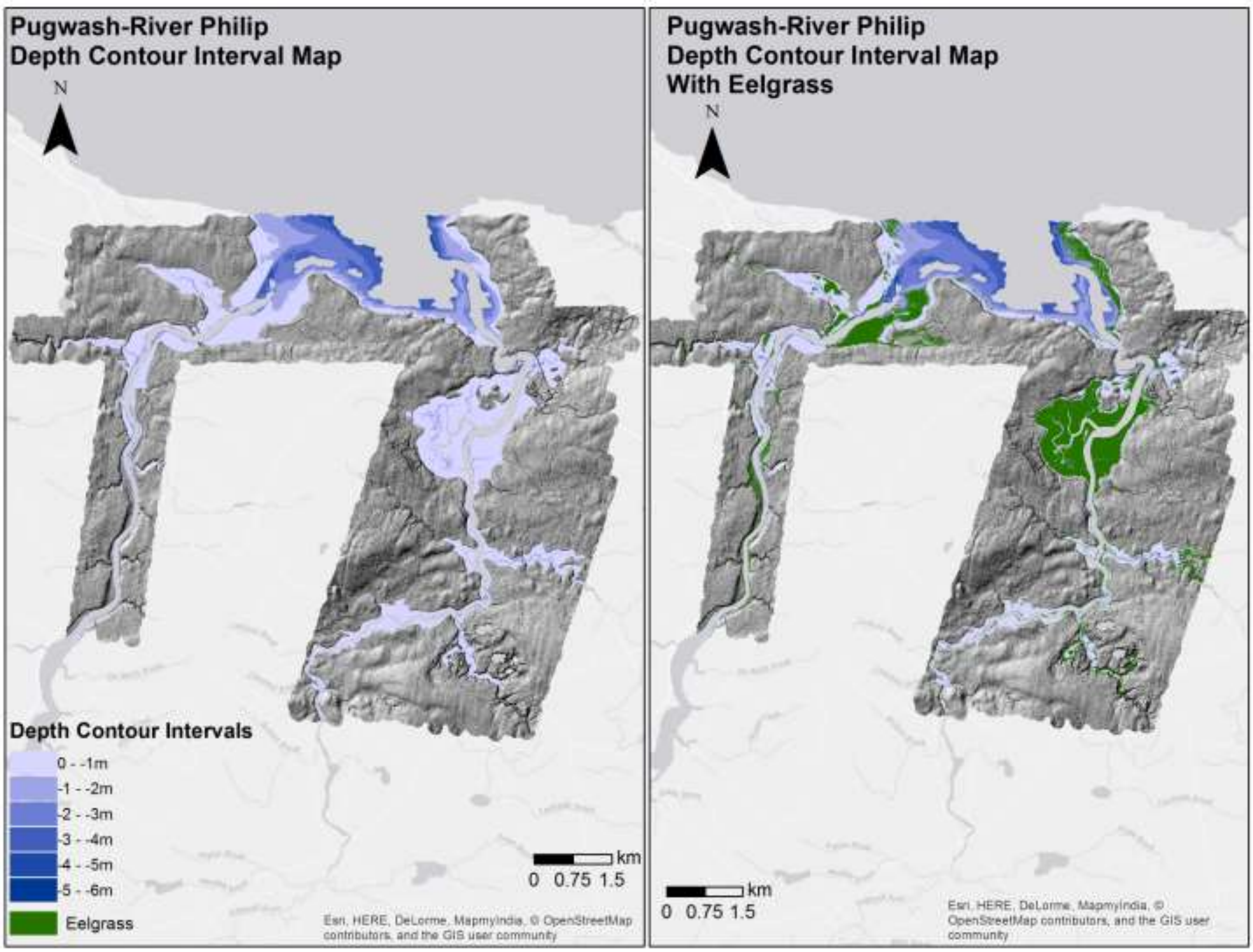


Figure 3-7: Pugwash-River Phillip lidar shaded relief map with 1 m depth contours (left); with eelgrass and depth contour lines (right).

Contour Interval	Total Area (m^2)	Eelgrass Area (m^2)	% Eelgrass
0 - -1m	8,037,155	3,537,575	44
-1 - -2m	1,855,990	506,143	27
-2 - -3m	1,481,991	19,166	1.3
-3 - -4m	771,486	7.15	0
-4 - -5m	101,972	0	0
-5 - -6m	82.08	0	0
Total Bay Area (HHWLT – to lidar depth extent)	14,283,408	4,062,891	28.5

Table 3.1: Eelgrass Area (m^2) and (%) by contour interval for Pugwash-River Philip.

3.2.1.2 Boat Harbour-Pictou Harbour

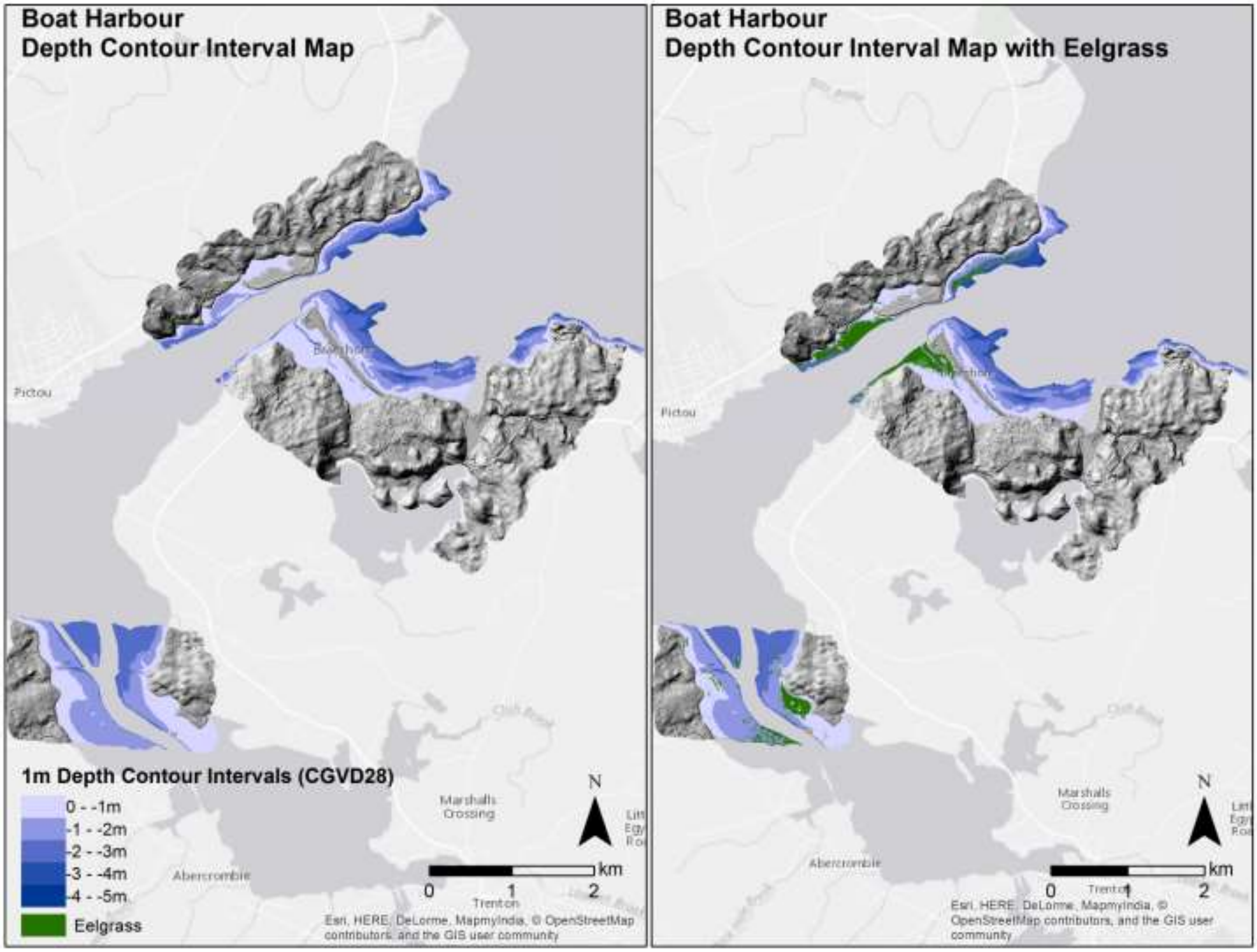


Figure 3-8: Pictou Harbour lidar shaded relief map with 1 m depth contours (left); with eelgrass and depth contour lines (right).

Contour Interval	Total Area (m^2)	Eelgrass Area (m^2)	% Eelgrass
0 - -1m	1,656,104	290,558	17.5
-1 - -2m	1,390,407	155,847	11.2
-2 - -3m	1,014,538	20,831	2.
-3 - -4m	219,683	52	0.02
-4 - -5m	6,804.55	0	0
Total Bay Area (HHWLT – to lidar depth extent)	4,727,609	467,288	9.9

Table 3.2: Eelgrass Area (m^2) and (%) by contour interval for Boat Harbour.

3.2.1.3 Merigomish

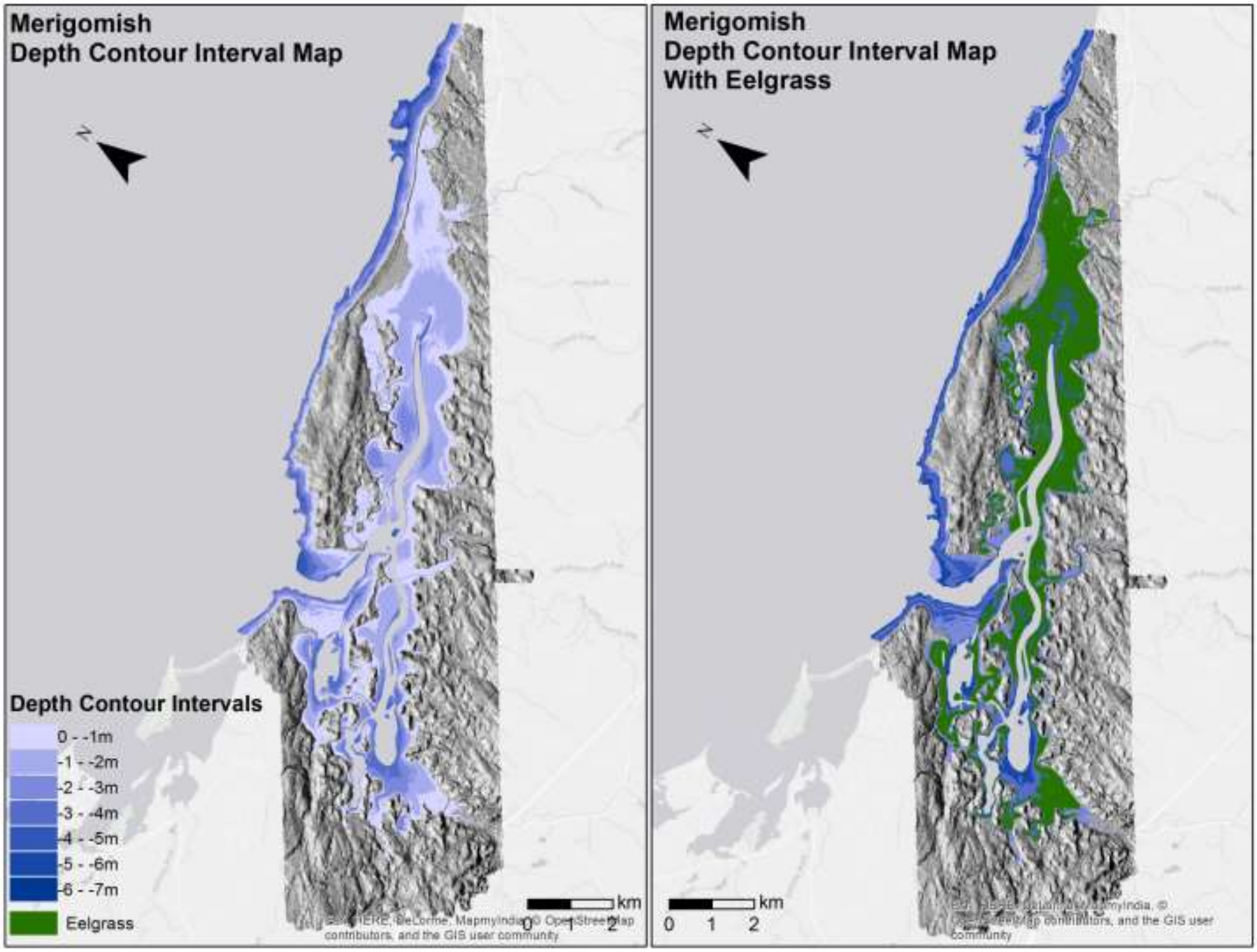


Figure 3-9: Merigomish Harbour lidar shaded relief map with 1 m depth contours (left); with eelgrass and depth contour lines (right).

Contour Interval	Total Area (m^2)	Eelgrass Area (m^2)	% Eelgrass
0 - -1m	10,238,676	5,008,766	48.9
-1 - -2m	8,660,126	6,285,895	72.6
-2 - -3m	3,545,780	910,242	25.7
-3 - -4m	2,591,283	19,501	0.75
-4 - -5m	785,226	27.5	0
-5 - -6m	65,577	0	0
-6 - -7m	1,053	0	0
Total Bay Area (HHWLT – to lidar depth extent)	24,647,666	12,224,432	49.6

Table 3.3: Eelgrass Area (m^2) and (%) by contour interval for Merigomish.

3.2.1.4 Mabou

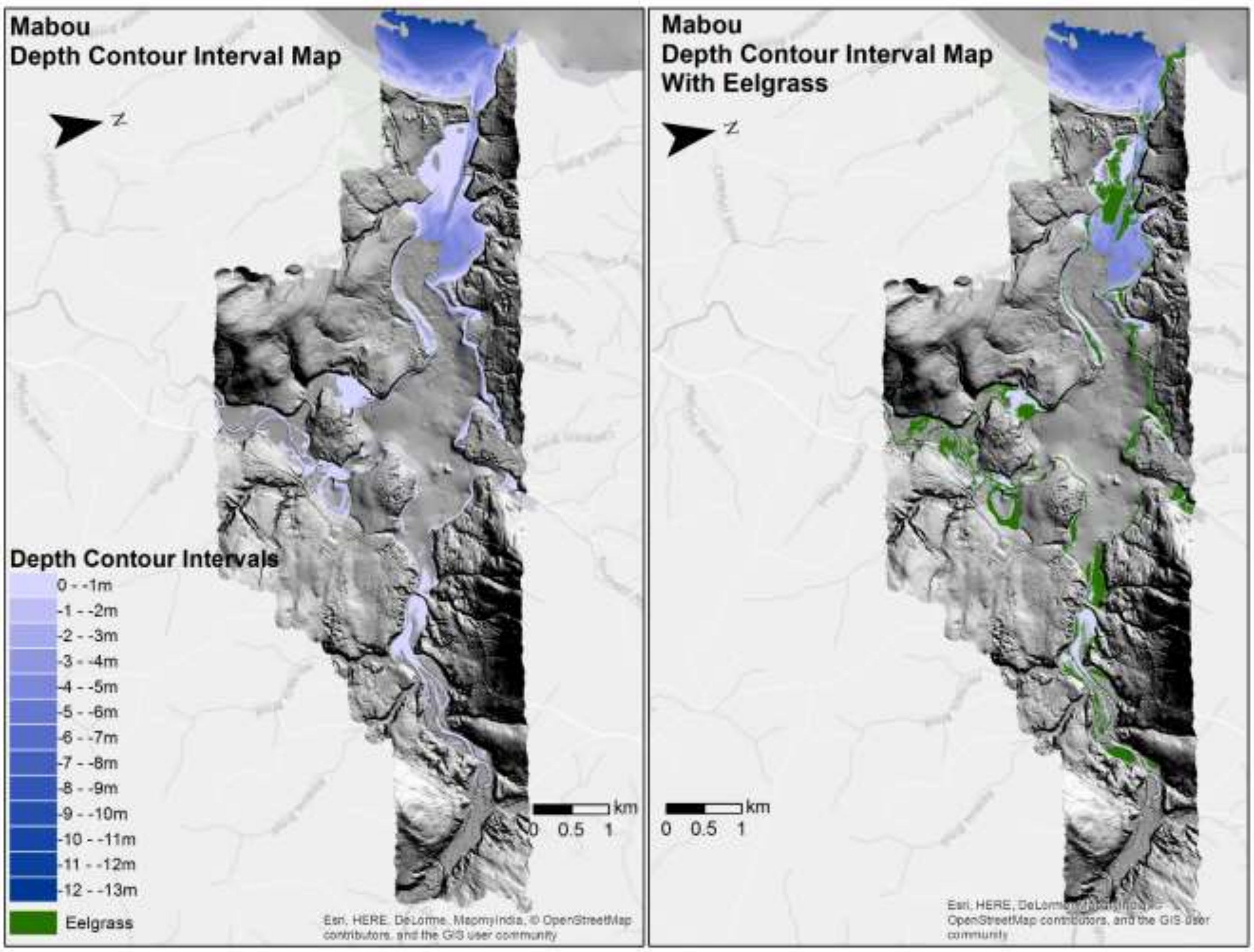


Figure 3-10: Mabou Harbour lidar shaded relief map with 1 m depth contours (left); with eelgrass and depth contour lines (right).

Contour Interval	Total Area (m^2)	Eelgrass Area (m^2)	% Eelgrass
0 - -1m	1,583,331	667,626.39	42.17
-1 - -2m	509,404	291,191.97	57.16
-2 - -3m	410,387	116,681.64	28.43
-3 - -4m	423,694	17,777.38	4.20
-4 - -5m	349,280	1,978.44	0.57
-5 - -6m	125,235.62	37.54	0.03
-6 - -7m	120,855.07	4.51	0
-7 - -8m	118,805.48	0	0
-8 - -9m	109,373.77	0	0
-9 - -10m	91,283.14	0	0
-10 - -11m	96,494.19	0	0
-11 - -12m	69,263.76	0	0
-12 - -13m	4,295.53	0	0
Total Bay Area (HHWLT – to lidar depth extent)	5,253,101	1,095,297.87	20.85

Table 3.4: Eelgrass Area (m^2) and (%) by contour interval for Mabou.

3.2.2 Intertidal Maps Derived from the Lidar DEM

The Higher High Water Large Tide (HHWLT) and Lower low Water Large Tide (LLWLT) define the intertidal area. Information on these tidal ranges was obtained from the Canadian Hydrographic Service with elevations referenced to Chart Datum and converted to CGVD28 in order to construct the maps.

Study Area	Tide Station	CD2000 – CGVD 28 (m)	LLWLT [CGVD 28] (m)	HHWLT [CGVD 28] m
Pugwash	Pugwash (1770)	1.38	-1.54	1.19
Pictou	Pictou (1630)	0.92	-1.01	1.13
Merigomish	Pictou (1630)	0.92	-1.01	1.13
Mabou	Port Hood (1560)	0.37	-0.37	0.96
Neguac				
Shediac				

Figure 3-11 Chart datum to CGVD28 and LLWLT-HHWLT values used.

3.2.2.1 Pugwash-River Philip

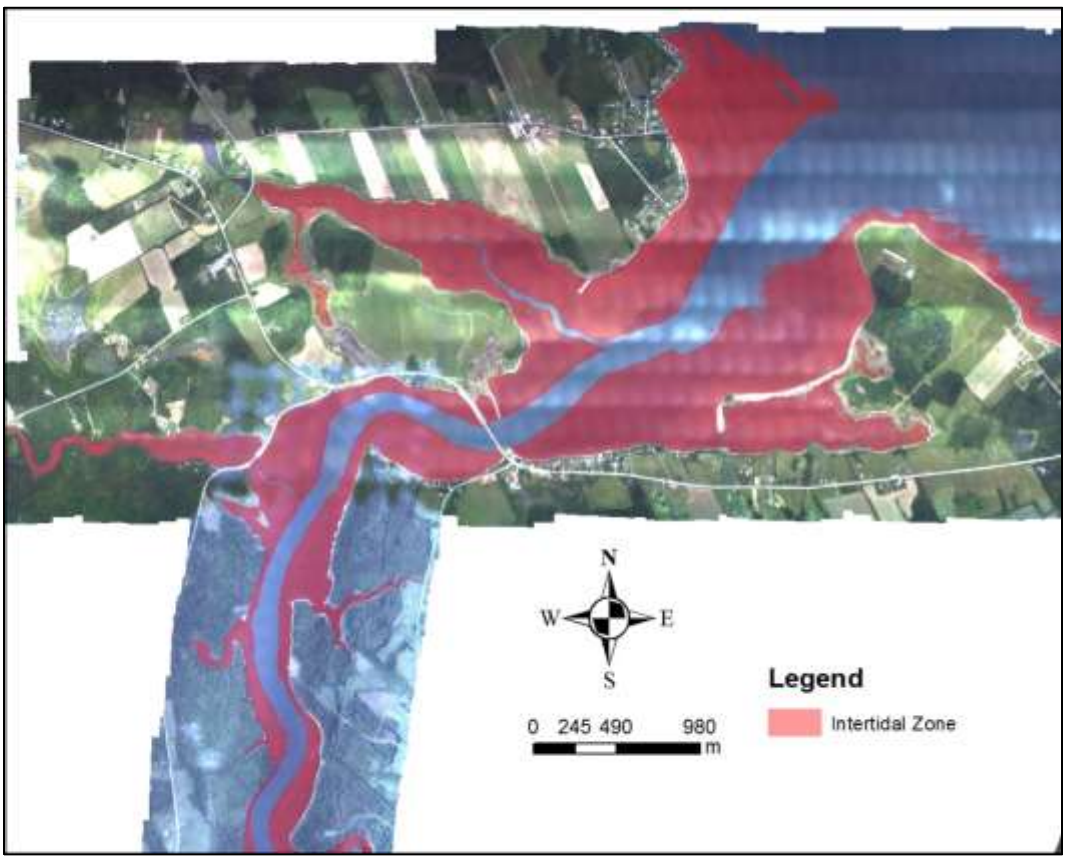


Figure 3-12 River Phillip intertidal zone (red).

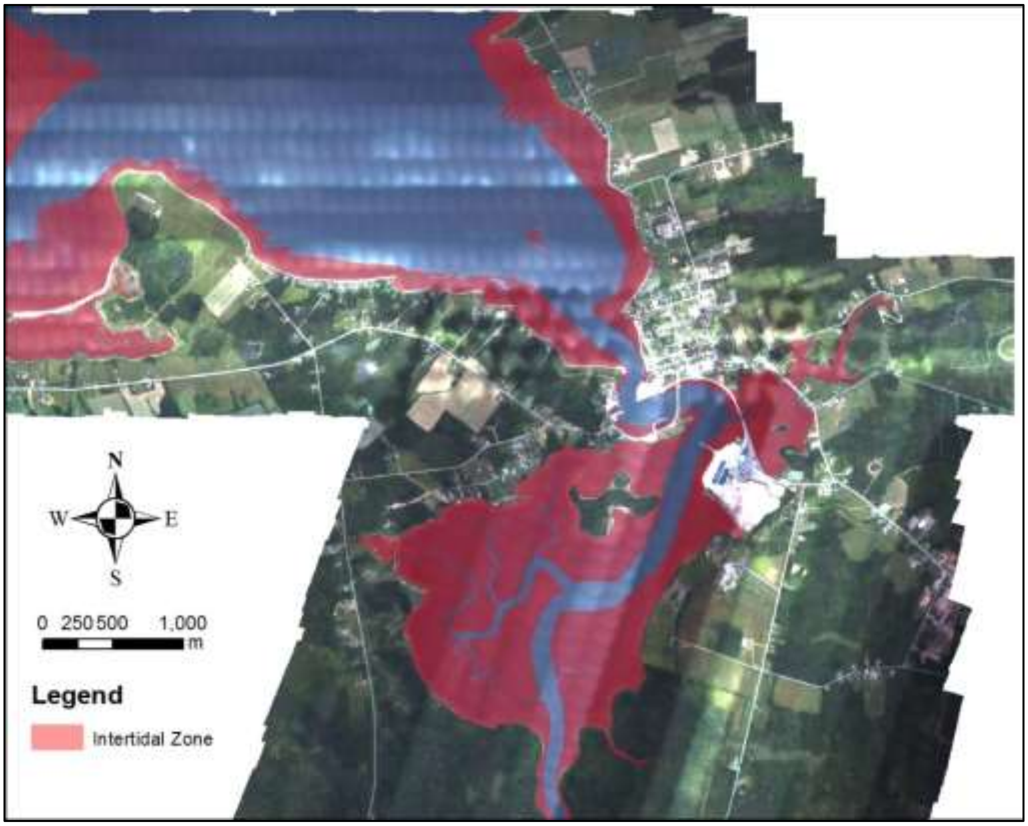


Figure 3-13 Pugwash intertidal zone (red).

3.2.2.2 Boat Harbour-Pictou Harbour

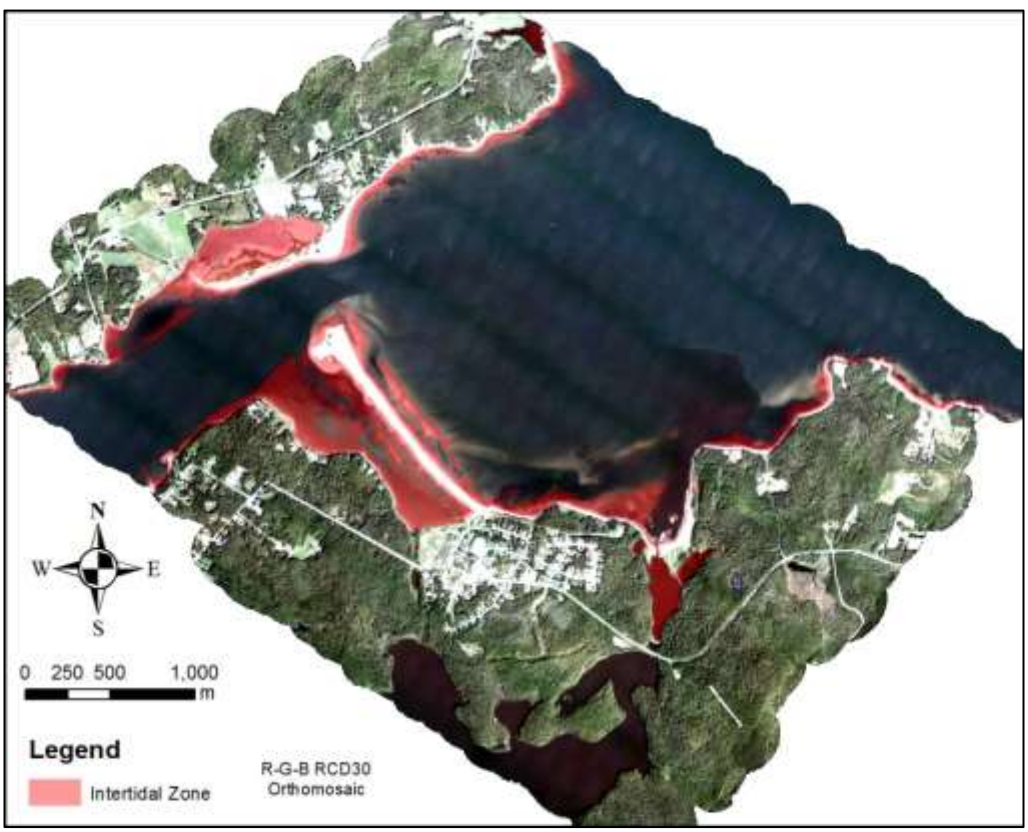


Figure 3-14 Pictou Harbour intertidal zone (red). Note the dark plume discharging from Boat Harbour. The lidar did not penetrate the plume to measure the seabed because of poor water clarity.

3.2.2.3 Merigomish

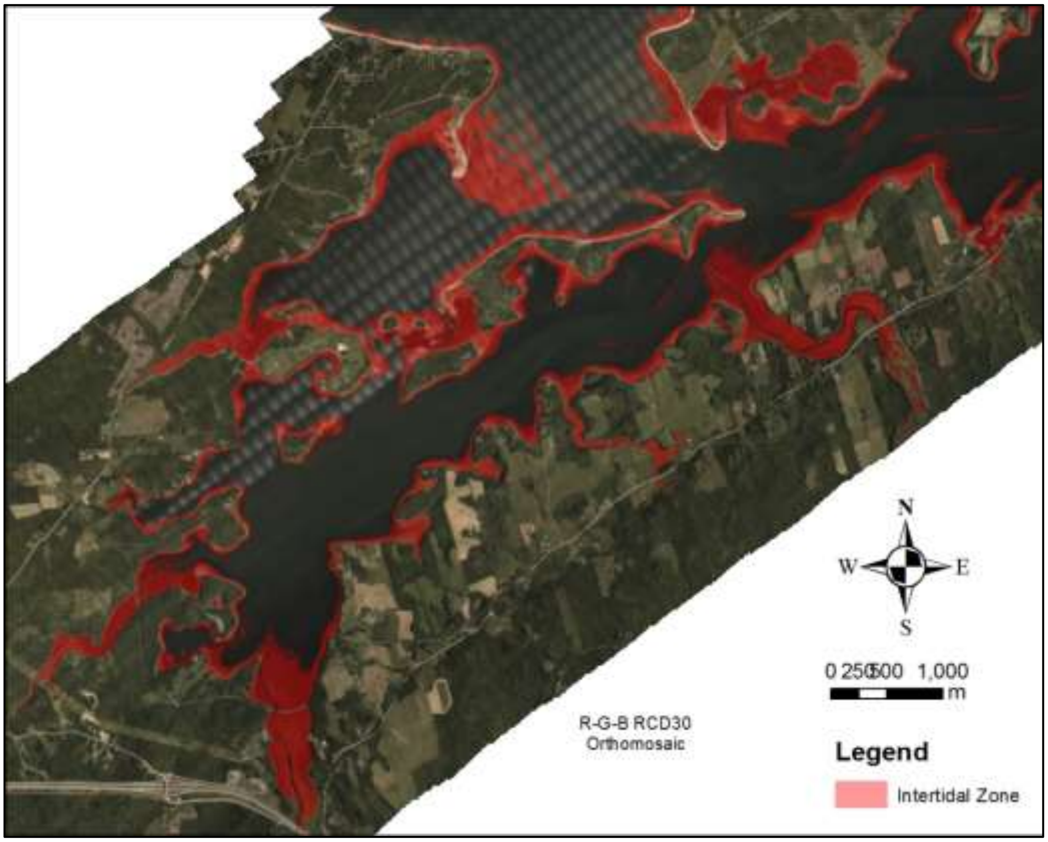


Figure 3-15 Southwest Merigomish Bay intertidal zone (red).

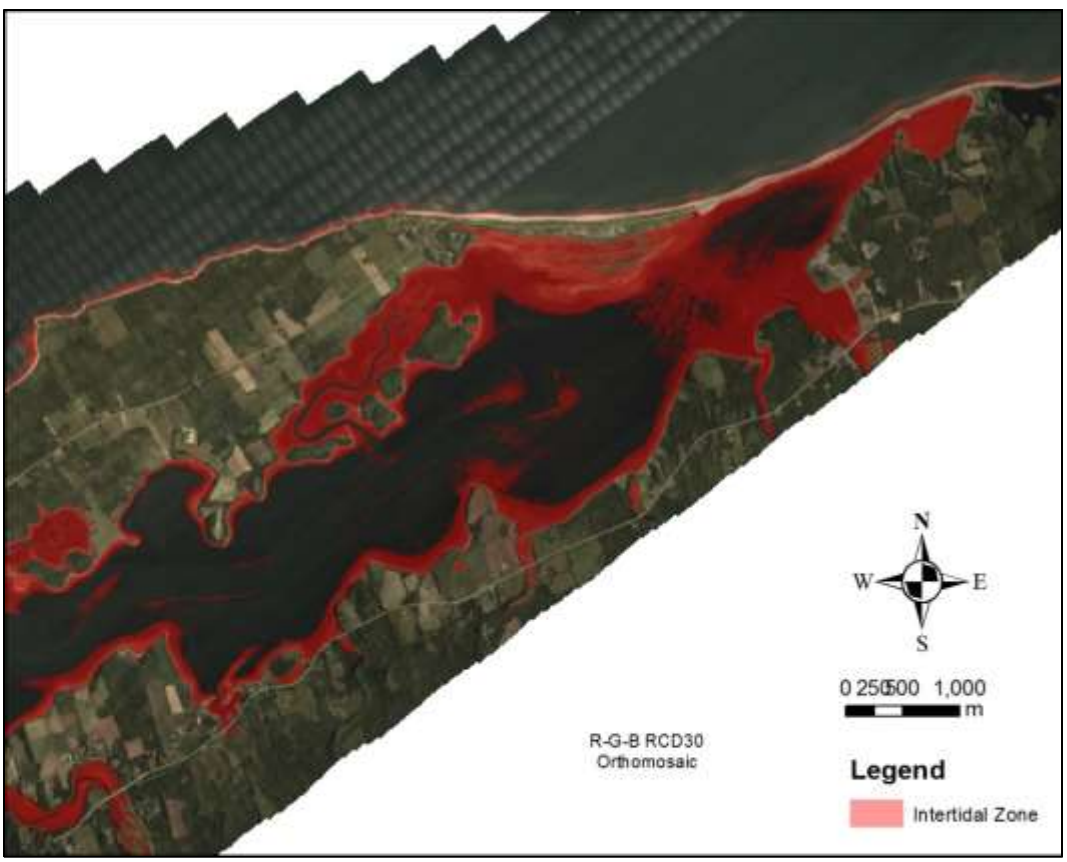


Figure 3-16 Northeast Merigomish Bay intertidal zone (red).

3.2.2.4 Mabou

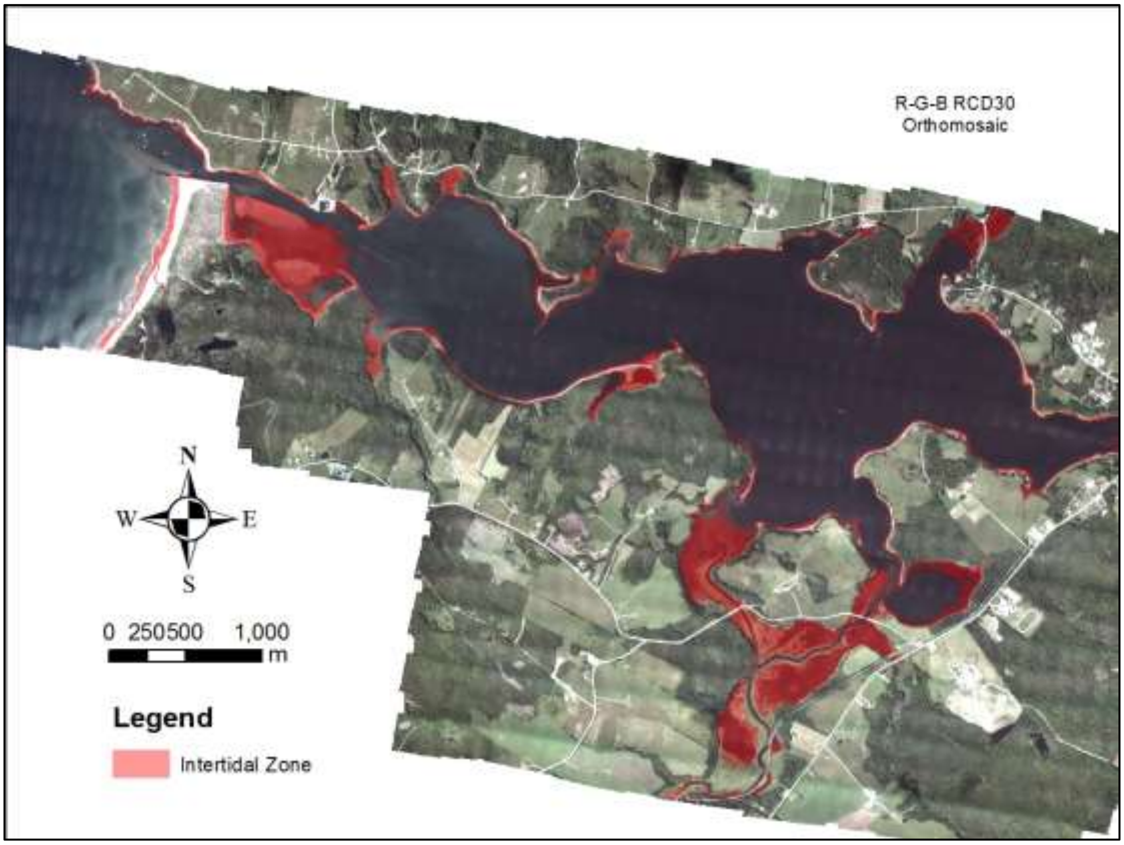


Figure 3-17 Western Mabou Harbour intertidal zone (red).

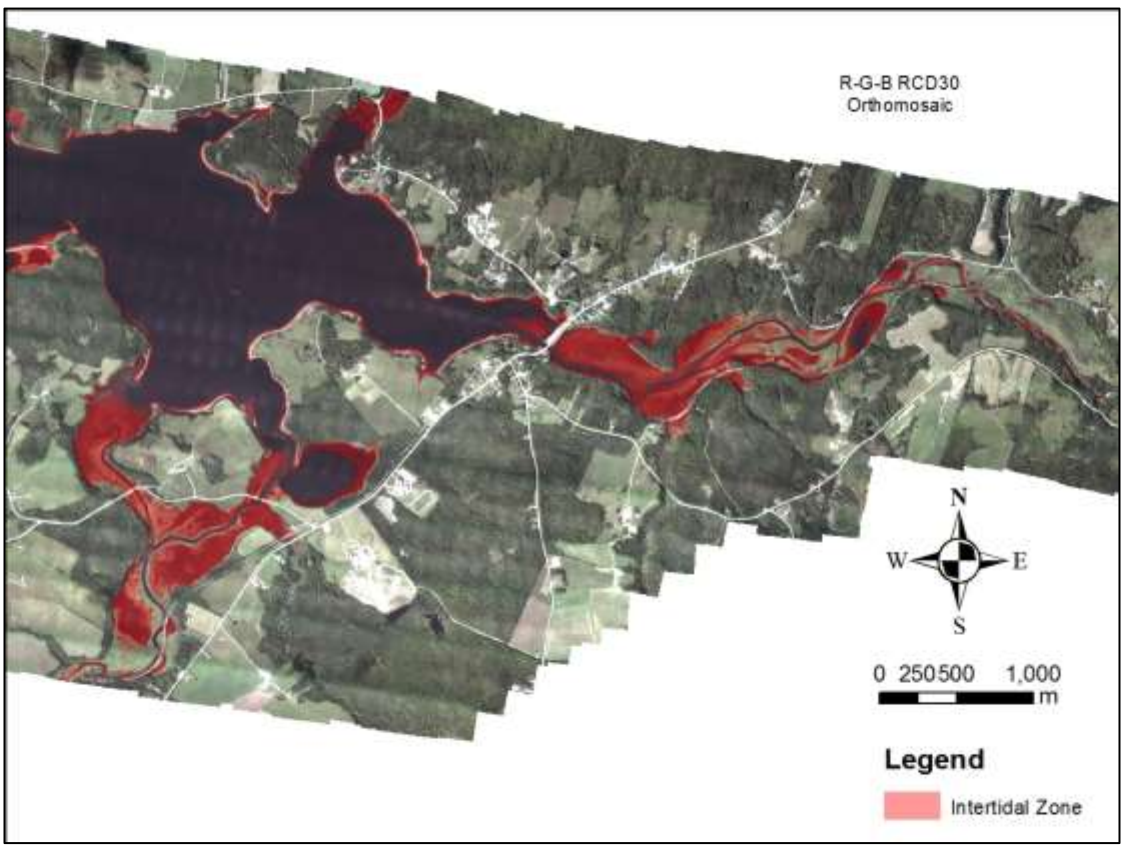


Figure 3-18 Eastern Mabou Harbour intertidal zone (red).

3.2.3 Submerged Aquatic Vegetation Maps

The submerged aquatic vegetation (SAV) maps developed using the lidar and photo products were compared to bottom classification data collected by AGRG using the GoPro underwater camera imagery presented in Section 3.1. Agreement of the SAV classification and the imagery ranged from 80% to 84% (Table 3.5, Figure 3-19, Figure 3-21, Figure 3-24, Figure 3-25). At Merigomish and Mabou, the SAV maps were evaluated against bottom classification data collected by DFO using a BioSonics instrument, which uses acoustics to map the submerged vegetation. At Merigomish, the derived SAV map agreed 83% of the time with the BioSonics vegetation detection map (Table 3.5, Figure 3-22, and Figure 3-23). At Mabou the derived SAV map agreed 59% of the time with the BioSonics vegetation detection map (Table 3.5, Figure 3-26, Figure 3-27).

Study Area	% Agreement of Eelgrass – AGRG Quadrat Camera Drops	% Agreement of Eelgrass - BioSonics
Pugwash-River Philip	80%	N/A
Pictou	81%	N/A
Merigomish	83%	83%
Mabou	84%	59%
Neguac	67%	N/A
Shediac	56%	N/A

Table 3.5: Percentage agreement of eelgrass with BioSonics and AGRG drops for each area.

3.2.3.1 Pugwash-River Philip

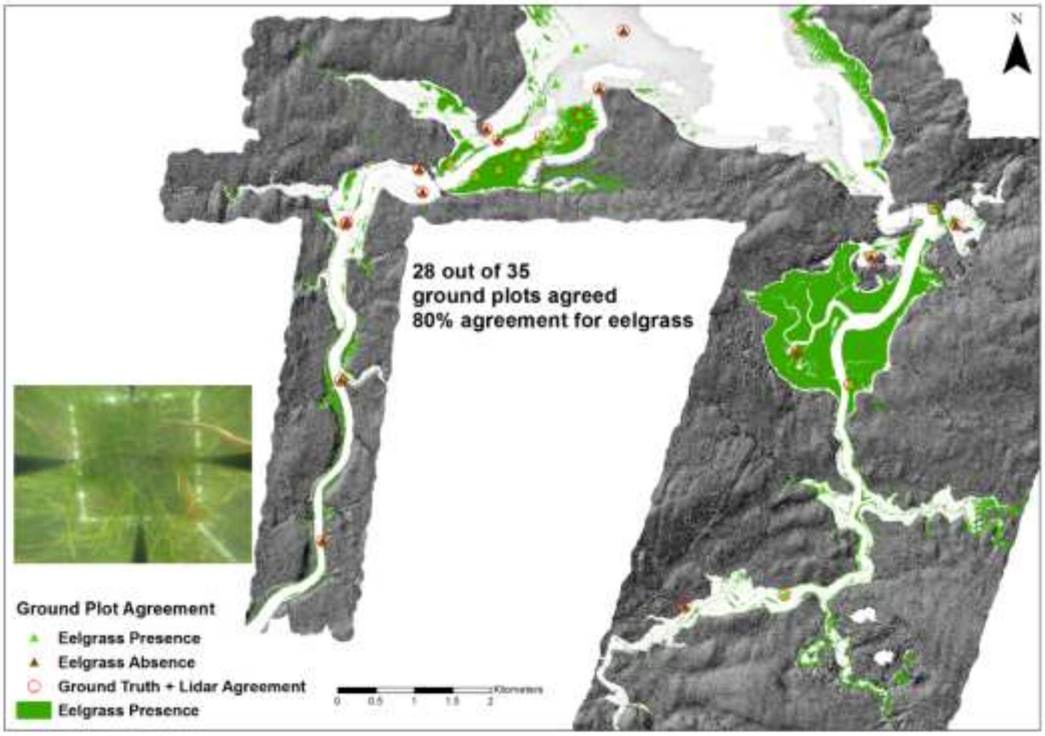


Figure 3-19: Correlation between eelgrass presence and AGRG ground truth results in PWRP.

3.2.3.2 Boat Harbour-Pictou Harbour

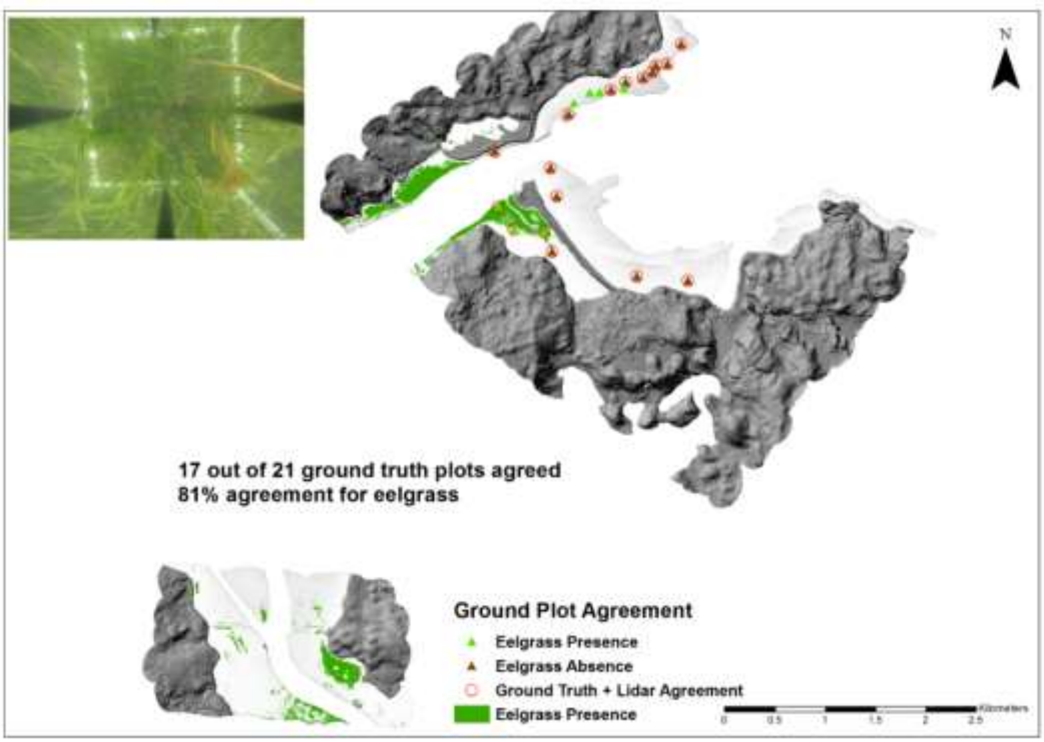


Figure 3-20: Correlation between eelgrass presence and AGRG ground truth results in Pictou.

3.2.3.3 Merigomish

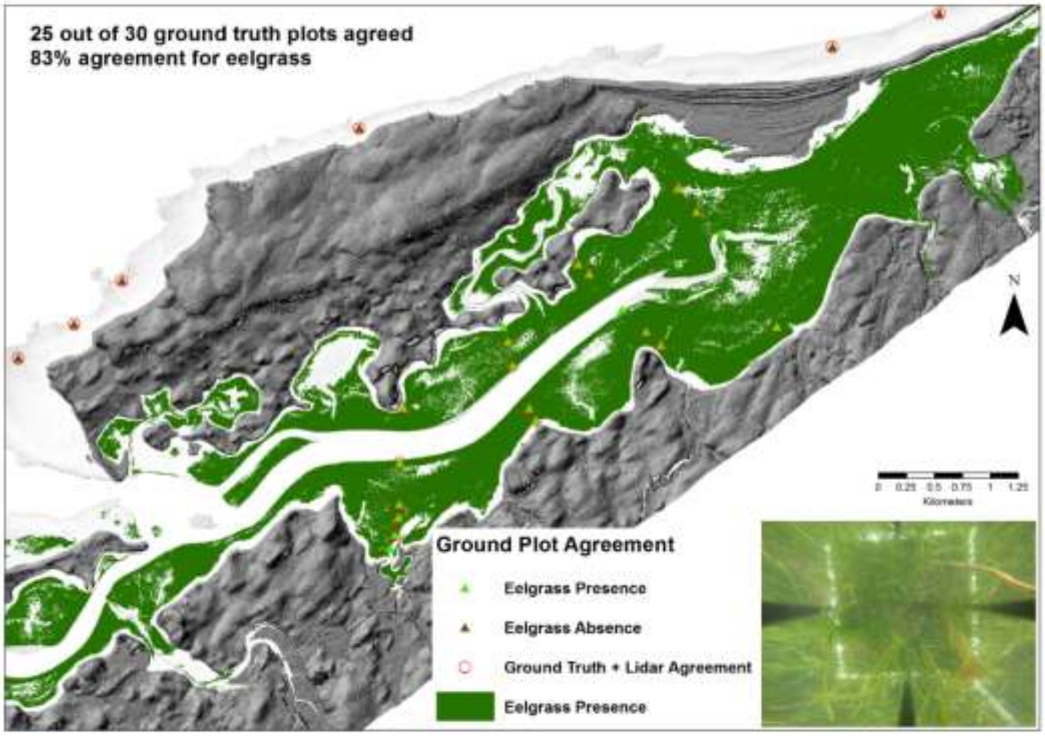


Figure 3-21: Correlation between eelgrass presence and AGRG ground truth results in northeast Merigomish Harbour.

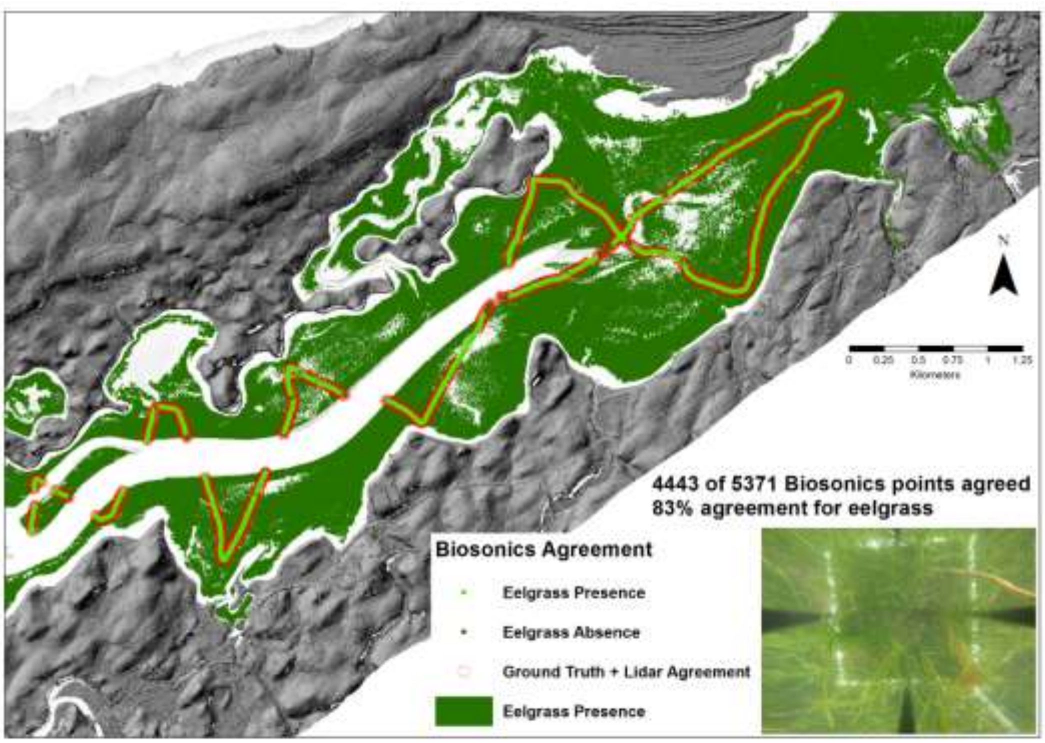


Figure 3-22: Correlation between eelgrass presence and DFO BioSonics results in northeast Merigomish Harbour.

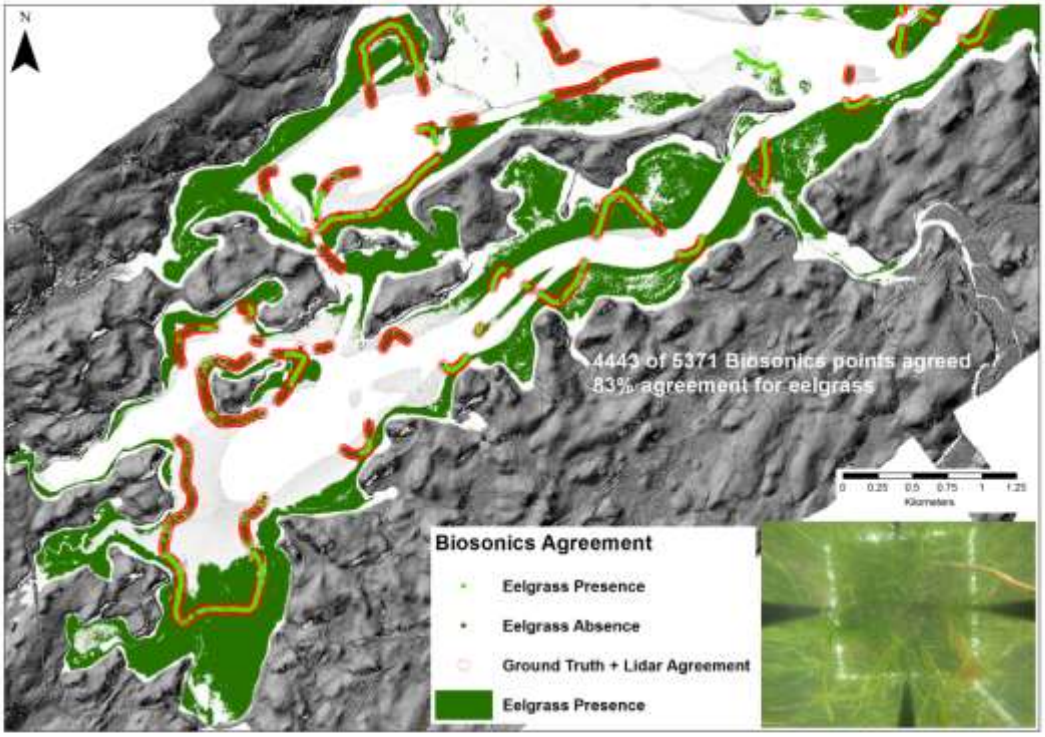


Figure 3-23: Correlation between eelgrass presence and DFO BioSonics results in southwest Merigomish Harbour.

3.2.3.4 Mabou

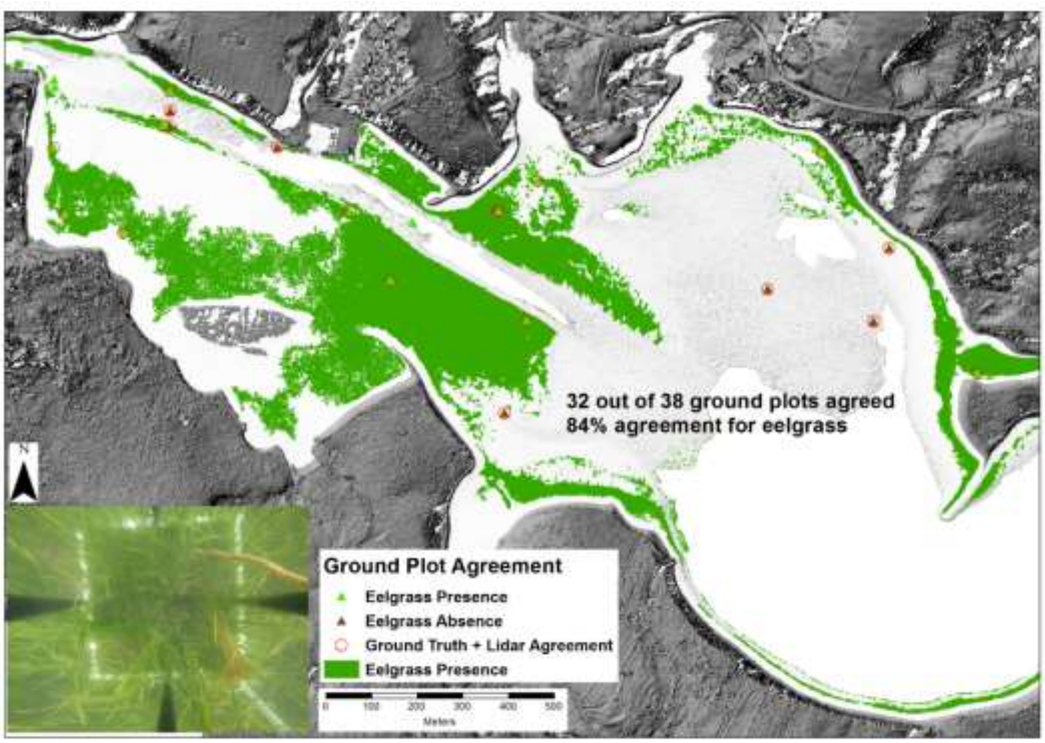


Figure 3-24: Correlation between eelgrass presence and AGRG ground truth results in Western Mabou Harbour.

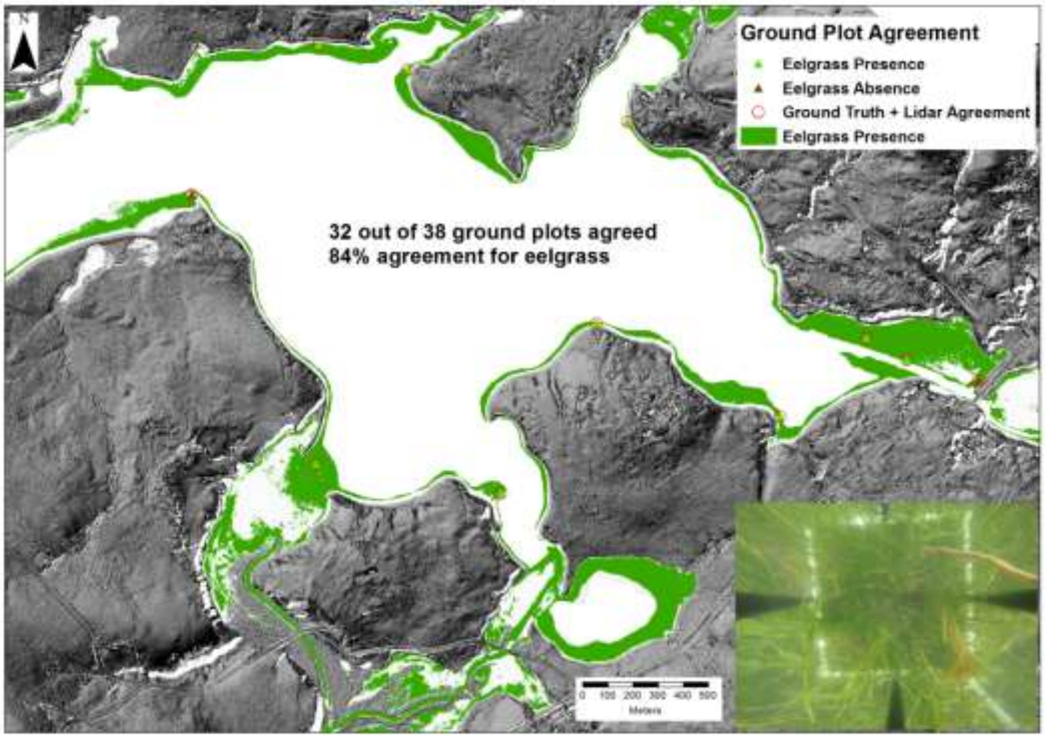


Figure 3-25: Correlation between eelgrass presence and AGRG ground truth results in Eastern Mabou Harbour.

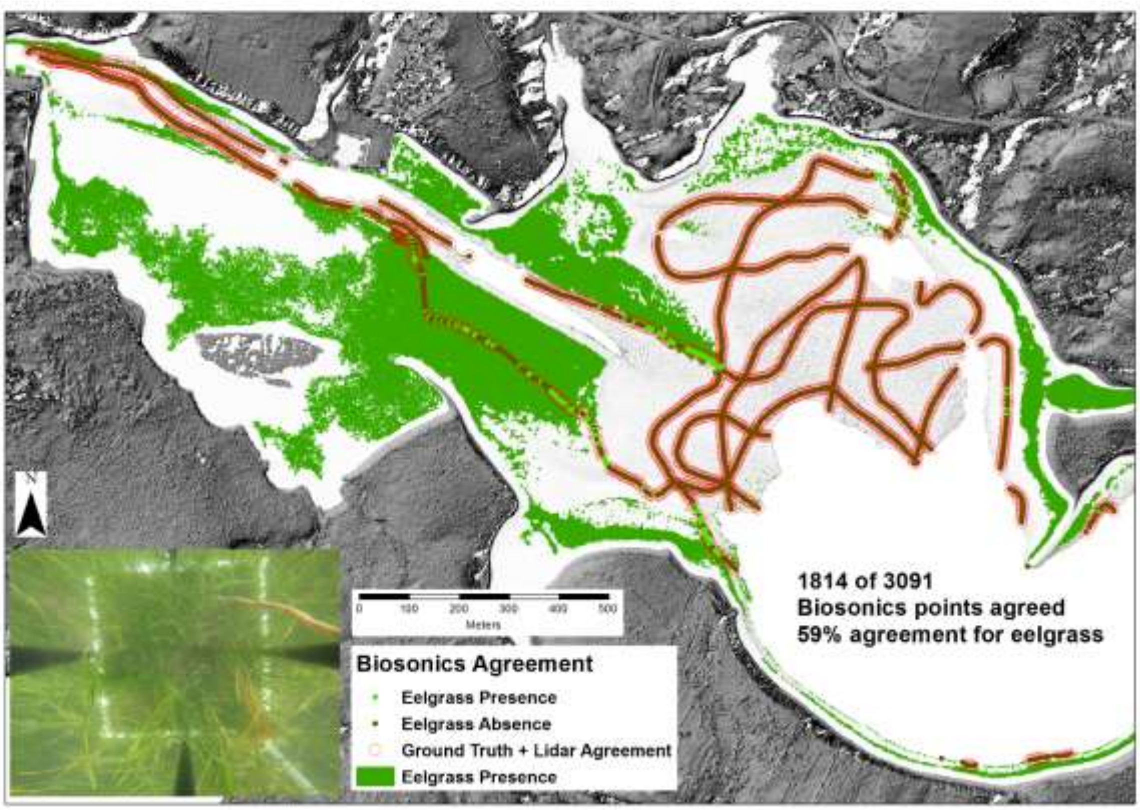


Figure 3-26: Correlation between eelgrass presence and DFO BioSonics results in Western Mabou Harbour.

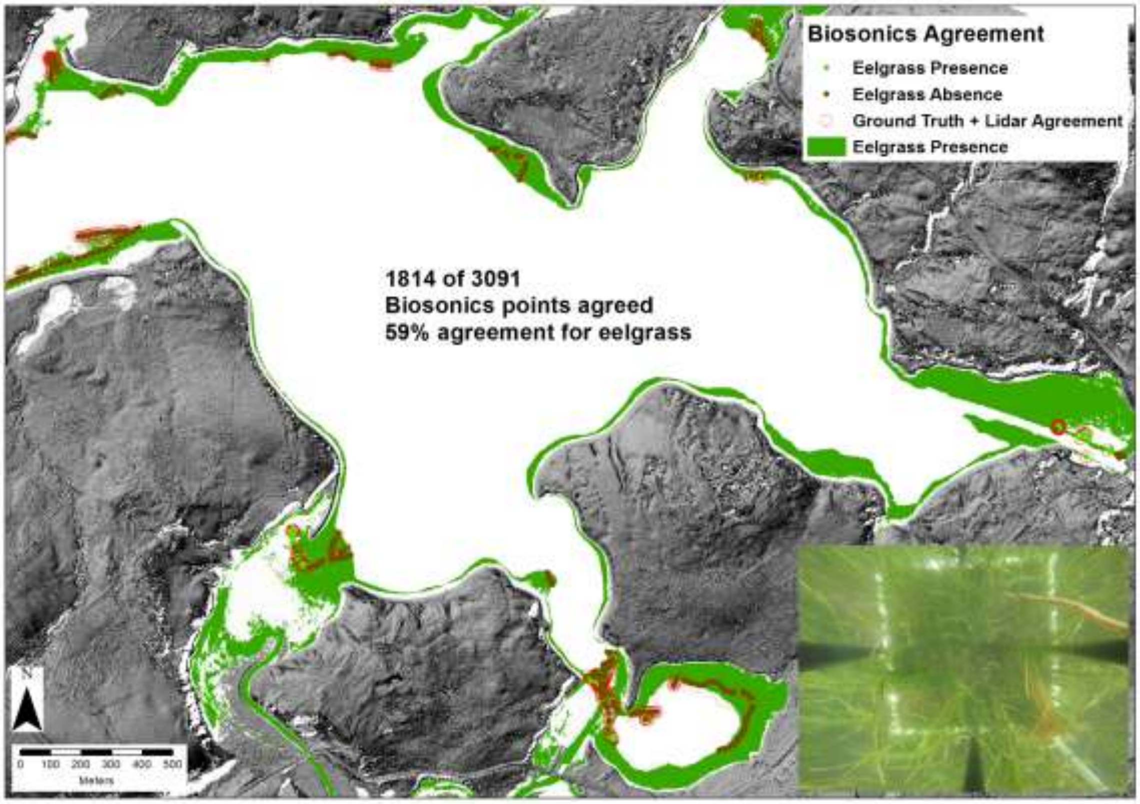


Figure 3-27: Correlation between eelgrass presence and DFO BioSonics results in Eastern Mabou Harbour.

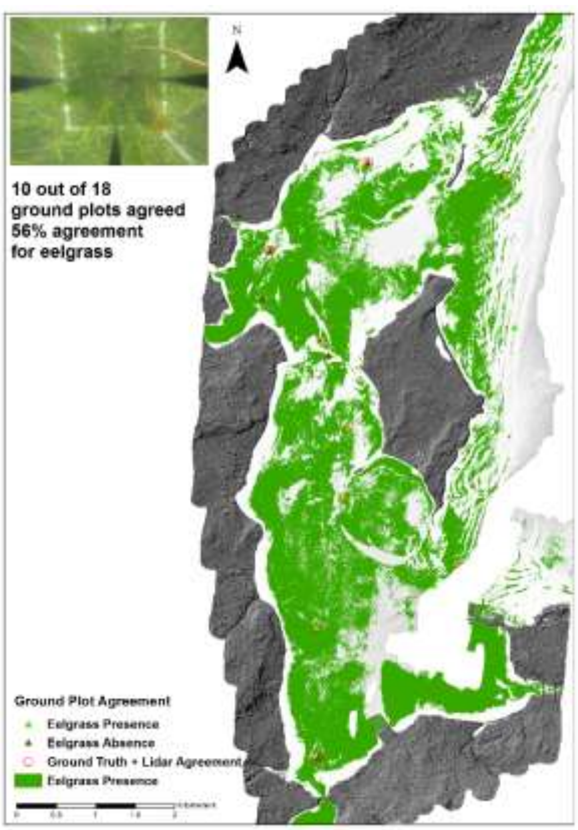


Figure 3-28: Correlation between eelgrass presence and AGRG ground truth plots in Shediac.

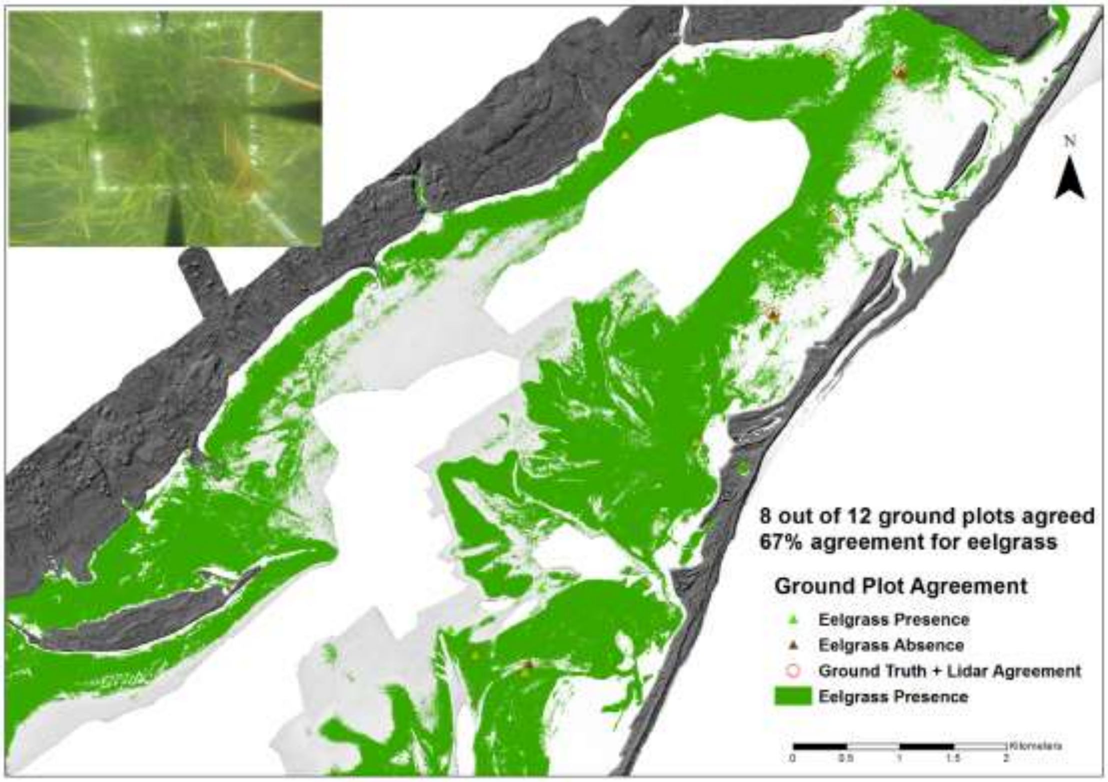


Figure 3-29: Correlation between eelgrass and AGRG ground truth plots in Neguac.

3.3 Aquaculture Quantification

The orthophoto mosaics were visually inspected for aquaculture in the four bays. Gear interpreted in photographs included strings, oystergro cages, floating bags, collector lines, sub-surface cages, darksea cages. When gear was found a line shapefile was created marking the position of the oystergro cages. The method follows Niles et al. (2014) to calculate the biomass of shellfish aquaculture.

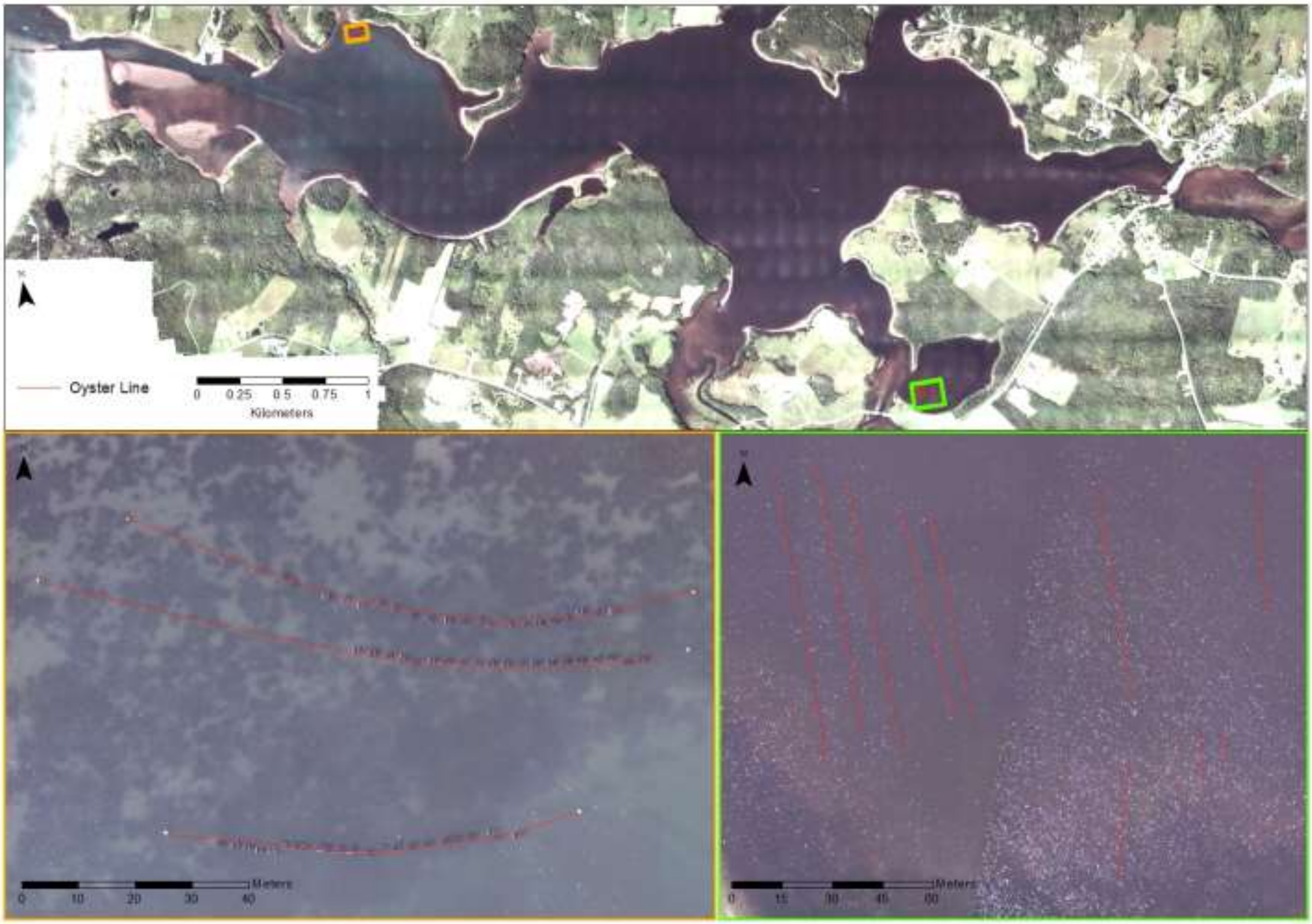


Figure 3-30 Mabou Harbour with inset locations, orange and green blocks (top image). Oyster aquaculture infrastructure in the western area (orange) on the left and western area (green) on the right.

Aquaculture gear was only observed in the Mabou study area for the four Nova Scotia bays. There were two areas in the Mabou study area where oyster cages were found. The estimate of the biomass is based on the line length and bag spacing:

$$biomass = line\ length\ x\ \frac{\#\ bags}{m}\ x\ \frac{6.04\ kg}{bag}$$

Shediac

Aquaculture

Neguac

4 Preparation for Future Work: Hosting on a web-based sharing platform

A client-side custom web application and a GIS web server are required to create a web-based platform for sharing the GIS data and information within DFO and with provincial colleagues. The web-based platform requires three phases to implement. Phase I will be the planning and assessment phase, Phase 2 will be the development phase and Phase 3 will be the testing and deployment phase.

Phase 1 planning will include defining the primary audience (end-users) of the GIS data and determining how they will use the GIS data. This phase will determine the requirements of the web-based platform such as the technical requirements (software, server specifications, client browser, etc.), design requirements (layout and usability) and tools needed (GIS processing, editing, viewing, etc.). A finalized development procedure created in this phase will be the outline of tasks used in the following two phases.

Phase 2 will be the development of the platform. The server will be set up in a development environment to the specification determined in Phase 1. The tools and processing techniques used by the server will be developed. The delivered GIS data will be structured and published on the development server as needed by the tools and client-side application. The design and layout of the client-side application will be finalized and implemented. Any additional features requested in Phase 1 will be added.

Phase 3 will be the testing and deployment of the platform. The client-side application and server will be tested to assure the platform works and performs as expected. Once assured, the platform will be moved to a production environment for use by the client. Finally, evaluation of the result and discussion on future enhancements and/or maintenance can occur as desired.

Phase I – Preliminary Planning

1. Determine Audience (end-users)
2. Define Requirements
    a. Content requirements (e.g. GIS data)
        i. Raster data
        ii. Vector data
        iii. Tabular data
        iv. Read-only, creation, editing
    b. Processing and tool requirements
        i. Server-side processing (e.g. ArcGIS python scripts)
        ii. Tools exposed to the end-user
        iii. Custom processing techniques
    c. Technical requirements
        i. Server Storage requirements
        ii. Database (if required) type and version (e.g. PostgreSQL 9.4, ArcGIS file geodatabase)
        iii. Server software required including version (e.g. ArcGIS 10.4, IIS 7, etc.)
        iv. Server-side programming interface(s) (e.g. PHP, asp.net, node.js)

            v. Hosting (GIS server, web server, domain, addressing, etc.)
            vi. Client-side descriptions (internet/intranet, targeted web browser software and versions)
    d. Preliminary design
        i. Determine required features, tasks and workflow needed by the end-user
        ii. Look and feel – mock-up of design
        iii. Usability and workflow – storyboards of how the web map application will operate
3. Finalize lifecycle and maintenance (if needed)
    a. Determine how the project will documented
    b. Determine how the source code will be distributed
    c. Determine how and if the web map application will be maintained
    d. Determine if training is required

Phase II – Develop

1. Prepare server
    a. Install required server software in a development environment
    b. Develop tools and processing techniques to be deployed on the server
2. Prepare content
    a. Organize and structure content on the server
    b. Begin testing content with tools and processing techniques
    c. Publish content as needed by the web map application
3. Development of the custom web map application
    a. Finalize design, layout and features started in phase 1.2.d
    b. Create working layout per design
    c. Develop features determined in Phase 1.2.d

Phase III—Test and Deploy

1. Deploy server
    a. Finish implementing any custom server software such as tools
    b. Test server and server tools
    c. Deploy server and server-side processing to production host server
    d. Publish content to production server
2. Deploy custom web map application
    a. Finish implementing features and design of phase 3.3
    b. Test features and web map application
    c. Deploy web map application to the production host server
3. Document and evaluate
    a. Provide documentation of server setup and deployment
    b. Provide source code
    c. Provide training if requested
    d. Evaluate project, maintenance plan and future project enhancements as required/needed

5 Discussion and Conclusions

The combination of aerial photos and lidar reflectance and depth maps were used to construct eelgrass maps. These maps were validated using ground truth in the form of quadrat drops of underwater photos and derived vegetation presence/absence from a BioSonics echo sounder collected by DFO Gulf Region scientists. The seamless lidar DEMs were used to construct 1 m depth contours from mean sea-level (CGVD28) to the maximum depth achieved by the lidar. Similarly, the seamless DEMs were used to construct intertidal zones for each study area by determining the areas covered between the elevations of HHWLT and LLWLT. The depth contours were intersected with the eelgrass maps and area and percentage values were calculated and presented. The orthophoto mosaics were inspected for aquaculture infrastructure and only observed in Mabou. The infrastructure was digitized from the orthophoto and an estimate of Biomass was calculated.

6 References

Niles, M., A. Locke, T. Landry, T.Webster, K. Collins, G. Robichaud, A. Hanson, M. Mahoney, H. Vandermeulen, S. Doiron, and M.-J. Maillet. 2014. Bivalve aquaculture and eelgrass coverage on a bay-wide scale utilizing bathymetric lidar and aerial photography. Can. Data Rep. Fish. Aquat. Sci. 3103: xiv + 82.p

Webster, T.L., McGuigan, K., Crowell, N., Collins, K., and MacDonald, C. (2016). Optimization of data collection and refinement of post-processing techniques for Maritime Canada's first shallow water topographic-bathymetric lidar survey. J. Coast. Res.