Lake Banook and Lake Micmac 2018 Post-Harvest Aquatic Vegetation Monitoring Report

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1.0 INTRODUCTION

In the fall 2013, the Halifax Regional Municipality (HRM) commissioned Stantec to provide an assessment of the overgrowth of submerged aquatic vegetation (SAV) in Lake Banook, Dartmouth, Nova Scotia and evaluate possible solutions for the removal of overgrowth of vegetation based on cost, feasibility, effectiveness, and risk (Stantec 2014). To supplement this assessment, Stantec further collected remote sensing acoustic and underwater video data from Lake Banook in October, 2014 (Stantec 2015). These data were analyzed to produce baseline maps of the bathymetry, distribution of sediment types, as well as the distribution, percent cover, and canopy height of aquatic vegetation in Lake Banook.

Based upon the results of the above-referenced Stantec reports, the Halifax Regional Council directed staff to implement the short-term control of weed management on Lake Banook and Lake Micmac through contracted mechanical weed harvesting services. These services were first undertaken for the lakes in August 2015. During this period, the mechanical weed harvesting contractor was instructed by HRM to focus their harvesting activities within target harvest areas (Areas of Focused Survey B to D, in Figure 1, undertaken in 2015 and 2016) to harvest the common SAV species *Potamogeton perfoliatus, P. foliosus,* and *Elodea canadensis* (Clasping Leaf Pondweed, Leafy Pondweed, and Canada Waterweed, respectively). The mechanical weed harvesting contractor was also instructed to opportunistically harvest in any locations outside of these target harvest areas, which they observed to have dense weed coverage while conducting harvesting. During 2015, opportunistic harvesting occurred in Areas F and G in Lake Micmac as well as Water Lots 3 to 6 in Lake Banook (refer to Figure 1 for the location of Areas). Additional target harvest areas were subsequently added for Areas H and I in Lake Banook to facilitate an adaptive management approach to address stakeholder concerns about weed proliferation in these areas.

Key criteria to assess the success of mechanical harvesting for the short-term control of weed management in each lake primarily include percent cover and plant height, with secondary consideration given to total surface area coverage by weeds and the distribution of the three species noted above. Results from submerged aquatic vegetation coverage mapping from 2017 (Stantec 2017b) indicated that the mechanical weed harvesting was resulting in reduced SAV coverage and/or height in targeted areas of Lake Banook and Lake Micmac. These results were observed when comparing pre- and post-harvest data from 2017 as well as when comparing percent SAV coverage between 2014 and 2017 post-harvest (Stantec 2017b).

As in previous years, prior to the mechanical harvesting of Lakes Banook and Micmac, Stantec collected pre-harvest acoustic and underwater video data to guide the mechanical harvesting efforts throughout the lakes (Stantec 2018). Natural Ocean Products Ltd. (NOP) conducted mechanical vegetation harvesting on Lakes Banook and Micmac from July 17 to August 2, 2018[1]. From August 20 to 23, 2018, Stantec

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[1] Due to late-season weed proliferation, NOP also conducted an additional two days of harvesting from August 14 to 15. This additional work was performed without data acquisition, with HRM's consent, to address weed proliferation within and adjacent to Area I and within the northernmost 400 m of the lanes.

collected acoustic and underwater video data from Lake Banook and Lake Micmac to replicate the previous surveys and assess the overall effectiveness of the harvesting within the lakes. The following report outlines the results of the 2018 post-harvest survey.

2.0 METHODS

2.1 MECHANICAL VEGETATION HARVESTING

NOP harvested aquatic vegetation from both Lake Banook and Lake Micmac using the same mechanical harvester used since 2015 (refer to Stantec 2016a for details on the harvester and its operations). The results from the 2018 pre-harvest monitoring (Stantec 2018) were used as a guide for harvest location selection with primary targeted areas being developed based on two criteria; the bottom elevation of the lake was ≤ 2.5 m and ≥ 50% of the vegetation canopy was harvestable. These criteria were created to maximize harvesting efficiency based on the harvester’s 1.7 m reach into the water column. Using these criteria, NOP was instructed by HRM to harvest targeted areas within Areas C, D, E, H, and south of Area I on Lake Banook, along with Areas F and G on Lake Micmac (Figure 1).

Stantec supplied NOP with a GPS chart plotter (GPSMAP 531s, Garmin International Inc., Olathe, Kansas, USA), a handheld GPS (GPSMAP 64st, Garmin International Inc., Olathe, Kansas, USA), a tablet digital data recorder (iPad, Apple Inc., Cupertino, California, USA) loaded with GIS software (Collector for ArcGIS, Esri, Redlands, California, USA) and equipped with a Bluetooth connected GPS antenna (Garmin Glo, Garmin International Inc., Olathe, Kansas, USA) as well as prepared data sheets for recording waypoints and times of harvesting activities. The goal of using the tracking equipment was to record areas that were harvested for aquatic vegetation and the effort exerted in each area. In the event of digital data recorder failure, NOP was instructed to revert to the paper data sheets for harvest tracking. Figure 1 depicts the tracks where the harvester operated, and Table 1 summarizes the transect information, duration of time spent harvesting in each target area, and field log notes recorded by NOP during harvesting.

Table 1 Summary of NOP's Field Notes and Harvest Duration for Each Transect Completed

Date	Duration	Area Harvested
17-Jul-18	0:22	E
17-Jul-17	2:02	H
18-Jul-18	3:47	E
19-Jul-18	2:23	C
19-Jul-18	2:16	D
20-Jul-18	2:43	D
20-Jul-18	3:09	H
23-Jul-18	3:44	B
23-Jul-18	3:00	C

Table 1 Summary of NOP's Field Notes and Harvest Duration for Each Transect Completed

Date	Duration	Area Harvested
24-Jul-18	1:48	D
24-Jul-18	2:58	G
25-Jul-18	0:53	E
25-Jul-18	1:15	G
26-Jul-18	2:17	D
26-Jul-18	1:12	E
26-Jul-18	2:17	H
27-Jul-18	2:47	F
30-Jul-18	0:28	F
30-Jul-18	1:03	G
31-Jul-18	3:34	G
1-Aug-18	0:24	B
1-Aug-18	0:46	I
1-Aug-18	4:53	Race Course
2-Aug-18	4:28	Race Course
Summary		
Area		**Duration of Total Harvest Time by Area (hh:mm)**
B		4:08
C		5:23
D		9:04
E		6:12
F		3:15
G		8:49
H		7:28
I		0:46
Race Course		9:22
Total Duration of Total Harvest Time (hh:mm)[1]		**54:26**

Note: [1] This amount of time was derived from GPS equipment and methods described above. Due to loss of signal and human error, not all harvesting effort was precisely recorded by this digital technique. NOP manual records indicated > 90 hrs of total harvesting effort while performing contracted activities.

2.2 ACOUSTIC DATA ACQUISITION

From August 20 to 23, 2018, data were collected using a vessel-mounted, single-beam sonar echosounder (Habitat MX Echosounder, BioSonics, Seattle Washington, USA). The primary acoustic survey equipment included the BioSonics transducer (204.8 kHz transducer, 8.6-degree conical beam angle, range accuracy 1.7 cm ± 0.2% of depth), BioSonics deck unit with integrated differential GPS (positional accuracy < 3 m, 95% typical), a field laptop (Toughbook 31, Panasonic Corporation of North America, Newark, NJ, USA), and an underwater video camera (Seadrop 950, Seaviewer, Tampa, USA).

A generalized acoustic survey was carried out by conducting vessel-based transects spaced approximately 50 m apart in a north-south and east-west direction in both Lake Banook and Lake Micmac to replicate data collected earlier in 2018 as well as 2015 through 2017.

Using the integrated differential GPS, the survey vessel navigated along each transect at approximately 4 to 5 km/h (approximately 2.5 knots; speed-over-ground). In addition to the generalized survey, a focused acoustic survey was carried out by conducting vessel-based transects spaced approximately 10 m apart in a north-south and east-west direction within the high weed abundance areas targeted by the weed harvesting contractor in both Lake Banook and Lake Micmac (Figure 1). In Figure 1, “Field Sample Location” denotes locations of continuous sonar data collection for the 2018 post-harvest survey.

2.3 ACOUSTIC DATA ANALYSIS

Acoustic data were analyzed using the Visual Habitat software package (BioSonics, Seattle, Washington, USA). Data were analyzed by replicating the methods used from 2015 to 2018 (Stantec 2015, 2016a, 2016b, 2017a, 2017b, 2018). The following outputs were produced from the acoustic data:

- submerged aquatic vegetation percent cover mapping;
- submerged aquatic vegetation canopy height mapping; and
- heat mapping of aquatic vegetation percent coverage change over time.

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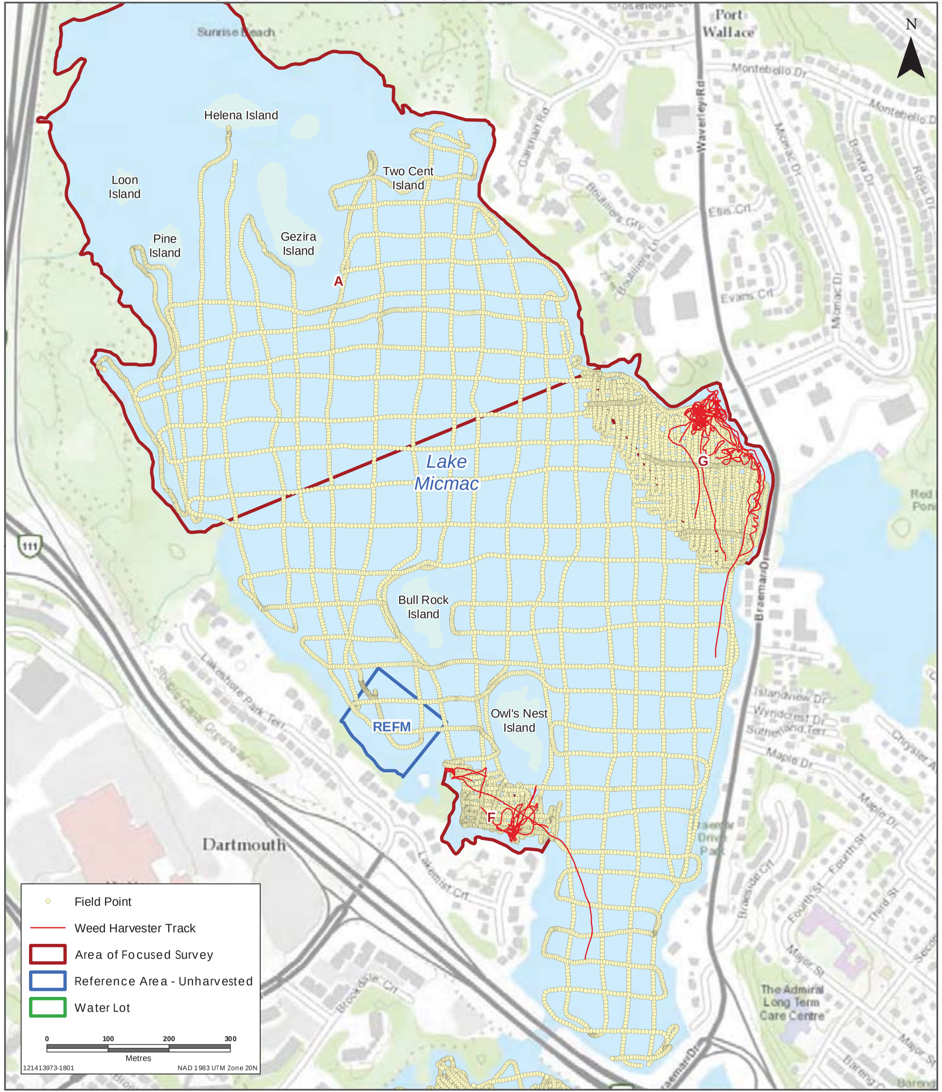
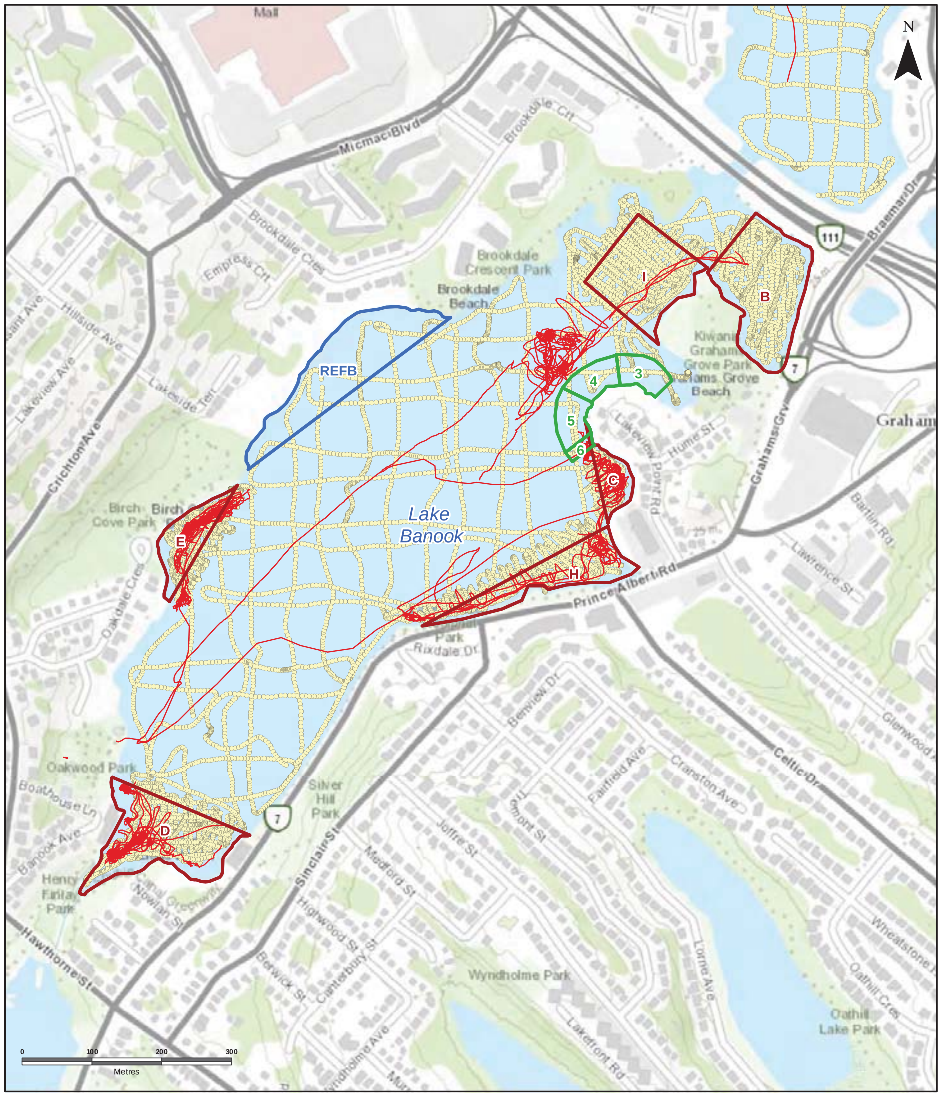


Sources: Base Data - Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



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2018 Post-Harvest Survey Sample Point Locations - Lake Micmac

2018 Post-Harvest Survey Sample Point Locations - Lake Banook

Figure 1

2.4 GROUND-TRUTH DATA AND ACCURACY ASSESSMENT

To ground-truth the acoustic mapping product as well as to assess its accuracy, a field survey was conducted to confirm SAV presence/absence. In total, 59 randomly collected sample points from the ground-truth video transects were assessed for the survey using a downward-facing underwater video camera (Seadrop 950, Seaviewer, Tampa, USA).

For the SAV percent cover mapping a confusion matrix was constructed to assess accuracy, including:

- Overall accuracy - the percentage of correctly classified points
- Errors of omission - the proportion of ground-truth sites incorrectly classified by the map production process resulting in “lost counts” from a particular class (false negatives)
- Errors of commission, the percentage of “counts gained” by incorrect classes (false positives)
- Consumer accuracy - the likelihood that a consumer (map user) will correctly find the habitat class as denoted on the map at a particular location, indicating how much confidence a consumer would have in using the map
- Producer accuracy - a measure of the proportion of times the classification conducted during the map creation correctly identified a habitat class when compared directly to ground-truth data

The Kappa coefficient was also calculated as a measure of accuracy assessment and to statistically compare the complementarity of the various mapping products (Congalton and Green 2008).

2.5 STATISTICAL ANALYSIS

Past monitoring of mechanical weed harvesting activities in Lake Banook and Lake Micmac have shown that evaluations using statistical methods can be challenging. To address statistical comparisons, a GIS-based semivariogram technique was used (detailed methodologies provided in Stantec 2016c) to address spatial autocorrelation and identify appropriate cell sizes at which the points become statistically spatially independent (*i.e.*, they are not spatially auto-correlated). This semivariogram approach (Haining 2003) indicated sampling points were statistically spatially independent within cells of a conservative area of 35 m^2.

All statistical analyses were conducted using the software package R (R Core Team, 2016). Confusion matrices were calculated with the “caret” (Classification and REgression Training) package in R (Kuhn 2016). Kappa coefficient calculations with Z- tests were calculated with the “irr” (Various Coefficients of Interrater Reliability and Agreement) package (Gamer at al. 2012). Temporal trend analyses were conducted with the “car” (Companion to Applied Regression; Fox and Weinberg, 2018) as well as “lsmeans” (Least Square Means; Lenth, 2016) packages.

All data were assumed to be independent and it was determined that normality assumptions were satisfied by visual inspection of residual plots, density plots, and/or quantile-quantile plots. Homogeneity of variances was assessed by examining residual plots (Zar 1999), and response variables were transformed to meet these assumptions where required (Draper and Smith 1998).

3.0 RESULTS AND DISCUSSION

3.1 SUBMERGED AQUATIC VEGETATION COVERAGE

SAV data from the post-harvest 2018 survey were used to create vegetation mapping for Lake Banook and Lake Micmac. Figure 2 depicts the SAV coverage as data points along each transect sampled in the field. Figures 3 and 4 represent interpolated mapping of the percent cover of SAV for Lake Banook and Lake Micmac, respectively, in which the raw data (Figure 2) were used to create SAV coverage mapping for the entire waterbody.

Acoustic mapping had an overall accuracy of 90% with a kappa value of 0.74 ($Z = 5.86$ $p < 0.001$)[2], which is indicative of substantial accuracy and agreement with ground-truth data (Table 2). The overall accuracy for single-beam sonar mapping was mostly a function of the misclassification of 6 sonar interpolated points as “present” when ground-truthing demonstrated they were absent, as evidenced by the elevated error of omission (33.3%) and decreased producer accuracy (PA) for the “SAV Present” class (Table 2).

Table 2 Presence/Absence Error Matrix for Single-Beam Sonar

		Ground-truth Points			Error	
Single-Beam Sonar		**SAV Present**	**SAV Absent**	**Row Totals**	**Errors of Commission (%)**	**Errors of Omission (%)**
	SAV Present	**41**	6	47	12.8	0.0
	SAV Absent	0	**12**	12	0.0	33.3
	Column Totals	32	30			
Producer Accuracy (%)		100.0	66.7	**Overall Accuracy (%)**		**90**
Consumer Accuracy (%)		87.2	100.0	**Kappa**		**0.74**

Dense vegetation coverage (> 70%) was identified throughout the majority of the nearshore areas of Lake Banook (Figure 3), particularly adjacent to Paddler’s Cove (Areas H & C) as well as Reference Area B. The area adjacent to Paddler’s Cove also demonstrated a large proliferation of dense weeds extending westward towards the middle, deeper portions of the lake. In Lake Micmac (Figure 4), dense vegetation was observed in the southern portion of the lake, in the nearshore portions of Area G, and south of Bull Rock and Owl’s Nest Islands.

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[2] Overall accuracy >70% is generally deemed acceptable. Kappa coefficients estimate agreement between ground-truth data and mapping products (Congalton and Green 2008). Kappa < 0.40 represents poor agreement, 0.41–0.80 moderate, and >0.80 –1 as almost perfect agreement.

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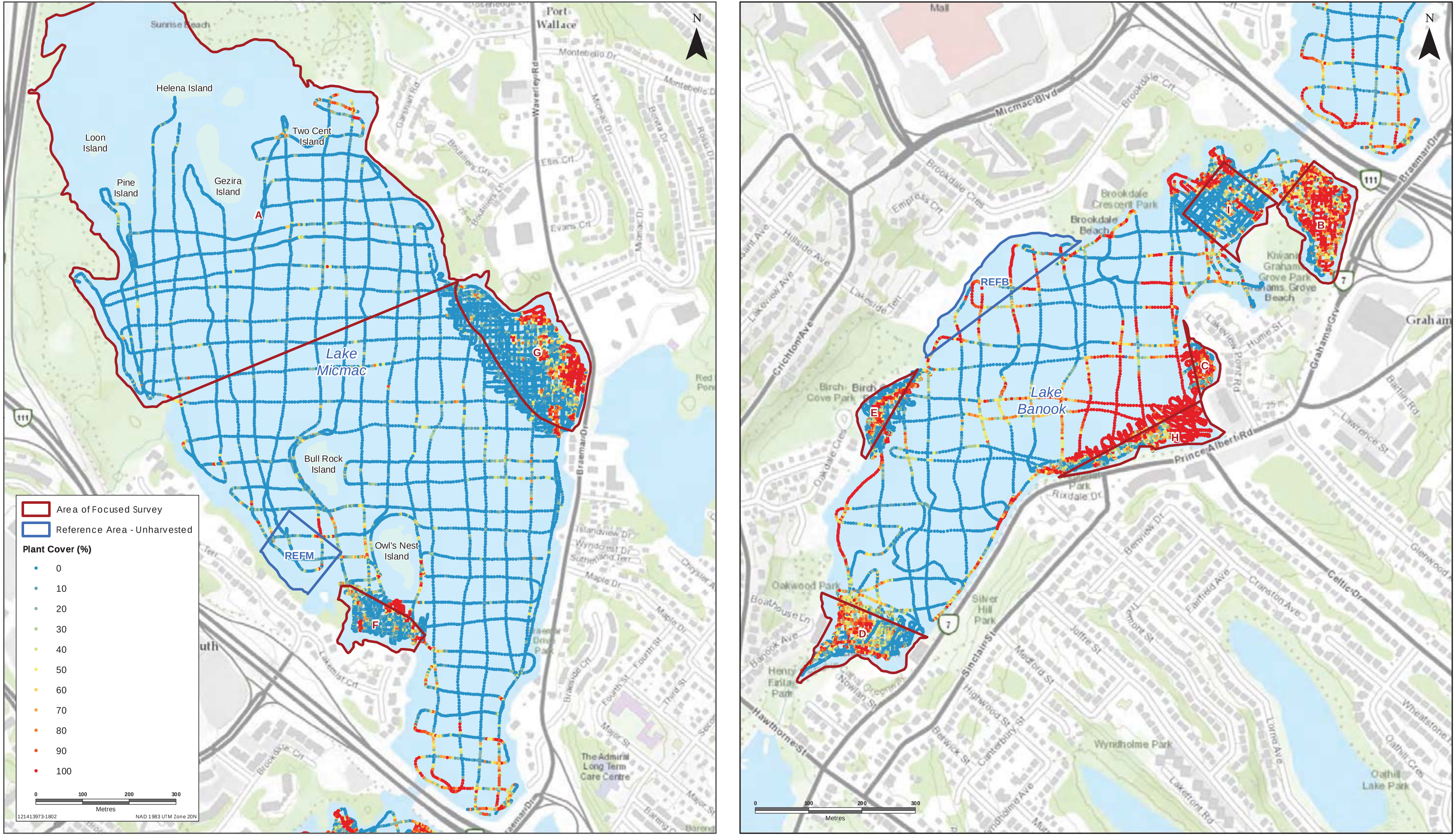

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Submerged Aquatic Vegetation Coverage, Post-Harvest 2018 – Field Points

Figure 2

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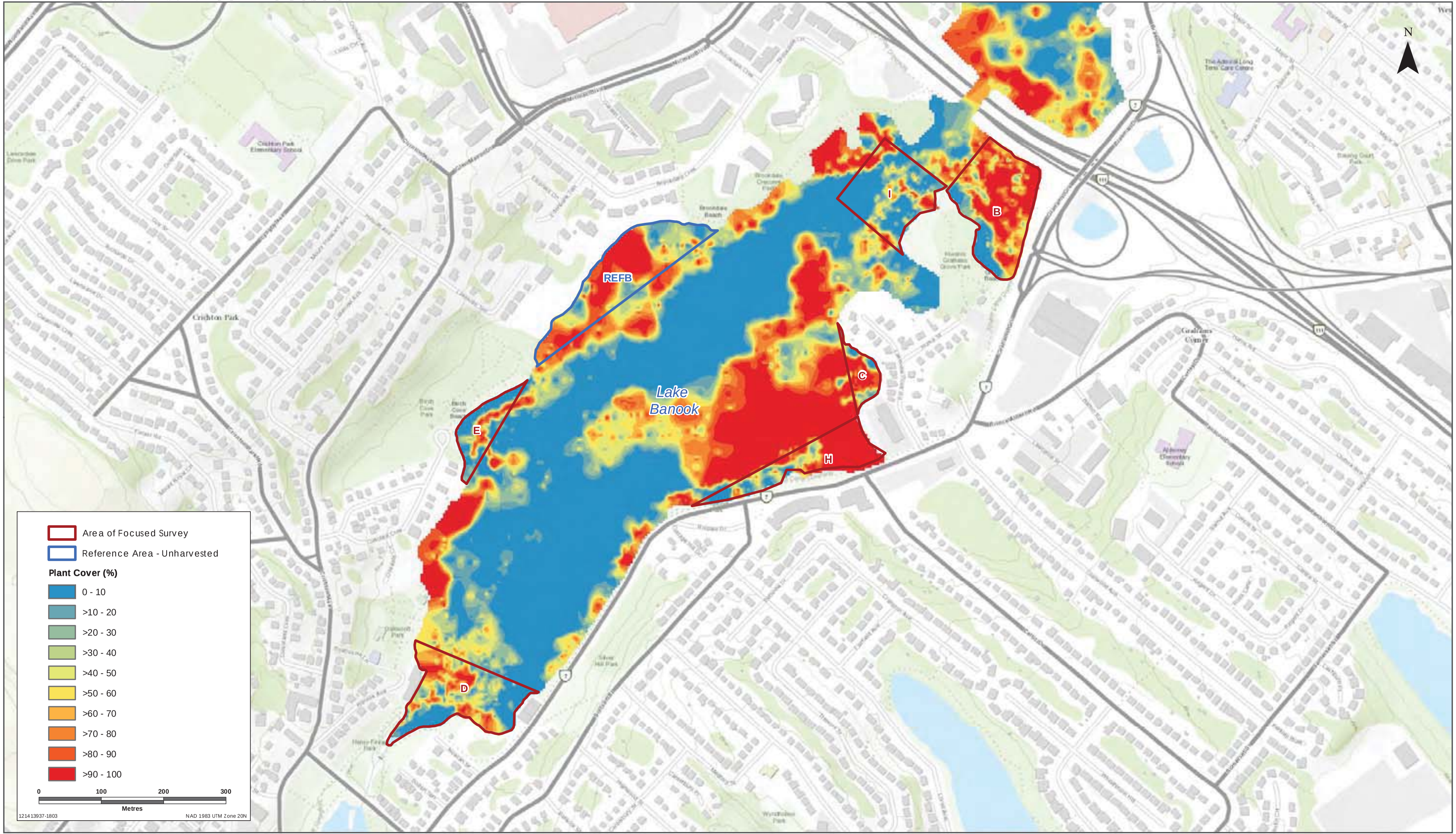

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Submerged Aquatic Vegetation Coverage of Lake Banook, Post-Harvest 2018 – Interpolated

Figure 3

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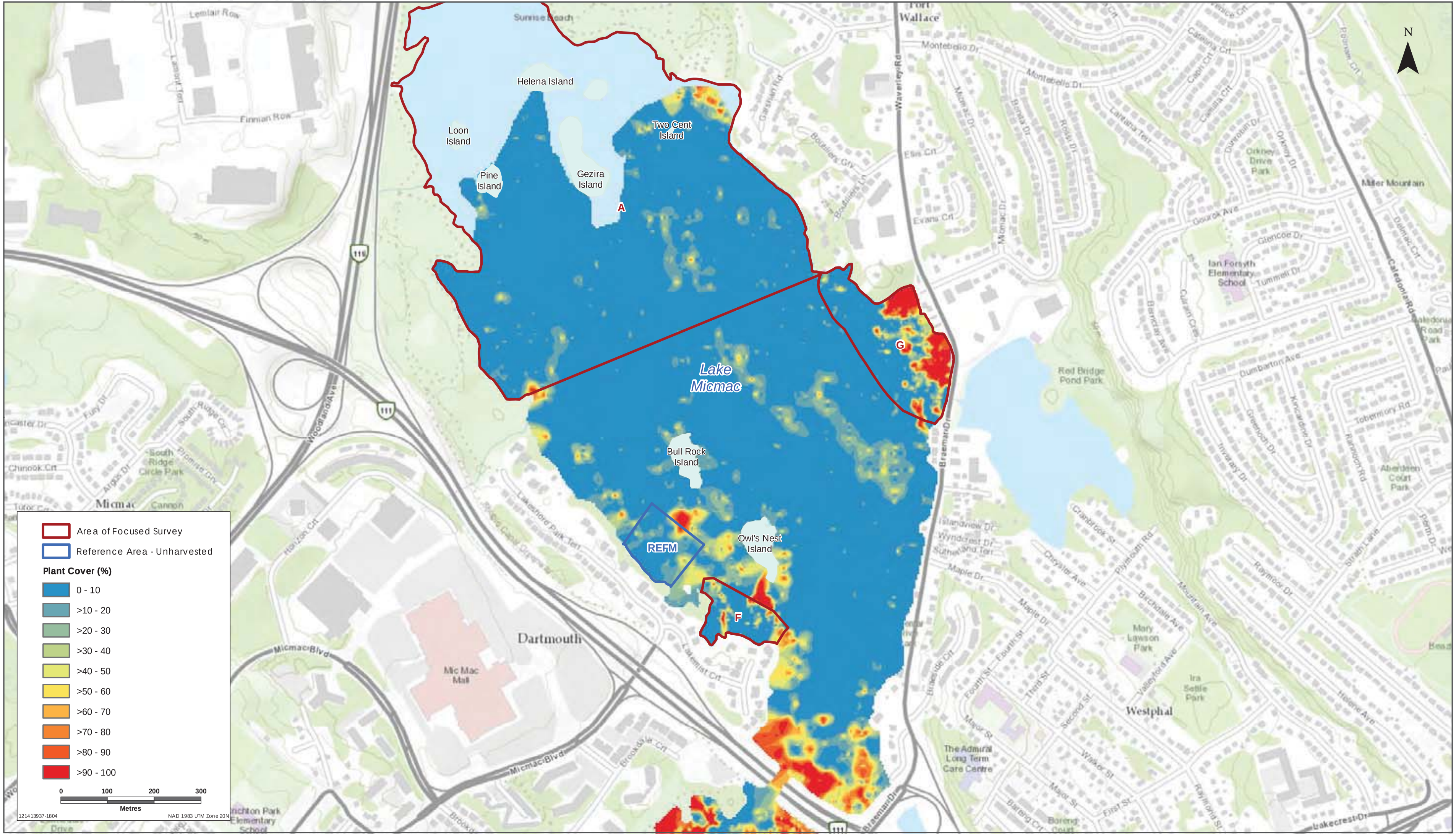

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Submerged Aquatic Vegetation Coverage of Lake Micmac, Post-Harvest 2018 – Interpolated

Figure 4

Heat maps were created to compare the percent cover of SAV in each lake with respect to pre- and post-harvest coverage and differences in coverage between sampling years. Figure 5 depicts the change in SAV cover between 2018 pre-harvest to 2018 post-harvest in Lake Banook and Lake Micmac with green indicating SAV cover increases, yellow indicating limited change, and purple indicating SAV cover declines for the 2018 post-harvest survey in comparison to the 2018 pre-harvest survey.

In Lake Banook, the general trend observed from pre-to post-harvest during 2018 was an overall increase in vegetation coverage. This contrasts with the trend observed in 2017 which saw declines immediately after harvesting (Stantec 2017b). Within the target harvest areas, prominent vegetation increases were noted in Areas B, C, D, H, and the reference area in Banook (REFB). Minimal areas of significant decline (purple) were noted in Area D (Figure 5) and corresponded to discrete regions the harvester was instructed to target. While discrete areas of SAV loss may be attributable to 2018 harvesting activities, areas of SAV gain are indicative of the seasonal growth patterns of these plants between early-July and late-August. As such, these intra-2018 trends must be interpreted with a degree of caution. Specifically, the contradicting intra-year trends between pre- and post-harvest surveys noted in 2018 (global increase in coverage) vs 2017 (global decrease in coverage) could be a function of a delayed initiation of the maximal growing season for these plants in 2018, which would have coincided with harvesting activity and therefore masked its apparent effectiveness. This hypothesis suggests factors beyond the control of HRM were responsible for the observed 2018 proliferation of plant cover.

Comparing Lake Micmac SAV coverage from pre-to post-harvest in 2018 depicted similar observations to previous years' surveys, with sporadic increases and decreases in vegetation coverage being observed throughout the lake (Figure 5). In Area G where the harvester was active, decreases in vegetation coverage can be seen. Conversely, zones of increase can be seen in the nearshore region of Area G, a small portion of Area F, as well as in the southern portion of the lake near the outlet to Lake Banook (Figure 5). Patterns of vegetation stasis were also evident in REFM, which was not subject to harvesting activity. Graphical examination of these trends in SAV percent cover further highlighted the generalized increase in the value as well as variation in percent cover responses for both lakes (Figures 6 and 7; Appendix B).

Representative comparisons to assess inter-annual trends potentially related to harvesting activity must be made between comparably timed surveys, such as those late-summer, post-harvest surveys which occurred from 2015-2018 in Lake Banook (as well as data from 2014 initial survey prior to harvesting) and 2015-2018 in Lake Micmac. When comparing SAV percent cover post-harvest between 2018 and 2017 in Lake Banook (Figure 8), substantial areas of increase were prevalent in all Target Areas particularly in Areas C and H, adjacent to Paddler's Cove, as well as the nearshore area between Areas D and E. This result contrasts greatly with the distinct SAV declines that had been observed from 2017-2016 (Appendix C; Stantec 2017b). Meanwhile, post-harvest data from 2018-2017 in Lake Micmac showed an overall similar trend to past surveys in which diffuse increases and decreases in SAV coverage can be seen in target harvest Areas F and G as well as in the reference area, REFM (Figure 8).

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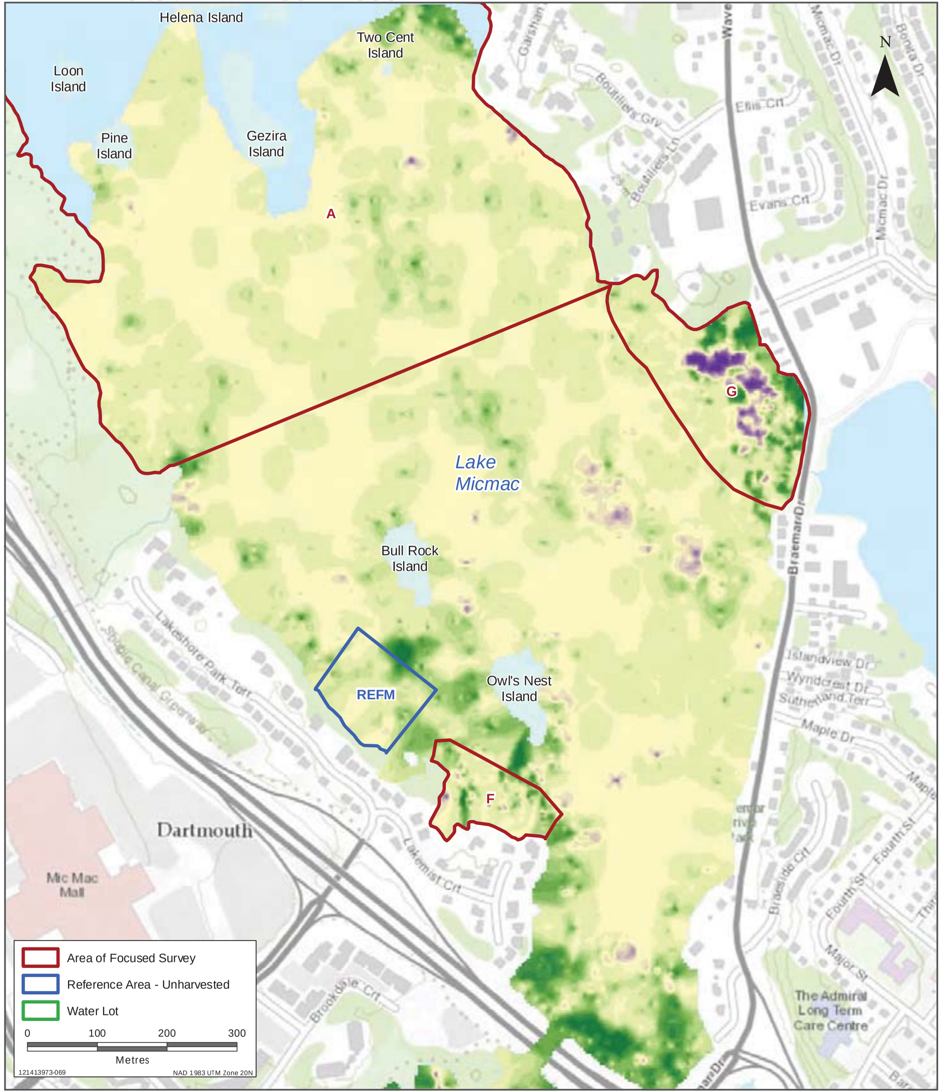

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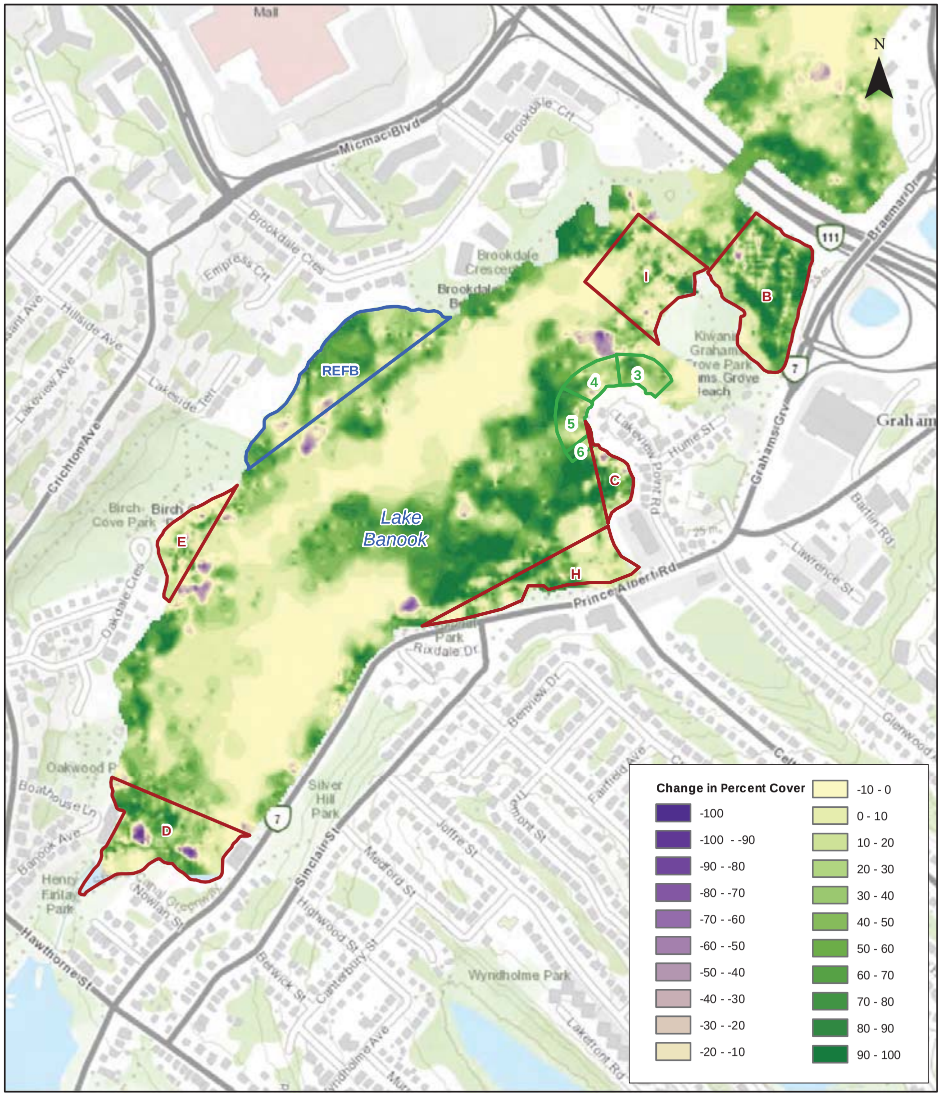
Change in Percent Cover: 2018 Post-Harvest to 2018 Pre-Harvest - Lake Micmac



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Change in Percent Cover: 2018 Post-Harvest to 2018 Pre-Harvest - Lake Banook

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Figure 5

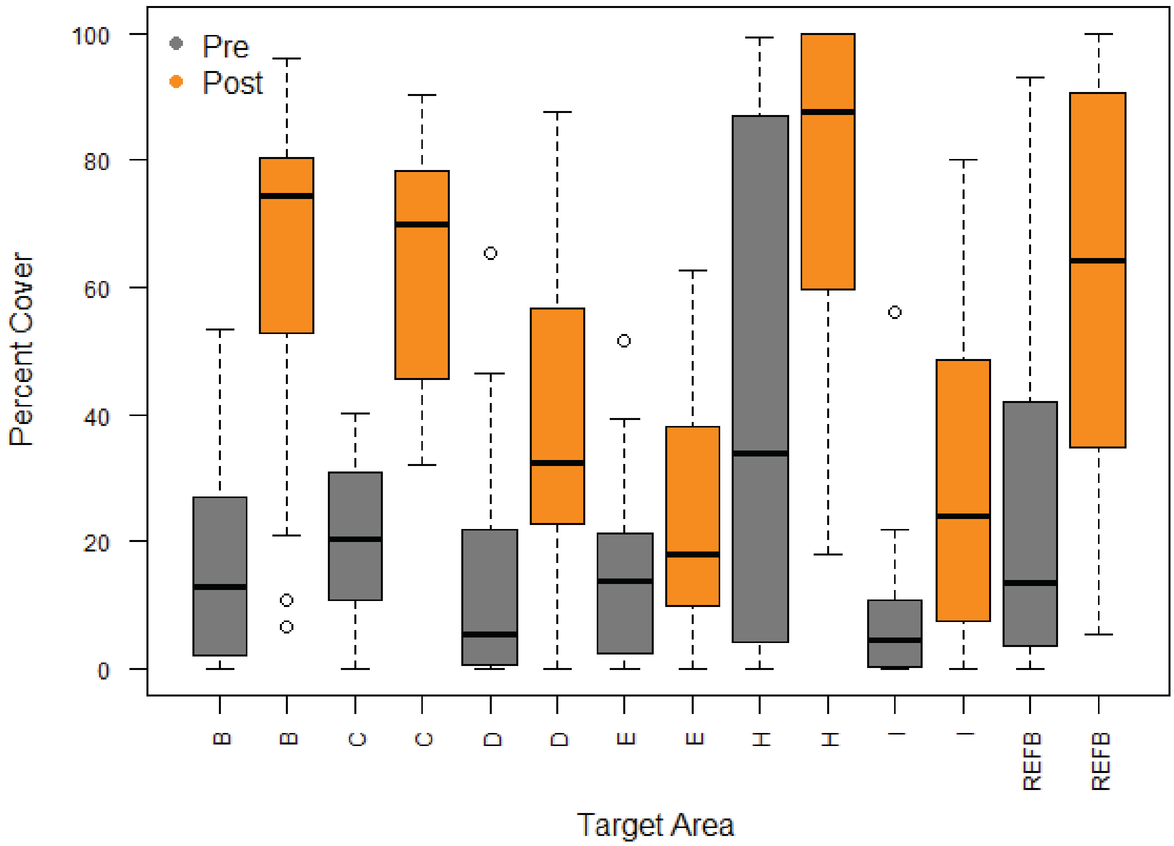

Figure 6 **Boxplots of SAV Percent Cover Areas in Lake Banook for 2018 Pre- vs. Post-Harvest**

Note: The centre line is the median. Ends of the box indicate the lower and upper quartiles. Ends of the whiskers indicate the quartile ±1.5 x interquartile spread. Open circles indicate values falling outside the quartile ±3 x interquartile spread. REFB = Reference Area B.

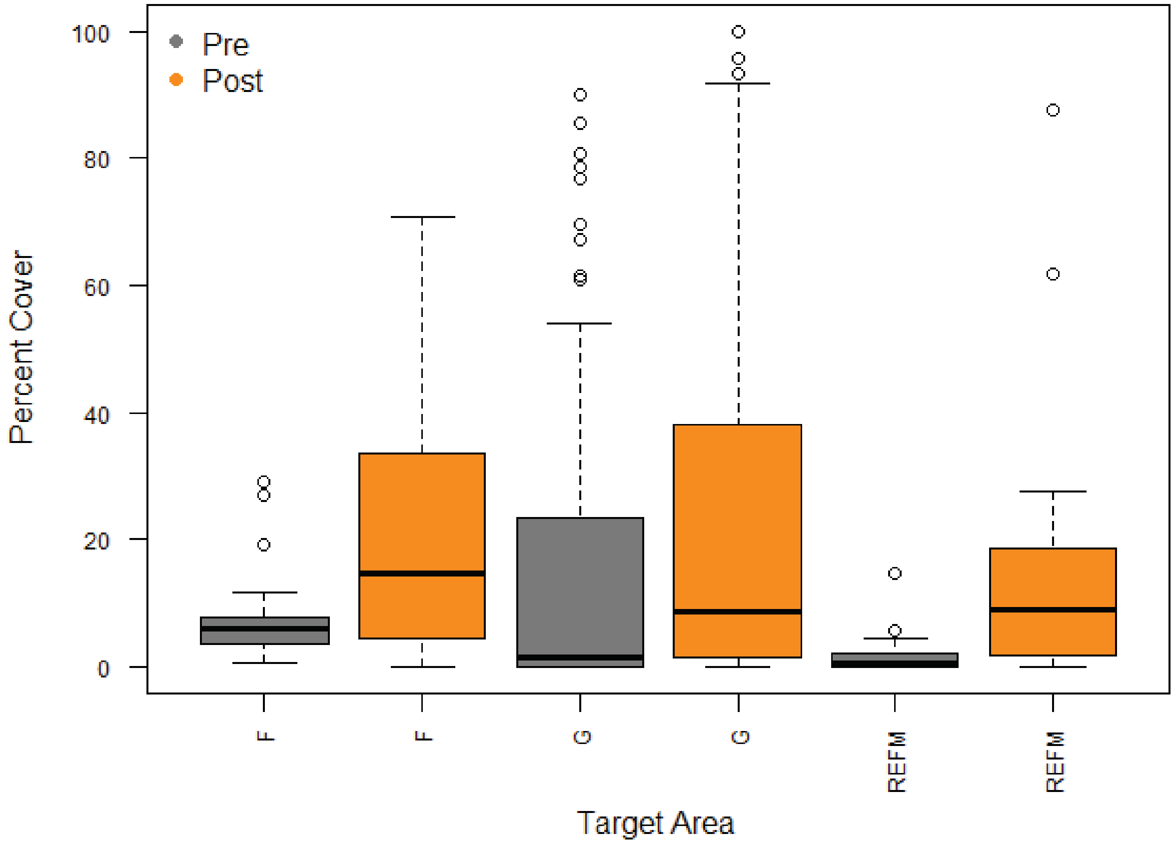

Figure 7 **Boxplots of SAV Percent Cover Areas in Lake Micmac for 2018 Pre- vs. Post-Harvest**

Note: The centre line is the median. Ends of the box indicate the lower and upper quartiles. Ends of the whiskers indicate the quartile ±1.5 x interquartile spread. Open circles indicate values falling outside the quartile ±3 x interquartile spread. REFM = Reference Area M.

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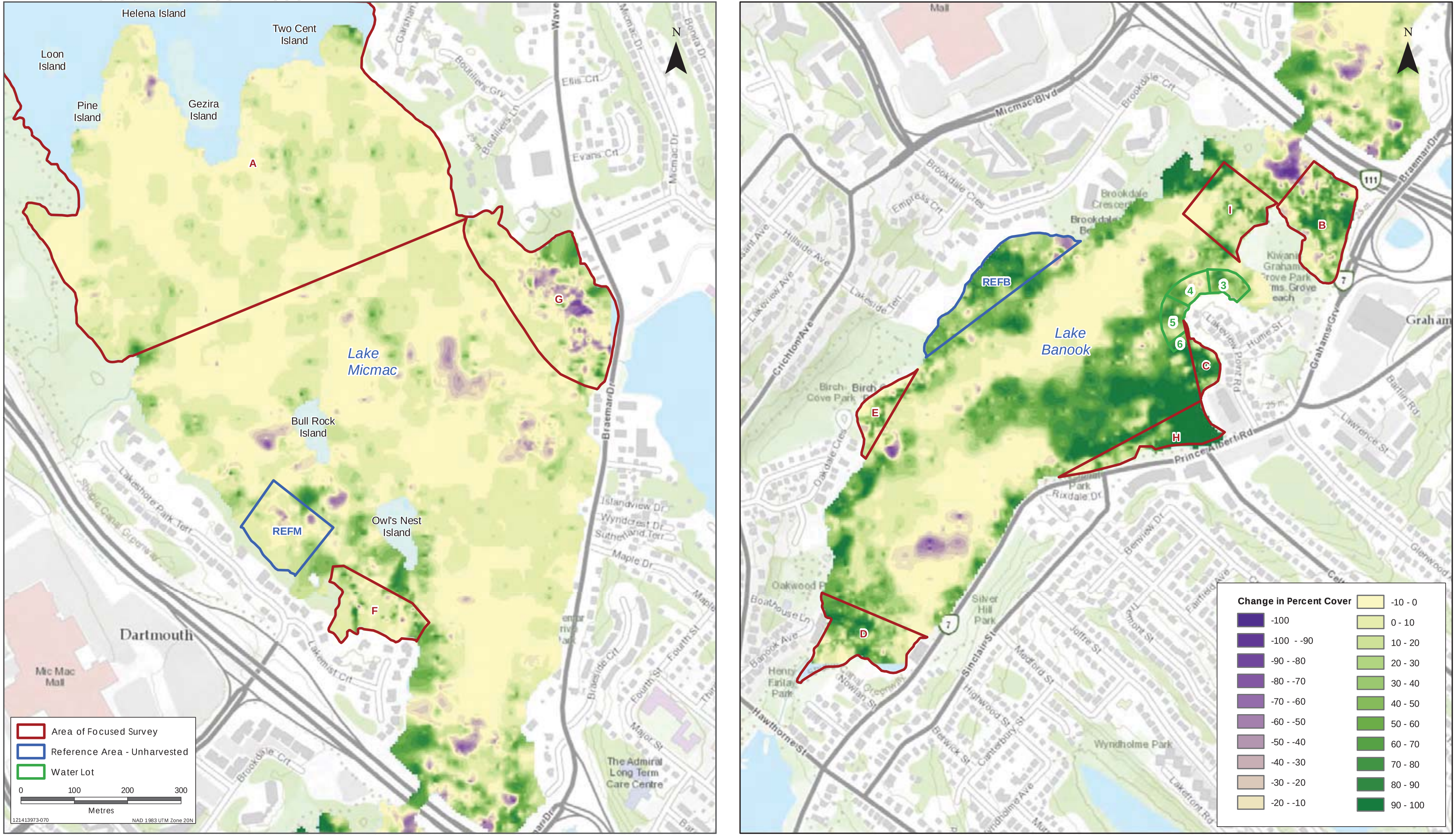

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Change in Percent Cover: Post-Harvest 2018 to 2017 Post Harvest– Lake Banook and Lake Micmac

Figure 8

Relative to baseline conditions in 2014, Lake Banook has shown a mixture of declining and increasing SAV coverage across discrete locations (Figure 9). Areas subjected to harvesting activity (C to E, H and I) displayed similar variability in SAV coverage with Areas D and H showing net increases; Areas C and I remaining relatively neutral; and Area E declining overall (Figure 9). Areas B and REFB were not subjected to harvesting but also had divergent trends; Area B was predominantly neutral while REFB showed significant net increases in SAV cover (Figure 9).

Lake Micmac baseline comparisons contrasted with those noted for Lake Banook. Heat mapping between 2018 and 2015 baseline in Lake Micmac indicated a broad decline in SAV percent cover with area-specific declines observed in each of Areas F, G, and REFM (Figure 10). Small pockets of discrete SAV increase were noted in the immediate nearshore region of Area G, the narrow zone south of Bull Rock and Owl’s Nest Islands, and the western shore at the outlet to Lake Banook (Figure 10).

Comparisons of temporal trends were assessed among the five survey events conducted in Lake Banook during late summer in 2014, 2015, 2016, 2017, and 2018 (Figure 11). Overall, varying degrees of SAV reductions were noted from 2014 to 2017; however, a drastic increase was noted from 2017 to 2018 in areas regardless of harvesting activity. As a result of this 2018 rebound in SAV percent cover, no statistically significant trends ($p < 0.05$) were detected for any area (Table 3) as 2018 SAV cover values were no different from 2014 baseline values.

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Change in Percent Cover: 2018 Post-Harvest to 2014 - Lake Banook

Figure 9

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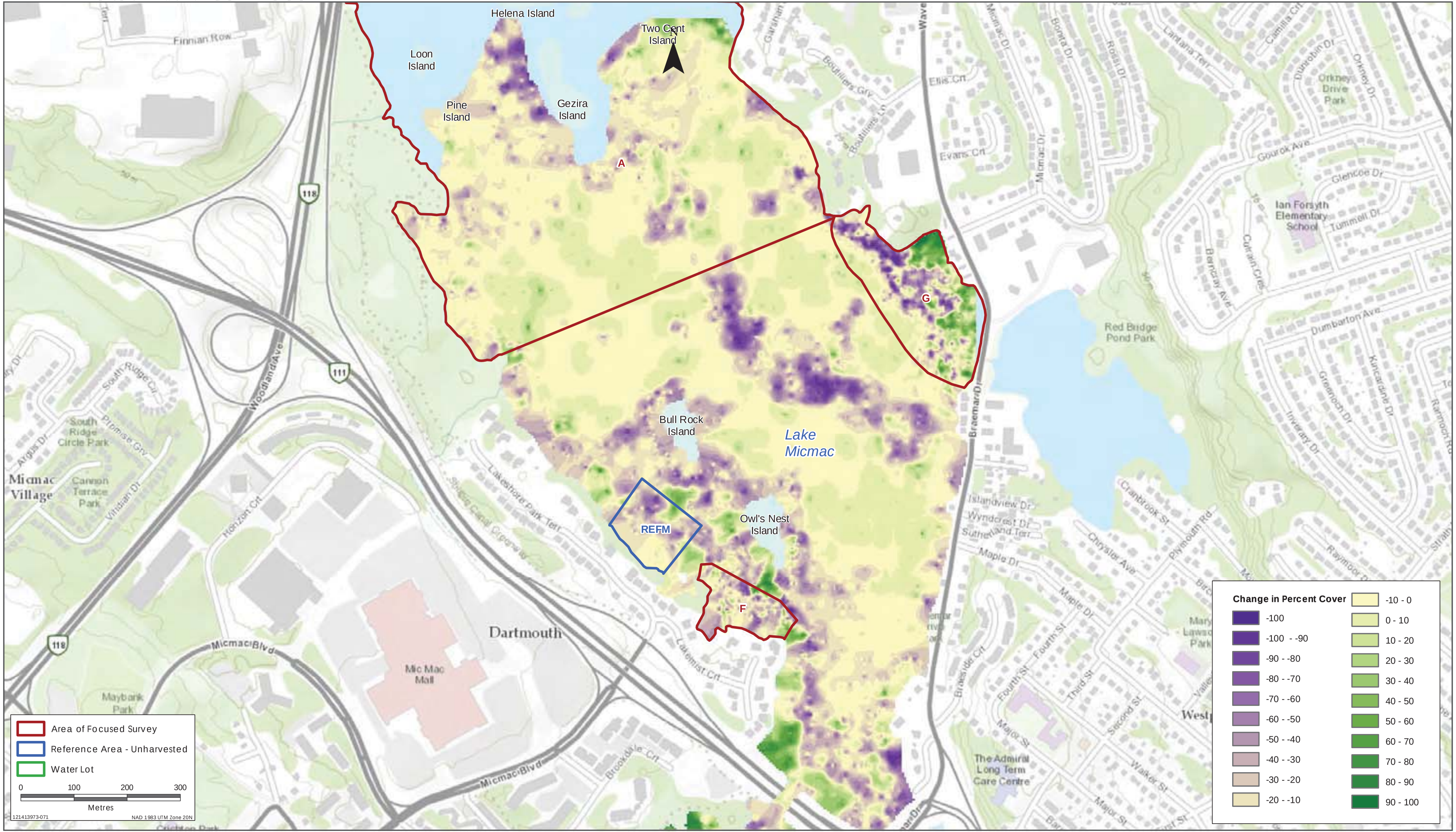

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Change in Percent Cover: Post-Harvest 2018 to 2015 - Lake Micmac

Figure 10

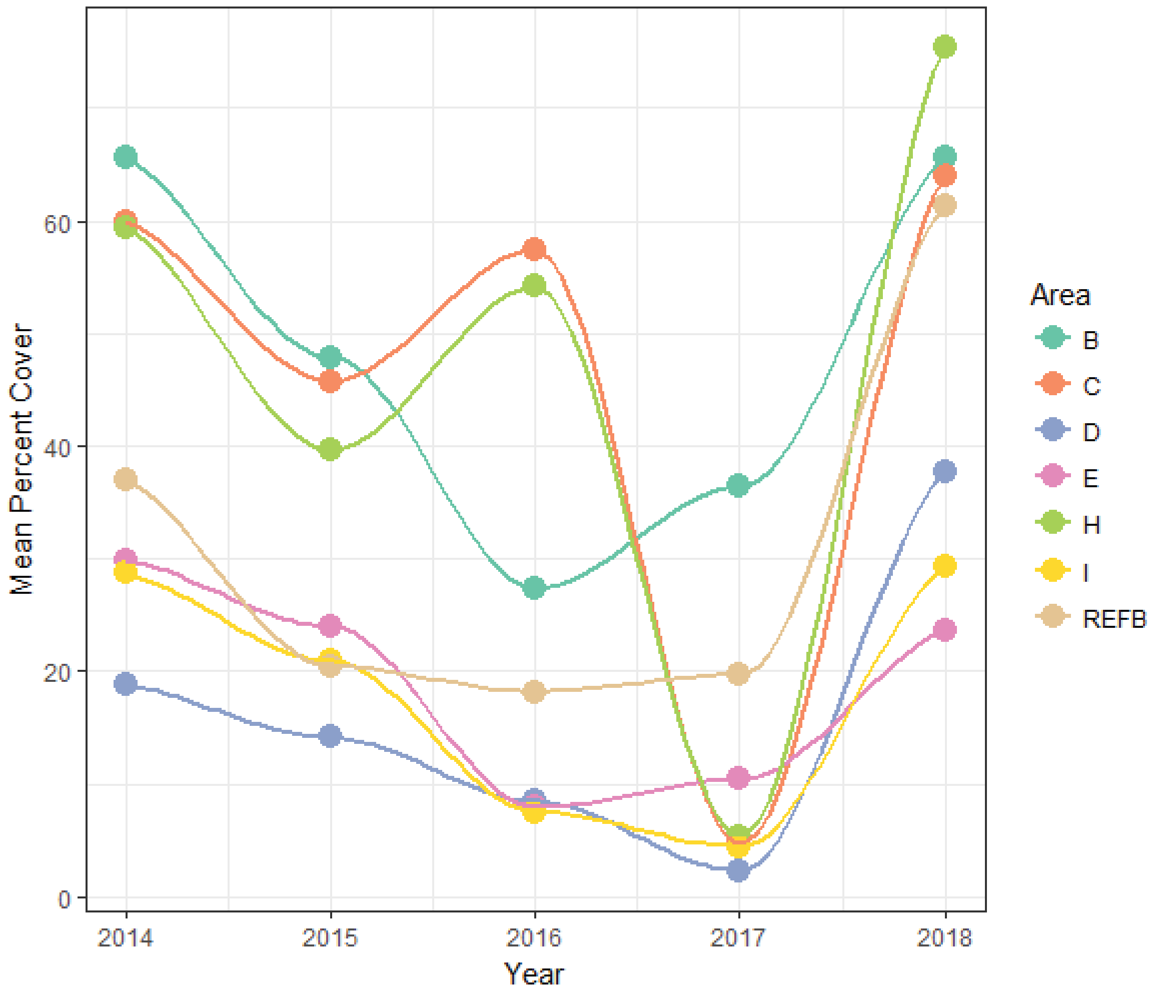

Figure 11 Temporal Trends of Mean Percent Cover by Area in Lake Banook (2014-2018)

Note: Loess smoother applied to data to highlight percent cover shifts between individual years.

Table 3 Linear Model Slope Estimates for Temporal Trends of Mean Percent Cover (Arcsine square root transformed) by Area in Lake Banook (2014-2018)

Area	Year Trend	df	Lower CL[1]	Upper CL[1]	*p*-value
B	-0.012	21	-0.191	0.168	0.893
C	-0.046	21	-0.226	0.134	0.599
D	0.022	21	-0.158	0.201	0.806
E	-0.038	21	-0.218	0.142	0.665
H	0.002	21	-0.177	0.182	0.979
I	-0.032	21	-0.212	0.147	0.713
RefB	0.053	21	-0.127	0.232	0.548

[1] CL = 95% confidence limit. df = degrees of freedom. Statistical significance assessed at a *p*-value (α) = 0.05. Data Arcsine square root transformed to satisfy statistical assumptions.

For Lake Micmac, declines were observed in all areas (Figure 12), though these trends were statistically insignificant ($p < 0.05$). Similar to Lake Banook, when declines were observed they were consistent until 2017 followed by a rebound in 2018 (Figure 12). This rebound trend was pronounced in Areas F and REFM while much more muted in Area G (Figure 12). The lack of statistically significant results was likely a function of low statistical power given the high variability in percent cover data among areas as well as among years, with the 2017-2018 rebound being most influential (Appendix B).

Assessment of SAV percent cover within only the target areas does not provide a complete picture of trends within the whole-lake ecosystems of Lakes Banook and Micmac. As evidenced by the most recent mapping showing broad-scale plant proliferation in the Paddler's Cove area of Lake Banook (Figure 3), reliance on such data would be myopic. The total areal coverage of plants within each lake (i.e., the surface area of lake bottom with any detectable plant coverage, calculated by GIS) demonstrates that after initial harvesting began in 2015, subsequent SAV declines continued until 2017, followed by the previously described SAV rebound in 2018 (Figure 13). In all, a slight increase in the total coverage of SAV (28 to 30ha) has been noted for Lake Banook between 2014 and 2018 while Lake Micmac SAV has reduced 33% (66 to 45 ha) from 2015 to 2018 (Figure 13).

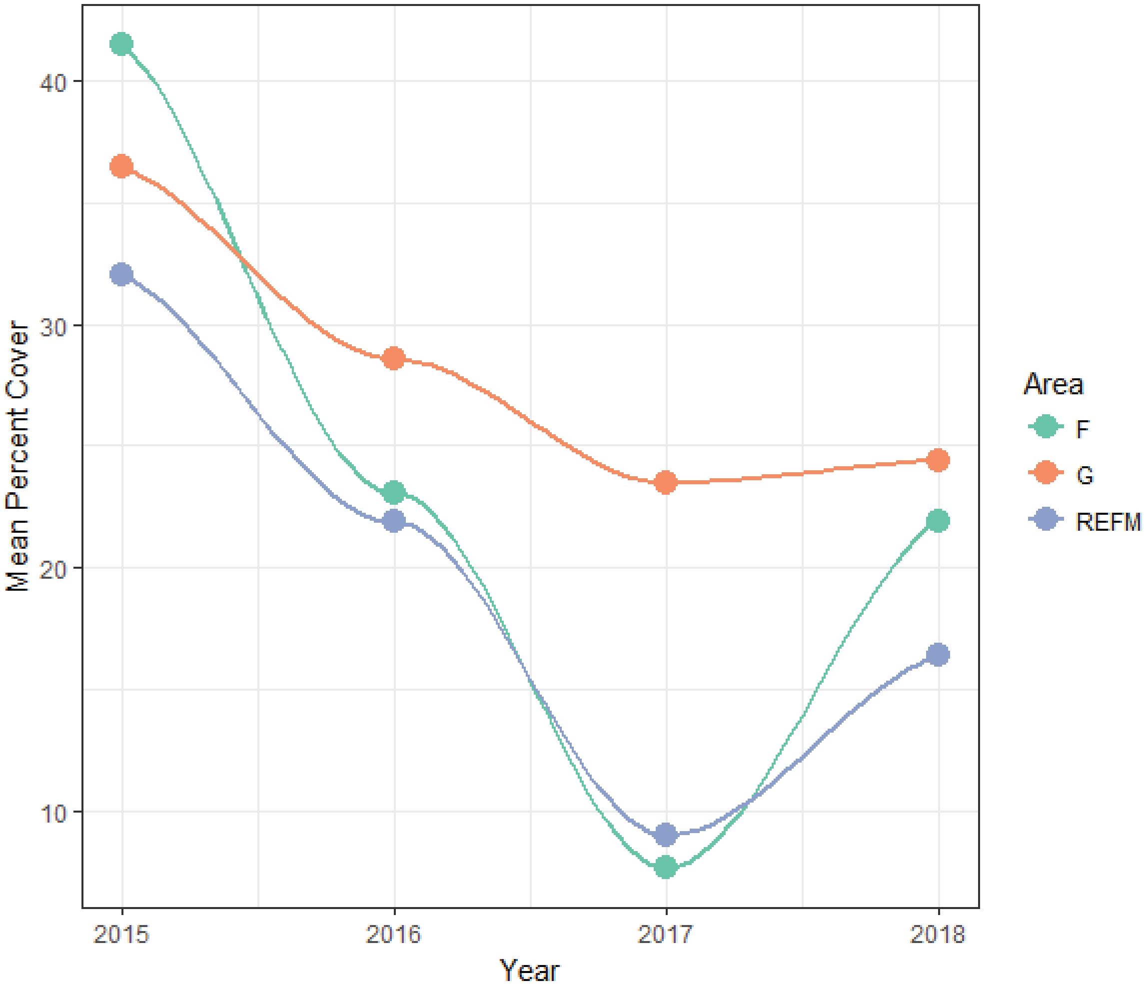

Figure 12 Temporal Trends of Mean Percent Cover by Area in Lake Micmac (2015-2018)

Note: Loess smoother applied to data to highlight percent cover shifts between individual years.

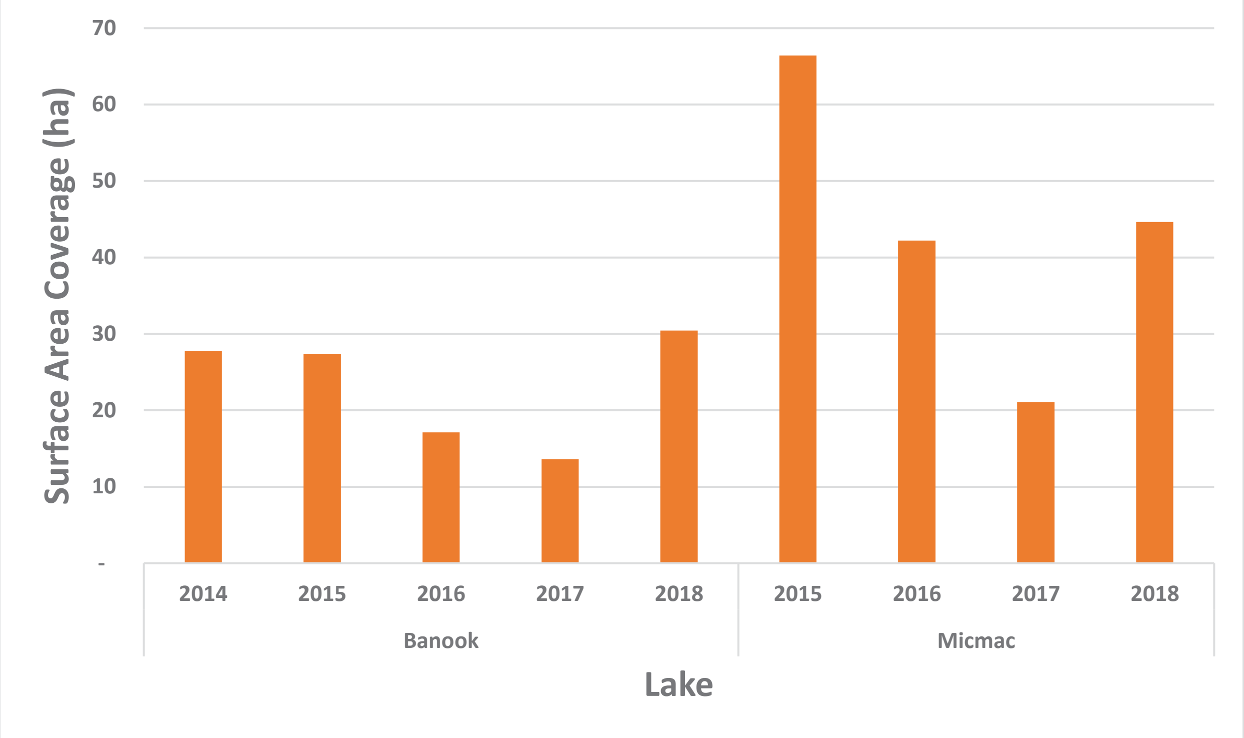

Figure 13 **Temporal Trends (2015-2018) of Total Surface Area Coverage by Plants– for Lake Banook and Lake Micmac**

3.2 SUMBERGED AQUATIC VEGETATION CANOPY HEIGHT

Aquatic canopy height was calculated for vegetation encountered in each lake, with the 2018 post-harvest results provided in Figure 14.

Due to the presence of false-positive plant identification for short plants that occurs because of a thick layer of silt in the lakes, a plant height cutoff of 0.25 m was applied to the BioSonics software for height identification. At the time of sampling, vegetation heights ranged from 0.25 m to greater than 1.4 m in Lake Micmac and 0.25 m to 1.8 m in Lake Banook (Figure 14), both of which maxima were substantially lower than those observed in previous years (Stantec 2017b).

Data collected in Lake Banook during the pre-harvest survey indicated that most of plants in the lake had heights within the 0 m – 0.5 m range. There were, however, areas where vegetation heights fell in the > 2.0 m range, such as in Area D. When compared to the post-harvest data (Figure 14), it appears that in areas where the harvester was targeting SAV, vegetative heights have been greatly reduced.

Canopy height observations reported for Lake Banook also generally apply to Lake Micmac (Figure 14). Data collected in Lake Micmac during the pre-harvest survey indicated that the majority of vegetation fell within the 0 m – 0.5 m range. However, these data also illustrated Area G vegetation reached heights in excess of 2.0 m (Stantec 2018). Post-harvest data indicate that in areas where the harvester targeted vegetation (Areas F and G), vegetation heights were reduced (Figure 14). This is especially apparent in Area G where heights were reduced to 1.0 m – 1.5 m. Conversely, in areas where the harvester was not active such as in the southern portion of the lake near the outlet to Lake Banook, vegetation heights increased when compared to those measured during the pre-harvest survey (Figure 14), as has been noted in previous years (Stantec 2017b).

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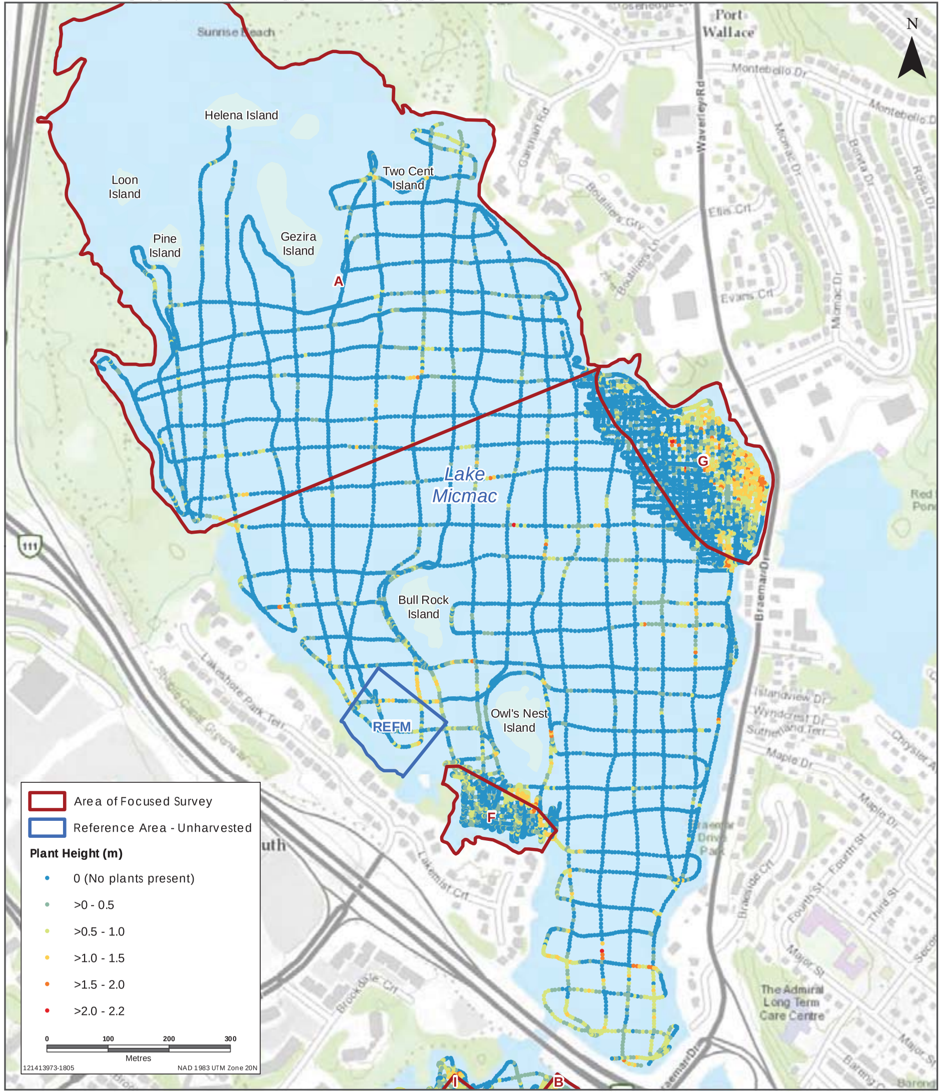
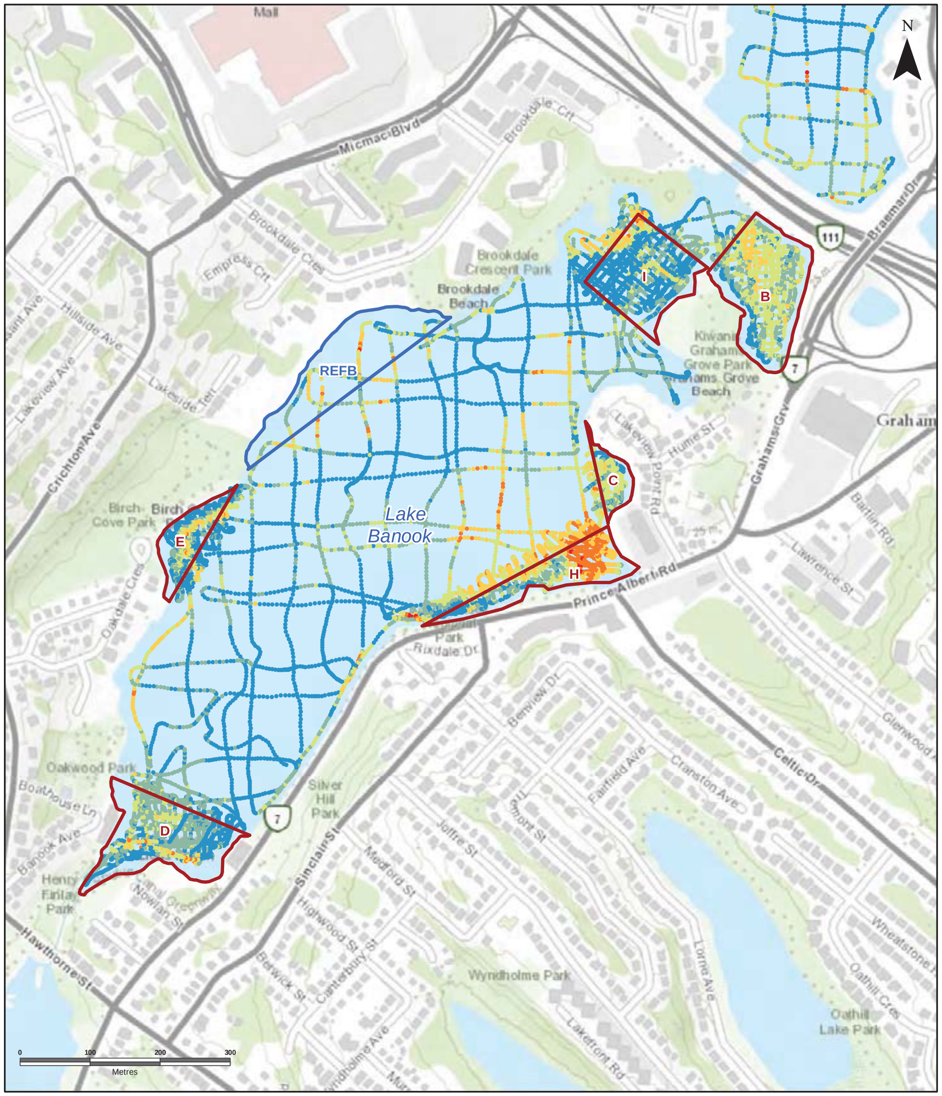


Sources: Base Data - Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Submerged Aquatic Vegetation Canopy Height of Lake Micmac Post-Harvest 2018 – Field Points



Disclaimer: This map is for illustrative purposes to support this project; questions can be directed to the issuing agency.

Submerged Aquatic Vegetation Canopy Height of Lake Banook Post-Harvest 2018 – Field Points

Figure 14

3.3 UNDERWATER VIDEO REVIEW AND DISTRIBUTION OF VEGETATION TYPES

Underwater benthic video was captured upon completion of harvesting in August 2018. In Lake Banook, Areas B, C, D, E, and H as well as Areas F and G in Lake Micmac were selected for video assessment of harvested areas (Figure 1). Area I video data were not collected in 2018 due to a camera malfunction. Indicators of potential harvest considered during analysis included disparity in lengths from the surrounding vegetation and bottom-strike marks.

Upon review of these videos, no evidence of bottom strikes was noted. Further, the remaining indications of harvesting activities were more apparent in some areas than others. This is not to express that those indicated as not showing signs of harvesting were in fact left unharvested, but rather that they exhibited no obvious signs of harvest and could therefore not be distinctly identified as such. For example, harvesting of specific regions composed predominantly of *E. canadensis* may have not been as apparent due to the physical appearance of the species, which often forms a relatively even ‘carpet’. Conversely, those areas where the much taller and variably growing species of *P. perfoliatus* and *P. foliosus* dominated often exhibited much clearer indications of being harvested.

It should be noted that this qualitative assessment of effectiveness of harvesting is potentially susceptible to the following biases:

- the level of effort for each of the harvested areas varied due to logistical and/or safety (*e.g.*, recreational watercraft users or rowing course submerged buoy cables);
- incomplete capture of all harvesting activity using GPS tools, as previously described;
- initial vegetation abundance in each of the harvested areas (*i.e.*, those areas largely bare prior to harvest, would appear to have had little harvested from them and therefore a falsely reduced efficacy); and/or
- video transects completed only captured the exact, narrow path the harvester followed and therefore only illustrate a small portion of each harvested area.

Within Area H, the continued absence of algal blooms was confirmed, indicating the 2017 pre-harvest observations of excessive algal blooms were an isolated event. A high prevalence of bare substrate was also noticed in these video data (Stantec 2017b). Re-examination of these previous data in light of 2018 results showing plant proliferation (Figure 3) indicates that the prevalence of bare substrate has been declining in Lake Banook since 2016 with Area C reducing from 56% to 16% bare substrate and Area H reducing from 54% to 10% bare substrate.

Underwater video transects were also collected to determine the species of aquatic vegetation in targeted harvest areas of Lake Banook and Lake Micmac. Abundant species such as *P. perfoliatus*, *P. foliosus*, and *E. canadensis* were common to both lakes. The following dominant species were identified in the targeted harvest areas in Lake Banook and Lake Micmac during post-harvest 2018:

- *Chara* sp.
- Canada Waterweed (*E. canadensis*)
- Clasping Leaf Pondweed (*P. perfoliatus*)
- Leafy Pondweed (*P. foliosus*)
- *Utricularia* sp.

The prevalence of *E. canadensis* was the greatest amongst all plants observed and has remained relatively stable or increased in most areas between 2015 and 2018 in Lake Banook (Figure 15). Notable increases occurred in most areas between 2015 and 2016 as well as in Area I from 2016 to 2017. In 2018, the greatest prevalence was noted in Areas B and C; the former only harvested during the 2015 season. Also of interest, progressive increases in prevalence of E. canadensis have been recorded at Areas D and E (Figure 15). In Lake Micmac, prevalence of this species has remained constant for Areas F and G (Figure 15).

P. foliosus prevalence also increased drastically in most areas between 2015 and 2016 followed by general decreases from 2016 to 2017 (Figure 15). From 2017 to 2018, certain locations, such as Areas C and H saw recovery to previous levels, while Areas D and E remained suppressed relative to 2016 levels (Figure 15). In Lake Micmac, contrasting trends were noted between Areas F and G, with the latter area declining in *P. foliosus* cover since a 2016 peak in prevalence (Figure 15).

P. perfoliatus prevalence has been more variable (Figure 15). After increasing drastically in Area E between 2015 and 2016, prevalence declined distinctly in 2017 then rebounded in 2018; Areas C and D have shown stable yet minimal increasing trends over the entire monitoring period, while Area H has shown stable yet declining prevalence over the same period (Figure 15). Area B, which was only minimally harvested in 2015, has been steadily increasing in prevalence of *P. perfoliatus* since 2016 (Figure 15). Areas G and F in Lake Micmac demonstrated prevalence trends with increases in 2016-2017 followed by declines in 2018 (Figure 15).

Based on the declining prevalence of bare area substrate, *P. foliosus* and/or *P. perfoliatus*, combined with increased prevalence of *E. canadensis*, we hypothesize a generalized ecological succession is occurring whereby *E. canadensis* is displacing the *Potamogeton* species. This is particularly evident in Area H and may provide evidence that the observed plant proliferation in the Paddler's Cove region is due to *E. canadensis* exploiting an available resource niche previously utilized by *Potamogeton* spp. The taller *Potamogeton* species would have established a taller canopy which would have competitively excluded light and space from *E. canadensis.* As video data collection outside of target harvest areas was outside of the scope of this project, we can only speculate at this point that the large area of high density plants in the Paddler's Cove region (Figure 3) are *E. canadensis;* however, the shorter observed canopy heights during the 2018 acoustic surveys suggests these plants are likely *E. canadensis*, which is the shortest of the three key plant species[3].

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[3] It is important to note that while plant prevalence data are related to percent cover data, the two datasets are not entirely comparable as prevalence is calculated from underwater video data which are collected from only few transects in each area in comparison to the tens of thousands of sonar data points used to assess cover. As, any direct comparison between these data types must be done cautiously.

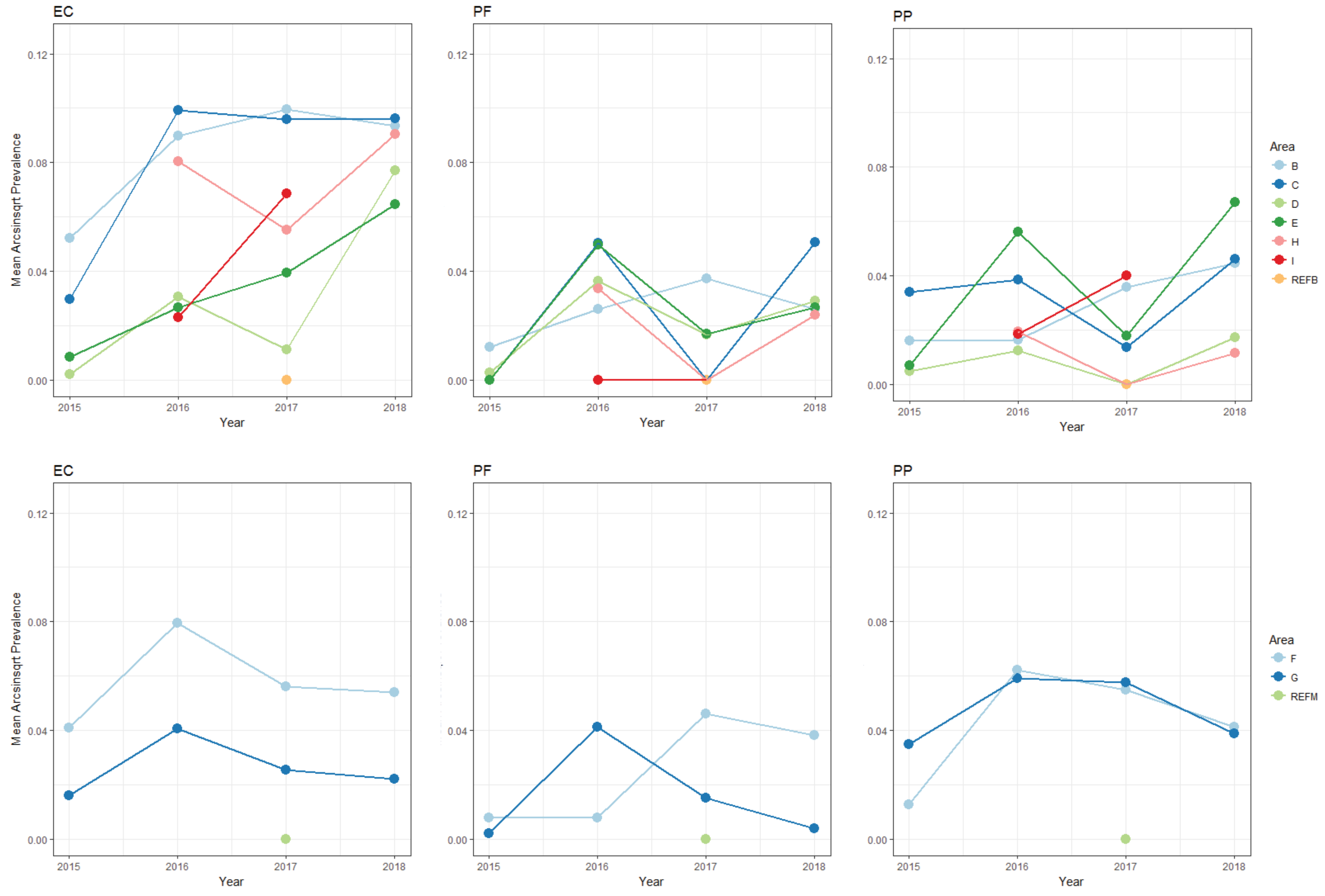

Figure 15 **Temporal Trends (2015-2018) of Mean Plant Prevalence (Arcsine square root transformed) by Area**

Note: Top row = Banook; bottom row = Micmac. Linear smoother applied to data. Arcsinsqrt = arcsine square root transformation. EC = *E. canadensis*, PP = *P. perfoliatus*, PF = *P. foliosus*. Video was only collected at REFB and REFM in 2017.

Overall, these *E. canadensis* trends are likely a function of multiple factors. First, from an operational point of view, *E. canadensis* was not actively targeted for harvesting as the taller *Potamogeton* species were prioritized due to stakeholder concerns around these taller species which had a higher likelihood for impairing swimming/paddling activity. Additionally, *E. canadensis* reproduces vegetatively and has a woody stem which can more readily break into small propagules that could escape the harvesting suction apparatus; therefore, it was deemed to have too high of a risk for inadvertent dispersion by targeted harvesting practices[4]. As such, this plant was left to persist while the *Potamogeton* species were exposed to substantial harvesting pressure. Secondly, where *E. canadensis* co-occurred with harvesting activity, the shorter canopy of *E. canadensis* was generally out of reach of the mechanical harvester except in the shallowest of areas. In contrast, *P. perfoliatus* is a tall plant which is very effectively targeted by the mechanical harvester and showed declining prevalence in areas that have been subjected to the most intensive harvesting activity, particularly Areas D and H. *P. foliosus* prevalence was comparable, including Areas G, H, and E.

The maximum functional operating depth of the mechanical harvester (1.7 m from the water surface) is another relevant factor in the distribution and persistence of SAV in Lake Banook and Lake Micmac. Detailed bathymetric mapping of each lake was collected in 2015 (Stantec 2015). The water depth in Lake Banook ranges from 0 m to 11.6 m. The deepest section of the lake is in the middle of the lake where there is a steep drop-off to a deep basin from relatively shallow depths. The shoreline of the lake is relatively shallow with average depths ranging from 0 m to 3 m with a gradual drop-off to deeper water. The northeast section of the lake has relatively low water depths with a shallow inlet (1 to 2 m), connecting Lake Banook to Lake Micmac, as well as other shallow bays. The southwest portion of the lake is relatively deep with an average depth of 5 m to 8 m, with water depths rapidly increasing closer to shore as compared to the northern section of the lake. The water depth in Lake Micmac ranges from 0 m to 7.5 m with the deepest sections of the lake being found in the central portion of the lake, north of Bull Island Rock and Owl’s Nest Island. The shallowest sections of the lake are found in the north and southwest sections with water depths ranging from 0 m to 2 m. The shoreline of Lake Micmac is fairly shallow with a gradual drop-off in the majority of the lake with exceptions being found on the east side of the lake near Braemar Drive and the northeast and northwest sections, where steep drop-offs from 0 m to 5 m can be found. These data indicate there is very limited areas within these lakes where effective SAV harvesting can be conducted. For ecological purposes, regions of each lake where ≥ 50% of the vegetation canopy was harvestable were given highest priority for harvesting. Contrasting 2018 post-harvest SAV cover data with the areas of each lake where effective harvesting could be conducted (Figure 16), it is readily evident that vast swathes of each lake are not available for ecologically effective harvesting to potentially control SAV distributions. It is critical to highlight the difference between ecologically effective harvesting and operationally effective harvesting. The former is intended to reduce the distribution and biomass of SAV over time while the latter is meant to provide SAV control to maintain stakeholder access to swimming, paddling, or other recreational activities.

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[4] Where *E. canadensis* occurs in multi-species stands, the harvester is unable to avoid incidental cutting/suction of this species. No evidence exists that inadvertent dispersion occurred due to harvesting. For example, Area G contains ample *E. canadensis* and was subject to substantial harvesting pressure with no proliferation of this species in or adjacent to Area G.

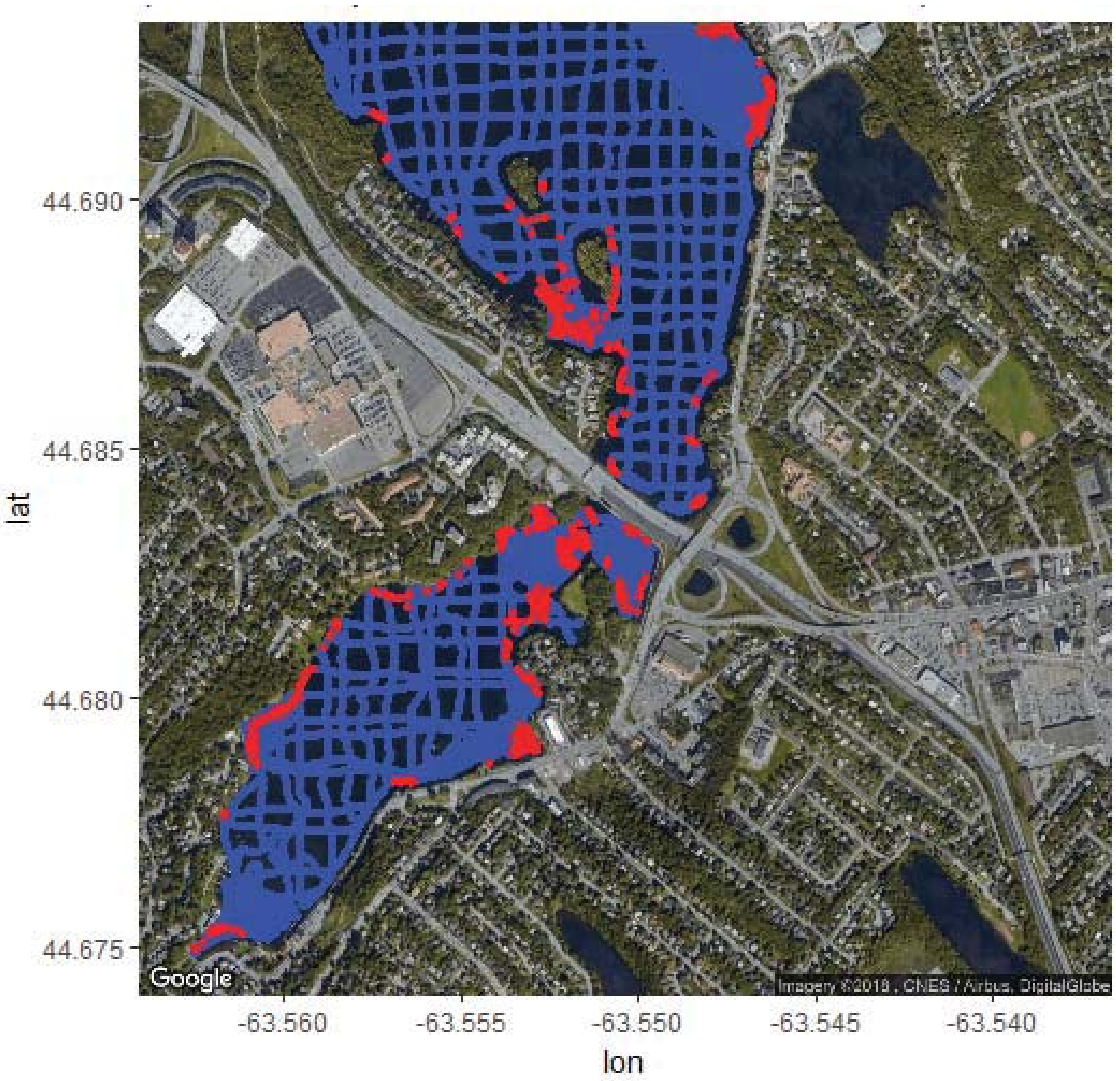

Figure 16 Areas of Ecological Effective SAV Harvest Remaining Post-Harvest 2018

Note: Blue = available data. Red = locations of ecologically effective harvest potential

Concerning SAV proliferation in general, nutrients, especially phosphorus and nitrogen, are necessary for the growth and development of aquatic vegetation. Rooted aquatic vegetation absorb nutrients from the sediment, with nutrient sources varying from decaying organic matter, runoff from riparian properties, and waste materials from animals living within the lake. When organic matter is deposited in sediments it undergoes decay. This decay releases inorganic nutrients into the pore waters, which typically result in elevated concentrations and an outward flux into the overlying waters (Woulds et al. 2009). However, the opposite can occur, with a reverse benthic flux (nutrients into the sediment), making them available for uptake via rooted vegetation. As a follow-up to a recommendation made during the 2016 monitoring program (Stantec 2016a), an investigation into nutrients found in the sediment in both targeted harvest areas as well as reference areas was conducted to determine whether concentrations are greater in these areas of continued SAV growth and available for nutrient uptake by the root system. High variability in nutrient concentrations in Areas D and H indicated elevated pore-water nutrients do exist; however, the extent to which this may be influencing SAV growth could not be conclusively determined based on the data collected (Stantec 2017b). As such, the potential influence of non-point source nutrient dynamics in the Lake Banook-Lake Micmac system is currently being investigated with results yet to be reported that may shed some light (Stantec 2019.

4.0 CONCLUSIONS

4.1 SUMMARY

In 2015, the Halifax Regional Council directed staff to implement the short-term (2015-2018) control of weed management on Lake Banook and Lake Micmac through contracted mechanical weed harvesting services. Stantec was subsequently retained by HRM with the primary goals to direct and document the extent and effectiveness of these weed harvesting activities.

Stantec's secondary objectives were to:

- document the change in distribution and abundance (i.e. percent cover) of aquatic weeds after each harvesting event, and after each harvesting season;
- identify all major aquatic weeds observed during each harvesting season; and
- identify and describe any conditions that may require the municipality to reassess project assumptions and associated harvesting and monitoring strategies.

Key criteria selected by Stantec to assess the success of mechanical harvesting for the short-term control of weed management in each lake primarily included percent cover and plant height, with secondary considerations given to total surface area coverage by weeds and the distribution of the three previously-noted SAV species.

Overall, the assessment of the mechanical weed harvesting performance indicated that the harvesting resulted in achieving HRM's goal of reduced SAV coverage and height in targeted areas, up to and including the 2017 assessment[5]. The ubiquitous reversal of these declining trends which resulted in SAV percent cover returning to or even exceeding pre-project levels in Lake Banook in 2018 was unexpected. The fact this SAV response was comparable yet muted in Lake Micmac was also not anticipated. Given these responses occurred throughout both systems would suggest broad-scale causal mechanism(s) with the leading hypothesis related to nutrient dynamics and/or warming water temperatures. A separate Stantec-led project is ongoing to assess and model nutrient loadings to each lake.

As HRM moves towards its goal of long-term management of SAV in these lakes, it is important to highlight that 2018 results have shown there are certain aspects of the mechanical harvester and the

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[5] The number of complaints regarding nuisance weeds dropped notably from 2015 through 2018. Further, the boating community, as represented by the ADCKC, found that harvesting activities successfully cleared floating weeds from areas used for boating and enabled safe ongoing recreational and competitive boating activities throughout the summers of all years, with rare and minor exceptions.

regulatory conditions it must operate under which combine to reduce its ecological effectiveness in SAV management. First, in order to avoid serious harm to fish under the *Fisheries Act* and based on guidance from Fisheries and Oceans Canada/Nova Scotia Environment, the harvester (a) cannot make contact with the lake bottom (fish habitat), and (b) must operate between early-mid July and early-mid August to reduce the risk of harm to fish and fish habitat in Nova Scotia, specifically spawning smallmouth bass. These conditions respectively serve to limit the effective amount of plant canopy which can be harvested (incomplete removal) as well as delay operations well into the SAV growing season, allowing the plants to recover from the previous year's harvesting efforts. Second, the mechanical harvester is depth-limited from being able to operate in a majority of the areas where SAV persists.

It is important to note trends in harvester effectiveness may have been masked in zones with stable or highly variable SAV due to the seasonal growth patterns of these plants between early July and late August. For example, SAV coverage may have increased even further had harvesting not occurred. Additionally, the mechanical harvester appeared to have high ecological effectiveness, prior to 2018. Therefore, it may be premature to draw conclusions on the longer-term influence of the mechanical harvester based on one adverse sampling event among many. Finally, the mechanical harvesting appears to have been very successful with regards to operational effectiveness as HRM was able to maintain stakeholder access to swimming, paddling, or other recreational activities as it related to SAV in these lakes. Any future SAV control scenarios may likely require operational harvesting, particularly for canoe and kayak lane maintenance.

4.2 RECOMMENDATIONS

Based on our most recent findings, we provide HRM with the following recommendations as the project transitions from short-term to long-term SAV control:

1. Findings indicated elevated pore-water nutrients do exist; however, the extent to which this may be influencing SAV growth cannot be assessed with the current data available. HRM should consider future pore-water sampling in concert with deployed dissolved oxygen probes at the deepest portions of each lake.

2. In the current absence of a long-term SAV strategy, HRM should extend mechanical harvesting and associated monitoring for a single year in 2019 to: a) attempt to confirm whether adverse 2018 results of increasing SAV in spite of harvesting efforts are repeatable; and, b) simultaneously develop a technically and economically feasible long-term control and monitoring strategy.

3. Related to the above, 2019 could allow exploration of commercial shading devices as well as reconsideration of other options as presented by Stantec (2014). For example, Stantec (2014) considered multiple options, including floating shade screens; however, other information sources have indicated bottom barrier shading (material affixed to the substrate) may be effective for SAV control in lake ecosystems without impairing stakeholder activities on the water's surface.

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APPENDIX A

JUNE 2018 SAV PERCENT COVER MAPPING

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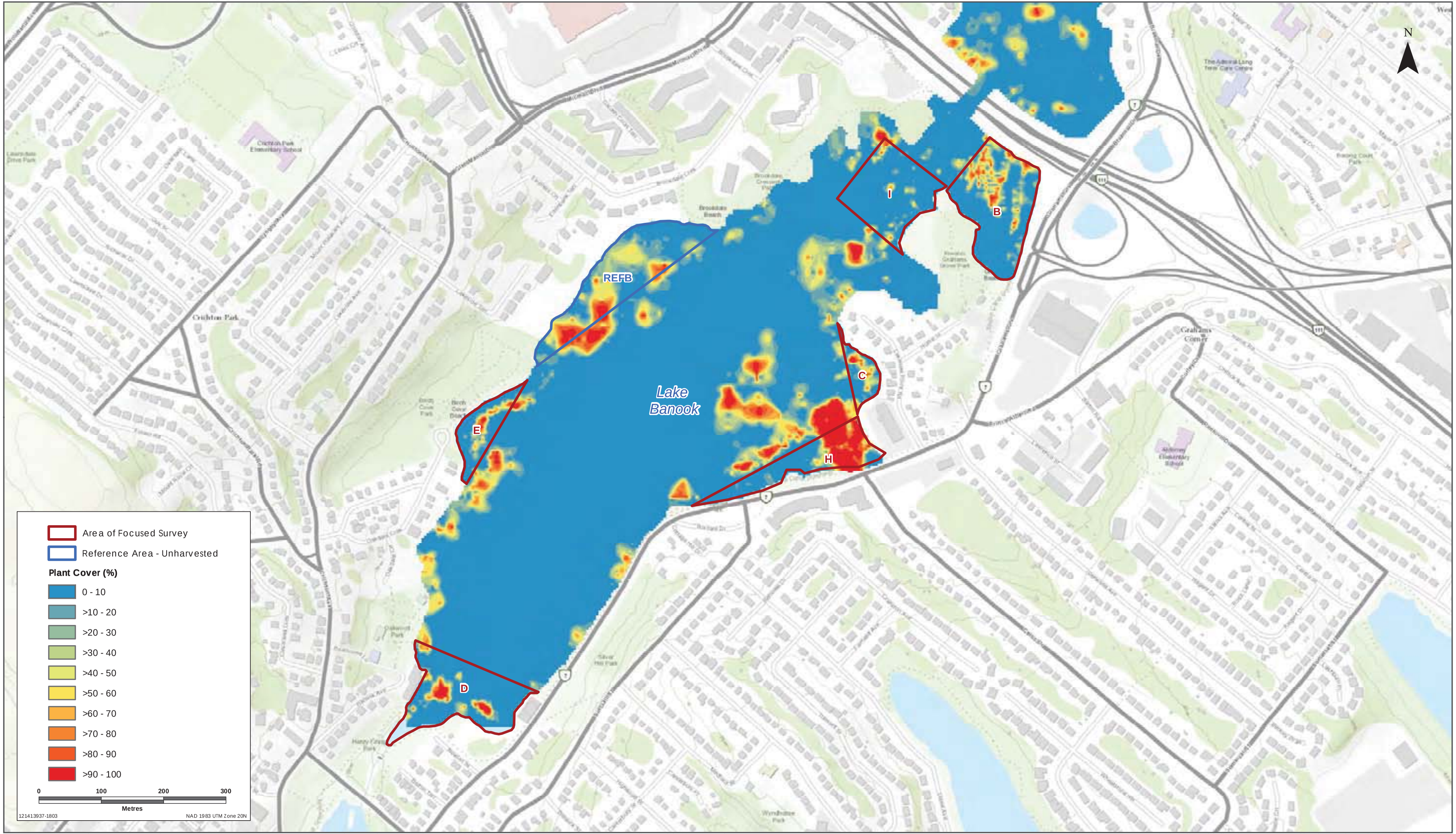

Sources: Base Data - Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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HRM - Pond Weed Monitoring Program

Submerged Aquatic Vegetation Coverage of Lake Banook, June, 2018 – Interpolated

Figure A-1

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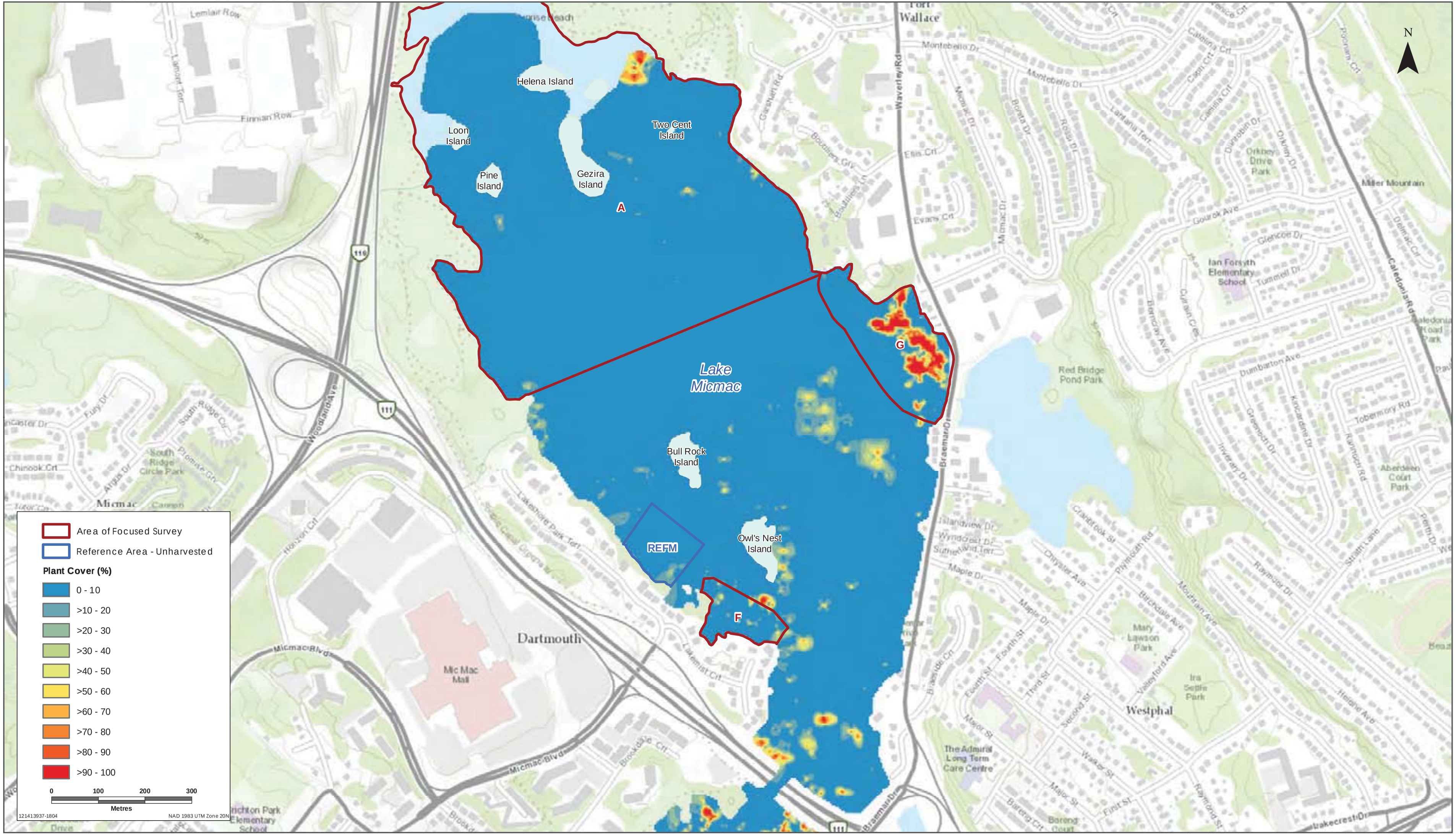

Sources: Base Data - Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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HRM - Pond Weed Monitoring Program

Submerged Aquatic Vegetation Coverage of Lake Micmac, June, 2018 – Interpolated

Figure A-2

APPENDIX B

QUANITIFICATION OF SAV – SUMMARY STATISTICS

Appendix B Summary Statistics for SAV Percent Cover (2014-2018)

Area	Year[1]	N	Min	Max	Median	IQR[2]	Mean	SD[2]
A	2015	207	0.67	83.75	12.86	15.62	17.99	15.71
	2016B	188	0.45	74.29	2.50	4.03	7.11	11.06
	2016A	91	0.22	100.00	4.33	11.84	11.51	17.81
	2017B	264	0.00	42.22	0.00	1.38	1.48	4.25
	2017A	273	0.00	32.50	0.00	4.00	3.16	5.71
	2018A	381	0.00	17.69	0.00	0.00	0.49	2.03
	2018B	329	0.00	60.00	0.00	4.00	3.97	9.11
B	2014	24	38.57	85.00	65.83	14.19	65.61	12.27
	2015	27	8.48	75.52	52.63	18.15	47.84	14.87
	2016B	25	0.26	65.44	21.49	37.97	27.38	22.14
	2016A	24	0.14	56.87	4.88	16.57	12.21	15.95
	2017B	26	0.00	92.20	31.83	43.49	36.37	24.68
	2017A	26	4.25	81.10	38.50	33.37	40.84	23.77
	2018A	27	0.00	53.48	12.82	25.37	17.13	16.95
	2018B	27	6.67	95.88	74.35	29.78	65.55	24.70
C	2014	10	10.00	87.50	63.33	23.61	59.94	22.13
	2015	11	13.33	72.00	48.07	25.16	45.77	17.85
	2016A	9	5.12	95.76	50.67	45.80	49.30	31.20
	2016B	9	6.79	89.17	60.22	44.04	57.45	28.20
	2017B	9	0.00	21.67	1.33	5.80	4.66	6.95
	2017A	9	2.31	76.04	11.89	23.52	22.22	22.87
	2018A	11	0.00	40.22	20.38	22.94	20.45	13.06
	2018B	9	32.08	90.20	70.00	33.55	63.99	19.72
D	2014	22	2.50	65.00	9.44	28.29	18.78	18.10
	2015	28	0.91	58.00	8.34	15.52	14.13	15.74
	2016A	23	0.27	89.23	9.87	34.62	22.61	24.33
	2016B	20	0.71	25.00	7.74	10.22	8.47	7.15
	2017B	24	0.00	18.10	0.70	2.36	2.31	4.07
	2017A	27	0.00	43.08	7.11	25.80	13.11	14.72
	2018A	30	0.00	65.52	5.40	21.22	13.84	17.85
	2018B	24	0.00	87.50	32.30	34.06	37.74	24.43
E	2014	13	1.05	69.47	24.29	39.97	29.90	22.71

Area	Year[1]	N	Min	Max	Median	IQR[2]	Mean	SD[2]
	2015	13	1.43	58.36	23.85	24.07	23.97	17.89
	2016A	13	0.97	44.29	18.89	27.95	18.73	15.11
	2016B	10	1.56	17.55	6.21	6.44	7.90	4.98
	2017B	14	0.00	32.97	6.70	15.89	10.37	10.60
	2017A	14	0.00	46.34	18.37	24.95	20.55	14.42
	2018A	15	0.00	51.66	13.97	20.18	14.76	15.36
	2018B	15	0.00	62.77	17.95	30.32	23.64	20.29
F	2015	24	20.40	78.33	38.27	16.83	41.46	14.11
	2016A	22	0.50	73.46	21.86	20.78	26.80	20.36
	2016B	25	2.29	68.00	19.83	29.37	23.04	18.43
	2017B	23	1.11	30.48	5.17	6.52	7.69	7.47
	2017A	24	0.77	52.39	21.69	19.81	23.41	12.98
	2018A	24	0.74	29.11	6.10	4.31	7.65	7.51
	2018B	24	0.00	70.71	14.88	29.03	21.93	20.26
G	2015	62	0.32	71.54	34.81	38.49	36.46	21.40
	2016A	58	0.17	94.77	13.85	51.75	27.98	31.74
	2016B	65	0.32	100.00	17.05	52.13	28.57	29.07
	2017B	66	0.00	100.00	6.61	36.35	23.45	29.98
	2017A	69	0.00	91.18	14.11	54.10	29.43	30.46
	2018A	74	0.00	90.00	1.58	23.13	16.95	25.77
	2018B	68	0.00	100.00	8.69	36.59	24.38	30.73
H	2016B	29	0.37	97.00	54.80	60.32	54.15	32.91
	2017B	22	0.00	45.53	1.01	3.33	5.38	11.33
	2017A	24	4.19	85.65	29.91	39.65	34.43	25.38
	2014	29	17.12	89.26	59.26	24.28	59.47	16.72
	2015	30	4.80	66.92	47.01	44.63	39.58	22.66
	2018A	24	0.00	99.19	33.91	82.60	42.63	40.02
	2018B	25	18.04	100.00	87.60	42.21	75.35	27.29
I	2016B	31	0.00	50.59	3.59	5.81	7.50	11.59
	2017B	28	0.00	24.62	3.05	3.29	4.47	6.45
	2017A	28	1.43	47.78	17.09	20.96	20.37	12.89
	2014	29	0.45	66.05	28.32	19.48	28.71	14.84
	2015	29	0.48	50.28	15.37	23.81	20.88	15.29
	2018A	30	0.00	56.00	4.63	10.61	7.79	11.28

Area	Year[1]	N	Min	Max	Median	IQR[2]	Mean	SD[2]
	2018B	30	0.00	80.00	23.93	41.07	29.24	24.35
REFB	2017B	30	0.00	62.73	13.61	26.33	19.70	20.57
	2017A	32	2.00	68.33	30.45	30.54	33.28	20.80
	2014	40	3.84	65.58	36.99	21.23	36.97	15.72
	2015	40	0.93	62.09	16.13	14.35	20.47	15.51
	2016A	34	0.04	86.95	9.14	17.84	15.62	19.56
	2016B	37	0.38	80.60	11.64	18.47	18.19	19.45
	2018A	33	0.00	92.86	13.53	39.17	25.07	28.41
	2018B	28	5.56	100.00	64.20	55.88	61.32	29.47
REFM	2017B	23	0.00	37.50	5.00	10.73	8.99	9.62
	2017A	23	0.00	43.08	21.67	20.99	19.39	12.97
	2015	32	11.83	59.69	29.52	24.46	32.05	14.47
	2016A	33	1.58	55.30	23.34	35.27	24.50	18.62
	2016B	32	2.35	80.20	15.71	25.50	21.88	19.29
	2018A	21	0.00	14.72	0.67	2.24	1.85	3.34
	2018B	20	0.00	87.50	8.95	16.78	16.37	22.06

[1] A = pre-harvest; B = post-harvest

[2] IQR = interquartile range; SD = standard deviation

APPENDIX C

HEAT MAPS OF SAV PERCENT COVER CHANGE

2018 HEAT MAPPING

Comparing Lake Banook post-harvest SAV percent between 2018 and 2016 shows areas of large increases in extent and percent cover throughout the system. In particular, large increases were noted in target harvest Areas B, C, and D, as well as REFB and large areas offshore of Area H (Figure C-1). Other increases were also generalized throughout the nearshore area of the lake. Areas of declining SAV were notes in Area H, the south of Area C, and general areas offshore of Water Lots 3-6 (Figure C-1). Area E also indicated a narrow band of SAV increase just offshore of the public beach in that area (Figure C-1). Lake Micmac, in contrast contained few areas of large SAV increase, and these were confined to the nearshore region of Area G as well as the southernmost area of the lake near the outlet to Lake Banook (Figure C-1). Large areas of SAV decline were observed in Area G as well as REFM, the latter of which was not subjected to mechanical harvesting (Figure C-1).

Lake Banook post-harvest SAV percent comparison between 2018 and 2015 (Figure C-2) followed very close to trends noted between 2018 and 2016 (Figure C-1) with increases in extent and percent cover throughout the system. Lake Micmac over the same period between 2018 and 2015 displayed large areas of SAV decline in each of Areas F and G (Figure C-2). There were also large SAV declines relative to 2015 data in the center of Lake Micmac where there had previously been a dense SAV patch that extended along a southeast to northwest axis which corresponds to a shallow plateau (Figure C-2).

2017 HEAT MAPPING

When comparing SAV percent cover post-harvest between 2017 and 2016 in Lake Banook (Figure C-3), there were substantial decreases in vegetation coverage in Areas C and H, as well as adjacent to Paddler’s Cove. Slight increases in SAV were observed in the nearshore of Area E, the nearshore and deeper sections of the southern portion of the lake, as well as in the northern portion of the lake near the inlet from Micmac (Figure C-3). Patchy increases and decreases were noted in target harvest Areas B, D, and I, while the unharvested REFB saw discrete area of increased cover in the southern portion of this area. Post-harvest data from 2017-2016 in Lake Micmac showed an overall similar trend to past surveys in which diffuse increases and decreases in SAV coverage can be seen in target harvest areas G and F, throughout the lake, as well as in the reference area, REFM (Figure C-3).

When looking at post-harvest data trends in Lake Banook between 2017 to 2015 (Figure C-4), there was a general decrease in vegetation coverage throughout most of the Target Harvest Areas as well as the majority of the lake. There were some increases in vegetation coverage noted when comparing these two years of data including parts of Area B as well as Reference Area B (REFB). Increases in vegetation were also noted in southern portions of the lake as well as the area west of Area H. When comparing post-harvest data from Lake Micmac from 2017 to 2015, there is an overall trend towards decreasing vegetation coverage throughout a majority of the lake with exceptions to Area G as well as the southern portion of the lake in the vicinity of the outlet to Banook (Figure C-4).

Post-harvest data between 2017 and 2014 from Lake Banook (Figure C-5) show an overall trend of significant decreases in vegetation coverage in all of the Target Harvest Areas as well as in the majority of the nearshore areas of the lake. There are a few discrete areas of increased vegetation coverage, specifically in the southern sections of the lake, around the inlet from Micmac in the north, and the western shore of the lake adjacent to Oakdale Court and Oakdale Crescent (Figure C-5).

2016 HEAT MAPPING

When comparing SAV percent cover post-harvest between 2016 and 2015 in Lake Banook, there was a trend towards decreasing vegetation coverage in most nearshore areas of the lake (Figure C-6). Major decreases in SAV coverage can be seen in the northern-most areas of the lake, particularly in proximity to Graham Grove Park and in Area B (Figure C-6). Similarly, in the nearshore areas along the eastern and western shorelines in the southern end of the lake, SAV coverage decreased greatly. In contrast, vegetation coverage has increased significantly in Paddler's Cove (Area C) as well as in Area H and the waters in their immediate vicinity. Furthermore, there seems to be sporadic increases in SAV coverage from 2015 to 2016 in shallow waters of the western portion of the lake adjacent to Brookdale Crescent (REFB, Figure C-6). From 2015 to post-harvest 2016 in Lake Micmac, there were decreases in SAV coverage throughout most of the lake (Figure C-6). There are three notable increases in SAV coverage, one throughout Area G and sporadic increases south of Bulls Rock Island and Owl's Nest Island (Figure C-6). Additionally, an area of dense SAV observed in 2015 (Stantec 2015c) along a shallow ridge running southeasterly though the middle of Lake Micmac greatly declined in 2016 (Figure C-6).

In Lake Banook, similar trends exist when comparing SAV percent coverage between 2014 and 2016 post-harvest (Figure C-7). There were distinct losses in SAV coverage in the shallow nearshore zones for all areas, except those adjacent to Paddler's Cove (Areas C and H). Of note, there were drastic declines in SAV in Area B, adjacent to Grahams Grove Park (Figure C-7).

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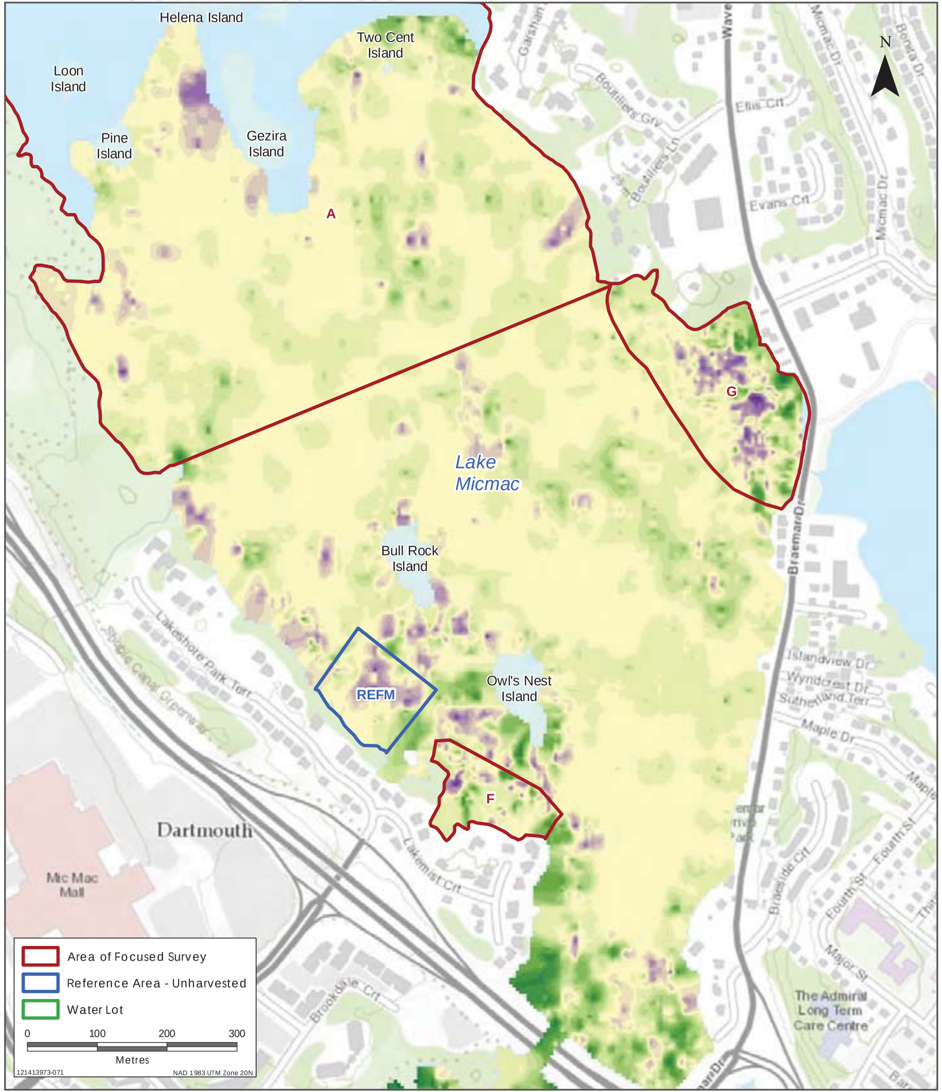

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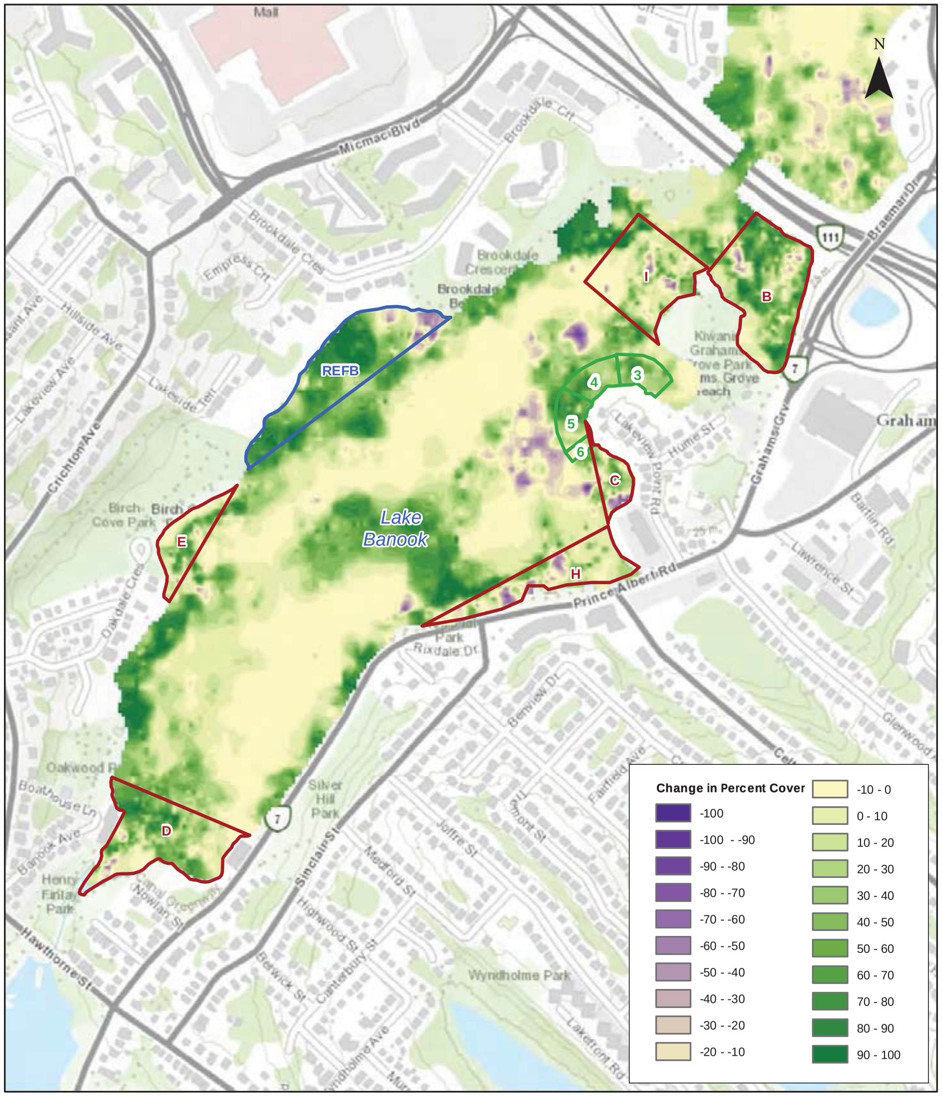

Disclaimer: This map is for illustrative purposes to support this project; questions can be directed to the issuing agency.

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HRM - Pond Weed Monitoring Program

Change in Percent Cover: Post-Harvest 2018 to 2016 - Lake Micmac

Change in Percent Cover: Post-Harvest 2018 to 2016 - Lake Banook

Figure C-1

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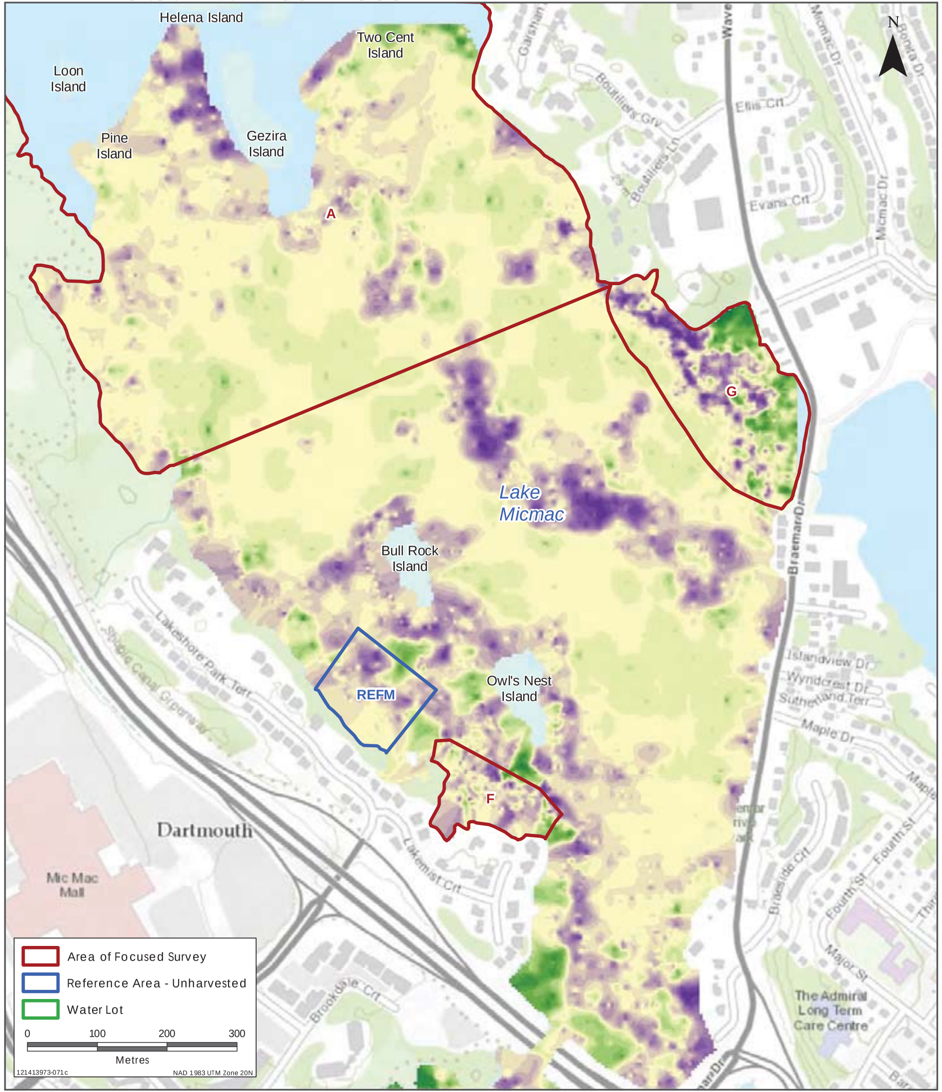

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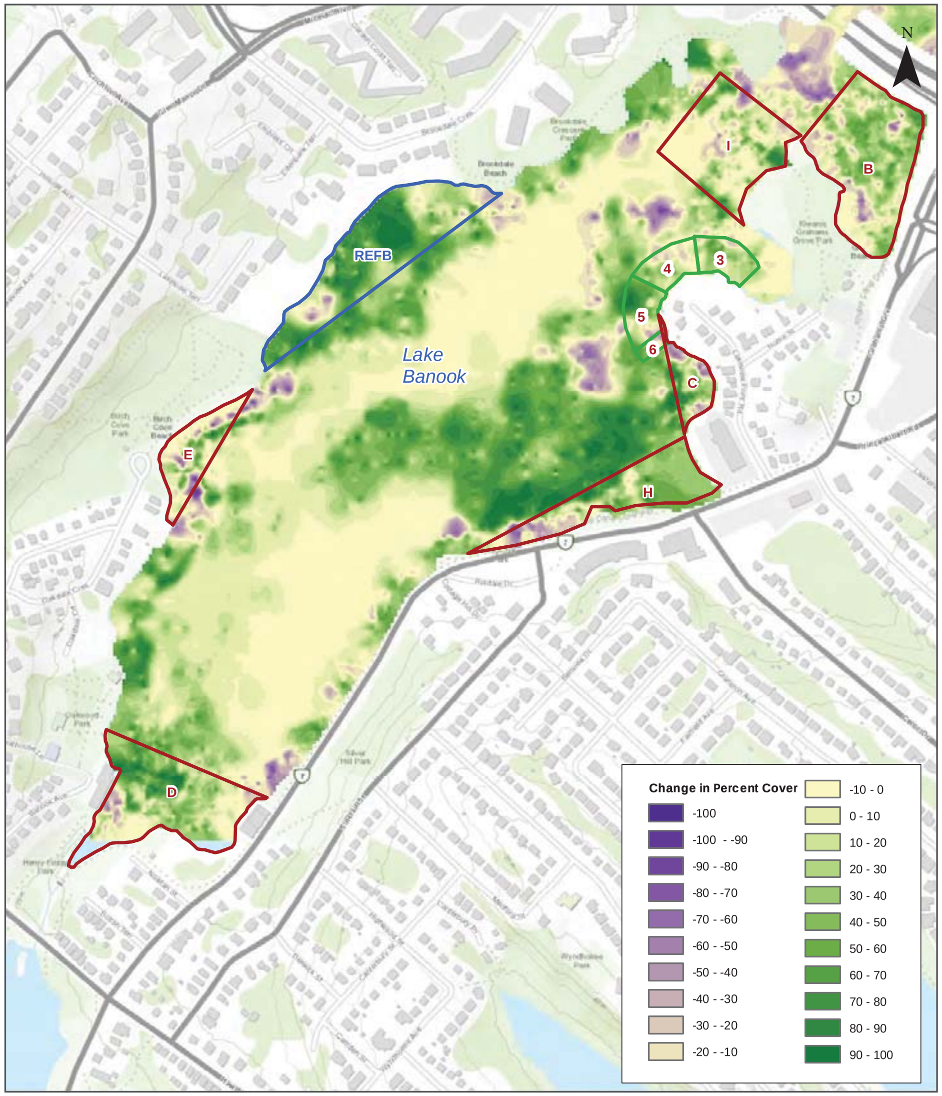

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Change in Percent Cover: Post-Harvest 2018 to 2015 - Lake MicMac

Change in Percent Cover: Post-Harvest 2018 to 2015 - Lake Banook

Figure C-2

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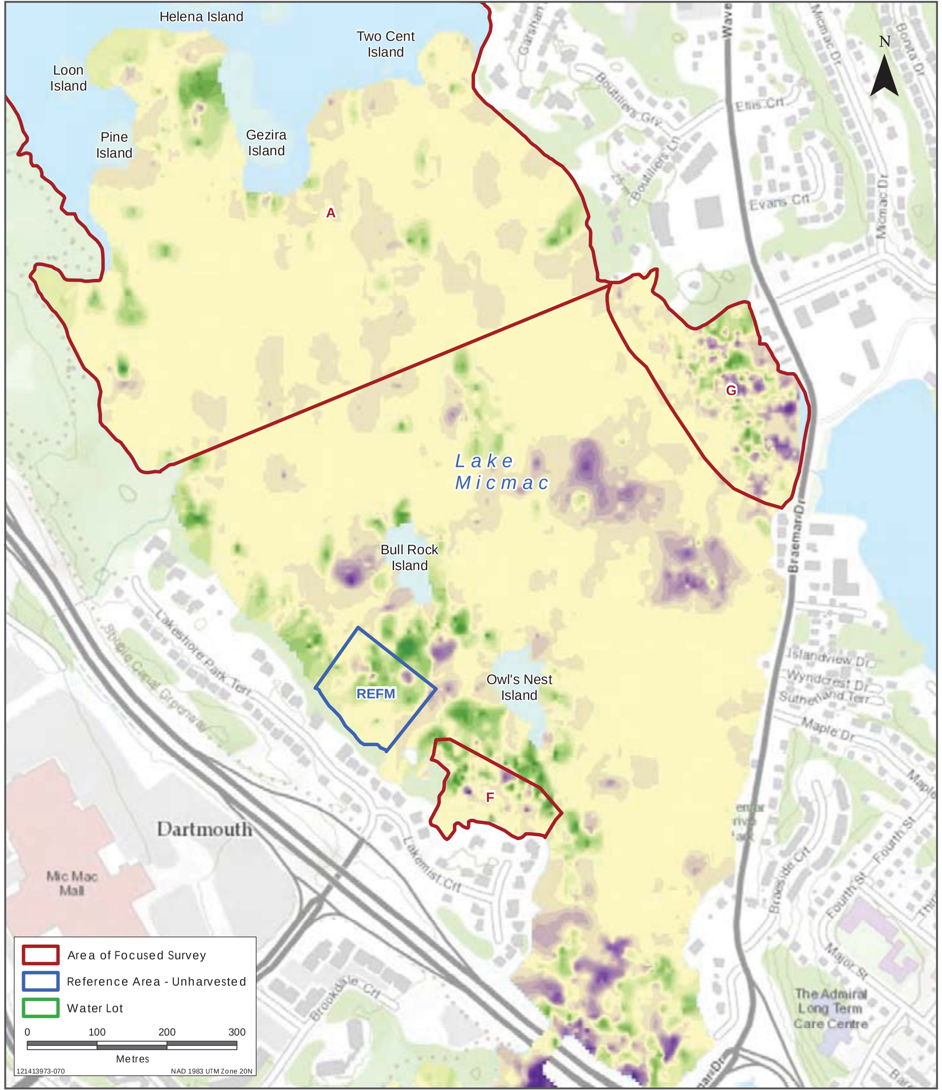

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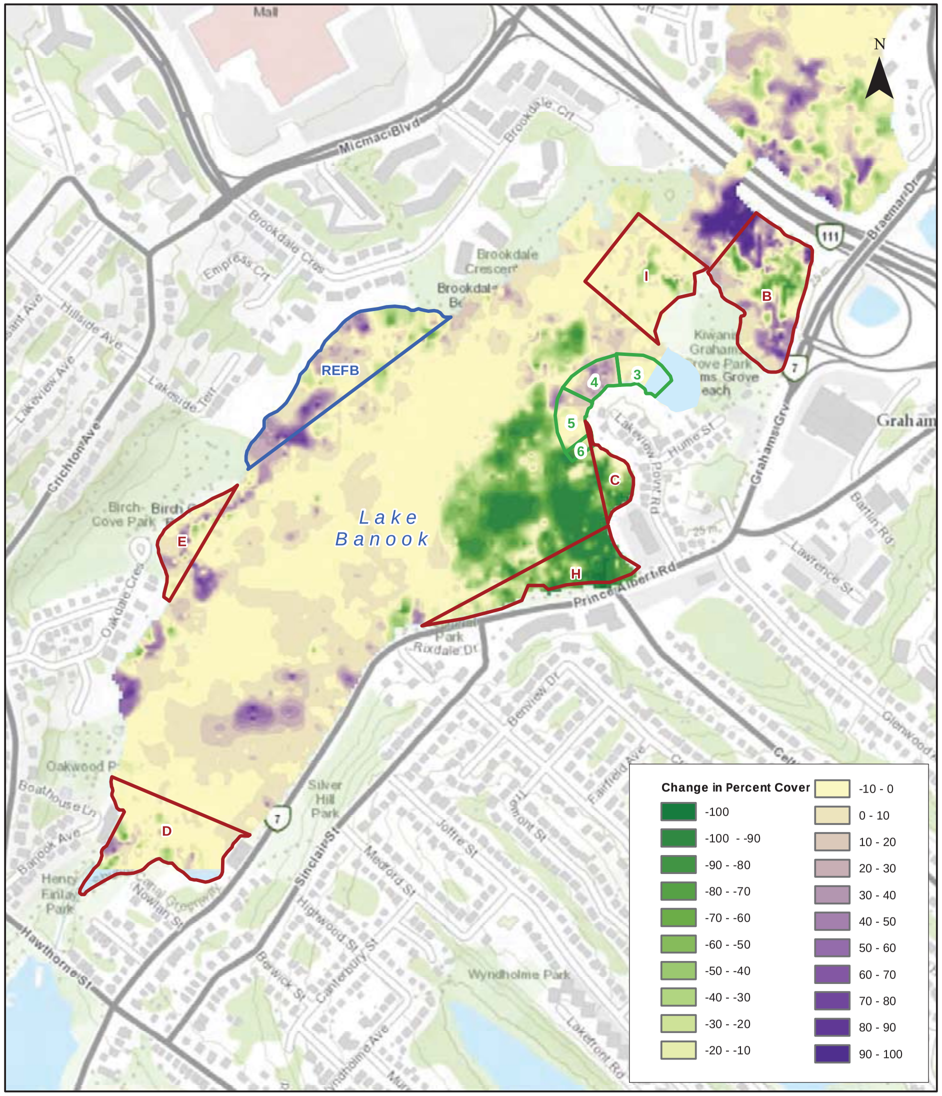
Change in Percent Cover: Post-Harvest 2017 to 2016 - Lake Micmac



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Change in Percent Cover: Post-Harvest 2017 to 2016 - Lake Banook

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Figure C-3

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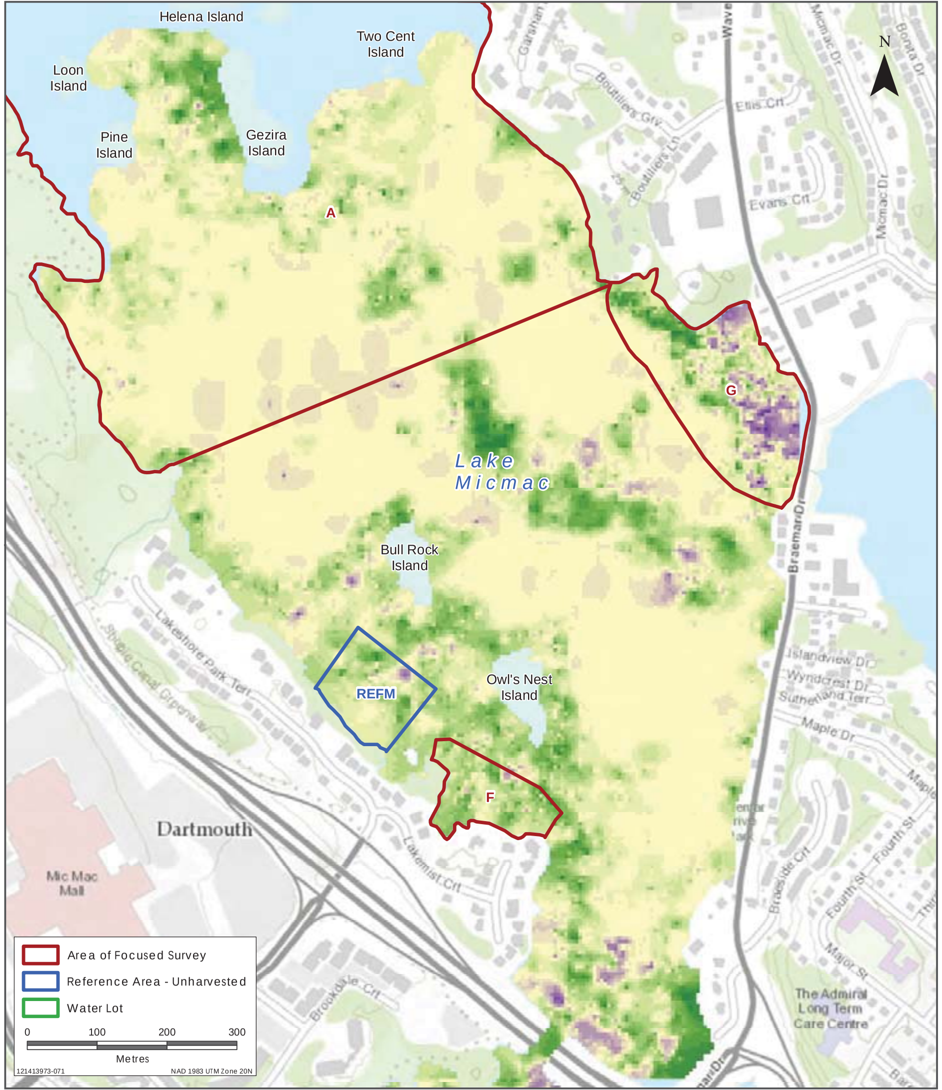

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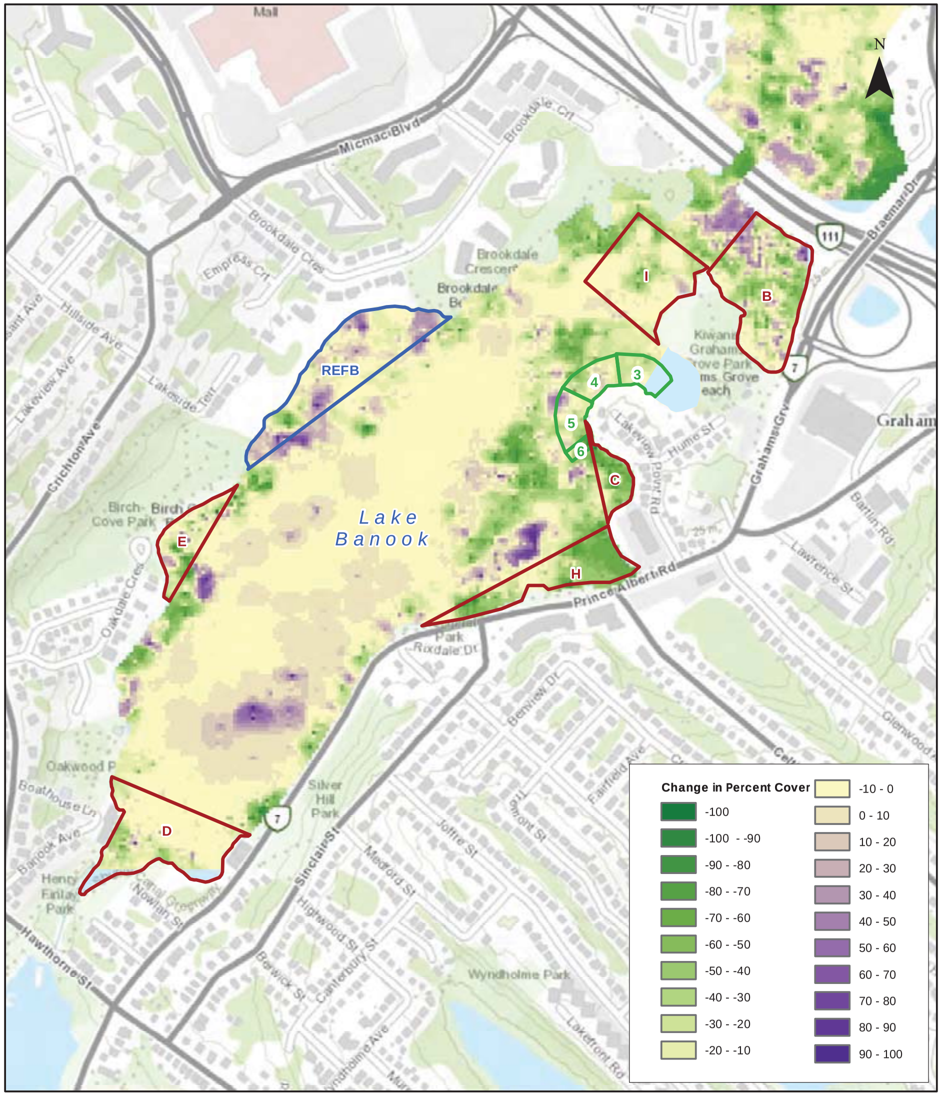
Change in Percent Cover: Post-Harvest 2017 to 2015 - Lake Micmac



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Change in Percent Cover: Post-Harvest 2017 to 2015 - Lake Banook

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Figure C-4

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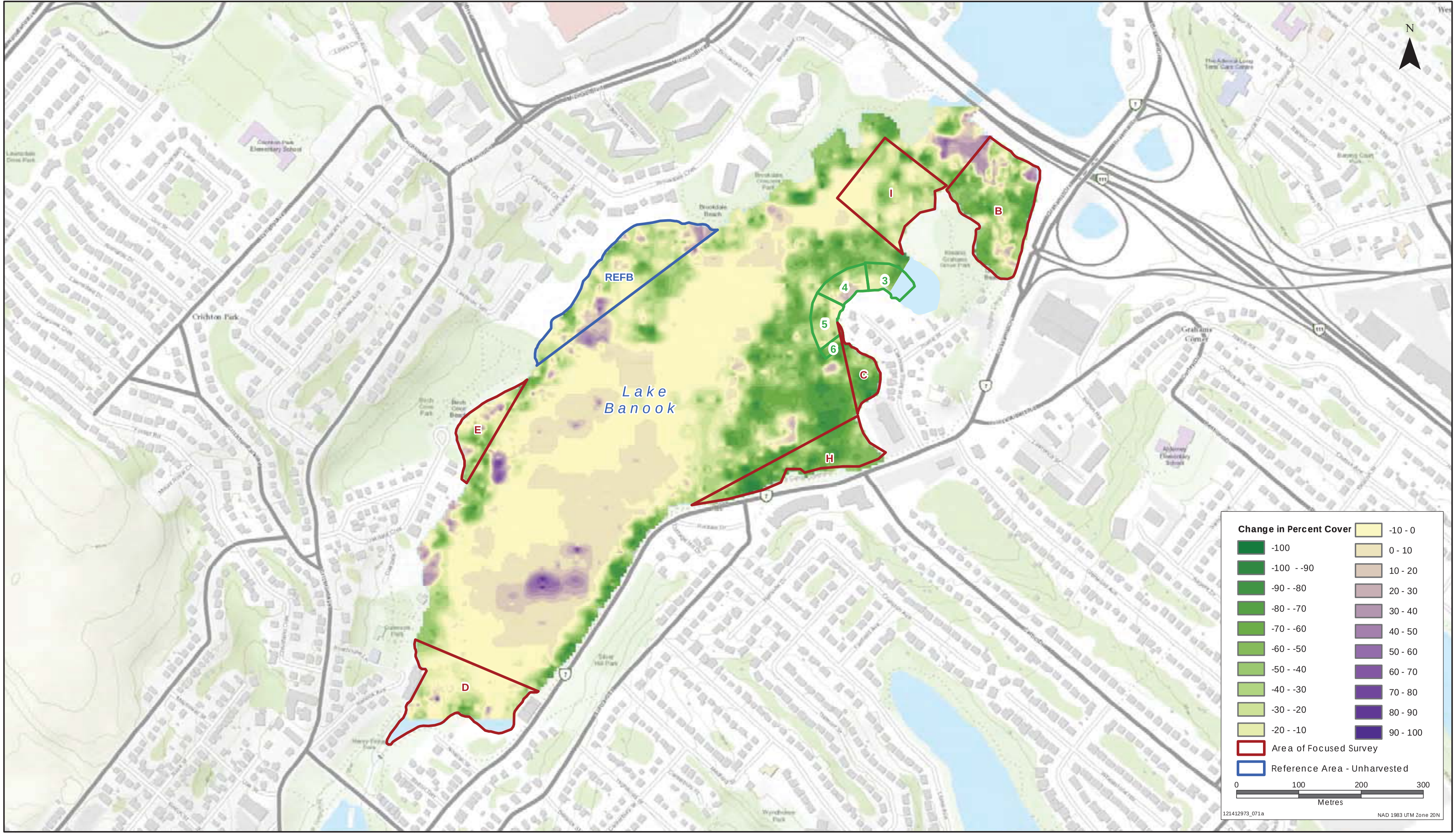

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Change in Percent Cover: 2017 Post-Harvest to 2014 - Lake Banook

Figure C-5

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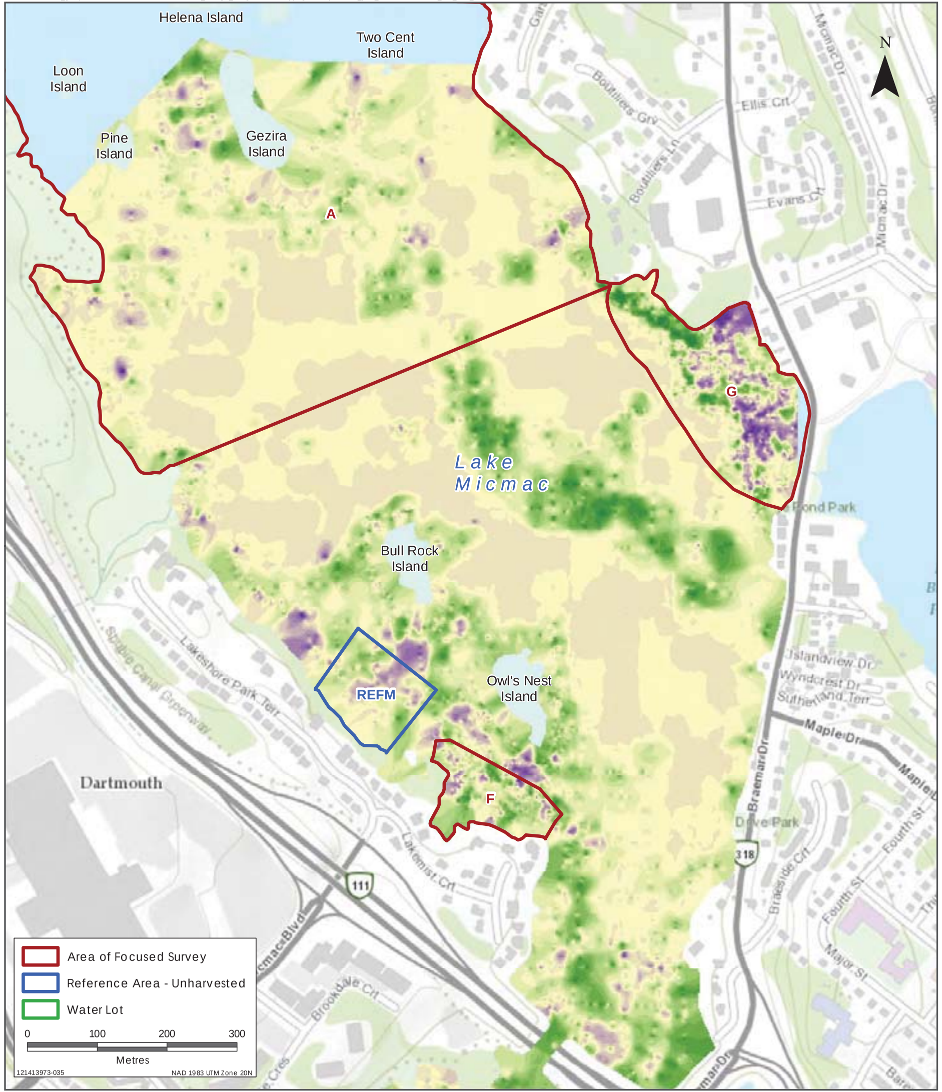

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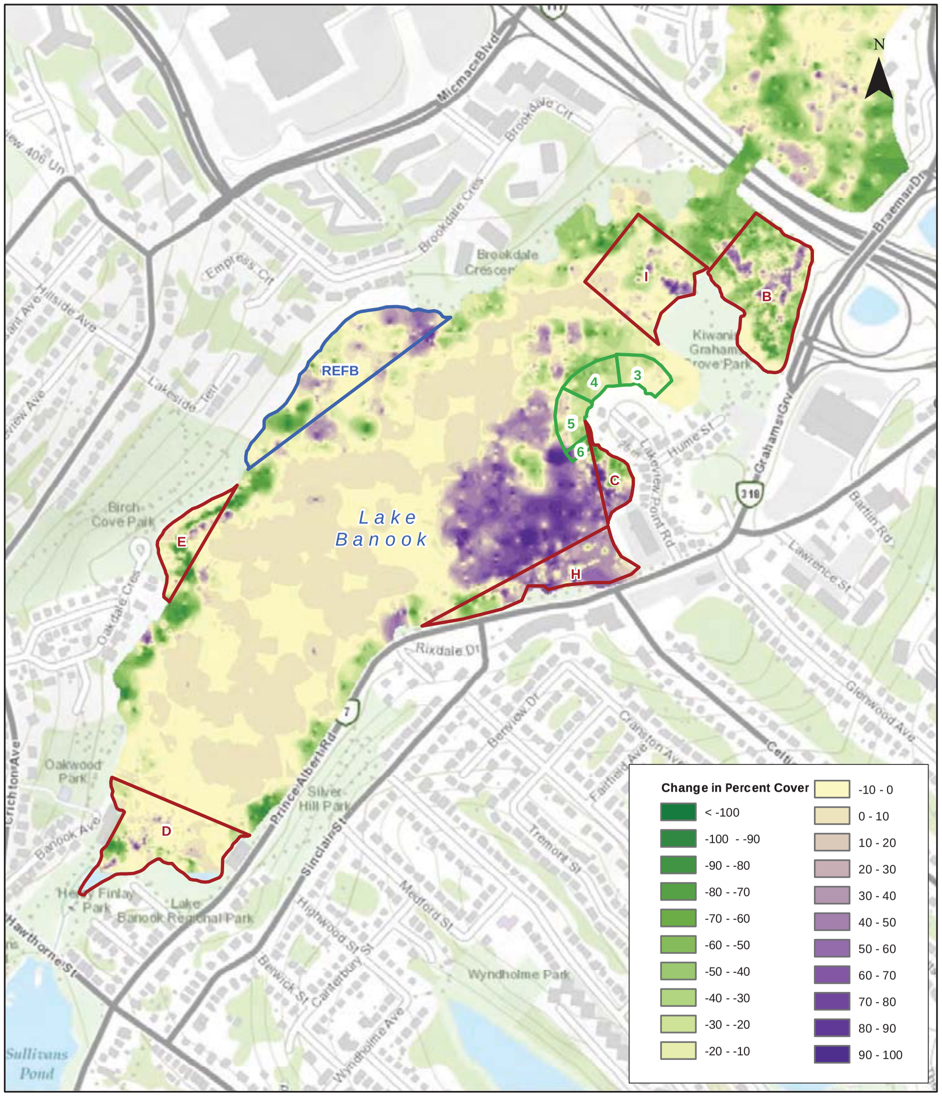
Change in Percent Cover: Post-Harvest 2016 to 2015 - Lake Micmac



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Change in Percent Cover: Post-Harvest 2016 to 2015 - Lake Banook

Figure C-6

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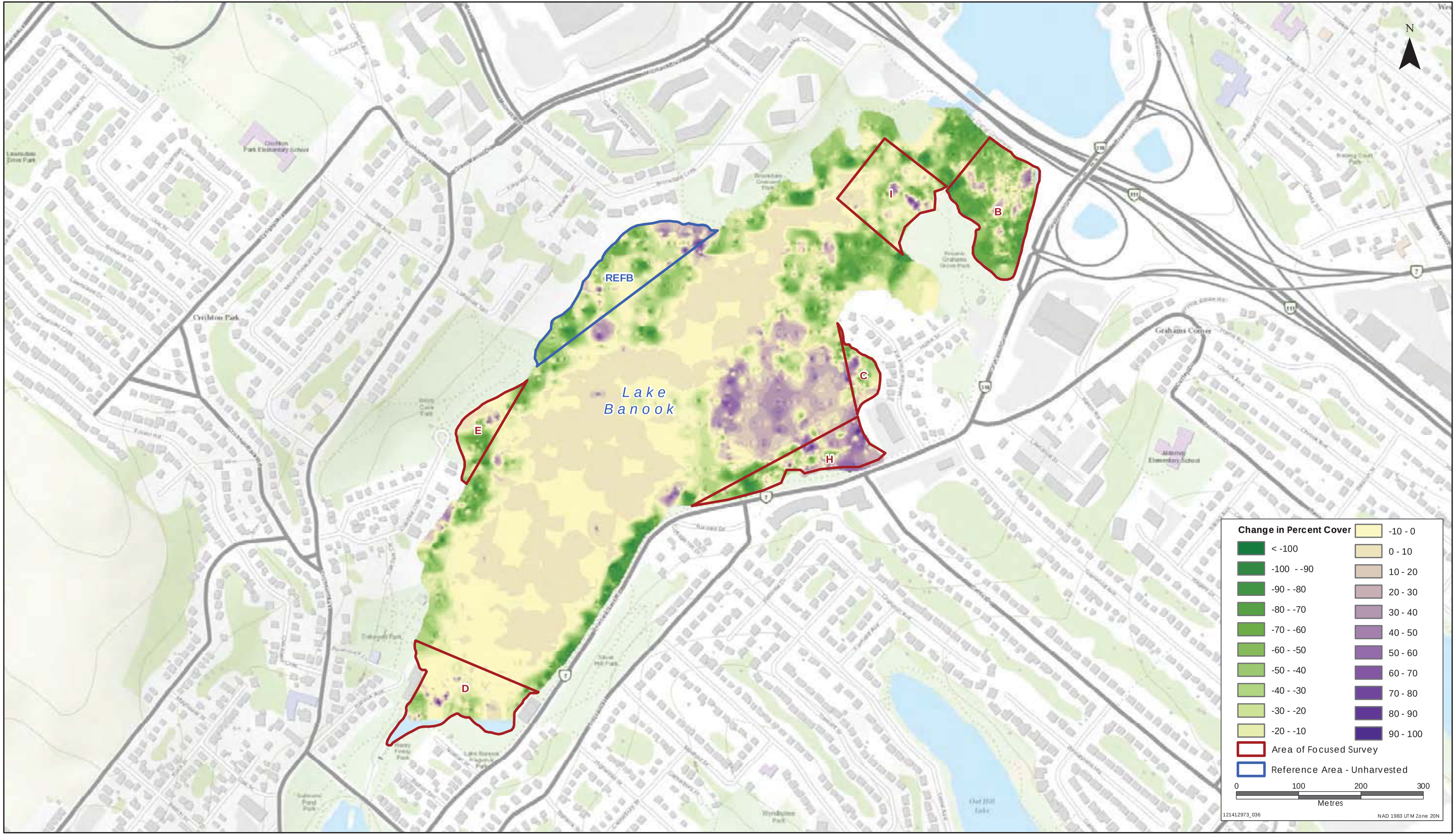

Sources: Base Data - - Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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Change in Percent Cover: 2016 Post-Harvest to 2014 - Lake Banook

Figure C-7

APPENDIX D

JUNE 2018 SAV CANOPY HEIGHT

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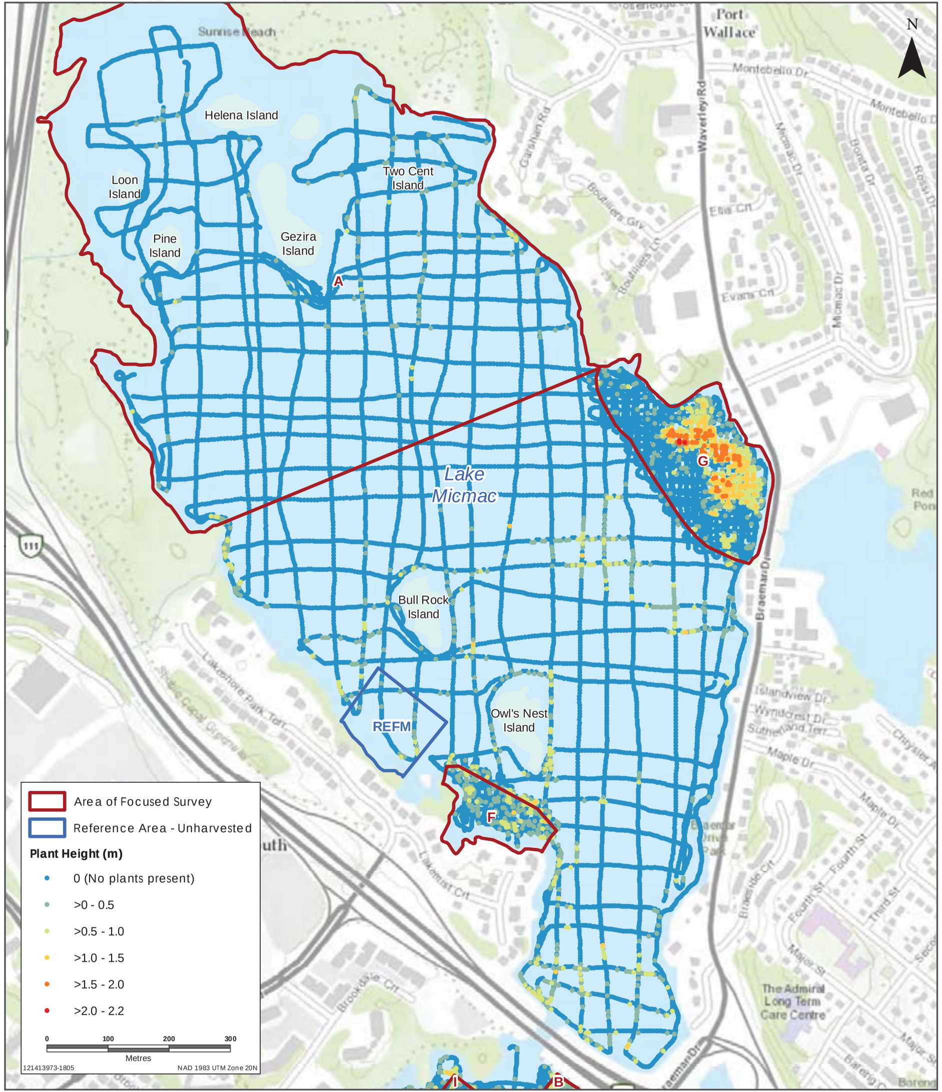

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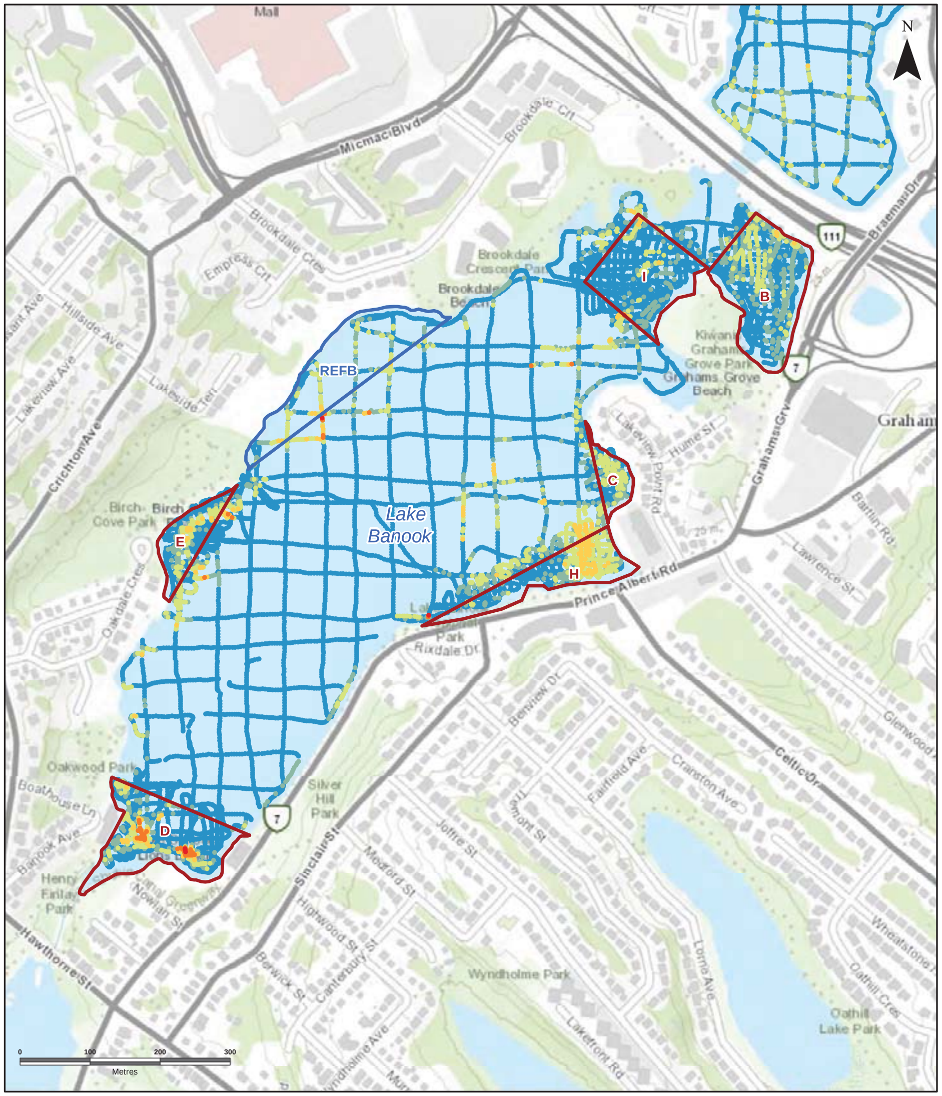
Submerged Aquatic Vegetation Canopy Height of Lake Micmac – Field Points



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Submerged Aquatic Vegetation Canopy Height of Lake Banook – Field Points

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Figure D -1