

Submerged aquatic vegetation survey in the Bay of Quinte, Lake Ontario, 2015

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by

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ABSTRACT

Gardner Costa, J., Leisti, K.E., Midwood, J.D., Doka, S.E. 2018. Submerged aquatic vegetation survey in the Bay of Quinte, 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3285: viii + 33 p.

The Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) conducted their fifth hydroacoustic submerged aquatic vegetation (SAV) survey in the Bay of Quinte (BQ) in 2015, collecting data along the same reference transects that have been surveyed since Project Quinte began in 1972 (Crowder and Bristow 1986). This technical document provides an update to some of the trends described in the BQ Beneficial Use Impairment (BUI) Fish Wildlife Habitat Status Report (Leisti et al. 2016). SAV data was collected using a combination of Biosonics hydroacoustic data and point sampling of vegetation communities (rake tosses). BQ upper bay mean bed extent on the reference transects has not changed between 2011 and 2015, and mean percent cover has increased by 20% during the same time period. With the exception of Belleville South (39%) and Big Bay North (48%), eight of 10 sample transects had % SAV cover > 50% (50% is the target cover for SAV for the BUI in the BQ), suggesting that most of BQ remains above the delisting target in an improved state.

RÉSUMÉ

Gardner Costa, J., Leisti, K.E., Midwood, J.D., Doka, S.E. 2018. Submerged aquatic vegetation survey in the Bay of Quinte, 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3285: viii + 33 p.

Le Laboratoire des Grands Lacs pour les pêches et les sciences aquatiques (LGLPSA) a effectué son cinquième relevé hydroacoustique permettant d'évaluer la végétation aquatique submergée dans la baie de Quinte en 2015, recueillant ainsi des données le long des mêmes transects de référence qui ont été étudiés depuis le début du projet dans la baie de Quinte en 1972 (Crowder et Bristow 1986). Le présent document technique constitue une mise à jour de certaines des tendances décrites dans le Rapport sur l'état de l'habitat faunique du poisson dans la baie de Quinte concernant les altérations d'utilisation bénéfique (Leisti *et al.* 2016). Des données sur l'étude de la végétation aquatique submergée ont été recueillies à l'aide d'une combinaison de données hydroacoustiques de Biosonics et d'échantillonnage ponctuel des communautés végétales (râteau d'échantillonnage). L'étendue du lit moyen de la baie dans la partie supérieure de la baie de Quinte sur les transects de référence n'a pas changé entre 2011 et 2015, et le pourcentage moyen de la couverture a augmenté de 20 % au cours de la même période. À l'exception de Belleville South (39 %) et du nord de Big Bay (48 %), huit des dix transects échantillonnés présentaient un pourcentage de couverture de la végétation aquatique submergée supérieur à 50 % (50 % représentent la couverture cible de la végétation aquatique submergée concernant les altérations d'utilisation bénéfique dans la baie de Quinte), ce qui laisse entendre que la majeure partie de la baie de Quinte demeure au-dessus de la cible de radiation dans un état amélioré.

1.0 INTRODUCTION

Bay of Quinte (BQ) is one of 43 severely impaired ecosystems (Areas of Concern; AOC) in the Great Lakes. Annex 2 of the Revised Great Lakes Water Quality Agreement of 1978 (IJC 1994) outlined a three stage Remedial Action Plan (RAP) process that called for the identification of Beneficial Use Impairments (BUIs; Stage I – completed 1990), their causes, and a plan (Stage II – completed 1993) for restoring the BUIs. The third and final stage (on-going) of the RAP process requires monitoring to measure the success of RAP implementation that should ultimately lead to delisting the BQ as an AOC (Geater et al. 2016).

The Department of Fisheries and Oceans (DFO) has monitored various ecosystem attributes related to BUI in the BQ. DFO has long term datasets for submerged aquatic vegetation (SAV) and has since produced a report compiling historical and contemporary data (as recent as 2011) to provide evidence for delisting (Leisti et al. 2016). Aquatic vegetation is an important component of fish habitat and is addressed under the BUI #14 (Loss of Fish and Wildlife habitat), under criteria FWH-1A and FWH-1B (see Leisti et al. 2016 for delisting definitions).

- 1) FWH-1A: 30% of total area of upper BQ has SAV coverage of more than 50% density.
- 2) FWH-1B: significant positive trends or change in both of the following plant community health measures:
 - a) Positive slope in total species diversity; or,
 - b) Positive difference in total plant species diversity; or,
 - c) Index values in 'good to excellent' range for 3 recent annual SAV surveys.

SAV cover greater than 50% for the upper bay is the target % SAV cover for SAV for the BUI in the BQ. The first mention of a density component of the SAV target appears in the 1993 RAP Stage 2 report (Bay of Quinte 1993), but we were unable to find any supporting documents describing why the value of 50% density was chosen. BUI 14 was recommended to be relisted from “impaired” to “not-impaired” in the 2016 final assessment report (Geater et al. 2016); however, continued monitoring of vegetation cover and extent was recommended and subsequently, SAV data were collected by DFO in the BQ in 2015.

SAV affects the physical and chemical nature of their local environment by: anchoring substrate to reduce sediment transport; reducing turbidity caused by the resuspension of sediments by winds; and affecting nutrient and oxygen cycling (Carpenter and Lodge 1986; Kalff 2002). SAV provides food and habitat for birds, mammals, invertebrates, reptiles, zooplankton, periphyton, and fish (Kalff 2002).

For fishes, SAV provides spawning, nursery, and adult habitat for numerous species; it is both a refuge from predation through the provision of cover and serves as habitat for macroinvertebrates, a source of food for some fishes (Gilinsky 1984). SAV presence

has been found to positively influence fish abundance (Chick and McIvor 1994), growth rates (Werner et al. 1983) and fish community structure (Weaver et al. 1997). Randall et al. (1996) concluded that sites with SAV had greater densities of fish and greater species richness than unvegetated sites in three bays in southern Ontario. Therefore, facilitating SAV recovery in the BQ is crucial to the recovery fish and wildlife habitat and essential to meeting the delisting criteria.

DFO's Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) conducted their fifth hydroacoustic submerged aquatic vegetation (SAV) survey in the BQ from August 17th to September 3rd, 2015. Data were collected along the same historic reference transects that have been surveyed since the beginning of Project Quinte in 1972 (Crowder and Bristow 1986). This report summarizes the results from the 2015 SAV survey and discusses them in context of the long-term SAV monitoring efforts that occurred in the BQ.

2.0 METHODS

Study site: Bay of Quinte

The BQ is a Z-shaped bay that opens out to the northeastern shore of Lake Ontario west of Kingston (Figure A1). The 254 km² bay is 64 km in length with a maximum width of 3.5 km. The 18,200 km² watershed consists of the Precambrian Shield in the north and Paleozoic limestones in the south (Johnson and Hurley 1986). The upper bay from Trenton to the Telegraph Narrows is 34 km long. Maximum depth range of the upper bay is 4 to 8 m. The greatest human population density in the bay is along its north shore in the urban centers of Trenton (amalgamated into Quinte West) and Belleville. The middle bay extends from Telegraph Narrows to the restriction at Glenora, with a total length of 13 km. Water depths of the middle bay increase from 6 m in the north to 17 m in the south. The lower bay area below Glenora is 16 km long with depths increasing to 52 m by the bay's mouth. The opening into Lake Ontario is split by Amherst Island into a lower and upper gap. Generally, bathymetry of the bays (upper, middle, lower) is steeper as you move from the upper to the lower bays. As a result, Trenton (upper bay) has one of the largest SAV bed extents and Conway (lower bay) has one of the shortest bed extents (Leisti et al. 2016). Slope can strongly influence SAV cover (Keddy 1983); therefore, it is expected (and has been previously noted in other reports; Leisti et al. 2006, 2012, and 2016) that SAV bed extent will be greater in the upper transects than the middle or lower bay transects, which are comparatively deeper with steeper slopes.

Water generally flows from west to east in the bay, with peak flows occurring from March to April (Minnset al. 1986). The Bay is usually ice-covered from the end of December to the beginning of April. In the summer, the shallow upper bay is well mixed with no permanent stratification, but during calm periods, the sediments and bottom waters can become temporarily anoxic, thus increasing phosphorus release from the sediments (Sly 1986). At Hay Bay and Conway, in the middle and lower bays, stratification begins near the end of April with turnover occurring in late September or

early October (Larocque and Doka 2014). Significant water exchange occurs between Lake Ontario and the lower bay through the upper gap. During the summer, there is backflow at depth through the Glenora gap with upwelling in the middle bay (Minns et al. 1986).

SAV cover and extent

Since 1972, twelve surveys have been conducted along ten transects located on the north and south shores at Trenton, Belleville, Big Bay, and Conway, and eastern and western shores of Hay Bay (Appendix Figure 1). These reference transects started at the nearshore in approximately 1 m water depth and ran offshore at least 100 m beyond the edge of the SAV bed. Gaps of < 90 m on the transect were allowed to account for SAV patchiness. Variables such as bed extent, % bottom cover (cover above sediment), and maximum depth of colonization were determined over this 43 year time period. Data from these surveys were used to build a SAV model for the upper BQ to address BUI delisting criteria targets (Leisti et al. 2016). For additional information regarding sampling methods over this time period, refer to Leisti et al. (2006) and for an analysis of the SAV data from 1972 to 2007, refer to Leisti et al. (2012). Floating vegetation was not considered in this survey.

In 2015, a BioSonics MX hydroacoustics system with a 205 kHz, 8° single-beam transducer (Seattle, WA, USA) was used for the SAV survey. In addition to the reference transects, supplementary echosounding included at least two other nearshore-to-offshore transects and a zig-zag transect that traced the edge of the SAV bed (Figures A2-A11). Point sampling of SAV was undertaken along the reference transects via rake toss to ground-truth the hydroacoustics and determine species composition. The point samples typically began at a water depth of 1 m and continued at half meter increments until just beyond the edge of the SAV bed. The number of point samples varied according to site conditions, but ranged from 15 at Trenton North to six at Trenton South. At least three rake tosses were made at each point sample location and SAV was visually assessed for cover (sparse, moderate, dense) and sorted by species. Nearshore Secchi depth was measured at 46 point sample locations that had sufficient water depth (where Secchi depth was greater than water depth, typically > 1 m). Echosounding was conducted in areas outside of the reference transects at Trenton and Muscote Bay to verify predictions from the 2015 SAV model (Leisti et al. 2016) and also along the north shore of Big Bay to support an assessment of the role of fetch in BQ SAV distribution.

Data analysis

The acoustic data were analyzed using BioSonics Visual Habitat software, version 2.0.29744 (BioSonics 2015) to determine bottom depth, SAV percent (%) bottom cover and SAV height. Default software parameters were used with the exception of -38 dB for the rising edge threshold for bottom detection, a plant detection length criterion of 15 cm and maximum plant depth of 10 m. All the output was scrutinized and manually adjusted to address issues such as incorrect delineation of bottom depths due to dense

SAV and fish schools near the bottom identified as SAV. The point sampling undertaken during the survey played a critical role in verifying maximum depths of SAV colonization (max depth of colonization was determined from the sonagram). The results from Visual Habitat were imported into ArcMap and the length of the reference transects (an indication of bed extent) was determined by measuring from a nearshore point that has been fixed since 2000 to the last plant on the transect (gaps of <90 m where SAV was absent were included). Mean percent cover (%) was calculated from the start of the transect to the last plant. Boxplots illustrating the mean, 25th and 75th quartiles of both percent cover and SAV height by depth range (1 m increments) were created using the reference transects and all supplementary echosounding data.

2.0 RESULTS

Maps of both bottom cover (Figures A2-A11) and plant height (example map of transects Trenton North and South; Figure A12) were created for all 10 reference and supplementary locations. A bathymetric base layer has been included with all maps to provide context to the presence/absence of vegetation. The upper bay is shallower, more protected, and generally more vegetated than either the middle or lower bays, and was the target area for BUI redesignation in Leisti et al. (2016). Two transect areas (Muscote Bay and Blessington Creek) were surveyed but not included in the analyses and therefore will not be discussed; they were collected for potential future modelling in the Bay. This report includes these maps as a record for posterity. SAV bed extent in the upper bay has not changed between the 2011 and 2015 surveys (Figure 1). Mean % SAV cover in this area has increased since 2011 from 50% to 70%, remaining well above the 50% SAV cover delisting target (Figure 1).

For the 2015 survey, bed extent (transect length) and % SAV cover ranged from 90 m (Conway South) to 1917 m (Trenton North) and from 39% (Belleville South) to 88% (Hay Bay West), respectively (Table 1, Figure 2). There were no obvious differences in bed extent among transects (with Trenton transects as the exception). However, percent cover was more variable and, as discussed below, transects that were exposed were more likely to have lower % SAV cover of vegetation (Appendix A1 -11). Only two of 10 transects fell below the 50% SAV cover target (Belleville South – 39% , Big Bay North – 48%); however, the overall mean % SAV cover for the BQ was 70%.

Between the 2011 and 2015 surveys, the length of three reference transects decreased [Trenton North by 73 m, Trenton South 26 m, and Conway South by 46 m] while other transects increased in length ranging from 14 m on Belleville South to 79 m on Belleville North. In general, increases in transect lengths in some locations offset the decreases in lengths at others resulting in a mean transect length roughly comparable to surveys in 2011 (Figure 1). The majority of the transects recorded an increase in SAV % SAV cover between the last two surveys, with the largest increase occurring on Hay Bay West where cover increased from 54 to 88%. The largest decrease in cover occurred on Hay Bay East, which saw cover drop from 84 to 65%. The largest reference transects in the BQ, Trenton North's cover increased from 50 to 74% (Table 1).

The influence of water depth (and associated Secchi depth) is clear in all the figures with areas of low % SAV cover (or no SAV). This is evident even in comparatively small and narrow deeper channels (i.e., channel emanating from the Trenton River; Figure A2); whereas, the shallower margins of BQ tend to support abundant SAV. The potential influence of exposure to wind and wave action and winter ice scour was evident in transects from Big Bay North and Big Bay South (Figures A4 and A5), with lower overall SAV cover and decreases in cover in shallower waters. Finally, the influence of bathymetric slope on bed extent is most evident at sites in the middle and lower bays, with generally deeper SAV, but shorter bed extents (i.e., Hay Bay East and West, and Conway North and South; Figures A7 and A8, and A11 and A12, respectively).

The maximum depth of SAV colonization (Z_C) also varies by location and appears to be influenced by Secchi depth (Figure 3). Mean Secchi depths (Table 2) recorded during the survey ranged from $1.4 \text{ m} \pm 0.0 \text{ SE}$ at Belleville North to $4.3 \text{ m} \pm 0.1 \text{ SE}$ at Conway North. Bi-weekly, seasonal (May 20 to September 9) data from the Project Quinte offshore stations confirm that mean Secchi depths at the Conway station are considerably deeper than other locations at $6.2 \text{ m} \pm 1.3 \text{ m}$ compared to Hay Bay, Napanee, and Belleville, which are all close to or less than 2.0 m. Deeper Secchi depths at the Conway Secchi station resulted in substantially deeper Z_C with SAV found at 6.0 and 7.7 m for transects Conway South and Conway North respectively, while the maximum Z_C for all other locations was 4.8 m, occurring at Hay Bay East. Upper bay (Trenton North and South, Belleville North and South, and Big Bay North and South) Z_C ranged from 3.6 m at Big Bay North to 4.4 m at Belleville South.

Boxplots of % bottom cover (Figure 5) and plant height (Figure 6) combine all data into six major areas. Across all sites, the greatest SAV % SAV cover occurred between 2-3 m water depth, although at some locations, such as Belleville North and South, and Trenton North and South, this peak extended to shallower depths of 1-2 m depth. High % SAV cover at Trenton North and South also extend into the 3-4 m depth range (Figure 5). In Conway North and South, the highest SAV % SAV cover shifted to deeper waters between 3-6 m. Beyond maximum % SAV cover, all transects recorded a decrease in % SAV cover in deeper waters close to the edge of the SAV beds.

For SAV height, all locations showed a unimodal relationship with maximum SAV height peaking between 2-3 m water depth. Conway North and South were once again an exception with the peak in maximum height occurring between 4-5 m. Overall, SAV was generally taller in the Trenton North and South, and Belleville North and South transects and shorter in the Big Bay North and South transects (Figure 6).

Point sampling on reference transects revealed that species richness in the upper bay ranged from six in Big Bay North to twelve in Trenton South. Both middle and lower bay richness ranged between 12 and 13 species. This is still within range of previous assessments (10 species in 2007, 12 in 2011; Leisti et al. 2016), with the exception of the comparatively low richness in the Belleville North and South transects. Species composition was variable among the reference transects, but pollution-tolerant, broad-

niche species *Vallisneria americana*, *Zosterella dubia* and *Certophyllum demersum* were found in at least one sample point on all ten reference transects (Figure 6). These three species were also the most commonly encountered within a transect. Both *Myriophyllum spicatum* and *Najas* sp. were recorded from at least one sample point on nine of the reference transects. *V. americana* was the dominant species in the BQ being present at 74% of the 80 vegetated sampling points, but was found more often on upper and middle bay transects (Table 3). *Elodea canadensis*, *Potamogeton zosteriformis* and *Chara* sp. were relatively more frequent in the middle and lower bay than in the upper bay.

The Wetland Macrophyte Index (WMI), developed by Croft and Fraser (2007), is an index used to determine the condition of wetland macrophyte communities. The species listed above are listed as tolerant or very tolerant, broad-niche plant species [see Table 2 from Croft and Fraser (2007) for tolerance ratings]. It was not within the scope of this report to rerun the WMI as was done in 2011; however, the dominant species in the survey area are tolerant species, suggesting the community is exposed to stressors. The community composition identified in this survey is consistent with data collected in the last 30 years for BQ (Leisti et al. 2016).

3.0 DISCUSSION

Substantial increases in the mean bed extent of the upper bay reference sites occurred between 1994 and 2000 (Figure 1). This increase follows the 1993 Zebra Mussel (*Dreissena* sp.) invasion and the subsequent significant increases in water clarity (Leisti et al. 2012). Another substantial increase in bed extent occurred between 2004 and 2007 and was principally due to SAV filling in previous spatial gaps that were > 90 m on the Trenton North transect. Mean bed extent decreased slightly after 2007, but has remained stable for the past two surveys. Mean % SAV cover has fluctuated between 42 and 69% with the decrease between 2004 and 2007, likely due to sparser SAV found in the area of the expanded beds. Results from the present survey suggest that bed extent has remained stable and % SAV cover has increased approximately 20% since the 2011 survey.

Although exposure, water clarity, and water depth (as a proxy for light penetration) are the main drivers that determine the distribution of SAV (Rooney and Kalff 2000), there are many other abiotic and biotic factors that influence SAV growth and establishment. Abiotic factors include sediment composition, slope, water clarity, temperature, current velocity, water chemistry, hydrostatic pressure and water level fluctuation (Kalff 2002). Angiosperms were generally absent beyond the euphotic zone in all transects, suggesting basin morphometry has a considerable effect on the ultimate extent of the SAV beds (Rooney and Kalff 2000). Biotic factors include periphyton abundance, grazing by invertebrates and waterfowl, uprooting by fishes such as Common Carp (*Cyprinus carpio*), plant diseases and invasion by exotic SAV (Kalff 2002). Collectively, these abiotic and biotic factors will dictate both the potential and realized distribution of SAV.

SAV growth may be anthropogenically controlled through mechanical, chemical or biological means. Response to these stressors can vary by SAV species due to differences in reproduction, life histories and morphologies, but these factors acting alone or in concert likely contribute to the observed patchiness along transects, as seen in the Trenton North and South transects. Vegetation cover was bare or sparse along the dredged channel coming from the Trenton River. The bare area in the southeastern corner of Trenton (Figure A2) may be influenced by the outflow of the river, either by sedimentation or scouring. Belleville South and Big Bay North were also patchy; likely a function of increased exposure at these locations limiting growth in shallow waters. The historical southern transect is located at the bottleneck of the bay, on a deeper slope compared with the north transect. The southern area is relatively deep (Figure A3) and likely has a higher flow, potentially depositing sediment along the edge and reducing vegetation growth. Patchiness can pose challenges in the application of simplistic models of SAV cover and distribution (Leisti et al. 2016) since comparatively stochastic process, like grazing, can produce apparent inconsistencies in the potential range of SAV (as modelled) and the realized range of SAV (as observed).

Depending on basin morphometry, processes affecting SAV growth associated with the shallow nearshore may include wave action and ice scouring (Istvanovics et al. 2008), while in the deeper waters, temperature, hydrostatic pressure (Schwarz et al. 2000) and light availability also influence SAV growth. We found evidence of this in the Big Bay North and Belleville South transects, where transects were patchy and were the only two transects below the 50% SAV cover target. The lack of *Myriophyllum spicatum*, a surface canopy-forming invasive on the Big Bay North reference transect, may also account for some of these differences in height, though fetch is likely the largest contributing factor.

Percent cover was highest around 2-3 m depth in most areas of the bay, often with sharp declines after 4-5 m (Figure 5). At Conway North and South, the deepest areas had SAV in 6-7 m of water with 100% SAV cover in the 5-6 m range. Peak cover is shifted at the Conway transects likely due to exposure limitations in the nearshore and light availability in deeper waters; this pattern is consistent with more exposed clear water sites as observed in Severn Sound, Lake Huron (Midwood and Doka 2017). From the patterns in the SAV % SAV cover maps and recorded Secchi depths plotted with max depth of colonization, we suspect a combination of exposure limited growth in shallow waters and clearer water (in Conway North and South) allowing peak cover to shift to deeper waters to be the greatest influence factors in differences of % SAV cover in the BQ.

It should be noted that a newer hydroacoustics system and software was used for the 2015 survey. Transducer frequency for the older system was 430 kHz while the new MX system is 205 kHz. The new system also has a slightly wider beam (8° vs 6° for the equipment used previously). The new system allows for sparse or patchy vegetation to be detected more easily in transects. For densely vegetated areas, detection is expected to be similar for both systems, and therefore should not have a large effect on

% SAV cover calculations in this report. In the past, we have underestimated % SAV cover in patchy areas compared to the new system. This equipment factor will be examined in the future through in the field calibration of the new equipment to the old to see if and by how much they differ.

When comparing SAV bed extents across reference transects in the BQ, the beds on Trenton North are at least 1.5 km larger than all the other locations. This is principally due to its' shallower, gently sloping basin morphemtry (Figure A1). All other bed extents range between 90 m at Conway South to 337 m at Hay Bay East. The potential for bed expansion in both Hay Bay and Conway transects is severely limited by the steep drop off into much deeper waters. Depth also plays a role in the bed extent at Belleville and Big Bay transects, but water clarity and other factors may also limit SAV growth in these areas. Percent SAV cover within the reference transects were > 62% (our target is > 50%) with the exception of Belleville South (39%), which is patchy over most of its' length and Big Bay North (48%) where there is a large gap prior to the last plant on the transect. The Belleville Secchi station has the lowest recorded Secchi depth (1.4 m) and this likely played a role in reducing mean cover and the patchiness of the bed. However, as noted above, multiple factors can play a role in SAV patchiness so the extent of the effect of solely limited to Secchi depth is hard to quantify.

4.0. CONCLUSION

The 2016 BUI redesignation of (degraded) Submerged Aquatic Vegetation report (Leisti et al. 2016) compares and contrasts several decades of SAV data and provides a rationale for the delisting but continual monitoring of SAV in the BQ. This scope of this technical report is limited to 2015 and was not used to update the BQ SAV model. Rather, the 2015 data serve to provide a snapshot of the state of SAV in BQ, to reinforce the results of the 2016 BUI report (Leisti et al. 2016) as well as to serve as a point in time for future analyses and surveys. The upper bay mean bed extent on the reference transects has not changed between 2011 and 2015 and mean percent cover has increased by 20% during the same time period. With the exception of Belleville South (39%) and Big Bay North (48%), eight of 10 sample transects had % SAV cover > 50%, suggesting that most of BQ remains above the delisting target in an improved state. The 2016 BUI report recommends future monitoring on (at least) a five-year cycle (Leisti et al. 2016). This report echoes those recommendations and will work with partners to accomplish those recommendations. DFO is currently working on an acoustic workshop to provide partners in the BQ with the equipment, protocols, and knowledge to perform SAV surveys in the BQ as well as other nearshore areas.

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Table 1. SAV bed extent (transect length) and percent (%) bottom cover \pm std. dev and SE for reference transects in the Bay of Quinte in 2015. See Figure 14 for the plot of bed extent and % SAV cover for the 2015 SAV survey.

	Bed Extent (m)	Mean % SAV cover (%)	Standard Deviation (\pm m)
Trenton North	1917	74	40
Trenton South	190	78	37
Belleville North	229	76	42
Belleville South	265	39	38
Big Bay North	172	48	36
Big Bay South	300	62	33
Hay Bay West	145	88	30
Hay Bay East	337	65	41
Conway North	128	82	32
Conway South	90	65	46

Table 2. Average nearshore Secchi depths (m) in Bay of Quinte recorded at the time of the survey, 2015.

	Mean (m)	Standard Error	Standard Deviation
Trenton North	2	0.1	0.3
Trenton South	1.5	0.1	0.2
Belleville North	1.4	0	0.1
Belleville South	1.4	0	0.1
Big Bay North	1.7	0.1	0.2
Big Bay South	1.9	0.1	0.2
Hay Bay West	1.5	0	0.1
Hay Bay East	1.7	0.1	0.1
Conway North	4.3	0.1	0.2
Conway South	3.7	0.2	0.3

Table 3. Relative percent (%) frequency of occurrence for the eight dominant species located via point sampling (rake tosses) on the ten reference transects during the Bay of Quinte 2015 SAV survey. Data is categorized by all bays (n = 80), Upper Bay (Trenton North and South, Belleville North and South, and Big Bay North and South, n = 48), Middle Bay (Hay Bay East and West, n = 16) and Lower Bay (Conway North and South, n = 16).

Species	All Bays	Relative Percent Frequency (%)		
		Upper Bay	Middle Bay	Lower Bay
<i>Vallisneria americana</i>	74	81	81	55
<i>Zosterella dubia</i>	48	60	37	23
<i>Ceratophyllum demersum</i>	41	48	37	31
<i>Myriophyllum spicatum</i>	39	42	25	55
<i>Najas</i> sp.	33	42	25	16
<i>Elodea canadensis</i>	26	15	50	47
<i>Potamogeton zosteriformis</i>	21	10	37	47
<i>Chara</i> sp.	15	0	25	62

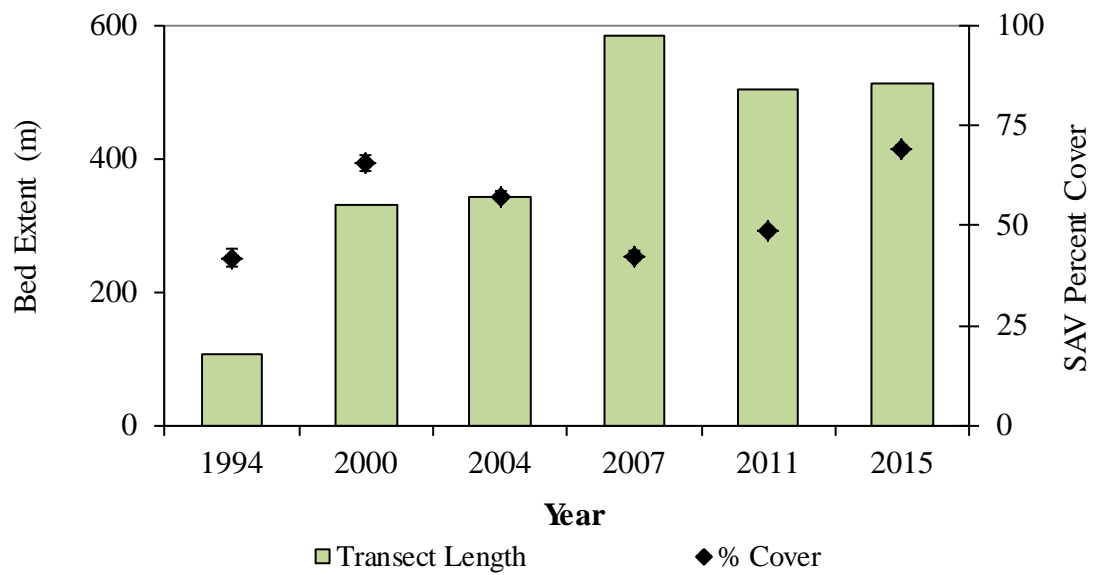


Figure 1. Means for transect length and SAV percent bottom cover from the six upper Bay of Quinte SAV reference transects (from 1994 to 2015. Error bars represent ± 1 SE. The six transects used to calculate the mean in the upper bay are: Trenton North and South, Belleville North and South, and Big Bay North and South.

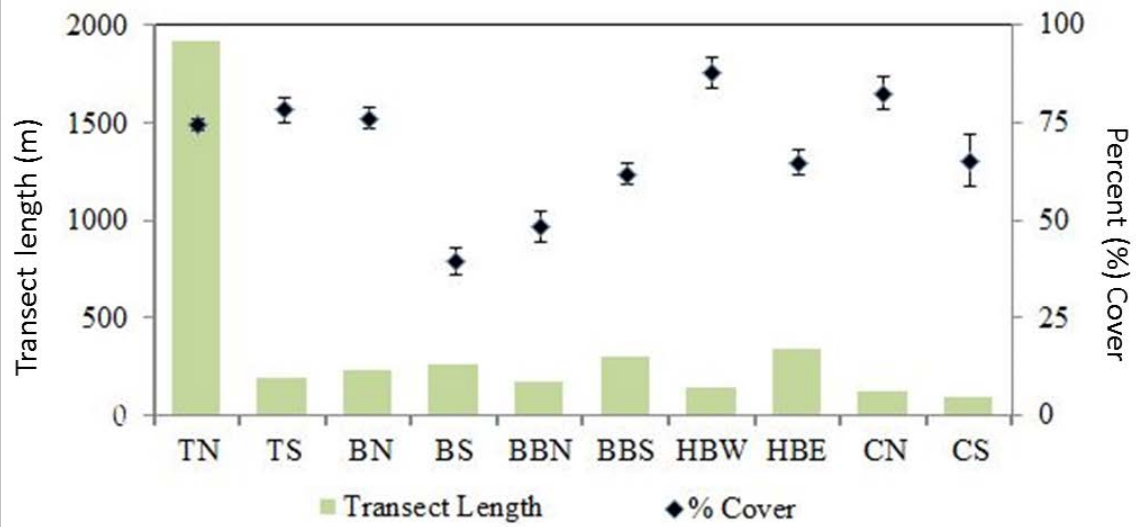


Figure 2. Summary of the 2015 Bay of Quinte acoustic data results from the reference transects showing both the transect length and mean percent cover of SAV. Error bars represent ± 1 SE. TN= Trenton North, TS= Trenton South, BN= Belleville North, BS= Belleville South, BBN= Big Bay North, BBS= Big Bay South, HBW=Hay Bay West, HBE= Hay Bay East, CN= Conway North, CS= Conway South.

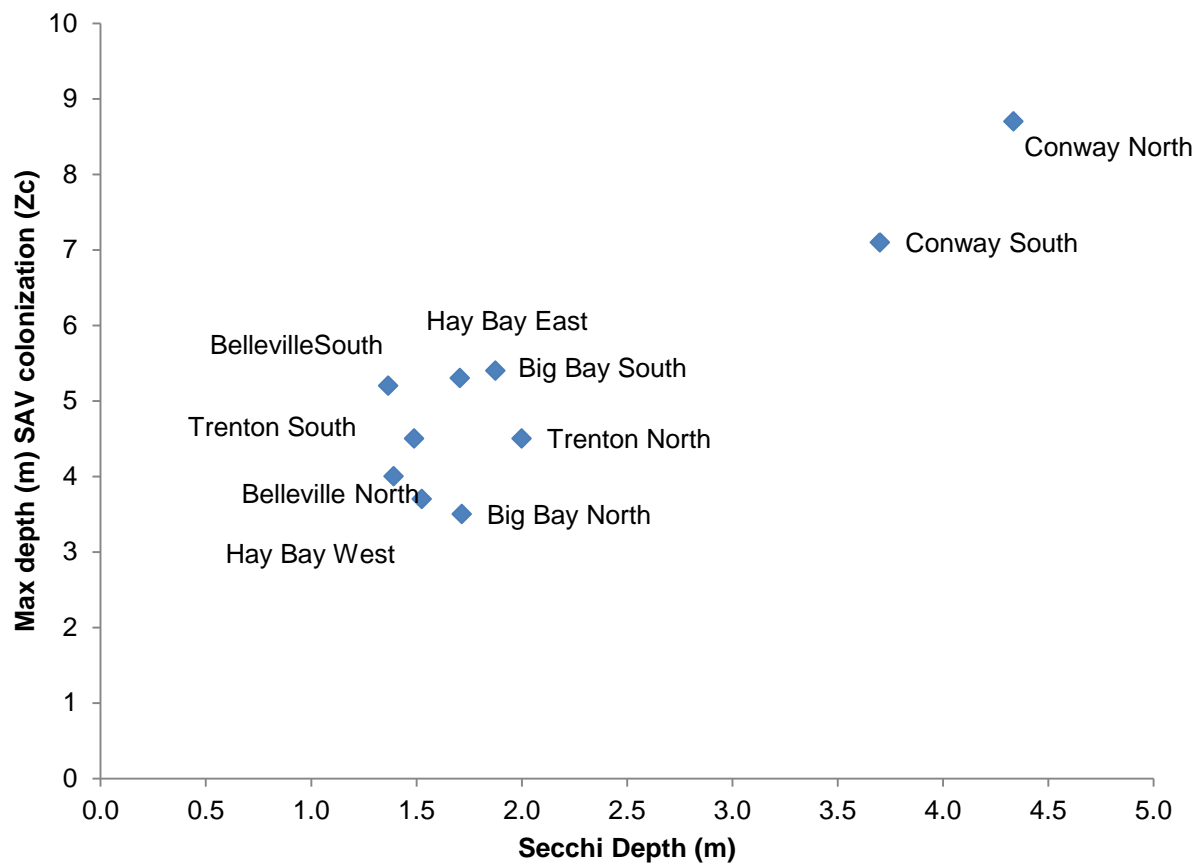


Figure 3. Maximum depth of SAV, (Zc) and Secchi depth from the reference transects in the 2015 Bay of Quinte SAV survey. Secchi taken in the nearshore were measured at the point sample locations during the survey.

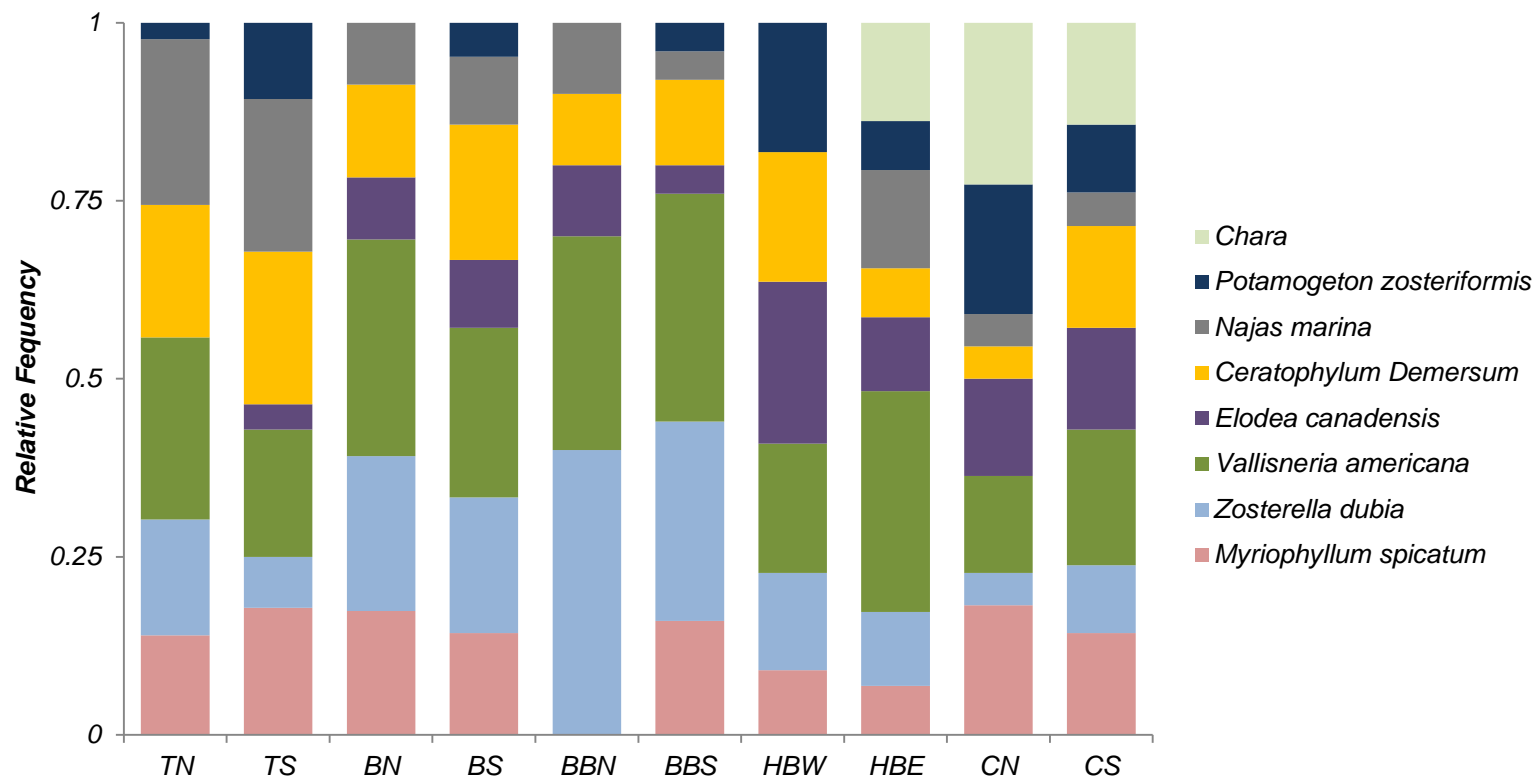


Figure 4. Relative frequency of occurrence of eight SAV species located via point sampling along the reference transects during the 2015 Bay of Quinte SAV survey. TN= Trenton North, TS= Trenton South, BN= Belleville North, BS= Belleville South, BBN= Big Bay North, BBS= Big Bay South, HBW=Hay Bay West, HBE= Hay Bay East, CN= Conway North, CS= Conway South.

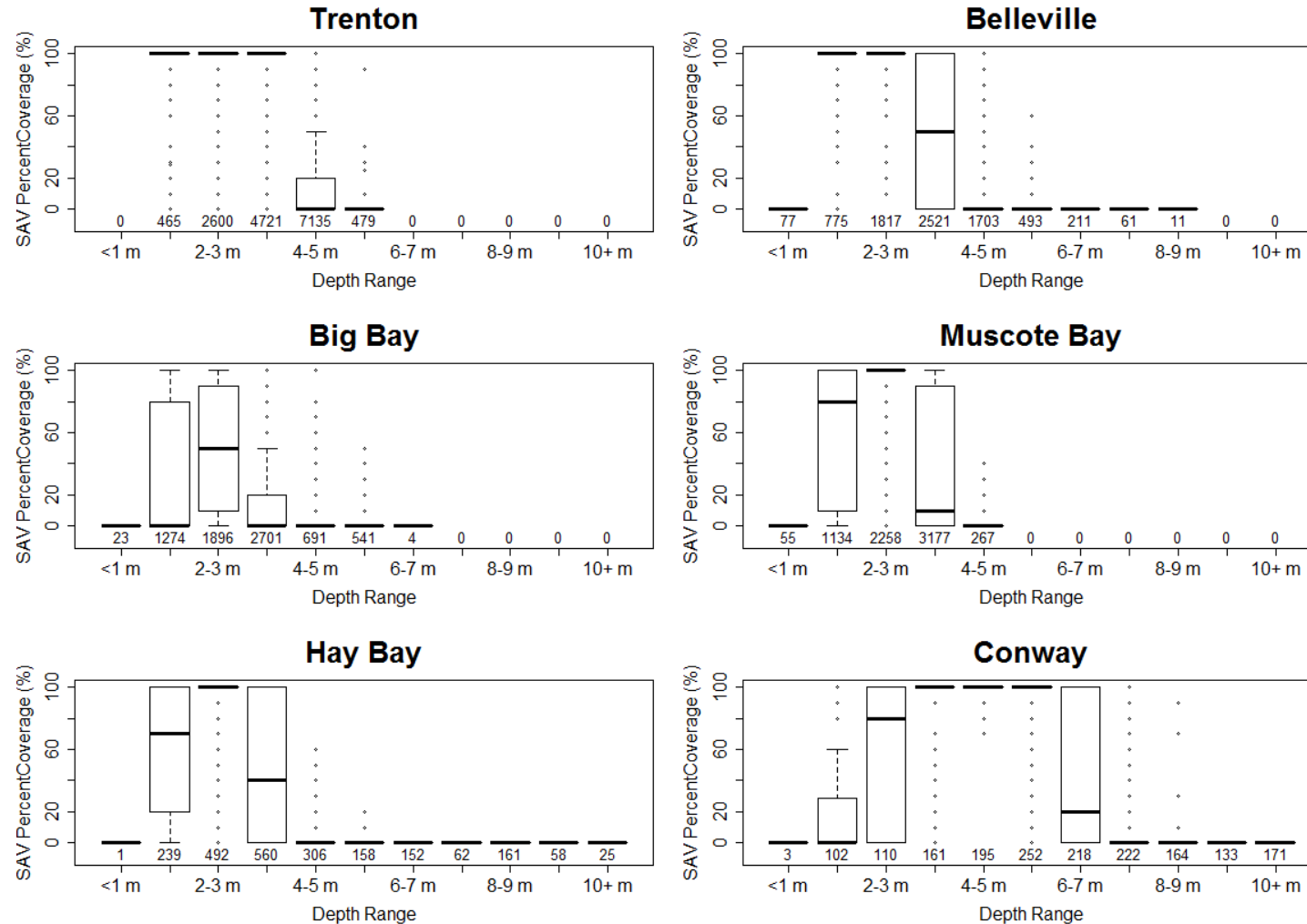


Figure 5. Boxplots by depth range of SAV % bottom cover determined for both reference and all supplementary transects at the six major locations in the Bay of Quinte from the acoustic analysis of the 2015 survey data. The numbers beneath each depth range represent the number of acoustic points within that depth bin.

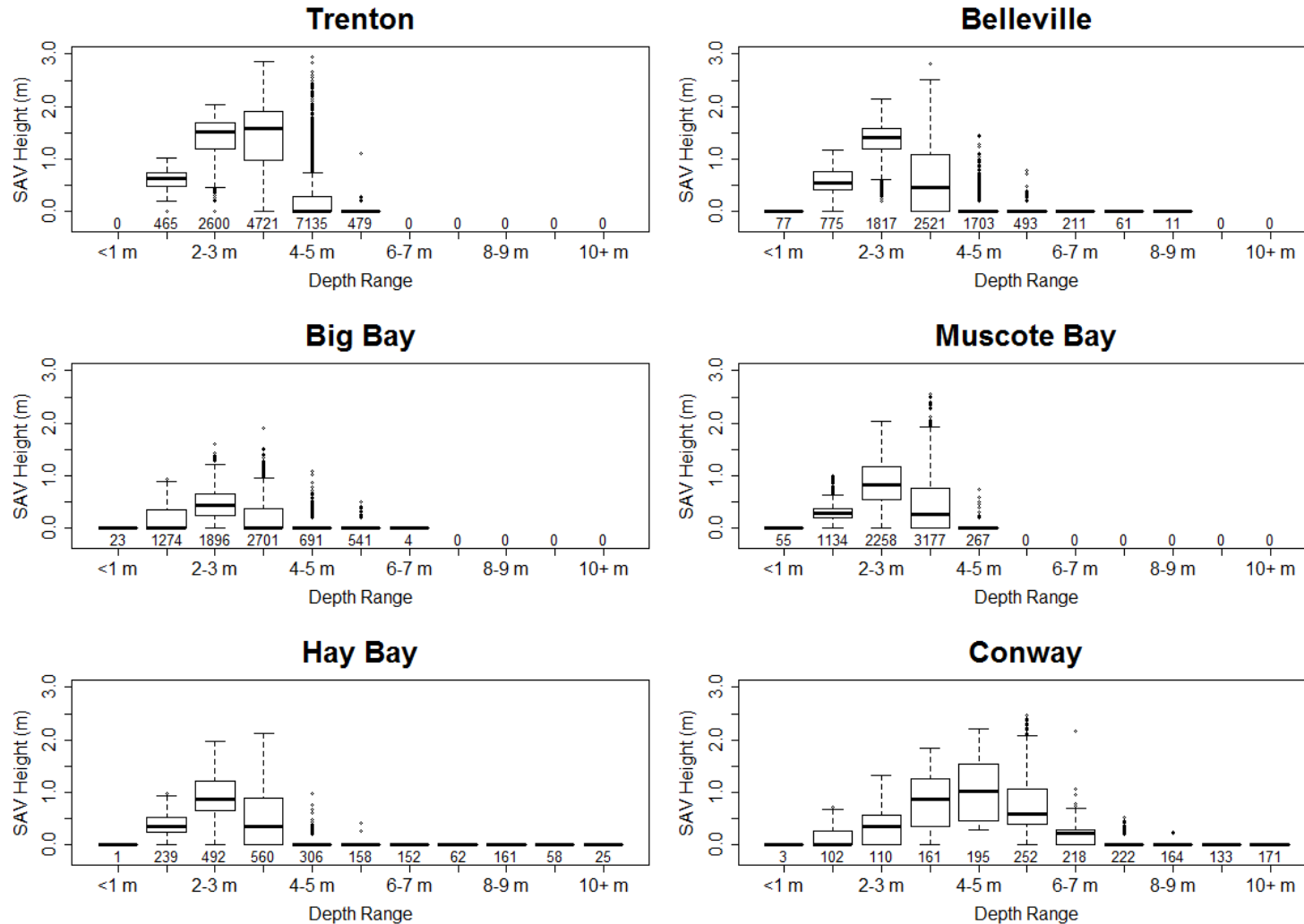


Figure 6. Boxplots by depth range of SAV height determined for both reference and all supplementary transects at the six major locations in the Bay of Quinte from the acoustic analysis of the 2015 survey data. The numbers beneath each depth range represent the number of acoustic points within that depth bin.

APPENDIX

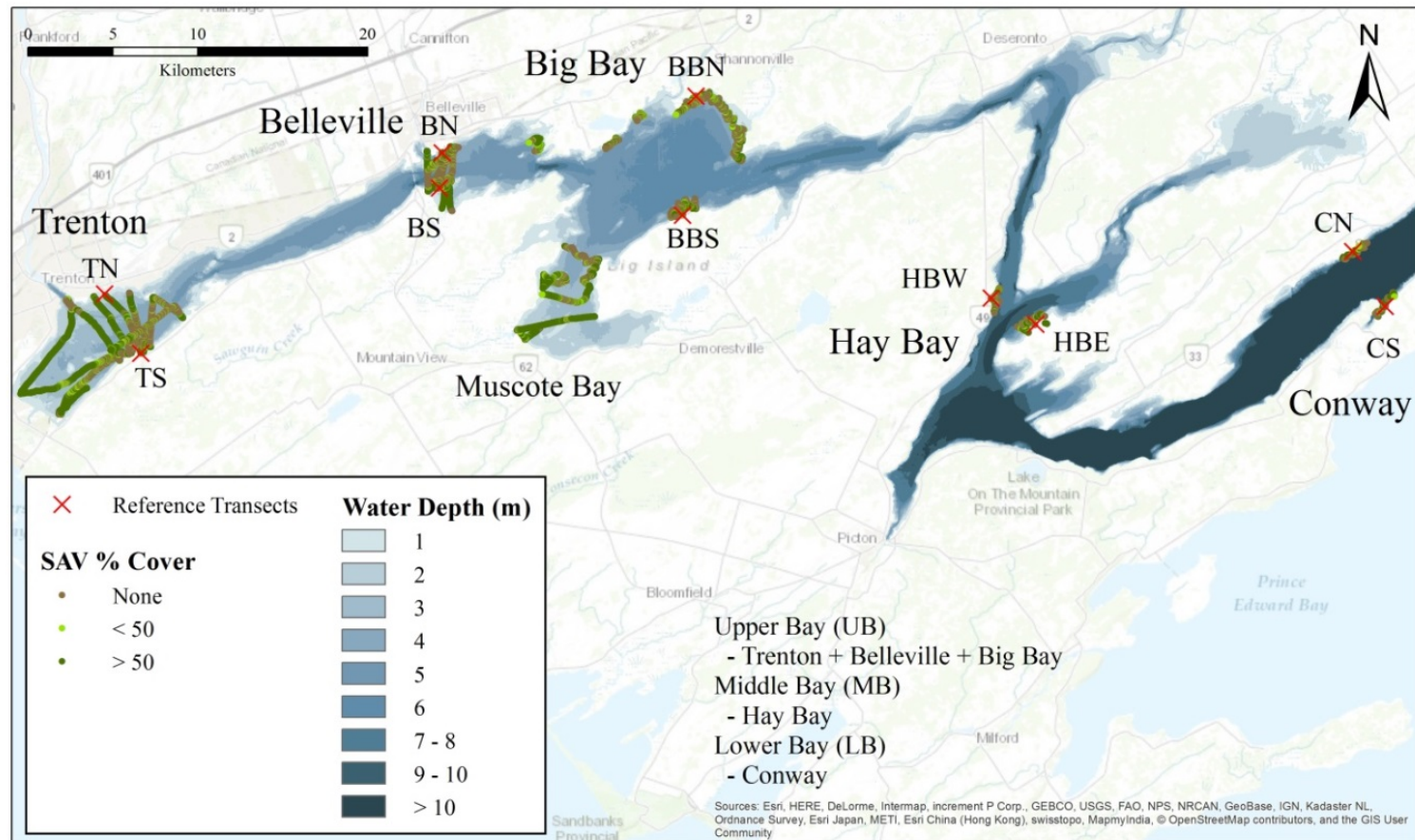


Figure A 1. Results from the 2015 Bay of Quinte submerged aquatic vegetation (SAV) acoustic survey. Also shown are the location and site codes for the ten reference SAV transects that have been sampled since 1972. Water depths are at IGLD 85 datum.

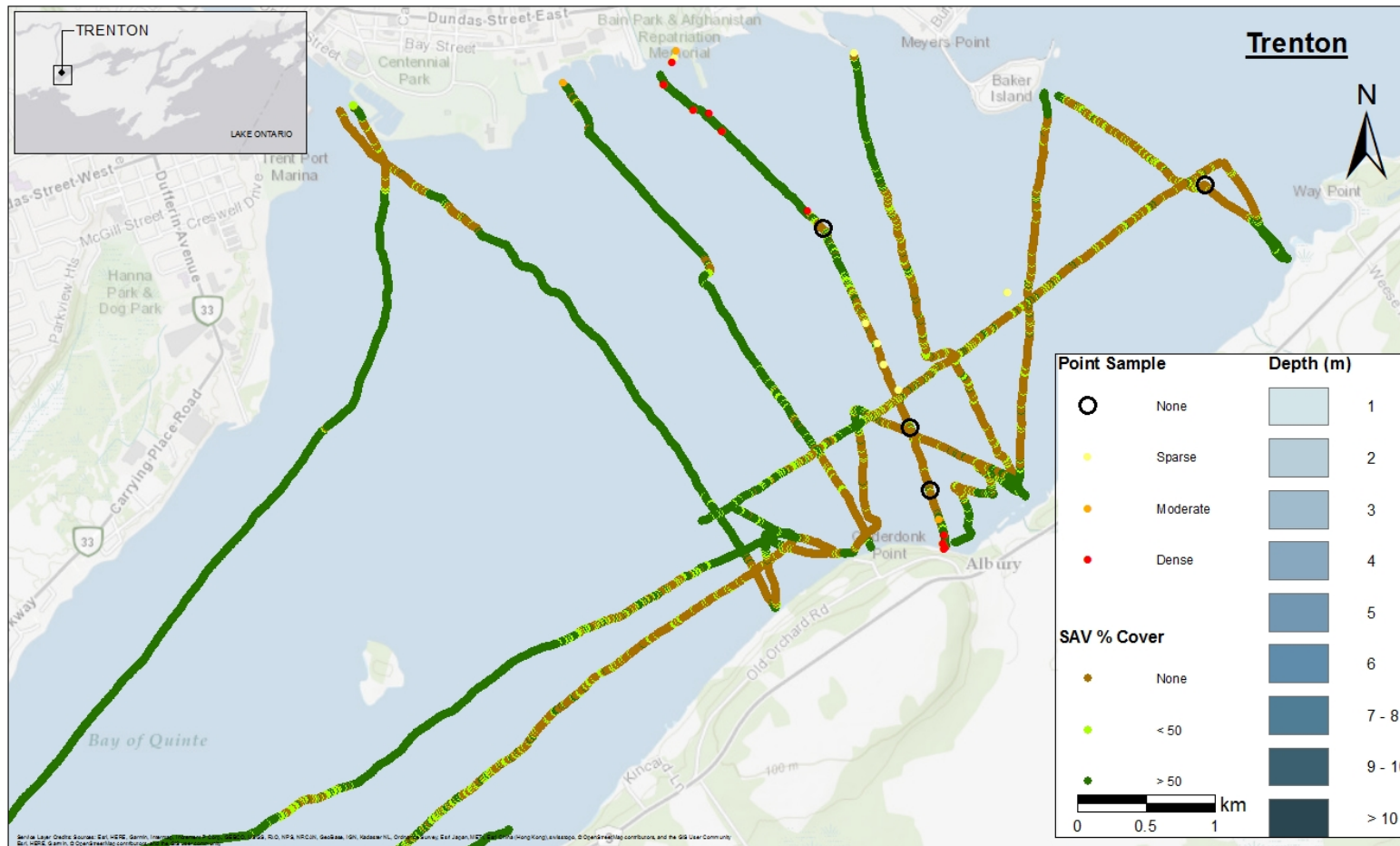


Figure A 2. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Trenton North and South Transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

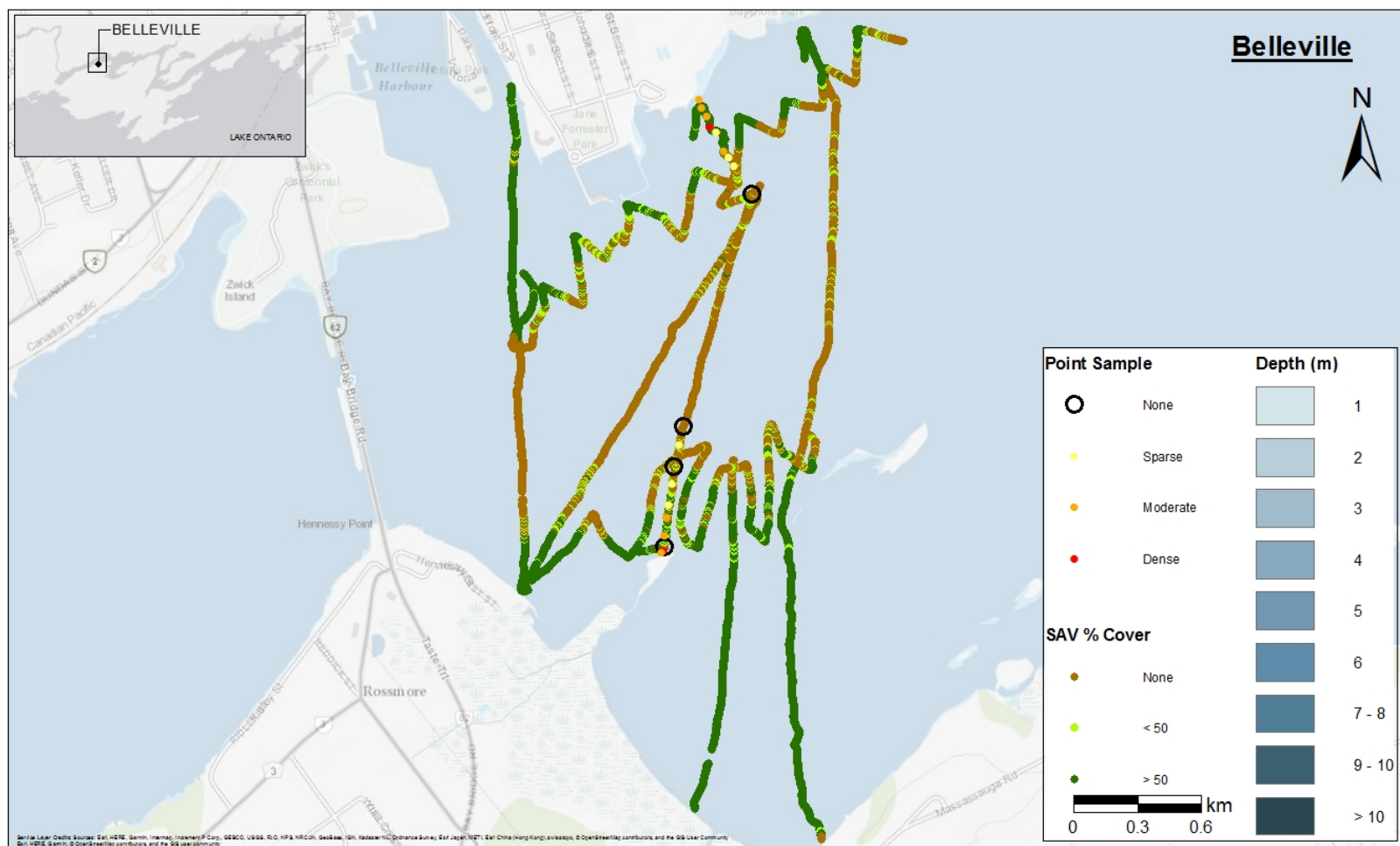


Figure A 3. SAV percent bottom as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Belleville North and South transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

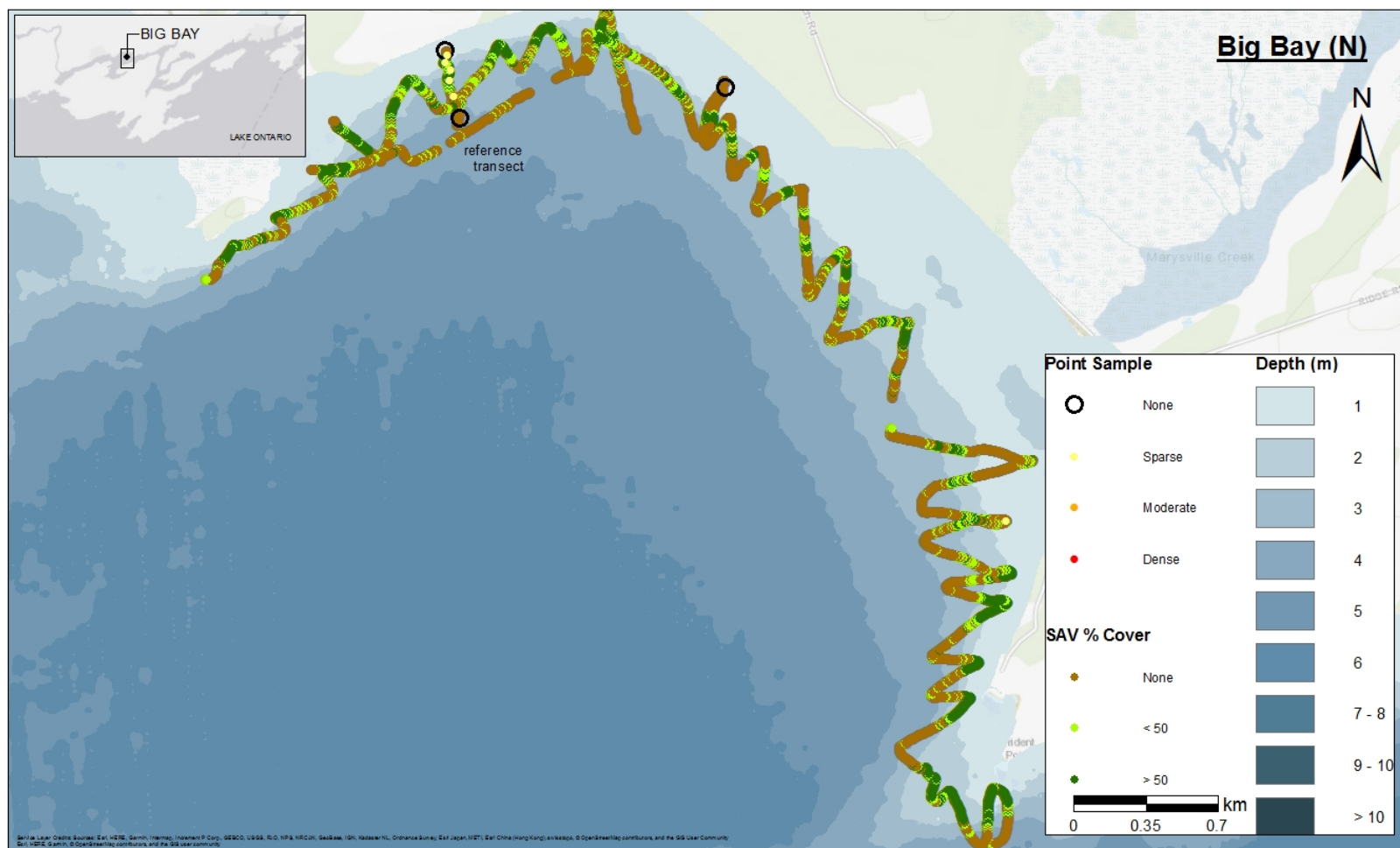


Figure A 4. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Big Bay North transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

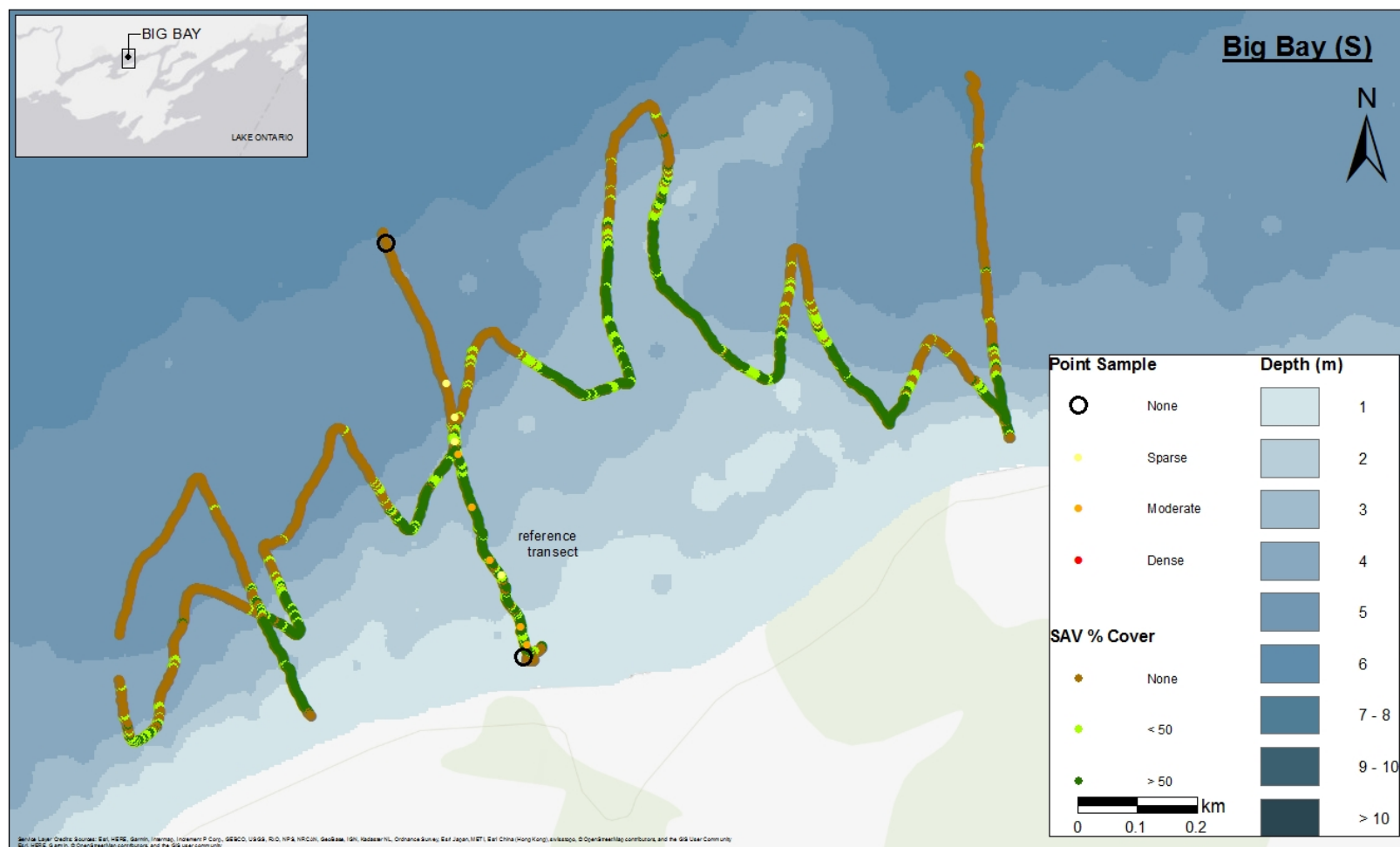


Figure A 5. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Big Bay South transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

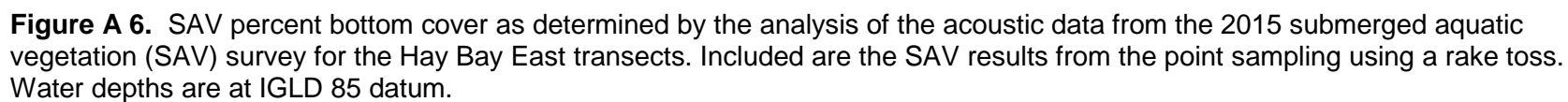




Figure A 7. SAV percent SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Hay Bay West transect. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

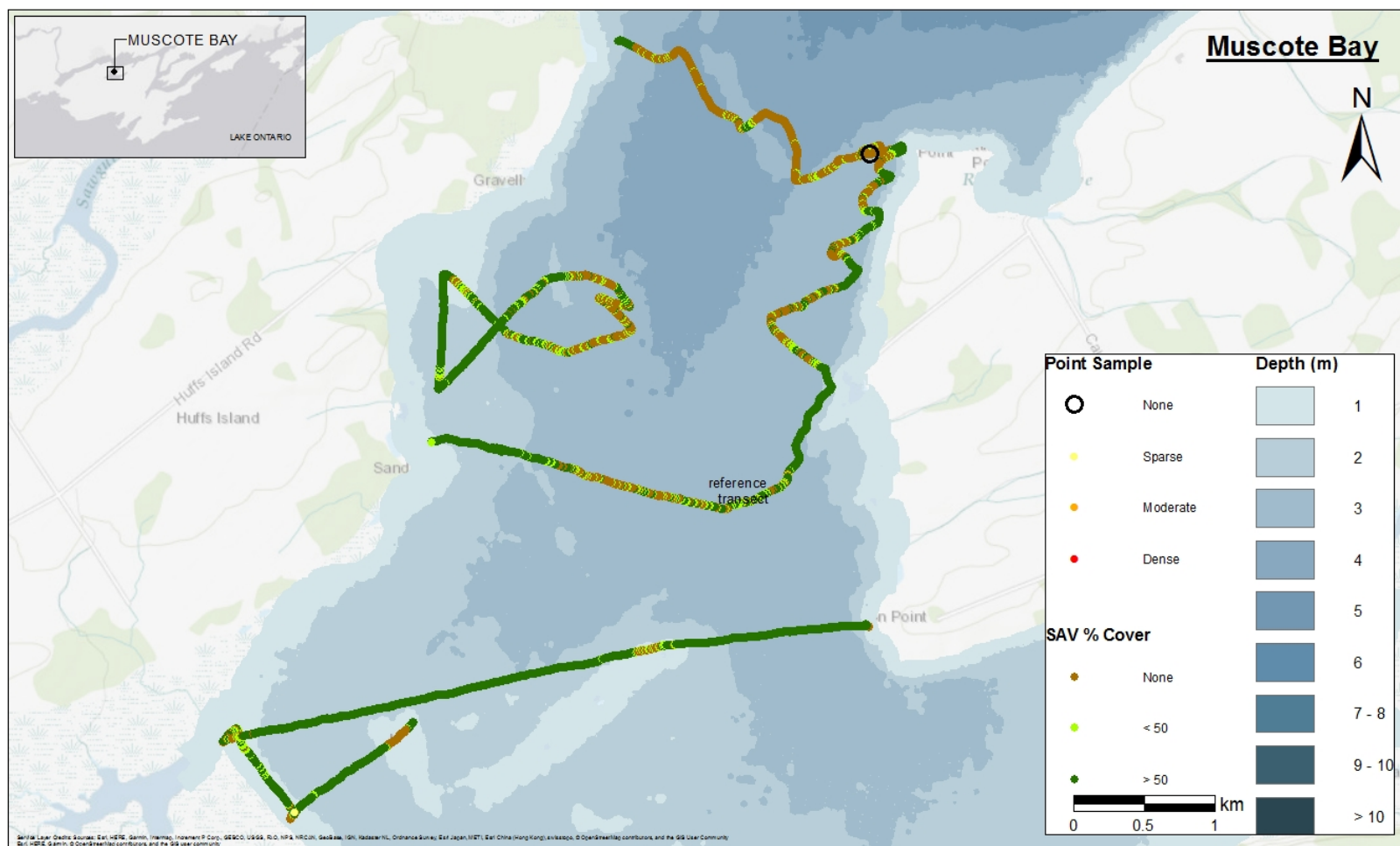


Figure A 8. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for Muscote Bay. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

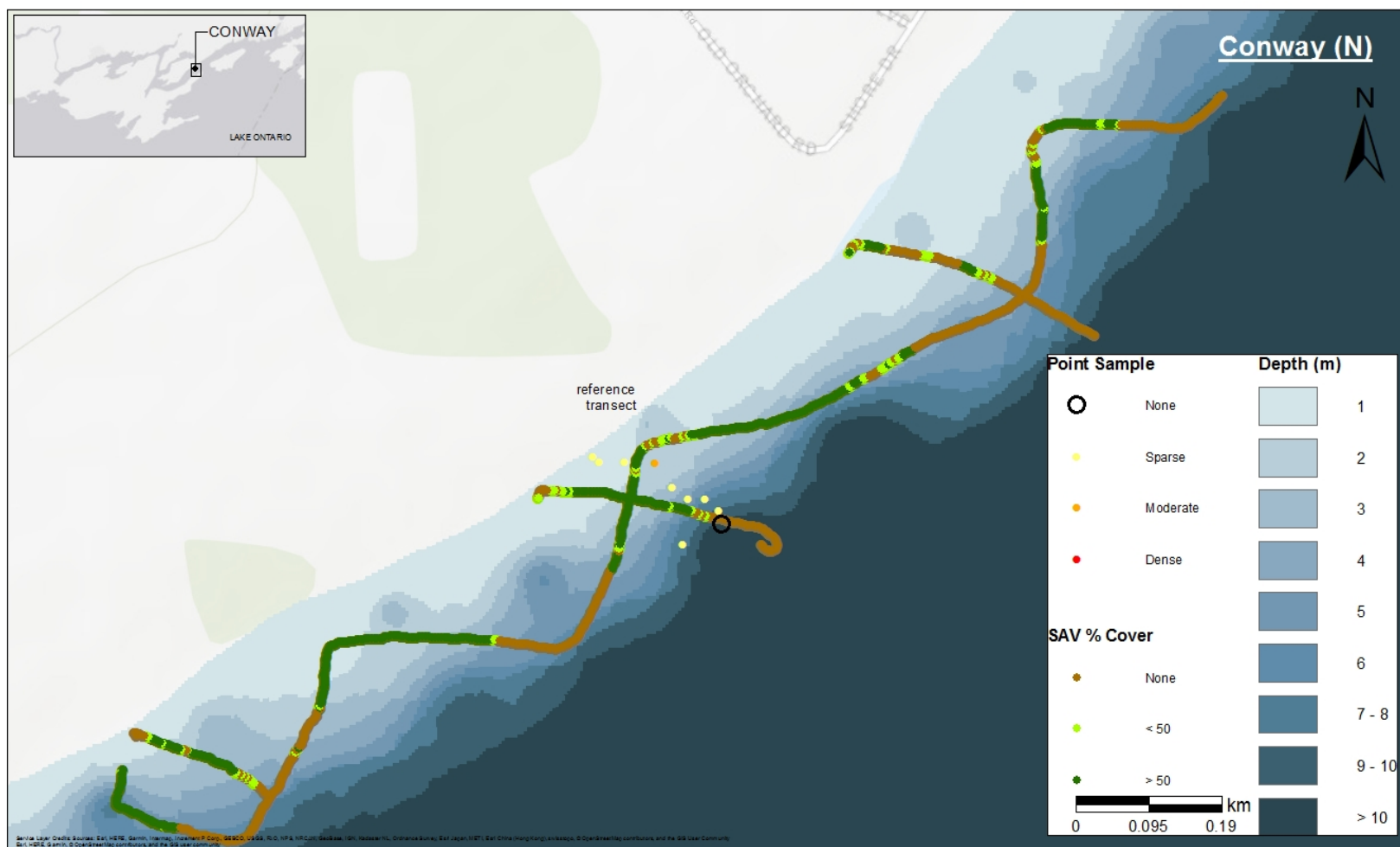


Figure A 10. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for Conway North transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

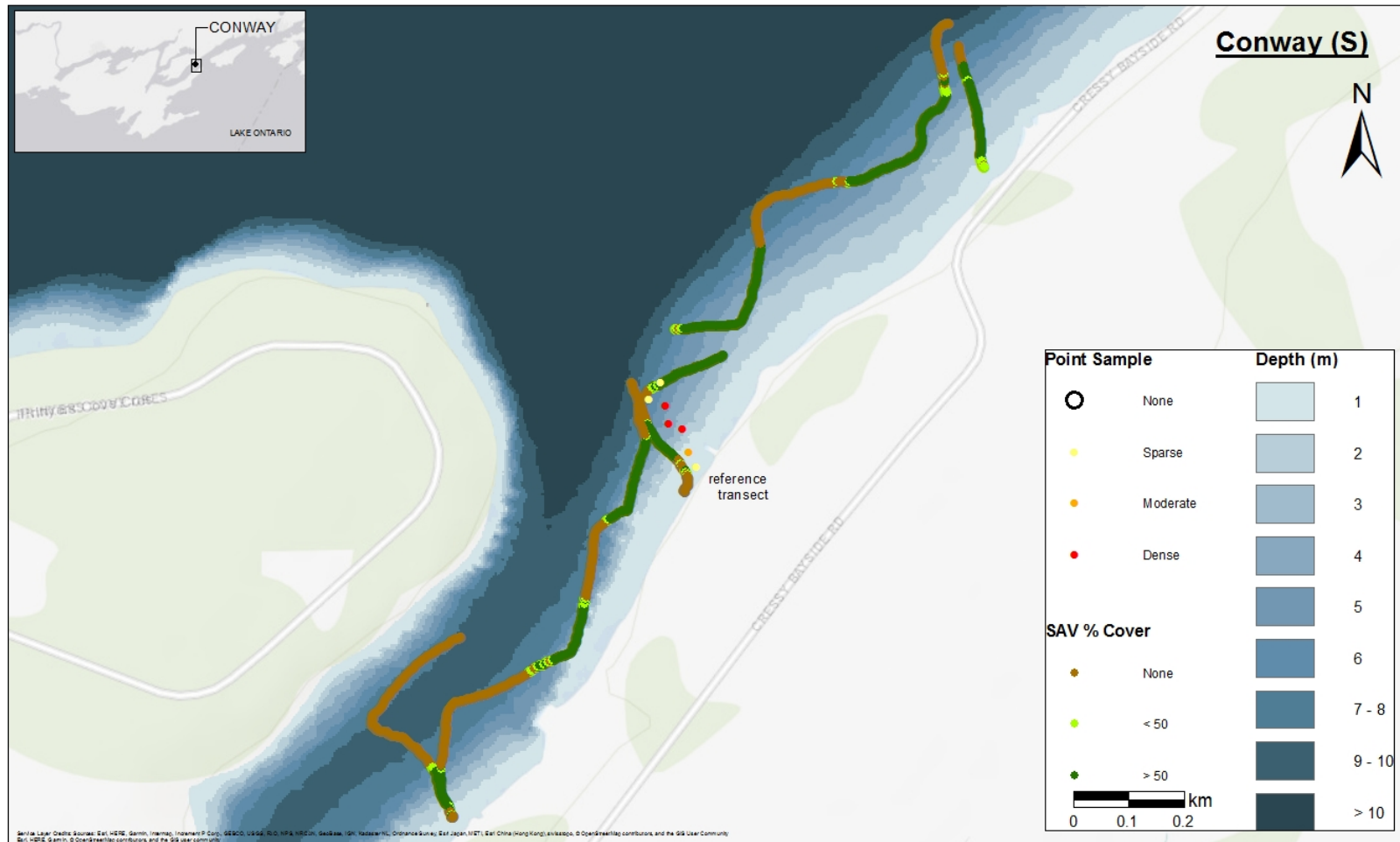


Figure A 11. SAV percent bottom cover as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for Conway South transects. Included are the SAV results from the point sampling using a rake toss. Water depths are at IGLD 85 datum.

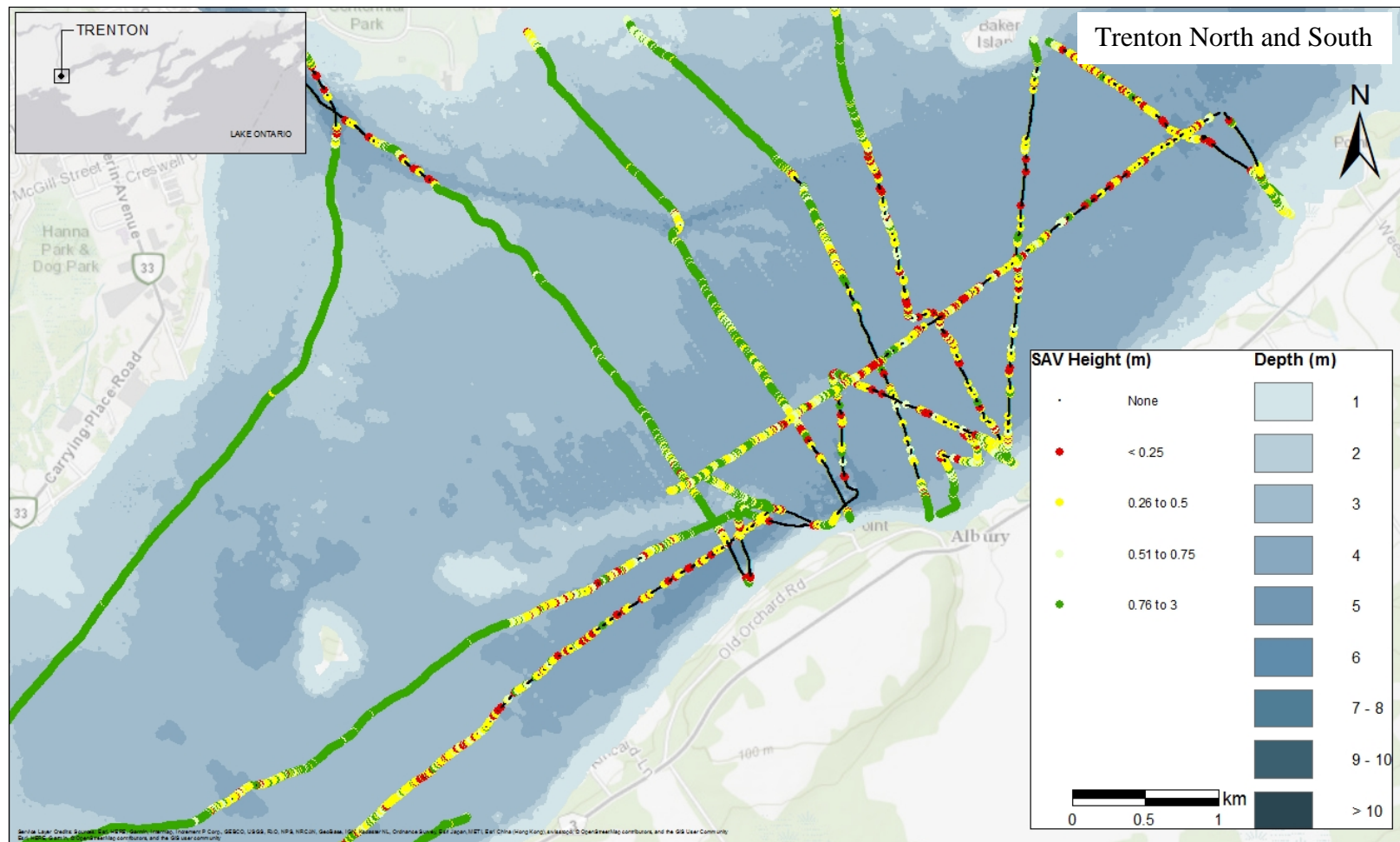


Figure A 12. SAV height as determined by the analysis of the acoustic data from the 2015 submerged aquatic vegetation (SAV) survey for the Trenton North and South transects. Water depths are at IGLD 85 datum.