Toronto Harbour 2012 Shoreline, Substrate, and Submerged Aquatic Vegetation Survey

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TORONTO HARBOUR 2012 SHORELINE, SUBSTRATE, AND SUBMERGED AQUATIC VEGETATION SURVEY

By

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ABSTRACT

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Under the Great Lakes Action Plan, Fisheries and Oceans Canada (DFO) is tasked with completing fish habitat assessments for the Toronto and Region Area of Concern. Baseline information is required for theses assessments, so DFO surveyed the Inner and Outer Harbours, Toronto Islands, and most cells and embayments of Tommy Thompson Park in July 2012 to fill data gaps in nearshore habitat information. The survey collected data on shoreline types, substrate, bathymetry, and submerged aquatic vegetation (SAV). With additional data from the Toronto and Region Conservation Authority, 99% of the shoreline within the study area was classified. Vertical walls were the dominant shoreline type, accounting for 33.6 km (37%) of the study area shoreline, and were typically associated with boating activities. Sand comprised 29% of the shoreline, including Hanlan's Point, and Cherry and Ward's Island beaches. Sand was the dominant substrate type in the Outer Harbour and offshore areas, while silt was generally dominant in the Inner Harbour, embayments, and cells. The highest density of SAV was found among and along the north fringe of the Toronto Islands, while generally sparser and lower-lying SAV was located in the Inner and Outer harbours, embayments, cells, and the offshore area south of Ward's Island. Results from the 2012 survey provide a baseline for future shoreline changes and GIS layers that can be used in fish habitat suitability modelling.

RÉSUMÉ

Leisti, K.E., Gardner Costa, J., MacEachern, J.T., Gertzen, E.L., and Doka, S.E. 2020. Toronto Harbour 2012 shoreline, substrate, and submerged aquatic vegetation survey. Can. Tech Rep. Fish. Aquat. Sci. 3379: viii + 47 p.

Dans le cadre du Plan d'action pour les Grands Lacs, Pêches et Océans Canada (MPO) est chargé d'exécuter les évaluations de l'habitat du poisson dans le secteur préoccupant de la région de Toronto. Puisque des renseignements de base sont nécessaires pour ces évaluations, le MPO a effectué en juillet 2012 un relevé dans les arrière-ports et les avant-ports, dans les îles de Toronto et dans la plupart des cellules et échancrures du parc Tommy Thompson afin de combler les lacunes liées aux données sur les habitats littoraux. Le relevé a permis de recueillir des données sur les types de rivages, le substrat, la bathymétrie et la végétation aquatique submergée (VAS). Grâce aux données supplémentaires de l'Office de protection de la nature de Toronto et de la région, 99 % du littoral de la zone d'étude a été classé. Les parois verticales, qui représentaient 33,6 km (37 %) du littoral de la zone d'étude, étaient le type de rivage dominant et étaient généralement associées aux activités nautiques. Le sable, y compris la pointe Hanlan's et les plages Cherry et Ward's Island, représentait 29 % du littoral. Le sable était le type de substrat dominant dans les avant-ports et les zones extracôtières, tandis que le limon était généralement dominant dans l'arrière-port, les échancrures et les cellules. La plus forte densité de VAS a été observée entre les îles et le long de la frange nord des îles de Toronto, tandis qu'une VAS généralement plus éparse et poussant plus en profondeur a été détectée dans les arrière-ports et les avant-ports, les échancrures, les cellules et la zone extracôtière au sud de Ward's Island. Les résultats du relevé de 2012 fournissent une base de référence pour les changements futurs qui toucheront le littoral et les couches du Système d'information géographique (SIG) qui peuvent être utilisées dans la modélisation de la qualité de l'habitat des poissons.

INTRODUCTION

The Toronto and Region (TH) Area of Concern (AOC) was identified as an AOC by the International Joint Commission in 1987 due to extensive habitat alteration and degradation (Toronto RAP 2013). As part of remediation efforts, Environment and Climate Change Canada (ECCC) has committed resources to ongoing research and monitoring in TH. Fisheries and Oceans Canada (DFO) supports ECCC by undertaking research on fish populations and aquatic habitats within the AOC. As part of this research, DFO will use the information presented in this report to support modelling fish habitat suitability along the central waterfront, including Toronto Islands, Tommy Thompson Park, and the Outer Harbour. This report will also support AOC assessments in the future. In order to assess the condition of fish habitat within the AOC, it is first necessary to map habitat variables throughout the study area, including bathymetry, substrate, and submerged aquatic vegetation (SAV). This report describes the shoreline, substrate, and bathymetry surveys conducted by DFO in summer of 2012 to fill gaps in existing baseline data in the central waterfront area of the AOC. Information on the types of shorelines in various parts of the AOC can inform an evaluation of where habitat may have been lost. Scheduling limitations precluded a full SAV survey in 2012, but SAV acoustic data were opportunistically collected during the bathymetric survey.

METHODS

STUDY AREA

Due to budget and time restrictions, the entire TH AOC was not surveyed; however, the study area spanned from the east end of Ontario Place, west to the mouth of Ashbridge’s Bay (Figure 1). The eastern shore of Tommy Thompson Park formed the eastern boundary and extended south offshore to the 30-m depth contour. The southern boundary followed this 30-m depth contour and the western boundary was positioned 750 m west of Centre Island. Humber Bay was partially covered in the acoustic surveys, however, open coastlines east of the Central Waterfront (within the TH AOC) were not surveyed.

SHORELINE SURVEY

An initial shoreline dataset was provided by the Toronto and Region Conservation Authority (TRCA) in which some of the vertical walls around TH were identified. Prior to the DFO survey, TRCA identified vertical walls along the northern shoreline that covered a length of approximately 23 km (25%) of the total shoreline. For an efficient use of resources in the field, aerial imagery (including ortho-imagery provided by TRCA) were used to classify the TH shoreline prior to field surveys to provide guidance on which shoreline areas would require validation in the field.

Several shoreline types could be easily identified using ortho-imagery, e.g., boulder, cobble, boardwalk, vertical walls, and rip-rap. Public beaches were classified as sandy shoreline, based on known characteristics and prior descriptions. Consequently, field crews were deployed to survey the shoreline segments that could not be classified from aerial imagery and to confirm imagery interpretation when deemed necessary. Further validation from field crews was requested for features identified on the aerial photographs such as the boardwalks.

Most of the field survey was conducted from a 5.2 m Boston Whaler over a two-week period in mid-July, 2012. Field crews identified the start and end of each shoreline segment based on uniform substrate characteristics and recorded the start and stop locations using a Trimble Nomad 900G (Sunnyvale, Calif., U.S.A.). All survey data were entered into the Trimble as well as a shoreline survey field sheet (as a backup, Appendix 1). Geo-referenced photographs of each site were taken using a Panasonic Lumix DMC-TS3 camera in case further classification or verification was required (Figure 2). The land/water interface was classified according to the following categories, which are described in detail in the report prepared for a 2006 shoreline survey completed in Hamilton Harbour (Gardner Costa et al. 2019):

1) Shoreline state (e.g. artificial, natural, island, inflow);
2) Shoreline composition and substrate type (e.g. sheet wall, sand, armor stone, silt/clay);
3) Vegetation type at shoreline or overhang (e.g. grass, shrub, tree)
4) Shoreline structure (e.g. dock, launch, breakwall)
5) Adjacent land use (e.g. park, transportation)

SUBSTRATE MAPPING

All known substrate data were compiled into a single map prior to the commencement of fieldwork (Figure 3). This included samples from ECCC, TRCA, and the Ontario Ministry of Natural Resources and Forestry (OMNRF). These data were used to identify areas in TH that required additional substrate information, essentially gaps greater than 250 m from a previously collected substrate sample. To accomplish this, a circular buffer of 250 m was created in ArcGIS around existing substrate samples, and then sampling points were marked to fill in any remaining gaps.

Identified sites were sampled by field crews during the weeks of July 16th and 23rd, 2012 and substrate samples were collected at each site using a petite Ponar grab with waypoints recorded on either a Garmin GPS 292 or Garmin 60CSx (Figure 4). Geo-referenced photographs were taken of the entire Ponar sample immediately after it was deposited in a sample tray on the boat. A portion of the top 2 to 3 cm of the Ponar sample was transferred into a 125-ml plastic jar and was placed in a cooler onboard the boat. These samples were subsequently stored in a 4 ˚C refrigerator until analyzed by the Aquatic Ecosystem Management Research Division sediment lab at the National Water Research Institute in Burlington.

Samples that were predominantly coarse material (sand and gravel) were run through a sieve tower and each fraction was weighed, while silt and clay dominated samples were sieved and subsequently sampled with a Horiba PARTICA LA-950 laser diffraction particle size analyzer (Table A2.1 for sieve sizes used). Samples were also analyzed for percent loss of ignition (LOI) to determine organic content.

Samples analyzed for LOI were passed through a 2-mm sieve to extract coarse sand, gravel, and other large debris. Samples were then split to the approximate weight of 2 g and were inscribed with their appropriate ID on an aluminum tare. The weight of tare was recorded. Samples were oven dried for an hour at a maintained temperature of 80 °C after which the combined weight of the dry sample and aluminum tare were recorded. Both the sample and tare were placed in the muffler oven at 500 °C for 2 h. From there, samples were placed in the desiccator, which contains preheated moisture absorbing particles, for 15 min. The weight of the combined ash and tare were then recorded and finally, all recorded data was entered in the computer program Loss by Ignition to calculate the percent loss.

Although a total of 58 substrate samples were collected, limitations in time and resources meant that sufficient samples could not be collected to fill all the gaps in the layer; therefore, priority was given to areas in the Inner Harbour that were accessible by boat or canoe for sampling. To avoid traffic from vessels, sampling effort did not include the east and west entrances of the Inner Harbour or the airport restricted zones around the Billy Bishop Toronto City Airport.

At depths where the bottom was not visible from the surface (and if conditions permitted), 10 to 30 s underwater video clips of the bottom were recorded at Ponar sites. The Ocean Systems Deep Blue Pro drop camera was attached to a custom-made 1 m high rebar “pyramid” mount with video recording beginning as it was lowered onto the bottom. The mount provided a steady platform for the camera that was not affected by wave-induced boat movement and also provided a standardized viewing distance to the bottom at all sites. A GeoStamp module connected to a Garmin 60CSx GPS was incorporated into the camera system to provide time, date, and GPS coordinates on the video segments. At deeper depths, lights mounted on the drop camera were used, but their efficacy in turbid water was limited. After the survey, the videos were processed to determine SAV presence, density, height, and species composition. Still images were extracted from video clips using Windows Media Player and the Snipping Tool (Figure 5).

HYDROACOUSTICS: BATHYMETRY AND SUBMERGED AQUATIC VEGETATION

At the time of the 2012 survey, there was no bathymetry information in the cells, embayments, and the northwest corner of the Outer Harbour. Hydroacoustics were used to collect bathymetric and SAV data in these areas. The hydroacoustics equipment was also run during portions of the shoreline survey to opportunistically collect additional SAV data.

A BioSonics DT-X echosounder with a 430 kHz single beam, 6˚ cone-width transducer was pole mounted on the port side of the Boston Whaler, approximately 1 m from the stern. For bathymetry, a series of parallel transects were run from shore to shore where possible with spacing ranging from approximately 10 m to 150 m depending on basin morphometry, weather conditions, and time constraints. Sampling was typically restricted to waters deeper than approximately 1.0 m due to the maneuverability of the Whaler in shallow waters and the near-field properties of the transducer. Shallow water was an issue on the southwest side of Embayment A, the northeast side of Embayment B and throughout Embayment D.

When time and weather conditions permitted, some SAV transects were run in the Inner and Outer Harbours, Tommy Thompson Park (TTPK), and an area of Humber Bay. These transects generally ran parallel with the shoreline and had a "zig-zag" pattern to detect the edge of the SAV beds. Under wavy conditions, transects were run either into or with the waves in order to minimize transducer movement. Since a full SAV survey was beyond the scope of this project, there was no attempt to determine SAV species composition through SAV point sampling. SAV presence was sampled opportunistically during the survey at shoreline and Ponar sampling locations using a variety of methods (Figure 6). These included visual assessment and underwater video when water clarity was sufficient and retrieval of SAV in Ponars or on the anchor when moored at point sampling locations. Underwater video proved to be the best method to determine SAV absence or presence during this survey due to the camera's large angle of view combined with high water clarity at most sampling locations. Data from these sources were used post-hoc to informally ground-truth the acoustic data. Locations where *Cladophora* was present were noted since it was anticipated that hydroacoustics would detect this type of algae (Depew et al. 2011).

The acoustic data were analyzed using Visual Habitat v2.0.2.9744 (BioSonics 2015), a two-stage software program for bottom depth and SAV detection. A rising edge threshold of -30 dB was initially used to detect the bottom, but this was subsequently adjusted to -38 dB to improve the fit of the bottom detection when viewed on the echograms. Plant detection settings included a length criterion of 10 cm with a maximum plant depth of 10 m with SAV percent cover calculated over a 10 ping report interval. All echograms were reviewed for goodness-of-fit of both the bottom and plant canopy with manual edits to these lines when required as detailed in the Visual Habitat User Guide (BioSonics 2016) (Example echogram in Figure 7). Several iterations were run with the plant height threshold varying between 0.10 m and 0.25 m since differences between the bottom and plant detection algorithms can result in plant detection errors. To determine the most appropriate plant height threshold, the various iterations were reviewed in ArcGIS along with the SAV point sampling data gathered during the survey. Through visual assessment, a plant height threshold of 0.15 m appeared to provide the best fit of the acoustic output to the SAV absence/presence data from the point sampling.

The Visual Habitat software calculated bottom depth, plant height, and SAV percent cover for each 10 ping interval, which was then output into a GIS readable file as a series of point samples along each of the transects (acoustic point samples). The interval distance between these acoustic point samples was dependent on boat speed, but typically varied between 2 and 4 m.

To compare hydroacoustic results across areas, we divided the TH into 11 analysis sectors (Figure 8), based on discrete basins, exposure, bathymetry, and water clarity. These sectors included the Inner Harbour (IH), Toronto Islands (TI), Outer Harbour (OH), Lake Ontario (LO), Humber Bay (HB), East Cove (ECo), the embayments A, B, and C (EA, EB, EC) and cell 2 and 3 (C2, C3). We calculated the mean (± standard deviation; SD), inter-quartile range, minimum, and maximum values for depth (m) and SAV percent cover for all the acoustic point samples that were on the hydroacoustic transects within each sector. Hydroacoustic sampling intensity varied considerably among the sectors, with the greatest proportion of all transects located in the Outer Harbour, while the fewest transects were in embayments A and B.

RESULTS

SHORELINE SURVEY

Using a combination of aerial imagery and field surveys, with additional data provided by TRCA after the 2012 survey, a total of 99% of the TH shoreline in the study area was classified (~ 91.1 km; Table 1). The dominant shore state along the TH shoreline was artificial, with vertical walls accounting for 37% (33.6 km) of shoreline composition along the TH shoreline (generally associated with boating and shipping activities; Figure 9). Sand was the most common substrate at 29% (26.5 km) of shoreline and was typically found in the embayments, the Long Pond area, Hanlan’s Point, Ward’s Island, and Cherry Beaches. Rubble and boulder accounted for 20 % (18.4 km) of the shoreline and was predominately located along TTPK. Approximately 1% (~500 m) of the shoreline remains unclassified (Table 1) and these segments are scattered throughout the AOC and are too small to see on the Figure 9 map.

SUBSTRATE MAPPING

A total of 58 benthic substrate samples were processed (Table 3, Figure 10). The dominant substrate type among samples was sand, which could be classified as ‘soft’ (a particle size equal to or smaller than gravel) substrate, which based on previously collected substrate samples, was expected for all of TH (Figure 9). At six sites, a visual assessment of the substrate was made because it was too coarse or hard to be sampled with the Ponar (Table A2.2). Samples ranged from 100% gravel to 73% clay (Table 3). The Inner Harbour was composed primarily of silt and clay (mud), while all other sites were dominated by sand. Only three of the sites (LO and EB) were composed of 100 percent gravel. LOI ranged from 0.5-13.1% for all sites and was generally higher in the Inner Harbour, which was primarily made of softer substrates, such as clay and silt. The sixteen samples from the IH sector had the highest mean organic content at 9.3 ± 3.0 %, followed by the samples from the embayments (4.6 ± 3.1%), OH and TI sectors (3.1 ± 1.8%, n = 6 and 3.0 ± 1.7%, n = 17, respectively), and LO with the lowest LOI (1.0± 0.7%).

HYDROACOUSTICS: BATHYMETRY AND SAV

Hydroacoustic transect data were incorporated into an existing digital elevation map of Toronto Harbour, of which the methods will be described in a future report (J. Dosen, Fisheries and Oceans Canada, Burlington, Ontario, personal communication, 2019; Figures 11 and 12). Point sampling estimated SAV among the Toronto Islands and in the Inner and Outer Harbours, TTPK and offshore of the Toronto Islands (Figure 13). Results of SAV point samples are not discussed but summarized in Table A3.1). The determination of SAV absence with Ponar sampling is problematic due to the small sample area, which would likely miss patchy or sparse SAV, so results using underwater video are more definitive. Unfortunately underwater video data are lacking in many locations, particularly the Inner Harbour due to scheduling, weather, water clarity, equipment issues, and the time intensive nature of processing video data.

Visual Habitat software was also used to determine SAV percent cover (Figure 14) and plant height (Figure 15). Most moderate to dense SAV was found within and along the north shore of the Toronto Islands while the embayments, cells, and Humber Bay generally contained sparse to no SAV. Much of the harbour has SAV that are less than 0.5 m in height, with taller SAV predominately found to the north and among the Toronto Islands.

Of the eleven analysis sectors (Figure 16), there were only four sectors in the harbour (EA, ECo, IH, TI) where SAV was present at greater than 50% of all the acoustic point samples (Table 2). The TI had the highest prevalence of SAV percent cover at 97%, while in EB and HB, SAV percent cover was 20%.

When SAV was present, the mean water depth ranged from a low of 1.6 ± 0.6 m at EB to a high of 7.6 ±1.9 m at IH with a maximum depth of SAV colonization of 13.2 m in LO. Six of the eleven sectors (C3, ECo, IH, OH, LO, HB) recorded SAV at water depths greater than 7 m (Figure 17, Figure 18). SAV density (zeroes from areas with no SAV were not included) was highest in TI with a mean SAV percent cover of 84.4 ± 24.7% and lowest in C2 at 27.0 ± 22.9%. Other sectors with <50% mean SAV percent cover included C3, EA, EB and HB.

Mean SAV height within the study area was 0.5 ± 0.4 m, (n = 19694). SAV at deep sites (> 7 m) was more low-lying than at shallower sites, where the mean SAV height for deeper sites in the harbour was 0.3 m. Mean SAV height ranged from a high of 0.8 ± 0.5 m in TI to a low of 0.2 ± 0.1 m in EA with six of the sectors recording mean height below 0.3 m (Figure 19, Figure 20).

Using both SAV presence and absence data, boxplots of SAV percent cover (Figure 17, Figure 18) as a function of water depth reveal varying patterns across analysis sectors.

Unimodal distributions of mean cover values were found in EC, IH, and LO while bimodal distributions were present in ECo and OH. Generally there was a decline in mean SAV percent cover with increasing water depth, with the exception of C3 and TI. In C3, there was a relatively constant < 20% across the depth range, dropping to 0% at 10+ m. In TI, SAV percent cover was typically >80% across all available depth ranges (0.9 – 6.7 m). There were three sectors where there was no SAV along the majority of transects; therefore mean SAV percent cover values in these sectors were close to zero (C2, EB, HB). The depth of highest mean SAV percent cover varied from 1.0-2.0 m (EA, EC), 2.0-3.0 m (ECo), 3.0-4.0 m (C3), 4.0-5.0 m (OH, LO) and across a range of depths for IH (2.0-8.0 m) and TI (1-5, 6.0-7.0 m; (Figure 17, Figure 18).

Boxplots of SAV height as a function of water depth (Figure 19, Figure 20) indicated that when SAV was present, it was predominantly low lying (<0.3 m, 3rd quartile) across all depths in the embayments, cells, Eco, and HB. In both OH and LO, mean SAV height peaked between 4.0-5.0 m, at 4.0-6.0 m in IH and 6.0-7.0 m in TI. While the tallest SAV (3.4 m) recorded for the survey was found in the 5.0-6.0 m depth range in TI, the greatest mean SAV height was in the 3.0-7.0 m depth range in IH.

DISCUSSION

As a result of this survey, 99% of the shoreline in Toronto Harbour has been classified, a substantial increase from the 25% that was classified prior to this work. These data will be used to create substrate layers as well as provide additional information to create a digital elevation model for the TH AOC. The SAV data collected will be used to test and validate a SAV model for the TH AOC (Midwood et al. in prep.). The created substrate, SAV, and elevation layers will be used to assess habitat suitability for the AOC in the evaluation of the habitat related Beneficial Use Impairment (#14).

The samples collected and compiled for Toronto Harbour show substrates were predominately silt and clay in the Inner Harbour, and sand in the Outer Harbour. Harder substrates (e.g., gravel) typically appear close to shore and along the western edge of the study area. The organic content in the substrate was highest in the IH and was likely a result of the deposition of organics and fine sediments from the Don River plume. The lowest percentage of organics was found in LO and is likely due to the higher wave energy resulting in coarser sediments and the flushing of organics. These results will provide context for the development and validation of a SAV model for the Toronto waterfront (Midwood et al. in prep).

If there is no need for future sampling, any gaps in the substrate data can be accepted as is and will be used to create an interim spatial layer of substrate. If further data resolution is needed, there are three sources of qualitative and classifiable acoustic data that have not been incorporated into the substrate database nor discussed in this report (Figure 21):

1) Visually delineated uniform substrate patches from the graduate work of Hennyey (2006);

2) Roxann data (hydro-acoustics data that can be classified into three broad bottom types); and
3) Multibeam backscatter data from CHS bathymetric surveys.

Each of these datasets presents special problems in assimilating the data into a single dataset. The Roxann and multibeam classifications, for example, will be simple descriptors (i.e. sand, mud, hard), and may not compare adequately with existing data classifications (and have not been validated with point samples). The Roxann data have been classified mostly into coarse sand, even in the Inner Harbour, where most of the grab samples show mostly silt and clay. However, these classifications could be viewed as simply homogeneous groupings, and substrate compositions could be assigned as a summary of nearby existing data. Similarly, visually delineated patches report only the most dominant substrate group.

Previously, Thiessen polygons have been created around substrate sample points that contain gravel and finer substrates. We could use a method similar to Doolittle et al. (2010) by adding a buffer to point samples and overlaying the Thiessen polygon with shoreline segments. Visual assessments from shoreline surveys have been used as substrate samples to fill in the nearshore areas, which are usually not heavily sampled. Therefore, creating a substrate layer with Thiessen polygons would create a reasonable estimate of the substrate types in the central Toronto waterfront area and fill in most of the data gaps, particularly if these data were paired with buffered shoreline classifications.

Acoustic water depth data collected during the 2012 survey have been incorporated into the most current version of the bathymetric layer for TH. This layer should be updated to reflect ongoing restoration efforts in TH (i.e., changes to geomorphology in Embayment D) and address shallow and other areas that hydroacoustics were unable to sample during the 2012 survey.

Hydroacoustic SAV data were opportunistically collected during the 2012 survey and identified the presence of SAV in all eleven analysis sectors of the harbour to a maximum water depth of 13.2 m. All of the SAV recorded at depths > 7 m were less than 0.3 m in height. As previously mentioned, the Visual Habitat software uses different algorithms to delineate the bottom and SAV canopy and this presents challenges when there are low-lying (<0.3 m) SAV. In these circumstances, errors in SAV detection can occur as a result of confusion between low-lying SAV and the sediment-water interface. It is therefore important to extensively ground-truth hydroacoustic data, which can be difficult if sparse SAV is encountered. Unfortunately, ground-truthing specifically for SAV was beyond the scope of this survey, so the low-lying SAV reported in the deeper waters in C3, ECo, IH, LO, and HB may be suspect. These false-positives detections are likely more prevalent in deeper waters or highly turbid locations where light penetration to the bottom is substantially reduced and therefore limits SAV growth. Therefore context is important when processing hydroacoustic data and it is recommended that a visual inspection is completed for hydroacoustic outputs to remove any errors.

Another issue with low-lying macrophytes is the difficulty in distinguishing between the algae *Cladophora* and other low-lying SAV, such as *Chara* species. Increased levels of phosphorus have been linked to nuisance levels of *Cladophora* for major cities bordering the Great Lakes (Herbst 1969). Reductions in phosphorus loadings in the early 1970s led to a decline in the biomass of *Cladophora*, but increased water clarity since the invasion of dreissenid mussels has resulted in the expansion of *Cladophora* into deeper waters, thus offsetting the nutrient related declines (Auer et al., 2010). More recent research has detailed benefits of *Cladophora* as an ecological engineer by providing habitat and refugia for microfauna and modulating biogeochemical cycles (Zulkifly et al. 2013). However, more research is required to determine the habitat suitability of *Cladophora* for freshwater fishes. Since *Cladophora* can become a nuisance species, extensive point sampling should be conducted in areas where the presence of *Cladophora* is suspected.

Although there are many factors that contribute to the distribution and density of SAV, the prime determinants of SAV presence are exposure and water clarity. A generalized SAV model developed for the 2005 Lake Ontario-St. Lawrence River Study predicted SAV when fetch values fell below 5 km (Doka et al. 2005). In the present study, SAV was found in more exposed areas, such as LO, with the density and height of SAV peaking between 3 m to 7 m water depths. This type of shift in the distribution of SAV may reflect the more exposed nature of the LO sector, which likely experiences increased disturbance by wave action and therefore scouring in shallower waters (1 m – 3 m) where SAV is usually more prevalent. Factoring in the influence of wind and wave action at different water depths will therefore be critical for the development of a regionally derived SAV model.

Previous studies have determined relationships between Secchi depth and the maximum depth of SAV colonization (Chambers and Kalff 1985; Hudon et al. 2000). Unfortunately, Secchi depths were not measured at the time of the survey, although many locations in TH have Secchi depths of 5.0 m (Currie et al. 2015). These Secchi depths are substantially higher than found in other Areas of Concern and can have a significant impact on the maximum depth that SAV can achieve. In Hamilton Harbour, the 2012 seasonal mean Secchi depth was 2.4 m (± 1.2 SD, range 0.8-5.5 m) and the mean maximum depth of SAV was 2.8 m (± 0.6 SD, range 1.4-3.9 m, n = 30; Leisti et al. 2016). Between 1995 and 2007 in the upper Bay of Quinte, the mean Secchi depth was 1.8 m (± 0.7 SD, range 0.5-4.2 m, n = 169) and the mean maximum depth of SAV was 3.5 m (± 0.6, range 2.6–4.5 m, n = 18; Leisti et al. 2012). As noted, Secchi depths in TH are generally higher and therefore SAV would be expected to colonize at deeper water depths when compared to other Areas of Concern (as was observed).

Based on their water depth and limited exposure, it was anticipated that the cells and embayments would have higher SAV distribution and density than was recorded during the 2012 survey. Unlike the main harbour, the embayments are sheltered from Lake Ontario and shallow. These areas can have poor water clarity as a result of disturbance either by dredging and dumping or carp, and a lack of a SAV seed bed as a result of ongoing dumping of dredged material. Regardless of the mechanism, these areas do not support extensive stands of dense stands of SAV; however, these areas do support diverse fish communities and may therefore provide a thermal refuge (Hlevca et al. 2015) rather than structured habitat and refuge from predators.

With proper ground-truthing, hydroacoustics are an ideal tool to rapidly determine the distribution and density of SAV. Point sampling is important for both verifying the acoustic results and determining species composition, since hydroacoustics are unable to distinguish SAV species. Alternative protocols need to be developed to sample SAV in water depths less than 1 m due to the limitations to distinguish signal from noise in shallow waters or in areas that are inaccessible by boat and underwater video.

GENERAL CONCLUSIONS

With 99% of the shoreline classified, the predominant shoreline composition is vertical wall (37%) and the dominant substrate is sand at (29%) of the total shoreline length (91.6 km) within the study area. Sand dominated the substrate types in the Outer Harbour and offshore of the Toronto Islands while silt was located in the Inner Harbour, cells and embayments. SAV was found throughout the harbour, but was typically sparse and low-lying. The exception was dense and taller SAV located in the shallower fringing areas to the north and among the Toronto Islands. The 2012 survey of the TH shoreline, substrate, and SAV was used to fill in data gaps in order to develop harbour-wide GIS layers to be used in future habitat assessments. These data will be used to either create or validate: depth, vegetation, substrate, and shoreline layers. These layers will specifically be used in the Habitat Evaluation/Assessment Tool to evaluate restoration projects completed in the Toronto and Region AOC since its designation.

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Table 1. Shoreline composition in Toronto Harbour. Segments were compiled and classified by the class type.

Class	Length (km)	%
Wall	33.7	36.7
Sand	26.5	28.9
Boulder	12.4	13.5
Cobble	8.1	8.9
Rubble	6	6.6
Bedrock	2.5	2.7
Gravel	1.2	1.3
Boardwalk	0.8	0.9
Unclassified	0.5	0.5
Total Length	**91.6**	**100**

Table 2. Summary statistics by analysis sector (Site) for water depth, submerged aquatic vegetation (SAV) percent cover, SAV presence or absence, and SAV height as determined by the analysis of hydroacoustic data from the Toronto Harbour 2012 survey.

				Depth (m)			SAV Percent Cover (%)			SAV Height (m)		
Site	**SAV Presence Absence**	**# Samples (n)**	**Proportion SAV**	**Mean**	**1st–3rd Quartile**	**Range**	**Mean**	**1st–3rd Quartile**	**Range**	**Mean**	**1st–3rd Quartile**	**Range**
Whole Harbour	Present	20781	0.5	4.7±2.4	2.8–6.2	0.4–13.2	65.9±34.5	30–100	10–100	0.5±0.4	0.2–0.6	0.2–3.4
	Absent	19694		6.1±3.6	2.8–9.9	0.2–16.8						
Cell 2	Present	441	0.2	1.9±0.4	1.7–2.0	1.1–4.4	27.0±22.9	40	10–100	0.2±0.1	0.2–0.3	0.2–1.1
	Absent	1533		2.0±0.4	1.8–2.1	1.2–4.5						
Cell3	Present	1609	0.5	5.1±3.2	1.5–8.0	0.9–11.0	46.1±31.6	20–70	10–100	0.2±0.1	0.2–0.3	0.2–1.0
	Absent	1949		7.5±3.7	4.5–10.5	0.9–11.9						
Embayment A	Present	386	0.6	3.5±1.2	2.7–4.4	1.0–5.8	45.3±28.3	20–70	10–100	0.2±0.1	0.2–0.2	0.2–0.7
	Absent	226		4.1±1.0	3.4–4.9	1.4–5.8						
Embayment B	Present	152	0.2	1.6±0.6	1.1–2.2	0.8–2.6	28.8±23.2	40	10–100	0.2±0.1	0.2–0.3	0.2–0.5
	Absent	627		1.9±0.5	1.6–2.4	0.7–2.7						
Embayment C	Present	1636	0.4	3.0±1.6	1.8–4.5	0.4–6.6	54.3±34.6	20–90	10–100	0.3±0.1	0.2–0.3	0.2–1.2
	Absent	2288		4.1±1.5	3.2–5.2	0.2–6.5						
East Cove	Present	710	0.6	5.3±2.1	3.8–6.5	0.7–10.6	52.7±32.2	20–80	10–100	0.3±0.1	0.2–0.3	0.2–1.2
	Absent	536		7.4±2.9	5.5–10.4	0.8–11.7						
Inner Harbour	Present	2984	0.7	7.6±1.9	6.8–8.9	1.0–10.7	75.5±32.4	50–100	10–100	0.7±0.6	0.2–1.0	0.2–3.0
	Absent	1236		9.7±2.0	9.1–11.0	0.2–12.0						
Outer Harbour	Present	4714	0.5	4.9±2.2	3.0–6.3	0.8–6.7	65.1±33.8	30–100	10–100	0.4±0.3	0.2–0.5	0.2–2.6
	Absent	4998		7.6±3.6	4.7–11.1	0.7–12.4						
Toronto Islands	Present	5175	1.0	3.5±1.0	2.8–4.1	0.9–6.7	84.4±24.7	80–100	10–100	0.8±0.5	0.4–1.0	0.2–3.4
	Absent	170		3.5±0.9	3.0–3.8	0.8–5.9						
Lake Ontario	Present	2376	0.4	5.3±1.7	4.2–6.1	1.2–13.2	58.7±35.9	20–100	10–100	0.4±0.3	0.2–0.4	0.2–2.2
	Absent	3735		5.5±3.1	2.9–7.5	0.2–16.8						
Humber Bay	Present	596	0.2	4.5±2.4	2.7–6.1	1.5–10.2	43.4±31.7	20–70	10–100	0.3±0.2	0.2–0.4	0.2–1.3
	Absent	2396		6.4±3.7	3.2–10.5	1.3–13.2						

Table 3. Particle size analysis of the Ponar samples collected around Toronto Region Area of Concern. Results are displayed as percent composition. Loss on ignition (LOI) analyses were also completed to determine the amount of organic content within a sample.

Sector	Sector name	Latitude	Longitude	Percent Composition (%)				LOI %
				Gravel	Sand	Silt	Clay	
EA	Embayment A	43.62038	-79.3410		96	2	2	5.6
EB	Embayment B	43.62366	-79.3424	100				2.3
EB	Embayment B	43.62712	-79.3415		100			9.1
EB	Embayment B	43.62308	-79.3392		99	1		3.5
ECo	East Cove	43.62122	-79.3249		97	2	1	3.3
IH	Inner Harbour	43.63321	-79.3927		5	85	10	7.7
IH	Inner Harbour	43.62813	-79.3708		4	79	17	9.1
IH	Inner Harbour	43.63467	-79.3604		3	78	19	10.7
IH	Inner Harbour	43.63467	-79.3604		6	78	16	10.1
IH	Inner Harbour	43.63712	-79.3784	1	1	77	21	13.1
IH	Inner Harbour	43.63467	-79.3759		6	77	17	11.6
IH	Inner Harbour	43.64043	-79.3683	3	2	77	18	9.7
IH	Inner Harbour	43.63501	-79.3648	3	4	76	17	8.2
IH	Inner Harbour	43.62988	-79.3618		10	74	16	12.5
IH	Inner Harbour	43.62988	-79.3618	3	2	69	26	9.2
IH	Inner Harbour	43.63188	-79.3639		3	41	56	11.5
IH	Inner Harbour	43.63501	-79.3648	1		26	73	11.0
IH	Inner Harbour	43.62441	-79.3697		100			1.3
IH	Inner Harbour	43.62813	-79.3708		100			1.4
IH	Inner Harbour	43.63381	-79.3544		99	1		1.0
IH	Inner Harbour	43.63660	-79.3562	3	90	4	3	5.4
IH//TI	Inner Harbour/Toronto Islands	43.62379	-79.3762		100			1.5
IH/TI	Inner Harbour/Toronto Islands	43.62471	-79.3657		100			4.6
LO	Lake Ontario	43.62375	-79.3600	100				N/A
LO	Lake Ontario	43.62023	-79.4072	100				N/A
LO	Lake Ontario	43.61025	-79.3664		3	77	20	7.7
LO	Lake Ontario	43.61529	-79.3553		100			0.6
LO	Lake Ontario	43.61510	-79.3605		100			1.1
LO	Lake Ontario	43.61830	-79.3683		100			0.9
LO	Lake Ontario	43.61025	-79.3664		100			0.7
LO	Lake Ontario	43.61362	-79.3962		100			0.5
LO	Lake Ontario	43.61025	-79.3664		100			1.4
LO	Lake Ontario	43.61729	-79.3644		100			0.9
LO	Lake Ontario	43.61409	-79.3664		100			0.6
LO	Lake Ontario	43.61233	-79.3757		100			2.7
LO	Lake Ontario	43.62070	-79.3573		99	1		0.7
LO	Lake Ontario	43.61851	-79.3540		99	1		0.9
LO	Lake Ontario	43.61233	-79.3620		99	1		0.5
LO	Lake Ontario	43.63068	-79.4061		99	1		1.9
OH	Outer Harbour	43.64315	-79.3223		99	1		3.5
OH	Outer Harbour	43.63746	-79.3240		99	1		0.9
OH	Outer Harbour	43.64258	-79.3329		94	3	3	3.7

Sector	Sector name	Latitude	Longitude	Percent Composition (%)				LOI %
				Gravel	Sand	Silt	Clay	
OH	Outer Harbour	43.63594	-79.3314	1	95	2	2	5.5
TI	Toronto Islands	43.61922	-79.3739		100			2.3
TI	Toronto Islands	43.61628	-79.379		100			1.4
TI	Toronto Islands	43.6192	-79.3895		100			1.9
TI	Toronto Islands	43.61598	-79.3846		100			1.8
TI	Toronto Islands	43.62074	-79.382		100			2.4
TI	Toronto Islands	43.6213	-79.3821		100			1.9
TI	Toronto Islands	43.61901	-79.3788		100			1.6
TI	Toronto Islands	43.62276	-79.3838		100			3.7
TI	Toronto Islands	43.62152	-79.366		100			5.8
TI	Toronto Islands	43.6207	-79.3707		100			2.2
TI	Toronto Islands	43.62476	-79.3624		99	1		3.1
TI	Toronto Islands	43.62428	-79.3889		99	1		1.6
TI	Toronto Islands	43.62645	-79.3877		99	1		2.1
TI	Toronto Islands	43.61418	-79.3856		99	1		7.4
TI	Toronto Islands	43.62716	-79.3579		98	1	1	3.8

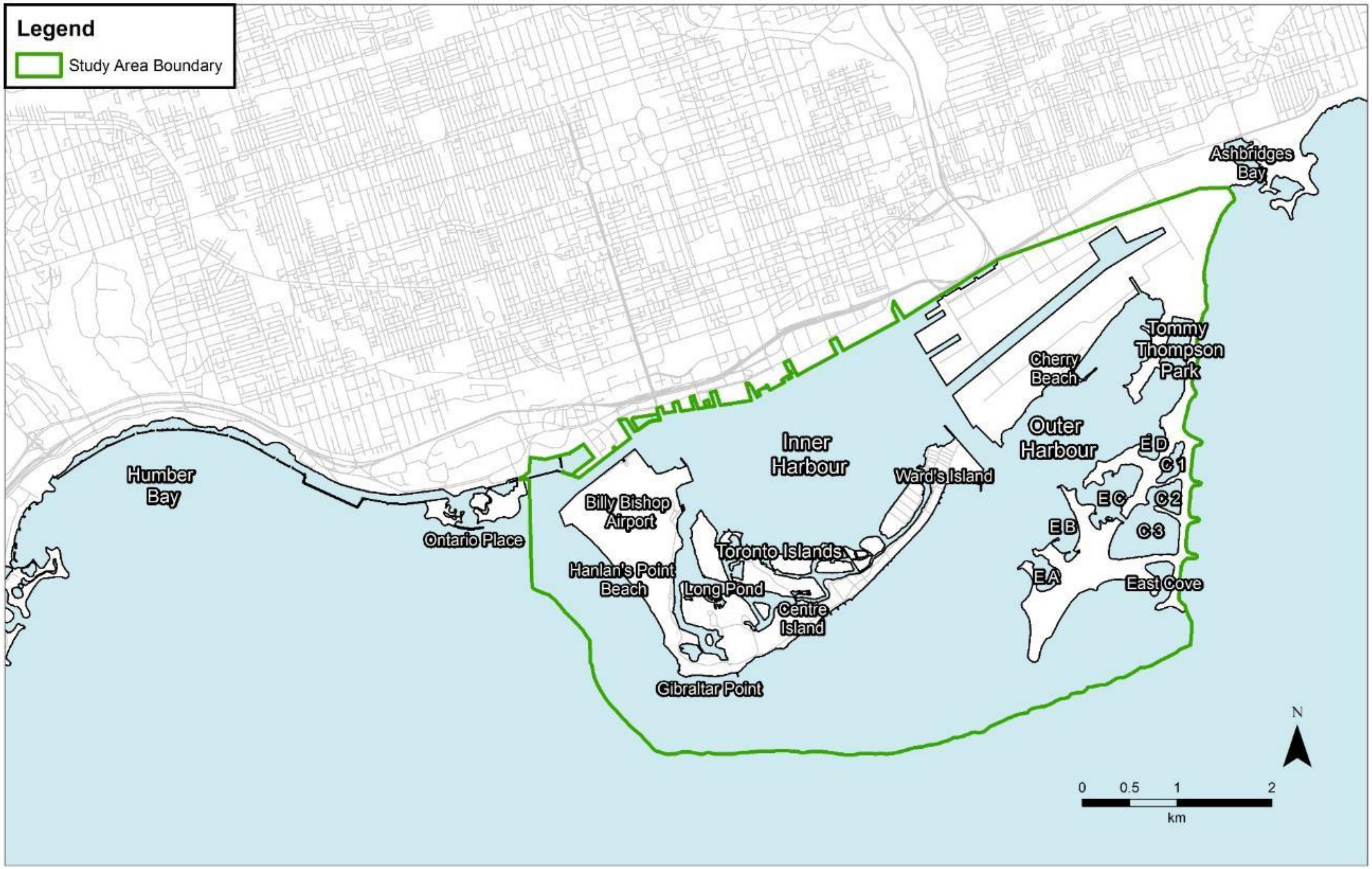

Figure 1. Map of the Toronto Harbour study area showing locations mentioned in this report. Embayments A, B, C and D are located in Tommy Thompson Park, along with Cells 1, 2, and 3. The boundary for the 2012 study area is outlined in green, with limited hydroacoustics run in Humber Bay during the survey.

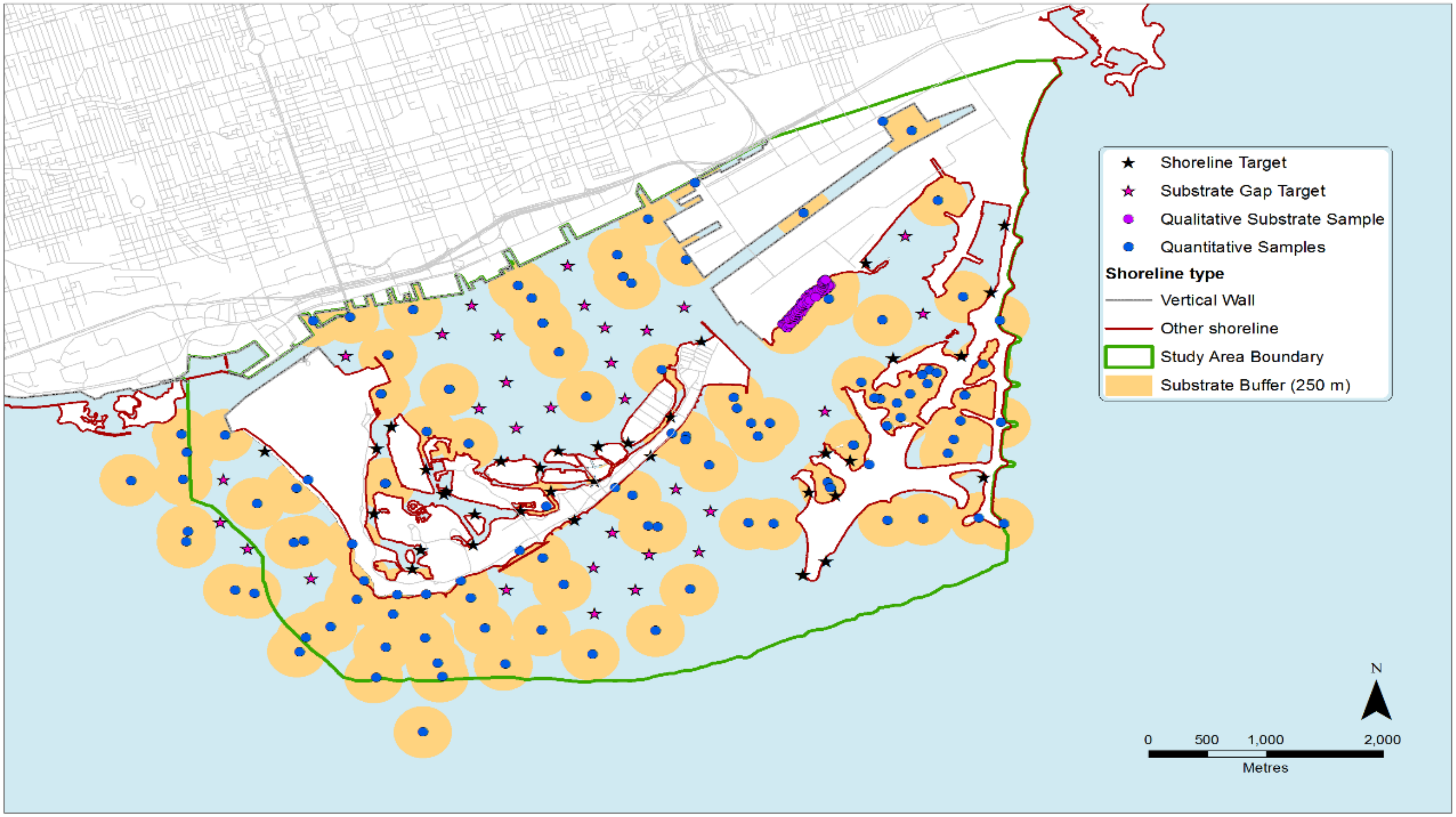

Figure 2. Project study area, existing substrate, and shoreline data and 2012 survey targets. Existing data provided by the Toronto and Region Conservation Authority (TRCA), Ontario Ministry of Natural Resources and Forestry, and Environment and Climate Change Canada. Existing substrate data farther than 500 metres from the study area boundary were excluded. TRCA Gibraltar Point samples group silt and clay into a single class. Additional qualitative information (e.g., hard substrates) were available for several of the quantitative points. Shoreline targets are meant to fill gaps in the substrate coverage and also confirm classifications derived from aerial photos. Gap targets are specific to filling gaps in the existing shoreline coverage.

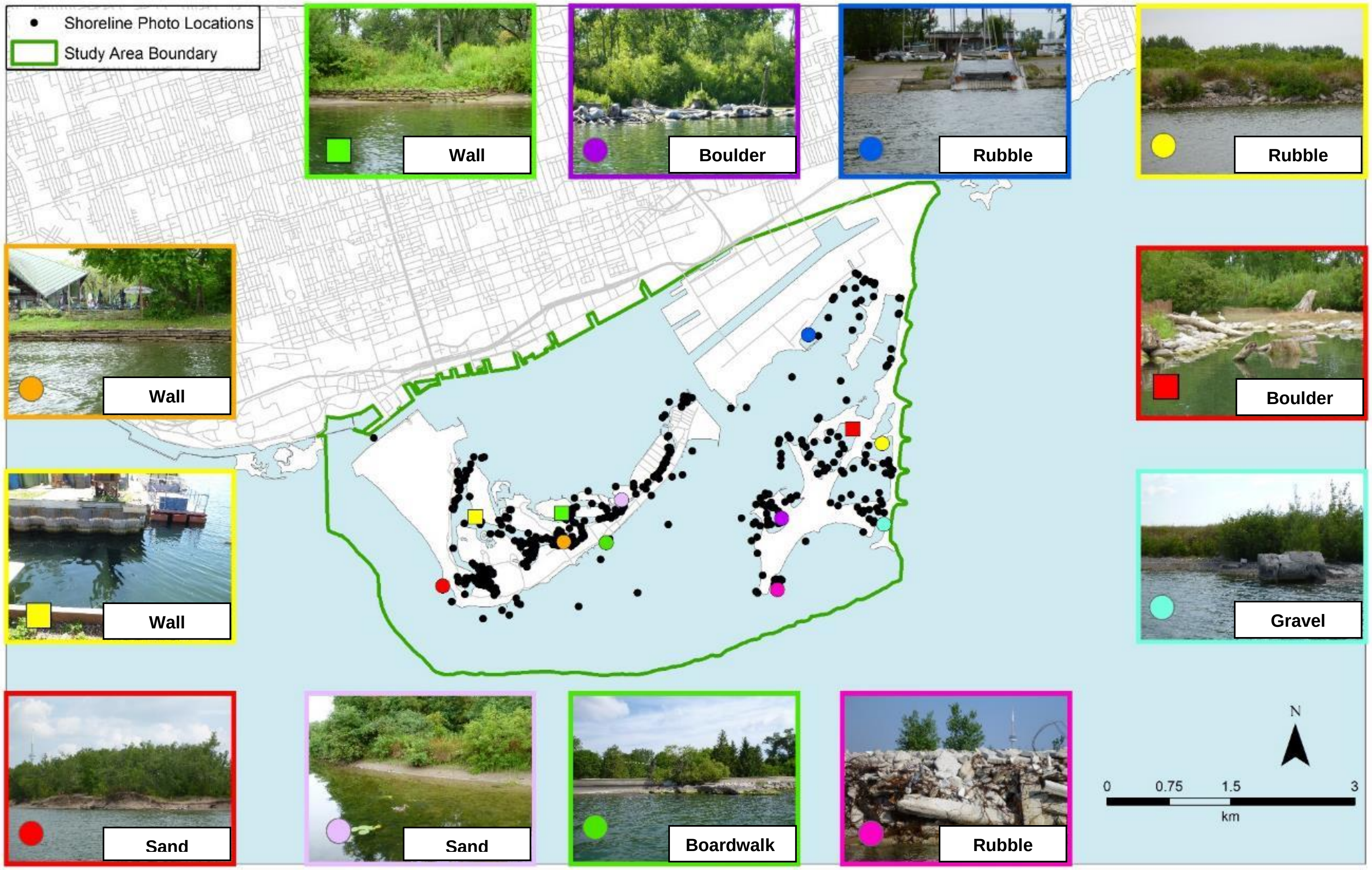

Figure 3. Location and examples of geo-referenced shoreline photos taken during the 2012 Toronto Harbour survey with associated shoreline composition types.

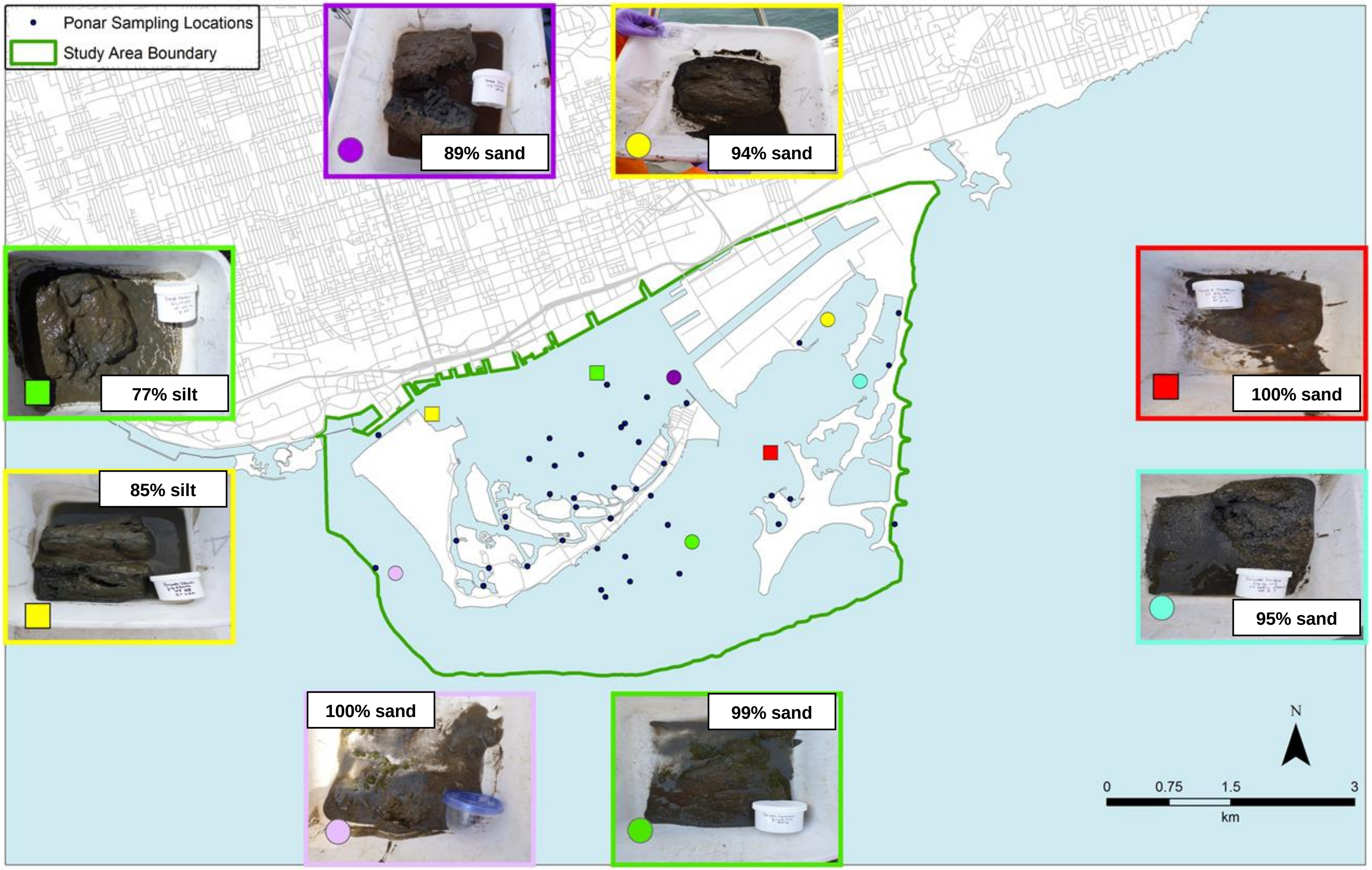

Figure 4. Locations and examples of geo-referenced Ponar sample photos taken during the 2012 Toronto Harbour survey. Includes the percent composition of the dominant sediment as determined by the Environment Canada sedimentology lab.

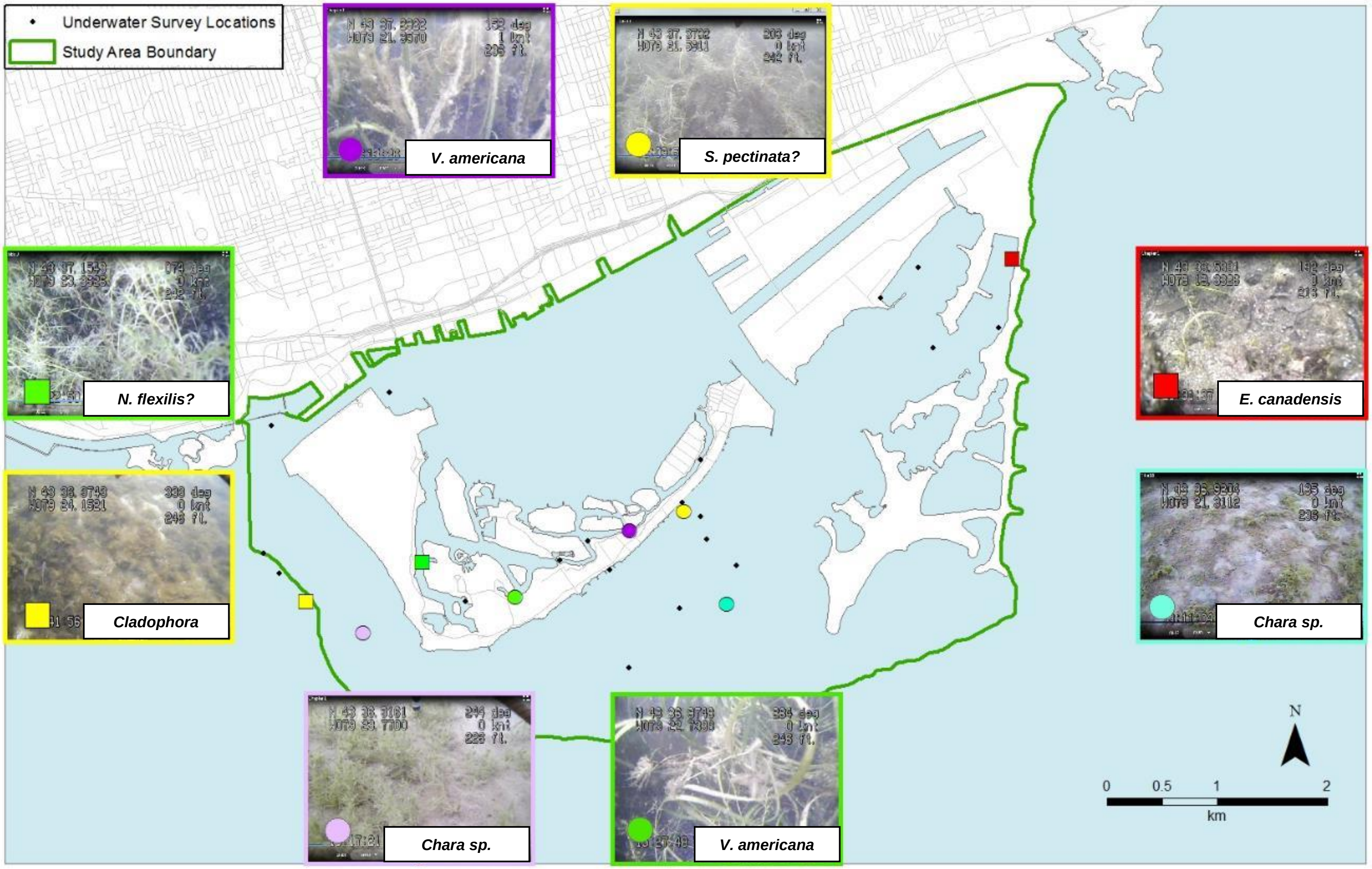

Figure 5. Location and examples of still photos extracted from the underwater video clips taken during the 2012 Toronto Harbour survey. Includes the submerged aquatic vegetation species that was dominant in the photo.

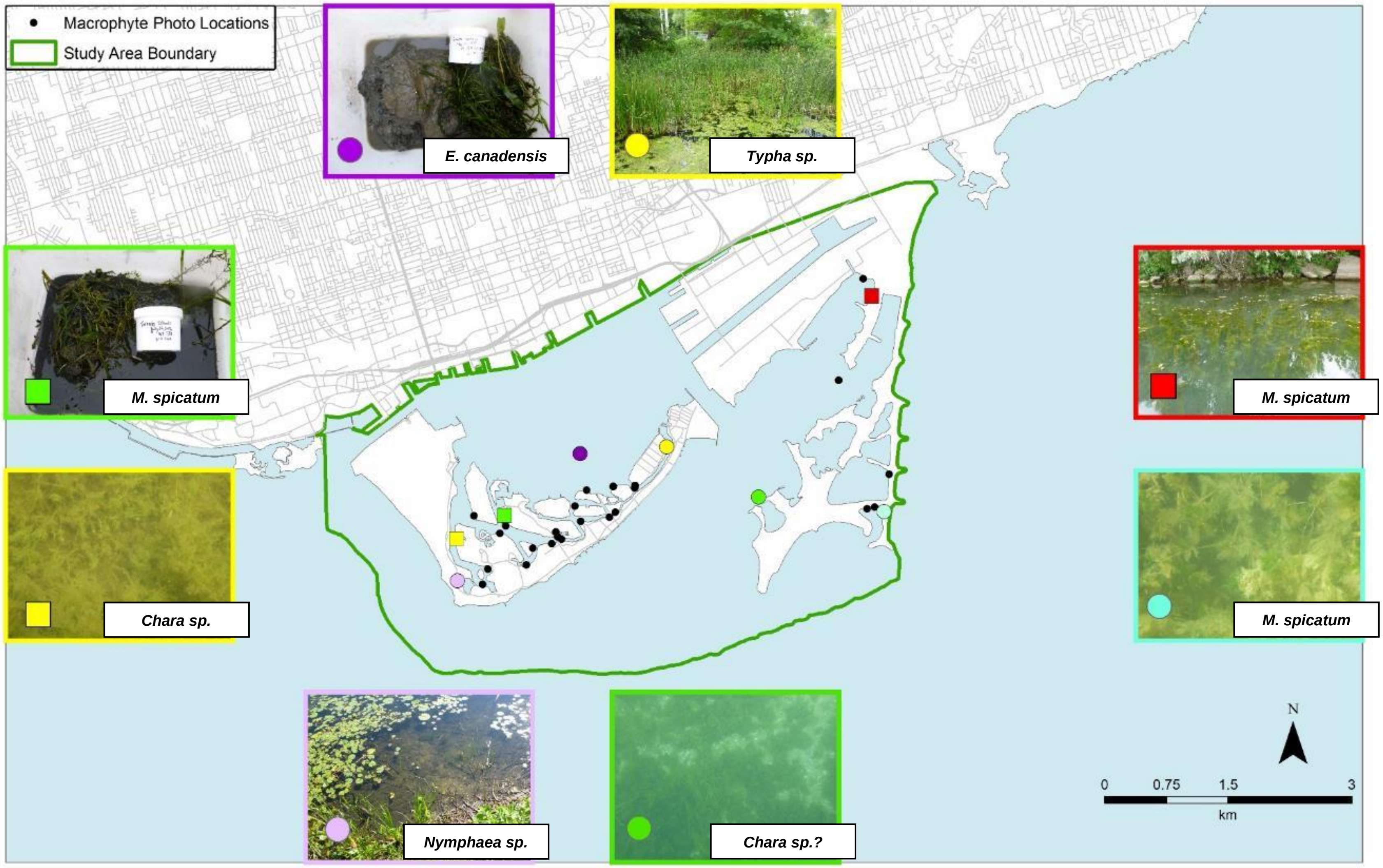

Figure 6. Location and examples of shoreline and Ponar samples that were associated with submerged aquatic vegetation, including the dominant species.

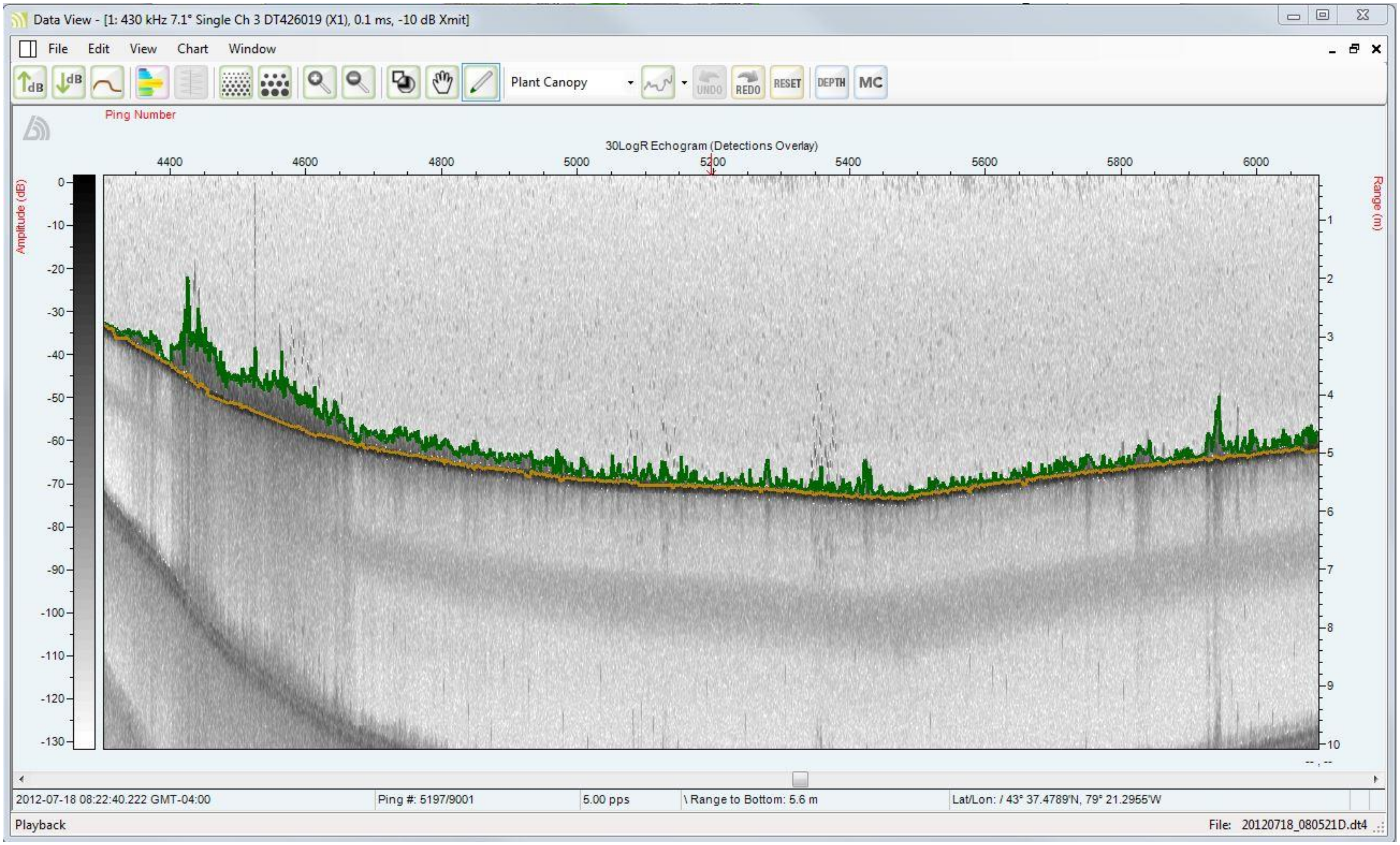

Figure 7. Echogram showing the bottom detection (brown line) and plant canopy (green line) as determined by the Visual Habitat software. This transect is located on the south-east side of Ward's Island.

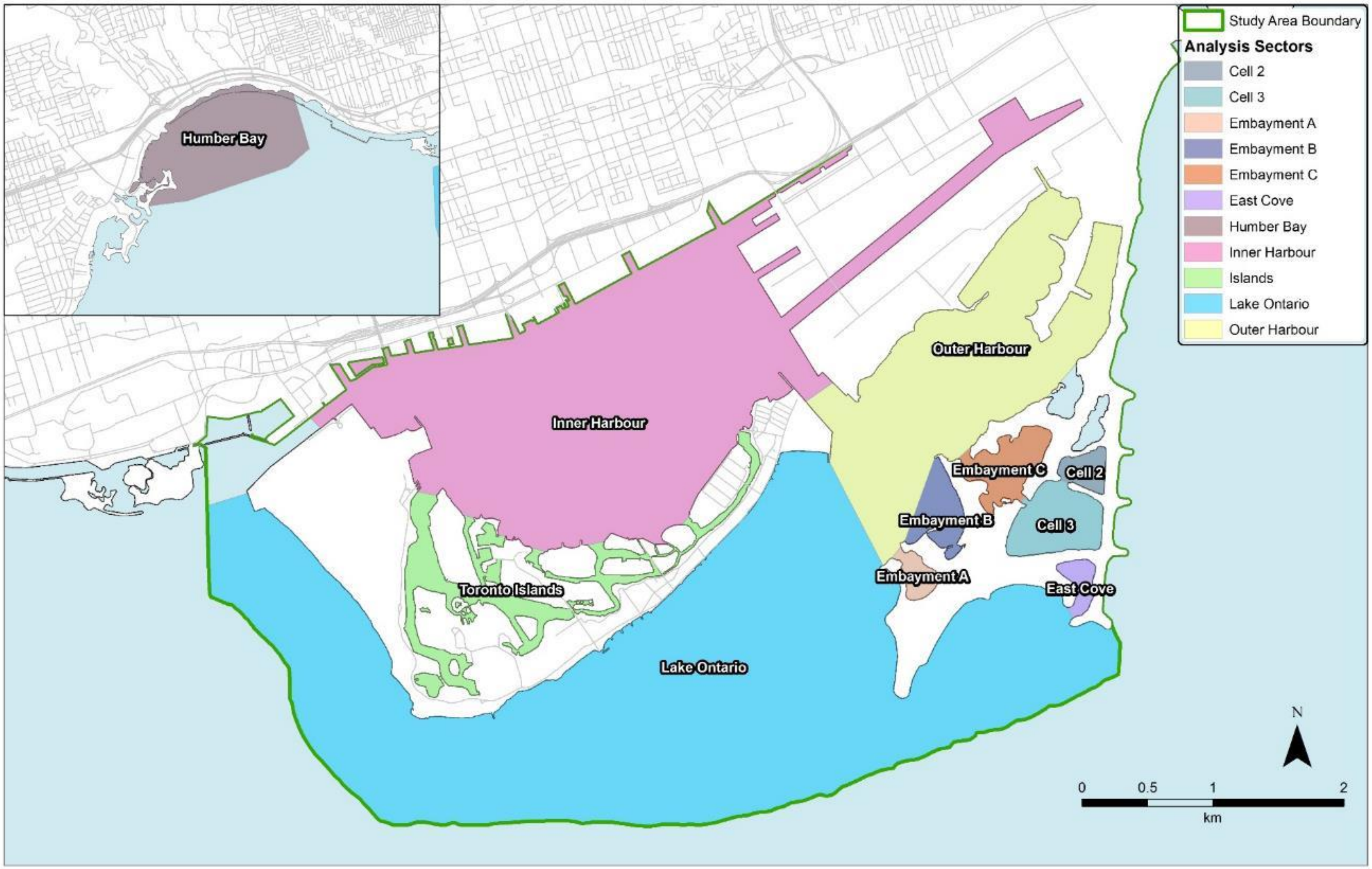

Figure 8. Submerged aquatic vegetation analysis-sectors for the Toronto Harbour 2012 survey.

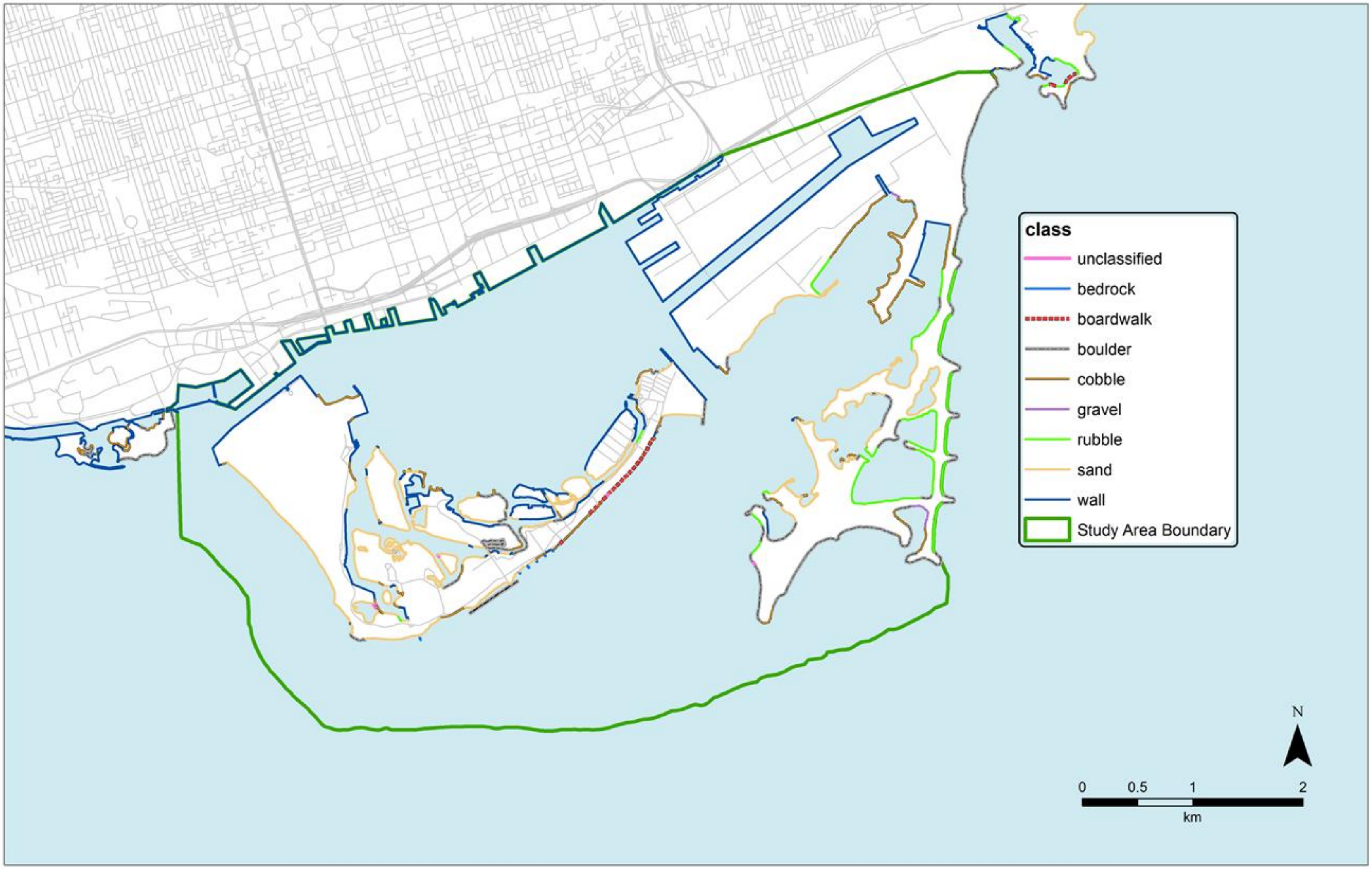

Figure 9. Final shoreline composition classification. Obvious shoreline classes were first identified from aerial imagery (ortho-imagery and Bing Maps: accessed May 2012). The subsequent shoreline survey focused on unclassified shoreline segments and confirmed photo interpretation when possible.

Figure 10. Sediment sample analysis results showing substrate composition of Ponar grab samples from the DFO 2012 survey (larger pie charts) and other agencies (smaller pie charts) that had sampled in previous years. The bottom was too hard to sample with the Ponar on six of the sites in the 2012 DFO survey.

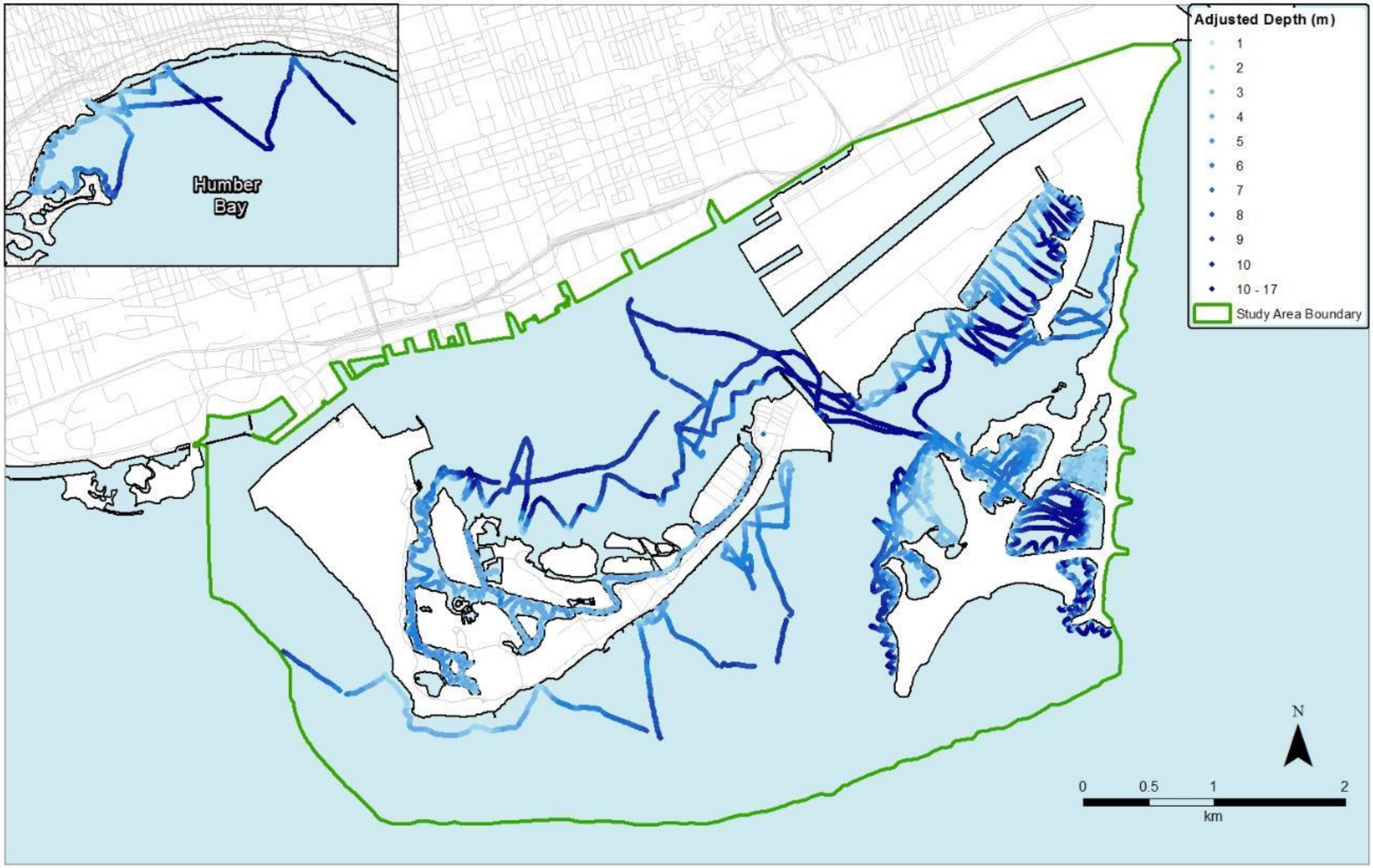

Figure 11. Toronto Harbour bottom depths along the 2012 hydroacoustic transects determined by Visual Habitat. A map showing the location of Humber Bay relative to the harbour can be found in Figure 1.

Figure 12. Bathymetry layer for Toronto Harbour as of March, 2016.

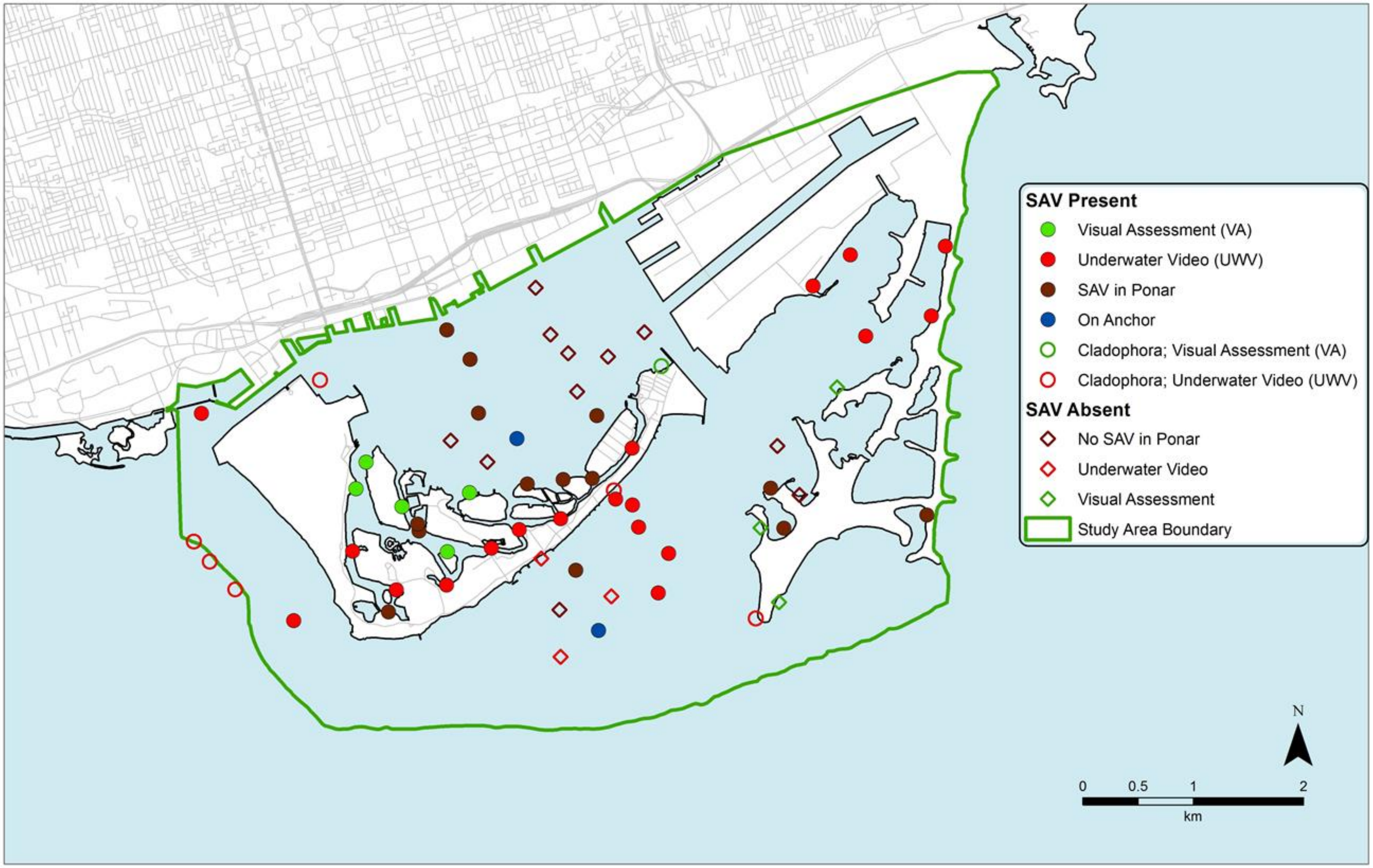

Figure 13. Point sampling locations in the 2012 Toronto Harbour survey that were associated with submerged aquatic vegetation (SAV).

Figure 14. Percent submerged aquatic vegetation bottom cover as determined by the analysis of hydroacoustic data from the Toronto Harbour 2012 survey. Water depths are referenced to International Great Lakes Datum 1985.

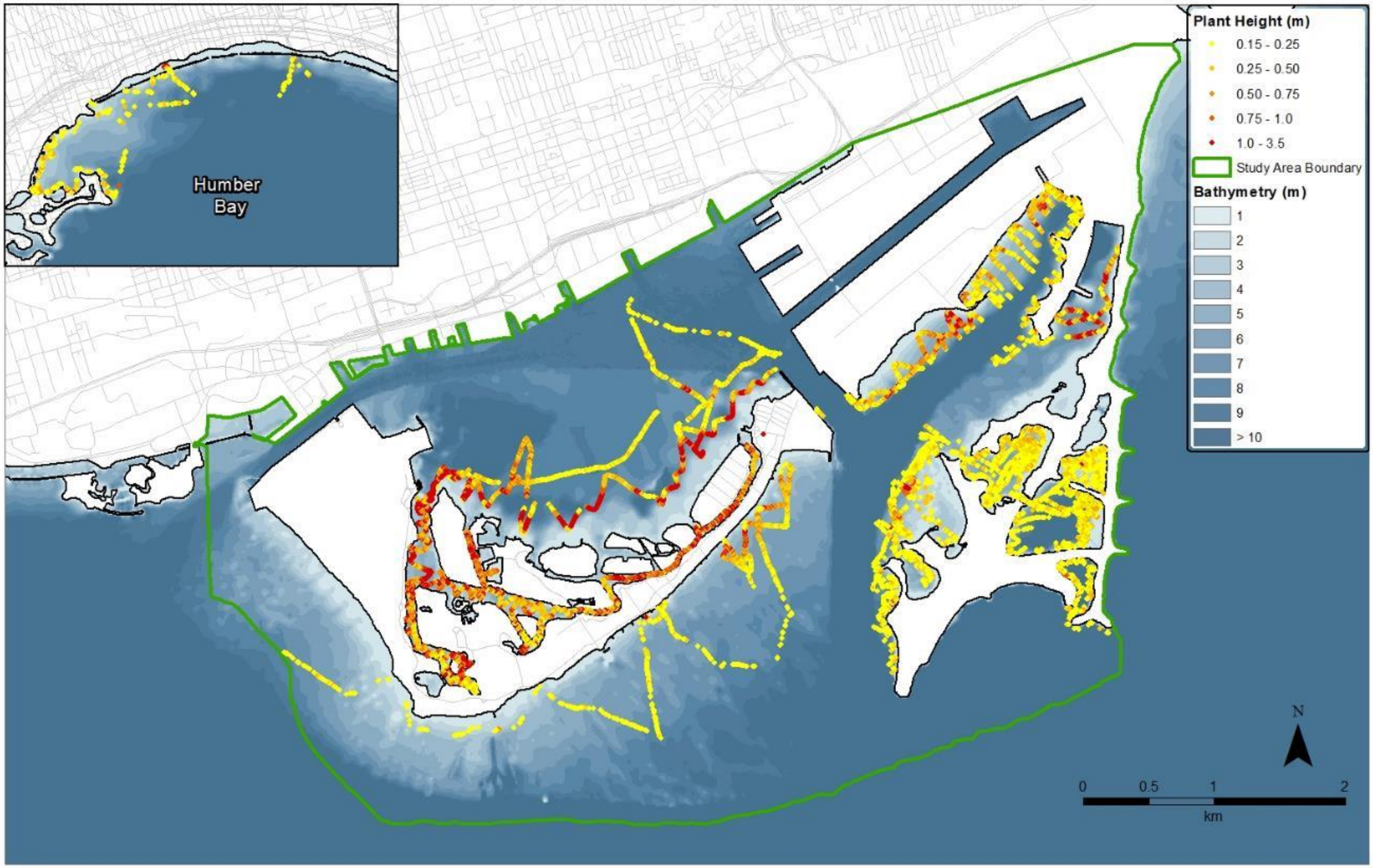

Figure 15. Submerged aquatic vegetation height as determined by the analysis of hydroacoustic data from the Toronto Harbour 2012 survey. Water depths are referenced to International Great Lakes Datum 1985.

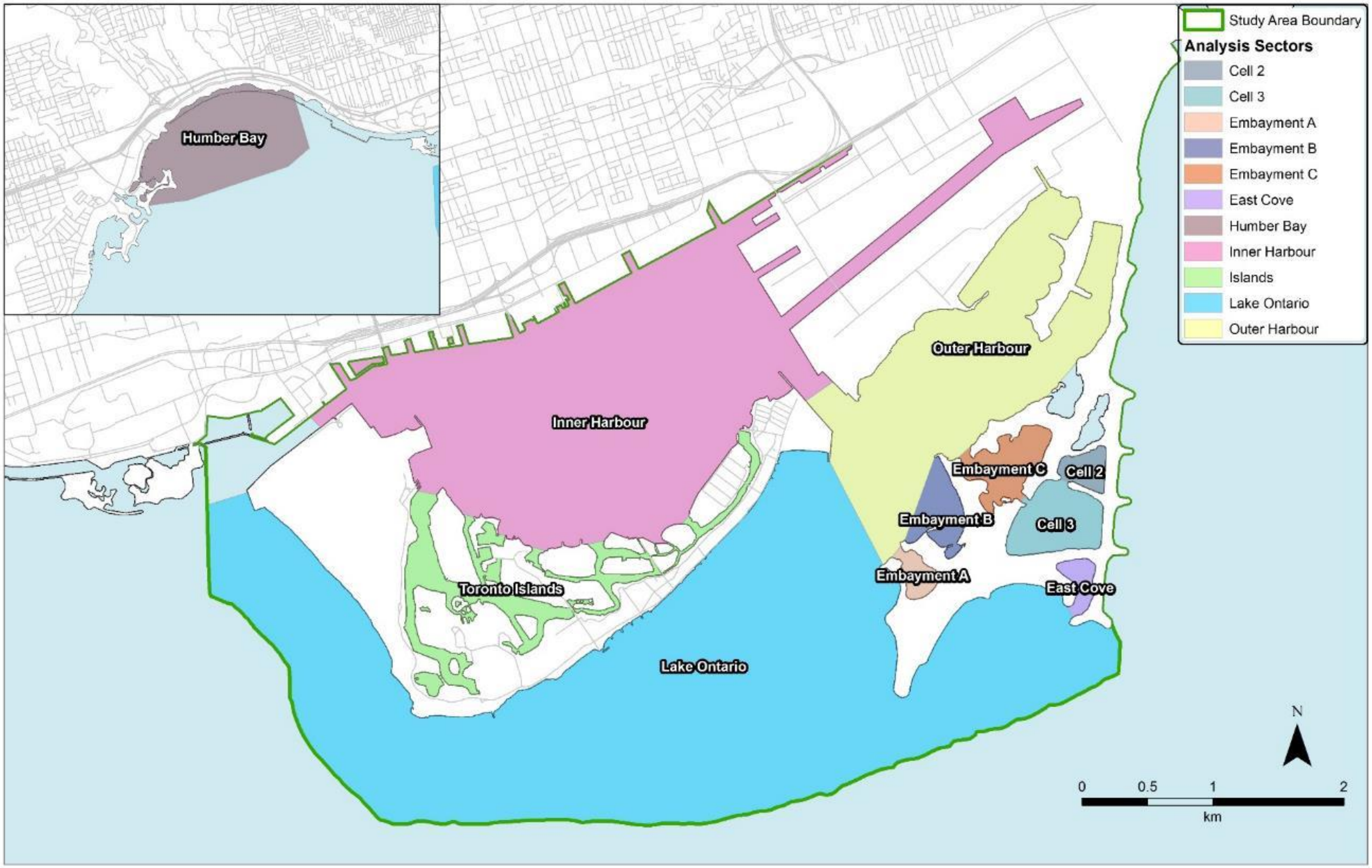

Figure 16. Submerged aquatic vegetation analysis sectors for the Toronto Harbour 2012 survey.

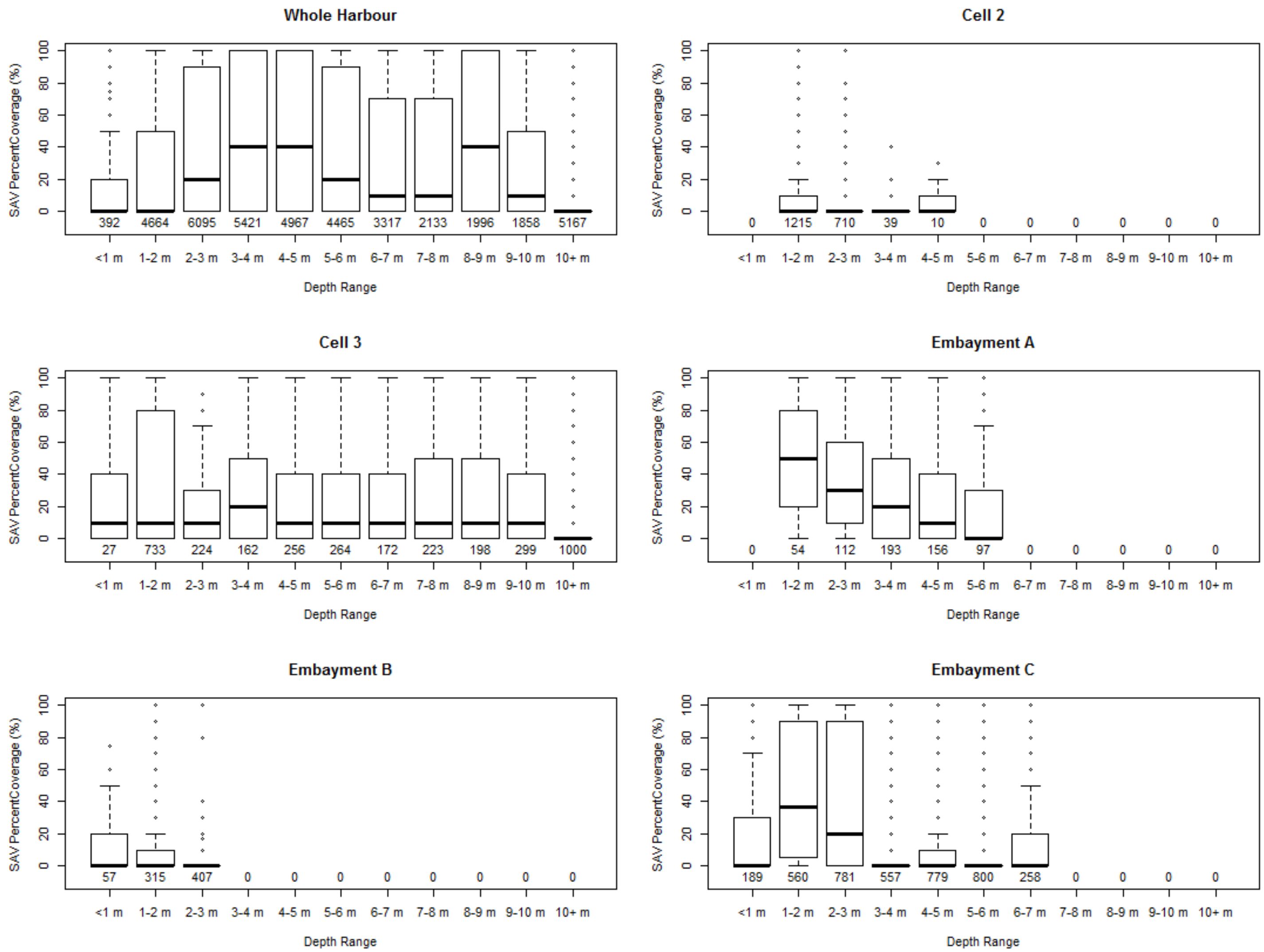

Figure 17. Boxplots by analysis sector of submerged aquatic vegetation (SAV) percent bottom cover as a function of water depth. Under each boxplot is the number of acoustic ping intervals within that bin as an indication of sampling intensity. Includes SAV presence and absence data.

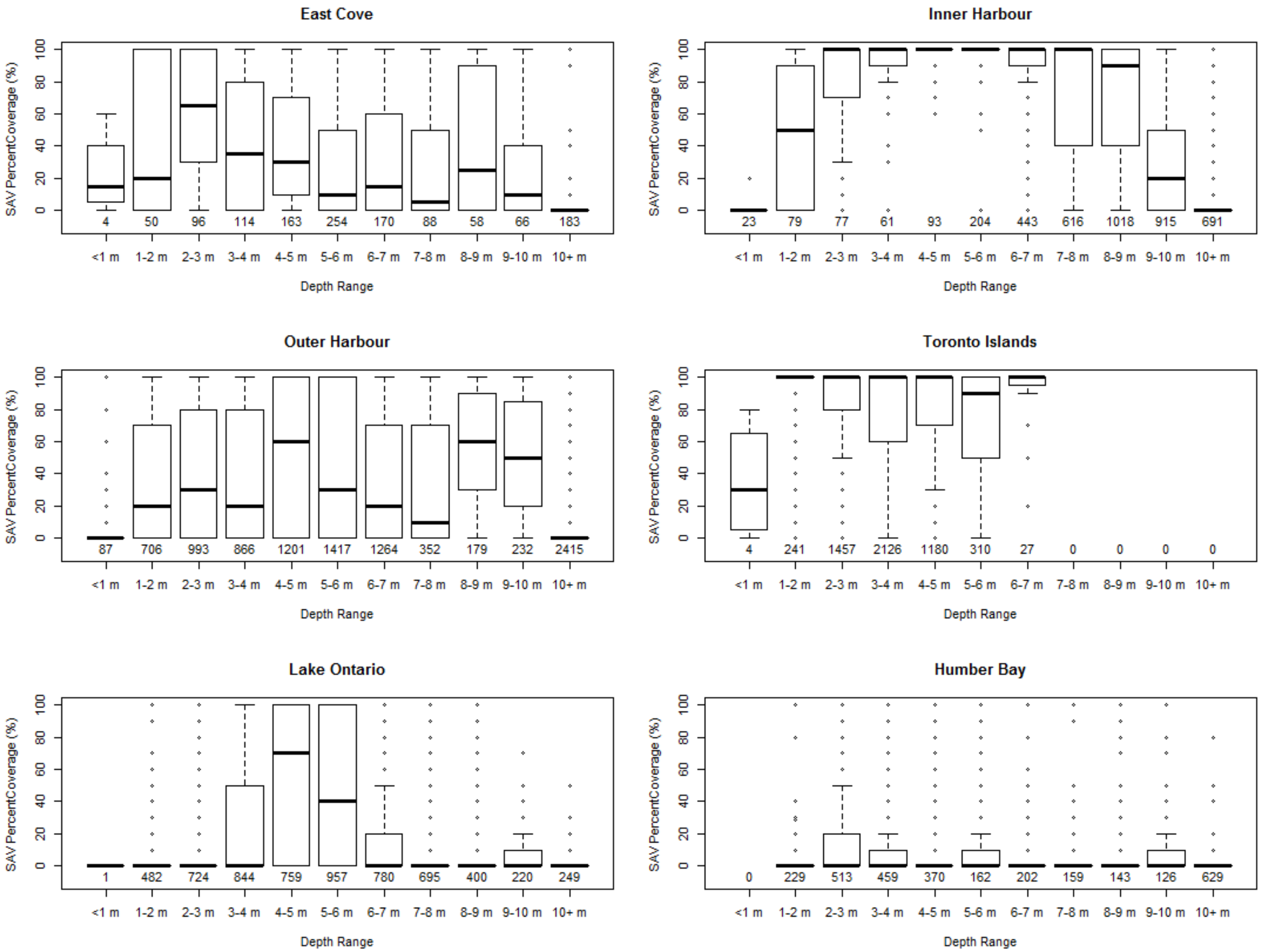

Figure 18. Boxplots by analysis sector of submerged aquatic vegetation (SAV) percent bottom cover as a function of water depth. Under each boxplot is the number of acoustic ping intervals within that bin. Includes SAV presence and absence data.

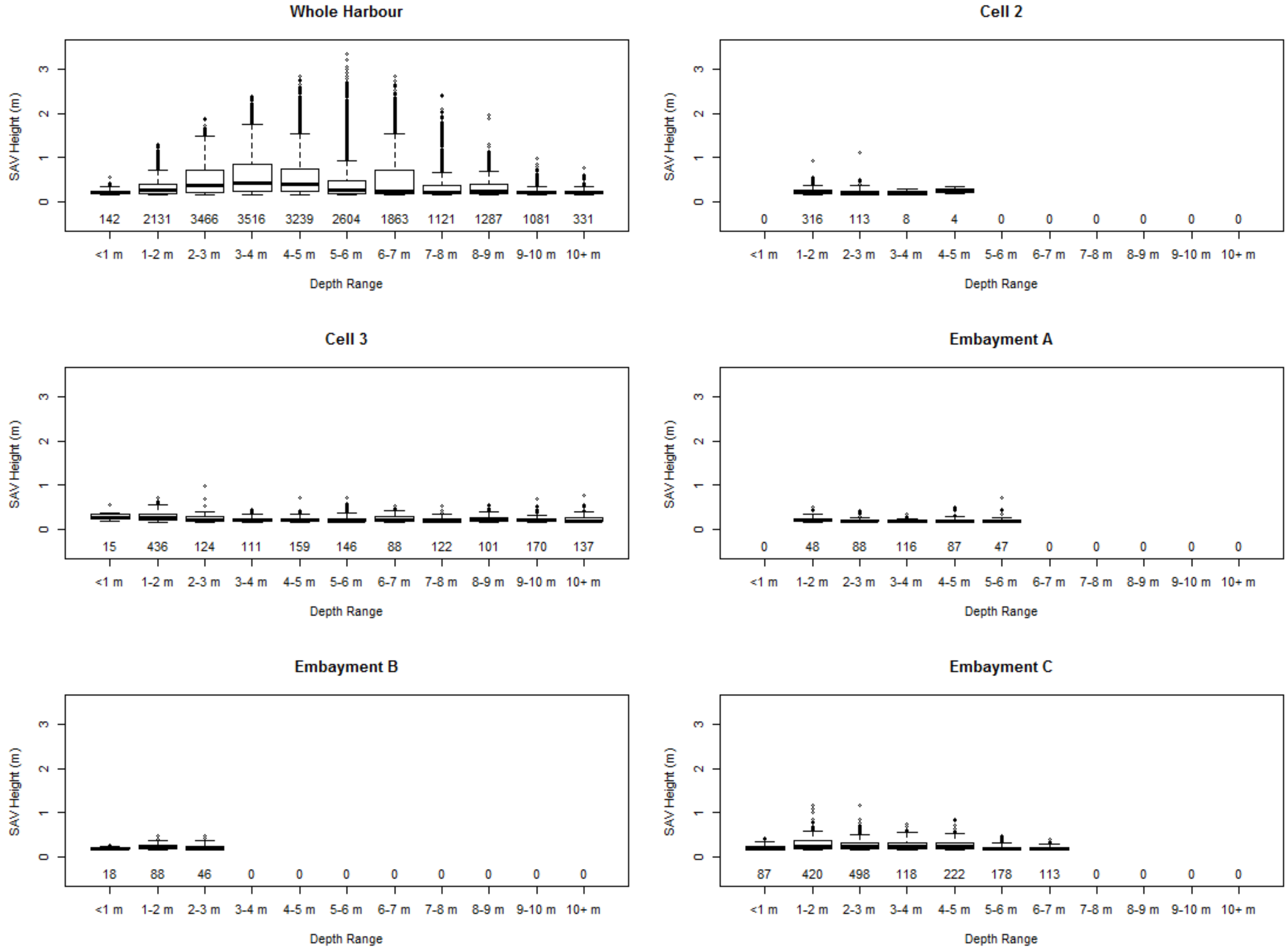

Figure 19. Boxplots by analysis sector of submerged aquatic vegetation (SAV) height when plants are present as a function of water depth. Under each boxplot is the number of acoustic ping intervals within that bin.

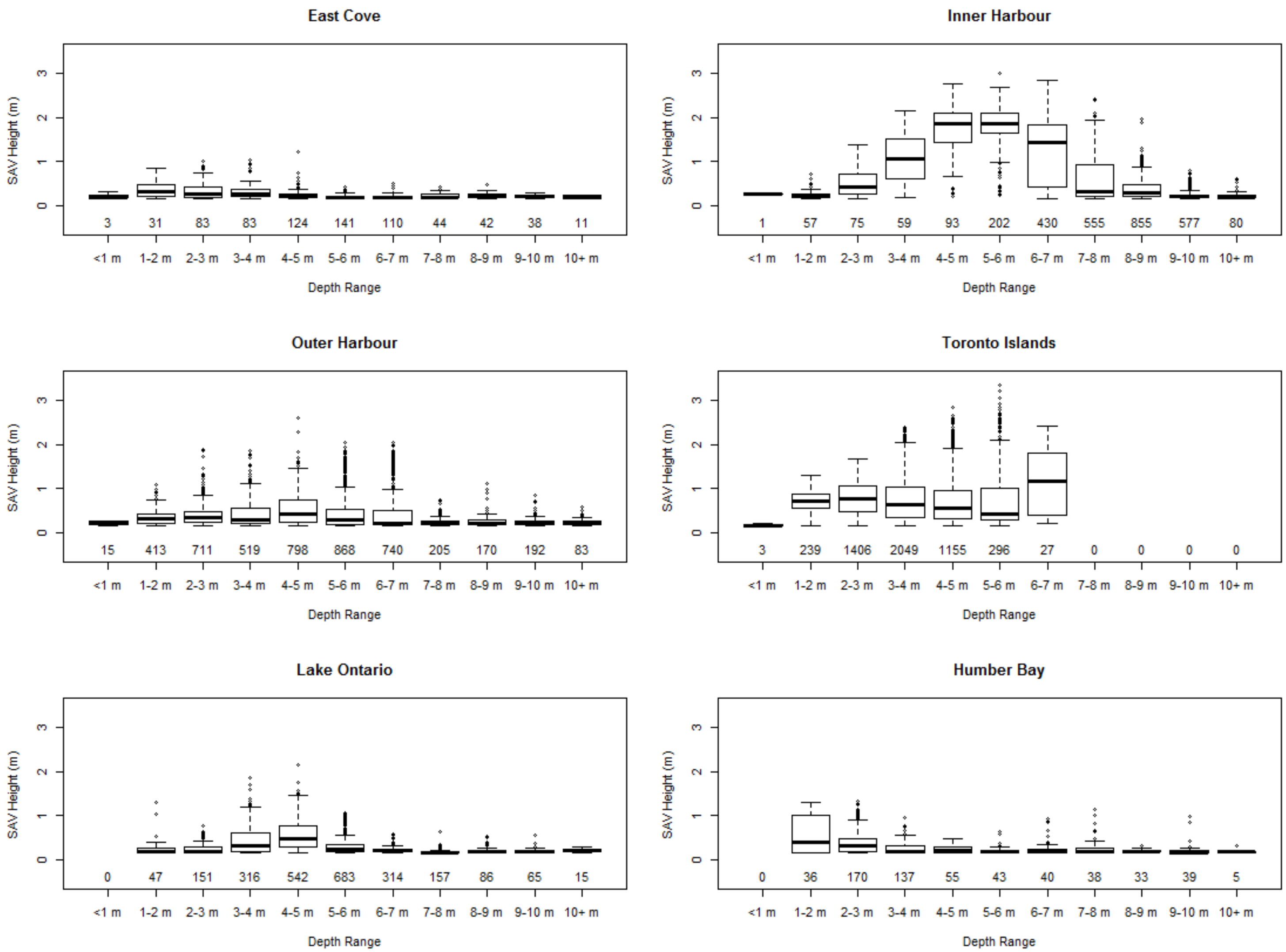

Figure 20. Boxplots by analysis sector of submerged aquatic vegetation (SAV) height when plants are present as a function of water depth. Under each boxplot is the number of acoustic ping intervals within that bin.

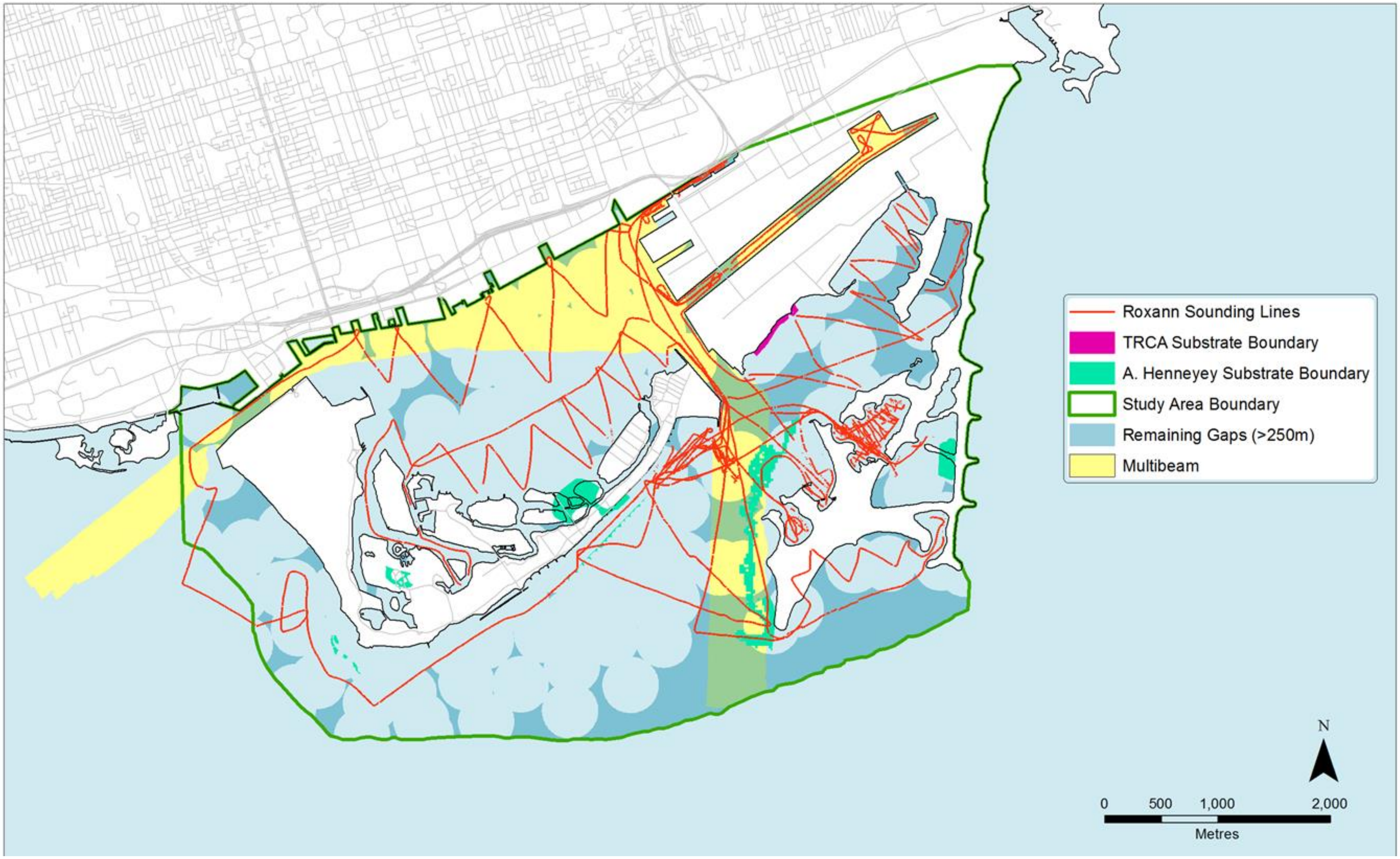

Figure 21. Additional qualitative substrate information. The datasets shown have not yet been incorporated into a compiled substrate database. Each presents unique problems for integration. They are each classified with a single qualitative descriptor that usually represents the dominant substrate class (i.e. sand or boulder). Remotely sensed data, such as Roxann and Multibeam, may not validate well against existing data but could be viewed as homogeneous groups that could be classified based on a summary of samples nearest to each group. Samples from Henneyey (2006) are of questionable spatial accuracy.

APPENDICES

APPENDIX I - Toronto Harbour 2012 Shoreline and Substrate Survey Field Data Sheet

Location: Toronto Harbour	Date: JULY 2012
Notes by: Leisti Gertzen Neigum	

Picture(s): Start#: ____ End #: ____		WAYPOINT # Time surveyed: ____		
Shoreline Type at Land/Water Interface				
State	Artificial □	Natural □	Island □	Habitat Creation □
Slope	Gradual/Low Plain/Beach □		Moderate / Low Bank □	
	Steep/Bluff □		Vertical wall □	
Composition (sums to 100%)	____ % Bedrock	____% Boulder	____% Cobble	____% Rubble
	____% Gravel	____% Sand	____% Silt/Clay	___%Other:____
Secondary structure None □	____% Woody Debris	____% Organic	____ % Rip Rap	
	____% Armor Stone	____% Metal	% Concrete	
Vegetation (overhanging or at interface) None □	Wetland:	Barrier □	Sheltered □	Open □
	Grass □	Shrub □	Treed □	Other: □
Inflow □ Outflow □ None □	Wetland □	Creek □	River □	
	Channel □	Culvert□	Estuary □	
Shore structure None □	Dock: Floating □ Anchored □	Launch □	Breakwall □	
	Wharf □	Jetty/Groin □	Other ____	
Adjacent Land Use	Residential □	Park/Recreation □	Industrial □	Transportation □
	Open/Forest □	Other ____		
Notes:				
Close Survey □ (If last segment or skipping a gap, record ending GPS waypoint):				

WAYPOINT #: ___________________________						
Nearshore (below boat where survey is assessed, max 5-m depth)						
Substrate Sample:	WP:		Depth: ______________________m			
	Distance to shore: ____ m					
	Underwater Video Time: ________________________________					
Composition (sums to 100%)	_____ % Bedrock	______% Boulder	_______% Cobble	______% Rubble		
	_____% Gravel	_____% Sand	____% Silt/Clay	_____%Other____________		
Secondary structure None □	_______% Woody Debris	________%Organic	________ % Rip Rap			
	________%Armor Stone	_________% Metal	________ % Concrete			
Submerged Veget'n	Not Visible □	None □	Sparse □	Moderate □	Dense □	
SAV Height	Low □	Medium □	Near □ or to □ surface			
SAV Species						
SAV Edge of Bed	Not Visible □	Waypoint: ______________________________________				
	Depth:______________________m	Distance to shore: _______________m				
Notes:						

APPENDIX II – Substrate Analysis Results from the 2012 DFO Survey

Table A2.1. Compiled sieve mesh-size intervals used by Fisheries and Oceans Canada (DFO), Environment Canada (EC), and Toronto and Region Conservation Authority (TRCA). Colours correspond to substrate classification in relation to DFO substrate classes. Intervals of sieve size used by DFO, EC, and TRCA placed in protocol substrate classes.

Substrate Classification	DFO Sieve Interval (mm)	EC Sieve Interval (mm)	TRCA Sieve Interval (mm)
Gravel	4.00 – 5.66		
			>4.00(>5 mesh)
	2.83 – 4.00		
	2.00 – 2.83		
			2.00– 4.00 (5, 10)
Sand	1.41 – 2.00	1.41 – 2.00	
	1.00 – 1.41	1.00 – 1.41	
			1.00 – 2.00 (10, 18)
	0.71 – 1.00	0.71 – 1.00	0.71 – 1.00 (18, 25)
	0.50 – 0.71	0.50 – 0.71	
	0.35 – 0.50	0.35 – 0.50	
			0.25 – 0.71 (25, 60)
	0.25 – 0.35	0.25 – 0.35	
	0.18 – 0.25	0.18 – 0.25	
			0.125 – 0.25 (60, 120)
	0.13 – 0.18	0.13 – 0.18	
	0.09 – 0.13	0.088 – 0.13	
			0.63 – 0.12 (120, 230)
	0.06 – 0.09	0.063 – 0.088	
	<0.0625*		<0.625 (<230)
	>0.0625*		
Silt	0.044 – 0.063	0.044 – 0.063	
	0.031 – 0.044	0.0313 – 0.044	
	0.022 – 0.031		
		0.0156 – 0.031	
	0.016 – 0.221		
	0.011 – 0.016		
		0.0078 – 0.016	
	0.0078 – 0.0111		
	0.0055 – 0.0078		
		0.0039 – 0.0078	

Substrate Classification	DFO Sieve Interval (mm)			EC Sieve Interval (mm)			TRCA Sieve Interval (mm)
	0.0039	–	0.0055				
	0.0028	–	0.0039				
Clay	0.0020	–	0.0028	0.0020	–	0.0039	TRCA did not analyze clays
	0.0014	–	0.0020	0.0014	–	0.0020	
			< .001				
	0.0010	–	0.0020				
	0.00069	–	0.00098				
	0.00049	–	0.00069				
	0.00035	–	0.00049				
	0.00024	–	0.00035				
	0.00017	–	0.00024				

*0.0625 mm is the sieve point at which the different instrument for sieve separation (Horiba PARTICA LA-950 or Sieve Tower) was used for DFO samples. Horiba PARTICA LA-950 used all intervals defining silt and clay while substrate defined as sand or gravel was in the grouping = >0.0625. Sieve Tower used all intervals defining sand and gravel while substrate defined as silt or clay in the grouping = <0.0625.

Table A2.2. Point sample locations where Ponar sampling did not occur because the bottom was too hard. EA = Embayment A; OH = Outer Harbour ; LO = Lake Ontario.

Sector	Latitude	Longitude
EA	43.62046	-79.3436
OH	43.63179	-79.3347
LO	43.61858	-79.4055
LO	43.61306	-79.3444
LO	43.61435	-79.3417
LO	43.61626	-79.4027

APPENDIX III – DFO 2012 Point Samples Related to Submerged Aquatic Vegetation

Table A3.1. Submerged aquatic vegetation data collected during point sampling with different methodologies (Ponar, underwater video, and visual assessment) in Toronto Harbour 2012. *Abbreviations within this table are defined at the bottom of this table.

					Ponar			Underwater Video			Visual Assessment			
Date	WP#	Latitude	Longitude	Depth (m)	Ponar	Density	Ponar Species	Density	Height	Species	Density	Height	Species	Notes
16-Jul-12	2	43.64315	-79.322255	3	YES			S	L	EC	NV		CD	CD on anchor, off port side of boat, dense band of MS just under surface approx 3 m from shore
16-Jul-12	6	43.63746	-79.323971	1	YES			S	L	pNL, Ch	S	M	MS	patches of MS
16-Jul-12	7	43.63594	-79.331374	4.5	YES			D	L	Ch	NV			
17-Jul-12	9	43.62716	-79.357864	1.45	YES	S_M	VA, MS, ZD?	M	M	MS, ZD, PR	D	U	VA, NF, EC, MS, PR, ZD	
17-Jul-12	16	43.62152	-79.366028	0.46	YES	S	VA	D	M	VA	D	U	VA, MS, NO, Ch?	periphyton
17-Jul-12	21	43.6207	-79.370706	0.97	YES	M	VA, NF	D	L	EC, VA	D	M	PC, VA, ZD, N, EC, pNL, NF, MS	periphyton
17-Jul-12	25	43.61922	-79.373882	1.6	YES	M	VA, EC	D	M	EC, VA	D	U	MS, VA, EC, NF	
17-Jul-12	30	43.61628	-79.378989	1.12	YES	S	VA	D	M	VA, MS, SP	D	U	VA, NF, MS, CD, pNL, PC, NO, ZD	
17-Jul-12	36	43.6192	-79.38946	0.86	YES	M	VA, ZD?	D	M	NF?	NR	L-M	Ch	
17-Jul-12	41	43.61598	-79.384632	1.27	YES	D	VA, NF, ZD?	D	M	VA	D	U	VA, MS, NO, pNL, PR, NF	
18-Jul-12	42	43.6207	-79.357295	6.1	YES	S	MS? pTL?	S	L	Ch or Cl	NV			
18-Jul-12	43	43.62375	-79.359999	1.8	YES		gravel	D	L	Cl	NR	NR		gravel, cobble
18-Jul-12	999	43.62302	-79.359812					D	L	SP?, PR	NR	NR		

Date	WP#	Latitude	Longitude	Depth (m)	Ponar			Underwater Video			Visual Assessment			
					Ponar	Density	Ponar Species	Density	Height	Species	Density	Height	Species	Notes
18-Jul-12	999	43.62253	-79.357938					D	L	Ch, pBL	NR	NR		
18-Jul-12	46	43.61851	-79.353991	8.6	YES	S	Ch?	M	L	N/Ch	NV			
18-Jul-12	47	43.61529	-79.355257	8	YES	S	Ch	S	L	Ch	NR	L	Ch, N	
18-Jul-12	48	43.6151	-79.360514	7.7	YES						NV			
18-Jul-12	53	43.6183	-79.368303	1.7	YES						NV			rippled sand on video
18-Jul-12	54	43.61025	-79.36635	7.6	YES						NV			
18-Jul-12	55	43.61362	-79.396219	4.6	YES	S	Ch	M	L	Ch	NV			
18-Jul-12	56	43.61858	-79.40551		YES		Cl	D	L	Cl	NR	NR		no note on substrate composition
19-Jul-12	58	43.63179	-79.334722	1.5							NV			gravel/cobble over sand (from digital photo)
19-Jul-12	142	43.64258	-79.332921	3.9	YES			VS	L	pNL	NV			
19-Jul-12	147	43.64012	-79.337199	0.9	YES			M	M	MS? pNL?	M	M	PR, CD	
24-Jul-12	82	43.61306	-79.344356	3.7							NV			cladophora cover on rocks
24-Jul-12	86	43.61435	-79.341717	1.5							NV			construction debris
24-Jul-12	94	43.62122	-79.324937	1.8	YES	D	SP				D	M	MS, SP	
25-Jul-12	104	43.62712	-79.341545	2	YES						NV			
25-Jul-12	108	43.62308	-79.339163	1.9	YES						NR	NR		sandy
25-Jul-12	109	43.62366	-79.342403	1.02	YES	S	SP?				S	L	Cl, TLp	dense cladophera, hard bottom
25-Jul-12	114	43.62038	-79.341009	2.6	YES	VS	EC?				VS	L	MS, Cl	dense cladophera, steep drop-off
25-Jul-12	119	43.62046	-79.343626	1.7							NV			
25-Jul-12	120	43.6366	-79.356222	9.5	YES						NV			no SAV on anchor
25-Jul-12	150	43.63467	-79.360363	7.4	YES						NV			no SAV on anchor
25-Jul-12	151	43.62988	-79.361762	4.1	YES	D	EC,CD				NV			
25-Jul-12	152	43.63188	-79.363911	7	YES						NV			
25-Jul-12	153	43.63501	-79.364835	7.2	YES		Cl?				NV			some cladaphora on anchor
25-Jul-12	154	43.63658	-79.366757	8.4	YES						NV			

Date	WP#	Latitude	Longitude	Depth (m)	Ponar			Underwater Video			Visual Assessment			
					Ponar	Density	Ponar Species	Density	Height	Species	Density	Height	Species	Notes
25-Jul-12	155	43.64043	-79.368338	8.5	YES						NV			last video for inner harbour
26-Jul-12	121	43.63381	-79.354355	1.1	YES						NV		Cl	patches of Cl, SAV further offshore
26-Jul-12	134	43.62476	-79.362381	1.06	YES	S	pNL?				D	S	VA, NF, pTL, MS, NO, CD	
26-Jul-12	136	43.62471	-79.365664	0.8	YES	VD	Ch				D	L	Ch, pTL	
26-Jul-12	145	43.62441	-79.369698	1.12	YES	D	Ch				D	L	Ch, MS	
26-Jul-12	147	43.62813	-79.37077	7.9	YES						NV		EC, CD, PR, NLp	on anchor
26-Jul-12	148	43.63712	-79.378409	8.9	YES	S	NF?				NV		EC	on anchor
26-Jul-12	149	43.63467	-79.375856	7.1	YES	D	EC, pBL				NV		EC, BLp	on anchor
26-Jul-12	150	43.63027	-79.375041	8.5	YES	S	MS?				NV			
26-Jul-12	151	43.62808	-79.378216	8.2	YES						NV			no SAV on anchor
26-Jul-12	153	43.62628	-79.374139	9.7	YES						NV			
26-Jul-12	171	43.62074	-79.38195	1.08	YES	S	Ch				D	M	NF, VA, EC, Ch	patchy, sparse to shore, dense other side of boat
26-Jul-12	173	43.6213	-79.3821	0.96	YES	D	EC, MS, NF, PZ				D	U	VA, MS, EC, NF, NO, PR, PC?, PZ, CD	
26-Jul-12	176	43.61901	-79.378839	1							D	L	Ch, VA, NF	
26-Jul-12	177	43.62276	-79.383817	1.19							D	NR	VA, NF	
26-Jul-12	178	43.62428	-79.388945	1.43							D	U	VA	
26-Jul-12	179	43.62645	-79.387743	0.45							D	L	Ch, SP	hard bottom
26-Jul-12	180	43.62379	-79.376221	0.81							D	L	Ch	
27-Jul-12	181	43.61233	-79.362037	8.4	YES						NV			Ch on anchor
27-Jul-12	182	43.61729	-79.36444	5.5	YES	S	Ch				NV			bit of Ch on anchor
27-Jul-12	183	43.61409	-79.36635	5.8	YES						NV			no SAV on anchor
27-Jul-12	184	43.61233	-79.375749	4.8							NV			no SAV on anchor

					Ponar			Underwater Video			Visual Assessment			
Date	WP#	Latitude	Longitude	Depth (m)	Ponar	Density	Ponar Species	Density	Height	Species	Density	Height	Species	Notes
27-Jul-12	185	43.61626	-79.402699	7.4				D	L		NV			gravel
27-Jul-12	186	43.62023	-79.407248	7	YES	D	Cl	D	L		NV			gravel
27-Jul-12	187	43.63068	-79.406111	4.1	YES	S-M	SP?	S	L		NV			
27-Jul-12	188	43.63321	-79.392743	6.6	YES			S	L		NV			no SAV on anchor
27-Jul-12	196	43.61418	-79.385555	1.48	YES	M	VA				D	M	VA, SP, PR, MS, NF, TLp, NO	

*Abbreviations in this table:

Density	Height	Species List	
NV = Not Visible	NR = Not Recorded	CD	*Ceratophyllum demersum*
NR = Not Recorded	L = Low	Ch	*Chara sp*
S = Sparse	M = Medium	Cl	*Cladophora*
M = Moderate	U = Upper Water Column	EC	*Elodea canadensis*
D = Dense	S = To Surface	MS	*Myriophyllum spicatum*
V = Very		N	*Nitella sp*
		NF	*Najas flexilis*
		NO	*Nymphaea odorata*
		PC	*Potamogeton crispus*
		PR	*Potamogeton richardsonii*
		PZ	*Potamogeton zosterformis*
		pBL	*broad-leaf potamogeton*
		pNL	*narrow-leaf potamogeton*
		pTL	*thread-leaf potamogeton*
		SP	*Stuckenia pectinata*
		VA	*Vallisneria americana*
		ZD	*Zosterella dubia*