# Temperature, dissolved oxygen, fish, vegetation, and substrate surveys in Lake Ontario coastal wetlands

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## ABSTRACT

Marshall, E.E.M., Larocque, S.M., Reddick, D.T., Midwood, J.D., and Doka, S.E. 2021. Temperature, dissolved oxygen, fish, vegetation, and substrate surveys in Lake Ontario coastal wetlands. Can. Tech. Rep. Fish. Aquat. Sci. 3385: viii + 50 p.

Anthropogenic development within, and adjacent to, coastal wetlands in Lake Ontario has had detrimental impacts on their local ecosystems, including fish habitat quality and quantity. Temperature and dissolved oxygen (DO) profiles were the primary focus of fish habitat assessments occurring throughout 2013, 2014, and 2015; with fish, aquatic macrophyte, and substrate data also being collected in the study wetlands. Ten wetlands on the Canadian side of Lake Ontario were surveyed. Results for temperature analysis showed typical seasonal variation across wetlands with some daily fluctuations likely attributed to local precipitation or lake events. Dissolved oxygen profiles suggested that many wetlands experienced periodic episodes of low DO during the growing season (May–September). Some sites were sampled with quadrats to ascertain macrophyte communities, while the vegetation at other sites was mapped using hydroacoustic surveys. Highly degraded areas had a lower diversity of aquatic macrophyte species and a lower mean submerged aquatic vegetation percent cover. Replicate Fyke-net sampling assessed the fish community at all sites, with warmwater fishes abundant at all sites, and catch-per-unit-effort varying both among sites and between years. This report provides a preliminary assessment of a subset of Lake Ontario wetlands that can be used to inform future fish habitat modelling in wetlands. The dataset also contributes to larger-scale assessments of DO and temperature habitat associations for fishes.

## RÉSUMÉ

Marshall, E.E.M., Larocque, S.M., Reddick, D.T., Midwood, J.D., and Doka, S.E. 2021. Temperature, dissolved oxygen, fish, vegetation, and substrate surveys in Lake Ontario coastal wetlands. Can. Tech. Rep. Fish. Aquat. Sci. 3385: viii + 50 p.

Le développement anthropique à l’intérieur et à proximité des zones humides côtières du lac Ontario a eu des effets néfastes sur les écosystèmes locaux et sur l’habitat du poisson. Les profils de température et d’oxygène dissous (O.D.) ont été le point de mire des évaluations de l’habitat du poisson qui ont eu lieu en 2013, 2014 et 2015, et des données sur les poissons, les macrophytes aquatiques et les substrats ont également été recueillies dans les zones humides étudiées. Dix zones humides situées sur la rive canadienne du lac Ontario ont été visées par l’évaluation. Les résultats de l’analyse des températures ont montré une variation saisonnière typique dans les zones humides, certaines fluctuations quotidiennes étant probablement attribuables aux précipitations locales ou aux événements survenus dans le lac. Les profils d’oxygène dissous suggèrent que de nombreuses zones humides ont connu des épisodes périodiques de faible O.D. pendant la saison de croissance (de mai à septembre). Certains sites ont été échantillonnés à l’aide de quadrats pour confirmer la présence de communautés de macrophytes, tandis que la végétation d’autres sites a été cartographiée à l’aide de relevés hydroacoustiques. Les zones fortement dégradées présentaient une plus faible diversité d’espèces de macrophytes aquatiques et un plus faible pourcentage moyen de couverture de végétation aquatique submergée. L’échantillonnage répété au verveux a permis d’évaluer les communautés de poissons sur tous les sites, les poissons d’eau chaude étant abondants sur tous les sites et les prises par unité d’effort variant à la fois d’un site à l’autre et d’une année à l’autre. Ce rapport fournit une évaluation préliminaire d’un sous-ensemble de zones humides du lac Ontario qui peut être utilisée pour orienter la modélisation future de l’habitat du poisson dans les zones humides. L’ensemble de données présenté dans ce rapport peut également contribuer à des évaluations à plus grande échelle des associations entre le niveau d’O.D. et la température de l’habitat du poisson.

## INTRODUCTION

Great Lakes coastal wetlands provide critical spawning, foraging, and nursery habitat for a majority of fishes during their life-cycle (Jude and Pappas 1992; Wei et al. 2004). Despite their ecological importance, many of these ecosystems have been lost, degraded, or altered as a result of anthropogenic activities (Snell 1987; Chow-Fraser 2006). The remaining habitat is threatened by ongoing anthropogenic activities and climate change-related environmental disturbances that may alter hydrologic regimes, water and air temperatures, and dissolved oxygen (DO; reviewed in Ficke et al. 2007; Lynch et al. 2010) among others.

Water temperature (T) and DO are of particular importance to freshwater fishes. Temperature is widely regarded as the most important abiotic factor for fishes since, as ectotherms, their physiology (e.g., growth and digestion) and life history (e.g., reproduction and migration) are directly affected by water temperature (Brett 1971; Fry 1971). Sufficient DO is also critical for respiration of virtually all Great Lakes fish species. Based on their thermal tolerance, Great Lakes fish species can be broadly grouped into coldwater (<19 °C), coolwater (19–25 °C), and warmwater (>25 °C) species (Gertzen et al. 2012). Similarly, DO levels greater than 5 mg/L represent a minimum threshold for most aquatic organisms (Stickney 2000), with hypoxia starting to occur when DO concentrations drop below 2–3 mg/L (Kalff 2002). Physically, temperature and DO are intimately linked because the solubility of oxygen in water is negatively correlated with temperature. Also, as temperatures increase, biological oxygen demand increases and so the already diminishing pool of DO in warming waters is consumed faster than at lower water temperatures (Kalff 2002). Therefore tracking both of these metrics was essential for assessing the suitability of aquatic habitats for freshwater fishes.

In addition, we included information on supersaturation which occurred in some wetlands. When the concentration of DO in water is in equilibrium with oxygen in the atmosphere, it is 100 percent saturated. DO in eutrophic conditions can become supersaturated when oxygen is produced by algae or rooted aquatic plants more quickly than it can escape into the atmosphere; DO concentrations can be greater than 200 percent saturation. When DO concentrations exceed 110 percent saturation it may harm fish and can lead to “gas bubble disease” in rare cases (Jones 2011).

Substrate forms an important component of physical habitat for aquatic organisms, providing cover and foraging opportunities (Lane et al. 1996). For some fishes, substrate is a key factor determining where they will spawn and whether eggs and fry will be successful (e.g., Walleye [*Sander vitreus*]; Corbett and Powles 1986). Submerged aquatic vegetation (SAV) presence, cover, and diversity are also important habitat features as SAV can reduce turbidity, stabilize substrates, and provide spawning and nursery habitat for a wide variety of fishes (Lacoul and Freedman 2006). SAV percent cover can be affected by altered water quality and changing abiotic factors (e.g. water levels and flows), and as such is vulnerable to environmental disturbances that influence overall habitat quality and quantity (Lacoul and Freedman 2006; Croft and

Chow-Fraser 2007). Collectively, substrate and SAV form essential physical components of fish habitat and are necessary for an evaluation of the condition of Great Lakes fish habitats.

While physical components are key parts of any habitat assessment, biotic communities have also been used extensively to gauge ecosystem or habitat condition. For example, indices of biotic integrity have been used frequently to measure the health of an ecosystem based on fish community assemblages (after Karr 1981). If piscivorous fish comprise around 20% of the community, it may correlate with better water quality, and an abundance of planktivorous-benthivorous fish may exacerbate existing poorer water quality. However, evidence of imbalances in the trophic composition of fish communities is contingent on the size of the systems and their biogeography too, and may not be strong indicators of impaired habitat or ecosystem health (Chow-Fraser et al. 1998). Although, it does appear that hyper-abundance of a few species with low richness is a sign of impairment in Lake Ontario nearshore systems, with particular significance in Hamilton Harbour and Toronto Harbour evaluations (Bowlby and Hoyle 2017). While there is no in-depth analysis of fish community structure in this study (e.g., indices of biological integrity), we document fish communities in various coastal wetlands to inform a more holistic assessment of ecosystem condition and impairment analysis as a current baseline for past and future trends, especially climate change assessment purposes.

Given the importance of Great Lakes coastal wetlands as fish habitat and the current and potential stressors on these areas, the objectives of this study were to document temperature and DO regimes in coastal wetlands in Lake Ontario, and provide a synoptic survey of substrate, aquatic macrophytes, and fish.

## METHODS

### *Overview*

Sampling sites were selected to capture the range of anthropogenic disturbances across Lake Ontario; coastal wetlands in the eastern part of the lake generally having low levels of disturbance and those in the west tending to be more degraded (Chow-Fraser 2006; Croft et al. 2017; Figure 1). Wetlands were selected along a gradient of habitat conditions outlined by the Durham Region protocol listings of coastal wetlands (Grabas et al. 2004)—which has been applied by various organizations for assessment (Environment Canada – Canadian Wildlife Service 2007, 2010)—and the Water Quality Index (Chow-Fraser 2006).

Ten wetlands on the Canadian side of Lake Ontario were sampled throughout July and August of 2013 and 2014. In 2013 and 2014, sampling occurred from July 3 to August 1 and July 24 to August 27, respectively. Sampling coverage within each wetland focused on the first kilometer upstream of the outlet of the wetland into Lake Ontario and sampling methods were consistent among all selected wetlands (i.e., <2 m depths, except hydroacoustic surveys). However, sampling effort among wetlands was variable

(Table 1). Temperature (°C), DO (mg/L), sediment type (Ponar grabs), SAV (hydroacoustic and plant community surveys), and fish (Fyke netting) were sampled at most wetlands (Table 1). If there were any issues with the quality of the initial assessment, then wetlands were sampled the following year (Table 1).

*Temperature and Dissolved Oxygen*

Onset Data HOBO™ loggers were used to monitor temperature (HOBO U22) and DO (HOBO U26) at two locations in each wetland (Figure 2). For each sampled wetland (Figure 1, except 15 Mile Creek), two sampling sites (or “sub-sites”) were selected to represent: i) low influence from Lake Ontario (“Inner”) and ii) high influence from Lake Ontario (“Outer”) (Figure 2). Temperature loggers were deployed in the majority of wetlands starting in July 2013 and continued until Fall 2015 at some sites (Table 1). To test for temperature variations vertically in the water column at each Inner and Outer sub-site, temperature loggers were deployed at the surface (<30 cm below surface) and also the bottom (30–50 cm from bottom depth; Figure 2). Not all wetlands were monitored for the entire duration of the study, however most temperature and DO loggers were maintained in 2013 and 2014 and retrieved in 2015 (Figure 2).

Loggers were set to record at 30-minute intervals. Loggers were deployed using U-moorings in water depths ranging from 1.5 to 2.0 m to ensure the loggers remained underwater, even during periods of low water (Figure 3).To identify the deployment site, a surface buoy was attached to a weight using stainless steel cable. The weight on the bottom was cabled to an additional weight, and a sub-surface buoy was attached to fix the loggers at approximately 30 cm above bottom to help avoid logger burial and dewatering. Loggers were attached inside a white PVC pipe to provide shading for the logger so temperatures should be reflective of the ambient conditions at this depth without being subject to solar heating. In the summer of 2014, temperature loggers were also deployed at the surface, just below the surface buoy. Prior to deployment, all loggers were calibrated and checked for performance to ensure their accuracy based on a pre-existing protocol (Larocque et al. 2020). Upon deployment and retrieval, GPS coordinates, water depth, logger ID, macrophyte density and type, substrate type, and distance to shore were recorded at the logger sites. Any notes regarding the quality of the deployment or retrieval were made; for example, if the logger was tampered with or buried in the sediment.

All logger data were processed for quality assurance and quality control in which any data collected during periods where loggers were not recording accurately (i.e., dewatered or buried) were removed, and a biofouling correction was applied where appropriate to DO loggers that had significant build-up (Larocque et al. 2020). Raw data was classified into ranges of temperature (warmwater >25 $^{o}$C; coolwater 19 $^{o}$C to 25 $^{o}$C; coldwater <19 $^{o}$C), and oxia (supersaturation >20 mg/L, normal >5 mg/L, hypoxic <5 and >2 mg/L, and anoxic <2 mg/L) that are relevant to fish. As well, frequency histograms and basic statistics for DO data were calculated in R Version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

*Substrate*

A total of 132 sediment samples were collected across all wetlands for 2013 and 2014, between April and October (Table 2). Sediment samples were primarily collected at SAV sampling sites for plant density, with additional sediment samples taken in each wetland to try and provide a more complete spatial coverage for mapping purposes (e.g., South Bay and Cootes Paradise).

A petite Ponar grab sampler was used to collect sediment samples, which were randomly subsampled when transferred to plastic sample jars. Photos were taken of all Ponar samples prior to being transferred to a sample jar. All samples were kept in a cooler and on ice until conveyance to the lab for analyses, where they were maintained at 4 °C until assessed. In addition, visual surveys in the field, classified sediment samples and in-water substrates into six size classes modified from the Wentworth scale: clay/silt, sand, gravel, cobble, rubble and boulder (Wentworth 1922). Wetlands are typically soft sediment environments so the larger substrate sizes (above gravel) were not found (with the exception of Humber Bay Park and shore areas in Cootes Paradise) and therefore visual substrate surveys are not presented or discussed further other than anecdotally.

Lab analyses of substrate samples included sieving (for particle or grain size) and loss on ignition tests (LOI: for organic carbon content). Detailed methods of the quantitative lab analyses of finer substrates were outlined in Gardner Costa et al. (2020). Grain size assessment separated substrate samples into size categories of gravel, sand, silt, and clay (Wentworth 1922) are presented as a percent composition of each size category. LOI assessment determined the amount of organic material in each sample by measuring the difference in mass of an oven-dried sample (i.e. no water content) before and after heating samples to 500 °C for two hours in a muffle furnace, thus removing organic content. All samples were processed by the NWRI Sedimentology Laboratory in Environment and Climate Change Canada.

*Vegetation - Quadrat Sampling*

In 2013, eight of the selected wetlands were sampled for vegetation using quadrat sampling, and in 2014 five of the selected wetlands were sampled for vegetation using the same protocol (Table 3). Quadrat sampling consisted of sampling all vegetation within a 1 m x 1 m area. Quadrat sites were chosen at the discretion of the field crew in an effort to best reflect total species richness in the fewest number of quadrats, as per the stratified protocol outlined in Croft and Chow-Fraser (2009). The assessment was completed visually in sites where water clarity allowed. Alternatively a hand rake or Ponar was used to retrieve vegetation samples for sites that could not be sampled visually due to water clarity or other factors (e.g., depth, dense algal growth). Within the 1-$m^2$ quadrat area, SAV and emergent plant species, species-specific percent cover, total percent cover, and percent algal cover were recorded. If a plant could not be identified in the field, a sample was taken in a plastic bag and kept moist for identification in the laboratory.

*Hydroacoustics (Vegetation & Depth)*

Hydroacoustic surveys were conducted to map SAV presence and cover in three wetlands; one in 2013 (Windermere Wetland) and two in 2014 (South Bay and Bayfield Marsh). A 204.8 kHz transducer with an 8.3 single beam (Biosonics MX Aquatic Habitat Echosounder unit) was towed through the water at approximately 4 knots. Hydroacoustic data were compiled and analyzed using Visual Habitat v2.0 (BioSonics Inc. Seattle, Wash.). For all three sites, bottom detection was set to -45 dB and plant detection was set to -70 dB. However, different maximum bottom depths were used in Bayfield Marsh and Windermere Wetland (5 m) in comparison to South Bay (25 m). Vegetation height was set to 10-cm due to the prevalence of *Chara* sp., particularly in South Bay. Vegetation detection was set to reset whenever a strong signal was lost. The bottom depth, vegetation height, and SAV percent cover were also calculated in Visual Habitat software (BioSonics Inc. Seattle, U.S.A.). These data were then exported, summary statistics were calculated in R Version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria), and the data were mapped in ArcMap 10.2 (ESRI Inc., Redlands, U.S.A.).

*Fish Community Sampling*

Wetlands were sampled using Fyke nets, with six sets per wetland, except South Bay which had 12 sets. South Bay is a large wetland complex with two distinct areas with different characteristics: one with dense SAV beds and one without. General dimensions of the Fyke nets were 3.6 m long with two 10 cm x 10 cm throats, and two 1.2 m x 0.9 m frames (set 0.9 m apart) followed by 5 hoops (0.76 m diameter) spaced 0.45 m apart, with the first hoop spaced 0.9 m from the second frame. The lead was 7.6 m x 0.9 m and the two wings were 3.6 m x 0.9 m and set at a 45° angle from the net mouth. The Fyke nets were made of nylon mesh with 4.8 mm mesh size. Nets were set in 3 main habitat types: 1) the emergent-SAV transition zone, where the lead started from emergent vegetation and moved offshore (perpendicular to the shoreline) with the throat facing the emergent vegetation; 2) within the SAV bed where the lead faced the nearest emergent vegetation; and 3) the SAV-open water transition zone where the lead faced the shoreline. Nets were set for approximately 24 hours in water depths ranging from 0.58 m to 1.00 m and had approximately a 15 cm of air in the cod-end to prevent turtles and other air-breathing vertebrates from drowning if trapped (Portt et al. 2006).

At each Fyke net site, GPS coordinates, weather, water depth, dominant species of macrophyte, date, and time were recorded when nets were set and retrieved. Upon net retrieval, fish were held in an aerated cooler until processed. Water in the aerated cooler was exchanged as necessary to ensure appropriate water temperatures and DO levels. Fish were identified by species, and measured for length (fork length ±1 mm) and wet mass (g). Fish were weighed using a digital balance to the nearest ±1 g, up to a maximum of 6000 g. Fish that were greater than 6000 g or that were too long to fit on a digital balance (e.g., Northern Pike; *Esox lucius*) were placed in a mesh sling and weighed with a hanging spring scale to the nearest 100 grams. Fish were weighed and measured individually up to a maximum of 20 fish per species per Fyke net. When samples of any species exceeded 20 fish, the fish were counted and batch weighed. All fish were released after processing. Fish that could not be identified in the field were measured, weighed, euthanized, and kept for identification as voucher specimens at a later date.

Turtles are often by-catch in Fyke nets, particularly in wetlands. Thus, all captured turtles were identified to species, their carapace length and width were measured to the nearest 1 mm, and they were weighed using a digital balance to the nearest 1 g, when possible. Sex was also recorded, when possible and all turtles were released. The presence of turtles was noted in fish community analyses.

## RESULTS AND DISCUSSION

*Temperature*

Temperature profiles in all wetlands followed a typical seasonal pattern that peaked in July and August, with temperatures ranging from approximately -10 °C to 33 °C throughout the year depending on the wetland (Note: 15 Mile Creek was not sampled). There was considerable daily variation at each site with some marked (5 °C to 10 °C) declines and increases, particularly during the spring and fall time periods, that could be attributed to diurnal fluctuations and not necessarily seiche events. However, possible explanations for rapid, large temperature fluctuations is precipitation and runoff or inflow increases, or intrusions of cold water from Lake Ontario, which was recently documented well in nearshore areas of the Toronto Region (Hlevca et al. 2015). Temperature loggers (and on occasion, DO loggers) could not always be retrieved and data gaps exist at certain wetlands (Figure 2).

From a fish habitat perspective, unsurprisingly, coastal wetlands did not provide appropriate thermal habitat for coldwater fishes (<19 °C), particularly from June to September (Table 4). Temperatures below 19 °C were frequently observed outside of this time period, but no fish surveys were conducted during this cold-water time to assess use of wetlands by coldwater species or to observe co-occurrence of coolwater and warmwater species. For coolwater fishes, temperatures above 25 °C occurred from June to September and, while all sites experienced higher temperatures, their duration was more variable among wetlands and between sampling sites (Table 5). Since the general temperature threshold for coolwater fishes is 25 °C, this would have implications for habitat use. Cootes Paradise, Jordan Harbour, and Windermere Wetland consistently had temperatures exceeding 25 °C in July and August (5–10 days), while Parrott’s Bay and Hay Bay had a less consistent pattern of warmer temperatures. Bayfield Marsh, Humber Bay Park, and South Bay had the shortest durations of temperatures greater than 25 °C. Finally, temperatures over 30 °C were seldom observed, but typically occurred in July (Table 6). Cootes Paradise, Jordan Harbour and Windermere Wetland had temperatures greater than 30 °C that lasted for more than a few hours in July of 2013 and 2015 (Table 6).

In the Great Lakes, climate change projections suggest that surface waters may increase by 1 °C to 7 °C by 2100 (Magnuson et al. 1997; Trumpickas et al. 2009).

Warming trends have already been documented in some nearshore areas (McCormick and Fahnenstiel 1999), as have shifts in the phenology of some Great Lakes species (e.g., Yellow Perch; *Perca flavescens*; Lyons et al. 2015). Along with increasing coastal development and habitat destruction, climate-change-mediated warming could have additive effects on the sensitive wetland ecosystems of Lake Ontario. Long-term monitoring of biotic and abiotic factors, such as temperature profiles, will provide crucial information for modelling and baseline comparisons designed to explore the potential effects of climate change on coastal wetland ecosystems.

*Dissolved Oxygen*

The majority of sites showed a normal distribution of DO values across the growing season (May to September; Figure 4–6). All sites (except 15 Mile Creek which was not sampled) experienced some periods of low DO (<5 mg/L), particularly during the growing season. Although, at most sites, the total time at low DO was less than 5–10 days for any month (Table 7). Hypoxia events (<2.5 mg/L) were infrequent and were only a concern at Bayfield Marsh (Inner), Cootes Paradise (Inner), and Windermere Wetland. Specifically in Bayfield Marsh, hypoxic conditions were present in the inner marsh throughout the growing season, peaking in July and August of 2014 when DO was below 2.5 mg/L for the entire duration. This may be attributed to burial as this is an unexpected result based on the plant conditions for this wetland but we did find elevated levels of silt at this site. Similarly at the constructed Windermere Wetland, hypoxia was most prevalent during July and August, but had a shorter duration than Bayfield Marsh. Finally, hypoxia in Cootes Paradise occurred in the early fall, which coincided with the senescence of aquatic macrophytes; however, the effects of water backflow from Hamilton Harbour may contribute to low DO levels, in addition to nutrient rich sediments and continued input from Dundas sewage treatment facility and combined sewer outfalls.

Complete winter data were only available for three wetlands: Windermere wetland, Cootes Paradise (both November 2014 to March 2015), and Huyck's Bay (November 2013 to January 2014) (Table 7 and Table 8). Windermere showed the longest periods of anoxia during the winter, particularly in February and March. In contrast, Cootes Paradise had only a short period of anoxia in March 2015 and, while DO in Huyck's Bay dropped below 5 mg/L in December 2013, it did not drop below 2.5 mg/L (Table 8). Limited overwinter hypoxia in these wetlands was not surprising, with the exception of Windermere Wetland, because they are all connected to moving waters, either in the form of an incoming channel or to Lake Ontario itself. These connections likely help to maintain oxygen levels for the duration of the winter even in shallow systems, while DO levels in Windermere wetland decline because it is separated from the main channel, flows are managed and pumped only occasionally (Table 7).

In addition to low DO posing potential problems for aquatic organisms, oxygen super-saturation can cause gas bubble disease in fishes and potentially lead to mortality (Rucker 1972). We estimated the duration and frequency of super-saturation in the growing season for plants (May–September). Super-saturation was based on DO levels of 20 mg/L or higher, which corresponds to 200% saturation at a water temperature of

20 °C at sea level. Super-saturation in nature can be caused by mechanical or biological means, and is usually associated with dam turbines or algal blooms (dams: Johnson et al. 2007; algae: Jones 2011). Presently, based on our data, super-saturation appears to be an uncommon but not abnormal event in Lake Ontario coastal wetlands, typically occurring for less than 24 hours in the span of a month (Table 9). However, highly productive and degraded wetlands, such as Cootes Paradise and Windermere Wetland, appear to undergo more frequent and variable super-saturation events, which may be abnormal. Huyck's Bay, Parrott's Bay, and Windermere Wetland all had slightly longer durations of super-saturation in June and July, but not for longer than 120 hours (5 days) in total. Note that these events were found to occur as part of diurnal oscillations such that super-saturation tended to coincide with peak photosynthesis midday before declining back to more typical DO levels overnight (Wetzel 2001).

*Substrate*

Most wetlands had 10 or more total substrate samples. South Bay had the most samples (38 samples over 2013 and 2014) and Windermere Wetland had the fewest samples (3 samples). Particle size analysis of collected subsamples quantified substrate size percent composition and dominant substrate type. Across all sites, silt and sand made up the majority of the sediment composition (mean 39.3 ± 28.3% and mean 45.5 ± 26.1% composition, respectively), followed by gravel and then clay (Table 10). Silt-dominated sites were located in channels and sheltered areas, whereas sites with higher exposure were found to be primarily sand-dominated (Table 10). Wetlands in eastern Lake Ontario primarily contained sand and silt (53.1± 30.7% and 40.4 ± 29.3% composition, respectively), with hardly any gravel or clay (Table 11). In contrast to wetlands in western Lake Ontario, where sand (41.3 ± 20.2%) was the dominant substrate, followed by silt (34.1 ± 27.7%) and gravel (20.8 ± 17.6%), suggesting a more heterogeneous substrate composition compared with eastern wetlands. It is uncertain whether this difference is geological or urban in nature. Although heterogeneity in substrate composition is generally attributed to geology; in western Lake Ontario substrate composition may be due to a higher intensity of development and armouring because of adjacent urban areas. Wetlands generally have higher proportions of small particle sizes suggesting that the more heterogeneous substrate composition in urban areas is not necessarily natural (Kronvang 2013; Russell et al. 2018).

Loss-on-ignition (LOI) organic content was variable across sites with a few outliers at both extremes: a mean equal to 15.0 ± 8.6% organic material content, and a range of values at each site of 2.3 to 27.9%. Where the mean LOI was above 10.0% (i.e. Cootes Paradise, Parrott's Bay, Jordan Harbour, Bayfield Marsh, Hay Bay, 15 Mile Creek; Table 10), it may have inhibitory effects upon SAV growth and percent cover (Barko and Smart 1983). Sites which were silt-dominated were found to consistently have the highest LOI values (>20%) (Table 10). This may indicate a tendency for SAV limitation, perhaps of certain species, in sheltered or high sedimentation areas, where silt was the most prevalent sediment type (grain size). Hydroacoustic analysis was only conducted at three sites, which does not provide enough data for comparison between sediment type and SAV coverage across wetland sites to test this correlation or effect.

*Vegetation Quadrat Sampling*

A total of 186 vegetation quadrats were sampled across the wetlands in 2013 and 2014. Most wetlands had more than 10 quadrats with some having more than 20 (e.g., South Bay had a total of 51 samples over 2013 and 2014). Two sites, Cootes Paradise and Windermere Wetland, had six quadrat samples each (Table 3).

Total species richness of all aquatic vegetation (submerged, floating, emergent) ranged from 3 (Jordan Harbour) to 18 species (Huyck's Bay and South Bay; Table 12). Although, there was considerable variation in the amount of effort in the different wetlands that skewed the interpretation of species richness (mean number of quadrats per site = 20 ± 14; range, 6–51). Controlling for effort, macrophyte species richness was still low at Jordan Harbour (0.20 species/quadrat) and highest at Parrott's Bay and Bayfield Marsh (1.8 and 1.3 species/quadrat, respectively). Regardless, there were spatial differences in macrophyte community richness, with higher diversity in the eastern Lake Ontario wetlands relative to those located in the west (Table 12). This result is consistent with previous vegetation surveys where lower diversity has been indicative of degraded vegetation communities in urbanized, western Lake Ontario (Croft and Chow-Fraser 2007; Grabas et al. 2012).

Total SAV percent cover was also higher (>50%) in the eastern Lake Ontario wetlands, with the exception of Bayfield Marsh where cover was less than 30%. This lower coverage in Bayfield Marsh is likely related to the location of the vegetation quadrats, which were primarily situated in the more open and exposed eastern part of the marsh because of accessibility issues. 15 Mile Creek was the sole site in western Lake Ontario that had greater than 50% SAV cover. It also had one of the higher overall species' (10) richness in this part of the lake (Table 12). A possible explanation for this higher SAV coverage is that water clarity at this site was greater than other western Lake Ontario wetlands.

In terms of species composition, non-native Eurasian milfoil (*Myriophyllum spicatum*) and native, floating, fragrant water lily (*Nymphaea odorata*) occurred at all but one site (Jordan Harbour; Table 12). These two species commonly occur in the Great Lakes and are can tolerate the degraded conditions found in most Ontario wetlands (Croft and Chow Fraser 2007). The absence of fragrant water lily at Humber Bay Park may be linked to the age of this wetland since it was completed in 1997 and therefore fragrant water lily may simply have not colonized this site yet as it is relatively isolated. Additionally, as a result of its recent creation, the substrate at this site was found to include cobble in visual surveys, which may exclude some common wetland plants that are dependent on finer sediments with more organic material. The absence of Eurasian milfoil from Cootes Paradise is surprising yet not unexpected when considering mid-season die-offs of SAV when turbidity increases (Tang et al. 2020). Other commonly occurring species throughout the survey included coontail (*Ceratophyllum demersum*), Canadian waterweed (*Elodea canadensis*) and a variety of *Potamogeton* species (e.g., *P. amplifolius*, *P. Richardsonii*, and the non-native *P. crispus*).

The invasive European water chestnut (*Trapa natans*) was observed at Bayfield Marsh on Wolfe Island in all but one of the quadrats. This species has been listed as a high-risk species for invasion within the Province of Ontario by the Ontario Ministry of Natural Resources (2010; *Field Guide to Aquatic Invasive Species*). It can form monocultures in shallow backwater areas and can out-compete a variety of native floating macrophytes and SAV. Monitoring and management of this species is ongoing in eastern Lake Ontario and should be expanded to other areas where this species may spread. We are unsure if the low DO conditions observed in Bayfield Marsh are related to the new invasive plant or high silt conditions or both.

*Hydroacoustics for Depth and Vegetation*

The hydroacoustic survey in South Bay was considerably more comprehensive than in either Bayfield Marsh or Windermere Wetland with an order of magnitude more sampling positions. Consequently, a spatial evaluation of SAV percent cover at Windermere Wetland and Bayfield Marsh in particular, is likely not appropriate, although the systems differ in size greatly. Regardless, at all three sites, SAV was detected at the vast majority of survey points, and where it was found, it typically had a high percent cover (Table 13; Figure 7–9). Both the Bayfield and Windermere surveys were conducted in relatively shallow water (<3 m), when compared with South Bay, which ranged in depth from 1 to 16 m (Table 13; Figure 10–12) and has a much greater extent than the other wetland areas. At South Bay, SAV tended to only occur in shallower water (<5 m). SAV occurred throughout Windermere wetland, which is entirely less than 2 m deep (Table 13).

Mean SAV height was highest in Bayfield Marsh, followed by Windermere Wetland, and then South Bay (Table 13; Figure 13–15). In South Bay, SAV height was typically low (<0.5 m) across the entire range of depths (Figure 16). Also, the wide spatial coverage of the survey at this site allowed for some high-level interpretation of the spatial coverage of SAV. In general, SAV percent cover was highest in the southern portion of the embayment, which is also the area with the lowest exposure to wind and wave action from Lake Ontario (Figure 7). SAV was absent from the deep, more open, part of the bay. However, it should be noted that the maximum depth for SAV was set to 10 m for the interpretation of the hydroacoustic data. Therefore, colonization beyond 10 m was not evaluated. Regardless, the mean and interquartile range for SAV presence shows that the majority of the vegetation occurs between 2 to 7 m. Note that max depth at the Windermere and Bayfield sites was 2.0 and 2.8 m, respectively.

*Fish Community Sampling*

In both 2013 and 2014, mean (± standard error) catch per unit effort (CPUE; number of fish per Fyke net hour) ranged from 0.5 ± 0.1 fish per hour in Jordan Harbour to 4.2 ± 2.1 fish per hour in Windermere Wetland (Table 14). In the three sites that were sampled in both 2013 and 2014, only Huyck's Bay showed consistent CPUE. In contrast, CPUE at both Humber Bay Park and South Bay was greater in 2014 than 2013. This may be explained by the increased spatial coverage of the net sets in South

Bay in 2014. For Humber Bay Park in 2014, a single net captured a large school of Emerald Shiner (*Notropis atherinoides*), likely skewing the CPUE at this site (Table 14). Similarly, high rates of capture of Fathead Minnow (*Pimephales promelas*; over 600 in three nets) in Windermere Wetland resulted in this site having the highest CPUE, despite it also having the lowest species richness (3) in 2014.

Windermere wetland was sampled again in 2015 and the mean CPUE was orders of magnitude higher than any previous recording in this study (1390 ± 327 fish/net hour). In contrast to the 2014 sampling, species richness was also much higher in 2015 (11 species; Table 15), but Fathead Minnow was again the most dominant species at the site with over 90,000 estimated in three nets. No or low piscivorous species were located in the system, therefore a low level of predation pressure on forage species may have allowed for the higher numbers, in addition to sheltered, warm conditions. Windermere wetland has a fishway barring fish wider than 5 cm from entering, further contributing to the lack of piscivorous species and thereby predation. Furthermore, Fathead Minnows are tolerant of low DO conditions, which likely allows them to thrive in the low DO and hypoxic conditions that were found to occur in Windermere Wetland in the winter and summer (Gertzen et al. 2012; Table 7; Table 8).

Pumpkinseed (*Lepomis gibbosus*) and Bluegill (*Lepomis macrochirus*) were found at all sampled sites (Table 15), they are both considered to be wetland-resident species (Jude and Pappas 1992) that are moderately tolerant to environmental degradation (Seilheimer and Chow-Fraser 2007; Barbour et al. 1999). Similarly, other commonly occurring species (e.g., Yellow Perch, Rock Bass, Brown Bullhead [*Ameiurus nebulosus*], Largemouth Bass [*Micropterus salmoides*], and Bowfin [*Amia calva*]); (Table 15), are all considered wetland-resident species (Jude and Pappas 1992) or are habitat generalists. Bowfin are of particular interest as they were captured in the largest numbers at Bayfield Marsh, a wetland that showed long periods of hypoxia during the summer and is not managed. The higher abundance of Bowfin at this site may be explained by their tolerance to low DO conditions as they are facultative air breathers (Horn and Riggs 1973) with access to a productive area.

Fish communities in all the wetlands were dominated by warmwater species and, while some coolwater species were present in our survey (e.g., Northern Pike [*Esox lucius*] and White Sucker [*Catostomus commersonii*]), their abundance was generally low during the summer sampling (Table 15). Some notable coolwater exceptions, included Emerald Shiner, Golden Shiner (*Notemigonus crysoleucas*), Yellow Perch (*Perca flavescens*), Rock Bass (*Ambloplites rupestris*), and the non-native Round Goby (*Neogobius melanostomus*), which were frequently found in the wetlands (Table 15). Alewife (*Alosa pseudoharengus*) was the only coldwater species detected and only a single individual was found at each Hay Bay and Humber Bay Park (Table 15). These two sites are in close proximity to open, coldwater pelagic areas, which may explain the capture of Alewife, although the species is known to reproduce in embayments (Klumb et al. 2003).

Round Goby, a non-native, invasive species was detected at five of seven sites in 2013 and three of five sites in 2014 (Table 15). When they were first detected in the Great

Lakes there was some suggestion that they may not enter vegetated areas or coastal wetlands, but there is increasing evidence that this is not true (Kornis et al. 2012; Midwood et al. 2015). Predation by Round Goby on a wetland spawning species (Muskellunge; *Esox masquinongy*) has also been reported (D. Weller, McMaster University, Hamilton, Ontario, personal communication, 2016.), suggesting this species may negatively affect native fishes by more than through habitat competition.

*Turtles*

Turtles were frequently captured as by-catch in the Fyke nets. Midland Painted Turtles (*Chrysemys picta marginata*) were the most common species and were captured in all wetlands except Huyck's Bay and Humber Bay Park (Table 16). However, given the wide-scale distribution of this species, it is likely that they also occur at or near these sites and were just not detected. Three turtle species that are listed under the Species at Risk Act in Ontario were captured during the fish surveys: an Eastern Musk Turtle (*Sternotherus odoratus*; status = threatened) was captured at Parrott's Bay in 2013, a Northern Map Turtle (*Graptemys geographica*; status = special concern) was captured at Humber Bay Park in 2013 and Common Snapping Turtles (*Chelydra serpintina*; status = special concern) were captured in two wetlands (South Bay in 2014 and Windermere Wetland in 2015). It should be noted that sampling efforts were limited given the size of some of the wetlands and deployments were not targeted specifically for turtles and are thus incidental. Alternate methods of sampling (i.e., baited nets, basking traps) would be required to fully assess the turtle assemblages in these coastal wetlands.

Turtles are most susceptible to low DO conditions during the winter. Midland Painted Turtles are generally considered to be more tolerant to low oxygen conditions (Jackson 2002). In contrast, Northern Map Turtles need higher levels of DO during overwintering and as such are likely only present near areas of strong water exchange and or groundwater upwelling. As winter DO levels were only measured at three sites, expanded sampling is likely required to evaluate the baseline DO conditions for turtles in winter.

## CONCLUSIONS

This report presents data collected as part of a baseline assessment of the status of Lake Ontario fish habitat in a subset of coastal wetlands to aide in present and future habitat and climate assessments. We briefly recapped the main findings of the baseline work and highlight interesting findings.

The temperature sampling showed similar seasonal variation in all wetlands. While most wetlands were found to be suitable habitat for warmwater and coolwater species, sustained warmer temperatures were observed in some wetlands in western Lake Ontario. One potential reason for elevated temperatures include increased degradation in the western Lake Ontario wetlands relative to the eastern wetlands, with varying degrees of wetland connectivity to the main lake, groundwater input, and vegetative cover depending on the particular wetland's hydro-geomorphology.

Dissolved oxygen monitoring showed DO regimes were similar across most wetlands, however, prolonged periods of hypoxia occurred in a subset of wetlands that are likely eutrophic (e.g., Cootes Paradise). Some hyper-oxygenation and high DO variability was also observed in a few cases.

Sediment sampling generally found the wetlands dominated by smaller particle sizes (e.g., silt and sand), although a recently restored site, Humber Bay Park, was predominantly cobble, which may also influence the establishment of aquatic vegetation. And western wetlands were silt dominant while eastern wetlands were sand dominant.

The species richness of vegetation and SAV percent cover were both found to be higher in the eastern wetlands relative to the western ones; these differences may be attributed to differing human impact intensities but in part may be due to geology. Different invasive plant species were present in different systems with no observable pattern without further analysis.

Fish community sampling was dominated in all wetlands by warmwater species, with some coolwater species captured in low abundances. Future analysis could include a fish-based index of biological integrity to expand upon this simple assessment of the fish community and may help assess ecosystem condition further.

Consideration for future studies would be to resample wetlands periodically to observe trends, and to increase the number of wetlands where the full suite of variables were collected to observe drivers of variability in biotic communities across the entirety of Lake Ontario, likely in partnership (e.g. Great Lakes Coastal Wetland Consortium). The information collected thus far will inform climate change modeling for the nearshore in Lake Ontario. The data collected during this study should prove useful for assessing wetland conditions within Lake Ontario, especially the hydroacoustic output from South Bay and other degraded and restored but artificial wetlands, that can contribute to the development of regional models for predicting SAV presence and cover under differing conditions.

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## TABLES AND FIGURES

**Table 1.** Summary of wetlands sampled by type, total and sampled area, and sampling conducted from 2013–2015.

| | | **15 Mile Creek** | **Bayfield Marsh** | **Cootes Paradise** | **Hay Bay (South)** | **Humber Bay Park** | **Huyck's Bay** | **Jordan Harbour** | **Parrott's Bay** | **South Bay** | **Windermere Wetland** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wetland Type** | | Riverine open, drowned river-mouth | Riverine connecting channel, protected bay | Riverine open, drowned river-mouth | Lacustrine protected bay | Lacustrine protected bay | Riverine barrier beach, drowned river | Riverine open, drowned river-mouth | Lacustrine protected bay | Lacustrine open bay | Riverine diked, protected |
| **Total Area (ha)** | | 40.8 | 475.2 | 320 | 1491.8 | 1.3 | 396.3 | 73.2 | 29.7 | 60.2 | 11.4 |
| **Year** | **Sampling Type** | **15 Mile Creek** | **Bayfield Marsh** | **Cootes Paradise** | **Hay Bay** | **Humber Bay Park** | **Huyck's Bay** | **Jordan Harbour** | **Parrott's Bay** | **South Bay** | **Windermere Wetland** |
| 2013 | Temp/DO | — | X | X | X | X | X | X | X | X | — |
| | Sediment | — | X | X | X | X | X | X | X | X | — |
| | Vegetation | — | X | X | X | X | X | X | X | X | — |
| | Acoustics | — | — | — | — | — | — | — | — | — | X |
| | Fish | — | X | — | X | X | X | X | X | X | — |
| Sampled Area (ha) | | 40.8 | 517.2*<br>...45.3 | 167 | 77.1 | 1.3 | 88.2 | 100 | 17.6 | 110 | — |
| 2014 | Temp/DO | — | X | X | X | X | X | X | X | X | X |
| | Sediment | X | — | — | — | X | — | — | — | X | X |
| | Vegetation | X | — | — | — | X | X | — | — | X | — |
| | Acoustics | — | X | — | — | — | — | — | — | X | — |
| | Fish | X | — | — | — | X | X | — | — | X | X |
| Sampled Area (ha) | | 13 | — | — | — | 1.3 | 88.2 | — | — | 1333*<br>… 128 | 7 |
| 2015 | Temp/DO | — | — | X | X | — | X | — | X | — | X |
| | Fish | — | — | — | — | — | — | — | — | — | X |
| Sampled Area (ha) | | — | — | — | — | — | — | — | — | — | 7 |

* Estimate of total wetland area taken from: Environment Canada – Canadian Wildlife Service 2007, 2010; "…" = area of wetland estimated by DFO sampling crew. Temp = temperature; DO = dissolved oxygen; — = not sampled; X = sampled.

**Table 2.** Number of sediment samples (petite Ponar grab) by wetland in 2013 and 2014.

| | Number of Samples | | |
|---|---|---|---|
| **Location** | **2013** | **2014** | **Total** |
| 15 Mile Creek | — | 6 | 6 |
| Bayfield Marsh | 10 | — | 10 |
| Cootes Paradise | 12 | — | 12 |
| Hay Bay | 11 | — | 11 |
| Humber Bay Park | 7 | 8 | 15 |
| Huyck's Bay | 14 | — | 14 |
| Jordan Harbour | 13 | — | 13 |
| Parrott's Bay | 10 | — | 10 |
| South Bay | 11 | 27 | 38 |
| Windermere Wetland | — | 3 | 3 |
| **Total** | **88** | **44** | **132** |

**Table 3.** Number of submerged aquatic vegetation quadrat samples by wetland in 2013 and 2014.

| | Number of Quadrats | | |
|---|---|---|---|
| **Location** | **2013** | **2014** | **Total** |
| 15 Mile Creek | — | 16 | 16 |
| Bayfield Marsh | 10 | — | 10 |
| Cootes Paradise | 6 | — | 6 |
| Hay Bay | 12 | — | 12 |
| Humber Bay Park | 8 | 14 | 22 |
| Huyck's Bay | 16 | 20 | 36 |
| Jordan Harbour | 15 | — | 15 |
| Parrott's Bay | 12 | — | 12 |
| South Bay | 11 | 40 | 51 |
| Windermere Wetland | — | 6 | 6 |
| **Total** | **90** | **96** | **186** |

**Table 4.** Total number of days within a month that bottom water temperature exceeded 19 °C (coldwater threshold) in wetlands, across years, at Inner and Outer sampling locations. Bolded values highlight exceedances greater than 5 days. [a,b,c]

| | | **Bayfield Marsh** | | **Cootes Paradise** | | **Hay Bay** | | **Humber Bay Park** | | | **Huyck's Bay** | | **Jordan Harbour** | | **Parrott's Bay** | | **South Bay** | | **Windermere Wetland** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inner | Outer (SLR) | Inner | Outer (HH) (Fishway) | Inner | Outer (BQ) | Inner | Mouth | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer |
| **2013** | **Jul** | | **7.0** | **23.0** | **23.0** | | | **10.7** | **12.4** | | **13.0** | | **28.0** | | **8.0** | | 2.0 | 2.0 | | |
| | **Aug** | | **31.0** | **30.8** | **30.9** | **30.0** | **30.0** | **11.8** | **16.7** | | **31.0** | | **31.0** | | **31.0** | | **31.0** | **31.0** | | |
| | **Sep** | | **15.1** | **17.0** | **17.6** | **17.1** | **12.9** | 4.1 | 4.6 | | **16.7** | | **18.4** | | **14.0** | | | **15.3** | | |
| | **Oct** | | 2.4 | 1.6 | 1.3 | 2.5 | 1.6 | 0.2 | 0.5 | | 2.8 | | 3.8 | | 2.1 | | | 1.8 | | |
| **2014** | **Apr** | 0.0 | 0.0 | | | 0.0 | 0.0 | | | | 0.0 | | | | 0.0 | 0.0 | | 0.0 | | |
| | **May** | **8.9** | 3.1 | **7.0** | **5.9** | 4.8 | **12.1** | | | | 1.3 | 0.8 | **6.2** | **7.0** | 1.9 | 0.1 | 0.6 | 0.0 | | |
| | **Jun** | **28.6** | | **29.9** | **29.6** | | **29.2** | 3.1 | 4.4 | 4.5 | | **26.8** | **30.0** | **29.9** | | **9.1** | **18.6** | **5.4** | | |
| | **Jul** | **30.5** | | **31.0** | **30.9** | | **31.0** | 2.1 | 2.4 | 1.4 | | **27.1** | **31.0** | **31.0** | | **30.7** | **31.0** | **14.8** | **7.0** | **7.0** |
| | **Aug** | **24.9** | | **29.6** | **28.8** | | **27.8** | **11.7** | **13.6** | **14.1** | | **27.7** | **31.0** | **30.9** | | **30.8** | **28.4** | **26.5** | **29.2** | **28.5** |
| | **Sep** | **11.1** | **5.0** | **17.5** | **16.3** | 4.1 | **12.0** | **5.9** | **6.4** | **6.8** | | **16.5** | **17.4** | **15.8** | **5.1** | **13.1** | **12.4** | **15.3** | **17.3** | **18.0** |
| | **Oct** | 0.5 | 1.4 | 0.6 | 1.3 | 1.2 | | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 1.7 | 1.2 | 2.5 | | 0.1 | 0.9 | 1.3 | 1.0 |
| **2015** | **Apr** | 0.2 | 0.0 | 0.2 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | 0.1 | | 0.5 | | 0 | 0.0 | 0.0 | 0.0 |
| | **May** | **11.1** | **10.4** | **17.5** | **11.0** | **14.3** | | 0.0 | 0.0 | | **8.7** | | **8.4** | | **17.6** | | **7.8** | 0.0 | **11.1** | 4.5 |
| | **Jun** | | | **25.7** | **24.6** | **24.2** | | 0.0 | 0.0 | | | | | | **23.4** | | | | **24.8** | **8.5** |
| | **Jul** | | | **31.0** | **31.0** | **30.0** | | | | | | | | | **29.7** | | | | **31.0** | **29.3** |
| | **Aug** | | | **31.0** | **30.9** | **31.0** | | | | | | | | | **31.0** | | | | **30.9** | **29.7** |
| | **Sep** | | | **23.9** | **24.2** | **21.8** | | | | | | | | | **22.4** | | | | **23.5** | **23.7** |
| | **Oct** | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.2 | | | | 0.0 | 0.0 |

[a] Temperatures measured from November to March were never >19 °C across all sites, so data are not presented here.

[b] Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario or Embayment, respectively.; Mouth at Humber Bay Park represents site at the mouth of Mimico Creek.

[c] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 5.** Total number of days within a month that bottom water temperature exceeded 25 °C (coolwater threshold) in wetlands, across years, at Inner and Outer sampling locations. Bolded values show exceedances greater than 5 days. [a,b,c]

| | | Bayfield Marsh | | Cootes Paradise | | Hay Bay | | Humber Bay Park | | | Huyck's Bay | | Jordan Harbour | | Parrott's Bay | | South Bay | | Windermere Wetland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inner | Outer | Inner | Outer (Fishway) | Inner | Outer | Inner | Mouth | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer |
| 2013 | Jul | | 1.5 | **14.0** | **13.0** | | | 0.4 | 2.4 | | **5.4** | | **19.0** | | 1.1 | | 0.0 | 0.0 | | |
| | Aug | | **5.8** | **12.0** | **5.4** | **7.5** | 4.8 | 0.0 | 0.4 | | **9.5** | | **11.0** | | 4.1 | | 2.1 | 1.5 | | |
| | Sep | | 0.9 | 1.9 | 0.7 | 1.9 | 1.2 | 0.0 | 0.0 | | 1.5 | | 2.4 | | 1.4 | | | 0.8 | | |
| | Oct | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | | 0.0 | | |
| 2014 | Apr | 0.0 | 0.0 | | | 0.0 | 0.0 | | | | 0.0 | | | | 0.0 | 0.0 | | 0.0 | | |
| | May | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | |
| | Jun | 0.8 | | **5.2** | 3.0 | | 4.1 | 0.0 | 0.0 | 0.0 | | 0.4 | **5.9** | 3.5 | | 0.0 | 0.6 | 0.0 | | |
| | Jul | 1.5 | | **8.3** | 3.7 | | **8.9** | 0.0 | 0.0 | 0.0 | | 1.8 | **8.5** | 4.1 | | 0.0 | 3.3 | 0.0 | 0.3 | 0.6 |
| | Aug | 0.0 | | **10.0** | 4.2 | | **8.1** | 0.0 | 0.0 | 0.0 | | 2.4 | **8.0** | 1.7 | | 0.0 | 1.9 | 1.7 | **6.0** | **8.7** |
| | Sep | 0.0 | 0.0 | 2.6 | 1.8 | 0.0 | 2.3 | 0.0 | 0.0 | 0.0 | | 1.1 | 1.9 | 0.9 | 0.1 | 0.0 | 0.1 | 0.0 | 1.5 | 2.0 |
| | Oct | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| 2015 | Apr | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | May | 0.9 | 0.0 | 0.6 | 0.2 | 0.0 | | 0.0 | 0.0 | | 0.0 | | 0.0 | | 3.1 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | Jun | | | 1.8 | 0.8 | 0.5 | | 0.0 | 0.0 | | | | | | 3.8 | | | | 1.1 | 0.0 |
| | Jul | | | **11.0** | **11.0** | **9.2** | | | | | | | | | **13.0** | | | | **5.9** | **8.6** |
| | Aug | | | **7.6** | 4.9 | **6.2** | | | | | | | | | **9.2** | | | | **5.4** | **5.9** |
| | Sep | | | **7.5** | **5.8** | 4.4 | | | | | | | | | **6.6** | | | | **6.8** | **7.6** |
| | Oct | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.0 | | | | 0.0 | 0.0 |

[a] Temperatures measured from November to March were never >25 °C across all sites, so data not included here.

[b] Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario or embayment, respectively; Mouth at Humber Bay Park represents site at the mouth of Mimico Creek.

[c] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 6.** Total number of days within a month that bottom water temperatures exceeded 30 °C (warmwater threshold) in wetlands, across years, at Inner and Outer sampling locations. There were no exceedances greater than 5 days. [a,b,c]

| | | Bayfield Marsh | | Cootes Paradise | | Hay Bay | | Humber Bay Park | | | Huyck's Bay | | Jordan Harbour | | Parrott's Bay | | South Bay | | Windermere Wetland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inner | Outer | Inner | Outer (Fishway) | Inner | Outer | Inner | Mouth | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer | Inner | Outer |
| 2013 | **Jul** | | 0.0 | 3.2 | 2.6 | | | 0.0 | 0.0 | | 0.0 | | 2.9 | | 0.0 | | 0.0 | 0.0 | | |
| | **Aug** | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.1 | | 0.0 | 0.0 | | |
| | **Sep** | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | | 0.0 | | |
| | **Oct** | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | | 0.0 | | |
| 2014 | **Apr** | 0.0 | 0.0 | | | 0.0 | 0.0 | | | | 0.0 | | | | 0.0 | 0.0 | | 0.0 | | |
| | **May** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | |
| | **Jun** | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | | |
| | **Jul** | 0.1 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Aug** | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Sep** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Oct** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| 2015 | **Apr** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | **May** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Jun** | | | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | | | | | | 0.0 | | | | 0.0 | 0.0 |
| | **Jul** | | | 0.0 | 0.1 | 0.0 | | | | | | | | | 0.0 | | | | 0.0 | 0.1 |
| | **Aug** | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.0 | | | | 0.0 | 0.0 |
| | **Sep** | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.0 | | | | 0.0 | 0.0 |
| | **Oct** | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.0 | | | | 0.0 | 0.0 |

[a] Temperatures measured from November to March were never >30.0 °C across all sites, so data not included here.
[b] Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario, respectively; Mouth at Humber Bay Park represents site at the mouth of Mimico Creek.
[c] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 7.** Total number of days within a month that bottom water dissolved oxygen was less than 5 mg/L (hypoxic) in wetlands, through sampled years. Bolded values show durations greater than 5 days. [a,b]

| | | Bayfield Marsh Inner | Cootes Paradise Inner | Cootes Paradise Outer (Fishway) | Hay Bay Inner | Humber Bay Park Inner | Huyck's Bay Inner | Jordan Harbour Inner | Parrott's Bay Inner | South Bay Inner | Windermere Wetland Inner |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | **Jul** | | 1.1 | | | | 0.0 | | 0.9 | | |
| | **Aug** | | 1.9 | | 0.3 | | 0.0 | | **7.8** | | |
| | **Sep** | | **11.3** | | 0.9 | | 0.0 | | **11.1** | | |
| | **Oct** | | **31.0** | | 0.1 | | 0.0 | | **8.4** | | |
| | **Nov** | | **13.5** | | 0.0 | | 0.0 | | 0.0 | | |
| | **Dec** | | | | | | **9.9** | | | | |
| 2014 | **Jan** | | | | | | 0.4 | | | | |
| | **May** | **9.0** | 0.1 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.1 | |
| | **Jun** | **30.0** | 3.9 | | 0.6 | 0.0 | 0.5 | 2.7 | 0.6 | **8.2** | |
| | **Jul** | **31.0** | 3.5 | | 2.5 | 0.1 | 0.0 | 3.0 | 0.8 | **9.6** | 0.0 |
| | **Aug** | **31.0** | 3.4 | | 1.1 | 0.6 | 0.0 | **7.7** | 1.6 | **6.5** | 0.1 |
| | **Sep** | **13.7** | **13.4** | | 1.0 | 3.5 | 0.0 | **7.3** | **7.8** | **8.5** | 0.0 |
| | **Oct** | | 2.6 | | | 0.6 | 0.0 | **8.1** | | **6.3** | 0.0 |
| | **Nov** | | | 0.0 | | 0.0 | | 0.0 | | | 0.0 |
| | **Dec** | | | 0.0 | | | | | | | 0.0 |
| 2015 | **Jan** | | | 0.0 | | | | | | | 0.7 |
| | **Feb** | | | 0.0 | | | | | | | **26.8** |
| | **Mar** | | | 1.4 | | | | | | | **20.6** |
| | **Apr** | | | **18.9** | | | | | | | 0.0 |
| | **May** | | | 1.4 | 0.0 | | | | 0.8 | | 0.6 |
| | **Jun** | | | **10.9** | 0.5 | | | | 0.5 | | 0.6 |
| | **Jul** | | | 4.9 | **5.1** | | | | **8.4** | | **21.1** |
| | **Aug** | | | **5.4** | 4.0 | | | | 1.0 | | **21.9** |
| | **Sep** | | | **8.3** | 1.5 | | | | 0.0 | | **12.5** |
| | **Oct** | | | **9.4** | 0.0 | | | | | | 2.3 |
| | **Nov** | | | 0.1 | 0.0 | | | | | | 0.0 |

[a] Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario, respectively.
[b] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 8**. Total number of days within a month that bottom water dissolved oxygen was less than 2.5 mg/L (anoxic) in wetlands, across years. Bolded values show durations greater than 5 days. [a,b]

| | | Bayfield Marsh Inner | Cootes Paradise Inner | Cootes Paradise Outer (Fishway) | Hay Bay Inner | Humber Bay Park Inner | Huyck's Bay Inner | Jordan Harbour Inner | Parrott's Bay Inner | South Bay Inner | Windermere Wetland Inner |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | **Jul** | | 0.0 | | | | 0.0 | | 0.0 | | |
| | **Aug** | | 0.0 | | 0.0 | | 0.0 | | 2.3 | | |
| | **Sep** | | **7.7** | | 0.1 | | 0.0 | | **5.1** | | |
| | **Oct** | | **30.9** | | 0.0 | | 0.0 | | 3.2 | | |
| | **Nov** | | **13.3** | | 0.0 | | 0.0 | | 0.0 | | |
| 2014 | **Dec** | | | | | | 0.0 | | | | |
| | **Jan** | | | | | | 0.0 | | | | |
| | **May** | 4.8 | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | |
| | **Jun** | **16.6** | 0.1 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | |
| | **Jul** | **26.1** | 0.0 | | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 1.7 | 0.0 |
| | **Aug** | **30.1** | 0.1 | | 0.0 | 0.0 | 0.0 | 2.5 | 0.1 | 1.4 | 0.0 |
| | **Sep** | **13.2** | **9.4** | | 0.0 | 0.3 | 0.0 | 2.8 | 4.6 | 3.8 | 0.0 |
| | **Oct** | | 1.4 | | | 0.0 | 0.0 | 2.1 | | 2.8 | 0.0 |
| | **Nov** | | | 0.0 | | 0.0 | | 0.0 | | | 0.0 |
| 2015 | **Dec** | | | 0.0 | | | | | | | 0.0 |
| | **Jan** | | | 0.0 | | | | | | | 0.0 |
| | **Feb** | | | 0.0 | | | | | | | **22.1** |
| | **Mar** | | | 1.3 | | | | | | | **20.6** |
| | **Apr** | | | **17.5** | | | | | | | 0.0 |
| | **May** | | | 0.5 | 0.0 | | | | 0.1 | | 0.0 |
| | **June** | | | **5.6** | 0.0 | | | | 0.0 | | 0.0 |
| | **Jul** | | | 0.9 | 0.5 | | | | 0.9 | | **15.4** |
| | **Aug** | | | 1.0 | 0.3 | | | | 0.0 | | **12.3** |
| | **Sep** | | | 1.9 | 0.0 | | | | 0.0 | | **6.8** |
| | **Oct** | | | 4.0 | 0.0 | | | | | | 0.7 |
| | **Nov** | | | 0.0 | 0.0 | | | | | | 0.0 |

[a] Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario, respectively.
[b] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 9.** Total number of days within a month that bottom water dissolved oxygen was >20 mg/L (indicative of super-saturation) in the wetlands sampled, across years. Bolded values show exceedances equal or greater than 1 day. [a,b]

| | | Bayfield Marsh Inner | Cootes Paradise Inner | Cootes Paradise Outer (Fishway) | Hay Bay Inner | Humber Bay Park Inner | Huyck's Bay Inner | Jordan Harbour Inner | Parrott's Bay Inner | South Bay Inner | Windermere Wetland Inner |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2013** | **Jul** | | 0.0 | | | | 0.0 | | 0.0 | | |
| | **Aug** | | 0.0 | | 0.0 | | 0.0 | | 0.0 | | |
| | **Sep** | | 0.0 | | 0.0 | | 0.0 | | 0.0 | | |
| **2014** | **May** | 0.0 | 0.0 | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | |
| | **Jun** | 0.0 | 0.0 | | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | |
| | **Jul** | 0.0 | 0.0 | | 0.0 | 0.0 | **5.1** | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Aug** | 0.0 | 0.0 | | 0.0 | 0.0 | 0.3 | 0.0 | **1.0** | 0.8 | 0.0 |
| | **Sep** | 0.0 | 0.1 | | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | **2.3** | 0.0 |
| **2015** | **May** | | | 0.3 | 0.0 | | | | 0.2 | | **1.1** |
| | **Jun** | | | 0.0 | 0.0 | | | | **3.3** | | **1.4** |
| | **Jul** | | | 0.0 | 0.0 | | | | 0.0 | | 0.0 |
| | **Aug** | | | 0.0 | 0.0 | | | | 0.0 | | 0.0 |
| | **Sep** | | | 0.1 | 0.0 | | | | 0.0 | | 0.0 |

[a] Only the growing season (May–September) was considered when water with DO levels of 20.0 mg/L were super-saturated due to peak photosynthesis.
[b] Blank cells represent times where there is no data – not collected or sampling failed (see Figure 2).

**Table 10.** Mean particle size (%) for sediment samples at all sites based on the Wentworth (1922) scale classification. Mean Loss on ignition (LOI) (%) for all sites is **bold**. Values equal to or above 80% are in red.[a]

| | 15 Mile Creek | Bayfield Marsh | Cootes Paradise | Hay Bay | Humber Bay Park | Huyck's Bay | Jordan Harbour | Parrott's Bay | South Bay | Windermere Wetland | Mean All | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gravel** | 10.5 | 5.3 | 4.8 | 5.4 | 27.3 | 5.1 | 8.9 | 7.3 | 5.1 | 52.4 | 12.8 | 13.9 |
| **Sand** | 18.0 | 10.7 | 54.6 | 87.5 | 68.3 | 64.4 | 18.0 | 23.1 | 79.8 | 47.6 | 45.5 | 26.1 |
| **Silt** | 56.8 | 80.6 | 39.3 | 7.1 | 4.5 | 30.5 | 69.7 | 69.1 | 14.8 | 0.0 | 39.3 | 28.3 |
| **Clay** | 14.8 | 3.5 | 1.4 | 0.1 | 0.0 | 0.1 | 3.4 | 0.5 | 0.4 | 0.0 | 2.4 | 4.1 |
| **LOI** | **23.0** | **20.4** | **12.2** | **15.9** | **2.3** | **7.2** | **15.4** | **27.9** | **10.0** | **4.4** | **15.0** | **8.6** |

[a] Sediment size classes based on Wentworth (1922) scale classification (in mm): gravel (2.0–16.0); sand (0.06–1.9); silt (<0.06); clay (<0.06)

**Table 11.** Mean percentage (%) for each sediment size class[a] and loss on ignition (LOI) (%) values for all eastern Lake Ontario sites (blue) and western sites (red) identified on the map in Figure 1.

| | Western Lake Ontario wetlands | | Eastern Lake Ontario Wetlands | |
|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev |
| Gravel | 20.8 | 17.6 | 5.6 | 0.8 |
| Sand | 41.3 | 20.2 | 53.1 | 30.7 |
| Silt | 34.1 | 27.7 | 40.4 | 29.3 |
| Clay | 3.9 | 5.6 | 0.9 | 1.3 |
| LOI | 11.5 | 7.5 | 16.3 | 7.4 |

[a] Sediment size classes based on Wentworth (1922) scale classification (in mm): gravel (2.0-16.0); sand (0.06-1.9); silt (<0.06); clay (<0.06).

**Table 12.** Summary of quadrat-based, vegetation-sampling effort and the number of plant species within each structural group (submerged, floating-leaved, and emergent) identified in each wetland across all quadrats.

| | | Number of Plant Species | | | |
|---|---|---|---|---|---|
| **Wetland** | **Total Quadrats** | **Submerged** | **Floating Leaved** | **Emergent** | **Total Species** |
| 15 Mile Creek | 16 | 6 | 4 | 0 | 10 |
| Bayfield Marsh | 10 | 11 | 2 | 0 | 13 |
| Cootes Paradise | 6 | 5 | 1 | 1 | 7 |
| Hay Bay | 12 | 12 | 1 | 2 | 15 |
| Humber Bay Park | 22 | 6 | 0 | 0 | 6 |
| Huyck's Bay | 36 | 18 | 2 | 3 | 23 |
| Jordan Harbour | 15 | 1 | 2 | 0 | 3 |
| Parrott's Bay | 12 | 15 | 5 | 1 | 21 |
| South Bay | 51 | 16 | 5 | 2 | 23 |
| Windermere Wetland* | 6 | -- | -- | -- | -- |
| **Total** | **186** | **21** | **8** | **4** | **33** |

***** No vegetation data collected

**Table 13.** Results from the hydroacoustic surveys for submerged aquatic vegetation (SAV) in the three wetlands sampled. The proportion of hydroacoustic points where SAV was present (Prop. SAV) is shown as the mean, inter-quartile range, and minimum to maximum depth (min–max) for SAV percent (%) cover and SAV height.

| | | SAV % Cover | | | SAV Height (m) | | |
|---|---|---|---|---|---|---|---|
| **Wetland** | **Prop. SAV** | **Mean** | **1st –3rd Quartile** | **Min–Max** | **Mean** | **1st – 3rd Quartile** | **Min–Max** |
| South Bay | 60 | 81.1 ± 27.9 | 70–100 | 10–100 | 0.39 ± 0.29 | 0.17–0.52 | 0.10–2.31 |
| Bayfield Marsh | 59 | 97.1 ± 10.5 | 100–100 | 0–100 | 0.86 ± 0.29 | 0.70–1.03 | 0.00–1.83 |
| Windermere Wetland | 66 | 73.4 ± 28.8 | 50–100 | 10–100 | 0.48 ± 0.22 | 0.28–0.62 | 0.10–1.17 |

**Table 14.** Fish catch-per-unit-effort (CPUE: number of fish captured per net-hour) at each wetland sampled across the three sampling years. The numbers of 24-hour Fyke nets set and the total count are also shown.

| Year | Location [a] | 24-hr Fyke Nets | Total Fish Count | CPUE | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean CPUE | SE | Min | Max |
| 2013 | Bayfield Marsh | 6 | 124 | 0.83 | 0.36 | 0.12 | 2.21 |
| | Hay Bay | 6 | 96 | 0.62 | 0.27 | 0.04 | 1.63 |
| | Humber Bay Park | 6 | 236 | 1.58 | 0.83 | 0.12 | 5.13 |
| | Huyck's Bay | 6 | 68 | 0.45 | 0.19 | 0.00 | 1.32 |
| | Jordan Harbour | 6 | 64 | 0.45 | 0.09 | 0.13 | 0.71 |
| | Parrott's Bay | 6 | 137 | 0.92 | 0.30 | 0.04 | 1.62 |
| | South Bay | 6 | 407 | 2.76 | 1.66 | 0.16 | 10.93 |
| | **Total** | **36** | **1008** | **19.00** | **0.28** | **0.00** | **10.93** |
| 2014 | 15 Mile Creek | 6 | 175 | 1.20 | 0.42 | 0.16 | 2.24 |
| | Humber Bay Park | 6 | 391 | 2.64 | 2.41 | 0.00 | 14.68 |
| | Huyck's Bay | 6 | 96 | 0.67 | 0.15 | 0.30 | 1.25 |
| | South Bay | 12 | 875 | 3.34 | 0.61 | 0.42 | 6.99 |
| | Windermere Wetland | 6 | 626 | 4.24 | 2.05 | 0.20 | 13.41 |
| | **Total** | **36** | **2163** | **2.57** | **0.57** | **0.00** | **14.68** |
| 2015 | Windermere Wetland | **3** | **100,091** | **1390.15** | **327.31** | **907.08** | **2014.29** |

[a] Fish surveys not conducted at Cootes Paradise; fish survey data is available from RBG (unpublished data) .

**Table 15.** List of fish species caught, their temperature guild, and total counts at each wetland across sampling years.[a,b]

| | | | 15 Mile Creek | Bayfield Marsh | Hay Bay | Humber Bay Park | | Huyck's Bay | | Jordan Harbour | Parrott's Bay | South Bay | | Windermere Wetland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Common Name** | **Temp. Guild** | **2014** | **2013** | **2013** | **2013** | **2014** | **2013** | **2014** | **2013** | **2013** | **2013** | **2014** | **2014** | **2015** |
| *Alosa pseudoharengus* | Alewife | Cold | | | 1 | 1 | | | | | | | | | |
| *Ambloplites rupestris* | Rock Bass | Cool | | 2 | 6 | 9 | 10 | 9 | 15 | | 4 | 40 | 126 | | |
| *Ameiurus nebulosus* | Brown Bullhead | Warm | 25 | 32 | 1 | 8 | | | | 7 | 6 | 6 | 9 | | 2 |
| *Amia calva* | Bowfin | Warm | 3 | 17 | 4 | 1 | | 2 | | | 3 | 1 | 2 | | |
| *Carassius auratus* | Goldfish | Warm | | | | 1 | | | | | | | | | 365 |
| *Catostomus commersonii* | White Sucker | Cool | | | | 1 | 1 | | | | | | 3 | | |
| *Culaea inconstans* | Brook Stickleback | Cool | | | | | | | | | | | 3 | | |
| *Cyprinella spiloptera* | Spotfin Shiner | Warm | | | 1 | | | | | | | | 3 | | |
| *Cyprinus carpio* | Common Carp | Warm | 1 | 4 | | 2 | | | | | | | | | 7 |
| *Dorosoma cepedianum* | Gizzard Shad | Cool | 1 | | | | | | | | | | 3 | | |
| *Esox lucius* | Northern Pike | Cool | 2 | 1 | | | | 2 | 2 | | 1 | | 1 | | |
| *Etheostoma olmstedi* | Tesselated Darter | Cool | | | | | | | | | | | 1 | | |
| *Fundulus diaphanus* | Banded Killifish | Cool | | | | | | 2 | | | | 14 | 50 | | |
| *Gasterosteus aculeatus* | Threespine Stickleback | Cool | | | | 1 | | | | | | | | | 2 |
| *Labidesthes sicculus* | Brook Silverside | Warm | | | | | | | | 1 | | | | | |
| *Lepisosteus osseus* | Longnose Gar | Warm | | | | | | 1 | | | 1 | | 2 | | |
| *Lepomis cyanellus* | Green Sunfish | Warm | 1 | | | 16 | 4 | | | 2 | | | | 1 | 617 |
| *Lepomis gibbosus* | Pumpkinseed | Warm | 16 | 22 | 12 | 84 | 9 | 14 | 18 | 28 | 32 | 80 | 60 | | 221 |
| *Lepomis macrochirus* | Bluegill | Warm | 107 | 16 | 14 | 76 | 2 | 29 | 25 | 13 | 33 | 3 | 15 | | 21 |
| *Micropterus dolomieu* | Smallmouth Bass | Cool | | | | 1 | | | | | | | 9 | | |
| *Micropterus salmoides* | Largemouth Bass | Warm | 5 | 12 | 7 | 1 | 1 | 4 | 4 | 2 | 19 | 125 | 318 | | |
| *Morone americana* | White Perch | Warm | 1 | | | | | | | | 5 | | | | 7 |
| *Neogobius melanostomus* | Round Goby | Cool | | | 4 | 13 | 11 | 1 | | 7 | | 4 | 200 | 9 | 5 |

| Species Name | Common Name | Temp. Guild | 15 Mile Creek | Bayfield Marsh | Hay Bay | Humber Bay Park | | Huyck's Bay | | Jordan Harbour | Parrott's Bay | South Bay | | Windermere Wetland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **2014** | **2013** | **2013** | **2013** | **2014** | **2013** | **2014** | **2013** | **2013** | **2013** | **2014** | **2014** | **2015** |
| *Notemigonus crysoleucas* | Golden Shiner | Cool | 5 | 1 | 2 | | | | 18 | | 11 | 3 | 3 | | |
| *Notropis anogenus* | Pugnose Shiner | Cool | | | | | | | | | | | **1** | | |
| *Notropis atherinoides* | Emerald Shiner | Cool | | | 1 | 7 | 353 | | | 2 | | | 2 | | |
| *Notropis bifrenatus* | Bridle Shiner | Cool | | | | | | | | | | | 4 | | |
| *Notropis heterodon* | Blackchin Shiner | Cool | | | | | | | | | | 33 | 26 | | |
| *Notropis hudsonius* | Spottail Shiner | Cool | | | | | | | | | | | | | 2 |
| *Noturus gyrinus* | Tadpole Madtom | Warm | 1 | | | | | 1 | | | | 5 | 27 | | |
| *Perca flavescens* | Yellow Perch | Cool | | 3 | 41 | 11 | | 1 | 10 | | 21 | 91 | 3 | | |
| *Pimephales notatus* | Bluntnose minnow | Warm | | | | | | 1 | 1 | 2 | | 2 | 3 | | |
| *Pimephales promelas* | Fathead Minnow | Warm | | | | 1 | | | | | | | | 616 | 98,840 |
| *Pomoxis nigromaculatus* | Black Crappie | Cool | 3 | 13 | 1 | 2 | | | 3 | | | | 1 | | |
| *Scardinius erythrophthalmus* | Rudd | Cool | 4 | | | | | | | | | | | | |
| *Umbra limi* | Central Mudminnow | Cool | | 1 | | | | | | | | | | | |
| **Total number of fish captured** | | | **175** | **124** | **95** | **236** | **391** | **67** | **96** | **64** | **136** | **407** | **875** | **626** | **100,089** |
| **Total species richness** | | | **14** | **12** | **13** | **18** | **8** | **12** | **9** | **9** | **11** | **13** | **25** | **3** | **11** |

[a] Blank cells indicate the species was not caught at the site in that year.

[b] Temp. Guild = Temperature Guild: Cold = coldwater; Cool = coolwater; Warm = warmwater.

**Table 16.** Summary of turtle by-catch in 2013, 2014, and 2015 Fyke net sets. Species are coded as Eastern Musk Turtle (STOD, *Sternotherus odoratus*), Midland Painted Turtle (CHPM, *Chrysemys picta marginata*), Northern Map Turtle (GRGE, *Graptemys geographica*), and Common Snapping Turtle (CHSE, *Chelydra serpentina*).[a]

| | 2013 | | | 2014 | | 2015 | | |
|---|---|---|---|---|---|---|---|---|
| **Wetland** | **STOD** | **CHPM** | **GRGE** | **CHPM** | **CHSE** | **CHPM** | **CHSE** | **Total Catch** |
| 15 Mile Creek | — | — | — | 11 | 0 | — | — | 11 |
| Bayfield Marsh | 0 | 9 | 0 | — | — | — | — | 9 |
| Hay Bay (north) | 0 | 4 | 0 | 0 | 0 | — | — | 4 |
| Humber Bay Park | 0 | 0 | 1 | 0 | 0 | — | — | 1 |
| Huyck's Bay | 0 | 0 | 0 | 0 | 0 | — | — | 0 |
| Jordan Harbour | 0 | 16 | 0 | — | — | — | — | 16 |
| Parrott's Bay | 1 | 8 | 0 | 0 | 0 | — | — | 9 |
| South Bay | 0 | 4 | 0 | 0 | 5 | — | — | 4 |
| Windermere Basin | — | — | — | 0 | 0 | 2 | 13 | 21 |
| **Total** | **1** | **41** | **1** | **17** | **5** | **2** | **13** | **60** |

[a] Zeros (0) indicate that no turtles were captured during surveys and a "—" indicates the site was not sampled that year.

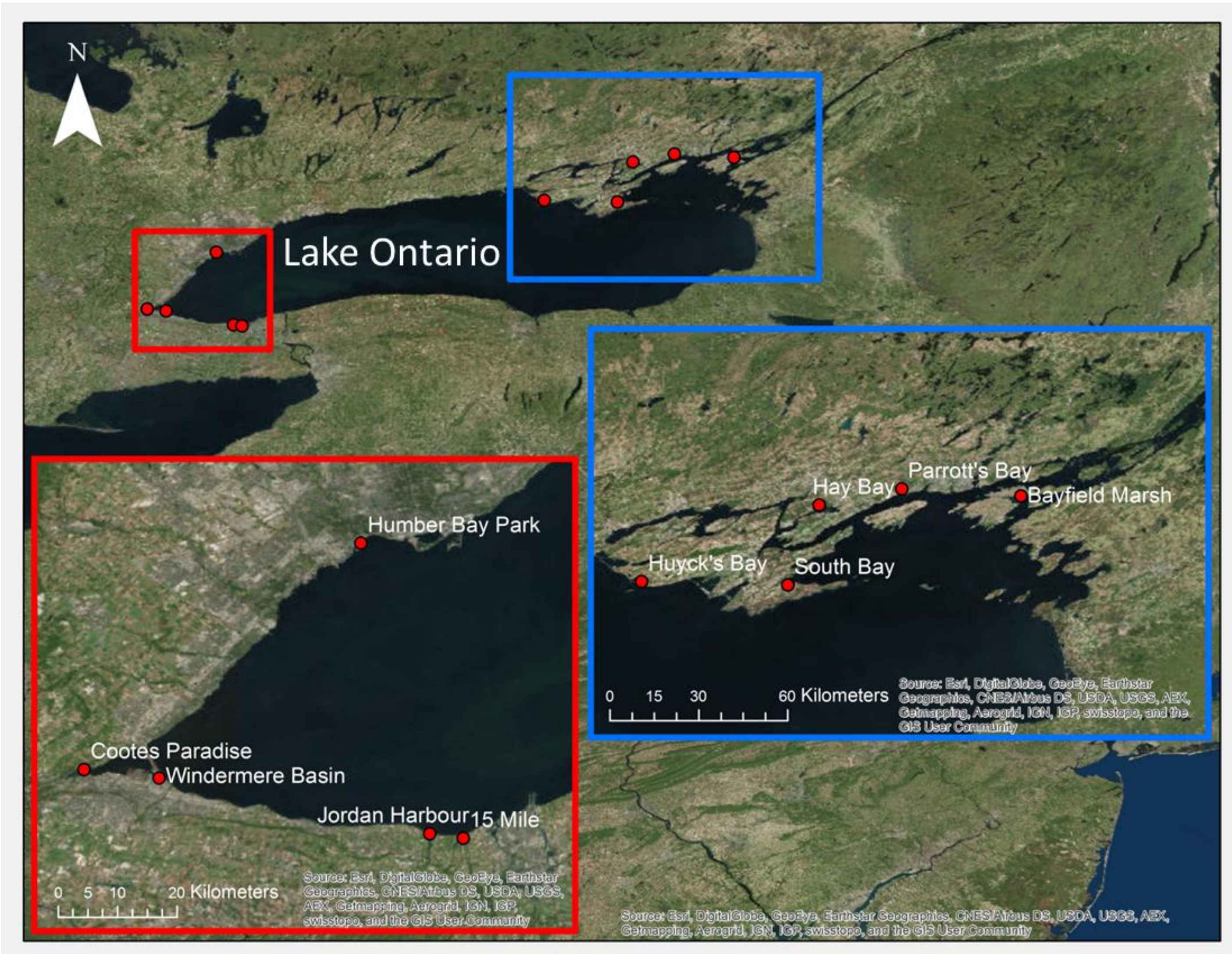


**Figure 1.** Location of wetlands assessed in the eastern (blue) and western (red) basins of Lake Ontario

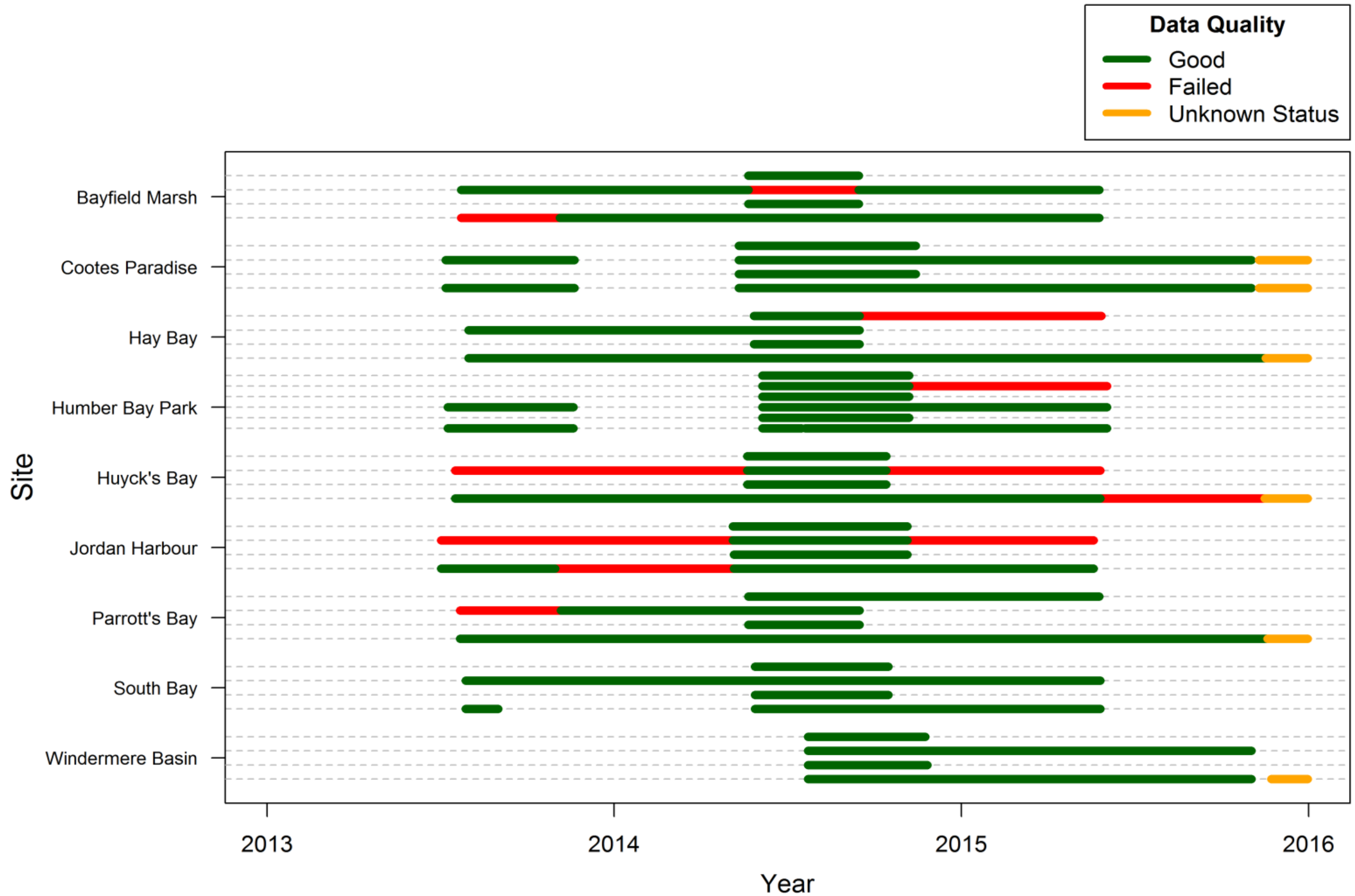


**Figure 2.** Summary of long-term temperature deployments and quality of data retrieved in wetlands from 2013–2015. Sites with four sub-sites (dashed lines) are from bottom to top: Inner-Bottom, Inner-Surface, Outer-Bottom, and Outer-Surface. Humber Bay Park site has six sub-sites that from bottom to top are: Inner-Bottom, Inner-Surface, Mouth-Bottom, Mouth-Surface, Outer-Bottom, and Outer-Surface. Inner and Outer sub-sites represent i) low connectivity to Lake Ontario and ii) high connectivity to Lake Ontario, respectively; Mouth at Humber Bay Park represents site at the mouth of Mimico Creek.

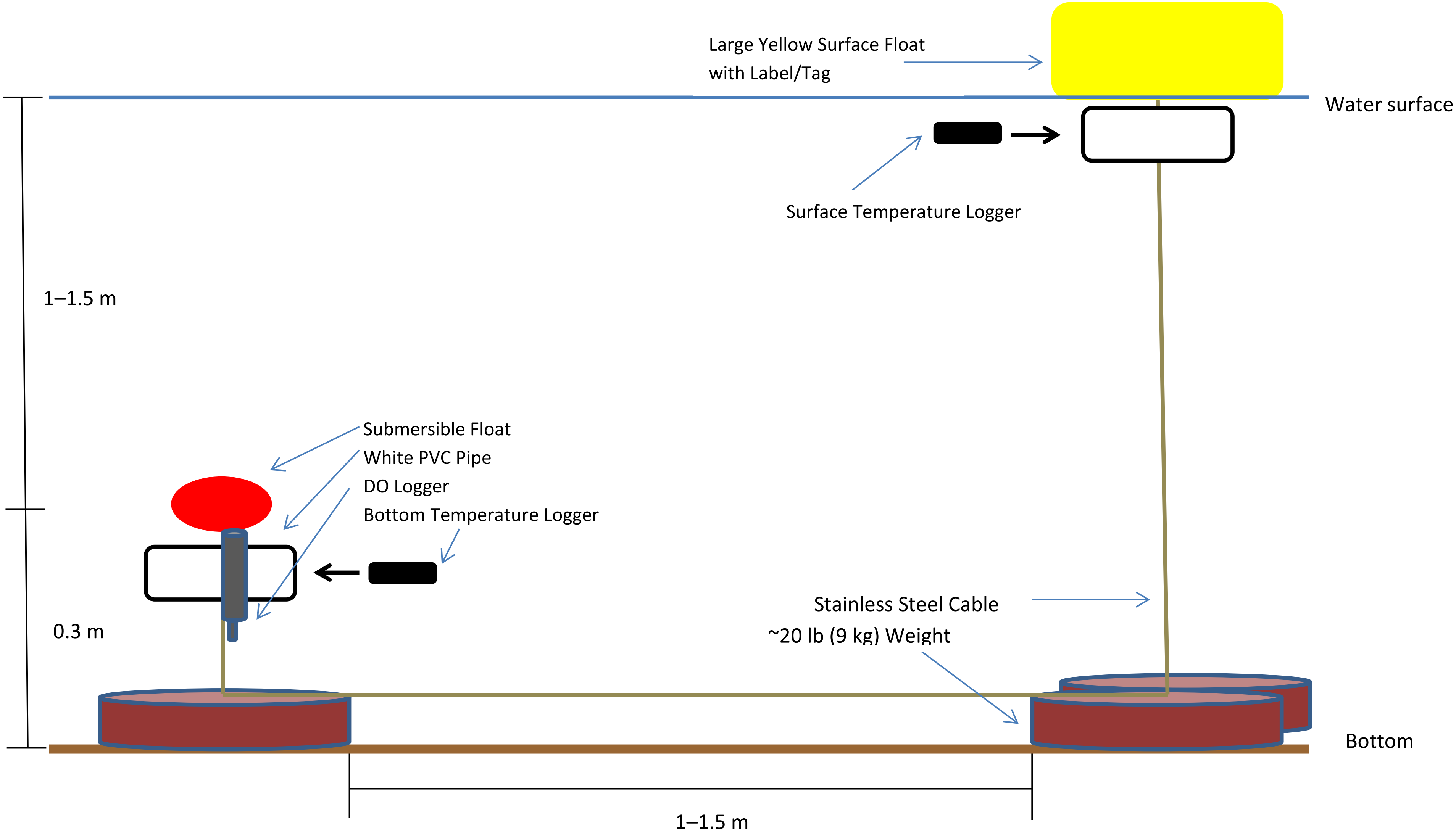


**Figure 3.** Typical logger deployment setup (including surface temperature logger).

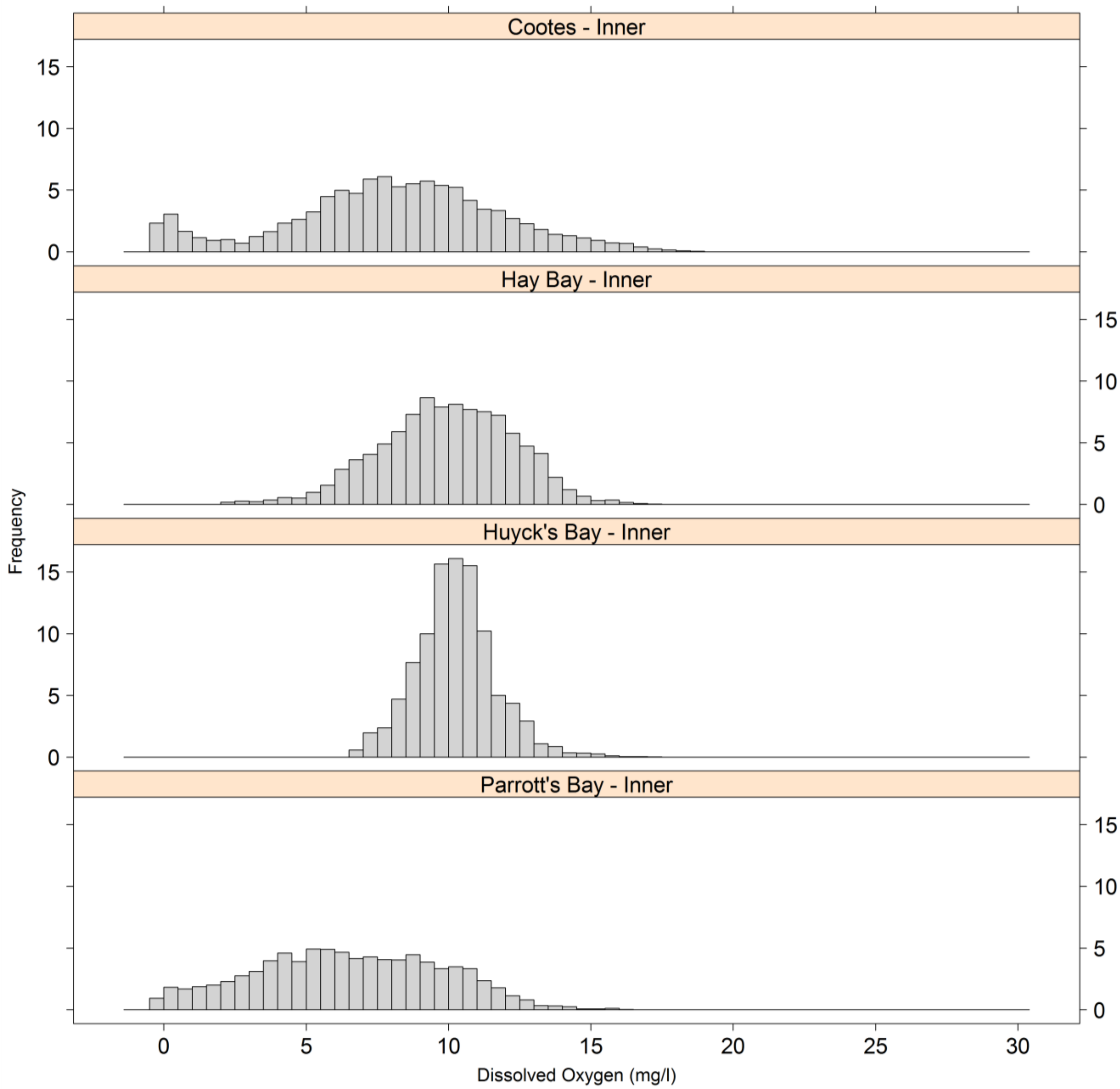


**Figure 4.** Frequency histogram of dissolved oxygen (mg/L) over the growing season (May through September) at wetlands sampled in 2013.

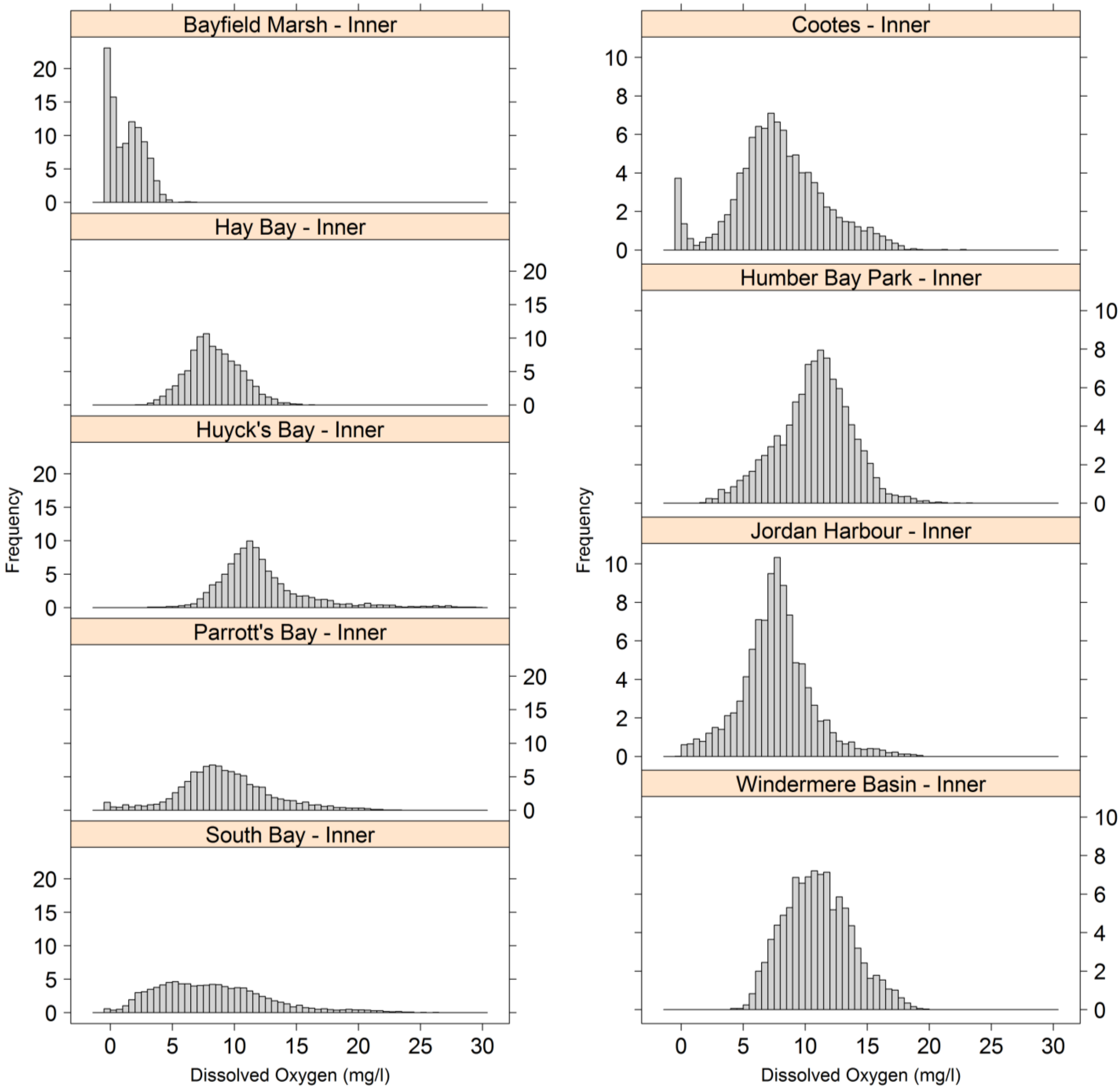


**Figure 5.** Frequency histogram of dissolved oxygen (mg/L) over the growing season (May through September) at wetlands sampled in 2014. Left column are wetlands on the eastern part of Lake Ontario, and the right column are wetlands on the western part of Lake Ontario.

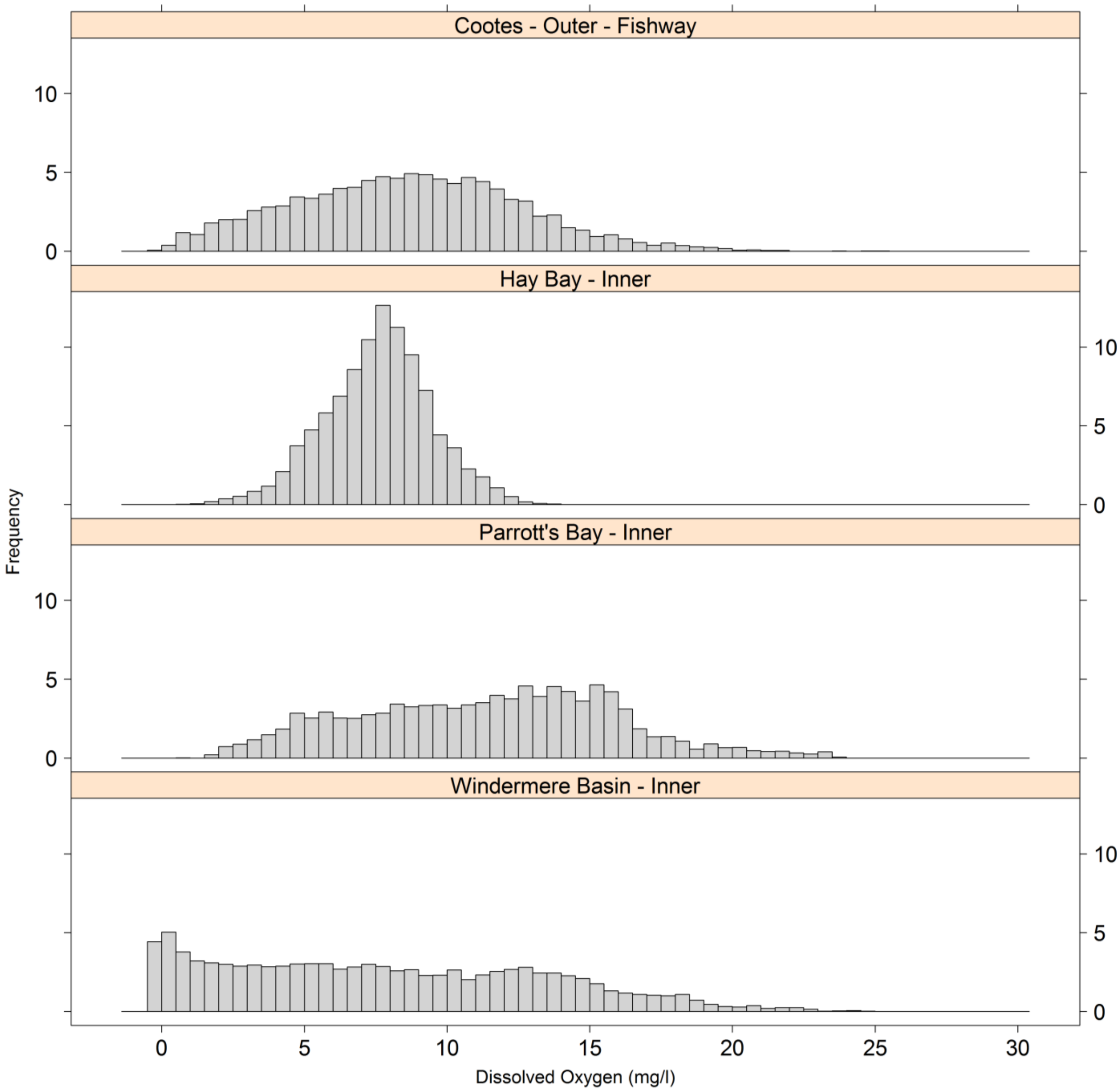


**Figure 6.** Frequency histogram of dissolved oxygen (mg/L) over the growing season (May through September) at wetlands sampled in 2015.

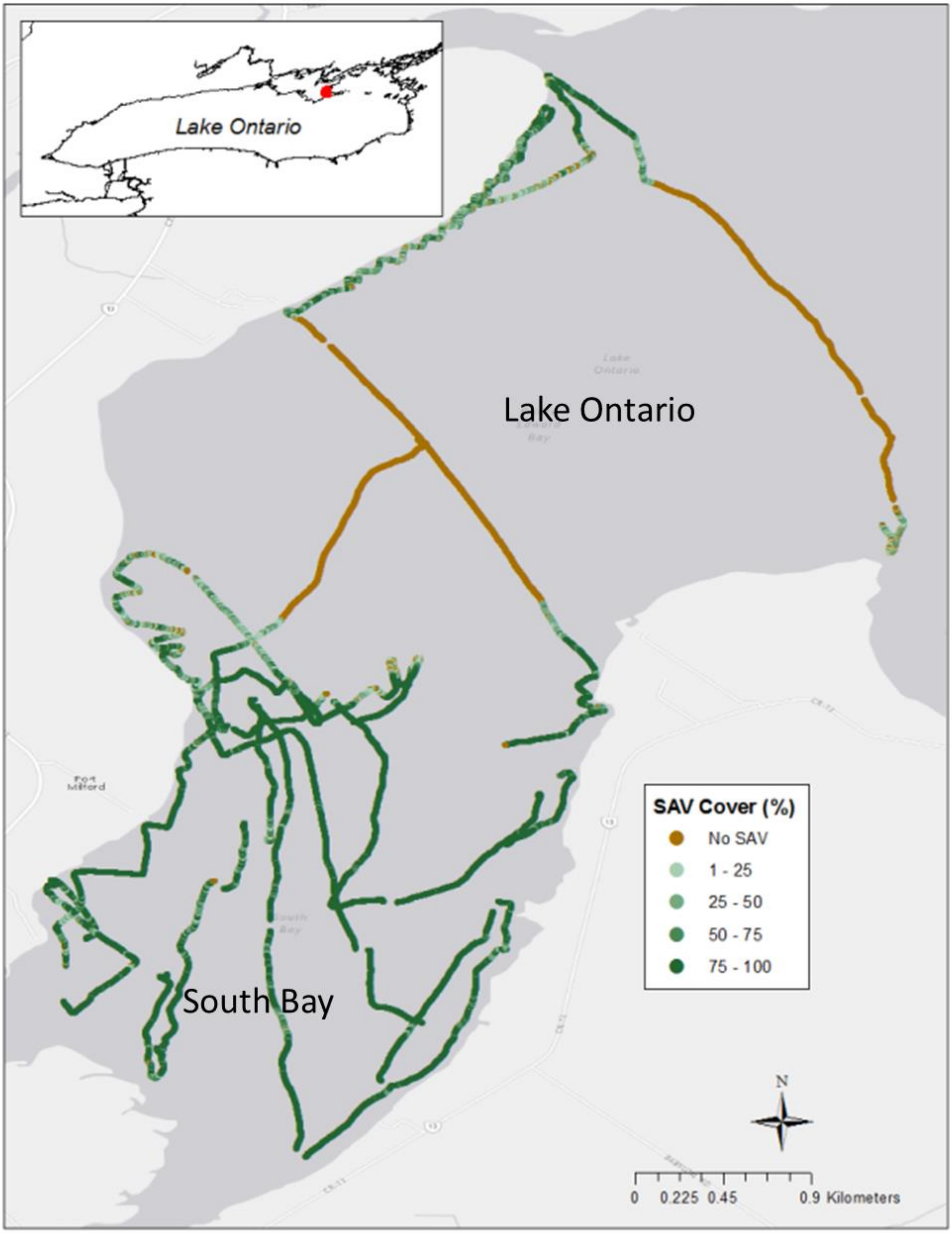


**Figure 7.** Submerged aquatic vegetation (SAV) percent cover as determined by hydroacoustic surveys at South Bay (Bay of Quinte) in 2014.

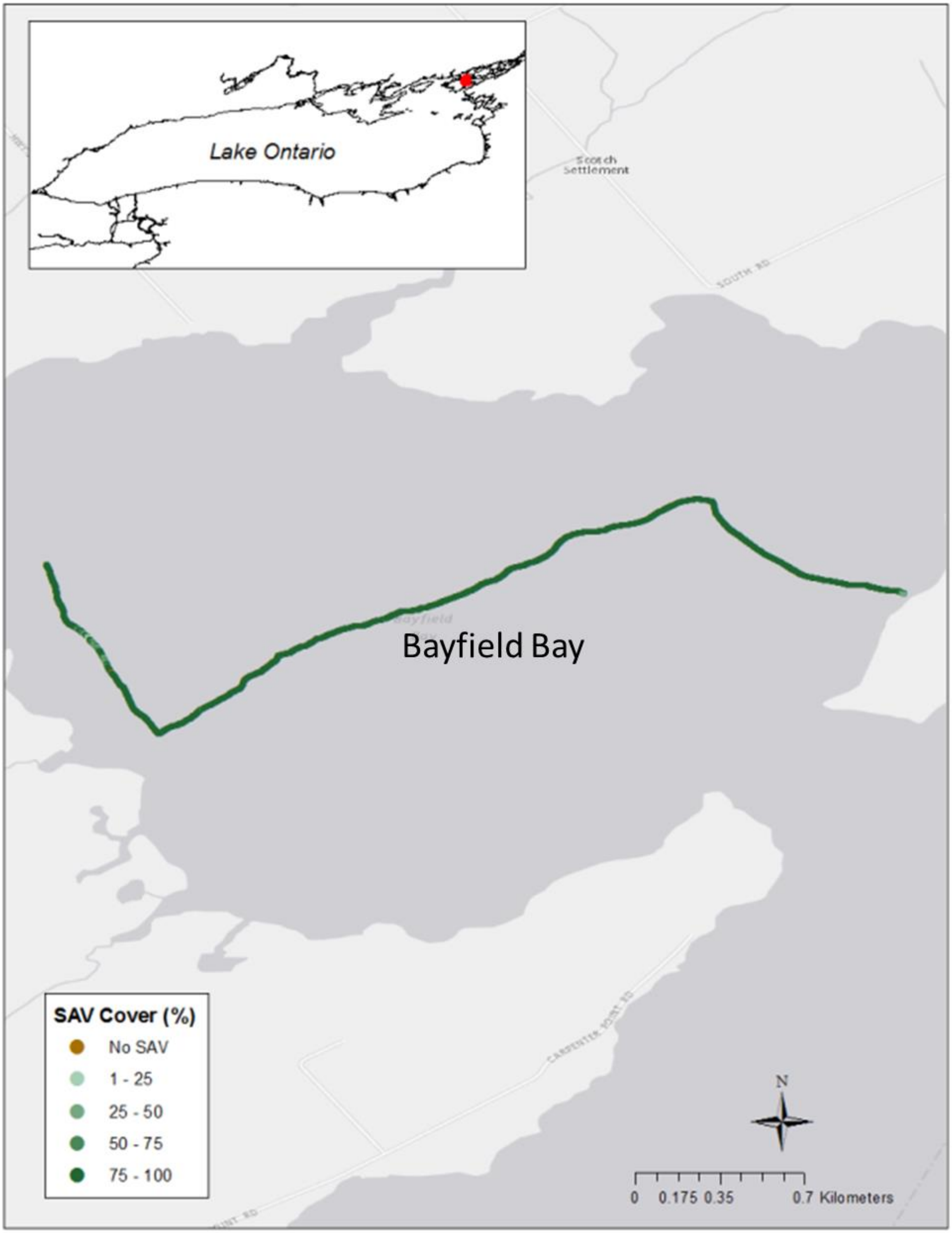


**Figure 8.** Submerged aquatic vegetation (SAV) percent cover as determined by hydroacoustic surveys at Bayfield Marsh in 2014.

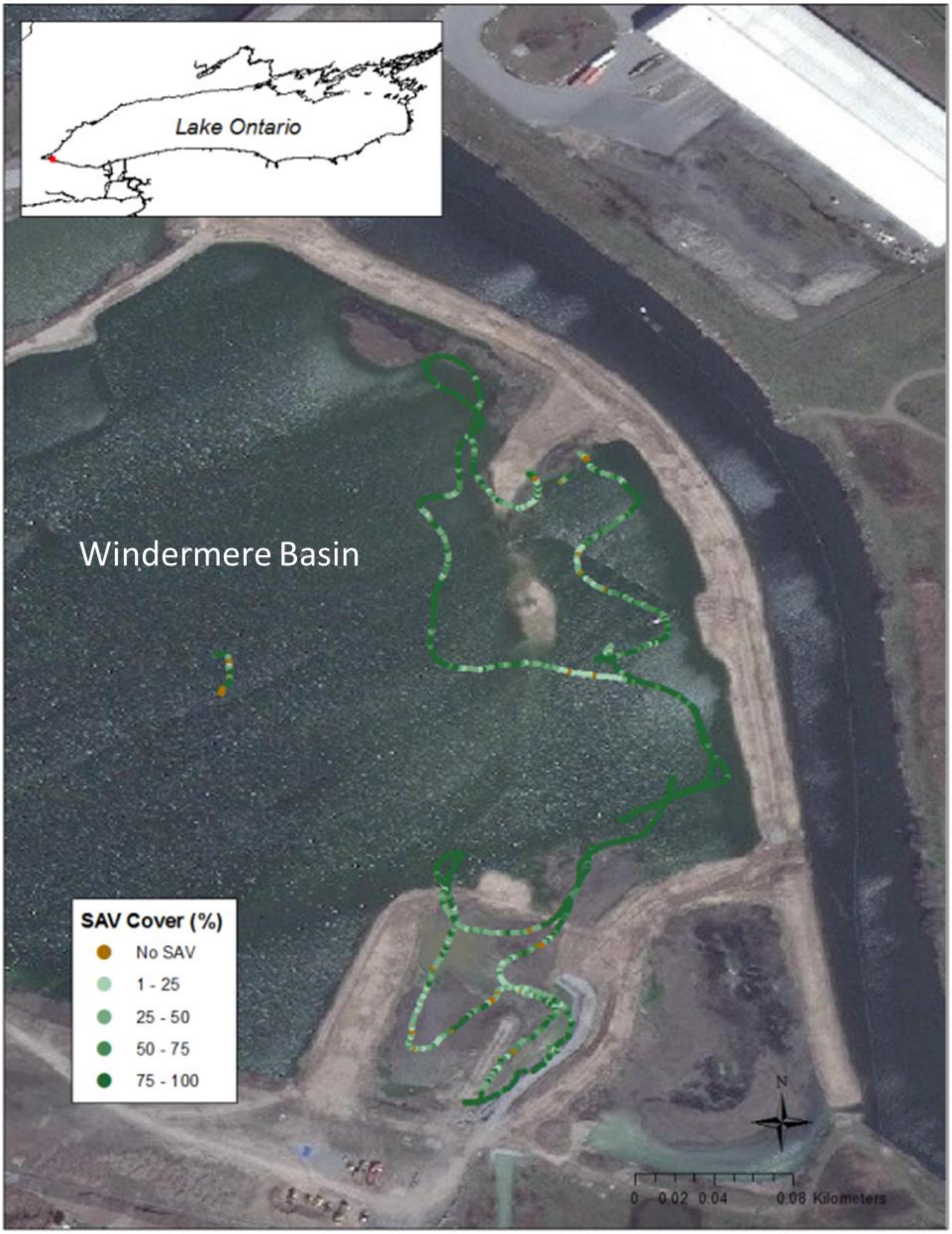


**Figure 9.** Submerged aquatic vegetation (SAV) percent cover as determined by hydroacoustic surveys at Windermere Wetland (in Hamilton Harbour) in 2013. (NB: the remote imagery used in the background is older than the sampling date.)

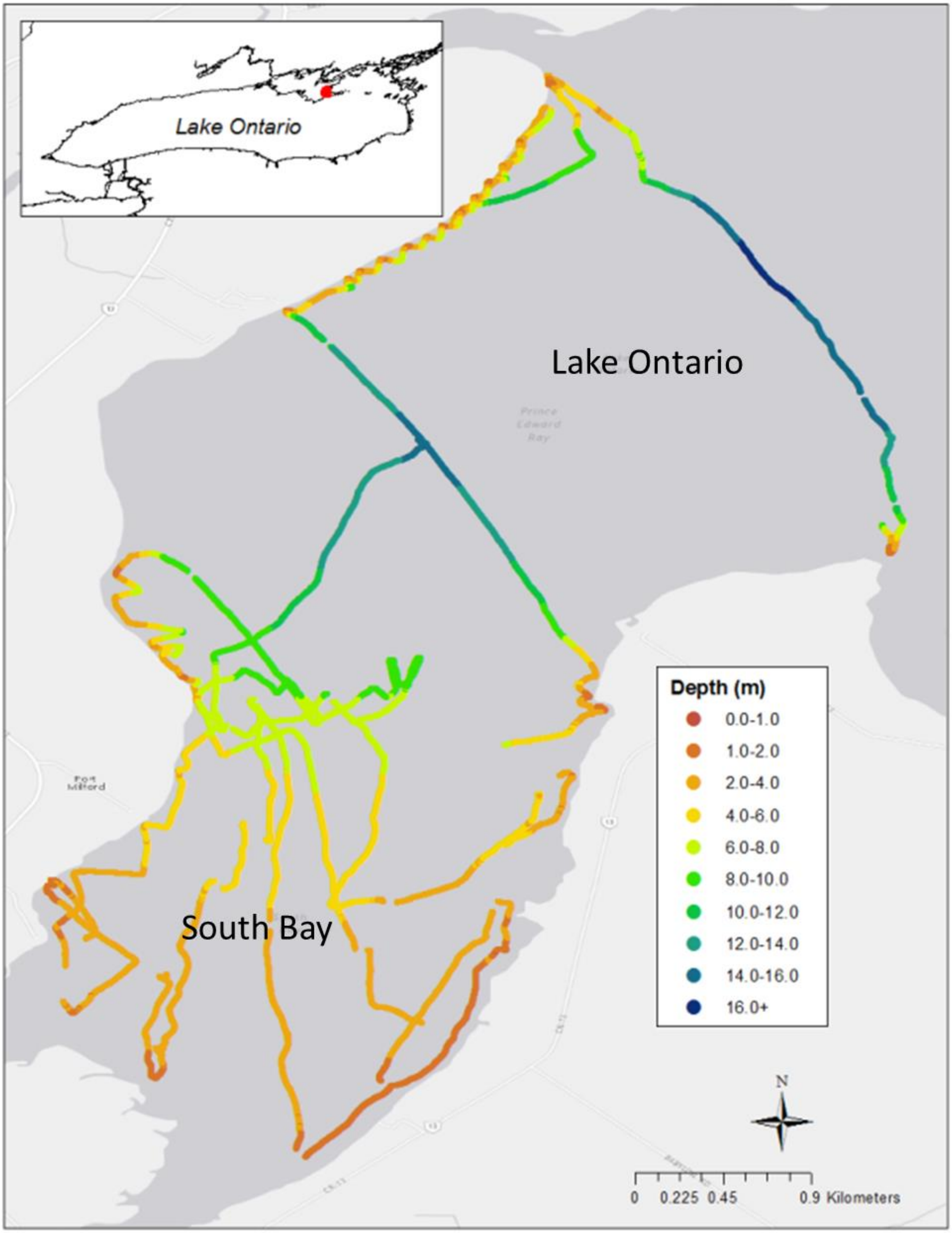


**Figure 10.** Water depth (m) as determined by hydroacoustic surveys at South Bay in 2014. Estimated depths ranged from 0.9 to 16.3 m, with a mean of 5.6 m.

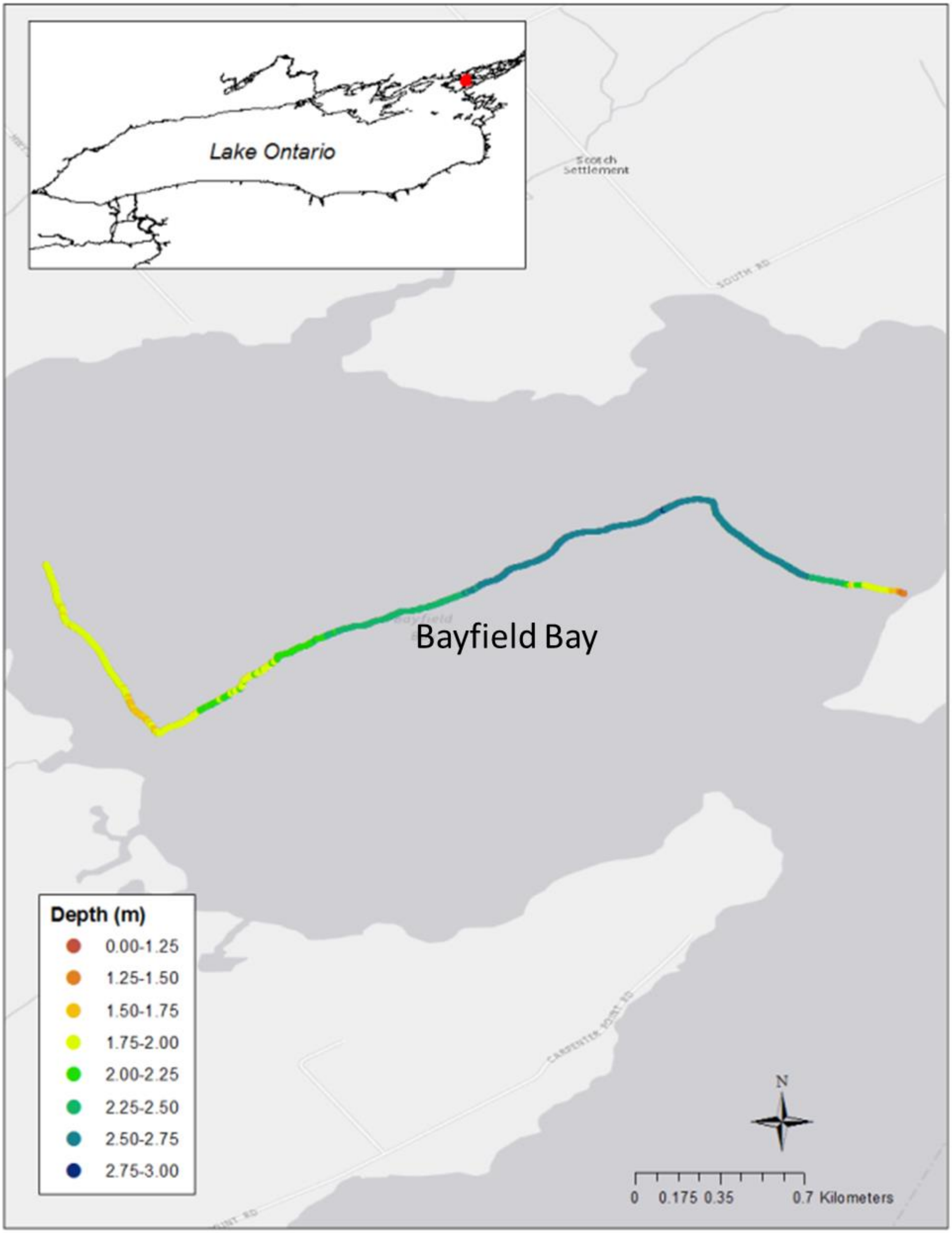


**Figure 11.** Water depth (m) as determined by hydroacoustic surveys at Bayfield Marsh in 2014. Estimated depths ranged from 1.3 to 2.8 m, with a mean of 2.2 m.

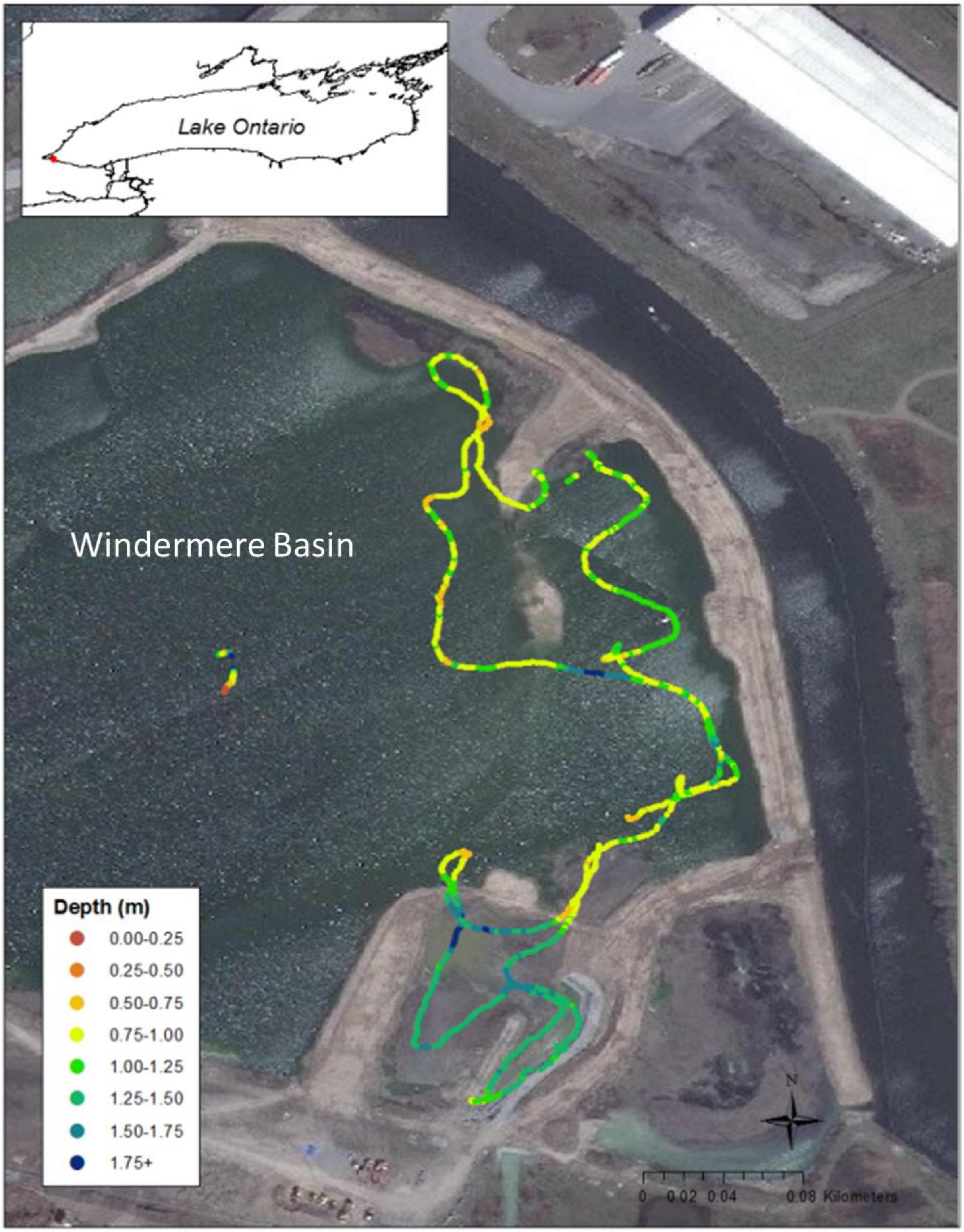


**Figure 12.** Water depth (m) as determined by the hydroacoustic surveys at Windermere Wetland (in Hamilton Harbour) in 2013. Predicted depths ranged from 0.2 to 2.0 m, with a mean of 1.1 m. (NB: the remote imagery used in the background is older than the sampling date.)

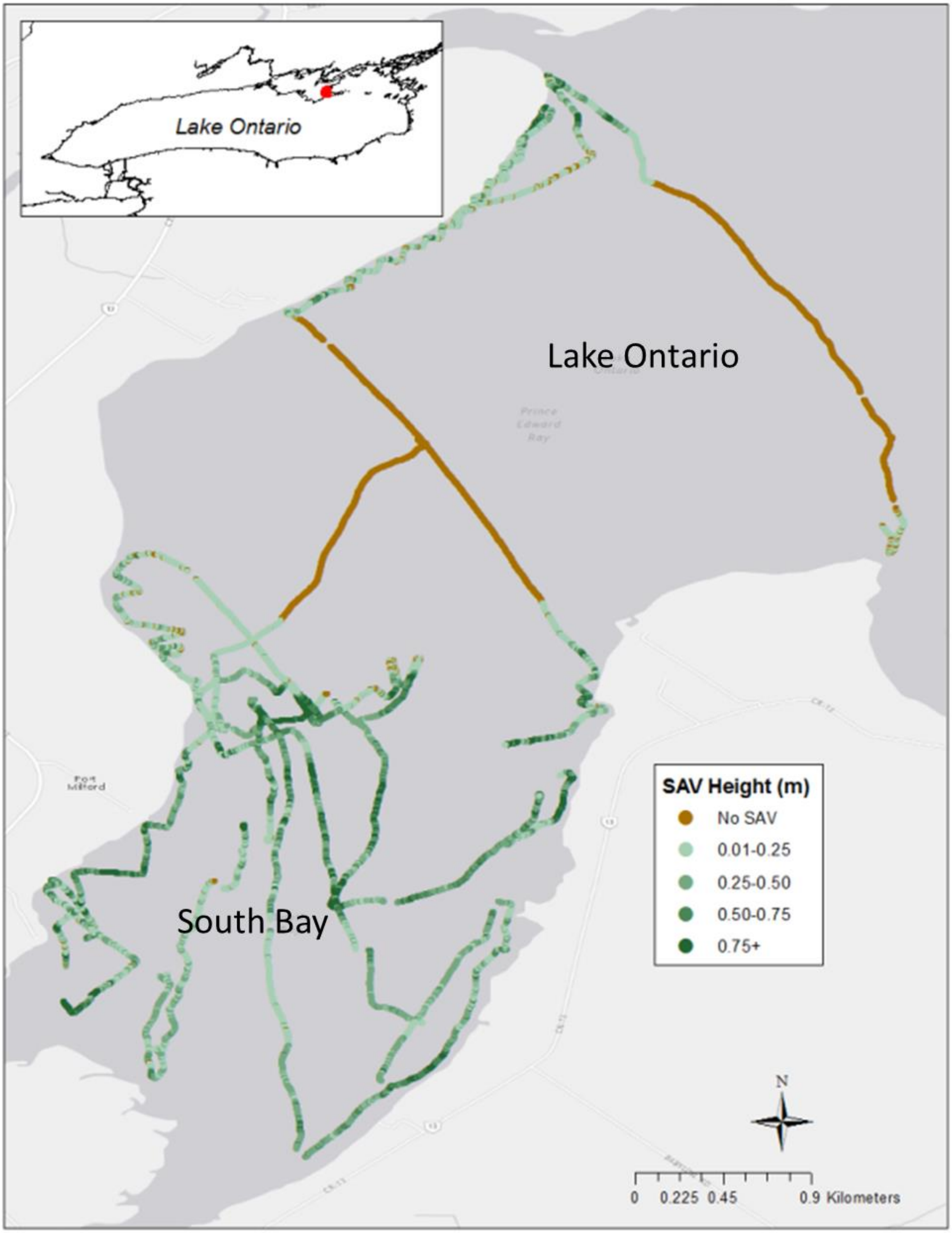


**Figure 13.** Submerged aquatic vegetation (SAV) height (m) as determined by hydroacoustic surveys at South Bay in 2014.

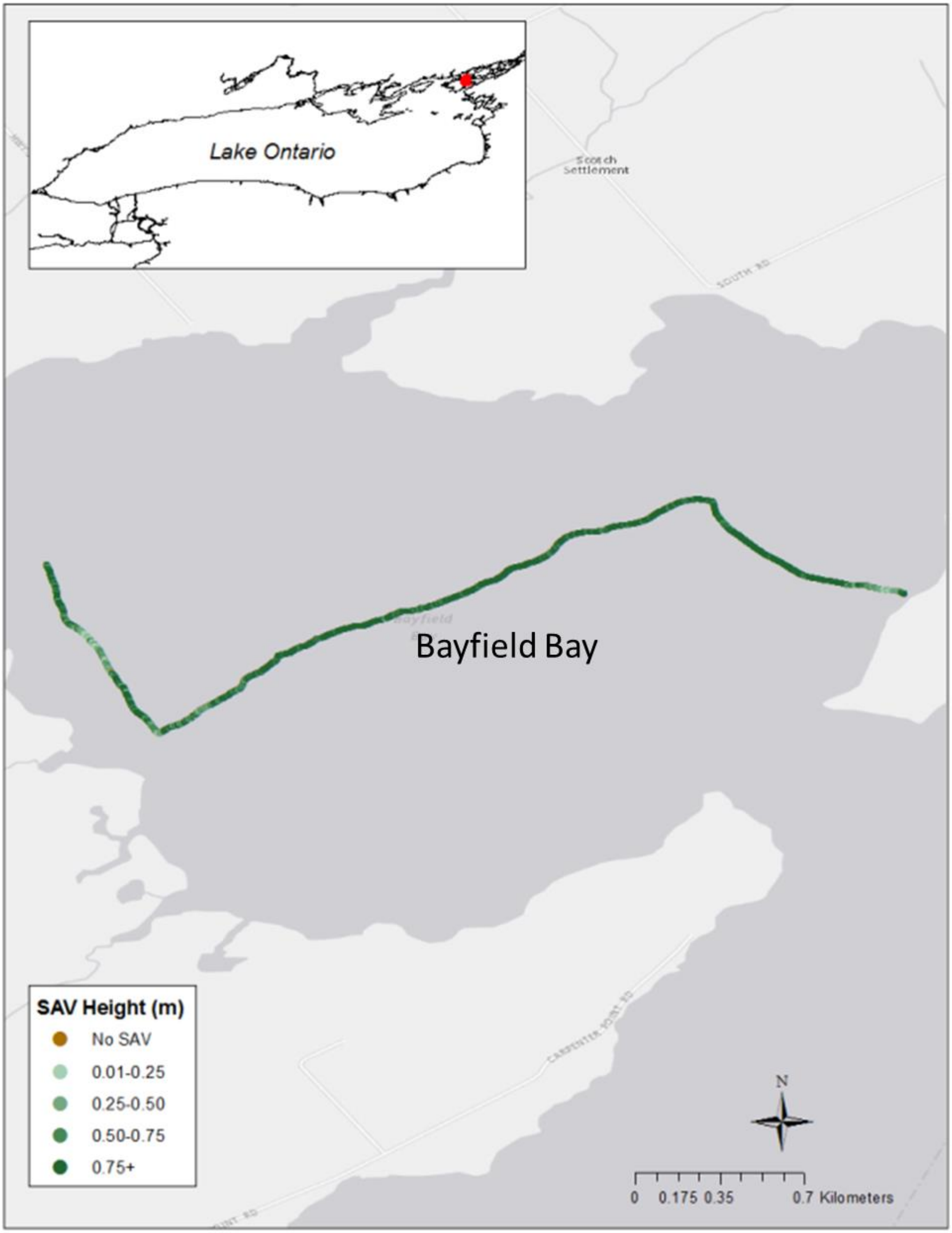


**Figure 14.** Submerged aquatic vegetation (SAV) height (m) as determined by hydroacoustic surveys at Bayfield Marsh in 2014.

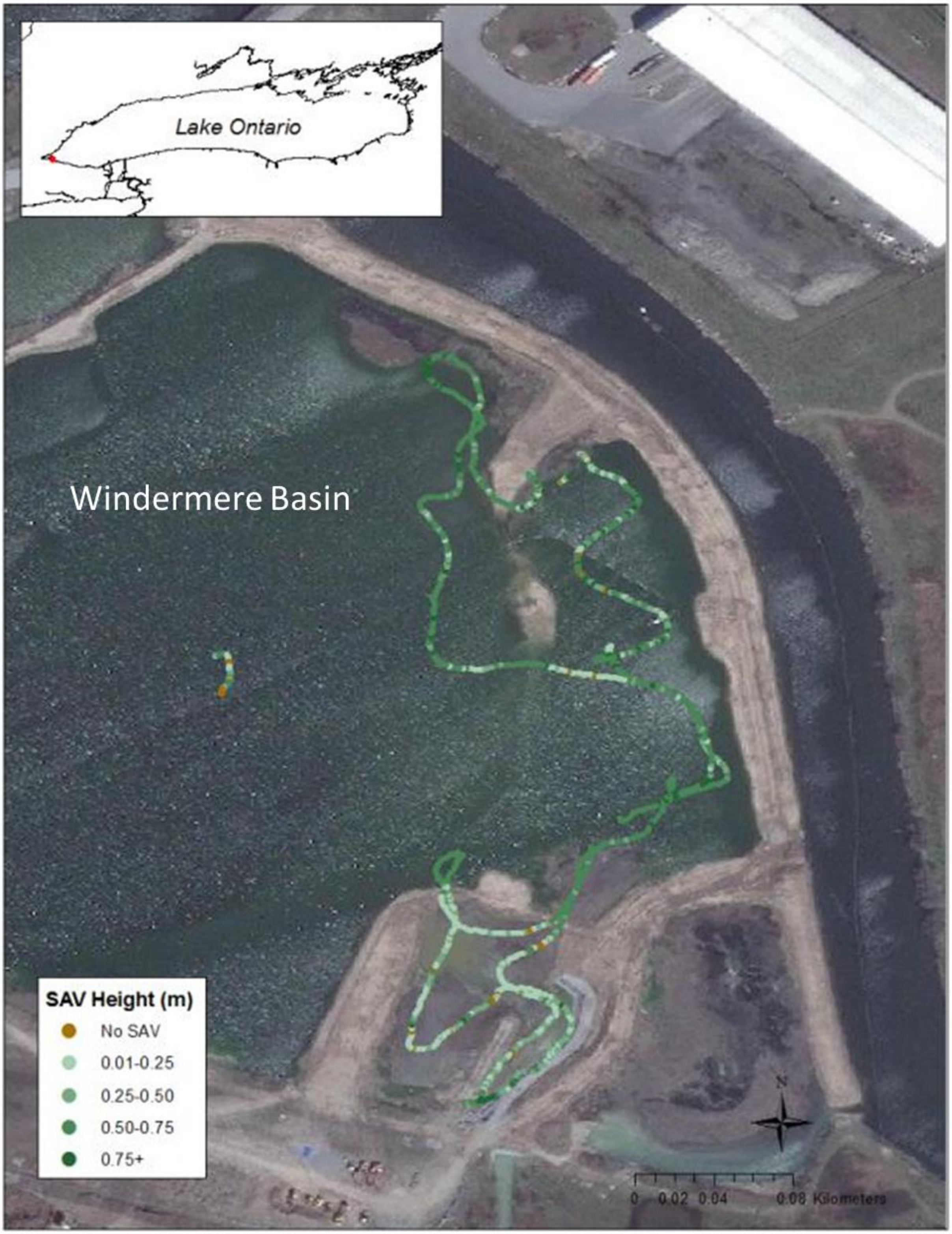


**Figure 15.** Submerged aquatic vegetation (SAV) height (m) as determined by hydroacoustic surveys at Windermere Basin Wetland (in Hamilton Harbour) in 2013. (NB: the remote imagery used in the background is older than the sampling date.)

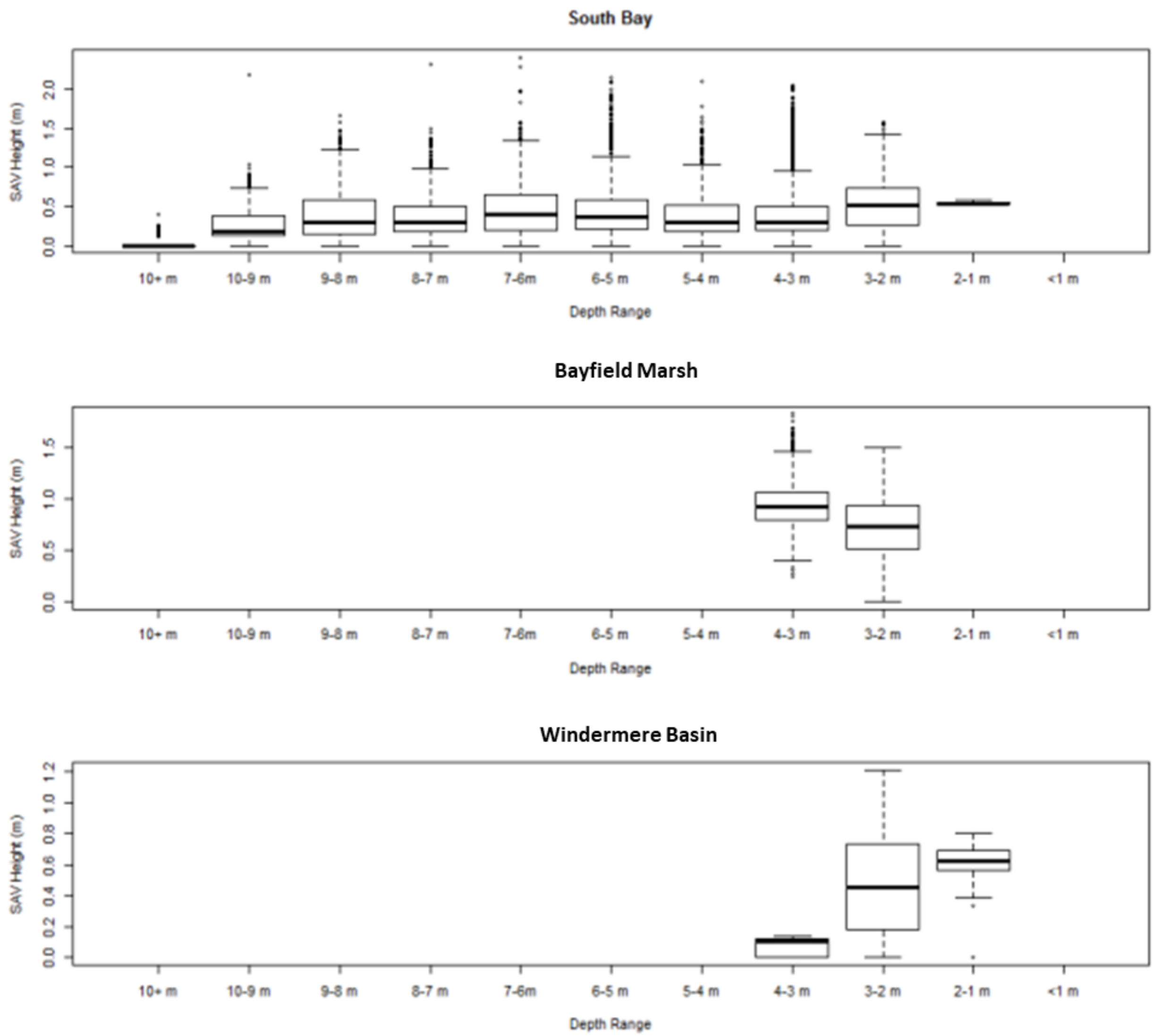


**Figure 16.** Submerged aquatic vegetation (SAV) height (m) as a function of depth range for each wetland assessed by hydroacoustic survey.