

# **Mapping and Assessing Coastal-Margin Aquatic Habitats in Severn Sound, Lake Huron**

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MAPPING AND ASSESSING COASTAL-MARGIN AQUATIC HABITATS IN SEVERN  
SOUND, LAKE HURON

by

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## **ABSTRACT**

Midwood, J.D., and Doka, S.E. 2018. Mapping and Assessing Coastal-Margin Aquatic Habitats in Severn Sound, Lake Huron. Can. Tech. Rep. Fish. Aquat. Sci. 3284: viii + 42p.

The coastal margin of Severn Sound, Georgian Bay has the most complex shoreline in the Great Lakes region and provides important habitat for a wide variety of species. Presently much of the shoreline is natural, but the coastal margin is increasingly affected by human development, water level fluctuations, and gradual warming of the air and water. To better assess the status of aquatic habitat in the coastal margin of this diverse region we: 1) mapped the extent of submerged aquatic vegetation (SAV) across a range of habitat conditions; 2) collected substrate samples to verify existing side-scan sonar; and 3) tracked dissolved oxygen (DO) and temperature dynamics in key regions. Results suggest that while much of the diversity in aquatic habitat conditions in Severn Sound is largely driven by natural factors, some regions exhibit some detrimental effects from human activities. SAV was abundant across much of the Sound with cover and depth distribution primarily restricted by exposure to wind and wave action (restricts distribution in shallow waters) and natural variation in water clarity due to dissolved organic carbon (primarily restricts the maximum depth of colonization). Sand dominated the majority of substrate samples, except in more protected areas that had higher organic content. Finally, DO profiles were also affected by the level of exposure with more stable DO levels at exposed sites and increasing hourly and daily variability in more protected areas. Extended periods of anoxia were not prevalent, but daily periods of anoxia were common at two of the more protected wetland areas suggesting these events were primarily driven by diurnal cycles in primary production. The results presented in this report can be combined with ongoing efforts by the Severn Sound Environmental Association and University of Windsor to help develop a complete fish habitat suitability model for the coastal margin of Severn Sound.

## **RÉSUMÉ**

Midwood, J.D., and Doka, S.E. 2018. Mapping and Assessing Coastal-Margin Aquatic Habitats in Severn Sound, Lake Huron. Can. Tech. Rep. Fish. Aquat. Sci. 3284: viii + 42p.

La marge côtière de la baie Severn, dans la baie Georgienne, possède la ligne de côte la plus complexe de la région des Grands Lacs et constitue un habitat important pour les espèces aquatiques. À l'heure actuelle, une grande partie du littoral est naturelle, mais la marge côtière est de plus en plus touchée par le développement humain, les fluctuations des niveaux d'eau et le réchauffement graduel de l'air et de l'eau. Pour mieux évaluer l'état de l'habitat aquatique dans la marge côtière de cette région diversifiée, nous avons 1) cartographié l'étendue de la végétation aquatique submergée dans diverses conditions d'habitat, 2) recueilli des échantillons de substrat pour vérifier le sonar à balayage latéral existant, et 3) effectué un suivi de la dynamique de l'oxygène dissous (OD) et des températures dans des régions clés. Les résultats donnent à penser que, bien qu'une grande partie de la diversité des conditions de l'habitat aquatique dans la baie Severn soit en grande partie attribuable à des facteurs

naturels, certaines régions présentent certains effets néfastes découlant des activités humaines. La végétation aquatique submergée était abondante dans la majeure partie de la baie, la couverture et la répartition en fonction de la profondeur étant principalement limitées par l'exposition au vent et à l'action des vagues (limite la répartition dans les eaux peu profondes) et par les variations naturelles de la limpidité de l'eau dues au carbone organique dissous (limite principalement la profondeur maximale de la colonisation). Le sable dominait la majorité des échantillons de substrat, sauf dans les zones plus protégées où la teneur en matières organiques était plus élevée. Enfin, les profils d'oxygène dissous étaient également influencés par le niveau d'exposition avec des niveaux d'oxygène dissous plus stables aux sites exposés et une variabilité horaire et quotidienne croissante dans les zones plus protégées. Les périodes prolongées d'anoxie n'étaient pas fréquentes, mais les périodes quotidiennes d'anoxie étaient courantes dans deux des zones de milieux humides les plus protégées, ce qui donne à penser que ces événements étaient principalement dus aux cycles diurnes de la production primaire. Les résultats présentés dans ce rapport peuvent être combinés aux efforts continus de la Severn Sound Environmental Association et de l'Université de Windsor pour aider à élaborer un modèle complet d'habitat propice du poisson pour la marge côtière de la baie Severn.

## 1.0 INTRODUCTION

The coastal margin is perhaps the most visible and ecologically significant zone of lake ecosystems. This is especially true of areas that have complex shorelines and high recreational use and thus economic value. The coastal margin of south-eastern Georgian Bay, Severn Sound in particular, has the most complex shoreline in the Great Lakes region and provides spawning, nursery, refugia and foraging habitats for fishes, birds, amphibians, and reptiles. This region was formerly a Great Lakes Area of Concern (AOC), but was delisted in 2003 following improvements to water quality. While presently much of this shoreline is natural, this zone is increasingly affected by landscape alterations for human development, gradual warming of the air and water, and marked fluctuations in water levels. Despite high levels of biodiversity, depth profiles and habitat features of much of the coastal margin of Severn Sound are poorly understood. Surveys of the coastal margin and nearshore of the Severn Sound region paired with classifications of habitat suitability are required in order to identify areas most in need of protection from water and land-based stresses and the best candidates for conservation and restoration efforts. Within the coastal margin, submerged aquatic vegetation (SAV) provides important habitat for the majority of freshwater fishes at all stages of their life-history. Consequently, SAV coverage is a strong predictor of the productivity of a freshwater ecosystem (Randall et al. 1996). Hydroacoustic technology allows for the assessment of the height and cover of SAV across a larger spatial scale than more typical transect- or quadrat-based assessments. Given the range of coastal margin types (exposed vs protected), which may influence the minimum depth of SAV colonization, as well as natural variability in water clarity (clear water vs dystrophic water), which may affect the maximum depth of SAV colonization, Severn Sound provides an excellent location to evaluate the various natural factors that influence the extent and cover of SAV in freshwater ecosystems.

Dissolved oxygen (DO) is an indicator of ecosystem productivity and also a critical limiting factor in aquatic ecosystems. Coastal areas that have high levels of human disturbance, via shoreline modification, agricultural run-off or municipal waste inflows, may experience eutrophication, leading to the development of harmful algal blooms and ultimately anoxia or supersaturation (DO levels exceeding the saturation threshold for a given atmospheric pressure and water temperature). The DO profile in coastal areas is therefore a limiting factor in the distribution of aquatic biota. Severn Sound provides an ideal opportunity to compare the DO dynamics of coastal areas across a range of natural (connectivity and exposure) and anthropogenic (sewage outflow) disturbances. A more detailed understanding of the factors that influence temporal and spatial differences in DO will help refine habitat suitability estimates in the coastal margins of Severn Sound. Since DO loggers also measure temperature

simultaneously, these loggers also provide vital temperature information that is helpful in modelling thermal habitat supply for biota and its dynamics in the area.

Given the unique environmental conditions in Severn Sound and the long-term goal of re-evaluating habitat suitability in this region, the objectives of the present report are to: 1) map the extent of SAV cover and height in representative portions (range of exposure, depths, and water clarity) of the coastal margin of Severn Sound; 2) verify substrate composition in existing side-scan sonar data with 99 validation samples; and 3) document the DO and temperature dynamics in key areas and provide a high-level comparison of these patterns across the range of environmental conditions present in Severn Sound.

## **2.0 METHODS**

### **2.1 SAV SURVEYS**

From 11 July until 27 July 2016, SAV cover and height were assessed in 20 regions throughout Severn Sound, Lake Huron, using hydroacoustic (Biosonics MX with 204.8 kHz and 8.4 °beam width; Figure 1). With this approach, sampling was limited to water depths that were greater than 1-m. The interpretation of the data collected for each hydroacoustic transect was completed in Visual Habitat (Biosonics, Seattle, WA). The first step in the interpretation was establishing the bottom depth and for this the “Rising Edge Threshold”, which determines where to assign the bottom echo, was set to -35 dB. This approach was frequently unable to detect the bottom echo due to either dense SAV or unconsolidated sediment; therefore, in these instances the bottom was manually delineated. After the bottom was determined, a plant detection analysis was completed using the default settings with a “Plant Detection Threshold” of -70 dB, maximum plant depth of 10 m and a plant detection length criterion of 10 cm (minimum height for an echo to be assigned as SAV). The resulting data were then exported for further analysis.

During the hydroacoustic surveys, additional data were collected at key points to 1) characterize local water chemistry, 2) determine the dominant species of SAV at each site, and 3) provide an opportunity to validate the hydroacoustic data. At four points in each of the 20 survey regions water chemistry readings of four parameters (temperature (°C), conductivity (µS/s), dissolved oxygen (mg/L and %), and turbidity (NTU)) were collected using a Sonde EXO multiprobe (YSI, Yellow Springs, OH, USA). Secchi depth was also determined where possible. Generally, these points were situated close to shore in shallow water (<2.0 m, N=2) and in more open and deeper waters (>4.0 m, N=2), although in some locations no deeper sites were present (e.g., Matchedash Bay). Verification points were flagged haphazardly along the hydroacoustics transects and surveyed posthumously using a rake-toss to collect samples of SAV and provide an indication of the dominant species and coverage. Finally, during the hydroacoustic transects the presence, relative cover (sparse [<25%

cover], moderate [25-75% cover], dense [>75% cover]) and height (low, mid-depth, high, surface) of SAV were visually estimated and recorded in relation to the hydroacoustic ping number. Since these data were collected concurrently with the hydroacoustic survey, they were used to provide a rough validation of the hydroacoustic output.

Following the interpretation of the hydroacoustic data, results were aggregated by site to provide the proportion of points where SAV were present, and summary details (mean  $\pm$  standard deviation, quartiles etc.) related to the water depth and percent cover and height of SAV. Percent cover and height of SAV were also plotted against water depth to provide an indication of the depth distribution of SAV. Finally, points were plotted in a GIS to allow for a spatial assessment of SAV height and cover. The effective fetch was also determined for each point and used to calculate an overall mean level of exposure for each survey region. Effective fetch information was extracted from a fetch model run using the proportion of time the wind spent in each of 16 equally spaced compass directions (after Rohweder et al. 2012). These wind data were compiled from the Environment Canada and Climate Change buoy 45143 (southern Georgian Bay) from 2005-2015.

## **2.2 DISSOLVED OXYGEN AND TEMPERATURE**

On 8 and 9 June, 2016, ten DO and temperature (DOT) loggers were deployed throughout Severn Sound (Figure 1). DOT loggers were calibrated using a 2-point calibration method using 100% and 0% saturated water. These loggers measure the DO and temperature of the water every 30 minutes for a total of 48 samples per day. The deployment set up consists of an anchor with a rope and float attached. The logger is then hung from secondary float that is suspended 30 cm above the anchor. Deployment locations were selected to explore several disturbance regimes prevalent in Severn Sound including: the influence of sewage plant effluents (Inner Penetang [proximate to STP outflow] vs Outer Penetang [control]), the effect of exposure and connectivity to Georgian Bay (influences water clarity and water chemistry parameters; Present Island [exposed – high connectivity], 100 Acre Wetland [protected wetland – medium connectivity], South Bay South [protected wetland – low connectivity], South Bay North [exposed wetland – low connectivity], and Green Island [protected wetland – high connectivity]), and the influence of inflowing streams (Sturgeon River [in river] vs others; Table 1). Loggers were retrieved on 12 and 13 October, 2016. Following comprehensive QAQC (outlined below), DO and temperature data from each logger were summarized by month, and the proportion of DO readings each day that fell below 3 mg/L (considered to be anoxic) and between 3-6 mg/L (lower than saturation), temporal trends in DO and temperature, and overall deviance of each DO reading from the daily mean were plotted for each site. This final measure provides an indication of the daily timing of the maximum and minimum DO reading.

## 2.3 SUBSTRATE

Sediment samples were collected at 99 sites spread throughout Severn Sound using a petit ponar (Figure 1). A 250 mL representative sample of material from the ponar was collected, frozen and later analyzed for composition and loss on ignition (organic content) following standardized protocols. Frozen samples were thawed at room temperature overnight and then placed in an oven for 4 hours at 30°C. Samples were then ground using a mortar and pestle until any clumps were broken up and the substrate was free flowing. It was then placed back in an oven for an additional 24 hours at 106°C to remove any remaining moisture. After cooling to room temperature, samples were sub-sampled (~ 3 g for fine sample such as mud and clay, ~ 20 g for samples with rocks, pebbles or large amounts of organic matter). A crucible for each subsample was weighed, tared, and then filled with the subsample and weighed (g) again. Subsamples were then placed in a muffle furnace for a total of 8 hours to burn off organic matter and determine the Loss on Ignition (LOI). The first hour was spent slowly raising the temperature up to 250°C. In the second hour, temperature was increased to 500°C. The subsamples remained in the furnace at full temperature for 6 hours. After 8 hours the muffle furnace was turned off and the subsamples were allowed to cool overnight. The following morning the subsamples were weighed and recorded and then subtracted from the pre-burn weight to determine LOI. The remaining material was further sieved to assign an overall composition based on the Wentworth scale (clay [ $<3.9\ \mu\text{m}$ ], silt [ $3.9\text{--}6.25\ \mu\text{m}$ ], sand [ $6.25\text{--}2\ \text{mm}$ ], gravel [ $2\text{--}16\ \text{mm}$ ], pebble [ $16\text{--}64\ \text{mm}$ ], cobble [ $64\text{--}256\ \text{mm}$ ], boulder [ $>256\ \text{mm}$ ]). Sediment left in the tray at the bottom of the sieve tower ( $< 63\ \mu\text{m}$ ) was weighed and recorded and placed in a scintillation vial with a cap and internal label and stored at room temperature for flow cytometry analysis.

Samples were prepared 24 hours before running to ensure particles did not clump before being run. Samples were taken from the scintillation vials using a scoopula, 0.05 g from each sample was mixed into a solution of 500  $\mu\text{m}$  of Fluorescent-Activated Cell Sorting (FACS) fluid in a weighing dish and wetted by mixing with a rubberized probe. This solution was then washed into a plastic 15 ml vial using 10 ml distilled water. The flow cytometer was calibrated with micro beads of 4 known sizes (2  $\mu\text{m}$ , 3.4  $\mu\text{m}$ , 7.4  $\mu\text{m}$  and 14.7  $\mu\text{m}$ ). The beads were run through the flow cytometer and their size distributions were plotted onto a scatter-plot using Becton, Dickson and Company Fluorescent-Activated Cell Sorting Diva (BD FACS Diva) software. A 4  $\mu\text{m}$  threshold was set to distinguish between silt ( $63\ \mu\text{m} - 4\ \mu\text{m}$ ) and clay ( $<4\ \mu\text{m}$ ).

In preparation for analysis, samples were agitated by shaking to re-suspend sediment particles into the solution; a ~ 2 ml of sample solution was transferred from its plastic vial into a glass test tube. The sample was then placed in the flow cytometer. Each sample was run as a separate tube in BD FACS Diva under the same parameters

– Forward Scattered light (FSC, x axis) was set to 88 volts, and Side Scattered light (SSC, y axis) was set to 110 volts. Samples were run for 10,000 events in BD FACS Diva unless data acquisition was significantly slower due to a more dilute sample, in which case samples were analyzed for 5000 or 1000 events. Samples ran for an average of 1-2 minutes. Data output for each sample consisted of a scatter-plot showing size fraction of calibration beads, a frequency histogram for each plot and a graph displaying relative percentage of particle size along a 4  $\mu\text{m}$  threshold. These percentages were then used to extrapolate the overall composition (% of silt and clay) of the sediment samples collected in each scintillation vial.

### **3.0 RESULTS**

#### **3.1 SAV SURVEYS**

##### *3.1.1 Water Chemistry*

Water chemistry parameters showed only limited variability within a site; however, among sites there were clear differences that were largely driven by the level of influence of Georgian Bay waters and exposure to wind and wave action. Not surprisingly, water temperatures were generally higher ( $\sim 25^{\circ}\text{C}$ ) in more protected regions compared with more exposed sites (Table 2). In terms of conductivity, Beausoleil West and Present Island provided a good reference for conditions in Georgian Bay ( $\sim 180\ \mu\text{S/s}$ ), while the North Bay and South Bay sites were influenced by dystrophic (soft) water coming off the Georgian Bay Fringe ( $114\text{-}159\ \mu\text{S/s}$ ). Sites with conductivity readings well above those found in Georgian Bay likely reflect some measure of anthropogenic disturbance (i.e., Matchedash Bay –  $330\ \mu\text{S/s}$  or Midland Bay East -  $205\ \mu\text{S/s}$ ; Table 2). While DO (both % and mg/L) were collected and are provided (Table 2), the DOT loggers likely provide a better measure of site variability since probe readings were collected during the day when DO levels are at their peak (see below). Finally, for many sites turbidity could not be estimated since the probe was not able to reliably measure turbidity levels less than  $0.05\ \text{NTU}$ . Where available, turbidity levels were generally low (mean across sites =  $0.13 \pm 0.32\ \text{NTU}$ ), therefore in Severn Sound turbidity is likely not a limiting factor in the establishment of SAV.

Secchi depth readings ranged from a low of approximately  $3.0\ \text{m}$  in South Bay and North Bay to a high of over  $5.0\ \text{m}$  outside in Penetanguishene Bay and around Beausoleil and Robert's Islands (Table 3). Similar to the conductivity measurements discussed above, lower secchi depths in South Bay and North Bay are likely driven by dystrophic water from their watersheds (high humic content and naturally brown-coloured waters).

### 3.1.2 Hydroacoustics

In each of the 20 regions, four transects were run perpendicular from shore either starting in or ending in approximately 1-m of depth and progressing beyond the edge of the SAV bed to a maximum depth of 13 m (Figure 1). This type of transect was not possible in all regions due to depth limitations. For example, surveys in Matchedash Bay and Sturgeon Bay were restricted to depth intervals between 1.32-1.83 m and 1.27-3.13 m, respectively, thereby preventing an assessment of the maximum depth of SAV colonization at these sites (Table 4). Similarly, while a wider range of depths were surveyed at several other stations, the maximum depth of SAV was often quite similar to the maximum depth surveyed (i.e., South Shore of Severn Sound – SAV Present = 1.16-9.86 m and SAV Absent = 1.08-9.83 m; Table 5). Bearing these caveats, across all regions the maximum depth at which SAV was detected was 10.49 m (Sucker Creek), with a considerably lower mean depth of SAV occurrence ranging from a low of 1.63 m (Matchedash Bay) to a high of 5.98 m (Midland West; Table 5; Figures 2 and 3). The proportion of each surveyed area that was covered in SAV was highly variable, from a low of 0.2 or less at sites that were generally more exposed to wind and wave action (i.e., Beausoleil Island West) to those where the entire survey area was covered in SAV (i.e., Matchedash Bay; Table 5).

The highest mean SAV percent cover was found in regions where SAV occurred at virtually all sampled positions; these areas also tended to have restricted sampling depths (see comment above; Table 5; Figures 4 and 5). Three distinct patterns in the distribution of SAV percent cover across depths were evident among sampling regions and differences were largely driven by variations in cover in shallow depths (<3 m; Figures 6, 7 and 8). The first group represented sites that generally had low levels of exposure (mean fetch <1200 m; Table 5) and consequently SAV percent cover was close to 100% down to the shallowest depth interval sampled (1-2 m). This group included many sites that were in or adjacent to coastal wetlands (e.g., 100 Acre Wetland, Green Island, Inner Hog Bay, etc.; Figures 6, 7 and 8) and the relationship between SAV percent cover and depth can best be described as logistic, with deep water limitations likely driven by water clarity. The next group represented exposed regions (mean fetch >3000 m; Table 5) and SAV percent cover was suppressed at these sites in shallow water (<3 m), peaking instead between 3-5 m (e.g., Outer Penetang, Beausoleil West, etc.; Figures 6, 7 and 8). The result is a relationship between SAV percent cover and depth that is more unimodal. The final group was intermediate between the exposed and protected sites (mean fetch = 1800 m; Table 5) with SAV percent cover being suppressed at depths less than 2-m and peaking in a similar depth range as the more exposed regions (e.g., Midland Bay East, Inner Penetang, etc.; Figure 6, 7 and 8). Two sites had more limited depth ranges (North Bay and South Bay), with SAV percent cover declining around 4-5 m as opposed to 5-7 m. Increased light attenuation, as documented with lower Secchi depths, was likely the causal factor

behind the narrower extent of SAV beds at these sites as well as their shallower mean depth of occurrence of SAV.

Not surprisingly, the regions with the highest mean SAV height were typically similar to those with the greatest SAV percent cover (Table 5). The three exposure groups outlined above were also generally consistent for SAV height with more exposed sites typically having shorter SAV and a peak shifted into deeper waters than more protected areas (Figures 9, 10 and 11). With only a few exceptions (e.g., North Bay, Beausoleil West), the relationship between SAV height and depth was quasi-unimodal generally peaking between 3-4 m at protected sites or sites with intermediate levels of exposure and between 4-5 m at exposed sites (Figures 9, 10 and 11).

### 3.1.3 Hydroacoustic Validation

Visual assessments were completed at 252 points and these were then linked to ping numbers from the hydroacoustic survey. Consistent with our past experience with validation of hydroacoustic data, density and height estimates from the hydroacoustics and field surveys did not match exactly, but rather showed similar trends. This is partly the result of how the hydroacoustic data are aggregated during interpretation wherein a single output data point is actually comprised of 10 “pings”. Furthermore, since the swath of the hydroacoustic beam covers a larger area than the visual point sampling, a lack of concordance between these two datasets is not surprising. As a result, the cover and height predictions from the hydroacoustic surveys tended to be of a higher magnitude than the actual observed values (Table 6); however, there was still a consistent relationship between the visual estimates of density and SAV height and those predicted by the hydroacoustics (i.e., highest cover values for the “dense” category and lowest for the “sparse” category; Table 6). In terms of predicting whether SAV were present or not, the visual assessment data suggested that the hydroacoustics were 83.3% accurate, with the majority of the errors those of commission (13.5%; SAV present when the visual assessment did not record SAV). For the majority of these sites (20/34), SAV cover was predicted to be less than 30%. For the few occasions where the hydroacoustics omitted SAV, the visual estimates primarily categorized the site as having either short or sparse SAV.

### 3.1.4 Dominant SAV

Data from 133 verification points were collected with SAV present at 103 of these points. In total 32 species were identified, with *Vallisneria americana* as the most common species (present at 50% of the points). Other common species included *Elodea canadensis* (41%), *Ceratophyllum demersum* (33%), *Najas flexilis* (33%), *Chara* spp (31% - technically a green algae, but structurally similar to SAV), and *Myriophyllum spicatum* (29%; Table 7). Across Severn Sound, species richness was quite variable

ranging from a low of 3 (Outer Penetang) to a high of 14 (Green Island and Robert's Island; Table 3).

### **3.2 DOT LOGGERS**

The majority of the loggers (9/10) were successfully retrieved in the fall of 2016; however, the logger placed along the eastern shore of Beausoleil Island could not be located. At the time of writing this logger has not been located, despite expanded surveys by Fisheries and Oceans Canada and Parks Canada staff. For the remaining loggers, data were QAQC'd following the standard operating procedure for the Fish Habitat Lab with the Great Lakes Laboratory for Fisheries and Aquatic Sciences at DFO. This includes the application of a biofouling correction, where appropriate, which can compensate for errors in recorded DO caused by the accumulation of biological material during deployment. This correction was applied to four loggers (Inner and Outer Penetang, Sturgeon River, and South Bay North). Also during the QAQC phase, the DO profiles for each logger were evaluated to determine whether the sensor had become submerged in substrate (a common occurrence in nearshore areas with soft substrates). Through this process, data from the logger deployed in Hog Bay were determined to be of questionable value due to a high probability of submergence in substrate (which artificially decreases DO measurements). Therefore, this logger was excluded and results are presented for the eight remaining loggers.

Water temperatures across sites generally showed a consistent pattern, increasing through the summer, peaking in August and declining into the fall (Table 8; Figure 12). There were two exceptions to this pattern, the Sturgeon River and Inner Penetang, which both had cooler and more stable temperatures across the sampling period. In the former case, ground water supplies into the Sturgeon River likely act to buffer warming from higher air temperatures and increased solar radiation. Similarly, for Inner Penetang, we hypothesize that cooler water temperatures were driven by the proximity of this station to Copeland Creek, a cold water stream that flows into southern Penetanguishene Bay.

We explored DO profile patterns several different ways to assess the influence of 1) sewage plant effluents, 2) exposure and connectivity to the Bay, and 3) the input of an agricultural stream. First, Inner Penetang (proximate to the STP) was compared with Outer Penetang since they occur in the same physiographic region (Simcoe Upland) and have similar levels of exposure. Across the sampling period it was clear that DO was more variable at Inner Penetang; indeed, Inner Penetang had the greatest range in DO values at any site sampled in Severn Sound and frequently reported DO levels at supersaturation (Table 8; Figure 13). DO levels at Outer Penetang only fell below 6 mg/L on two occasions, in contrast, starting in late June, DO levels at Inner Penetang were typically below this threshold for between 6-12 hours each day and in several instances fell below 3 mg/L (Figure 13). The dynamic nature of Inner Penetang was

most apparent on an hourly basis, peaking on average 7 mg/L above the daily mean between 14:00-16:00 and declining through the night and into the early morning (Figures 14 and 15). While peak DO at Outer Penetang occurred during the same time period, mean, minimum and maximum readings were considerably less variable, typically changing by only  $\pm 2$  mg/L within a 24-hr period (Figures 14 and 15).

The DOT logger at Present Island served as a control location for Severn Sound since it was exposed and, based on water chemistry data presented above, representative of waters in Georgian Bay proper. It is therefore likely indicative of the DOT profile for Bay waters, with DO rarely falling below 6 mg/L and fluctuations being primarily influenced by shifts in temperature and the corresponding change in saturation capacity (Table 8; Figure 13). Daily peaks in DO were still evident between 14:00-19:00, with slight declines (2-3 mg/L) to a low between 03:00-08:00 (Figures 14 and 15). A similar pattern (albeit larger magnitude) was also evident in three of the four wetland areas (South Bay North, South Bay South, and Green Island), with the sole exception being 100 Acre Wetland where DO levels peaked earlier in the day (10:00-14:00). This site also recorded consistently low DO levels throughout the study period and had the greatest number of records where DO was below both 6 and 3 mg/L. While the other three wetland sites did see DO levels below 3 mg/L, these were typically less frequent and of a shorter duration.

The two sites in South Bay were selected to reflect wetlands that were more influenced by their watersheds than the Bay (as indicated by their lower conductivity readings relative to Present Island) and allow a comparison between DO profiles in a fringing wetland (South Bay North) and more protected embayment (South Bay South). Despite apparent differences in geomorphology, DO profiles at these sites were quite similar with only slightly more DO readings below 6 mg/L at South Bay South (Figure 13). In contrast, both the 100 Acre Wetland site and Green Island were thought to be more influenced by water from the Bay, but this influence seems to have been mitigated by other conditions at these sites that appear to have facilitated declines in DO (discussed below).

The final area of interest was the Sturgeon River, which drains an area of 98.3 km<sup>2</sup> and, while it has considerable natural cover in this watershed, mixed-use agriculture is also present. We found no evidence that waters entering Severn Sound from the Sturgeon River had a DO profile different from those observed at our control site at Present Island (Figure 12 and Figure 13).

### **3.3 SUBSTRATE**

Substrate composition from the 99 samples collected throughout Severn Sound suggested that sand (6.25  $\mu$ m-2 mm) was by far the most dominant component, comprising an average of 95.2% of the overall sample (Table 9). There were a few samples where sand was less dominant, notably single samples in Honey Harbour (#3),

100 Acre Wetland (#1), Midland Bay (#10), Robert's Inlet (#3), and Beausoleil West (#2) where gravel (2-16 mm) comprised over 20% of the sample. Silt and clay rarely comprised more than 5% of the overall sample and no larger material (cobble [64-256 mm], boulder [>256 mm]) was found; however, this is likely more a function of sampling limitations with petit ponar than the absence of these substrate types in Severn Sound. Finally, loss on ignition (organic content) was low when averaged across all samples (6.5%); however, there were some regions that had greater than 10% organics across all samples including: North Bay (34.6%), South Bay (16.9%), Matchedash Bay (12.5%), Hog Bay (12.2%), and Green Island (10.7%); all areas that were categorized as being protected.

#### **4.0 DISCUSSION**

This report outlines a comprehensive spatial survey of submerged aquatic vegetation, substrate composition and dissolved oxygen profiles in Severn Sound, Lake Huron. In 2003, this region was delisted as a Great Lakes AOC, but ongoing monitoring of environmental conditions in the Sound is critical to ensure aquatic conditions remain unimpaired. A major ongoing component of this is the completion of a fish habitat suitability assessment for Severn Sound and the work presented here will support these efforts by 1) mapping SAV cover across a range of water depths and environmental gradients to contribute to the development of a regionally derived spatial SAV model, 2) aid in the interpretation of substrate composition from side-scan sonar data by providing field validation samples, and 3) assess dissolved oxygen variability by comparing dissolved oxygen profiles in regions influenced by sewage treatment plant outflows, across a range of exposure, and in a tributary.

Based on SAV surveys in 20 regions of Severn Sound it is clear, although not surprising, that the cover and depth distribution of SAV are heavily influenced by exposure to wind and wave action and water clarity (dystrophic vs non-dystrophic in particular). The primary literature strongly supports these results (reviewed in Lacoul and Freedman 2006) with exposure largely dictating the minimum depth of SAV establishment (largely driven by the removal of propagules by waves or ice scour; Stewart and Freedman 1989) and water clarity dictating the maximum depth of SAV establishment (based on the rate of attenuation of photosynthetically active solar radiation; Chambers and Prepas 1988). In the exposed regions surveyed for the present report, it was evident that SAV was largely absent in water depths less than 3 m, particularly as the mean effective fetch for the survey region surpassed 3 km. SAV was still present at many of these more exposed sites, but the peak in cover and SAV height were shifted into deeper water, relative to more protected areas. This shift likely influences our ability to accurately assess the fish community assemblage in more exposed areas since many commonly used fish sampling methods are not effective past depths of 2-3 m (i.e., electrofishing or fyke nets), while other gear cannot be deployed

along exposed coastlines (trap nets). Invariably, fish are using these deeper beds of SAV, so alternative sampling methods (e.g., gill nets) may be required to assess their contribution as fish habitat to Severn Sound, especially given the abundance of exposed coastal shorelines in the Sound.

In contrast to many nearshore areas of the lower Great Lakes, turbidity was comparatively low in all surveyed areas in Severn Sound (Chow-Fraser 2006). This likely contributed to the generally high Secchi depth readings and establishment of SAV at water depths exceeding 7-m in many regions. The maximum depth of SAV colonization was only notably shallower at two sites (North Bay and South Bay), where water colour was more dystrophic due to watershed inputs draining off of granitic formations in the Georgian Bay Fringe. Past SAV surveys along the eastern coast of Georgian Bay have documented a similar trend of reduced maximum depth of SAV colonization in more dystrophic waters (Midwood 2012). It is important to note that this variability in water colour is natural; therefore, SAV modelling efforts in Severn Sound will need to incorporate a measure of water colour or, alternatively, an estimate of the relative influences to water chemistry of the local watershed and Georgian Bay waters.

The data presented in the current report will be critical in the development and validation of a SAV model for Severn Sound. A two-stage model will likely be the most appropriate with the first step outlining where SAV are likely to be present and the second step applying either a unimodal distribution of SAV height/cover (for more exposed sites) or a logistic distribution of SAV height/cover (for protected sites). Several spatial layers that will be necessary for this modelling exercise have already been compiled (i.e., effective fetch and a digital elevation model); however, additional layers will need to be developed to incorporate variability in water colour and connectivity to Georgian Bay.

Similar to SAV, there were clear differences in DO profiles along a gradient of exposure, with relatively stable DO levels at the more exposed sites and increasing hourly and daily variability at more protected sites. With a few exceptions (100 Acre Wetland in particular), most protected areas did not experience extended periods of anoxia, suggesting that low DO is not a recurring issue in Severn Sound. That being said, the two regions where the lowest DO levels were recorded were coastal wetland sites, therefore a more detailed assessment of the spatial and temporal variability of DO in these types of systems is likely warranted. Identifying the driving factor behind the observed anoxic periods in coastal wetlands will help to establish whether this is largely a natural phenomenon and, if so, DO targets in wetlands currently undergoing remediation in other AOCs can be adjusted to account of this natural variability. There are several potential reasons why low DO may occur in a seemingly healthy coastal wetland. First, high productivity in coastal wetlands often results in the development of sediments with a considerable amount of organic material undergoing decay. The breakdown of this material consumes oxygen and, depending on where in the water

column the DOT logger is situated, may result in an apparent decline in DO levels. Our loggers were only situated 30 cm off the bottom of the substrate, therefore, if decomposition rates are high, oxygen may be consumed from this depth stratum. An alternate hypothesis for the observed low DO levels is that of a shading effect from floating vegetation (i.e., pond or water lilies). This may be particularly true for the 100 Acre Wetland DOT logger, which was deployed in a stand of *Nuphar variegata* that had almost completely covered the surface of the water at the time of retrieval. This covering may limit photosynthesis by SAV and phytoplankton growing underneath the floating vegetation thereby reducing DO levels (as has been observed in *Eichhornia crassipes*, Rai and Datta Munshi 1979 and *Trapa natans*, Caraco and Cole 2002). The documented shift in the timing of peak DO levels to earlier in the day at this site may further corroborate this hypothesis since this is the window when the sun would be close to its zenith and therefore the angle of light would also be at its lowest value allowing for maximum light penetration into the water column. Further exploration of the cause of low DO in coastal wetlands is warranted and Severn Sound presents an ideal location to explore various mechanisms, while controlling for many of the anthropogenic influences prevalent in other Great Lakes ecosystems.

The lone site where an influence from anthropogenic activity was most acute was Inner Penetang, which is proximate to an STP outflow. While this STP has been recently upgraded to reduce nutrient release into adjacent waters, any additional nutrient input into the typically oligotrophic or mesotrophic waters may be at least partially responsible for the observed large hourly and daily fluctuations in DO. Dense stands of SAV (*Chara* spp. with epiphytic algae) in the area proximate to the logger likely also contributed to the observed high rates of primary productivity during the day. The result is a DO profile that has long been deemed indicative of a eutrophic system (Wetzel 2001). While the hourly cycle peaked during a similar time-window as control sites, the magnitude of the change in DO at Inner Penetang was considerably larger, often reaching supersaturation during peak DO (17-22 mg/L). This level of productivity was unparalleled in the system, and may result in short-term exclusion of some fishes due the potential for the development of gas bubble disease (Weitkamp and Katz 1980; Weitkamp 2007). For fishes this is largely a species-specific response; however, even short durations (hours) of extreme supersaturation (>200%) can cause increased mortality, particularly for small-bodied fishes that cannot easily regulate excess O<sub>2</sub> in their swim bladders (Weitkamp and Katz 1980; Weitkamp 2007). That being said, fish community surveys undertaken concurrently with the present work found that southern Penetanguishene Bay was actually one of the most productivity regions in Severn Sound in terms of fish productivity (C. Boston, pers. comm.). This suggests that despite the documented occurrence of supersaturation, there is no clear response in the proximate fish community. The documented supersaturation may therefore affect only a small portion of Penetanguishene Bay (thus fish will use other areas of the Bay with

more favourable conditions) or the comparatively short duration of supersaturation may not be of a sufficient duration or rate change to negatively affect fishes. A more in-depth survey of how fish and fish productivity responds to short-term occurrences of supersaturation is therefore warranted to assess the potential influence of STPs. Indeed, a relatively recent review of the subject suggested there had been no population-level evaluations of the effect of supersaturation on fish populations (Weitkamp 2007). This is of particular interest since the majority of studies that have explored negative effects of gas bubble disease are focused on hydro dams and fish passage through supersaturated race-ways (Weitkamp and Katz 1980; Weitkamp 2007). Furthermore, negative effects of supersaturation may represent more of an acute, sub-lethal effect, which may or may not have long-term consequences on affected individuals.

Across virtually all substrate samples, sand was the dominant substrate type. The most apparent differences, from a regional perspective, were associated with the mean loss on ignition or percent organics. The highest measures of organic content tended to be found in areas that were protected from wind and wave action. This finding is to be expected since high wave energy (exposure) has a negative effect on the amount of organic material in the substrate through the erosion of fine organic particles (Madsen et al. 2001). The primary purpose for the collection and analysis of substrate samples was to inform the interpretation of substrate data surveys that have been completed using sidescan sonar and hydroacoustics. These works are ongoing and the 99 samples collected for the present report will be integral to these efforts.

## **5.0 CONCLUSIONS**

The results of the 2016 survey clearly show the wide range of habitat conditions present in Severn Sound, Georgian Bay. While currently the major drivers behind site variability appear to be largely natural (exposure), it is evident that some regions are affected by human activities, southern Penetanguishene Bay in particular, but also Matchedash Bay and Midland Bay. By integrating the present work with efforts by the Severn Sound Environmental Association and University of Windsor, a complete fish habitat suitability model for the nearshore environment of Severn Sound can be created.

There were several avenues identified for future research that would benefit both the assessment of Severn Sound and contribute to our overall knowledge of freshwater ecosystems. First, it would be prudent to conduct a more detailed spatial exploration of DO profiles within coastal wetlands to determine the causal mechanism behind extended periods of anoxia in these systems and the extent to which the entire wetland is affected. This has important implications since wetlands are critical spawning and nursery habitat for a majority of fish species, therefore natural periods of low DO may affect both recruitment and growth of dependent fishes. Also, anoxia has been identified as a concern in many Great Lakes AOCs (e.g., Cootes Paradise in Hamilton Harbour),

therefore an understanding of natural DO cycles is critical for establishing DO targets for delisting. Next, in the present study we were unable to assess local productivity (based on chlorophyll a for example) in the areas near our DOT loggers. A more thorough assessment of the source of the oxygen that is driving supersaturation is therefore warranted to determine whether harmful algal blooms, which may pose additional ecological concerns, are causing the observed spike in DO. During our brief review of the literature regarding supersaturation, it quickly became apparent that there is limited species-specific information on tolerance levels for the majority of warmwater fishes. A more detailed assessment of the responses of warmwater fishes to supersaturation would help assess whether the levels observed at Inner Penetang and elsewhere pose risks to the growth and survival of local fishes. In addition, a more spatially comprehensive assessment of DO levels in southern Penetanguishene Bay and the identification of potential refugia from supersaturation would help determine the magnitude of the influence from the STP and likelihood of fish exposure to supersaturation. Finally, our SAV surveys identified a habitat zone that is likely under-represented in current fish community sampling efforts, specifically SAV along exposed open coasts. Given the well documented associations between fish and SAV (Randall et al. 1996), this area is likely important habitat for some species yet it is not being incorporated into current assessment programs. This is particularly true during the summer when nearshore areas are too warm for coolwater fishes (e.g., northern pike, *Esox lucius*) and this heterogeneous habitat in deep water may then serve as an important thermal refuge. Future assessments of this habitat zone are therefore warranted; with gill nets, underwater video, or angling providing some strong alternatives.

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**Table 1.** Summary details for each dissolved oxygen (DO) logger site with coordinates, disturbance category, physiographic region, and mean/max effective fetch.

Site Name	Easting	Northing	Disturbance Category	Location	Physiographic Region	Mean Fetch (m)	Max Fetch (m)
Inner Penetang	583625	4957650	Treatment Plant	STP	Simcoe Upland	568 ± 18	595
Outer Penetang	584430	4961090	Protected Coast	Coast	Simcoe Upland	621 ± 18	641
Present Island	591424	4963380	Exposed Coast	Coast	Simcoe Upland	2209 ± 263	2536
Sturgeon River	599989	4954440	River Outflow	River	Simcoe Upland	1119 ± 77	1214
Hog Bay*	594810	4954160	Protected Coast	Wetland	Simcoe Upland	393 ± 83	529
Green Island	599517	4960350	Protected Coast	Wetland	Georgian Bay Fringe	625 ± 96	784
100 Acre Wetland	595735	4966140	Protected Coast	Wetland	Georgian Bay Fringe	166 ± 24	198
Beausoleil East*	589855	4966580	Exposed Coast	Coast	Simcoe Upland	2295 ± 91	2419
South Bay N	595956	4968550	Exposed Coast	Wetland	Georgian Bay Fringe	204 ± 10	218
South Bay S	595495	4970050	Protected Coast	Coast	Georgian Bay Fringe	214 ± 7	221

“\*” Loggers were not included in the analysis of dissolved oxygen profiles because the logger could not be recovered (Beausoleil East) or the logger was partially buried in the sediment (Hog Bay).

**Table 2.** Water chemistry data from probe readings collected during daytime SAV surveys (11 July until 27 July 2016). A malfunction in the turbidity probe early on during the assessment prevented this component from being collected at some locations; however, readings were generally quite low relative to other locations in the Great Lakes suggesting that turbidity is typically not an issue in GB. All values are mean  $\pm$  standard deviation.

Site	Date Sampled	Temperature (°C)	Conductivity ( $\mu$ S/s)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Turbidity (NTU)
100 Acre South	27/07/2016	25.0 $\pm$ 1.1	187 $\pm$ 1	8.54 $\pm$ 0.28	104 $\pm$ 4	0.45 $\pm$ 0.77
Beausoleil East	19/07/2016	22.3 $\pm$ 0.4	181 $\pm$ 2	8.10 $\pm$ 0.32	93 $\pm$ 4	0.05 $\pm$ 0.03
Beausoleil West	12/07/2016	22.9 $\pm$ 0.2	183 $\pm$ 1	9.70 $\pm$ 0.12	113 $\pm$ 2	
Green Island	13/07/2016	25.5 $\pm$ 0.3	242 $\pm$ 1	9.47 $\pm$ 0.13	115 $\pm$ 1	
Inner Hog Bay	27/07/2016	25.6 $\pm$ 0.5	205 $\pm$ 6	9.06 $\pm$ 0.78	111 $\pm$ 10	0.07 $\pm$ 0.29
Inner Penetang	21/07/2016	23.4 $\pm$ 0.5	189 $\pm$ 5	9.45 $\pm$ 0.62	111 $\pm$ 8	0.00 $\pm$ 0.05
Matchedash Bay	13/07/2016	26.2 $\pm$ 0.2	330 $\pm$ 9	9.86 $\pm$ 0.64	121 $\pm$ 6	
Midland Bay East	20/07/2016	24.1 $\pm$ 0.3	208 $\pm$ 27	8.81 $\pm$ 0.43	105 $\pm$ 5	0.19 $\pm$ 0.08
Midland Bay West	12/07/2016	24.1 $\pm$ 0.2	189 $\pm$ 1	9.74 $\pm$ 0.05	116 $\pm$ 1	
Musky Bay	27/07/2016	24.6 $\pm$ 0.1	191 $\pm$ 1	8.45 $\pm$ 0.10	101 $\pm$ 1	0.40 $\pm$ 0.11
North Bay	14/07/2016	26.1 $\pm$ 0.2	114 $\pm$ 1	9.19 $\pm$ 0.22	114 $\pm$ 2	
Outer Hog Bay	11/07/2016	24.8 $\pm$ 0.9	191 $\pm$ 1	9.75 $\pm$ 0.26	116 $\pm$ 3	
Outer Penetang	21/07/2016	23.4 $\pm$ 0.3	183 $\pm$ 1	8.75 $\pm$ 0.16	103 $\pm$ 2	0.00 $\pm$ 0.03
Present Island	11/07/2016	23.5 $\pm$ 0.3	179 $\pm$ 3	10.07 $\pm$ 0.38	118 $\pm$ 5	
Robert's Island	27/07/2016	25.6 $\pm$ 0.8	189 $\pm$ 2	8.86 $\pm$ 0.36	108 $\pm$ 5	0.26 $\pm$ 0.09
South Bay	14/07/2016	26.2 $\pm$ 0.0	159 $\pm$ 2	9.19 $\pm$ 0.10	113 $\pm$ 1	
SS South Shore	20/07/2016	24.2 $\pm$ 0.5	199 $\pm$ 7	8.65 $\pm$ 0.52	103 $\pm$ 7	0.11 $\pm$ 0.07
Sturgeon Bay	13/07/2016	26.9 $\pm$ 0.7	230 $\pm$ 19	13.31 $\pm$ 3.84	164 $\pm$ 49	
Sucker Creek	12/07/2016	23.0 $\pm$ 0.2	181 $\pm$ 2	10.00 $\pm$ 0.44	116 $\pm$ 5	
Treasure Bay	19/07/2016					
<i>Regional Mean</i>		24.6 $\pm$ 1.4	196 $\pm$ 41	9.42 $\pm$ 1.36	113 $\pm$ 18	0.13 $\pm$ 0.32
<i>Minimum-Maximum</i>		22.3-26.9	114-330	8.10-13.31	93-164	0.00-0.45

**Table 3.** Secchi depth for each of the submerged aquatic vegetation (SAV) hydroacoustic survey sites. The number of Secchi depth records for each site is also presented and for sites with two or fewer records no standard deviation was calculated. The number of SAV species detected at each site is listed. Finally, the categorical exposure ranking for each site is also provided as well as the mean (with standard deviation) and maximum effective fetch.

Site Name	# Secchi Records	Mean Secchi (m)	SAV Species Richness	Exposure Category	Effective Fetch (m)	
					Mean $\pm$ S.D.	Maximum
100 Acre South	3	4.71 $\pm$ 0.14	12	Protected	1702 $\pm$ 694	2779
Beausoleil East	3	4.35 $\pm$ 0.26	8	Exposed	2883 $\pm$ 294	3351
Beausoleil West	5	4.81 $\pm$ 1.03	5	Exposed	3425 $\pm$ 233	3785
Green Island	2	4.31 $\pm$ NA	14	Protected	1100 $\pm$ 202	1475
Inner Hog Bay	3	4.16 $\pm$ 0.33	12	Protected	1492 $\pm$ 485	2575
Inner Penetang	3	4.93 $\pm$ 0.23	11	Intermediate	735 $\pm$ 48	796
Matchedash	2	3.95 $\pm$ NA	10	Protected	1039 $\pm$ 47	1112
Midland Bay East	3	4.23 $\pm$ 0.15	8	Intermediate	1816 $\pm$ 515	2553
Midland West	3	4.37 $\pm$ 0.16	7	Intermediate	1654 $\pm$ 202	2030
Musky Bay	3	3.90 $\pm$ 0.15	9	Exposed	4647 $\pm$ 413	5222
North Bay	6	3.10 $\pm$ 0.38	8	Protected	369 $\pm$ 47	433
Outer Hog Bay	5	3.48 $\pm$ 0.31	9	Exposed	2493 $\pm$ 683	3742
Outer Penetang	3	5.35 $\pm$ 0.08	3	Exposed	1866 $\pm$ 229	2308
Present Island	4	4.14 $\pm$ 0.73	8	Exposed	4213 $\pm$ 692	4811
Robert's Island	3	5.01 $\pm$ 0.19	14	Intermediate	1198 $\pm$ 245	1664
South Bay	6	2.86 $\pm$ 0.25	9	Protected	353 $\pm$ 64	438
SS South Shore	3	4.17 $\pm$ 0.13	8	Intermediate	3747 $\pm$ 317	4226
Sturgeon Bay	3	4.04 $\pm$ 0.17	10	Protected	1530 $\pm$ 202	1939
Sucker Creek	5	4.38 $\pm$ 0.52	11	Exposed	3513 $\pm$ 588	4345
Treasure Bay	1	4.61 $\pm$ NA	12	Protected	1404 $\pm$ 364	1832

**Table 4.** Results from the hydroacoustic (HA) surveys showing the number of pings where SAV was present (P) or absent (A). The mean, inter-quartile range and min/max depth where SAV were present or absent are also presented.

Site Name	SAV P/A	# Pings	Mean	1st –3rd Quartile	Min – Max
Beausoleil East	P	544	5.73 ± 1.42	4.99-6.43	1.20-9.44
	A	971	7.21 ± 2.55	6.96-9.01	1.10-9.64
Beausoleil West	P	48	5.79 ± 3.08	2.51-8.46	1.52-10.30
	A	286	7.04 ± 4.51	2.49-11.42	1.87-12.99
Green Island	P	1013	3.63 ± 1.13	2.68-4.57	1.28-5.95
	A	12	2.04 ± 1.56	1.32-1.46	1.29-5.50
100 Acre Wetland	P	1100	5.18 ± 1.64	4.14-6.31	1.02-9.90
	A	365	8.26 ± 1.20	7.57-9.05	1.22-9.92
Hogg Bay Inner	P	2525	4.54 ± 1.29	3.77-5.65	1.02-7.98
	A	186	5.64 ± 2.26	6.09-6.56	1.14-8.02
Hogg Bay Outer	P	704	3.55 ± 2.06	1.75-5.39	1.05-8.24
	A	28	5.70 ± 2.80	1.81-7.72	1.12-8.26
Matchedash Bay	P	731	1.63 ± 0.07	1.59-1.68	1.32-1.83
	A	0	NA	NA	NA
Musky Bay	P	633	4.89 ± 1.16	3.83-5.38	0.99-9.30
	A	1589	8.68 ± 1.83	7.92-9.80	1.11-10.20
Midland East	P	631	4.24 ± 2.30	2.09-6.09	1.35-10.42
	A	1224	8.64 ± 3.24	7.26-11.39	1.38-12.42
Midland West	P	164	5.98 ± 2.43	3.67-7.87	0.98-9.86
	A	641	9.94 ± 1.22	9.24-10.87	1.40-12.50
North Bay	P	559	3.16 ± 0.82	2.59-3.68	0.98-5.53
	A	74	8.14 ± 3.16	5.60-11.38	1.28-12.58
Inner Penetang	P	1367	5.37 ± 1.30	4.94-6.21	1.04-8.02
	A	169	6.48 ± 1.89	6.57-7.41	1.05-8.05
Outer Penetang	P	129	3.78 ± 2.78	1.05-5.97	0.94-10.47
	A	1098	7.29 ± 3.24	7.60-9.20	1.02-12.74
Present Island	P	911	4.65 ± 1.83	3.96-5.66	1.28-9.43
	A	523	5.42 ± 3.36	1.58-9.14	1.28-9.61
Roberts Island	P	973	5.26 ± 1.90	3.78-6.83	1.10-8.34
	A	219	5.92 ± 2.87	1.76-7.92	1.06-8.38
South Bay	P	158	3.88 ± 2.02	2.19-5.36	1.25-9.03
	A	334	8.68 ± 2.04	6.92-10.16	1.42-12.77
Sucker Creek	P	217	4.64 ± 2.47	2.47-6.77	1.29-10.49
	A	89	4.91 ± 3.95	2.02-7.94	1.29-12.92
Severn South Shore	P	392	3.93 ± 1.76	2.22-5.35	1.16-9.86
	A	872	8.34 ± 2.19	8.36-9.51	1.08-9.83
Sturgeon Bay	P	1471	2.39 ± 0.46	2.09-2.75	1.27-3.13
	A	0	NA	NA	NA
Treasure Bay	P	747	3.55 ± 1.04	2.80-4.17	1.64-6.05
	A	2	1.89 ± 0.03	1.88-1.90	1.86-1.91

**Table 5.** Results from the hydroacoustic surveys for SAV. The proportion of hydroacoustic points where SAV was present (Prop. SAV) is shown as are the mean, inter-quartile range and min/max for SAV percent cover and SAV height.

Site Code	Prop. SAV	SAV Percent Cover			SAV Height (m)		
		Mean	1st – 3rd Quartile	Min – Max	Mean	1st – 3rd Quartile	Min – Max
Beausoleil East	0.36	75.7 ± 32.6	50-100	10-100	0.40 ± 0.31	0.16-0.56	0.10-1.90
Beausoleil West	0.14	39.4 ± 30.1	10-50	10-100	0.24 ± 0.15	0.12-0.32	0.10-0.69
Green Island	0.99	96.0 ± 14.2	100-100	10-100	0.78 ± 0.37	0.51-1.04	0.10-2.07
100 Acre Wetland	0.75	86.2 ± 25.9	80-100	10-100	0.73 ± 0.41	0.42-1.02	0.10-2.21
Hogg Bay Inner	0.93	90.6 ± 23.0	100-100	10-100	1.06 ± 0.60	0.60-1.49	0.10-2.61
Hogg Bay Outer	0.96	50.0 ± 33.9	30-100	10-100	0.33 ± 0.32	0.12-0.41	0.10-1.86
Matchedash Bay	1.00	99.4 ± 3.7	100-100	40-100	1.07 ± 0.19	0.97-1.21	0.14-1.44
Musky Bay	0.28	69.3 ± 33.1	40-100	10-100	0.27 ± 0.18	0.15-0.31	0.10-1.73
Midland East	0.34	72.5 ± 35.6	40-100	10-100	0.42 ± 0.33	0.17-0.58	0.10-1.72
Midland West	0.20	58.2 ± 35.4	20-100	10-100	0.40 ± 0.44	0.12-0.51	0.10-1.75
North Bay	0.88	92.4 ± 18.9	100-100	10-100	0.46 ± 0.28	0.28-0.54	0.12-2.01
Inner Penetang	0.89	93.3 ± 19.9	100-100	10-100	0.90 ± 0.43	0.58-1.21	0.10-2.36
Outer Penetang	0.11	58.9 ± 38.4	20-100	10-100	0.54 ± 0.32	0.20-0.70	0.10-1.96
Present Island	0.64	78.2 ± 33.1	60-100	10-100	0.29 ± 0.20	0.16-0.34	0.10-1.92
Roberts Island	0.82	80.1 ± 30.1	60-100	10-100	0.67 ± 0.48	0.20-1.03	0.10-2.57
South Bay	0.32	69.5 ± 37.2	30-100	10-100	0.48 ± 0.29	0.22-0.70	0.10-1.24
Sucker Creek	0.71	56.0 ± 34.5	20-100	10-100	0.29 ± 0.28	0.12-0.33	0.10-1.80
Severn South Shore	0.31	82.7 ± 29.2	77.5-100	10-100	0.53 ± 0.43	0.22-0.62	0.10-2.34
Sturgeon Bay	1.00	99.9 ± 1.5	100-100	70-100	1.08 ± 0.41	0.74-1.39	0.22-2.32
Treasure Bay	1.00	98.1 ± 10.4	100-100	10-100	0.80 ± 0.38	0.53-1.04	0.10-2.41

**Table 6.** Comparison of the mean SAV percent cover and height determined via analysis of hydroacoustic data with the visual assessment categories.

Visual Categories	# Samples	Hydroacoustic Mean	
		SAV Cover (%)	SAV Height (m)
Surface-Dense	10	100.0 $\pm$ 0.0	1.08 $\pm$ 0.21
Surface-Moderate	3	100.0 $\pm$ 0.0	0.64 $\pm$ 0.03
Surface-Sparse	4	75.0 $\pm$ 50.0	0.71 $\pm$ 0.54
High-Dense	39	99.7 $\pm$ 1.62	1.19 $\pm$ 0.52
High-Moderate	19	96.3 $\pm$ 16.1	0.94 $\pm$ 0.44
High-Sparse	5	82.0 $\pm$ 40.2	0.74 $\pm$ 0.61
Mid-Dense	36	95.8 $\pm$ 16.5	1.06 $\pm$ 0.46
Mid-Moderate	27	92.6 $\pm$ 19.9	0.84 $\pm$ 0.55
Mid-Sparse	8	80.0 $\pm$ 38.5	0.65 $\pm$ 0.51
Low-Dense	8	85.0 $\pm$ 35.1	0.80 $\pm$ 0.64
Low-Moderate	6	60.0 $\pm$ 40.5	0.66 $\pm$ 0.54
Low-Sparse	8	50.0 $\pm$ 53.5	0.46 $\pm$ 0.58
No SAV	79	19.4 $\pm$ 32.4	0.17 $\pm$ 0.28
Overall Means	Dense	95.1 $\pm$ 13.3	
	Moderate	87.2 $\pm$ 19.1	
	Sparse	71.8 $\pm$ 45.6	

**Table 7.** List of aquatic macrophyte species and Chara sp. collected at the 133 verification points and their mean coverage at points where they were found to occur.

Species	Common Name	# of Occurrences	Mean Cover (%)
<i>Vallisneria americana</i>	Wild Celery	51	23.7
<i>Elodea canadensis</i>	Common Waterweed	42	19.6
<i>Najas flexilis</i>	Slender Naiad	34	22.1
<i>Ceratophyllum demersum</i>	Coontail	34	37.6
<i>Chara</i> spp.	Stonewort	32	56.4
<i>Myriophyllum spicatum</i>	Eurasian Milfoil	30	29.8
<i>Heteranthera dubia</i>	Water Stargrass	24	18.0
<i>Potamogeton richardsonii</i>	Richardson's Pondweed	20	28.8
<i>Potamogeton robbinsii</i>	Fern-leaf Pondweed	19	26.9
<i>Myriophyllum sibiricum</i>	Northern Milfoil	16	15.6
<i>Potamogeton zosteriformis</i>	Flat-Stemmed Pondweed	12	15.8
<i>Megalodonta beckii</i>	Beck's Marsh Marigold	11	5.3
<i>Potamogeton pusillus</i>	Slender Pondweed	10	39.2
<i>Potamogeton perfoliatus</i>	Claspingleaf Pondweed	7	12.7
<i>Potamogeton amplifolius</i>	Large-leaf Pondweed	6	12.5
<i>Utricularia vulgaris</i>	Common Bladderwort	6	23.5
<i>Potamogeton</i> spp.	Pondweed Species	5	25.0
<i>Nitella</i> spp.	Brittlewort Species	4	28.0
<i>Potamogeton crispus</i>	Curly Pondweed	3	9.0
<i>Zizania palustris</i>	Wild Rice	3	8.0
<i>Potamogeton friesii</i>	Flat-stalked Pondweed	3	48.3
<i>Potamogeton gramineus</i>	Variable-Leaved Pondweed	2	26.5
<i>Nuphar variegata</i>	Yellow Pond Lily	2	10.5
<i>Najas</i> spp.	Water-nymph Species	2	19.2
<i>Utricularia minor</i>	Lesser Bladderwort	2	17.0
<i>Potamogeton foliosus</i>	Leafy Pondweed	1	2.0
<i>Nymphaea odorata</i>	Fragrant Water Lily	1	96.0
<i>Ranunculus</i> spp.	Crowfoot Species	1	2.0
<i>Sagittaria graminea</i>	Grassy Arrowhead	1	15.0
<i>Schoenoplectus acutus</i>	Hard-stem Bulrush	1	20.0

**Table 8.** Summary data from dissolved oxygen (DO) loggers deployed at eight locations throughout Severn Sound. The top group show the range of observed temperatures, the middle group the raw DO readings, and the bottom group the range DO saturation levels corrected for shifting temperatures.

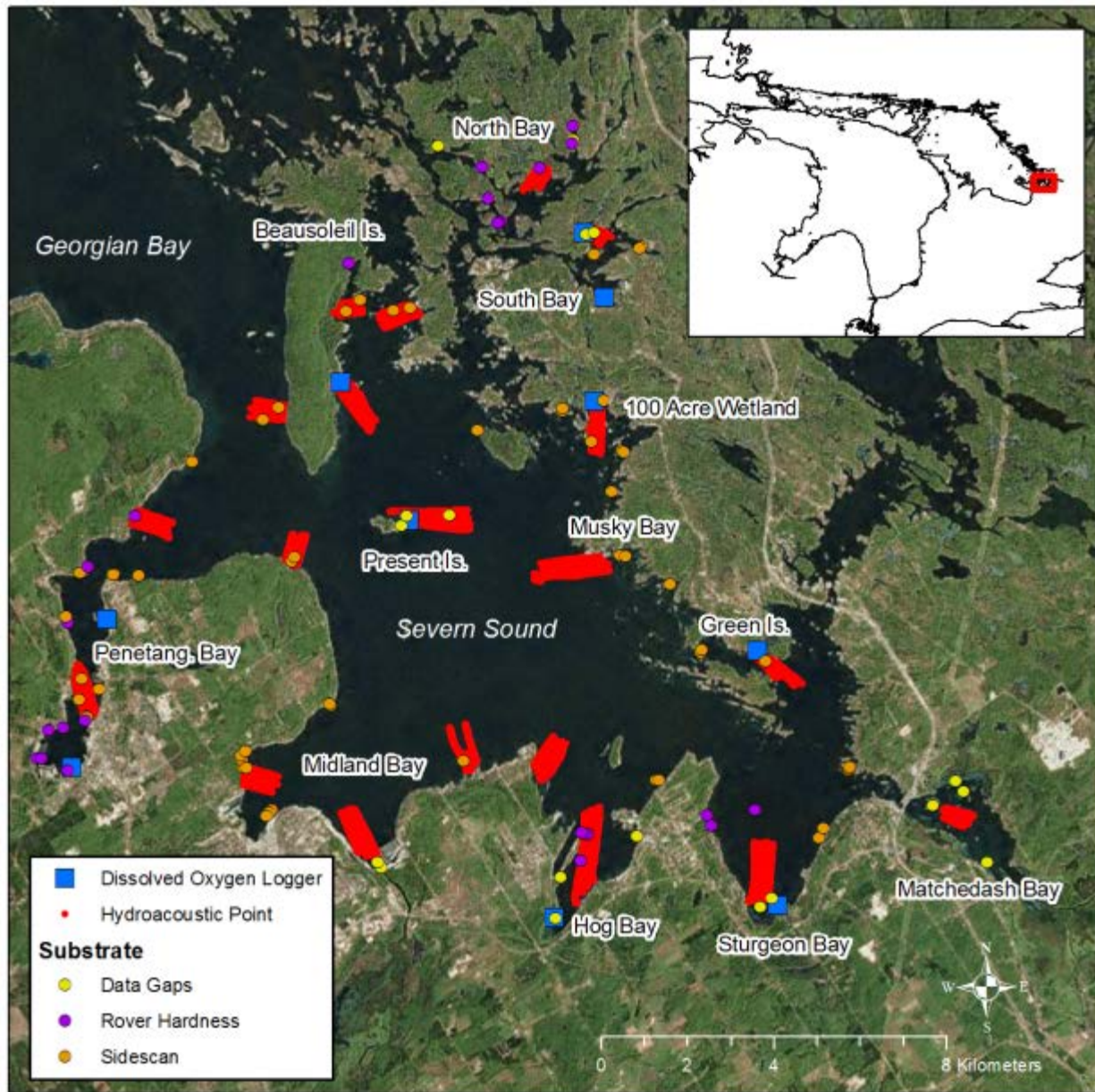
Temperature (°C)	Mean ± SD					Min-Max				
	June	July	August	September	October	June	July	August	September	October
Green Island	21.7 ± 2.6	24.7 ± 1.3	24.4 ± 1.2	20.3 ± 2.6	16.3 ± 1.6	16.0 - 26.3	20.6 - 28.1	21.5 - 27.5	14.7 - 25.4	13.2 - 20.0
100 Acre Wetland	20.9 ± 2.6	24.2 ± 1.3	24.6 ± 1.1	20.7 ± 2.3	16.8 ± 1.4	6.1 - 25.1	20.5 - 26.7	21.0 - 27.2	15.5 - 24.9	13.4 - 19.5
Present Island	19.8 ± 2.2	23.3 ± 1.4	24.3 ± 1.2	21.3 ± 1.8	17.4 ± 1.1	15.0 - 25.3	18.8 - 26.6	21.3 - 27.9	16.5 - 25.8	14.5 - 19.5
Outer Penetang	19.8 ± 2.6	23.8 ± 1.1	24.9 ± 1.1	21.8 ± 1.7	17.8 ± 0.8	15.0 - 24.8	20.6 - 26.4	22.3 - 27.5	18.2 - 25.5	15.6 - 19.5
Inner Penetang	20.4 ± 3.0	19.3 ± 1.6	18.5 ± 1.7	15.3 ± 1.9	12.7 ± 1.3	13.6 - 25.7	15.7 - 25.8	15.0 - 23.6	11.5 - 19.8	10.4 - 16.7
Sturgeon Bay	16.5 ± 2.20	18.5 ± 1.6	18.3 ± 1.2	14.5 ± 1.9	12.4 ± 2.0	11.4 - 20.7	14.0 - 23.6	15.2 - 21.5	10.4 - 19.5	7.5 - 15.0
South Bay North	21.8 ± 2.10	24.8 ± 1.1	25.3 ± 1.0	22.1 ± 1.9	17.9 ± 1.0	17.6 - 24.9	21.9 - 27.7	21.2 - 27.6	17.7 - 25.4	15.8 - 20.7
South Bay South	22.1 ± 2.50	25 ± 1.3	24.8 ± 1.3	20.9 ± 2.3	16.4 ± 1.4	16.4 - 26.0	20.9 - 27.9	21.9 - 28.2	15.7 - 26.1	13.3 - 19.4
DO (mg/L)	Mean ± SD					Min-Max				
	June	July	August	September	October	June	July	August	September	October
Green Island	8.43 ± 1.48	6.94 ± 2.43	4.91 ± 2.37	5.27 ± 2.17	7.14 ± 1.98	2.52 - 11.98	0.00 - 14.27	0.00 - 11.87	0.16 - 10.56	2.26 - 11.12
100 Acre Wetland	8.44 ± 1.58	6.73 ± 2.22	2.79 ± 2.10	2.80 ± 1.85	5.26 ± 1.96	3.27 - 12.94	0.00 - 10.91	0.00 - 9.41	0.00 - 8.21	0.09 - 9.31
Present Island	9.48 ± 0.85	7.83 ± 0.74	7.98 ± 0.76	8.86 ± 0.64	9.40 ± 0.49	5.77 - 12.26	5.14 - 10.13	5.08 - 10.36	4.87 - 10.56	7.56 - 11.16
Outer Penetang	9.85 ± 0.91	8.69 ± 0.78	8.89 ± 1.14	9.04 ± 0.71	9.29 ± 0.63	7.75 - 13.79	3.67 - 12.07	6.27 - 13.01	5.99 - 12.38	7.94 - 11.46
Inner Penetang	11.87 ± 1.40	10.87 ± 5.15	8.25 ± 4.30	8.46 ± 4.55	7.88 ± 3.89	8.40 - 18.33	2.32 - 22.68	1.62 - 22.20	1.91 - 18.71	2.58 - 17.18
Sturgeon Bay	8.84 ± 1.01	8.27 ± 1.32	8.14 ± 1.09	8.93 ± 1.18	9.35 ± 1.23	6.42 - 11.17	2.58 - 11.51	4.10 - 11.43	2.17 - 11.92	6.01 - 12.86
South Bay North	8.91 ± 0.63	8.07 ± 1.66	7.76 ± 2.28	8.78 ± 1.98	9.75 ± 1.44	6.25 - 10.87	1.57 - 12.78	0.27 - 13.76	1.44 - 14.23	5.43 - 12.39
South Bay South	9.58 ± 1.38	8.45 ± 2.05	6.20 ± 1.38	6.15 ± 1.40	7.29 ± 1.07	5.58 - 13.77	3.88 - 14.30	0.79 - 10.01	0.66 - 9.11	3.13 - 9.65
DO Sat.(%)	Mean ± SD					Min-Max				
	June	July	August	September	October	June	July	August	September	October
Green Island	98.0±18.0	85.4±29.9	60.2±29.4	59.6±25.0	74.5±21.2	29.9-146.4	0.0-172.0	0.0-144.3	1.9-126.3	22.2-120.6
100 Acre Wetland	96.5±18.3	81.9±27.0	34.3±26.0	31.8±20.8	55.7±21.4	40.0-129.1	0.0-133.9	0.0-118.6	0.0-90.3	0.9-99.5
Present Island	106.1±9.9	94.0±10.4	97.6±10.1	102.2±8.5	100.1±5.7	64.9-150.4	60.2-126.9	60.6-131.2	57.5-126.7	81.9-119.9
Outer Penetang	110.3±11.0	105.1±10.4	109.9±15.6	105.2±9.8	99.7±7.4	88.7-167.1	44.3-149.7	75.1-164.9	72.3-150.8	85.0-126.4
Inner Penetang	134.7±18.7	121.2±58.9	90.9±49.2	86.9±47.8	76.4±38.8	89.2-222.3	25.0-254.8	16.9-247.4	18.5-197.4	23.6-171.9
Sturgeon Bay	92.2±9.6	90.1±14.1	88.3±11.7	89.3±10.9	89.1±9.5	70.4-113.8	29.0-125.5	45.6-122.6	22.2-115.5	60.0-112.4
South Bay North	103.6±8.9	99.5±21.0	96.8±29.3	102.7±23.5	105.0±16.0	76.0-127.1	19.7-163.5	3.2-176.0	16.5-173.0	58.9-137.5
South Bay South	112.5±19.4	104.4±25.0	76.6±17.9	70.4±16.9	76.1±11.6	66.2-171.2	47.6-178.8	9.4-129.4	7.7-114.6	32.9-107.0

**Table 9.** Substrate composition at the 99 sites surveyed in 2016. Data points were collected to validate substrate hardness from data collected by the University of Windsor (Rover), validate data collected using sidescan sonar (Sidescan), and to fill gaps in existing substrate data layers (Data Gaps).

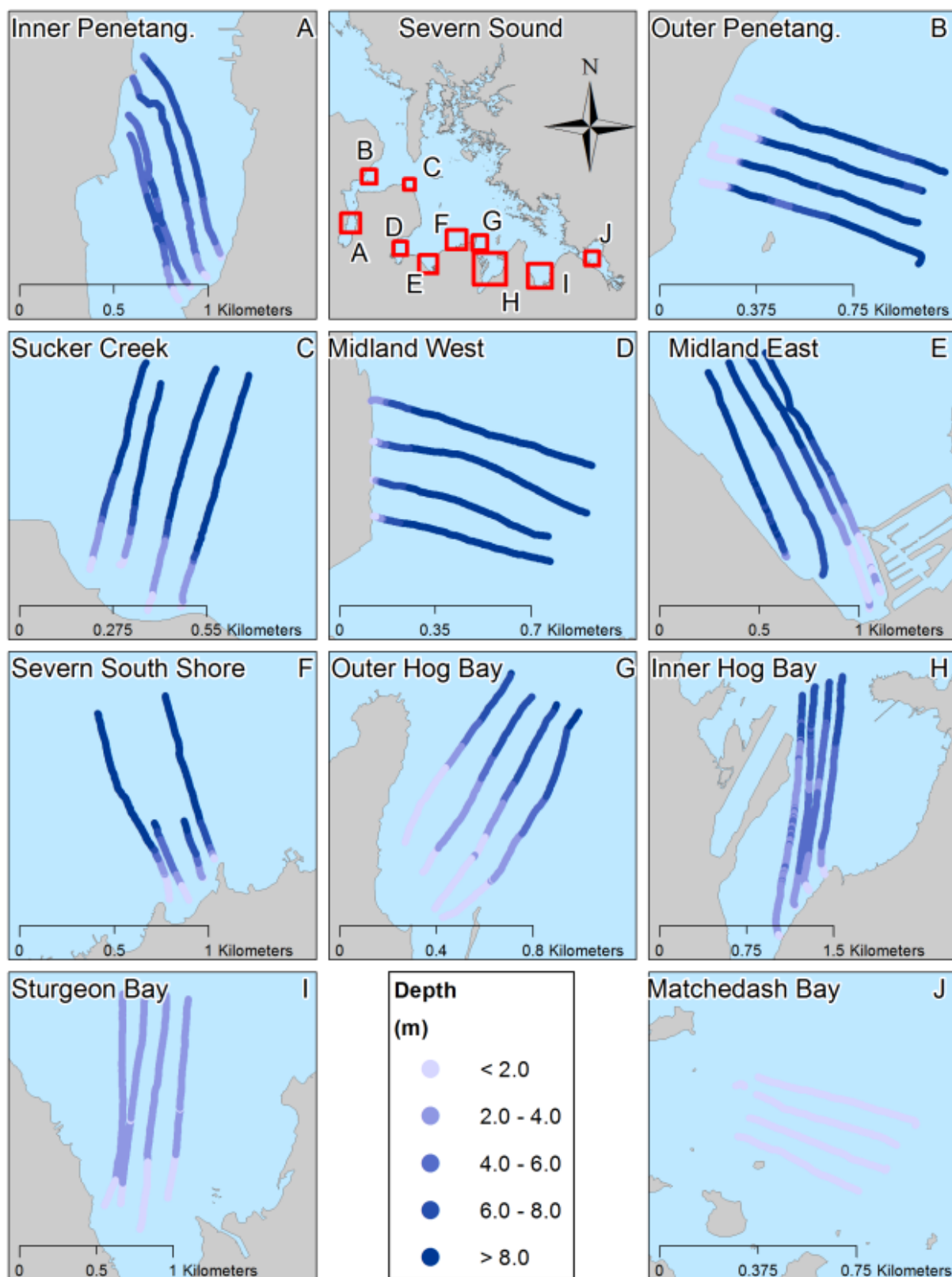
Site	Sample Num.	Collection Purpose	Boulder (+256 mm)	Cobble (64-256 mm)	Pebble (16-64 mm)	Gravel (2-16 mm)	Sand (0.625-2 mm)	Silt (0.0039-0.0625)	Clay (<0.0039)	Loss on Ignition (%)	Latitude	Longitude
100 Acre	1	Sidescan	0.0	0.0	0.0	30.9	68.9	0.1	0.2	2.56	44.83380	-79.78970
100 Acre	2	Sidescan	0.0	0.0	0.0	2.0	97.9	0.0	0.1	0.38	44.84240	-79.78600
Beausoleil Island	1	Rover	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.46	44.87171	-79.86021
Beausoleil West	1	Sidescan	0.0	0.0	0.0	0.1	99.9	0.0	0.0	0.49	44.84191	-79.88139
Beausoleil West	2	Sidescan	0.0	0.0	0.0	21.1	78.9	0.0	0.0	0.41	44.83923	-79.88604
Green Island	1	Sidescan	0.0	0.0	0.0	0.0	98.3	0.5	1.1	9.59	44.78938	-79.75873
Green Island	2	Sidescan	0.0	0.0	0.0	0.0	99.5	0.1	0.3	11.27	44.78990	-79.75848
Green Island	3	Sidescan	0.0	0.0	0.0	0.0	97.8	0.8	1.4	11.26	44.78733	-79.73972
Hog Bay	1	Data Gaps	0.0	0.0	0.0	0.0	99.0	0.4	0.7	21.26	44.73426	-79.80251
Hog Bay	2	Data Gaps	0.0	0.0	0.0	0.0	99.0	0.3	0.7	0.96	44.74294	-79.80063
Hog Bay	3	Data Gaps	0.0	0.0	0.0	1.6	98.2	0.1	0.1	0.39	44.75118	-79.77820
Hog Bay	4	Sidescan	0.0	0.0	0.0	0.0	99.4	0.2	0.5	2.47	44.76288	-79.77227
Hog Bay	5	Sidescan	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.39	44.76280	-79.77152
Hog Bay	6	Rover	0.0	0.0	0.0	0.7	96.3	0.9	2.1	5.10	44.75182	-79.79250
Hog Bay	7	Rover	0.0	0.0	0.0	16.5	82.6	0.2	0.7	1.57	44.75192	-79.79363
Hog Bay	8	Rover	0.0	0.0	0.0	1.1	98.7	0.0	0.1	4.55	44.75208	-79.79447
Hog Bay Inner	1	Rover	0.0	0.0	0.0	0.2	99.1	0.2	0.5	12.21	44.74620	-79.79460
Honey Harbour	1	Rover	0.0	0.0	0.0	1.8	97.6	0.2	0.4	4.32	44.89152	-79.82083
Honey Harbour	2	Data Gaps	0.0	0.0	0.0	0.0	99.9	0.0	0.0	10.30	44.89588	-79.83340
Honey Harbour	3	Data Gaps	0.0	0.0	0.0	47.3	52.7	0.0	0.1	0.55	44.89607	-79.83357
Honey Harbour	4	Rover	0.0	0.0	0.0	0.0	97.4	0.7	1.9	7.70	44.88488	-79.81900
Honey Harbour	5	Rover	0.0	0.0	0.0	0.0	96.4	1.5	2.1	4.83	44.88007	-79.81530
Honey Harbour	6	Rover	0.0	0.0	0.0	0.0	99.4	0.2	0.4	1.64	44.87975	-79.81600
Honey Harbour	7	Rover	0.0	0.0	0.0	0.4	99.4	0.0	0.1	0.45	44.87975	-79.81628
Matchedash	1	Data Gaps	0.0	0.0	0.0	0.0	93.5	1.7	4.7	11.33	44.74464	-79.67573
Matchedash	2	Data Gaps	0.0	0.0	0.0	0.0	98.8	0.4	0.9	9.92	44.75663	-79.69146
Matchedash	3	Data Gaps	0.0	0.0	0.0	0.5	97.5	0.7	1.3	11.80	44.76168	-79.68464
Matchedash	4	Data Gaps	0.0	0.0	0.0	0.0	99.1	0.3	0.6	16.87	44.75947	-79.68247
Midland Bay	1	Sidescan	0.0	0.0	0.0	0.0	97.4	0.8	1.8	11.82	44.77937	-79.86750
Midland Bay	2	Sidescan	0.0	0.0	0.0	0.3	97.3	0.7	1.6	1.64	44.77980	-79.86757
Midland Bay	3	Sidescan	0.0	0.0	0.0	0.0	98.8	0.5	0.7	1.95	44.76668	-79.89308
Midland Bay	4	Sidescan	0.0	0.0	0.0	0.1	99.9	0.0	0.0	0.30	44.76828	-79.89345
Midland Bay	5	Sidescan	0.0	0.0	0.0	2.2	97.7	0.0	0.1	0.34	44.76918	-79.89387
Midland Bay	6	Sidescan	0.0	0.0	0.0	0.0	98.0	0.7	1.3	4.10	44.77007	-79.89248
Midland Bay	7	Sidescan	0.0	0.0	0.0	3.0	97.0	0.0	0.0	0.78	44.80967	-79.87802
Midland Bay	8	Sidescan	0.0	0.0	0.0	2.6	96.8	0.2	0.3	1.63	44.75780	-79.88498
Midland Bay	9	Sidescan	0.0	0.0	0.0	0.0	99.1	0.2	0.7	1.23	44.75722	-79.88583
Midland Bay	10	Sidescan	0.0	0.0	0.0	22.5	73.6	0.9	3.0	6.66	44.75657	-79.88660
Midland Bay	11	Data Gaps	0.0	0.0	0.0	0.2	95.5	1.4	2.8	4.62	44.74548	-79.85328
Midland Bay	12	Data Gaps	0.0	0.0	0.0	0.0	92.9	2.1	4.9	1.61	44.74653	-79.85413
Midland Bay West	1	Sidescan	0.0	0.0	0.0	0.0	95.6	1.6	2.8	7.99	44.76672	-79.89222

Moore Point	1	Sidescan	0.0	0.0	0.0	0.2	99.3	0.1	0.4	11.26	44.80373	-79.76733
Moore Point	2	Sidescan	0.0	0.0	0.0	4.4	95.6	0.0	0.0	0.60	44.82338	-79.78407
Moore Point	3	Sidescan	0.0	0.0	0.0	3.7	96.2	0.0	0.2	1.54	44.80992	-79.78193
Moore Point	4	Sidescan	0.0	0.0	0.0	0.6	98.9	0.1	0.3	1.91	44.80970	-79.78025
North Bay	1	Rover	0.0	0.0	0.0	0.0	96.5	1.3	2.3	15.69	44.89118	-79.80388
North Bay	2	Data Gaps	0.0	0.0	0.0	0.0	99.0	0.3	0.6	28.73	44.89692	-79.79378
North Bay	3	Rover	0.0	0.0	0.0	0.0	98.4	0.5	1.1	50.53	44.89983	-79.79380
North Bay	4	Rover	0.0	0.0	0.0	0.0	98.1	0.7	1.2	43.59	44.89622	-79.79422
Penetang Inner	1	Sidescan	0.0	0.0	0.0	0.0	97.7	0.7	1.6	7.76	44.78140	-79.94100
Penetang Inner	2	Sidescan	0.0	0.0	0.0	0.0	99.2	0.2	0.6	7.23	44.78580	-79.94010
Penetang Outer	1	Rover	0.0	0.0	0.0	0.0	99.7	0.1	0.2	0.16	44.81960	-79.92390
Penetanguishene	1	Sidescan	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.39	44.80777	-79.94025
Penetanguishene	2	Rover	0.0	0.0	0.0	0.0	99.9	0.0	0.1	0.33	44.80904	-79.93808
Penetanguishene	3	Sidescan	0.0	0.0	0.0	0.0	99.5	0.1	0.4	1.78	44.80706	-79.92305
Penetanguishene	4	Sidescan	0.0	0.0	100.0	0.0	0.0	0.0	0.0		44.80738	-79.93060
Penetanguishene	5	Sidescan	0.0	0.0	0.0	4.9	94.7	0.1	0.3	0.50	44.78345	-79.93498
Penetanguishene	6	Rover	0.0	0.0	0.0	0.9	96.3	1.1	1.7	1.97	44.76653	-79.94474
Penetanguishene	7	Rover	0.0	0.0	0.0	0.0	95.2	0.9	3.9	10.51	44.77509	-79.95012
Penetanguishene	8	Rover	0.0	0.0	0.0	0.0	99.6	0.1	0.3	1.27	44.77549	-79.94570
Penetanguishene	9	Rover	0.0	0.0	0.0	0.0	88.5	5.1	6.3	19.20	44.76925	-79.95357
Penetanguishene	10	Rover	0.0	0.0	0.0	0.0	99.3	0.2	0.5	25.50	44.76915	-79.95217
Penetanguishene	11	Sidescan	0.0	0.0	0.0	0.0	97.1	1.0	1.9	9.59	44.77785	-79.93907
Penetanguishene	12	Sidescan	0.0	0.0	0.0	0.0	99.9	0.0	0.1	0.00	44.77765	-79.93892
Penetanguishene	13	Rover	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.48	44.77697	-79.93928
Penetanguishene	14	Rover	0.0	0.0	0.0	11.5	87.4	0.2	0.9	1.43	44.79743	-79.94418
Penetanguishene	15	Sidescan	0.0	0.0	0.0	0.4	97.8	0.4	1.4	20.47	44.83080	-79.90695
Penetanguishene	16	Sidescan	0.0	0.0	0.0	0.0	99.3	0.2	0.5	1.47	44.80763	-79.93027
Penetanguishene	17	Sidescan	0.0	0.0	0.0	3.1	96.8	0.0	0.0	0.14	44.80737	-79.93057
Penetanguishene	18	Sidescan	0.0	0.0	0.0	0.0	24.0	0.2	0.4	2.02	44.79868	-79.94453
Present Island	1	Data Gaps	0.0	0.0	0.0	0.6	99.2	0.1	0.2	18.97	44.81890	-79.83164
Present Island	2	Data Gaps	0.0	0.0	0.0	0.4	99.5	0.0	0.1	0.88	44.81680	-79.84579
Present Island	3	Data Gaps	0.0	0.0	0.0	1.0	98.9	0.0	0.0	0.74	44.81873	-79.84431
Quarry Island	1	Sidescan	0.0	0.0	0.0	0.0	98.7	0.4	0.9	4.64	44.84020	-79.79815
Quarry Island	2	Sidescan	0.0	0.0	0.0	0.0	98.6	0.3	1.1	3.87	44.84073	-79.79815
Quarry Island	3	Sidescan	0.0	0.0	0.0	1.3	98.7	0.0	0.0	0.44	44.83654	-79.82313
Robert's Inlet	1	Sidescan	0.0	0.0	0.0	0.2	99.3	0.2	0.3	12.30	44.83183	-79.78097
Robert's Inlet	2	Sidescan	0.0	0.0	0.0	1.2	98.7	0.0	0.0	2.04	44.83157	-79.78030
Robert's Inlet	3	Sidescan	0.0	0.0	0.0	21.7	77.9	0.1	0.4	2.19	44.86180	-79.84730
Robert's Inlet	4	Sidescan	0.0	0.0	0.0	2.6	97.2	0.1	0.2	1.04	44.86220	-79.84230
South Bay	1	Sidescan	0.0	0.0	0.0	0.1	98.4	0.5	1.0	10.36	44.87288	-79.78812
South Bay	2	Sidescan	0.0	0.0	0.0	0.0	98.1	0.6	1.3	17.47	44.87432	-79.77430
South Bay	3	Sidescan	0.0	0.0	0.0	0.0	99.2	0.2	0.6	15.90	44.87393	-79.77472
South Bay	4	Data Gaps	0.0	0.0	0.0	0.0	98.5	0.6	0.9	25.75	44.87714	-79.79034
South Bay	5	Data Gaps	0.0	0.0	0.0	1.5	97.4	0.4	0.7	14.97	44.87739	-79.78808
SS South Shore	1	Sidescan	0.0	0.0	0.0	3.9	95.9	0.1	0.2	0.54	44.76750	-79.82870
Sturgeon Bay	1	Sidescan	0.0	0.0	0.0	1.5	97.7	0.2	0.6	2.63	44.76425	-79.71593
Sturgeon Bay	2	Sidescan	0.0	0.0	0.0	0.3	99.7	0.0	0.0	0.03	44.76457	-79.71570
Sturgeon Bay	3	Sidescan	0.0	0.0	0.0	4.5	95.1	0.1	0.2	0.57	44.76505	-79.71558
Sturgeon Bay	4	Rover	0.0	0.0	0.0	0.0	95.8	1.3	2.8	0.87	44.75327	-79.75647
Sturgeon Bay	5	Rover	0.0	0.0	0.0	5.9	87.1	1.9	5.0	3.51	44.75534	-79.75761

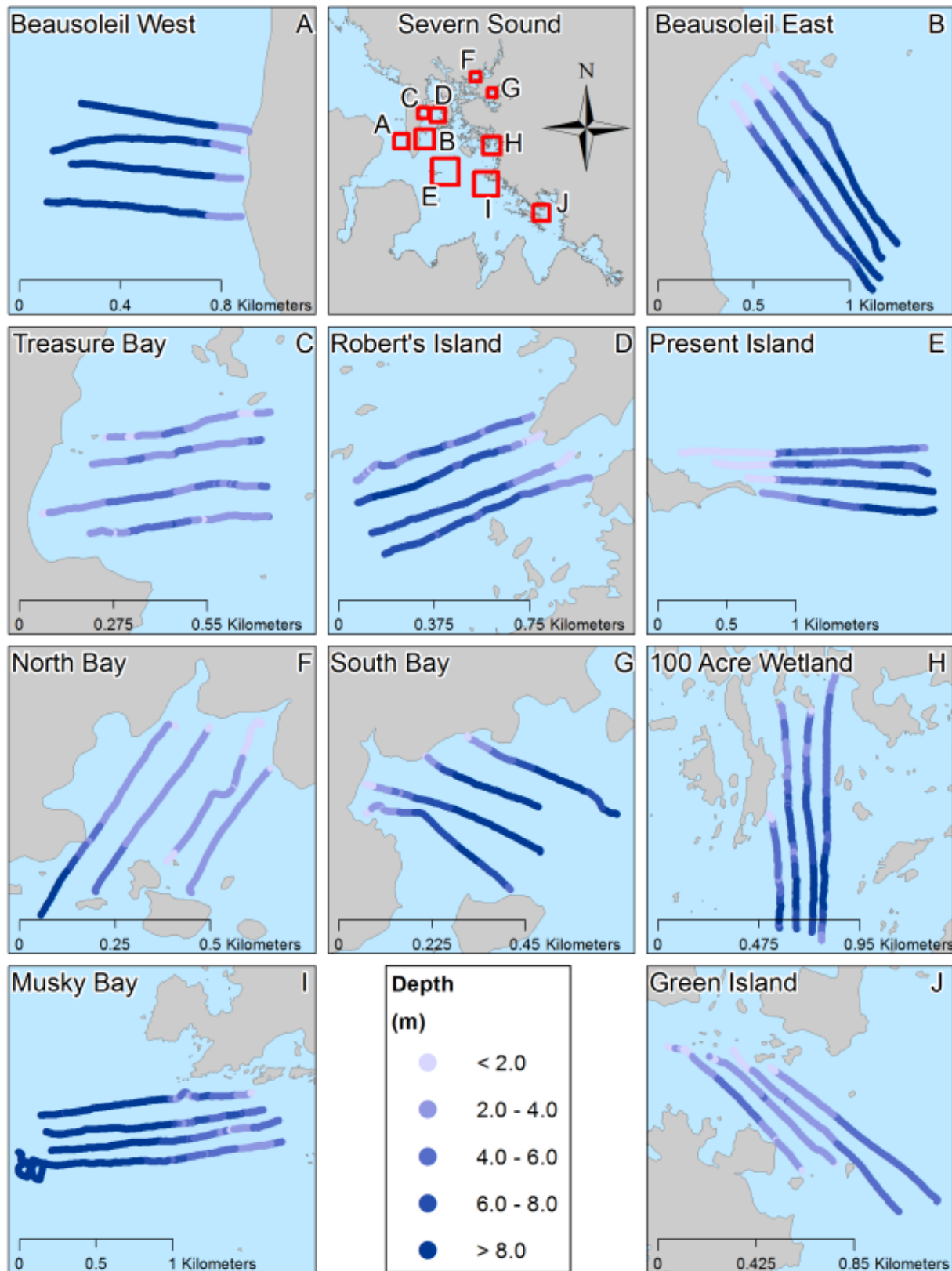
Sturgeon Bay	6	Sidescan	0.0	0.0	0.0	0.0	99.7	0.1	0.2	0.50	44.75036	-79.72484
Sturgeon Bay	7	Sidescan	0.0	0.0	0.0	0.2	99.6	0.1	0.1	0.49	44.75218	-79.72351
Sturgeon Bay	8	Data Gaps	0.0	0.0	0.0	0.4	95.2	1.6	2.7	2.48	44.73788	-79.73893
Sturgeon Bay	9	Data Gaps	0.0	0.0	0.0	0.0	99.7	0.1	0.2	0.86	44.73600	-79.74227
Sturgeon Bay	10	Rover	0.0	0.0	0.0	0.0	97.7	0.8	1.5	9.14	44.75625	-79.74350
Sucker Creek	1	Sidescan	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.41	44.81054	-79.87722
Treasure Bay	2	Sidescan	0.0	0.0	0.0	0.5	97.9	0.6	1.0	9.83	44.86180	-79.86110
Treasure Bay	3	Sidescan	0.0	0.0	0.0	2.5	97.4	0.0	0.1	0.00	44.86400	-79.85710



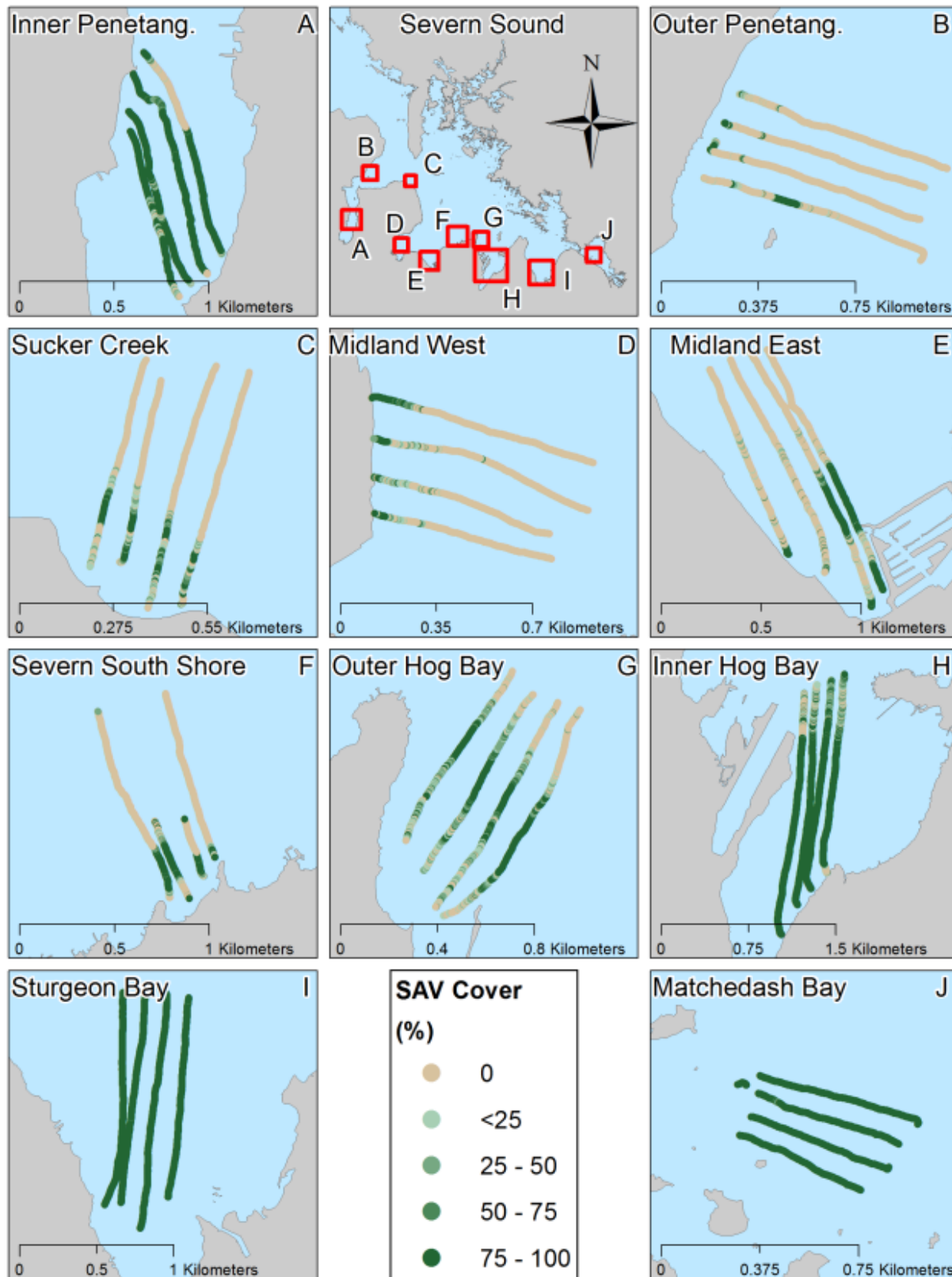
**Figure 1.** Location of SAV acoustic transects (red lines), dissolved oxygen loggers (blue squares), and substrate samples in Severn Sound. Substrate samples were selected to help fill existing data gaps (yellow circle), to cover a gradient of substrate hardness values (purple circle) and to support the interpretation of sidescan sonar data.



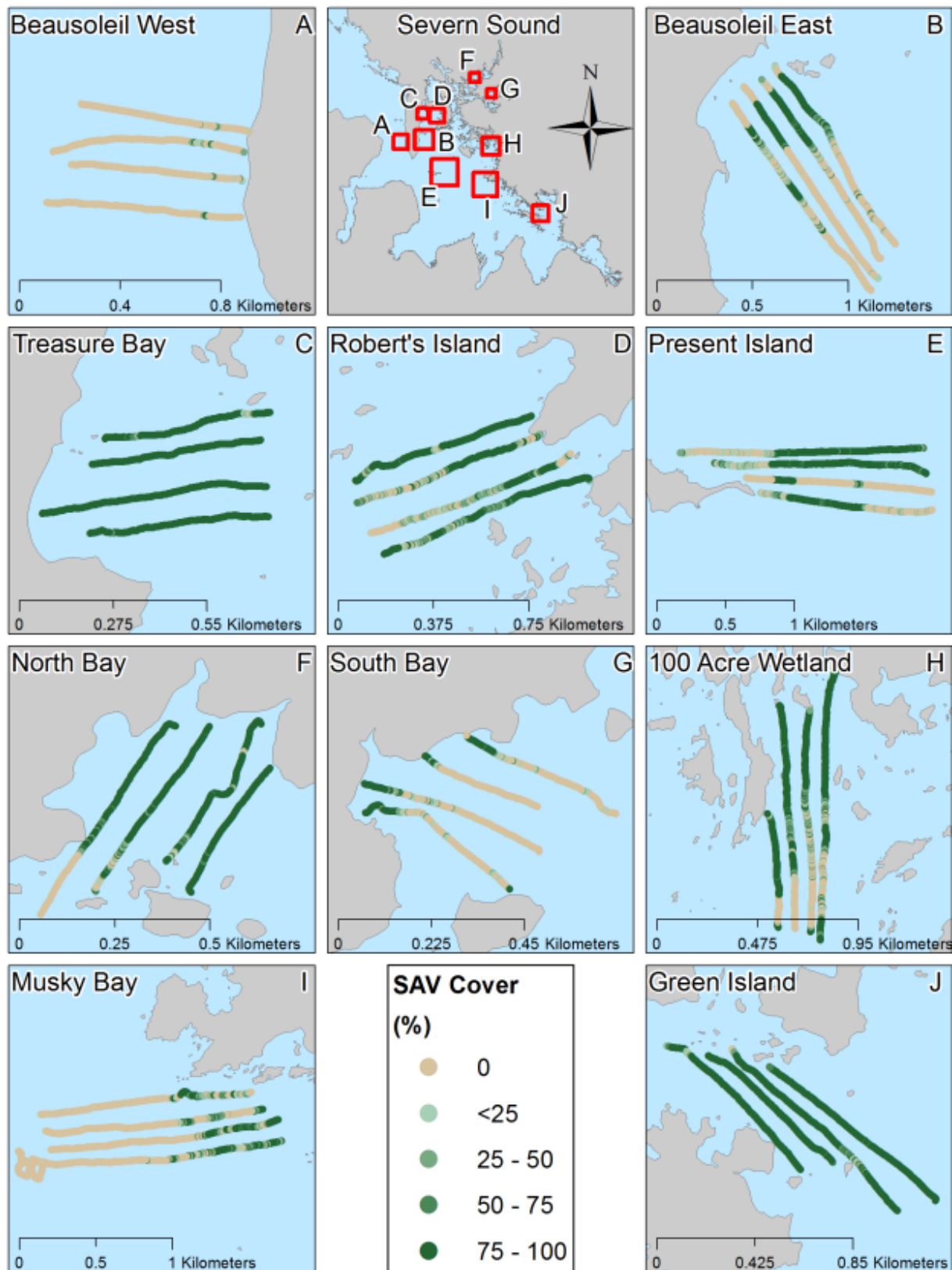
**Figure 2.** Water depth as determined by the hydroacoustic surveys in lower Severn Sound.



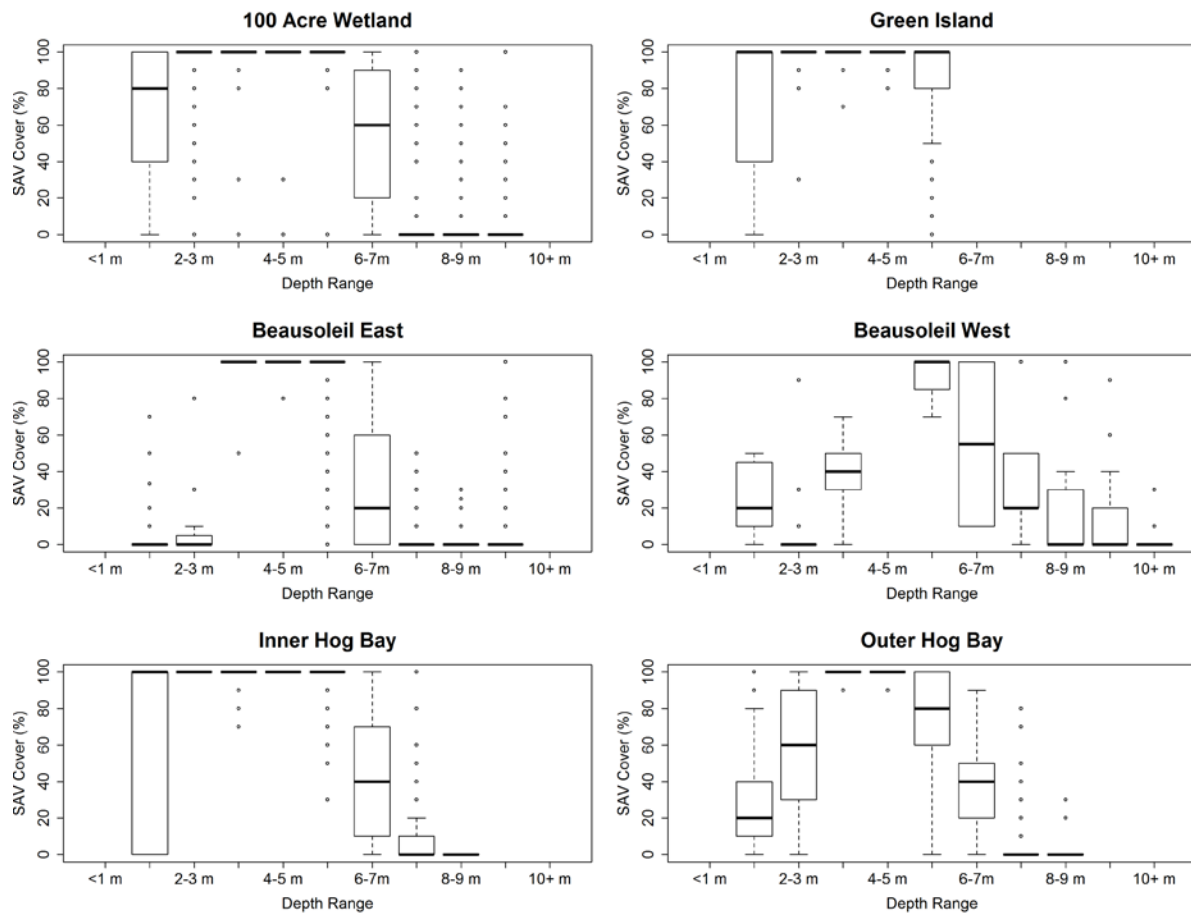
**Figure 3.** Water depth as determined by the hydroacoustic surveys in upper Severn Sound.



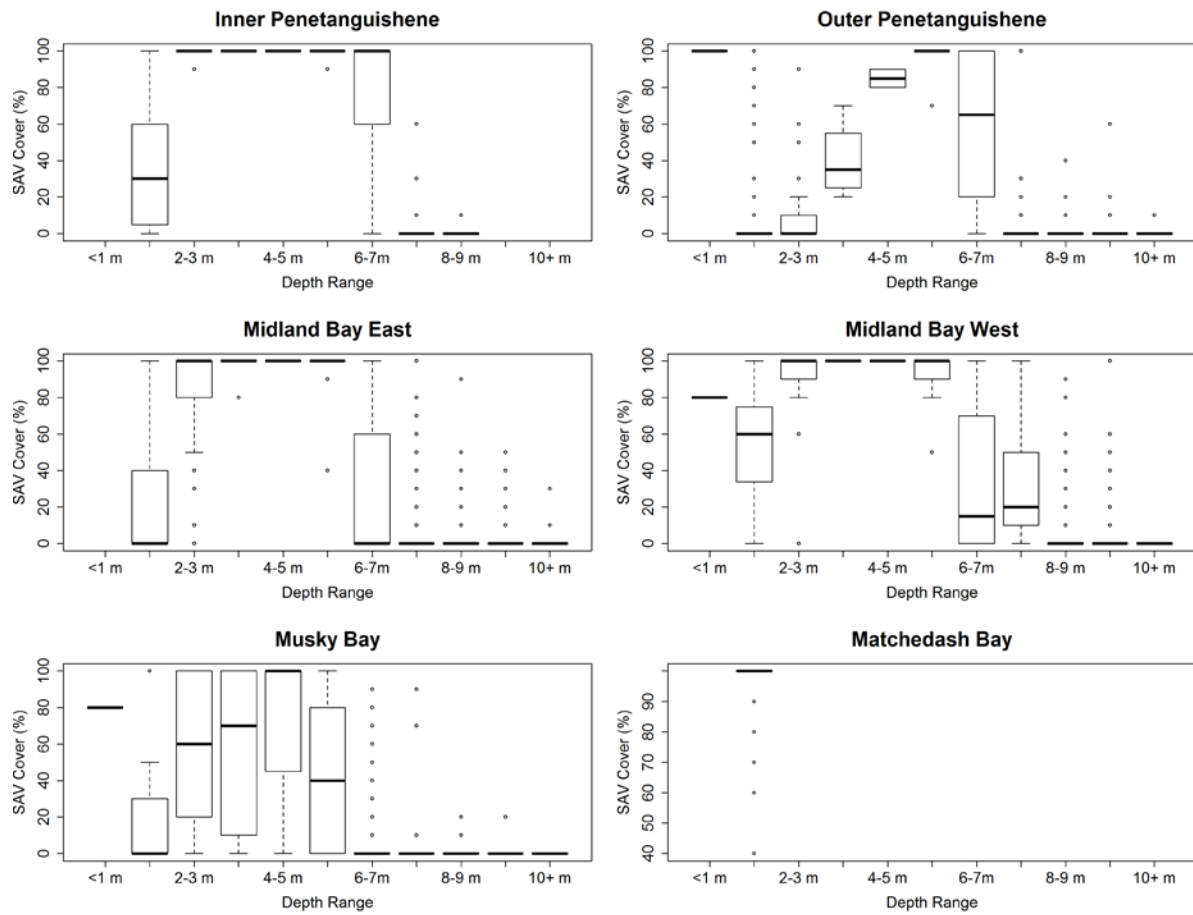
**Figure 4.** SAV percent cover as determined by the hydroacoustic surveys in lower Severn Sound.



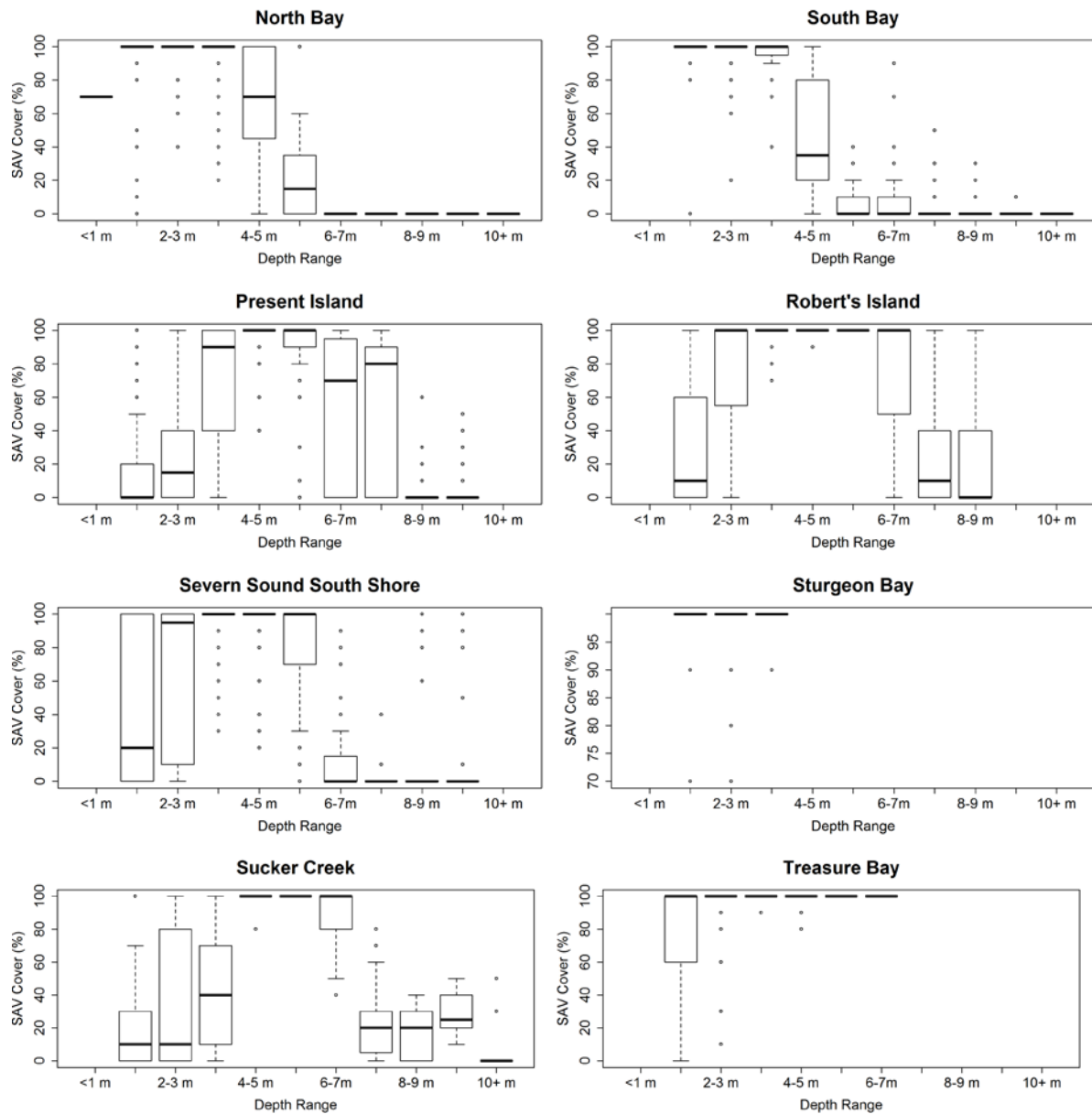
**Figure 5.** SAV percent cover as determined by the hydroacoustic surveys in upper Severn Sound.



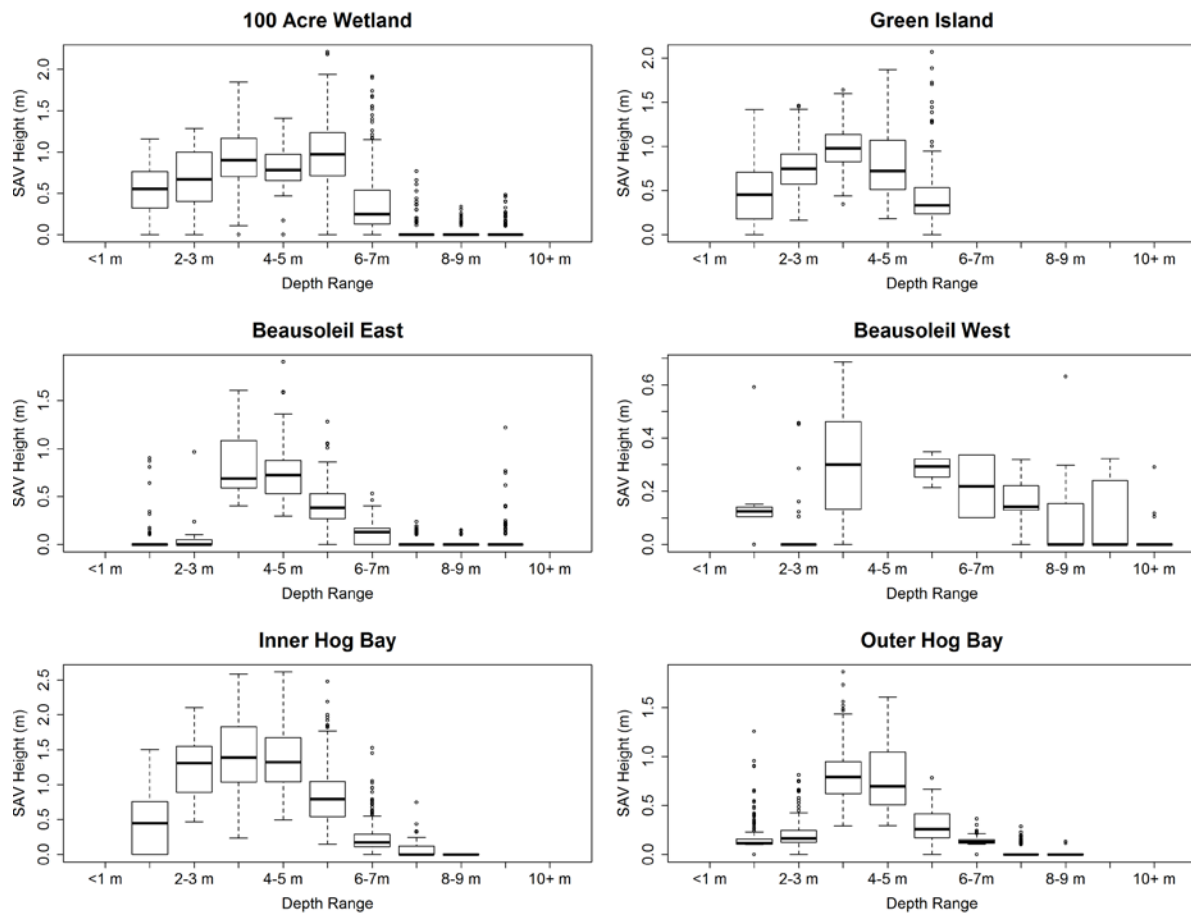
**Figure 6.** SAV percent cover as a function of depth range for a subset of the surveyed regions.



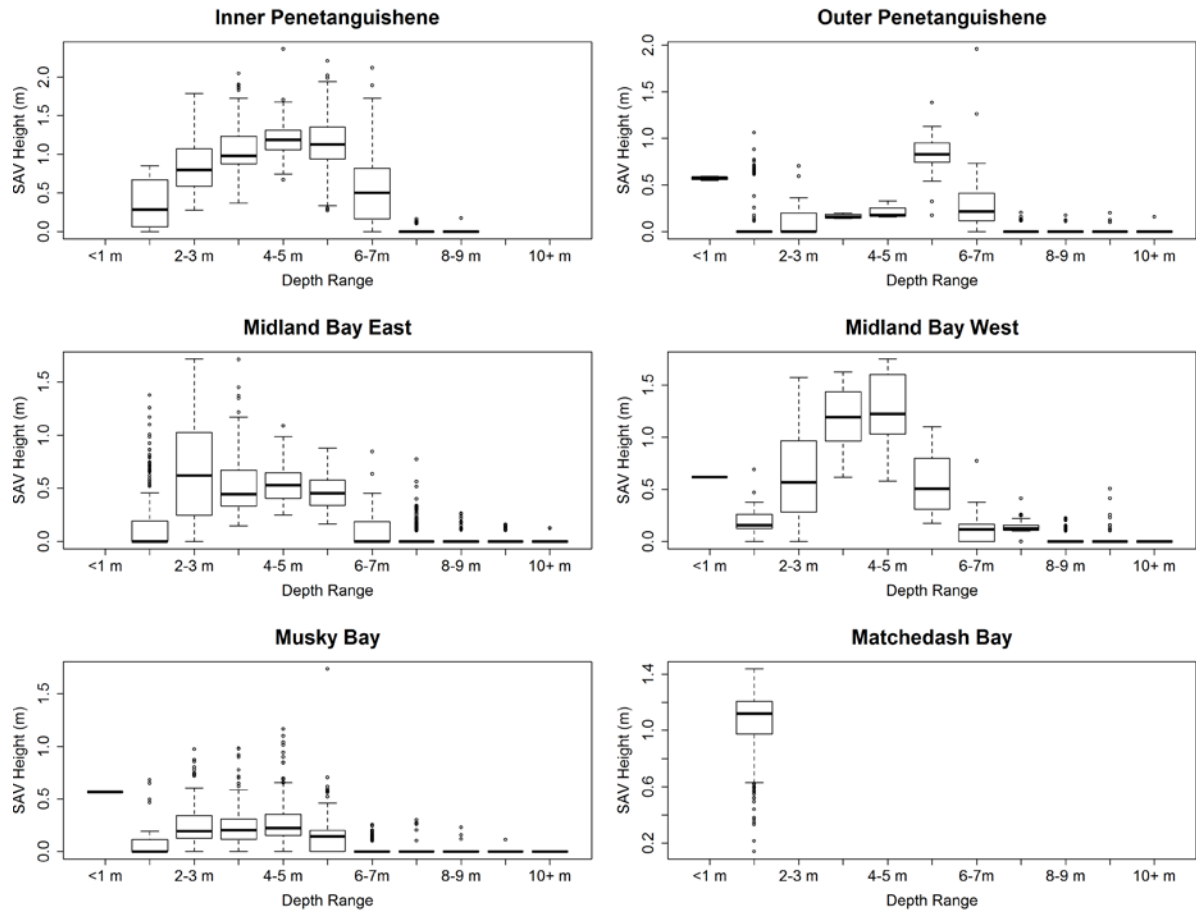
**Figure 7.** SAV percent cover as a function of depth range for a subset of the surveyed regions.



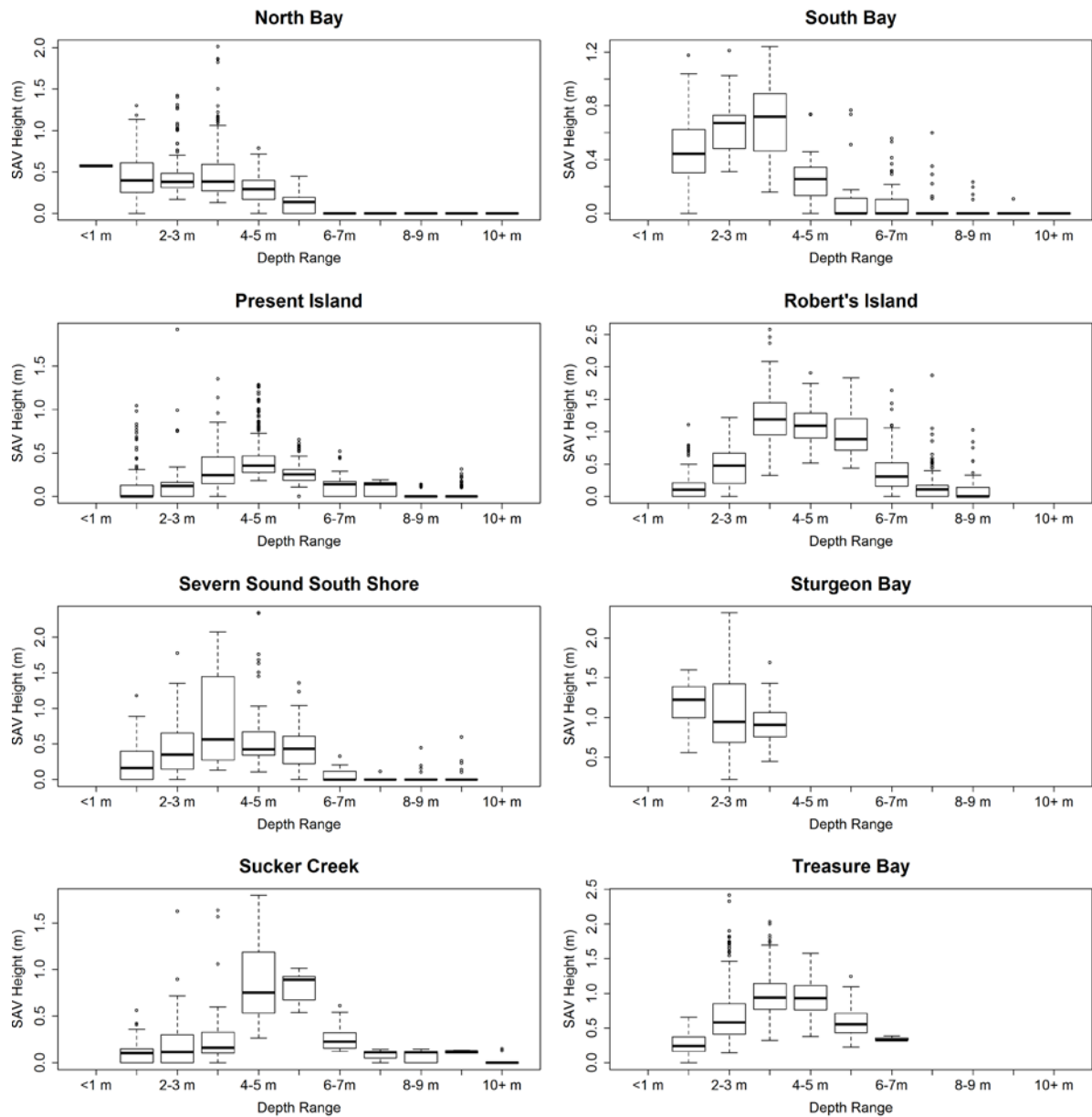
**Figure 8.** SAV percent cover as a function of depth range for a subset of the surveyed regions.



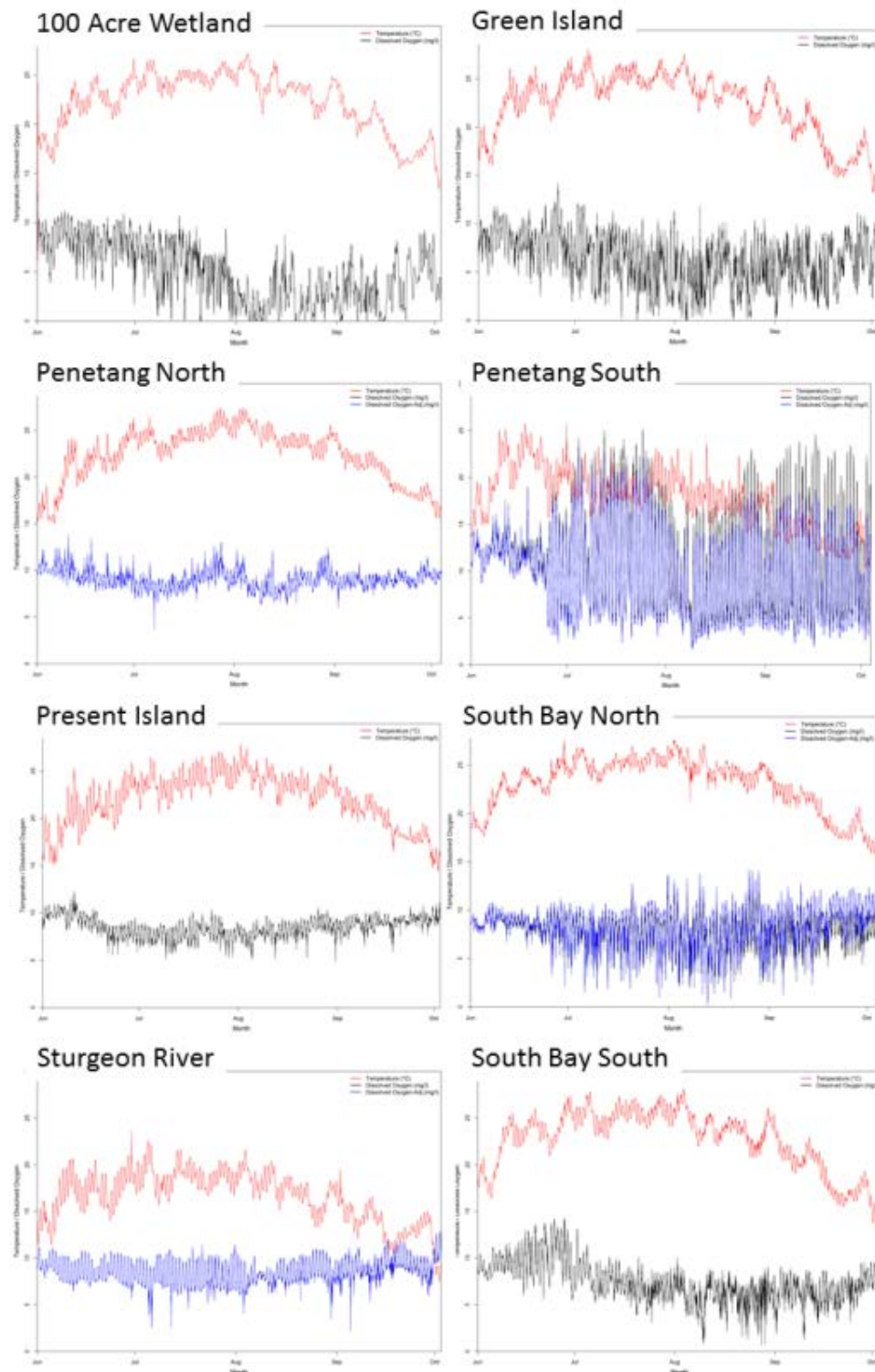
**Figure 9.** SAV height (m) as a function of depth range for a subset of the surveyed regions.



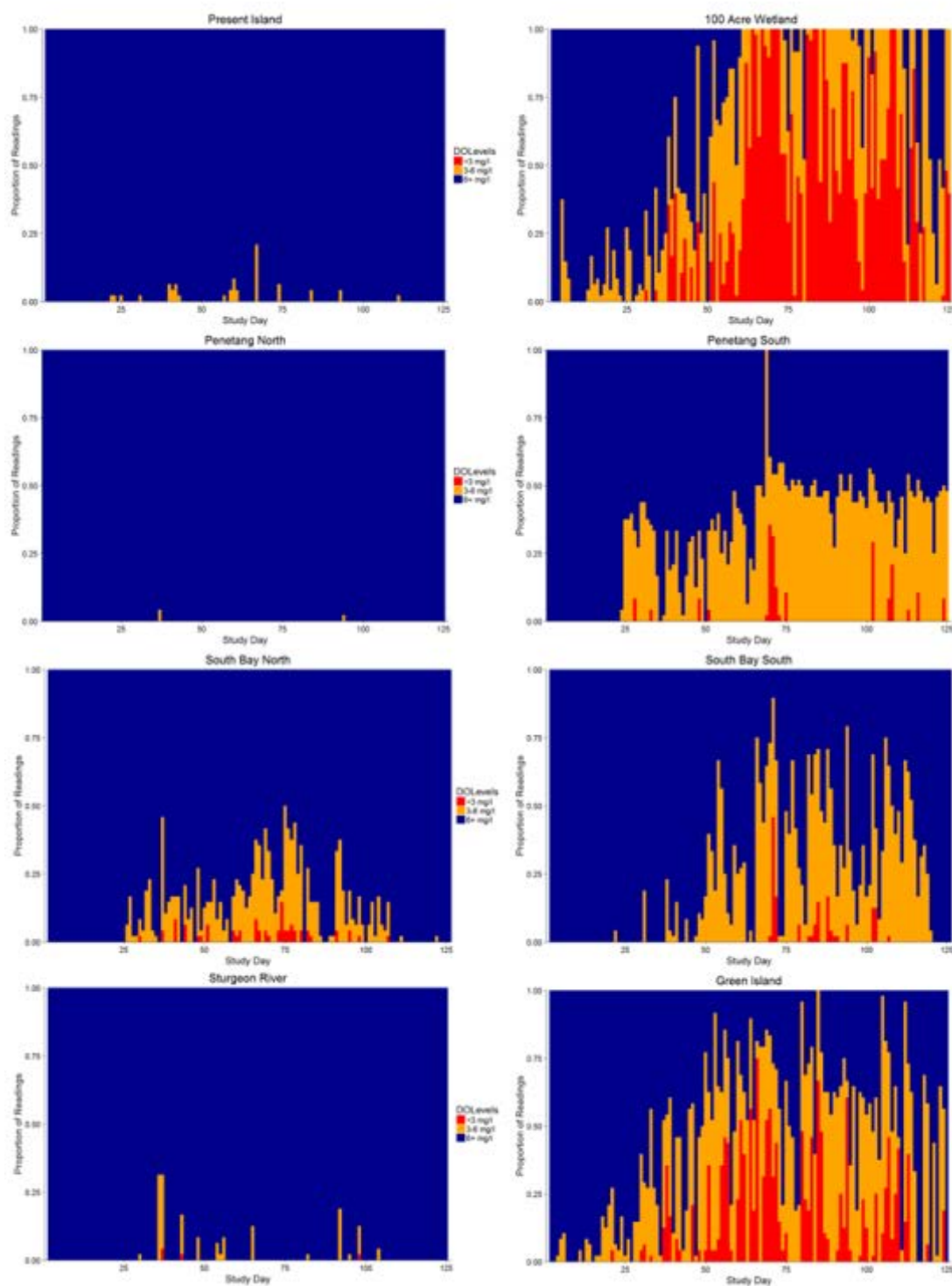
**Figure 10.** SAV height (m) as a function of depth range for a subset of the surveyed regions.



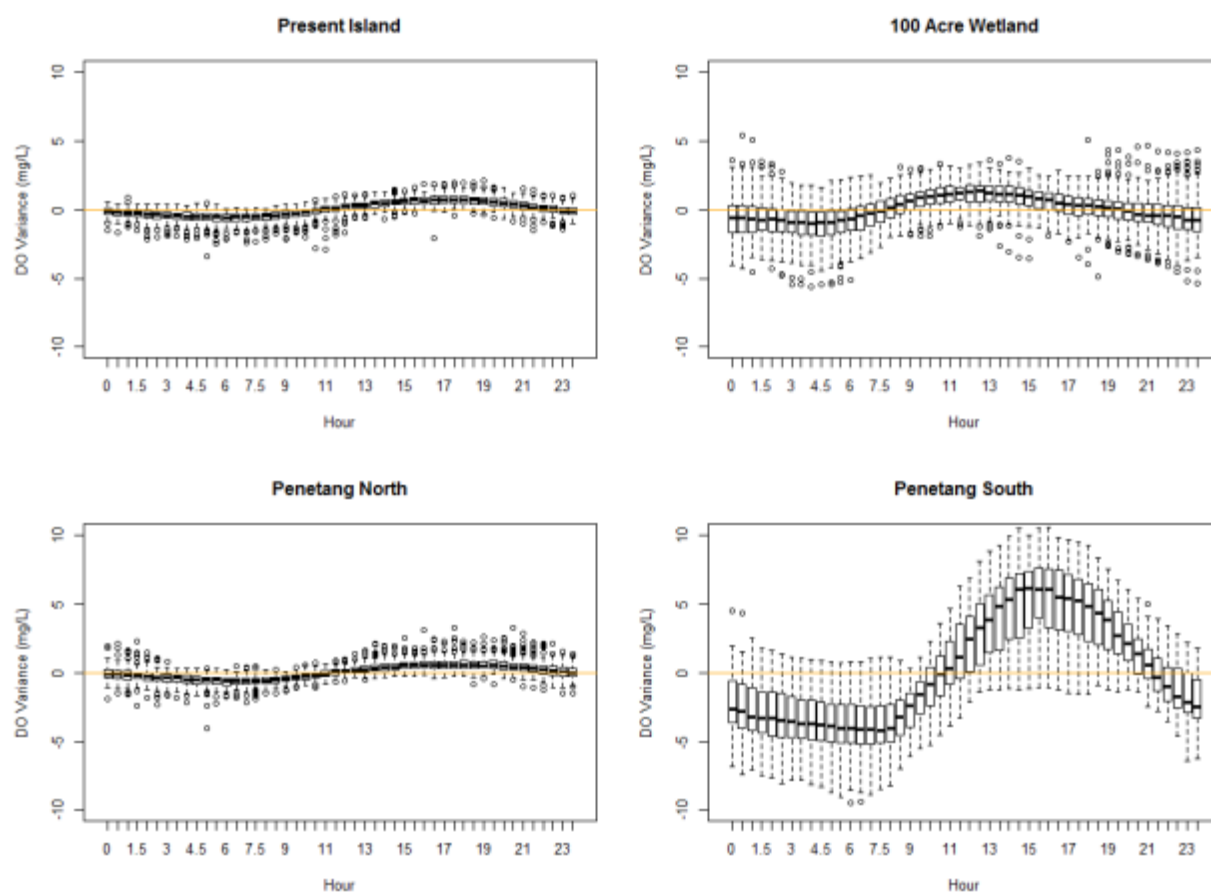
**Figure 11.** SAV height (m) as a function of depth range for a subset of the surveyed regions.



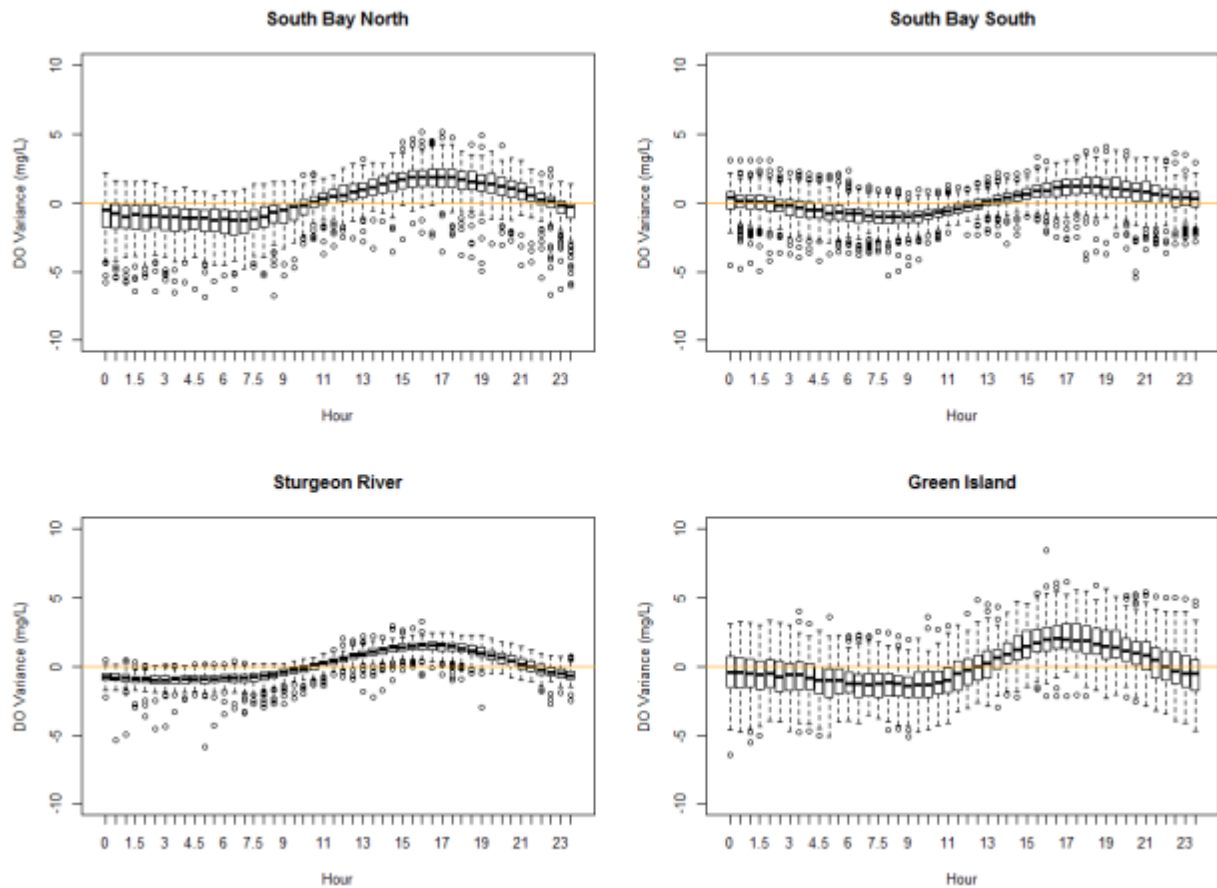
**Figure 12.** Dissolved oxygen (black, blue = corrected raw values) and temperature (red) profiles for loggers deployed at a subset of locations in Severn Sound. Loggers were deployed from 8-9 June, 2016 until 12-13 October 2016. Penetang North = Outer Penetang and Penetang South = Inner Penetang.



**Figure 13.** Proportion of each 24-hr time period when dissolved oxygen levels (as measured by dissolved oxygen loggers reading every 30 minutes) were greater than 6.0 mg/L (blue), between 3.0-6.0 mg/L (orange) and less than 3.0 mg/L (red). Values less than 3.0 mg/L are generally considered to reflect anoxic conditions. Penetang North = Outer Penetang and Penetang South = Inner Penetang.



**Figure 14.** Hourly variability in dissolved oxygen (DO) for each logger across the entire sampling period (June – October, 2016). Variance was calculated as the difference between the recorded DO value at each time interval and the daily mean DO associated with that value. Therefore, positive variances indicate DO readings that are higher than the daily mean and negative values those that are lower than the daily mean. Penetang North = Outer Penetang and Penetang South = Inner Penetang.



**Figure 15.** Hourly variability in dissolved oxygen (DO) for each logger across the entire sampling period (June – October, 2016). Variance was calculated as the difference between the recorded DO value at each time interval and the daily mean DO associated with that value. Therefore, positive variances indicate DO readings that are higher than the daily mean and negative values those that are lower than the daily mean.