Braddock Bay Ecosystem Restoration Monitoring Report-Fall 2016

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Vegetation Sampling

All of the plant data were collected between 19 July 2016 and 15 August 2016. Once entered into a spreadsheet, each plant species was given a corresponding C-score based on the New York State preliminary C-score list with reference to the Michigan C-score list. These C-scores for each individual species were then averaged to determine mean C-scores for each quadrat, which were then compiled for each zone (see below) and were used to calculate the Floristic Quality Assessment Index (FQAI) for each zone. This FQAI statistic is used to evaluate the nativeness of an area based on the plant species present. A C-score of 0 indicates non-native taxa with a widened range of tolerance in terms of environmental limits, with a score of 10 being a very specialized, narrow range of limits that the specific plant species can handle. These scores were then averaged to yield a mean FQAI and mean C-score for each transect, which were then grouped into zones. All of these data were averaged to determine a mean FQAI and C-score for all of the channel transects and all of the pothole transects, respectively. The means for total species within each quadrat, zone, and transect were calculated similarly. The overall mean values are shown in Table 1.

The calculated mean values show a trend of pothole transects having the highest mean FQAI and mean C-score, followed by channel transects, then the control quadrats. Pothole and channel transects both had 6.0 species in each quadrat, on average, as opposed to 4.7 within the control quadrats. From this broader point of view, we can then look further into Braddock Bay by separating these transect data to look at each individual habitat type within a group, or zone, that contains transects based on location or pothole variation.

We grouped channel transects into three zones (Figure 1) based on their location and proximity to one another. Throughout the three separate zones, there is a general trend of the sedge-grass meadow (SGM) having the highest values for mean FQAI and mean C-score (Table 2). The higher mean FQAI in SGM was driven by both higher mean-C and species richness within the zone. The sedge-grass zone is expected to have some species, such as *Carex lacustris* (C-score of 6.5), *Fraxinus pennsylvanica* (C-score of 5.5), and *Calamagrostis Canadensis* (C-score of 5) with C-scores higher than other habitat types in these transects. These species were present in the sedge-grass meadow, which is expected, and created high zone FQAI values of 9.8 in Zone 1 and 8.4 in Zone 3 (Table 2). These data also show that the mound (M) habitat has the most species, on average, across all zones.

We were able to separate the pothole transects into two different groupings: 1) individual zones based on location and proximity to each other (Figure 2) and 2) connected vs isolated potholes (Figure 3). The only zone that does not differ between pothole groups is the zone of isolated potholes (Table 3 – zone 3, Table 4 – zone 2).

In group 1, the mound (M) habitats seem to have the highest FQAI values and average number of species (Table 3), which may be correlated since a greater number of plant species with a high C-score could potentially increase the average and FQAI. The mounds are expected to have some species with higher C-scores than the bench and deep water habitat types, such as *Decodon verticillatus* (C-score of 7.5), *Cephalanthus occidentalis* (C-score of 6.5), and *Thelyptris palustris* (C-score of 6). The deep water zone has the highest mean C-score, which can be attributed to the significantly fewer average plant species found in each plot. Very few species with higher C-scores will drive the average up. These species were mainly *Utricularia vulgaris* (C-score of 6) and *Stuckenia pectinata* (C-score of 5.5).

In Group 2, when data are grouped by connected vs isolated potholes (Figure 3), the results are the same, with the mound (M) habitats having the highest mean FQAI value and average species per plot, and the deep water zone having the highest mean C-score values (Table 4). Similar to the previous pothole groupings, species presence and abundance of certain species can explain these observations. The same species are responsible for these trends as those in the grouping based on location and proximity.

Within the channel transects, few species were dominant (mean cover percentage > 10.00) within each habitat type (Table 5). In the sedge grass meadow (SGM), the dominant vegetation was *Carex lacustris*, *Typha x glauca*, *Acer saccharinum*, and *Salix fragilis*, with all species having a mean percent cover of at least 10.0. In the treatment area (TR), the dominant vegetation was *Typha x glauca*, despite the fact that vegetation surveys were performed after the initial round of cattail treatment, and had a mean percent cover of 22.3. On the mounds (M), the dominant vegetation included *Persicaria hydropiper*, *Lythrum salicaria*, P*ersicaria lapathifolia*, and *Typha x glauca*. On the shallow bench (SB), the dominant vegetation was *Typha x glauca*, which had a mean percent cover of 48.9. On the intermediate bench (IB), the dominant vegetation was *Hydrocharis morsus-ranae*, *Lemna minor*, *Elodea canadensis*, and *Utricularia vulgaris*. Within the channel (C), the dominant vegetation was *Utricularia vulgaris* and *Hydrocharis morsus-ranae*, with mean percent covers of 22.0 and 11.0, respectively.

Within the pothole transects, there were even fewer dominant plant species within each habitat type (Table 6). The deep water zone (D) was the zone with the least vegetative cover in the pothole transects, and only *Utricularia vulgaris* was dominant with a mean percent cover of 17.7. On the bench habitat (B), only *Hydrocharis morsus-ranae* was dominant, and had a mean percent cover of 25.2. The mounds (M) had the most vegetation on the pothole transects; *Lythrum salicaria* and *Typha x glauca* were the dominant vegetation, with mean percent cover of 38.8 and 16.7, respectively. Lastly, within the control quadrats, only Typha x glauca was dominant (Table 7).

Bird and Anuran

Although grant contract writing process was not complete at the time, The College at Brockport surveyed the bird and amphibian community in Braddock Bay during the spring of 2016 for another project, and these data were made available for the restoration project monitoring. Surveys were conducted at three locations throughout the bay (Figure 4), with three visits for the anuran community that followed traditional Marsh Monitoring Protocol (MMP) timing. Anuran surveys were 3 minutes long, with surveyors recording all species detected in the marsh using call codes that serve as an index of abundance. Call code descriptions are provided in Appendix 1. The bird community was surveyed with an intensified version of the MMP, using roughly weekly samples during the bird survey period for five surveys per point. Methods set forth in MMP were followed for survey weather limitations, survey timing and length, and data recording. Briefly, these include morning (half hour before to four hours after sunrise) and evening surveys (four hours before to one half hour after sunset); each survey was 15 minutes long and contained 5 minutes of passive listening, 5 minutes of marsh bird song audio playback to entice calls, and a final 5 minutes of passive listening; all birds detected either aurally or visually were recorded.

A total of 28 and 25 bird species were detected in survey stations 1 and 2, the survey locations that cover the cattail treatment, channel, and pothole portions of the restoration (Table 8). Survey station 3, the station furthest away from the cattail treatment, channel, and potholes of the restoration had 27 species present. Red-Winged Blackbird (*Agelaius phoeniceus*) was the most commonly detected species across all points, with a total of 100 individuals detected, across the three locations and was generally more prevalent in survey stations 1 and 2. Barn Swallow (*Hirundo rustica*), Marsh Wren (*Cistothorus palustris*), Ring-Billed Gull (*Larus delawarensis*), and Tree Swallow (*Tachycineta bicolor*) were the next four most commonly detected species, each with greater than 50 detections across all surveys and locations. Two invasive bird species, Mute Swan (*Cygnus olor*) and Double-Crested Cormorant (*Phalacrocorax auritus*) were detected in the surveys and were mostly observed at survey station 3, the station with the best view of open water where these species are often detected. Few marsh-nesting obligate focal species were detected, with only two Least Bittern (*Ixobrychus exilis*), one American Bittern (*Botaurus lentiginosus*), and one American Coot (*Fulica americana*) detected across all surveys and locations. Both Least Bitterns were detected at station 3, away from the marsh restoration activities, while the single American Coot and American Bittern were detected at survey station 2, close to the restoration activities.

Six anuran species were detected during the three surveys in spring of 2016 (Table 9). We report anuran abundance data using only the maximum call code (Appendix 1) recorded by species as the maximum call code mitigates some of the issues encountered with estimating calling anuran abundance, including their sensitivity to slight weather changes affecting calling intensity and the difficulty in estimating the true abundance in the field based on calls. American bullfrog (*Lithobates catesbeianus*) and American toad (*Anaxyrus americanus*) were the species of the lowest calling intensity, call code 1. Green frog (*Lithobates clamitans*), grey tree frog (*Hyla versicolor*), and leopard frog (*Lithobates pipiens*) were detected in greater numbers, call code 2.

Finally, spring peeper (*Pseudacharis crucifer*) was the only species to be detected in Braddock Bay with a full chorus, call code 3.

Tables

Table 1. Overall FQAI, mean C, and mean species richness values based on the different sampling areas.

	Control Quadrats	***Channel Transects***	***Pothole Transects***
Mean FQAI	5.6	6.4	6.8
Mean C	2.4	2.6	3.0
Mean # of spp.	4.7	6.0	6.0

Table 2. FQAI, mean C, and mean species richness for all channel transects and individual zonation of these transects based on location, with zone groupings shown in Figure 1 (SGM = Sedge-grass meadow, TR = Treatment area, M = Mound habitat, SB = Shallow Bench habitat, IB = Intermediate Bench habitat, C = Channel habitat).

ALL CHANNEL ZONES							
All Zones		**SGM**	**TR**	**M**	**SB**	**IB**	**C**
	Mean FQAI	8.4	6.2	6.8	4.9	5.9	5.9
	Mean C	3.5	2.5	2.5	2.0	2.4	3.0
	Mean # of spp.	6.1	6.3	7.6	5.6	6.1	4.5
Zone 1		**SGM**	**TR**	**M**	**SB**	**IB**	**C**
	Mean FQAI	9.8	6.0	7.2	6.6	6.6	5.3
	Mean C	3.7	2.5	2.6	2.5	2.6	2.5
	Mean # of spp.	7.6	5.6	8.1	6.9	7.0	4.8
Zone 2		**SGM**	**TR**	**M**	**SB**	**IB**	**C**
	Mean FQAI	6.5	5.9	6.1	4.3	5.2	5.7
	Mean C	3.4	2.2	2.3	1.8	2.1	2.9
	Mean # of spp.	3.8	8.8	7.2	5.8	5.9	4.3
Zone 3		**SGM**	**TR**	**M**	**SB**	**IB**	**C**
	Mean FQAI	8.4	5.5	6.8	3.1	5.5	6.9
	Mean C	2.9	2.7	2.5	1.5	2.4	3.9
	Mean # of spp.	6.3	6.8	7.4	4.0	5.8	4.3

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Table 3. FQAI, mean C, and mean species richness for all pothole transects and individual zonation of these transects based on their location, with transect and quadrat zone groupings shown in Figure 2 (D = Deep water habitat, B = Bench habitat, M = Mound habitat).

ALL POTHOLE ZONES				
All Zones		**D**	**B**	**M**
	Mean FQAI	5.2	7.1	8.0
	Mean C	3.6	2.7	2.8
	Mean # of spp.	2.4	7.3	8.4
Zone 1		**D**	**B**	**M**
	Mean FQAI	5.3	6.4	9.7
	Mean C	3.0	2.2	3.1
	Mean # of spp.	3.3	8.0	9.7
Zone 2		**D**	**B**	**M**
	Mean FQAI	5.2	7.4	5.8
	Mean C	3.5	2.5	2.1
	Mean # of spp.	2.4	8.5	8.2
Zone 3		**D**	**B**	**M**
	Mean FQAI	4.6	5.5	8.1
	Mean C	4.8	3.4	3.0
	Mean # of spp.	0.7	3.0	8.4
Zone 4		**D**	**B**	**M**
	Mean FQAI	5.7	7.9	10.1
	Mean C	3.9	2.6	3.2
	Mean # of spp.	2.2	8.8	9.1
Zone 5		**D**	**B**	**M**
	Mean FQAI	5.3	7.6	7.7
	Mean C	3.1	2.6	2.8
	Mean # of spp.	3.3	8.0	7.3

Table 4. FQAI, mean C, and mean species richness for the connected and isolated potholes, with quadrat and transect groupings shown in Figure 3 (D = Deep water habitat, B = Bench habitat, M = Mount habitat).

Connected potholes				
Zone 1		**D**	**B**	**M**
	Mean FQAI	5.3	7.4	7.9
	Mean C	3.4	2.5	2.7
	Mean # of spp.	2.8	8.3	8.4
Isolated potholes				
Zone 2		**D**	**B**	**M**
	Mean FQAI	4.6	5.5	8.1
	Mean C	4.8	3.4	3.0
	Mean # of spp.	0.7	3.0	8.4

Table 5. Mean percent cover by species found in channel transects (SGM = Sedge-grass meadow, TR = Treatment area, M = Mound habitat, SB = Shallow Bench habitat, IB = Intermediate Bench habitat, C = Channel habitat).

Channel Transects						
SPECIES	**SGM**	**TR**	**M**	**SB**	**IB**	**C**
Acer saccharinum	10.0	1.8	0.0	0.0	0.0	0.0
Acer spp.	0.0	0.5	0.1	0.1	0.0	0.0
Alisma triviale	0.0	0.2	0.0	0.0	0.0	0.0
Apios americana	0.5	0.1	0.0	0.0	0.0	0.0
Asclepias incarnata	0.0	0.0	0.1	0.0	0.0	0.0
Azolla caroliniana	0.0	0.0	0.0	0.0	0.1	0.1
Bidens cernua	0.0	1.3	1.4	0.2	0.2	0.2
Bidens frondosa	0.2	2.1	2.8	5.8	0.3	0.2
Butomus umbellatus	0.0	0.0	0.0	0.0	0.1	0.5
Calamagrostis canadensis	8.9	0.7	1.5	0.0	0.0	0.0
Calystegia sepium	1.4	0.4	0.3	0.2	0.0	0.0
Carex comosa	0.0	0.0	0.1	0.0	0.0	0.0
Carex lacustris	22.1	1.9	3.3	1.8	0.2	0.3
Carex stricta	0.0	0.0	1.1	0.2	0.0	0.0
Ceratophyllum demersum	0.0	0.0	0.0	0.0	1.4	8.0
Chamerion angustifolium	0.0	0.0	0.0	0.2	0.0	0.0
Chara vulgaris	0.0	0.0	0.0	0.0	1.5	0.7
Cicuta bulbifera	0.0	0.5	0.4	3.6	1.0	0.1
Cirsium arvense	0.2	0.2	0.9	0.9	0.0	0.0
Cornus spp.	0.7	0.0	0.0	0.0	0.0	0.0
Cuscuta spp.	0.0	0.0	0.0	0.2	0.0	0.0
Cyperus esculentus	0.0	0.9	2.6	0.4	0.5	0.1
Cyperus fuscus	0.0	0.0	0.1	0.0	0.0	0.0
Cyperus odoratus	0.0	0.4	0.2	0.0	0.0	0.0
Decodon verticillatus	0.0	0.0	1.1	0.0	0.0	0.0
Dichanthelium clandestinum	0.2	0.0	0.0	0.0	0.0	0.0
Eleocharis obtusa	0.0	0.2	0.1	0.0	0.0	0.0
Elodea canadensis	0.0	0.0	0.0	0.0	10.5	9.4
Elymus virginicus	1.3	0.0	0.3	0.0	0.0	0.0
Equisetum arvense	0.8	0.0	0.0	0.0	0.0	0.0
Eupatorium spp.	0.0	0.0	0.1	1.8	0.0	0.0
Fraxinus pennsylvanica	5.5	0.0	0.0	0.0	0.0	0.0
Galium trifidum	1.3	4.2	9.3	8.7	0.3	0.1
Hibiscus moscheutos	0.0	1.4	0.0	0.2	0.0	0.0
Hydrocharis morsus-ranae	0.0	0.9	0.1	6.6	37.1	11.0

Impatiens capensis	1.3	1.3	0.2	1.9	0.0	0.0
Iris spp.	1.7	0.8	0.6	0.4	0.0	0.0
Juncus effusus	0.3	0.4	0.0	0.0	0.0	0.0
Juncus spp.	0.0	0.1	0.3	0.0	0.0	0.0
Lathyrus palustris	0.5	0.0	0.0	0.0	0.0	0.0
Lemna minor	0.0	0.1	0.0	0.2	13.8	5.6
Lemna trisulca	0.0	0.0	0.0	0.0	0.5	0.0
Lycopus americanus	0.3	0.4	0.4	0.4	0.0	0.0
Lycopus spp.	0.0	0.0	0.0	0.1	0.0	0.0
Lycopus virginicus	0.7	0.3	0.1	0.0	0.0	0.0
Lythrum salicaria	1.6	4.1	12.5	4.1	0.2	0.0
Mentha arvensis	4.5	1.3	0.7	1.0	0.1	0.0
Myosotis scorpioides	0.0	0.1	0.5	0.2	0.0	0.0
Myriophyllum spicatum	0.0	0.0	0.0	0.0	5.2	5.6
Najas flexilis	0.0	0.0	0.0	0.0	0.2	0.0
Najas minor	0.0	0.0	0.0	0.0	2.1	4.2
Nymphaea odorata	0.0	0.0	0.0	0.0	0.2	0.9
Onoclea sensibilis	1.3	0.0	0.0	0.0	0.0	0.0
Oxybasis glauca	0.0	0.0	0.0	0.0	0.0	0.0
Persicaria amphibia	0.0	0.3	0.1	0.1	0.2	0.1
Persicaria hydropiper	1.7	1.7	19.8	1.6	0.0	0.0
Persicaria hydropiperoides	7.8	1.5	5.4	1.0	0.0	0.0
Persicaria lapathifolia	0.9	0.5	11.4	0.0	0.0	0.0
Persicaria maculosa	0.3	0.0	0.2	0.0	0.0	0.0
Persicaria sagittata	1.8	0.9	3.2	0.6	0.0	0.0
Persicaria spp.	0.5	0.0	0.0	0.0	0.0	0.0
Populus tremuloides	4.2	0.0	0.0	0.0	0.0	0.0
Potamogeton crispus	0.0	0.0	0.0	0.0	0.1	0.6
Potamogeton folioses	0.0	0.0	0.0	0.0	0.7	0.2
Ranunculus aquatilis	0.0	0.2	0.1	0.0	0.0	0.0
Ranunculus spp.	0.2	0.0	0.1	0.0	0.0	0.0
Rhus typhina	0.0	0.0	0.1	0.0	0.0	0.0
Rorippa palustris	0.0	0.0	0.5	0.0	0.0	0.0
Rumex orbiculatus	0.0	0.0	2.5	0.0	0.0	0.0
Sagittaria latifolia	0.0	0.2	0.6	2.9	0.2	0.1
Salix fragilis	10.0	0.0	0.0	0.0	0.0	0.0
Schoenoplectus tabernaemontani	0.0	0.1	0.0	0.0	0.0	0.0
Scirpus fluviatilis	0.2	0.5	0.2	0.0	0.0	0.0
Scutellaria galericulata	0.9	0.2	0.8	0.4	0.0	0.0
Solanum dulcamara	0.0	0.2	0.2	0.2	0.0	0.0
Sparganium spp.	0.2	2.2	0.6	0.3	2.0	0.5

Spiraea latifolia	0.2	0.0	0.0	0.0	0.0	0.0
Stuckenia pectinata	0.0	0.0	0.0	0.0	8.7	2.8
Thelyptris palustris	1.0	0.4	0.0	0.0	0.0	0.0
Typha x glauca	10.0	22.3	11.6	48.9	1.2	0.3
Unknown fungus	0.0	0.0	0.0	0.0	0.0	0.0
Unknown moss	0.2	0.0	0.0	0.0	0.0	0.0
Utricularia vulgaris	0.0	0.0	0.0	0.0	10.2	22.0
Verbena hastata	1.0	0.8	4.0	1.8	0.0	0.0
Vitis riparia	1.7	0.0	0.0	0.0	0.0	0.0

Table 6. Mean percent cover by species found in pothole transects (D = Deep water habitat, B = Bench habitat, M = Mount habitat).

Pothole Transects			
SPECIES	**D**	**B**	**M**
Alisma triviale	0.0	0.9	0.0
Azolla caroliniana	0.0	0.1	0.0
Bidens cernua	0.0	2.5	0.7
Bidens frondosa	0.1	1.3	0.8
Calystegia sepium	0.0	0.0	0.1
Carex lacustris	0.0	0.2	0.1
Carex spp.	0.0	0.0	0.1
Cephalanthus occidentalis	0.0	0.0	1.9
Ceratophyllum demersum	0.3	0.2	0.0
Chamerion angustifolium	0.0	0.0	0.1
Chara spp.	1.9	0.0	0.0
Cicuta bulbifera	0.0	0.9	0.4
Cirsium arvense	0.0	0.0	0.8
Comarum palustre	0.0	0.0	0.1
Cuscuta spp.	0.0	0.3	2.0
Cyperus esculentus	0.1	3.0	1.4
Decodon verticillatus	0.2	2.6	7.3
Eleocharis obtusa	0.1	2.0	0.3
Elodea canadensis	1.0	0.0	0.0
Elymus virginicus	0.0	0.0	0.2
Gallium trifidum	0.0	3.4	9.6
Hydrocharis morsus-ranae	1.8	25.1	0.1
Impatiens capensis	0.0	0.2	9.4
Juncus canadensis	0.0	0.1	0.0
Juncus effusus	0.3	0.2	0.0
Juncus spp.	0.0	0.1	0.2
Lemna minor	1.2	4.3	0.1
Lemna trisulca	0.0	0.6	0.0
Lycopus americanus	0.0	0.0	0.1
Lycopus virginicus	0.0	0.2	0.8
Lythrum salicaria	0.1	9.0	38.8
Myriophyllum spicatum	1.8	0.5	0.0
Najas minor	0.2	0.1	0.0
Persicaria amphibia	0.1	0.3	0.2

Persicaria hydropiper	0.0	0.8	8.1
Persicaria hydropiperoides	0.0	0.0	2.1
Persicaria lapathifolia	0.0	0.0	1.8
Persicaria maculosa	0.0	0.0	0.5
Persicaria sagittata	0.0	0.0	1.7
Pontederia cordata	0.0	0.1	0.0
Potamogeton folioses	0.1	0.0	0.0
Ranunculus aquatilis	0.0	0.1	0.0
Rhus typhina	0.0	0.0	0.6
Rorippa palustris	0.0	0.0	1.3
Sagittaria latifolia	0.4	1.6	0.2
Schoenoplectus tabernaemontani	0.0	0.0	0.1
Scutellaria galericulata	0.0	0.0	1.5
Solanum dulcamara	0.0	0.0	0.5
Sparganium spp.	0.5	3.0	0.2
Stuckenia pectinata	2.5	0.0	0.0
Thelyptris palustris	0.0	2.7	6.1
Typha x glauca	0.5	7.4	16.7
Unknown algae (1)	0.6	0.0	0.0
Unknown fern (1)	0.0	0.0	0.2
Unknown forb (1)	0.0	0.0	0.1
Unknown forb (2)	0.0	0.0	0.2
Unknown moss (1)	0.0	0.0	0.2
Unknown SAV (1)	0.2	0.0	0.0
Utricularia vulgaris	17.7	4.2	0.0
Verbena hastata	0.0	0.7	4.4
Vitis spp.	0.0	0.0	0.1

Table 7. Mean percent cover by species found in control quadrats in the unrestored cattail zone (CAT = cattail mat).

Control Quadrats	
SPECIES	**CAT**
Bidens frondosa	1.2
Calystegia sepium	2.8
Cicuta bulbifera	0.5
Decadon verticillatus	2.8
Galium trifidum	1.3
Hibiscus moscheutos	5.0
Hydrocharis morsus-ranae	0.2
Impatiens capensis	9.7
Juncus canadensis	2.2
Lathyrus palustris	0.8
Lemna minor	1.3
Lycopus virginicus	0.2
Lythrum salicaria	2.3
Mentha arvense	0.5
Onoclea sensibilis	0.7
Persicaria amphibia	0.3
Persicaria hydropiper	0.8
Persicaria hydropiperoides	3.0
Phragmites australis	2.5
Sagitaria latifolia	1.3
Scirpus fluviatilis	0.2
Scutellaria galericulata	2.5
Solanum dulcamara	1.8
Sphagnum spp.	6.2
Thelyptris palustris	6.8
Triadenum fraseri	0.5
Typha x glauca	51.7
Unknown fern (1)	2.3
Verbena hastata	3.3

Table 8: Bird species ranked by total abundance across the three survey stations in Braddock Bay during the spring 2016 surveys. Abundance data show the total number of detections across five surveys for each location.

Species	Braddock 1	Braddock 2	Braddock 3	Total Abundance
Red-Winged Blackbird	39	39	22	100
Barn Swallow	29	13	12	54
Marsh Wren	30	7	17	54
Ring-Billed Gull	19	29	5	53
Tree Swallow	23	11	18	52
Swamp Sparrow	13	21	2	36
Yellow Warbler	6	8	11	25
Canada Goose	19	5		24
Common Yellowthroat	10	7	3	20
Song Sparrow	6	10	4	20
Mute Swan	2		16	18
Wilson's Flycatcher	7	6	1	14
Common Grackle	2	3	7	12
Mallard	9		3	12
European Starling	6		4	10
Caspian Tern	3		6	9
American Robin	4	2	2	8
American Goldfinch		6	1	7
Warbling Vireo	2		5	7
Gray Catbird	1	1	4	6
Purple Martin		3	3	6
Cedar Waxwing		1	4	5
Northern Cardinal	3		2	5
Bank Swallow	3			3
Double-Crested Cormorant	1		2	3
Eastern Kingbird	3			3
Osprey		3		3
Bald Eagle	1	1		2
Great Blue Heron		1	1	2
Killdeer		2		2
Least Bittern			2	2
American Bittern		1		1
American Coot		1		1
American Kestrel		1		1
Baltimore Oriole			1	1
Bobolink	1			1
Great-crested Flycatcher		1		1
Great Egret			1	1
Mourning Dove	1			1

Northern Rough-Winged Swallow	1			1
Red-Bellied Woodpecker	1			1
Grand Total	**245**	**183**	**159**	**587**

Table 9: Anuran species detected in Braddock Bay in spring 2016, ranked by the maximum call code. Call code descriptions are provided in Appendix 1.

Common Name	**Scientific Name**	**Maximum Call Code**
American bullfrog	*Lithobates catesbeianus*	1
American toad	*Anaxyrus americanus*	1
Green frog	*Lithobates clamitans*	2
Grey tree frog	*Hyla versicolor*	2
Northern leopard frog	*Lithobates sylvaticus*	2
Spring peeper	*Pseudacris crucifer*	3
	Species Richness	**6**

Figures

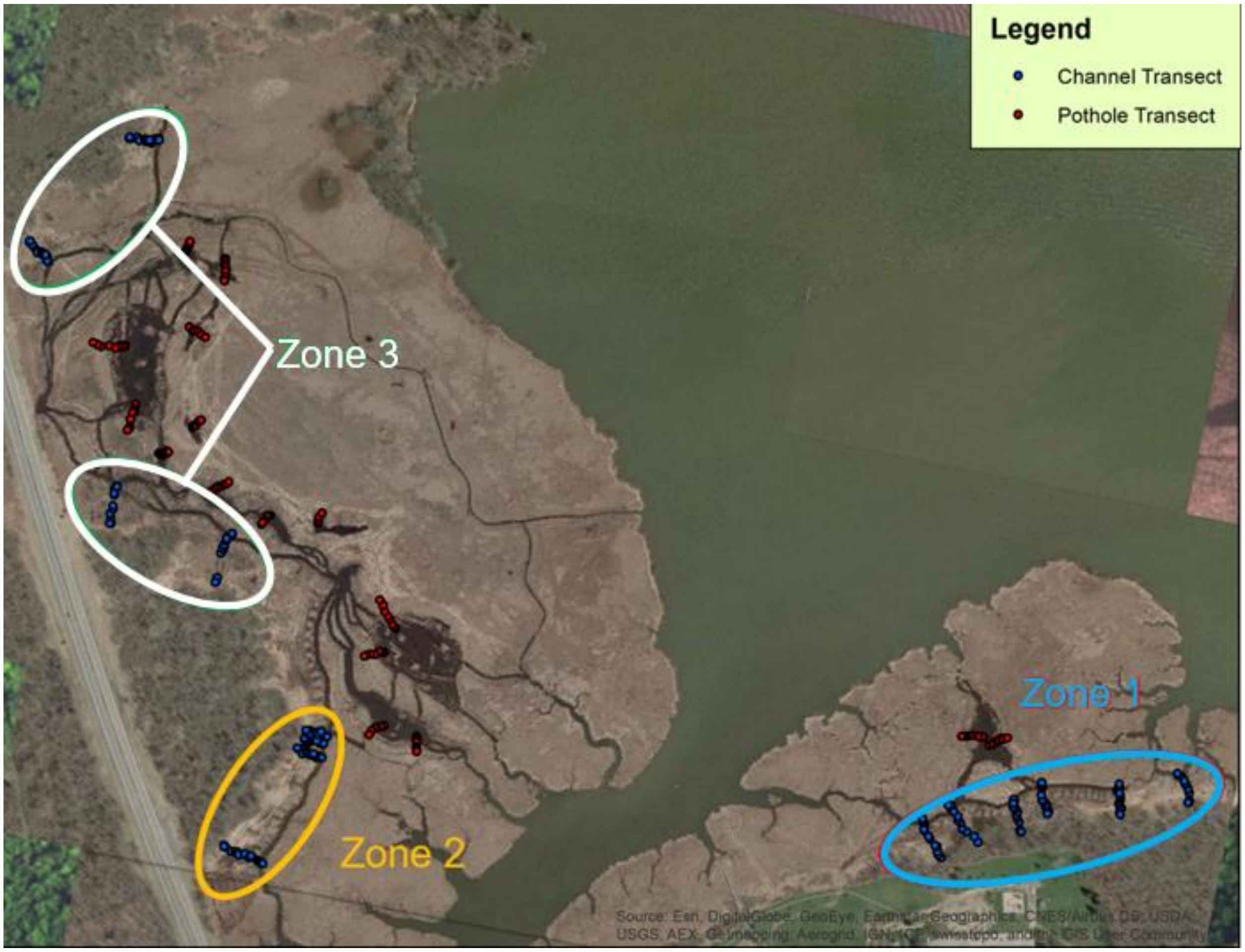

Figure 1. Transect grouping for channel transects, with data presented in Table 2.

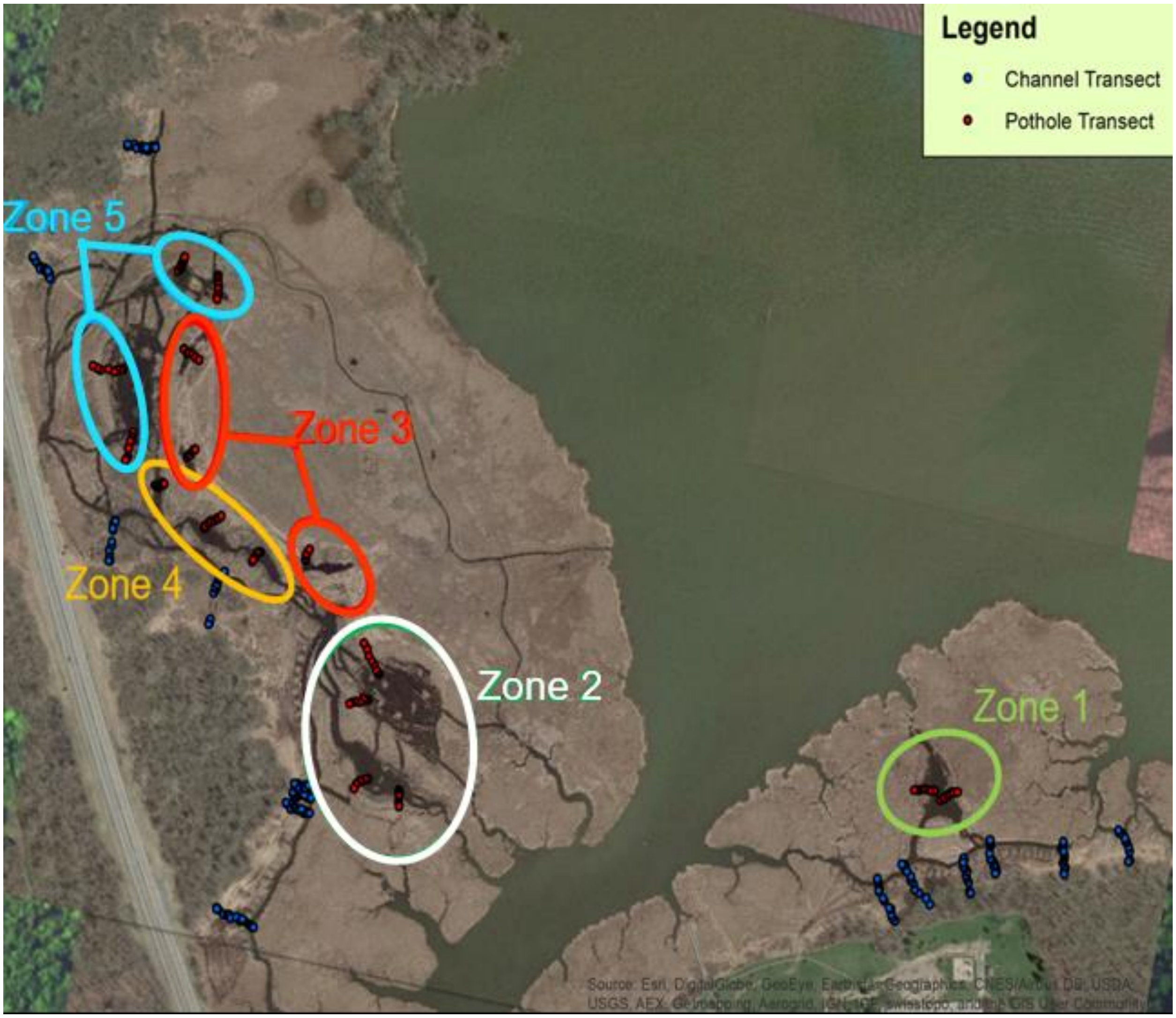

Figure 2. Quadrat and transect grouping to calculate FQAI for the pothole and channel transect breakout, with data shown in Table 3.

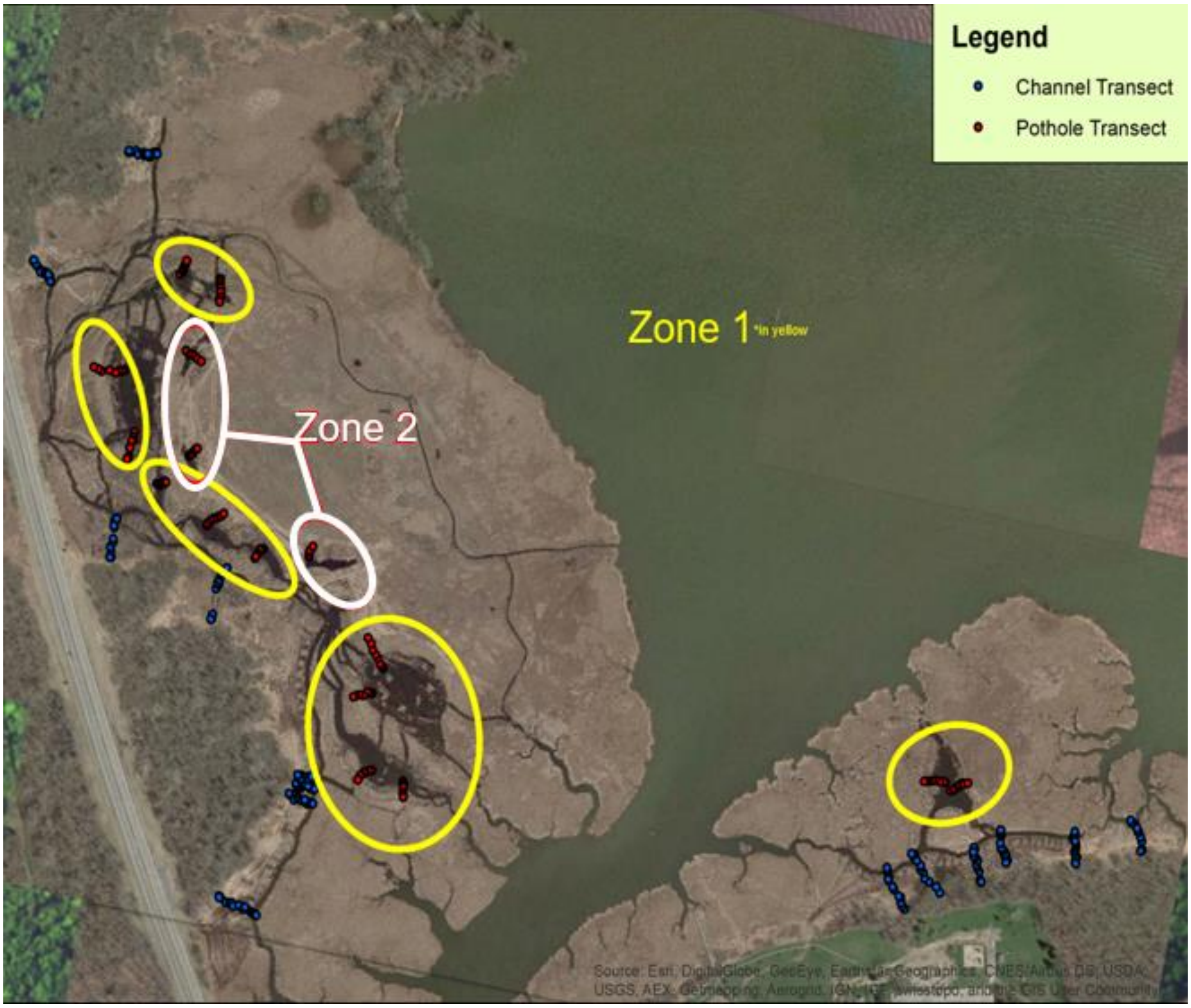

Figure 3. Transect and quadrat grouping used to calculate FQAI for connected and isolated potholes, with data shown in Table 4.

Figure 4: Spring 2016 bird and anuran survey locations in Braddock Bay.

Appendices

Appendix 1: Description of the anuran call codes.

Call Code	
1	Calls not simultaneous, number of individuals can be accurately counted.
2	Some calls simultaneous, number of individuals can be reliably estimated.
3	Full chorus, calls continuous and overlapping, number of individuals cannot be estimated.

Braddock Bay 2016 Fish Survey

Addendum to the Braddock Bay Ecosystem Restoration Monitoring Report – Fall 2016

SUNY Brockport

2/6/2017

Methods

The College at Brockport sampled the fish community in newly-created potholes and previously existing shallow water areas in Braddock Bay from Oct 7th to Oct 16th, 2016. Survey crews used both large mesh (6.25mm) and small mesh (2.4mm) nets evenly in both habitats to balance out the biases present in both mesh sizes. Each mesh size was fished for four net-nights in each habitat, for a total of eight net-nights of fishing per habitat and 16 net-nights overall. Figure 1 shows the net locations in the newly-created and control zones. Nets were placed in water between 0.5 and 1.0m deep for approximately 18-24 hours. All species encountered, both fish and non-fish, were identified, aged as either "Young of Year (YOY)" or "Other", and counted the following morning. All fish were returned back to the water and the net was re-set for the following night. Fish data were summarized to compare the two different habitats sampled, the newly created and un-restored "control" habitats, with a focus on species presence and YOY fish use. Since sampling effort was equal between the two habitats, the results are reported using raw count data and percentages by age class rather than catch-per-unit-effort (CPUE).

While this habitat comparison allows us to compare the newly-created habitat against previously-occurring, natural habitats to show how the restoration is affecting the fish community, the comparison is not without potential problems. The newly-created habitat pools were made to re-create open areas of shallow water nestled within the emergent marsh zone that were lost due to cattail expansion, which by definition is a habitat that no longer exists.

Using shallow portions of the mouth of Buttonwood Creek in Braddock Bay is the next best location, as it is in the same general area of Braddock Bay, is reasonably protected from significant wave attack, and contains the same vegetation species as what we expect to be found in the newly-created habitat pools. That said, using the creek mouth as the “control” may be problematic as we may have encountered deeper water species,\ or have inflated fish counts due to fish movement up and down the creek that is not typical of a pool habitat.

We used fyke nets that were of two mesh sizes, 12.7mm and 4.7mm square measurement, as a way to balance out the biases present when using larger and smaller mesh sizes. All other aspects of the fyke nets were the same, with 0.9m tall by 7.62m long leads, two 0.9m tall by1.8m long wings, 1.2m by 0.9m trap frames, and the traps contained two 16.5 cm funnels.

Results

The control habitats, pre-existing bodies of water that were not modified by the restoration, yielded nearly three times as many fish as the newly-created habitat, with 1282 and 445 fish in the control and created habitats, respectively (Table 1). The age class breakdowns were nearly identical in the control and created habitat, with YOY fish making up 12.1% and 13.3% of the community, respectively (Table 1). The majority of YOY fish in both habitats were bluegill sunfish (*Lepomis macrochirus*) and pumpkinseed sunfish (*Lepomis gibbosus*), who combined made up greater than 95% of the YOY catch in both habitats (Table 2). The next most prevalent YOY fish was central mudminnow (*Umbra limi*), with 16 YOY fish in the newly created habitat. As a whole, bluegill and pumpkinseed sunfish were the most prevalent species caught in across both habitats (Table 3). Two northern pike (*Esox lucius*) “other” age class fish were caught in the newly created habitats; however, no YOY pike were caught in either habitat.

At this point, it is not clear why the newly-created habitats contained roughly one-third of the fish as the control habitats. The possibilities include the fact that the control zone was more riverine while the created potholes are semi-isolated pools; the fact that the newly created potholes do not have a fully-developed submersed aquatic vegetation community yet; or because the severely dry summer caused the potholes to be shallower than anticipated and resulted in a low dissolved oxygen environment.

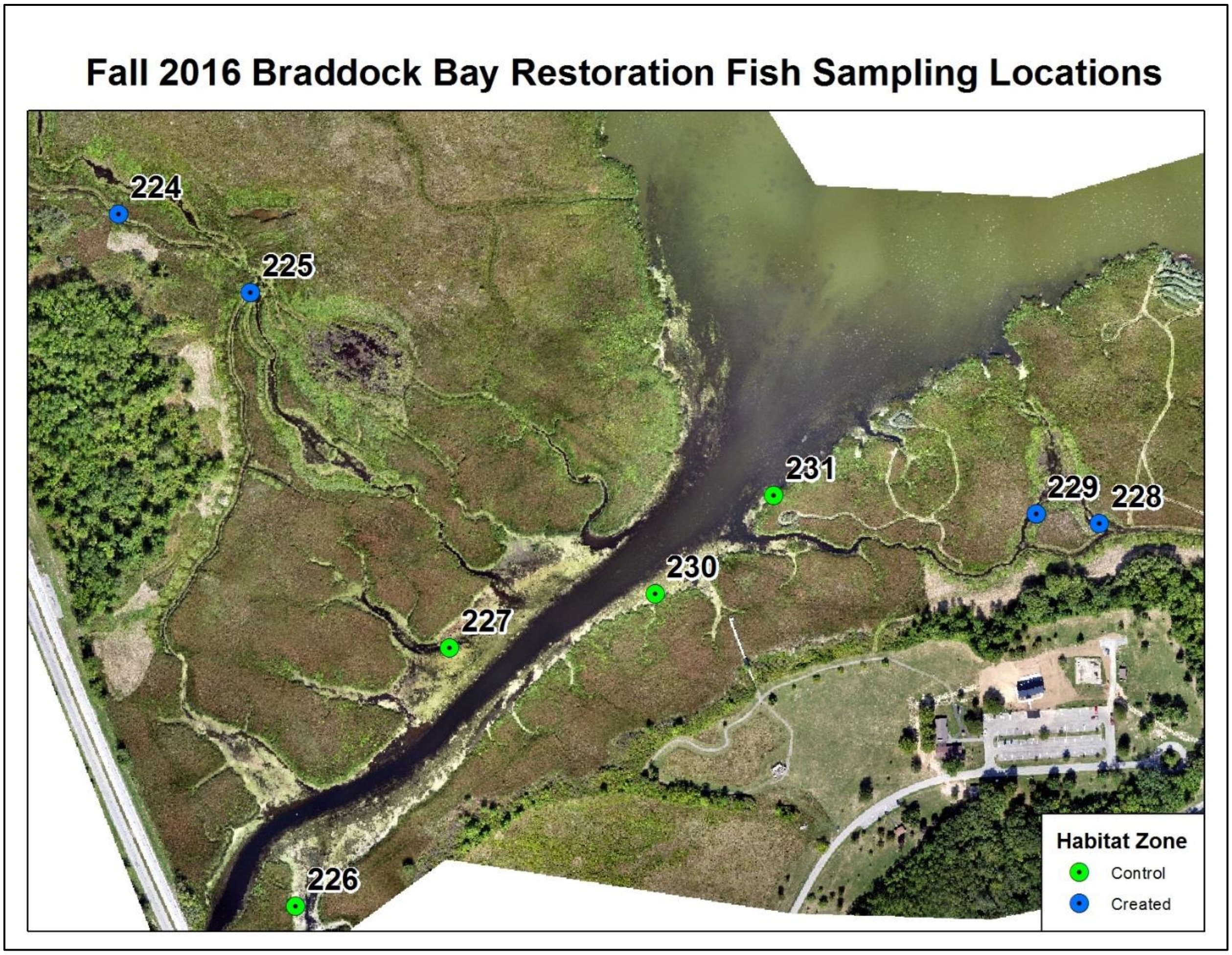

Figure 1: Fall 2016 net locations in newly-created and un-restored “control” habitats in Braddock Bay. Net locations in the created habitats were constrained by water depth; therefore, some of the larger potholes were not surveyed. Each net location was sampled for two net-nights and then moved to another survey location.

Table 1: Count raw count and percent of "Other" and "YOY" age class fish in the control and newly-created pothole habitats in fall 2016. Non-fish species such as turtles and tadpoles were not included in this summary.

	Control		Created habitat	
	Count	Percent	Count	Percent
Other	155	12.1	59	13.3
YOY	1127	87.9	386	86.7
Total	**1282**		**445**	

Table 2: "Other" and "YOY" age class breakdown by sampling habitat for fish species that had both age classes present during sampling in fall 2016.

	Control		Created habitat	
Species	**Other**	**YOY**	**Other**	**YOY**
Bluegill Sunfish	8	552	1	47
Central Mudminnow			18	16
Largemouth Bass	4	1	12	
Pumpkinseed Sunfish	83	567	1	323
Rock Bass		5		
Yellow Perch	36	2		
Grand Total	**131**	**1127**	**32**	**386**

Table 3: Raw count of all species caught in the control and newly-created pothole habitats in fall 2016, including incidental, non-fish species.

Species	Control	Created habitat	Grand Total
Pumpkinseed Sunfish	650	324	974
Bluegill Sunfish	560	48	608
Yellow Perch	38		38
Central Mudminnow		34	34
Painted Turtle	12	10	22
Brown Bullhead	8	13	21
Largemouth Bass	5	12	17
Round Goby	8		8
Bowfin	2	5	7
Crayfish		6	6
Tadpole Madtom	3	3	6
Rock Bass	5		5
Golden Shiner	3		3
Green Sunfish		2	2
Northern Pike		2	2
Tadpole		2	2
Common Carp		1	1
Northern Leopard Frog		1	1
Grand Total	**1294**	**463**	**1757**

Braddock Bay Restoration: 2015 and 2016 Water Quality Monitoring Report

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Executive Summary

Baseline conditions of Braddock Bay were established for barrier pre-construction during summer of 2015 and 2016. Baseline conditions indicate eutrophic to hyper eutrophic conditions within Braddock Bay. Braddock Bay water quality average (95% confidence interval) conditions for nutrient and ecosystem target criteria were phosphate of 0.014 mg/L (0.003 to 0.131), total phosphorus (TP) of 0.102 mg/L (0.033 to 0.200), ammonia of 0.050 mg/L (0.013 to 0.213), nitrate+nitrite of 0.136 mg/L (0.000 to 0.704), total kjeldahl nitrogen (TKN) of 1.123 mg/L (0.573 to 1.800), chlorophyll a of 41.6 μg/L (11.5 to 86.8), Secchi disc depth of 1.9 ft (1.0 to 3.4), and trophic state index (TSI) of 67 (61 to 75). Ecosystem target criteria were exceeded 86.1%, 80%, 85%, and 94.4% of the time at sites within Braddock Bay for Secchi depth, TP, chlorophyll a, and TSI, respectively.

Braddock Bay baseline water quality conditions significantly differed between sampling years. 2015 was a normal to wet year. 2016 was a drought year. Nitrogen, in all forms measured, was higher during 2015 than during 2016. Conductivity and turbidity were higher during 2015 than during 2016. Chlorophyll a and phosphate levels did not significantly differ between years, but tended to be higher in 2016 than during 2015. TP and TSI were higher during 2016 than during 2015. These results suggest much strong riverine and sediment resuspension influences in the bay during 2015 and perhaps enhanced internal cycling of nutrients and phytoplankton bloom maintenance in 2016.

Despite evidence of water exchange between the bay and lake, the poor water quality conditions seem to be isolated to Braddock Bay and rarely caused undesirable conditions in near shore Lake Ontario. Lake Ontario was nitrate+nitrite rich relative to the bay and the tributaries. The bay and tributaries were phosphorus and bound nitrogen rich relative to Lake Ontario. The tributaries were typically high in phosphate. Braddock Bay was relatively rich in phosphorus relative to nitrogen, suggesting conditions of nitrogen limitation might exist within the bay. During the 2016 phytoplankton bloom, TKN was the best predictor of chlorophyll a ($r = 0.95$). Across all sampling events, chlorophyll a did not correlate to TP ($r = -0.35$ for 2015, $r = 0.25$ for 2016). In 2015, TKN was a poor predictor of chlorophyll a ($r = 0.02$). Differences in correlations among water quality variables between years, suggest baseline conditions in 2015 were dictated largely by tributary inputs and sediment resuspension, while baseline conditions in 2016 (a drought year) were dictated by internal processes associated with a large phytoplankton bloom.

All together, these findings suggest a dual nutrient reduction strategy within the Braddock Bay watershed might be needed to control phytoplankton blooms and promote oligotrophication in the bay. It is unclear what impact barrier construction will have on the eutrophic state of Braddock Bay. If Lake Ontario is a significant N source to the bay, then the barrier might reduce the supply of N for phytoplankton. Barrier construction should help stabilize wetland erosion and reduce sediment resuspension but it is unclear from the baseline data how this will influence Braddock Bay. In 2015, much of the turbidity in the bay seemed linked to sediments but in 2016 the turbidity was caused by phytoplankton. Hence, the impact of the barrier on Braddock Bay water quality seems likely to be driven by the barriers impact on water exchange and movement within the ecosystem and how these changes impact nutrient dynamics and the development of phytoplankton blooms.

1.0 Purpose

Braddock Bay is undergoing restoration to improve wetland habitat and protect the wetland from erosion (USACE 2015). Water quality samples were collected from Braddock Bay, its tributaries, and Lake Ontario to determine barrier pre-construction condition of Braddock Bay. Samples were collected from June to September over two years (2015 and 2016). These data will allow adaptive management of Braddock Bay as well as comparison with barrier post-construction water quality conditions (USACE 2015). These baseline data will help establish the pre-restoration nutrient dynamics in Braddock Bay, which can be used to determine the impacts of restoration on eutrophication of the ecosystem.

2.0 Methods

To determine the baseline conditions of Braddock Bay, water samples were collected at five locations within Braddock Bay (SG2, SG3, SG4, SG5a, and SG5b), at the two main tributary inputs to the bay (Salmon Creek (SC) and Buttonwood Creek (BW)), and at a near shore location just outside the bay in Lake Ontario (LO1; Fig. 1). Samples were collected from June to September four times during 2015 and six times during 2016. The last two sampling events of 2016, however, were collect during barrier construction and are not included in this report as baseline samples. Samples collected during construction are used for comparison and to establish relationships between variables within Braddock Bay. During 2015, some sampling events were influenced by storm events. During 2016, samples were not collected within five days of a major storm event, which was taken to mean a rain event of 0.5 inches within a 24 hour period. 2016 was a drought year. For both years when possible, sample events were spaced at least 15 days apart. During both years, water samples were collected 1 to 1.5 ft below the water's surface at four locations around the sampling site coordinates (Fig. 1). During both years, multi-probe sensor measurements and Secchi disc depth were collected at the sampling point. During 2015, water samples were put on ice and shipped to an analytical lab for processing (USACE 2016). During 2016, water samples for total nutrients, chlorophyll, suspended solids, and turbidity were stored on ice and filtered or digested within 36 hours of collection. During 2016, dissolved nutrient samples were filtered through a 0.45 µm polycarbonate membrane filter on site, stored on ice for transport back to the lab and analyzed fully within 36 hours.

Water quality monitoring variables were determined using standard (SM), Environmental Protection Agency (EPA) and/or American Public Health Association (APHA) methods. Water quality monitoring parameters were Secchi disc depth (ft), Turbidity (NTU), Temperature (C), Specific Conductivity (µS/cm). Oxidation Reduction Potential (ORP; mV), Dissolved Oxygen (DO; mg/L), pH, Phosphate (PO4; mg/L), Total Phosphorus (TP; mg/L), Ammonia (NH4; mg/L), Nitrite plus Nitrate (NO2NO3; mg/L), Total Kjeldahl Nitrogen (TKN; mg/L), Total Suspended Solids (TSS; mg/L), and Chlorophyll a (CHL; µg/L). Hereafter, abbreviations are used to identify water quality variables. Specific methods of analysis, level of detection, and holding times are listed in Table 1. Data with measurements below detection limit were listed as 0. Values above the detection limit but below the reporting level were retained as measured.

All data analysis was conducted in R using R-Studio. To establish baseline conditions, sites were grouped as Braddock Bay, Tributary, and Lake Ontario. Summary statistics and 95% confidence intervals were determined for each group across all pre-construction sampling events. Analysis of variance was used to look for differences between years. Pearson's correlation and univariate regression analysis was used to look for trends between variables. Carlson's Trophic State Index (TSI) was calculated using Secchi Depth, TP, and CHL (Carlson 1977). The average of the three parameter TSI scores was used for each site. For Braddock Bay, water quality target criteria (Secchi disc depth = 3.28 ft, TP = 0.048 mg/L, CHL = 20 µg/L, and TSI = 60) were used to access how frequent the baseline (barrier pre-construction) condition fail to meet the water quality objectives (USACE 2015). All data are presented in Appendix A and B. This report will focus on nutrient dynamics, CHL, Secchi disc depth, and TSI.

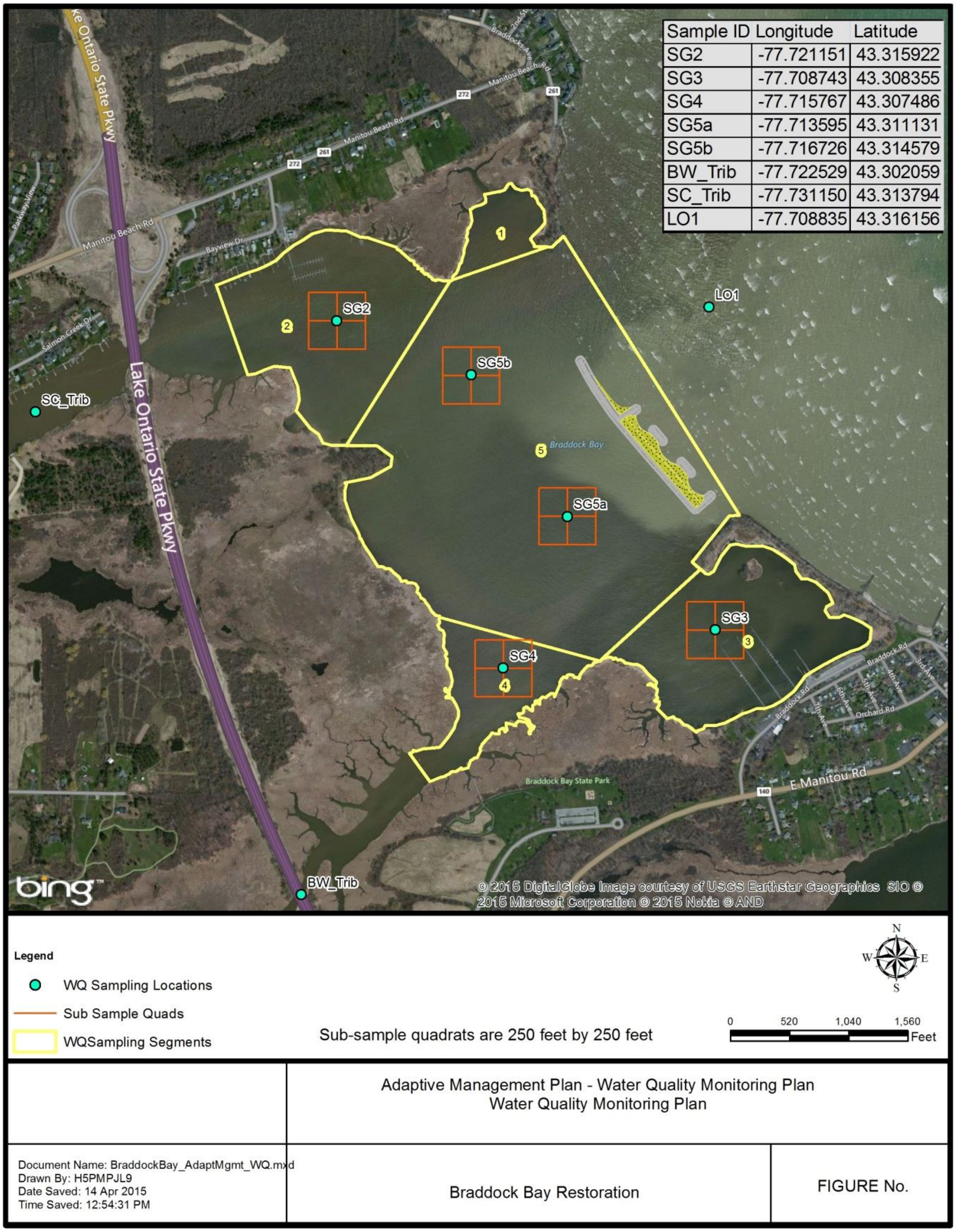

Figure 1. Braddock Bay and Water Quality Monitoring Sites (Reproduced from USACE 2015), Braddock Bay Restoration: Monitoring and Adaptive Management Plan

Table 1. List of parameter methods used during the 2015 and 2016 Braddock Bay water quality monitoring.

Parameter	2015 Method	2016 Method	Precision and Accuracy (≤% RPD)	Range	Units	Preservation	Sample Fraction	Method Holding Times	Project Holding Times
Nitrogen - Ammonia	SM_4500-NH3-D	SM 4500-NH3 G-97	20%	0.002 - 1	mg/L	Chill to 4°C; acidify	Filtered (≤ 0.45 µm)	36 H; 28 D	36 H; 14 D
Nitrogen – Nitrate/Nitrite	SM_4500-NO3-H	SM_4500-NO3-F	20%	0.002 - 2	mg/L	Chill to 4°C; acidify	Filtered (≤ 0.45 µm)	36 H; 28 D	36 H; 14 D
Nitrogen - Total Kjeldahl	EPA_351.2	TN (SM 4500 P J) minus SM 4500-NO3- F	20%	0.01 - 2	mg/L	Digested; Chill to 4°C	Total	36 H; 28 D	36 H; 14 D
Phosphorus, Total	SM_4500-P-F	SM_4500-P-F	20%	0.01 - 1	mg/L	Digested; Chill to 4°C	Total	36 H; 28 D	36 H; 14 D
Phosphorus, Dissolved (Ortho)	EPA 365.1	EPA 365.1; SM_4500-P-F	20%	0.002 - 1	mg/L	Chill to 4°C; acidify	Filtered (≤ 0.45 µm)	36 H; 28 D	36 H; 14 D
Total Suspended Solids (TSS)	SM_2540D	SM 2540-D	25%	NA	mg/L	Chill to 4°C	Particles Filtered on to Whatman GF/C	1 W	1 W
Chlorophyll a	APHA (2012) Method 10200H.2 (Spectrophotometric)	APHA (2012) Method 10200H.2; EPA 445.0	25%	NA	µg/L	Chill to 4°C; Frozen at -20°C	Particles Filtered on to Whatman GF/C; Particles	36 H; 28 D	36 H; 14 D
Temperature, pH, DO, ORP, Conductivity, Turbidity, Secchi Disk	Field Measurement	Field Measurement	NA	NA	Multiple Field		Field	Field	Field
Nitrogen - Total	Not Determined	SM 4500 P J; SM 4500 NO3- F	20%	0.01 - 2	mg/L	Digested; Chill to 4°C	Total	36 H; 28 D	36 H; 14 D

NA = Not Applicable

3.0 Results and Discussion

Table 2. Summary water quality conditions (minimum, maximum, mean, and 95% confidence interval) for Lake Ontario, Braddock Bay, and its Tributaries for barrier pre-construction sampling events.

	min	max	mean	95% CI
Phosphate (PO4; mg/L)				
Lake Ontario	0.002	0.028	0.010	0.003 to 0.022
Braddock Bay	0.002	0.259	0.014	0.003 to 0.131
Tributaries	0.057	0.267	0.154	0.060 to 0.237
Total Phosphorus (TP; mg/L)				
Lake Ontario	0.006	0.022	0.009	0.006 to 0.018
Braddock Bay	0.030	0.284	0.102	0.033 to 0.200
Tributaries	0.140	0.330	0.201	0.140 to 0.297
Ammonia (NH4; mg/L)				
Lake Ontario	0.010	0.047	0.030	0.015 to 0.043
Braddock Bay	0.011	0.300	0.050	0.013 to 0.213
Tributaries	0.017	0.310	0.071	0.020 to 0.243
Nitrate+Nitrite (NO2NO3; mg/L)				
Lake Ontario	0.000	1.700	0.311	0.000 to 1.217
Braddock Bay	0.000	2.400	0.136	0.000 to 0.704
Tributaries	0.000	1.500	0.142	0.000 to 0.668
Total Kjeldahl Nitrogen (TKN; mg/L)				
Lake Ontario	0.130	1.000	0.497	0.173 to 0.972
Braddock Bay	0.190	2.200	1.123	0.573 to 1.800
Tributaries	0.290	7.200	1.334	0.487 to 3.150
Chlorophyll a (CHL: µg/L)				
Lake Ontario	1.3	20.3	6.2	1.8 to 19.3
Braddock Bay	2.7	122.8	41.6	11.5 to 86.8
Tributaries	1.3	30.7	7.6	1.3 to 17.3
Secchi Disc Depth (ft)				
Lake Ontario	3.7	6.8	5.8	4.0 to 6.6
Braddock Bay	1.0	3.7	1.9	1.0 to 3.4
Tributaries	1.1	8.0	5.0	1.7 to 7.7
Trophic State Index (TSI)				
Lake Ontario	39	56	44	40 to 52
Braddock Bay	58	77	67	61 to 75
Tributaries	54	69	61	54 to 67

Baseline conditions for Braddock Bay, Lake Ontario, and Tributaries for the study period (2015 – 2016) are listed in Table 2. The 95% confidence interval was used in this report as the estimate for the normal range for baseline conditions prior to barrier construction. This provides a conservative estimate of normal conditions in Braddock Bay and statistically reduces the impact of extreme events or outlier measurements on baseline conditions in the ecosystem. For Braddock Bay, mean and confidence intervals for ecosystem target criteria were 0.014 mg/L (0.003 to 0.131) for PO4, 0.102 mg/L (0.033 to 0.200) for TP, 0.050 mg/L (0.013 to 0.213) for NH4, 0.136 mg/L (0.000 to 0.704) for NO2NO3, 1.123 mg/L (0.573 to 1.800) for TKN, 41.6 μg/L (11.5 to 86.8) for CHL, 1.9 ft (1.0 to 3.4) for Secchi depth, and 67 (61 to 75) for TSI. Ecosystem target criteria were exceeded 86.1%, 80%, 85%, and 94.4% of the time at sites within Braddock Bay for Secchi depth, TP, chlorophyll a, and TSI, respectively. Water quality conditions were much better at the Lake Ontario site than in Braddock Bay and Tributaries (Table 2). Tributary inputs to Braddock Bay were nutrient rich, especially with respect to PO4. Tributaries were generally free of phytoplankton blooms and relatively clear. The Tributaries always loaded PO4 but often had levels of dissolved inorganic nitrogen (NO2NO3 + NH4) near detection limits. Hence, the Tributary complexes of Braddock Bay are significant source of phosphorus to the bay but typically buffer against nitrogen contaminants entering the bay. Interesting, Lake Ontario has higher levels of NO2NO3 on average than Tributaries and could act as a nitrogen source to Braddock Bay.

The two sampling years included in this study were significant different in terms of weather and water chemistry. 2015 was a normal to wet year and 2016 was a drought year. The water quality of Braddock Bay was influenced by these differences in weather patterns. NH4 ($F = 11.5$, $p = 0.001$), NO2NO3 ($F = 8.6$, $p = 0.005$), TKN ($F = 10.2$, $p = 0.002$), Conductivity ($F = 96.9$, $p < 0.001$), and Turbidity ($F = 46.8$, $p < 0.001$) were higher during 2015 than during 2016. TP ($F = 14.3$, $p < 0.001$) and TSI ($F = 8.2$, $p = 0.006$) were significantly higher during 2016 than during 2015. CHL, PO4, TSS, and Secchi depth did not differ between years, though CHL tended to be higher in 2016. During 2015 phytoplankton blooms were not reported and the water appeared turbid due to sediment resuspension (USACE 2016). In contrast during 2016, Braddock Bay experienced a large phytoplankton bloom with little evidence of sediment resuspension. The water quality conditions during 2015 seem to be driven by sediment resuspension and tributary inputs. The water quality conditions during 2016, with low tributary flows, likely were controlled by internal nutrient cycling and perhaps exchange with Lake Ontario, which favored phytoplankton bloom development. Without prior experience in Braddock Bay, this report cannot speculate on which year had the more typical conditions in the bay. Most sampling events during both years failed to meet water quality target criteria for ecosystem health.

Given the differences in water quality between years, it is not surprising that relationships among water quality parameters were not always consistent between years (Table 3). Phytoplankton blooms are a major concern in water quality studies. To help facilitate better understanding of blooms in Braddock Bay, this report investigates what covaries with blooms in the bay. In both years, CHL correlated negatively with PO4 but did not correlate with TP (Fig. 2). During 2015, CHL did not correlate well with any other water quality parameters. In contrast, during 2016 CHL correlated strongly with TKN, Turbidity, and Secchi depth (Table 3; Fig. 4). These relationships suggest the phytoplankton bloom drove poor water clarity conditions in 2016 but less so in 2015. During 2015, water clarity was associated with DO, pH, NH4, and Conductivity (Table 3), factors that are influenced strongly by riverine inputs and sediment resuspension in embayments. There were two outliers in the CHL vs Turbidity relationship that once removed, do show negative impact of phytoplankton on water clarity in 2015. Given the high levels of phosphorus in 2016 and the strong correlation between CHL and TKN, it is likely that the phytoplankton bloom was nitrogen limited. In both years, CHL negatively related to PO4 suggesting increased uptake and use of phosphorus as phytoplankton blooms increase in size. These findings suggest that both nitrogen and phosphorus pollution are important to control in order to improve TSI in Braddock Bay.

Table 3. Correlation matrix of water quality parameters within Braddock Bay. Lower matrix are correlations for 2015. Upper matrix are correlations for 2016. Significant correlations are in bold and italic type. Values are correlation coefficients.

	CHL	PO4	NH4	NO2NO3	TP	TSS	TKN	pH	DO	ORP	Cond	Turbidity	Secchi	TSI
CHL	-	***-0.37***	***-0.43***	-0.33	0.25	***0.80***	***0.95***	***0.38***	***0.48***	0.31	***-0.39***	***0.92***	***-0.89***	-
PO4	**-0.47**	-	0.11	-0.11	***0.43***	-0.38	-0.23	0.10	-0.19	-0.02	***0.64***	-0.25	***0.41***	-0.20
NH4	-0.42	***0.55***	-	0.17	-0.21	-0.02	***-0.43***	-0.10	***-0.47***	-0.06	0.23	***-0.50***	0.36	-0.33
NO2NO3	-0.23	0.15	0.11	-	-0.30	-0.27	-0.34	-0.21	-0.30	-0.08	-0.18	-0.21	***0.47***	***-0.58***
TP	-0.32	***0.87***	***0.65***	0.01	-	0.09	***0.36***	0.29	0.26	0.28	0.08	0.23	-0.16	-
TSS	-0.05	0.27	***0.70***	-0.20	0.45	-	***0.78***	***0.39***	***0.51***	0.15	-0.31	***0.72***	***-0.78***	***0.77***
TKN	0.02	0.12	-0.02	**0.55**	-0.12	0.01	-	0.41	***0.53***	0.25	-0.28	***0.90***	***-0.86***	***0.91***
pH	0.21	***-0.57***	***-0.68***	0.12	***-0.73***	***-0.65***	0.13	-	***0.73***	-0.16	-0.03	***0.44***	***-0.50***	***0.52***
DO	-0.18	-0.20	***-0.58***	0.36	-0.39	***-0.77***	0.08	***0.77***	-	-0.10	-0.36	***0.48***	***-0.53***	***0.53***
ORP	0.32	0.27	0.33	-0.41	0.34	***0.51***	-0.03	***-0.64***	***-0.82***	-	-0.06	0.31	-0.09	0.19
Cond	-0.05	***0.53***	***0.63***	-0.05	***0.80***	***0.58***	-0.39	***-0.74***	***-0.53***	0.38	-	-0.37	0.27	-0.26
Turbidity	-0.08	0.30	***0.72***	-0.16	0.41	***0.95***	0.11	***-0.62***	***-0.78***	***0.58***	***0.48***	-	***-0.89***	***0.84***
Secchi	-0.16	0.03	***-0.55***	0.24	-0.23	***-0.86***	0.10	***0.56***	***0.78***	***-0.49***	-0.44	***-0.82***	-	-
TSI	-	0.13	0.21	-0.27	-	***0.49***	-0.16	***-0.53***	***-0.57***	***0.53***	***0.66***	0.39	-	-

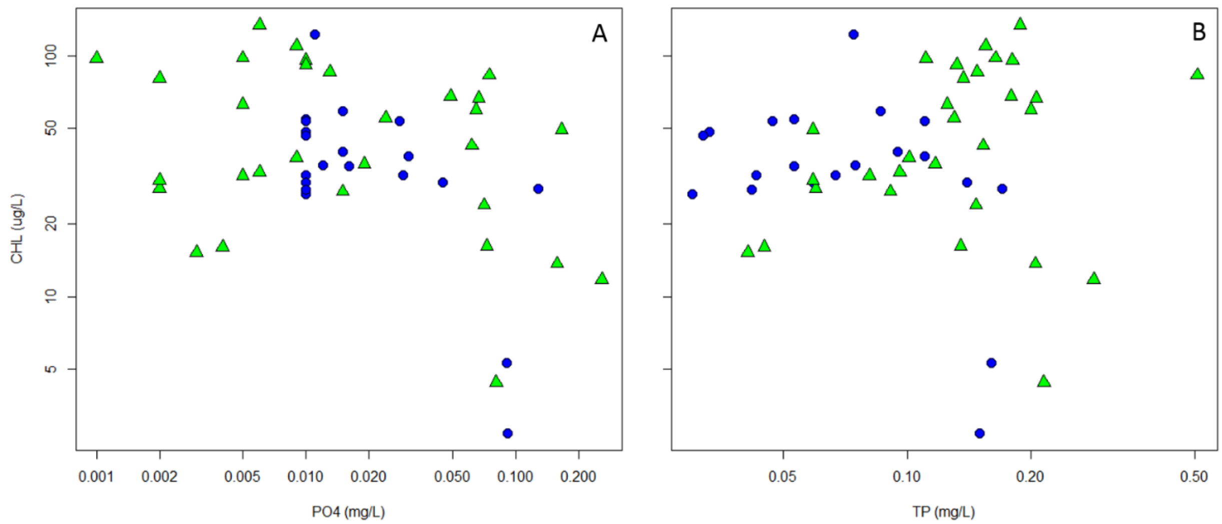

Figure 2. For Braddock Bay sites only, relationship between phytoplankton biomass (CHL) and phosphorus in the form of PO4 (A) and TP (B). CHL negatively correlated with PO4 in both years and did not correlate with TP in both years. Green Triangles are 2016. Blue Circles are 2015.

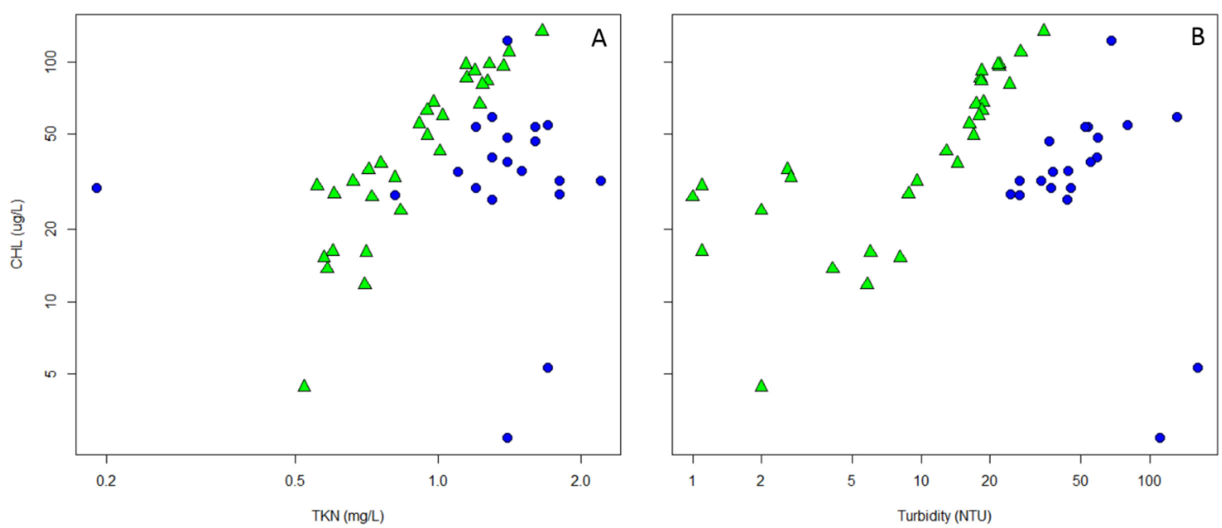

Figure 3. For Braddock Bay sites only, relationship between phytoplankton biomass (CHL) and TKN (A) and Turbidity (B). CHL positively correlated with TKN during 2016 not 2015. Turbidity positively correlated with CHL in 2016 not 2015, though the poor correlation in 2015 is caused by two data points. Green Triangles are 2016. Blue Circles are 2015.

4.0 Conclusion

Pre-barrier construction, baseline conditions in Braddock Bay indicate eutrophic to hyper eutrophic conditions. Ecosystem target criteria were exceeded 86.1%, 80%, 85%, and 94.4% of the time at sites within Braddock Bay for Secchi depth, TP, chlorophyll a, and TSI, respectively. The bay significantly differed in its water quality between sampling years, but frequently exceeded target criteria in both sampling years. Phytoplankton biomass is high in Braddock Bay. The evidence suggests that both nitrogen and phosphorus are important in understanding blooms in the bay and, hence, effort is needed to mitigate nutrient pollution into Braddock Bay to limit bloom development. Despite evidence of water exchange between the bay and lake, the poor water quality conditions observed in Braddock Bay rarely caused undesirable conditions in near shore lake Ontario. With barrier construction, this pattern seems unlikely to change. Lake Ontario is nitrate+nitrite rich relative to the bay. The tributaries and the lake could both be important sources of nitrogen to the bay. If this is the case, then barrier construction, which might restrict connectivity between bay and lake, could reduce nitrogen availability within the bay. Conversely, if the 2016 bloom was bolstered by drought conditions, that reduced the connectivity between tributaries, bay, and lake, then barrier construction could enhance the prevalence and magnitude of phytoplankton blooms in Braddock Bay. Overall, it is unclear from the data collected in this study how barrier construction and wetland restoration will impact water quality in Braddock Bay. Still, this study does provide a solid dataset collected under very different weather patterns that can be used to assess how Braddock Bay responds to restoration. The pre-restoration water quality conditions in Braddock Bay are currently poor and management actions should be taken to help improve ecosystem health. Reducing phosphorus and nitrogen loading from the watershed is likely required in this system in order to control phytoplankton blooms.

5.0 References

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography, 22(2):361-369.

U.S. Army Corps of Engineers (USACE). 2015. Braddock Bay Restoration: Monitoring and Adaptive Management Plan. Buffalo District.

U.S. Army Corps of Engineers (USACE). 2016. Braddock Bay Restoration: 2015 Water Quality Monitoring. Buffalo District.

Appendix A. 2015 and 2016 pre-barrier data set

Site	date	CHL µg/L	PO4 mg-P/L	NH4 mg-N/L	NO2NO3 mg-N/L	TP mg-P/L	TSS mg/L	TKN mg/L
BW	6/12/2015	5.3	0.081	0.310	0.210	0.140	8.0	1.700
BW	7/16/2015	5.3	0.206	0.076	0.000	0.330	2.0	1.300
BW	8/14/2015	3.2	0.156	0.062	0.000	0.200	2.0	0.290
BW	9/23/2015	1.3	0.201	0.056	0.390	0.210	2.0	7.200
BW	6/28/2016	12.0	0.126	0.028	0.000	0.186	6.2	0.683
BW	7/5/2016	8.6	0.195	0.042	0.015	0.244	6.6	0.713
BW	7/27/2016	6.1	0.202	0.053	0.017	0.231	2.6	0.719
BW	8/11/2016	7.0	0.227	0.021	0.000	0.257	1.0	0.729
LO1	6/12/2015	2.7	0.010	0.027	0.320	0.008	8.0	0.920
LO1	7/16/2015	1.3	0.010	0.010	0.000	0.006	0.0	0.740
LO1	8/14/2015	20.3	0.010	0.034	0.000	0.022	7.0	0.130
LO1	9/23/2015	6.7	0.010	0.035	1.700	0.008	2.0	1.000
LO1	6/28/2016	6.0	0.004	0.023	0.156	0.006	3.3	0.314
LO1	7/5/2016	5.4	0.004	0.047	0.025	0.010	3.4	0.328
LO1	7/27/2016	4.0	0.028	0.031	0.133	0.007	1.6	0.289
LO1	8/11/2016	2.8	0.002	0.030	0.153	0.006	1.7	0.254
SC	6/12/2015	5.3	0.090	0.220	0.110	0.140	22.0	1.300
SC	7/16/2015	30.7	0.057	0.017	0.000	0.150	10.0	1.800
SC	8/14/2015	6.4	0.119	0.047	0.000	0.160	6.0	0.920
SC	9/23/2015	1.3	0.168	0.069	1.500	0.180	0.0	1.400
SC	6/28/2016	12.8	0.061	0.024	0.011	0.153	7.2	0.730
SC	7/5/2016	4.1	0.117	0.048	0.000	0.157	6.0	0.669
SC	7/27/2016	6.1	0.267	0.036	0.023	0.286	2.3	0.630
SC	8/11/2016	5.3	0.191	0.021	0.000	0.190	1.1	0.553
SG2	6/12/2015	2.7	0.092	0.300	0.770	0.150	32.0	1.400
SG2	7/16/2015	53.4	0.028	0.021	0.000	0.110	27.0	1.200
SG2	8/14/2015	29.9	0.045	0.080	0.000	0.140	14.0	0.190
SG2	9/23/2015	28.0	0.129	0.063	0.610	0.170	6.0	1.800
SG2	6/28/2016	35.5	0.019	0.023	0.026	0.117	15.3	0.713
SG2	7/5/2016	24.0	0.071	0.041	0.000	0.147	14.0	0.833
SG2	7/27/2016	49.4	0.166	0.028	0.000	0.059	14.6	0.949
SG2	8/11/2016	11.8	0.259	0.030	0.016	0.284	8.8	0.700
SG3	6/12/2015	122.8	0.011	0.038	0.000	0.074	24.0	1.400
SG3	7/16/2015	54.7	0.010	0.022	0.000	0.053	16.0	1.700
SG3	8/14/2015	35.2	0.012	0.060	0.000	0.075	18.0	1.500
SG3	9/23/2015	32.0	0.010	0.038	2.400	0.043	8.5	2.200
SG3	6/28/2016	31.7	0.005	0.021	0.006	0.081	13.2	0.661
SG3	7/5/2016	27.3	0.015	0.029	0.000	0.091	13.5	0.725
SG3	7/27/2016	55.1	0.024	0.027	0.000	0.130	11.9	0.912

SG3	8/11/2016	85.6	0.013	0.022	0.013	0.148	21.8	1.147
SG4	6/12/2015	40.1	0.015	0.210	0.280	0.095	19.0	1.300
SG4	7/16/2015	53.4	0.010	0.011	0.000	0.047	17.0	1.600
SG4	8/14/2015	38.4	0.031	0.050	0.000	0.110	19.0	1.400
SG4	9/23/2015	32.0	0.029	0.027	0.700	0.067	12.0	1.800
SG4	6/28/2016	37.7	0.009	0.024	0.023	0.101	21.4	0.757
SG4	7/5/2016	16.2	0.073	0.038	0.000	0.135	11.6	0.599
SG4	7/27/2016	67.7	0.049	0.023	0.000	0.179	23.4	0.977
SG4	8/11/2016	66.6	0.067	0.024	0.014	0.206	23.3	1.224
SG5a	6/12/2015	58.7	0.015	0.150	0.200	0.086	42.0	1.300
SG5a	7/16/2015	48.1	0.010	0.011	0.000	0.033	14.0	1.400
SG5a	8/14/2015	29.9	0.010	0.027	0.000	0.059	16.0	1.200
SG5a	9/23/2015	46.7	0.010	0.017	0.130	0.032	14.0	1.600
SG5a	6/28/2016	28.2	0.002	0.023	0.012	0.060	8.8	0.603
SG5a	7/5/2016	32.8	0.006	0.039	0.000	0.096	18.0	0.810
SG5a	7/27/2016	62.8	0.005	0.022	0.000	0.125	18.1	0.947
SG5a	8/11/2016	110.0	0.009	0.017	0.000	0.155	24.7	1.410
SG5b	6/12/2015	5.3	0.091	0.260	0.059	0.160	53.0	1.700
SG5b	7/16/2015	26.7	0.010	0.013	0.000	0.030	13.0	1.300
SG5b	8/14/2015	27.8	0.010	0.055	0.000	0.042	11.0	0.810
SG5b	9/23/2015	34.7	0.016	0.020	0.078	0.053	13.0	1.100
SG5b	6/28/2016	16.1	0.004	0.020	0.034	0.045	6.6	0.705
SG5b	7/5/2016	30.4	0.002	0.043	0.000	0.059	16.0	0.555
SG5b	7/27/2016	15.3	0.003	0.032	0.084	0.041	8.2	0.574
SG5b	8/11/2016	59.5	0.065	0.018	0.000	0.200	14.7	1.022

ND = not determined

Values below detection limit are listed as 0

Appendix A. 2015 and 2016 pre-barrier data set continued

Site	Date	pH	DO	ORP	Conductivity	Turbidity	Secchi Depth
			mg/L	mV	µS/cm	NTU	ft
BW	6/12/2015	7.39	3.7	210	0.744	33.9	2.3
BW	7/16/2015	6.78	2.8	176	0.830	1.2	3.4
BW	8/14/2015	7.15	5.8	176	0.788	3.9	5.2
BW	9/23/2015	7.48	7.4	179	0.722	3.3	7.5
BW	6/28/2016	7.15	5.6	142	0.524	3.6	3.8
BW	7/5/2016	7.16	5.1	74	0.574	0.0	ND
BW	7/27/2016	7.12	4.7	176	0.527	1.9	7.4
BW	8/11/2016	7.18	5.3	131	0.558	1.6	8.0
LO1	6/12/2015	8.30	7.1	222	0.456	4.4	6.2
LO1	7/16/2015	7.99	5.8	210	0.446	18.5	4.7
LO1	8/14/2015	8.49	9.7	164	0.049	10.4	3.7
LO1	9/23/2015	8.36	9.4	179	0.465	3.5	6.8
LO1	6/28/2016	8.15	10.7	66	0.299	1.0	6.2
LO1	7/5/2016	8.37	9.6	139	0.301	0.0	5.3
LO1	7/27/2016	8.20	9.4	155	0.310	1.4	6.1
LO1	8/11/2016	8.16	10.0	50	0.301	1.2	5.4
SC	6/12/2015	6.83	5.3	184	0.835	86.8	1.1
SC	7/16/2015	7.57	6.8	185	0.966	36.2	1.9
SC	8/14/2015	7.57	10.0	187	0.984	12.0	3.7
SC	9/23/2015	6.85	10.5	196	0.800	3.8	6.5
SC	6/28/2016	8.06	8.3	120	0.691	2.6	4.2
SC	7/5/2016	8.24	9.3	129	0.682	0.0	5.4
SC	7/27/2016	8.28	7.3	151	0.542	1.5	7.6
SC	8/11/2016	7.93	6.5	100	0.441	0.6	6.7
SG2	6/12/2015	7.41	4.9	202	0.744	111.0	1.1
SG2	7/16/2015	7.73	5.3	183	0.736	53.9	1.6
SG2	8/14/2015	7.77	8.6	182	0.855	37.0	2.1
SG2	9/23/2015	7.79	9.3	202	0.680	24.6	3.3
SG2	6/28/2016	7.90	7.9	81	0.470	2.6	2.2
SG2	7/5/2016	8.13	7.2	129	0.605	2.0	ND
SG2	7/27/2016	8.17	8.2	152	0.576	17.0	1.5
SG2	8/11/2016	8.28	8.1	75	0.466	5.8	3.4
SG3	6/12/2015	8.21	5.9	220	0.680	67.8	1.3
SG3	7/16/2015	8.41	7.2	194	0.509	80.2	2.1
SG3	8/14/2015	8.23	9.6	149	0.549	44.0	1.8
SG3	9/23/2015	8.49	11.6	137	0.529	26.9	2.4
SG3	6/28/2016	8.00	8.8	133	0.359	9.6	1.7
SG3	7/5/2016	8.02	7.3	84	0.358	1.0	ND
SG3	7/27/2016	8.21	8.8	116	0.354	16.3	1.7

SG3	8/11/2016	8.28	9.6	110	0.334	18.2	1.3
SG4	6/12/2015	7.76	5.2	200	0.694	58.9	1.9
SG4	7/16/2015	7.79	5.6	233	0.520	52.2	1.9
SG4	8/14/2015	7.87	8.3	188	0.562	55.1	1.8
SG4	9/23/2015	8.13	9.5	168	0.579	33.5	2.7
SG4	6/28/2016	8.16	8.4	115	0.365	14.4	2.1
SG4	7/5/2016	7.98	7.7	148	0.403	1.1	3.7
SG4	7/27/2016	8.36	10.1	149	0.380	18.7	1.2
SG4	8/11/2016	8.50	10.8	94	0.360	17.4	1.4
SG5a	6/12/2015	7.45	4.6	219	0.777	132.0	1.0
SG5a	7/16/2015	8.09	6.9	197	0.495	59.5	2.0
SG5a	8/14/2015	8.40	9.3	184	0.550	45.1	2.1
SG5a	9/23/2015	8.50	10.1	165	0.526	36.4	2.4
SG5a	6/28/2016	8.03	8.9	140	0.355	8.8	2.9
SG5a	7/5/2016	7.95	7.3	116	0.367	2.7	ND
SG5a	7/27/2016	8.36	9.5	147	0.392	18.5	1.3
SG5a	8/11/2016	7.83	8.4	126	0.348	27.3	1.0
SG5b	6/12/2015	7.55	4.4	212	0.755	162.0	1.0
SG5b	7/16/2015	8.05	8.1	183	0.507	43.8	1.9
SG5b	8/14/2015	8.50	9.8	157	0.525	26.9	2.7
SG5b	9/23/2015	8.35	9.8	176	0.580	37.8	2.3
SG5b	6/28/2016	8.00	9.2	109	0.343	6.0	3.5
SG5b	7/5/2016	8.01	7.6	129	0.367	1.1	ND
SG5b	7/27/2016	7.86	7.7	160	0.333	8.1	3.4
SG5b	8/11/2016	8.25	8.8	96	0.395	17.9	1.5

ND = not determined
Values below detection limit are listed as 0

Appendix B. 2016 during barrier construction data set

Site	date	CHL µg/L	PO4 mg-P/L	NH4 mg-N/L	NO2NO3 mg-N/L	TP mg-P/L	TSS mg/L	TKN mg/L
BW	8/30/2016	4.3	0.300	0.012	0.000	0.355	1.5	0.754
BW	9/18/2016	4.3	0.186	0.000	0.000	0.209	0.4	0.722
LO1	8/30/2016	7.7	0.001	0.018	0.103	0.010	2.1	0.338
LO1	9/18/2016	5.7	0.000	0.009	0.208	0.007	0.0	0.263
SC	8/30/2016	5.9	0.160	0.008	0.000	0.198	1.6	0.535
SC	9/18/2016	5.4	0.062	0.000	0.000	0.078	1.0	0.506
SG2	8/30/2016	13.7	0.158	0.015	0.005	0.205	3.1	0.583
SG2	9/18/2016	4.4	0.081	0.000	0.000	0.215	1.6	0.522
SG3	8/30/2016	95.9	0.010	0.018	0.000	0.180	19.8	1.373
SG3	9/18/2016	91.6	0.010	0.000	0.000	0.132	18.6	1.194
SG4	8/30/2016	83.1	0.075	0.018	0.000	0.507	15.8	1.270
SG4	9/18/2016	42.4	0.062	0.000	0.000	0.153	10.8	1.008
SG5a	8/30/2016	134.4	0.006	0.012	0.000	0.188	34.4	1.655
SG5a	9/18/2016	80.8	0.002	0.000	0.000	0.137	21.5	1.240
SG5b	8/30/2016	98.0	0.005	0.018	0.000	0.164	25.6	1.281
SG5b	9/18/2016	97.5	0.001	0.000	0.011	0.111	11.7	1.144

ND = not determined

Values below detection limit are listed as 0

Appendix B 2016 during barrier construction data set continued.

Site	Date	pH	DO	ORP	Conductivity	Turbidity	Secchi Depth
			mg/L	mV	µS/cm	NTU	ft
BW	8/30/2016	7.08	ND	230	0.542	1.4	8.0
BW	9/18/2016	7.11	ND	72	0.540	1.1	7.5
LO1	8/30/2016	7.96	ND	205	0.309	2.5	5.5
LO1	9/18/2016	7.96	ND	143	0.314	2.2	5.1
SC	8/30/2016	7.05	ND	232	0.443	1.2	7.6
SC	9/18/2016	7.39	ND	109	0.500	1.1	7.3
SG2	8/30/2016	7.88	ND	214	0.443	4.1	3.6
SG2	9/18/2016	7.70	ND	133	0.456	2	3.2
SG3	8/30/2016	7.88	ND	175	0.332	22.0	1.0
SG3	9/18/2016	8.17	ND	131	0.343	18.4	1.4
SG4	8/30/2016	8.31	ND	201	0.381	18.3	1.2
SG4	9/18/2016	8.21	ND	79	0.414	12.9	1.8
SG5a	8/30/2016	8.06	ND	202	0.343	34.5	0.8
SG5a	9/18/2016	8.31	ND	114	0.362	24.4	0.9
SG5b	8/30/2016	8.32	ND	184	0.370	22.1	1.0
SG5b	9/18/2016	8.29	ND	128	0.357	21.7	1.0

ND = not determined

Values below detection limit are listed as 0