Durham Region Coastal Wetland Monitoring Project:

Year 2 Technical Report

March 2004

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Central Lake Ontario Conservation

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EXECUTIVE SUMMARY

The primary goal of the Durham Region Coastal Wetland Monitoring Project (DRCWMP) is to implement a long-term monitoring program that enables reporting on the condition of coastal wetlands in the Region. This project was initiated in 1999 and a background summary and project proposal was released in February 2001. An Implementation Committee, consisting of stakeholders from various governmental and non-governmental organizations, developed a set of goals and objectives for this project. A Methodology Committee was formed to describe the specific protocols for a monitoring program to meet those objectives. The first approximation of the Methodology Handbook, which detailed these monitoring activities, was released in March 2002.

The initial Methodology Handbook was considered a work in progress. Following 2002 field testing of the protocols, some revisions were necessary and the handbook was updated accordingly. In addition, some methodologies require further development and refinement before use in the field.

Fifteen Durham Region coastal wetlands that vary in size, level of disturbance, and hydrogeomorphic features are being monitored through this project. Plant, fish, aquatic macroinvertebrate, bird, and amphibian community condition are the focus of biological condition assessment, while abiotic wetland and watershed variables are examined to assess the present geophysical condition.

The wetland and watershed attributes being monitored were identified by drawing largely on previous coastal wetland indicator development through the State of the Lakes Ecosystem Conferences (SOLEC) and Bird Studies Canada's Marsh Monitoring Program. The biennial SOLEC conferences focus on reporting progress being made towards the goals of the Great Lakes Water Quality Agreement, which are to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem.

This technical report evaluates data collected during 2002 and 2003 and proposes a multi-metric approach for simplifying comparisons among biotic communities, and across years of the study. Metrics are biological attributes that are known to respond in specific and predictable ways to changes in wetland condition. Individual metrics can then be combined to create an Index of Biotic Integrity (IBI) for biological monitoring. Additional data from other coastal wetlands within Lake Ontario were used to provide a lake-wide context for comparison and to support broader conclusions.

Measures of wetland disturbance are estimated primarily by using geophysical data collected through this project as human-induced wetland disturbance can affect biotic communities. Wetland disturbance has been assessed using a multivariate statistical approach. Overall, Durham Region coastal wetlands experience high levels of disturbance compared to other Lake Ontario coastal wetlands. Within the region, more easterly sites were generally subject to less disturbance than sites closer to Toronto.

The intensity of disturbance in Durham Region sites has affected the condition of the biotic communities. While biotic communities generally scored low IBIs and were in poor, fair and sometimes good condition, certain biotic communities at some sites were in very good or excellent condition compared to other Lake Ontario sites. Examples of these are fish at Wilmot Creek Marsh and breeding birds at Cranberry, Oshawa Second, Wilmot Creek, and Westside marshes.

There is a clear need to better understand the limitations of reporting results through IBIs. In particular, additional data collection is required to refine estimates of error around IBI values. Knowing the confidence limits of IBIs will help provide an understanding of long-term trends and aid in restoration and conservation decisions.

This report will allow the DRCWMP Implementation and Methodology Committees to assess project progress and make recommendations regarding the direction and priorities of the project. In addition, stakeholders will be able to recognize the value of this project, while still in its initial reporting stages.

This Year 2 technical report:

1. details the current biological and geophysical state of Durham Region wetlands;
2. provides a valuable resource for directing coastal wetland restoration and conservation projects in Durham Region, and;
3. provides a foundation and methodology for regionally-based monitoring in the Great Lakes.

The Great Lakes Coastal Wetlands Consortium (GLCWC) is a project under the leadership of the Great Lakes Commission, which will develop and implement a monitoring framework for coastal wetlands at the Great Lakes basin-wide level. The Consortium is a three-year project initiated in November 2000 with funding from the U.S. Environmental Protection Agency. The Consortium arose from the SOLEC process and is composed of U.S. and Canadian scientists, policy-makers, and others dedicated to Great Lakes coastal wetland science, monitoring, and conservation. The Consortium is focused on refining coastal wetland indicators, as recommended at SOLEC 1998, and developing long-term binational monitoring strategies.

Development of the monitoring framework for the Durham project will draw on the GLCWC initiative and new information will be incorporated into the monitoring design as it becomes available. Compatibility between the Durham and the GLCWC projects will allow comparison of Durham Region coastal wetlands to other wetlands around the Great Lakes and the use of Durham project results will enable reporting on the state of Great Lakes coastal wetlands.

RÉSUMÉ

L’objet principal du Projet de surveillance des terres humides riveraines de la Région de Durham (DRCWMP) consiste à mettre en application un programme de surveillance à long terme qui permette de rendre compte de l’état des terres humides riveraines de la Région. On a lancé ce projet en 1999 et publié une proposition de projet en février 2001. Un Comité de mise à exécution, composé d’intervenants de divers organismes gouvernementaux et non gouvernementaux, a établi une série d’objectifs pour ce projet. On a formé un Comité des méthodes chargé de décrire les protocoles particuliers d’un programme de surveillance pour la réalisation de ces objectifs. La première ébauche du manuel des méthodes, qui exposait en détail ces activités de surveillance, a été publiée en mars 2002.

Le Manuel initial des méthodes était considéré comme un travail en cours. À la suite de l’essai des protocoles sur le terrain, des révisions se sont révélées nécessaires et l’on a mis à jour le manuel en conséquence. En outre, certaines méthodes nécessitent un complément d’élaboration et d’amélioration avant leur utilisation sur le terrain.

Dans le cadre de ce projet, on surveille quinze terres humides riveraines de la Région de Durham, qui varient en superficie, en niveaux de perturbation et en éléments hydrogéomorphiques. L’état des végétaux, des poissons, des macro-invertébrés aquatiques, des oiseaux et des batraciens est au cœur de l’évaluation de l’état biologique, tandis qu’on examine les variables des bassins hydrologiques et des terres humides abiotiques pour évaluer l’état géophysique actuel.

Les attributs des bassins hydrologiques et des terres humides soumis à la surveillance ont été établis en s’inspirant dans une large mesure de l’élaboration antérieure de l’indicateur des terres humides riveraines par l’entremise des Conférences sur l’état de l’écosystème des Grands Lacs (CÉÉGL) et du Programme de surveillance des marais de *Bird Studies Canada.* Les conférences CÉÉGL biennales se concentrent sur le compte rendu des progrès accomplis dans la réalisation des objectifs de l’Accord sur la qualité de l’eau dans les Grands Lacs, visant à restaurer et à maintenir l’intégrité chimique, physique et biologique de l’écosystème du bassin des Grands Lacs.

Ce rapport technique évalue les données recueillies pendant 2002 et 2003 et propose une approche à paramètres multiples pour la simplification des comparaisons parmi les collectivités biotiques et suivant les années de l’étude. Les paramètres sont des attributs biologiques qui, a-t-on établi, réagissent de façons déterminées et prévisibles aux changements survenant dans l’état des terres humides. On peut alors combiner les paramètres individuels, afin de créer un indice d’intégrité biotique (IIB) pour la surveillance biologique. On a utilisé des données d’autres terres humides riveraines du lac Ontario pour fournir un contexte panlacustre aux fins de comparaisons et étayer des conclusions plus étendues.

On estime les mesures de perturbation des terres humides en utilisant surtout les données géophysiques recueillies à la faveur de ce projet, les perturbations anthropiques des terres humides pouvant influer sur les collectivités biotiques. On a évalué la perturbation des terres humides en utilisant une approche statistique à variables multiples. Dans l’ensemble, les terres humides riveraines de la Région de Durham connaissent de hauts niveaux de perturbations par rapport aux autres terres humides riveraines du lac Ontario. Dans la région, les sites plus à l’est étaient généralement soumis à moins de perturbations que les sites plus proches de Toronto.

L’intensité des perturbations des sites de la Région de Durham a influé sur l’état des collectivités biotiques. Les collectivités biotiques ont généralement enregistré de faibles

IIB et se trouvaient dans un état médiocre, passable, parfois bon, mais certaines collectivités biotiques, à certains sites, étaient dans un état bon ou excellent par rapport à d'autres sites du lac Ontario. Citons par exemple les poissons au marais de Wilmot Creek et les oiseaux nicheurs aux marais de Cranberry, Oshawa Second, Wilmot Creek, et Westside.

Il y a clairement lieu de mieux comprendre les limites de la communication de résultats par IIB. En particulier, il faut recueillir d'autres données pour affiner l'estimation des erreurs de valeurs de l'IIB. En connaissant les limites de confiance des IIB, il sera plus facile de comprendre les tendances à long terme et de prendre des décisions de restauration et de conservation.

Ce rapport permettra aux Comités de mise en application et des méthodes du DRCWMP d'évaluer l'avancement du projet et de formuler des recommandations touchant l'orientation et les priorités du projet. En outre, les intervenants pourront reconnaître la valeur de ce projet, alors qu'il en est encore à ses étapes initiales de comptes rendus.

Ce rapport technique de l'année 2 :

1. expose en détail l'état biologique et géophysique actuel des terres humides de la Région de Durham;
2. fournit une précieuse ressource d'orientation des projets de restauration et de conservation des terres humides riveraines de la Région de Durham;
3. fournit la base et la méthode de surveillance à l'échelon régional des Grands Lacs.

Le *Great Lakes Coastal Wetlands Consortium* (GLCWC) est un projet relevant de la Commission des Grands Lacs, qui établira et mettra en application une structure de surveillance pour les terres humides riveraines à l'échelon du bassin des Grands Lacs. Le *Consortium* est un projet de trois ans lancé en novembre 2000 et financé par l'*U.S. Environmental Protection Agency*. Il découle du processus de la CÉÉGL et se compose de scientifiques, de décisionnaires et d'autres personnes, américaines ou canadiennes, qui se consacrent à la science, à la surveillance et à la conservation des terres humides riveraines des Grands Lacs. Il s'attache à améliorer les indicateurs des terres humides riveraines, comme on l'a recommandé à la CÉÉGL de 1998, et à établir des stratégies binationales de surveillance à long terme.

La création de la structure de surveillance du projet de Durham s'appuiera sur l'initiative du GLCWC et on incorporera de nouveaux renseignements dans la conception de la surveillance à mesure qu'ils seront disponibles. La compatibilité qui existe entre les projets de Durham et du GLCWC permettra de comparer les terres humides riveraines de Durham avec d'autres terres humides des Grands Lacs. L'utilisation des résultats du projet de Durham permettra de rendre compte de l'état des terres humides riveraines des Grands Lacs.

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1. INTRODUCTION

1.1 BACKGROUND AND DIRECTION

The Durham Region Coastal Wetland Monitoring Project (DRCWMP) has evolved from an initial concept and agreement in principle in 1999, to a detailed monitoring plan that was implemented in 2002. The first step in the process was development of a project concept and background report on the coastal wetlands within the area of interest. Environment Canada and Central Lake Ontario Conservation Authority (2001) compiled this information, as well as a summary of recent monitoring activities. The benefits of a coordinated monitoring approach are many, and include:

- Sharing of resources and costs;
- Ability to identify common trends across several watersheds;
- Implementation of a practical, standardized and scientifically-robust monitoring program;
- Data sharing among agencies to reduce duplication;
- Improved support to deliver a long-term monitoring project; and
- Assessment of coastal wetlands at a regional scale.

Building on this background report, Monitoring and Implementation Committees were established to oversee project development and delivery, respectively. The Monitoring Committee, made up of interested stakeholders, was charged with the development of specific project goals and objectives, and with recommending monitoring protocols to meet those objectives, which were compiled in April 2001 (Gartner Lee Limited 2001).

In March 2002, a monitoring methodology handbook was released to direct data collection efforts within the project (Environment Canada and Central Lake Ontario Conservation Authority 2002a). The first year of data collection and compilation occurred during 2002.

In June 2003, the Durham Region Coastal Wetland Monitoring Project: Interim Report (Environment Canada and Central Lake Ontario Conservation Authority 2002b) outlined Year 1 findings based on preliminary data and analysis. The report also evaluated the suitability of the data collection methodology and analysis. Methodologies were revised accordingly in spring 2003 and data collection resumed through the 2003 field season.

This technical report: 1) details the current biological and geophysical state of Durham Region wetlands; 2) serves as a resource for directing coastal wetland restoration and conservation projects in Durham Region; and, 3) provides a foundation and methodology for regionally-based monitoring in the Great Lakes.

1.2 PROJECT FRAMEWORK

The primary goal of the Durham Region Coastal Wetland Monitoring Project is to implement a long-term monitoring program that enables reporting on the condition of coastal wetlands in the Region. Additionally, the information collected through the monitoring program will be used to assess the impacts of human activities on the condition of these wetlands and provide direction for actions where appropriate. These goals were incorporated into a framework (Figure 1.2-1), which provides the basis for development of the Durham Region Coastal Wetland Monitoring Project.

To summarize, biological monitoring requires five types of information (Karr and Chu 1999):

1) present biological condition;
2) reference biological condition (i.e., no or minimal human disturbance);
3) present geophysical setting;
4) reference geophysical setting; and
5) activities of humans that are likely to alter both the biological and geophysical conditions.

Managers, policy-makers and society-at-large can use this information to decide if current wetland condition is acceptable or not, to set biological goals that are appropriate for the wetland, and to assist in the development of appropriate conservation activities.

Although the Implementation Committee has been responsible for defining the project direction, identifying resourcing requirements and publicizing the project, the Monitoring Committee has identified and set priorities for specific wetland attributes of importance to the stakeholders (Gartner Lee Limited 2001). These attributes were identified by drawing largely on coastal wetland indicators as identified in the State of the Lakes Ecosystem Conferences (SOLEC) (Bertram and Stadler-Salt 2000) and Bird Studies Canada's Marsh Monitoring Program (Weeber and Vallianatos 2000). The biennial SOLEC conferences focus on reporting on progress being made towards the goals of the Great Lakes Water Quality Agreement, which are to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem (www.on.ec.gc.ca/solec).

An additional initiative currently underway that has direct relevance to this project is the Great Lakes Coastal Wetlands Consortium (GLCWC) project under the leadership of the Great Lakes Commission (GLC). This bi-national, multi-partnered initiative arose from the SOLEC process and is focused on developing and implementing a monitoring framework for coastal wetlands at the Great Lakes basin-wide level (www.glc.org/monitoring). The first step in this multi-year initiative will provide a scientific evaluation of coastal wetland indicators and monitoring methodologies. Development of the monitoring framework for the Durham project will draw on the GLCWC initiative and new information will be incorporated into the monitoring design as it becomes available. Activities planned in the GLCWC initiative that have specific value to the Durham project are referenced below. Compatibility between the Durham and the GLCWC projects will enable comparison of Durham Region coastal wetlands to other wetlands around the Great Lakes. Compatibility will also allow the use of Durham project results in reporting on the state of Great Lakes coastal wetlands.

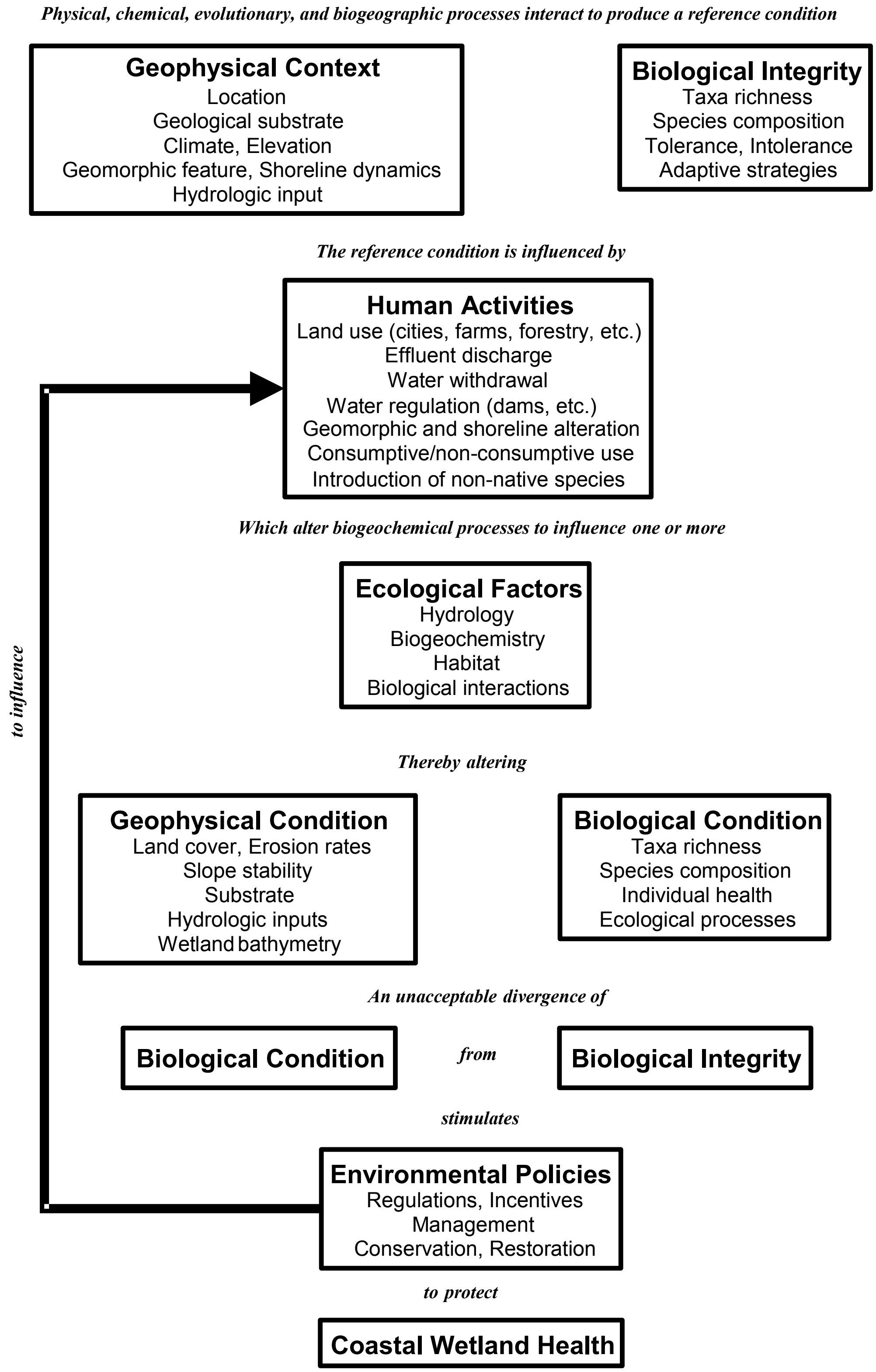

Figure 1.2-1. Relationships among attributes to be measured, understood, and evaluated through biological monitoring. Biological condition is the endpoint of concern (adapted from Karr and Chu 1999 and Mack *et al.* 2000).

1.3 ASSESSING COASTAL WETLAND CONDITION

Wetland Health vs. Integrity

Karr (1996) and Karr and Chu (1999) provide discussions regarding the definition and use of the terms "health" and "integrity" to describe biological systems. The following discussion summarizes and simplifies the points made in these two papers and outlines the applicability of "health" and "integrity" in this report.

Karr and Chu (1999) note that:

> *Webster's dictionaries define health as a flourishing condition, well being, vitality, or prosperity. A healthy person is free from physical disease or pain; a healthy person is sound in mind, body and spirit. An organism is healthy when it performs all its vital functions normally and properly, when it is able to recover from stresses, when it requires minimal outside care. A country is healthy when a robust economy provides for the well-being of its citizens. An environment is healthy when the supply of goods and services required by both human and nonhuman residents is sustained. To be healthy is to be in good condition.* [p. 16]

It is clear that health is a subjective term. For coastal wetlands, one person may define a healthy wetland as one that affords ample opportunities for observing different bird species. Another person may define it as one that provides a good harvest of wild rice. Other definitions may be related to pike habitat, plant assemblage, or water quality.

For the DRCWMP, coastal wetland health can be defined through the overall condition of biotic communities being monitored (e.g., fish, birds, amphibians, vegetation). But how is the condition of a biotic community defined – how is its health measured? A tool used to measure biotic community health is the community's biotic integrity. Karr (1996) defines biotic integrity as:

> *…the capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat of a region.* [p. 101]

Karr (1997) clarifies that:

> *Inherent in this definition is that: (1) living systems act over a variety of scales from individuals to landscapes; (2) a fully functioning living system includes items one can count (the elements of biodiversity) plus the processes that generate and maintain them; and (3) living systems are embedded in dynamic evolutionary and biogeographic contexts that influence and are influenced by their physical and chemical environments.* [p. 483]

So what range of biotic integrity is considered healthy or unhealthy? A healthy level of integrity can be subjective and must be defined by the DRCWMP stakeholders. However, the definition of a healthy wetland should be based on Lake Ontario coastal wetlands that experience the least disturbance (Figure 1.3-1). Using these less disturbed wetlands, the stakeholders can objectively set thresholds of biotic integrity that reflect a healthy wetland.

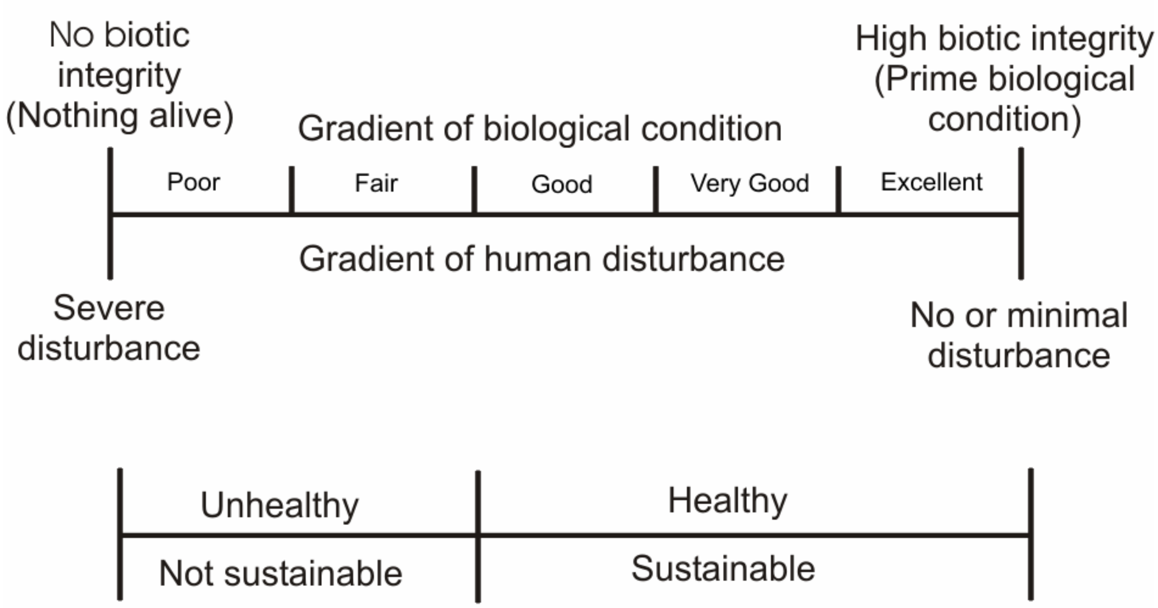

Figure 1.3-1. Gradient of biological condition in relation to a level of human disturbance (top). By combining the condition of several biological communities, a parallel gradient (bottom) representing the health of the wetland can be determined. Subsequently, a specific range on the health gradient can be set as a goal for each wetland (adapted from Karr and Chu 1999).

1.4 DETERMINING BIOTIC INTEGRITY OF WETLAND COMMUNITIES

A multimetric approach was used to determine biotic integrity of coastal wetland communities. Metrics are biological attributes that are known to respond in specific and predictable ways to changes in wetland condition (Figure 1.4-1). For example, coastal wetland biological community metrics for the submerged aquatic vegetation (SAV) community could be percent cover, exotic species richness, mean coverage of turbidity intolerant taxa, or overall floristic quality. In Figure 1.4-1, biological attribute A increases with increasing disturbance and is an appropriate metric for biological monitoring. Conversely, biological attribute B is robust within the range of disturbances experienced and does not respond predictably to wetland disturbance. Biological attribute B is not a suitable metric.

Once a suite of suitable metrics are defined for a biotic community, the metrics are scored, standardized and combined. This creates an Index of Biotic Integrity (IBI) for the particular community. The multimetric IBI incorporates several suitable biological attributes to increase the accuracy in describing the condition of the particular biological community. Details of the scoring, standardizing, and combining metrics are described in section 3.2.

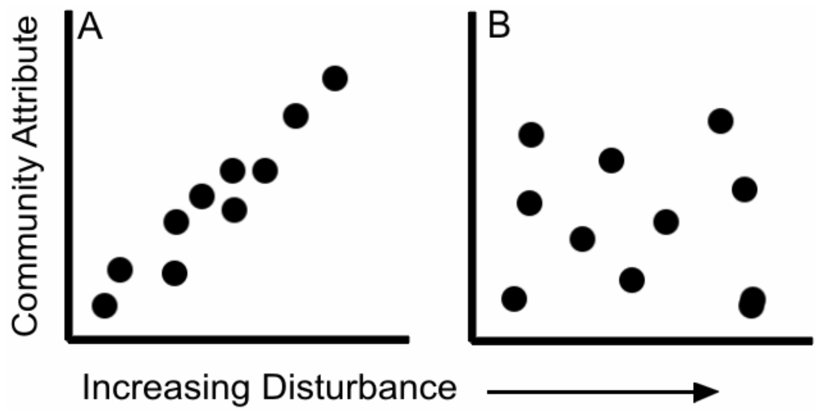

Figure 1.4-1. The theoretical response of biological community attributes A and B to increasing disturbance.

1.5 STUDY SITES

Fifteen coastal wetlands have been identified for monitoring within Durham Region (Figure 1.5-1). These wetlands vary in size, level of disturbance and hydrogeomorphic features. The source of hydrologic input to the wetland is an important factor in determining the influence of adjacent human activities on the biological condition of the wetland. For this reason, coastal wetlands are divided into two classes based on the geomorphic formation and dominant hydrological input, i.e., barrier beach lagoon or drowned river-mouth (Table 1.5).

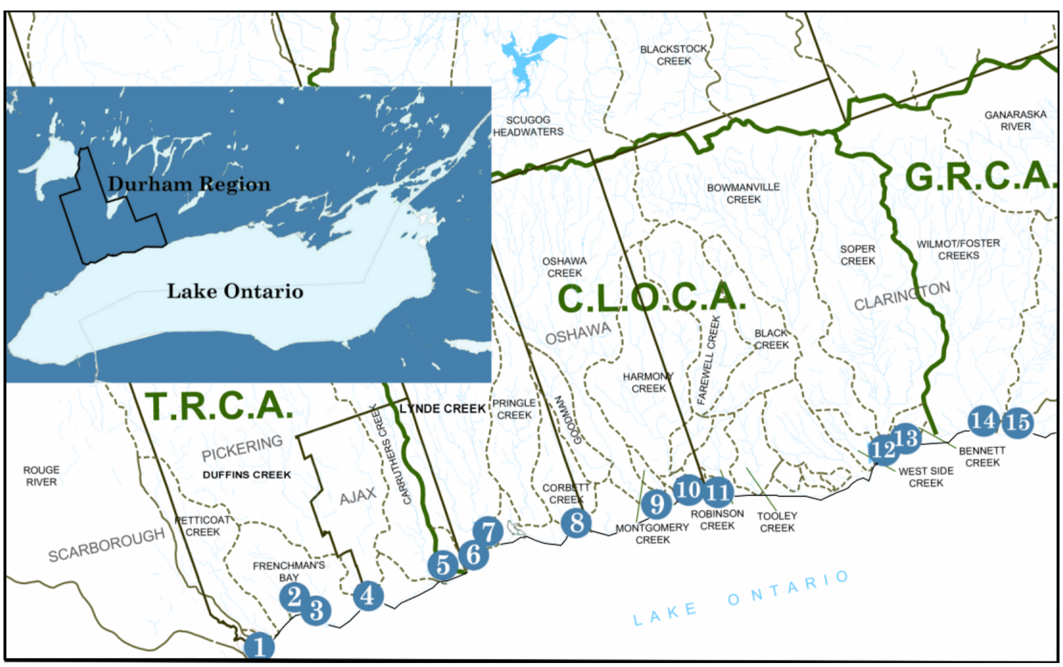

Figure 1.5-1. The location of the 15 Durham Region coastal wetlands. Wetlands associated with keymap numbers are located in Table 1.5-1.

The following classification is based on the GLCWC Great Lakes Coastal Wetlands Classification System (Albert *et al.* 2003):

1) **Barrier Beach Lagoon:** These wetlands form behind a sand beach or dune barrier. Because of the barrier, there is reduced mixing of lake and wetland water.

These wetlands can become hydrologically isolated from the lake. The frequency and length of isolation can vary greatly among sites and between years.

2) **Drowned River-mouth**: These wetlands form where tributary rivers enter the lake, representing a zone of transition from stream to lake. They are characterized by meandering stream channels that are backflooded during high lake levels.

Table 1.5-1. Durham Region coastal wetlands included in the monitoring program.

Wetland Name	Keymap Number	Wetland Type*	Conservation Authority**	Area (hectares)
Rouge River Marsh	1	DR	TRCA	59
Frenchman's Bay Marsh	2	BB	TRCA	23
Hydro Marsh	3	BB	TRCA	24
Duffins Creek Marsh	4	DR	TRCA	69
Carruthers Creek Marsh	5	DR	TRCA	141
Cranberry Marsh	6	BB	CLOCA	47
Lynde Creek Marsh	7	DR	CLOCA	130
Corbett Creek Marsh	8	DR	CLOCA	21
Pumphouse Marsh	9	BB	CLOCA	7
Oshawa Second Marsh	10	BB	CLOCA	133
McLaughlin Bay Marsh	11	BB	CLOCA	42
Westside Marsh	12	BB	CLOCA	45
Bowmanville Marsh	13	DR	CLOCA	29
Wilmot Creek Marsh	14	DR	GRCA	26
Port Newcastle Wetland	15	DR	GRCA	8

Shading indicates priority sites (see text)
* DR = drowned river-mouth; BB = barrier beach lagoon
** TRCA = Toronto and Region Conservation Authority
CLOCA = Central Lake Ontario Conservation Authority
GRCA = Ganaraska Region Conservation Authority

Priority Sites

Priority sites (Table 1.5-1) were selected by the DRCWMP Monitoring Committee (as reported in Gartner Lee Ltd. 2001) that represented the typical coastal wetlands in the Region. The selection criteria for the priority sites include:

1) wetlands with barrier beach and those that are more or less permanently open to Lake Ontario;
2) wetlands that may be subject to significant change;
3) sites with different landowners or managers; and
4) sites that attract a variety of stakeholder interest.

These sites are a priority for monitoring in the event of resource limitations and for pilot methodology testing.

Additional Wetlands

The condition of biotic communities in Durham Region coastal wetlands was assessed in the context of additional Lake Ontario coastal wetlands. These additional wetlands represent sites that experience a range of disturbance but, in general, are less disturbed than the Durham Region counterparts (Figure 1.5-2).

1.6 REPORT LAYOUT

The main purpose of this report is to describe physical and biotic conditions in Durham Region coastal wetlands and watersheds (Table 1.6-1). The physical conditions are described first (section 2). A subset of these physical parameters (e.g., turbidity, adjacent land-use) is analyzed to create estimates of wetland disturbance for each site in section 3. Using these disturbance estimates, the approach and methods used to create the IBIs are described. These methods are applied to the data collected for each biotic community monitored in section 4. IBIs developed in this report are based on published literature and current science (Table 1.6-1). However, the IBIs referred to in the table were not designed specifically for Durham Region or Lake Ontario coastal wetlands. Therefore, the suitability of using these IBIs to report on Durham Region coastal wetlands is also examined in section 4. In addition, the extent and nature of land cover within and adjacent to the wetland is examined.

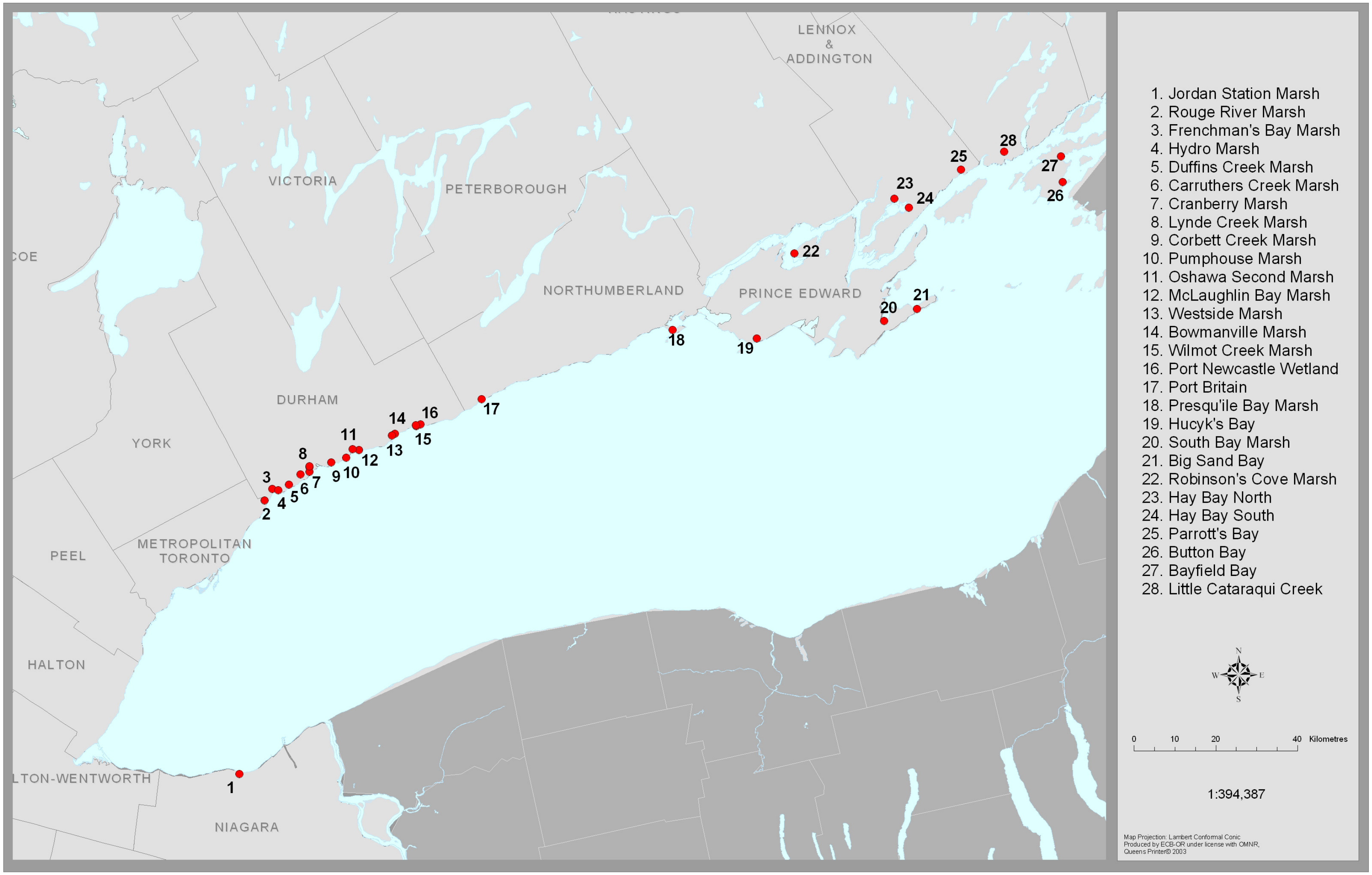

Figure 1.5-2. The location and names of Durham Region and additional Lake Ontario coastal wetlands

Table 1.6-1. Summary of goals and monitoring tasks for the Durham Region Coastal Wetland Monitoring Project.

Goals		Monitoring Task	Method Summary
GEOPHYSICAL CONDITION	Wetland	Turbidity	• Monthly collections of multiple geo-referenced samples of each wetland during the growing season • At more intensive/key sites, measurements taken at weekly intervals during the summer growing period to capture temporal variation
		Water levels	• Lake Ontario water level data used for wetlands with constant connection to the lake • For wetlands frequently closed off from the lake, water level data loggers were used
		Sediment quality	• Sediment contaminant analysis (Metals, PCBs, OCs, PAHs) • 3 homogenized surficial sediment samples stratified across wetland
		Water quality	• One-time collection of water quality parameters • Data used to assess disturbance at wetland
		Wetland bathymetry	• Pilot methodology employed (2002-2003) to determine the efficacy of bathymetric monitoring using a boat equipped with depth sounding and GPS equipment
	Watershed	Land cover	• Entire watersheds mapped using air photos with focus on land cover • ELC (Community Series) to incorporate all cultural designations (currently under development) and summarize to subwatershed
		Land-use changes in adjacent uplands	• Land-use within 1,000 metres of the MNR evaluated wetland boundary identified and monitored for change • Data used to assess disturbance at wetland
		Land-use change in watershed	• Map at Regional or Municipal Official Plan level
		Public ownership of watershed lands	• Using digital parcel data (Terranet), if available; liaising with municipalities
		Sediment and nutrient loads	• When available use Digital Elevation Model for each watershed (basic quantitative data for deriving terrain elevation, slope and/or surface roughness information)

Table 1.6-1 Continued.

Goals		Monitoring Task	Method Summary
BIOLOGICAL CONDITION	Plant Community Condition	Wetland and adjacent land vegetation communities	• Wetland and adjacent upland cover mapped through current Ecological Land Classification (ELC) methodology to the community unit of Vegetation Type
		Key habitats	• Identification and mapping of specific habitats of known importance to species at risk in Ontario • GIS analysis task that requires data acquisition from ELC undertaken within this program as well as other appropriate sources
		Submerged plant community condition	• Submerged aquatic vegetation (SAV) sampled in 20 one-metre square quadrats randomly located within the open water zone of each wetland • Data analyzed by calculating an IBI based on Albert and Minc (In press)
	Fish and Wildlife Community Condition	Aquatic macroinvertebrate community condition	• Collected aquatic macroinvertebrates from water column at three replicate locations using sweep net sampling • Data analyzed by calculating an IBI based on Burton *et al.* (1999)
		Fish community condition	• Collected fish through electrofishing in various habitat types along a 44-m transect • Index of Biotic Integrity (IBI) analysis used to compute an IBI based on Minns *et al.* (1994)
		Breeding bird community condition	• Data collected through Marsh Monitoring Program (MMP) • Data analyzed by calculating an IBI based on Great Lakes Coastal Wetlands Consortium findings
		Amphibian community condition	• Data collected through Marsh Monitoring Program (MMP) • Data analyzed by calculating an IBI based on Great Lakes Coastal Wetlands Consortium findings
		Measure wildlife species richness (birds, amphibians)	• Objective not being reported on, but records will be collected through “Identification of Key Habitats” protocol

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2. GEOPHYSICAL CONDITION

2.1 WETLAND

2.1.1 Turbidity

Objective

To assess and monitor turbidity in Durham Region coastal wetlands.

Method Summary

The original methodology (Environment Canada and Central Lake Ontario Conservation Authority 2002) prescribed using Secchi disk depths as a measure of turbidity. However, in 2002 those partner agencies that had suitable equipment also measured turbidity in Nephelometric Turbidity Units (NTUs). Turbidity was measured monthly during the growing season, i.e., from May to September, at priority sites (see Table 1.5-1) and at least once at the other Durham coastal wetlands.

In 2003, measurements of turbidity were made only using meters capable of recording in NTUs. Turbidity readings were taken monthly during the growing season at most of the 13 coastal wetlands in the TRCA and CLOCA jurisdiction. Samples were taken from at least three locations (inlet, middle, and outlet) in single basin marshes, and one sample was taken from each basin in multi-basin wetlands (e.g., Duffins Creek Marsh). During subsequent sampling events measurements were taken at the same general locations.

Turbidity was also measured once during each of the following monitoring activities: submerged aquatic vegetation (SAV) community sampling (20-30 samples/wetland; section 4.1.3), macroinvertebrate community sampling (six samples/wetland; section 4.2.1) and fish community sampling (4-12 samples/wetland; section 4.2.2). In 2002, GRCA wetlands were sampled for turbidity only during sediment sample collection and in 2003 only during the fish community sampling. GRCA currently does not have turbidity measurement equipment that records in NTUs (M. Desjardins, pers. comm.).

Turbidity readings were taken once in 2003 at additional Lake Ontario wetlands (see Figure 1.5-2) to permit comparison along a gradient of disturbance.

In 2003, turbidity was measured weekly at Lynde Creek Marsh to determine site-specific variability and the potential relationship to local daily rainfall.

Westside Marsh was undergoing construction/enhancement work during 2003, so monthly readings were not taken. However, measurements were taken at this marsh during invertebrate sampling and bird survey fieldwork (section 4.2.3).

Data Analysis

Secchi Depth

By comparing the 2002 turbidity data obtained using a Secchi disk and turbidimeter, it was determined that due to the shallow depth of some coastal wetlands, Secchi depths were not providing accurate turbidity measurements (Environment Canada and Central Lake Ontario Conservation Authority 2003). When Secchi depths were measured it was apparent that, in many instances, only water depths were actually being recorded, i.e., the Secchi disk was still visible when resting on the bottom of the wetland. As such, turbidity measurements in NTU were recommended for future work.

Turbidimeter Measurements

Turbidity data were gathered from regular visits to the study wetlands. Additional turbidity readings were taken during other DRCWMP monitoring tasks mentioned above. During SAV sampling, at least 20 separate turbidity measurements were taken in the wetland, while only three measurements were taken during regular sampling. A monthly mean calculated directly from these data would be greatly influenced by the SAV turbidity samples. To eliminate a bias toward days with many samples, the daily mean was considered as the sampling unit and the monthly mean was calculated from the daily means.

Overall mean turbidity measurements were plotted for all Durham Region coastal wetlands as well as non-Durham coastal wetlands. This method compares marshes with variable sampling efforts (n=3-20), and only general conclusions can be made. This will help determine general trends among these wetlands and reveal how Durham wetlands compare to other Lake Ontario coastal wetlands. A turbidity reading of 30 NTU was used as a benchmark for high turbidity in the coastal wetlands (Canadian Council of Ministers of Environment 1999).

Results

Mean turbidity at all coastal wetlands measured varied greatly (Figure 2.1.1-1). In general, turbidity decreased from west to east, i.e., from more heavily urbanized watersheds to more rural ones. Five of the Durham Region coastal wetlands had mean turbidity values below a threshold of 30 NTU: Cranberry, Corbett Creek, Pumphouse, Oshawa Second, and Wilmot Creek marshes. During 2002, however, Pumphouse Marsh had the highest mean turbidity (Environment Canada and Central Lake Ontario Conservation Authority 2003). In 2003, Corbett Creek Marsh had beaver dams just upstream of the wetland on both the east and west branches, which likely held back much of the sediments.

Only two of the other Lake Ontario wetlands, Jordan Station and Port Britain, had mean turbidity values over 30 NTU. The watersheds of these two wetlands are primarily agricultural.

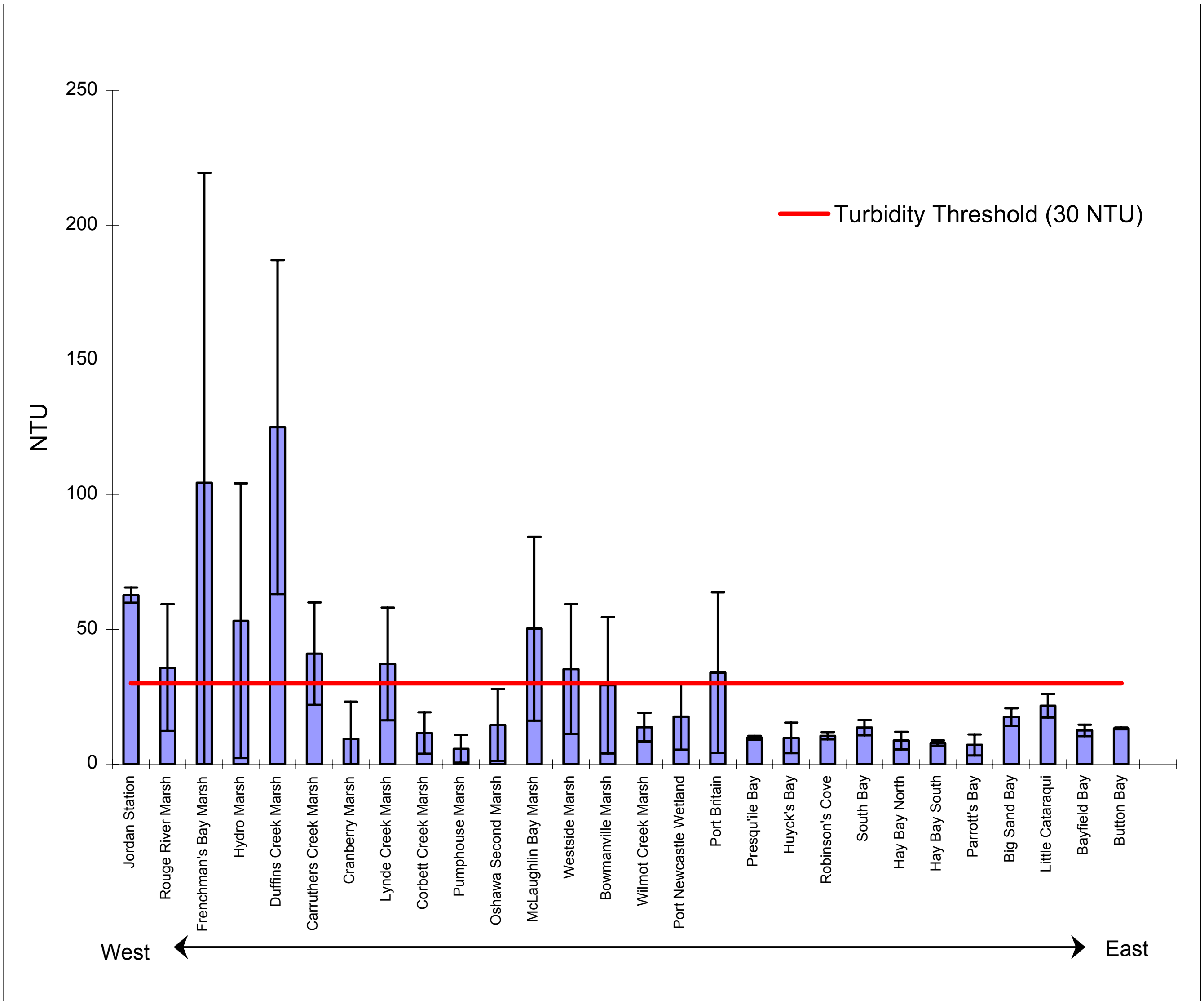

Figure 2.1.1-1. Mean and standard deviation of turbidity readings from May to September, 2003 from Durham Region coastal wetlands and additional Lake Ontario wetlands.

To assess variability at a representative wetland, turbidity was measured weekly at Lynde Creek Marsh during 2003 (Figure 2.1.1-2). Mean daily turbidity ranged from a low of 13.3 NTU to a high of 64.7 NTU. The mean overall turbidity was relatively high at 37.2 NTU.

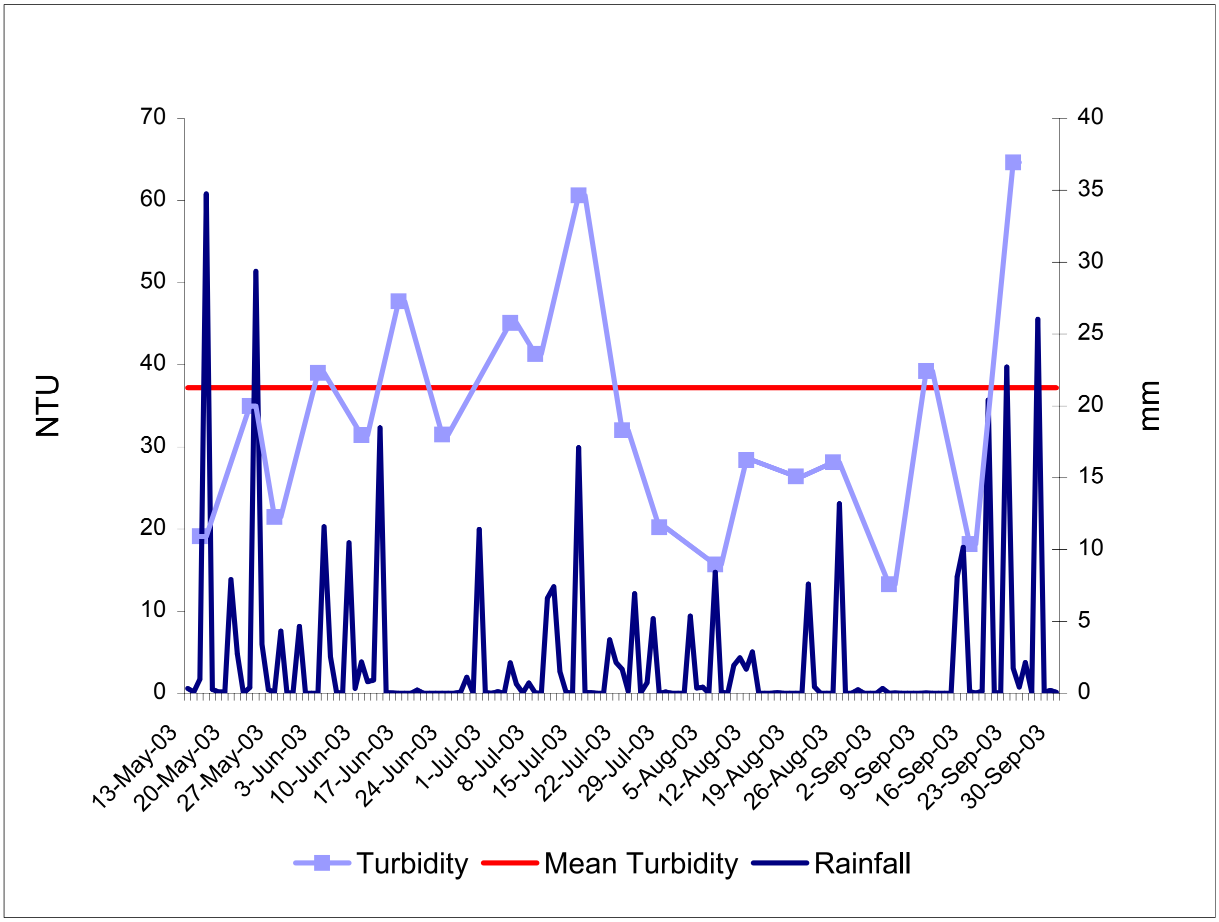

Figure 2.1.1-2. Weekly mean turbidimeter readings (May to September, 2003) from Lynde Creek Marsh and total daily rainfall. Mean overall turbidity at this wetland is shown for comparison.

There is a relationship between turbidity at Lynde Creek Marsh and total daily rainfall (Figure 2.1.1-2). A significant correlation exists between the mean daily turbidity and two-day rainfall totals, i.e., a sum of rainfall on the day of the measurement and the previous day ($r=0.49$, $p=0.03$, $n=20$). However, from field observations it was apparent that local wind speed and wildlife activity (e.g., carp and waterfowl) could also affect turbidity values at this marsh. Common carp (*Cyprinus carpio)* are known to increase the turbidity of the water they inhabit (Parkos *et al.* 2003).

Inter-annual variation was high at Frenchman's Bay, Hydro, Duffins Creek, Carruthers and Pumphouse marshes (Figure 2.1.1-3). In 2003, mean turbidity was higher at all wetlands except Pumphouse Marsh.

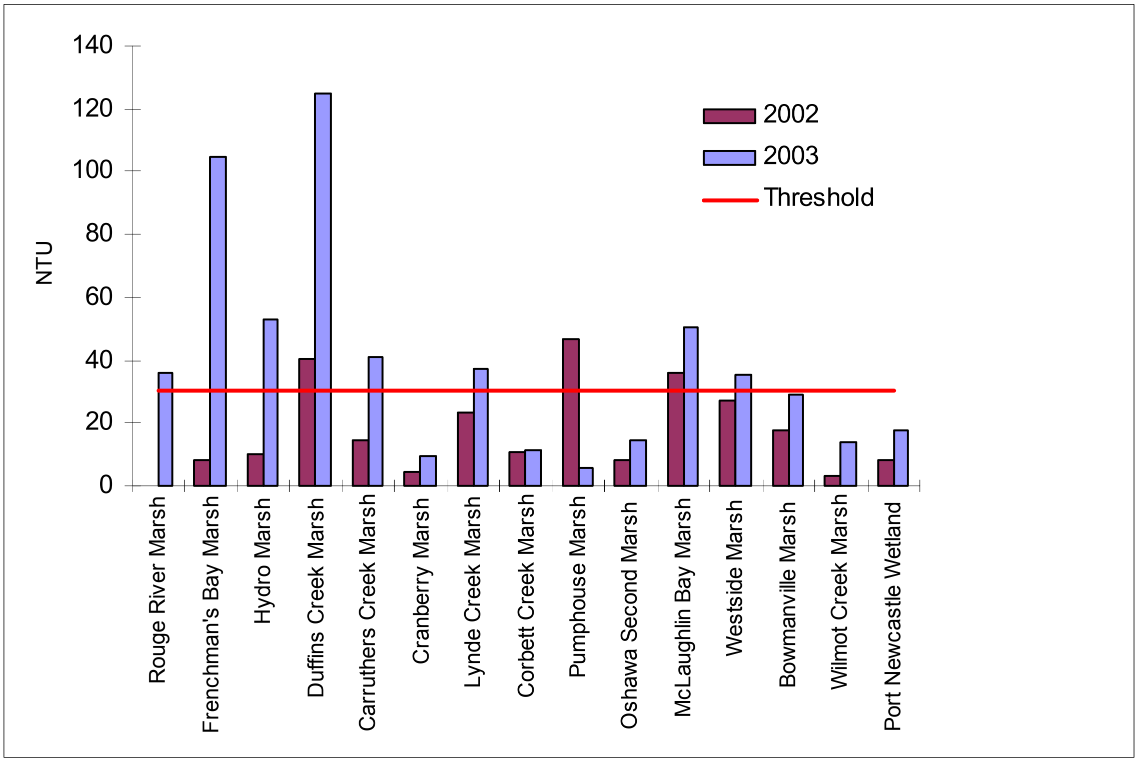

Figure 2.1.1-3. Overall mean turbidity as measured at 15 Durham Region coastal wetlands during 2002 and 2003.

Discussion

Turbidity is a measurement of water clarity and can be impacted by both organic (e.g., algae) and inorganic (e.g., sediment) suspended solids. Turbid waters generally have poorer submerged aquatic vegetation species richness (Lougheed *et al.* 2001) and growth since light is unable to penetrate sufficiently deep in the water column. Decreased aquatic vegetation cover can in turn lower the attractiveness of an area for bird nesting and feeding habitat (Prince 1985). High turbidity can affect the prey capture rate by piscivorous fish, therefore conveying an advantage to prey fish species (De Robertis *et al.* 2003).

CLOCA wetlands were consistently measured for turbidity during 2003 (except Westside Marsh as described above). While some of the wetlands appeared to show similar trends as were noticed in 2002, some were quite different. It is apparent that additional data are required before more sound results and conclusions can be presented.

Of the wetlands with the lowest turbidity, Cranberry, Pumphouse and Oshawa Second marshes have no defined tributaries, no common carp population, and a small watershed. However, Oshawa Second Marsh is only temporarily in this state due to its current state of isolation from Farewell Creek. In contrast, Duffins Creek Marsh (2003) had a very high daily mean turbidity reading (125 NTU). This reading is quite elevated, particularly when instantaneous turbidity values greater than 50 NTU are considered unacceptable to aquatic life (Harvey 1989). Turbidity, based on 10-day averages, is considered at an acceptable level to aquatic life if below 25 NTU.

The weekly turbidity measurements at Lynde Creek Marsh revealed high temporal variability. Unless continuous turbidity monitoring takes place using a data logger or until many more years' of data have been collected, it is unlikely that any further conclusions can be made. In 2002, the mean turbidity at this wetland did not exceed the threshold level, but it did during 2003.

Sources of variability in turbidity measurements include: 1) high rain events during the previous 24-48 hours; 2) some sample areas may have been located where strong winds could create turbid conditions; and 3) carp activity during the spawning season. These may be difficult to control but wind strength and general weather patterns from the previous 48 hours are recorded when taking turbidity measurements. Wind speed data from local weather stations are unlikely to correlate well with turbidity measurements unless the station is immediately adjacent to the wetland in question.

In general, ecological response to increasing levels of turbidity is not well documented for wetland environments; however, ecological impacts are likely as turbidity values increase above 10 NTU (Canadian Council of Ministers of the Environment 1999). Turbidity values >30 NTU represent highly turbid water. Growing season turbidity values below 10 NTU are common for less impacted coastal wetlands associated with Lake Ontario and the Great Lakes basin (Environment Canada 2003, Crosbie and Chow-Fraser 1999).

Eight of the wetlands had a mean turbidity that is considered high (>30 NTU). Increased monitoring efforts (i.e., once weekly or daily readings for a 10-day period) may be needed to determine whether these are real trends.

Future Considerations

Although turbidity measurements were not taken 10 days in a row for this project, it is possible that both Duffins Creek and Lynde Creek marshes would have exceeded the threshold level of >30 NTU for a 10-day average. As suggested previously (Environment Canada and Central Lake Ontario Conservation Authority 2003), collecting 10-day averages should be considered in wetlands with consistently high turbidity readings over the growing season.

Continuous automated water quality monitoring of turbidity would be ideal in terms of data collected; however, the loggers are high maintenance items due to the buildup of algae, etc. on the logger or its housing (Burke 2002). The set up of such a device is beyond the scope of this project at this time.

Lougheed *et al.* (2001) concluded that high nutrient and turbidity values in lower Great Lakes coastal wetlands were strongly linked to watershed land-use. As a larger percentage of a watershed is occupied by typical urban land-use patterns (i.e., a high percentage of impervious ground cover and storm sewers that flow directly into creek), the greater the likelihood of high-flow storm events in the tributaries leading to the wetland. These storm events typically have high erosion potential and result in increased sediment load. As more data are collected, analyses comparing watershed land-use and turbidity will be performed.

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2.1.2 Water Levels

Objective

To monitor water levels in Durham Region coastal wetlands.

Method Summary

In 2003, water levels were measured using Solinst Mini LT water level data loggers at the seven wetlands that may periodically close off from the lake due to barrier beach or sand bar formation. The data loggers were installed in May in most cases and taken out in October 2003. Calibration of the loggers to Lake Ontario level was done using a laser level and information regarding current (±15 minutes) lake levels from the Canadian Hydrographic Survey. Water levels in wetlands that were always connected to the lake were gathered from data published by the Canadian Department of Fisheries and Oceans (http://chswww.bur.dfo.ca/danp/network_means.html).

In 2002, volunteers recorded once-weekly water levels at seven of the wetlands. However, data loggers provide near-continuous monitoring of water levels which, unfortunately, is not possible through the use of volunteers. The potential errors in conversion from wetland water level to lake level and the desire to obtain continuous water levels to capture significant rainfall events suggest that using data loggers may be preferable. Also, the staff gauges can be targeted by vandals.

Results

The data logger at McLaughlin Bay was lost, likely due to the heavy recreational usage of this wetland. Obtaining the precise UTM coordinates when installing the loggers was critical, since some would otherwise have been very difficult to relocate.

The daily mean water levels for the wetlands show patterns reflecting their connectivity to the lake (Figure 2.1.2-1). Cranberry, Pumphouse and Oshawa Second marshes were closed off from the lake for the entire period of water level measurements (March to November). Not surprisingly, their water levels do not mirror Lake Ontario levels. In early 2003, the water at Oshawa Second Marsh was partially drawn down, which is reflected in the relatively low water levels at this wetland.

Lynde Creek Marsh was open to the lake during the entire field season and its level most closely follows the lake level. Corbett Creek Marsh was open or closed to the lake at various times of the year. Its water levels may have been affected by the construction of a second beaver dam along the west branch of the creek. Wilmot Creek Marsh was similarly open and closed but it tended to be perched above the lake, which was particularly apparent during the low lake levels in late summer (Figure 2.1.2-1).

Total daily rainfall (a mean of several stations in south Durham Region) does correspond well to water levels at some of the wetlands (Figure 2.1.2-1). At those wetlands with little or no creek inflow, Cranberry, Pumphouse, and Oshawa Second marshes, water levels did not show the sharp peaks associated with high rainfall events that were apparent at some other wetlands (e.g., Corbett Creek and Wilmot Creek marshes).

The other Durham Region coastal wetlands were open to the lake throughout the year and those with marinas will always be open (i.e., Frenchman's Bay Marsh and Hydro Marsh, Bowmanville Marsh, and Port Newcastle Wetland). Rouge River, Duffins Creek, and Carruthers Creek marshes were also open to the lake and their water levels fluctuate with lake levels. In 2002, staff gauges were installed at Frenchman's Bay, Hydro Marsh, Duffins Creek, and Carruthers Creek marshes, but these were quickly vandalized (TRCA, pers. comm.).

Westside Marsh was not included in data collection efforts in 2003, due to the recent wetland alteration and construction activity.

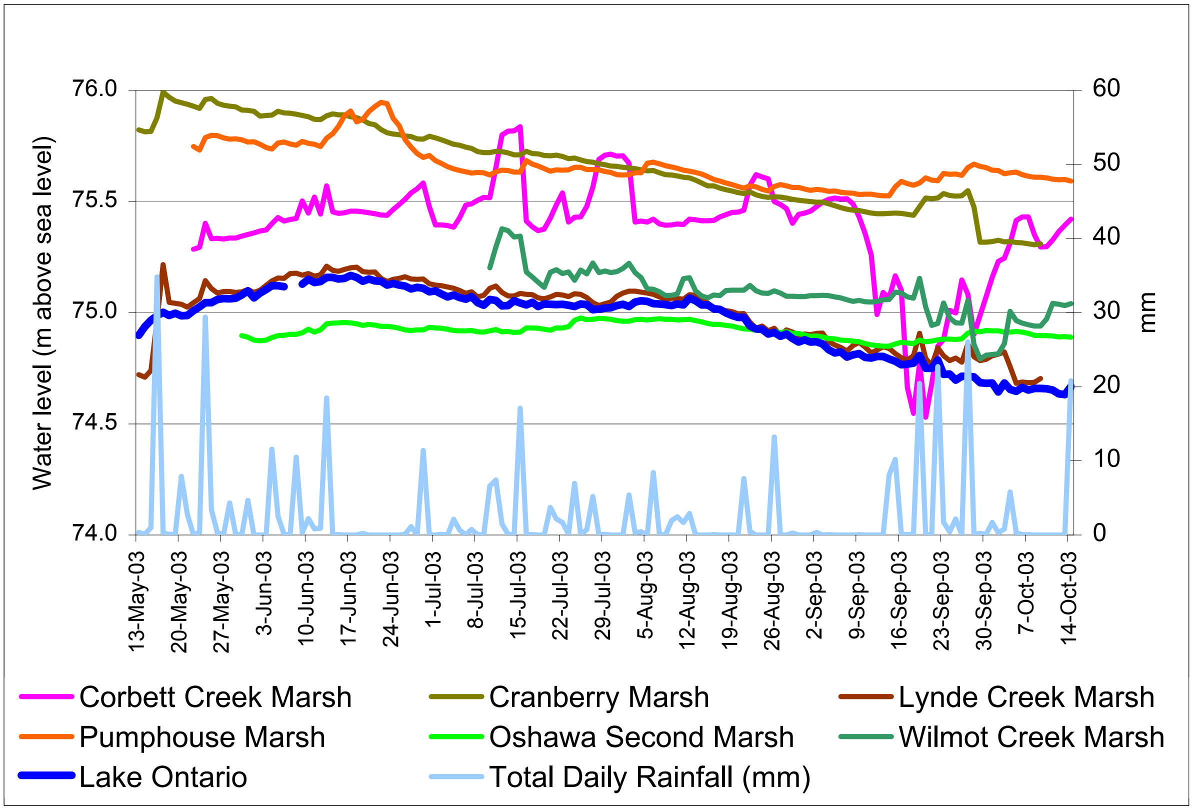

Figure 2.1.2-1. Water levels from six Durham Region coastal wetlands with actual or potential hydrological isolation from Lake Ontario (through barrier beach formation).

Discussion

Water levels at Cranberry Marsh and Oshawa Second Marsh were primarily influenced by water control structures. At Cranberry Marsh, CLOCA has been undertaking a rehabilitation project. During April and May of 2002, water levels in the wetland were deemed undesirably high to permit regeneration of aquatic plants, particularly soft-stemmed bulrush (*Scirpus validus*), so the control structure was opened to permit flows out of the wetland (I. Kelsey, CLOCA, pers. comm., May 2002). The levels were not manipulated during the rest of the season. During 2003, high levels were maintained early in the field season since the marsh had almost dried out during the late summer of 2002.

In 2001, a Ducks Unlimited Canada (DUC) project was initiated at Oshawa Second Marsh. The first stages involved building a dike along the west side of the wetland and diverting its tributary, Farewell Creek, directly into Lake Ontario. A fishway was built between the marsh and creek to facilitate fish passage. The water level control structure with a fishway and carp barrier kept marsh water levels above creek water levels for much of the summer (O. Steele, DUC, pers. comm.).

Water level data can provide insight into possible stressors or a diagnostic understanding of changes (e.g., meadow marsh plant species composition, emergent macrophyte expansion) that occur within the wetland. Water levels within Great Lakes coastal wetlands can fluctuate significantly over short periods of time (days) due to the effects of lake seiches and closures at the outlet of a wetland to the lake.

For wetlands that periodically close off from the lake due to sand bar formation, monitoring water levels is important as they can vary by up to ±1 metre compared to lake levels. This magnitude of fluctuation can have dramatic effects on aquatic plant communities and water level-sensitive fauna (e.g., Black Tern [*Chlidonias niger*] floating nests), but would not be apparent from Lake Ontario water level data. It is important, therefore, to continue monitoring wetland water levels annually.

Water levels on the Great Lakes fluctuate on three different time-scales: short-term (i.e., measured in minutes or days; regular seasonal fluctuations; and longer term (i.e., those measured in years or decades) (Mortsch 1998). Short-term changes in water levels, such as those caused by wind, storm surges and seiches do not generally result in long-term ecological change (Whillans 1985). Extreme water level increases can, however, be sufficient to drown nests of some bird species and are still important to track and understand.

The timing of water level fluctuations can also affect vegetation communities. For example, water levels that are lowest in winter (as they usually are in Great Lakes coastal wetlands) and highest in early summer, yield desirable balance of open water and emergents (Mortsch 1998). The Durham Region coastal wetlands that are open to lake inundations (Rouge River Marsh, Frenchman's Bay Marsh, Hydro Marsh, Duffins Creek Marsh, Carruthers Creek Marsh, Bowmanville Marsh, and Port Newcastle Wetland) do follow this general pattern of low winter and higher summer water levels. Many of these wetlands, however, are impacted by other factors and therefore do not display the balanced open water/emergent habitats. Cranberry and Pumphouse marshes, both isolated from the lake throughout the year, display a water level cycle that is generally more associated with inland wetlands, where maximum levels occur in spring after snowmelt and lowest levels are in the autumn (Mortsch 1998). These wetlands therefore may not fit with the classic definition of Great Lakes coastal wetlands.

Since 1958, Lake Ontario water levels have been regulated at the Saunders-Moses dam in Cornwall, which results in less extreme levels than would naturally be the case. Water level fluctuations are necessary to maintain high vegetation species diversity in wetlands: dominant emergent species (e.g., *Typha* spp.) can be curtailed when water levels are not suitable for them. In addition, fluctuating water levels help flush out the wetlands and, during low water periods, favourable conditions for seed germination often occur in exposed sediments.

Through long-term monitoring of this parameter, changes in Durham Region coastal wetland water levels can be tracked and, with increased data, water level changes can be related to changes in other biotic and abiotic features.

Future Considerations

Water levels will continue to be monitored every year during the growing season. Further efforts will be made to better understand the dynamics of each wetland. The possibility of climate change altering water levels in the Great Lakes (Mortsch 1998) adds another reason for the continued monitoring of this parameter.

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2.1.3 Sediment Quality

Objective

To assess and monitor the quality of sediments at sites upstream of and within each Durham Region coastal wetland.

Method Summary

Sediment samples, consisting of many subsamples, were taken from each site in a manner that was representative of the overall sediment quality at that site. Only the very fine-grained surface deposits, to a maximum depth of approximately one or two cm, depending on the site, were collected. These surface sediments better represent relatively recent rather than historic deposition.

Targeted compounds include those that are typically associated with sediment, such as organochlorines (including DDT and PCBs), metals, and polycyclic aromatic hydrocarbons (PAHs). Targeting these compounds is appropriate for sediment quality investigations since there is increased probability of detecting these compounds, compared with water quality measurements, if they exist at the site. Additional and more detailed methods are in Appendix F.

Data Analysis

The sediment quality results were compared with federal (Canadian Council of Ministers of the Environment; CCME 2002) and provincial (Persaud *et al.* 1992) sediment quality guidelines. In total, 32 parameters were compared to the federal guidelines and 40 parameters could be compared with the provincial guidelines. Twenty-three of the parameters are common between the two guidelines.

The Canadian Environmental Quality Guidelines (CCME 2002) are derived from available toxicological information and provide scientific benchmarks and reference points for evaluating the potential for observing adverse biological effects in aquatic systems. A lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), represents the level above which adverse effects are expected to occur frequently. Fewer than 25 percent of adverse effects (in the CCME Biological Effects Database for Sediments) occur below the TEL and more than 50 percent of adverse effects occur above the PEL.

Ontario's Sediment Quality Guidelines (Persaud *et al.* 1992) include a lowest effect level (LEL) and a severe effect level (SEL). The LEL and SEL are based on the long-term effects that the contaminants may have on sediment-dwelling organisms. The LEL indicates a level of contamination that has no effect on the majority of the sediment-dwelling organisms. Levels of contaminants at or above the SEL are considered heavily polluted and likely to adversely affect the health of sediment-dwelling organisms. If the level of contaminant exceeds the LEL or the SEL then testing may be required to determine if the sediment is acutely toxic to organisms.

A Sediment Quality Index (SQI) was calculated for each wetland and tributary site using the procedures first developed for the calculation of a Water Quality Index (WQI; CCME 2001) and adopted for sediments by EHD-OR, Environment Canada. The SQI integrates the sediment chemistry information to provide a relative assessment of the risk to sediment-dwelling organisms at a particular site based upon comparison with sediment quality guidelines. Briefly, the SQI calculates the number of sediment quality exceedences and the magnitude of those exceedences at a given site, and provides an integrated score to indicate the overall contaminant status of the sediments at the site. It differs from the WQI in that the *frequency* of any guideline exceedences is not considered. The SQI was intended for comparison with federal environmental quality guidelines and, as such, interpretation of the scores depends upon the particular federal sediment quality guidelines that are used (i.e., TELs vs. PELs). For this study, the more stringent TELs were used for SQI calculation. The categorization and interpretation of index values is currently based upon those developed for the WQI (Table 2.1.3-1). SQI values were not calculated for the wetland outflow sites sampled by CLOCA and GRCA because only metals and physical property results were reported for those sites.

Table 2.1.3-1. Sediment Quality Index classification and interpretation.

Sediment Quality Index	Classification of Index Values	Interpretation of Index Values
95 – 100	Excellent	Virtual absence of threat or impairment; conditions very close to natural levels
80 – 94	Good	Minor degree of threat or impairment; (few) conditions depart from natural or desirable levels
65 – 79	Fair	Usually protected but occasionally threatened or impaired; (some) conditions depart from natural or desirable levels
45 – 64	Marginal	Threatened or impaired; (many) conditions depart from natural or desirable levels
0 – 44	Poor	Threatened or impaired; (most) conditions depart from natural or desirable levels

The sediment quality results for tributary inflow sites were also compared with other tributaries sampled by EHD-OR in 100 Canadian tributaries draining into Lake Erie and 130 tributaries draining into Ontario in 2001 and 2002, respectively (Dove *et al.* 2002, 2003). Such comparisons are useful for ranking the contaminant status with respect to other tributaries to the lower Great Lakes.

Results

All laboratory results are provided in Appendix F. Several parameters, most notably the PCBs and PAHs, were observed to be lower for wetland and outflow sites sampled by the Toronto and Region Conservation Authority (TRCA) compared with the inflow (tributary) sites sampled across Durham Region by Environment Canada and the other wetland and outflow sites sampled by the other conservation authorities. The cause of these differences is not clear but is most likely due to variations of analysis protocols and equipment used by different laboratories. The source of the differences is currently under investigation.

The sediment quality results were compared with the federal sediment quality guidelines. A tabulation of the number of sediment quality guideline exceedences is provided in

Table 2.1.3-2. The sediment quality guideline exceedences are listed more explicitly for each marsh in Table 2.1.3-3. In general, the most numerous exceedences were observed for PAH compounds and the fewest exceedences were noted for organochlorine compounds.

Organochlorines
The banned pesticide DDT (including its metabolites DDD and DDE) was the most commonly detected organochlorine. This result is consistent with the results noted for lower Great Lakes tributaries (Dove *et al.* 2002, 2003). DDT is known to be highly persistent, and it is thought that this persistence, rather than continued use, accounts for its presence in tributary and marsh sediments.

Table 2.1.3-2. Summary of federal sediment quality guideline exceedences in inflow and marsh sites in 2002.

Organochlorines			Metals			Polycyclic Aromatic Hydrocarbons		
Parameter	TEL	PEL	Parameter	TEL	PEL	Parameter	TEL	PEL
Endrin aldehyde	0	0	Arsenic	1	0	Naphthalene	0	0
Toxaphene	0	0	Cadmium	22	0	Acenaphthylene	8	0
Lindane	0	0	Chromium	2	1	Acenaphthene	5	0
Chlordane	0	1	Copper	10	0	Fluorene	4	0
t-DDD	0	1	Lead	7	1	Phenanthrene	8	1
t-DDE	11	9	Zinc	12	2	Anthracene	5	0
t-DDT	3	0	Mercury	1	0	Fluoranthene	17	0
Dieldrin	0	0				Pyrene	17	2
Endrin	0	0				Benzo(a)anthracene	19	1
Heptachlor epoxide	0	0				Chrysene	15	1
PCB Aroclor 1254	0	0				Benzo(a)pyrene	14	1
Total PCB	5	0				Dibenzo(a,h)anthrac-ene	7	1

Table 2.1.3-3. The number of organochlorine (PCB and pesticide), PAH, and metal parameters exceeding federal TEL and PEL sediment quality guidelines at wetland sites in 2002.

		Pesticide		PAH		Metal	
Wetland	Sampled By:	TEL	PEL	TEL	PEL	TEL	PEL
Rouge River Marsh	TRCA	0	0	0	0	0	0
Frenchman's Bay Marsh	TRCA	0	0	0	0	1	0
Hydro Marsh	TRCA	0	0	2	0	4	1
Duffins Creek Marsh	TRCA	0	0	0	0	0	0
Carruthers Creek Marsh	TRCA	0	0	0	0	0	0
Cranberry Marsh	CLOCA	0	1	1	0	2	0
Lynde Creek Marsh	CLOCA	0	1	5	0	0	0
Corbett Creek Marsh	CLOCA	2	0	1	0	1	0
Pumphouse Marsh	CLOCA	2	1	5	5	2	1
Oshawa Second Marsh	CLOCA	1	0	8	0	0	0
McLaughlin Bay Marsh	CLOCA	1	0	2	0	0	0
Westside Marsh	CLOCA	0	1	2	0	0	0
Bowmanville Marsh	CLOCA	0	1	0	0	0	0
Wilmot Creek Marsh	GRCA	0	1	0	0	0	0
Port Newcastle Wetland	GRCA	0	2	0	0	0	0
Number of guidelines examined		**12**	**12**	**12**	**12**	**7**	**7**

Chlordane was only detected in one site, Pumphouse Marsh, but it was found at a concentration of 10 nanograms/gram, exceeding the Probable Effect Level of 8.9 ng/g. Chlordane is a banned organochlorine insecticide that was used on crops and for fleas and ticks on pets. Canada discontinued its use in 1990 due to its persistence and toxicity. In a survey of sediment quality in approximately 230 tributaries to the lower Great Lakes, Dove *et al.* (2002, 2003) detected chlordane in only about 20 tributaries. Only seven sites had chlordane concentrations of 10 ng/g or higher.

PCB concentrations were generally low, with concentrations ranging from below detection limit (approximately two ng/g or parts per billion) to 210 ng/g. Most sites had total PCB concentrations below 60 ng/g. The maximum value of 210 ng/g was observed in West Corbett Creek, a tributary to the Corbett Creek wetland. This value exceeds the Threshold Effect Level (TEL; 34.1 ng/g) but not the Probable Effect Level (PEL; 277 ng/g) for Total PCBs. Further downstream in the Corbett Creek wetland, 80 ng/g total PCBs was observed.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbon (PAH) concentrations commonly exceeded federal sediment quality guidelines, particularly the lower Threshold Effect Levels (TELs). Only eight sites out of a total of 30 tributary and wetland sites sampled by Environment Canada, CLOCA, or GRCA showed no sediment quality exceedences for PAHs. In contrast, only one site sampled by TRCA, the Hydro Marsh outflow, was found to show TEL exceedences for any PAH compound. As mentioned previously, a different laboratory was used by TRCA for sediment quality analyses; this is thought to account for the difference in PAH concentrations.

Pumphouse Marsh contained the highest concentration of PAHs, with a total PAH (sum of 16 parameters) concentration of 11,880 ug/kg (ppb). Five TEL exceedences (acenaphthene, fluorene, phenanthrene, anthracene and fluoranthene) and five PEL exceedences (pyrene, benzo(a)anthracene, chrysene, benzo(a)pyrene, and dibenzo(a,h)anthracene) were observed at this site. In follow-up sampling conducted by CLOCA in Pumphouse Marsh in 2003, concentrations of total PAH at three sites in the marsh ranged from 294 to 4,587 ug/kg. Concentrations were higher in the northern portion of the wetland. It appears that PAHs are elevated in the marsh, but that the spatial distribution of that contamination is limited.

Besides Pumphouse Marsh, the only other PEL exceedences were noted at the Hydro Marsh inlet for pyrene and phenanthrene. Oshawa Second Marsh contained the second highest level of PAHs, at 4,426 ug/kg. Eight individual PAH compounds exceeded TEL guidelines, but none exceeded PEL guidelines. In a survey of sediment quality in approximately 230 tributaries to the lower Great Lakes, Dove *et al.* (2002, 2003) found 15 percent of tributaries had total PAH concentrations exceeding the total PAH concentration observed in Oshawa Second Marsh.

Metals

A number of sediment quality guideline exceedences were noted for metal parameters. The greatest number of metals exceedences was observed for cadmium, but it should be noted that the laboratory detection limit for samples collected by Environment Canada, CLOCA and GRCA was one microgram/gram, which is greater than the TEL of 0.6 ug/g. Since samples with 0.55 ug/g cadmium might be reported as one ug/g, it is not clear whether samples with reported cadmium concentrations of one ug/g represent true exceedences of the TEL. Only five sites showed cadmium concentrations in excess of one ug/g.

At most sites, the detection of metals was likely related to the natural occurrence of trace elements in stream sediments. For some metals, however, concentrations appeared to be elevated to a degree that may be considered to be toxic to aquatic biota. These metals included chromium, lead, and zinc.

The concentration of chromium exceeded the PEL (90 ug/g) at West Corbett Creek (311 ug/g) but, as explained below, follow-up sampling in 2003 showed lower chromium values in the creek. Both Robinson Creek (116 ug/g) and Pumphouse Marsh (105 ug/g) showed lead concentrations in exceedence of the PEL (91.3 ug/g). The Hydro Marsh inlet (389 ug/g) and a tributary to Frenchman's Bay at Bayly Street (319 ug/g) showed zinc concentrations in exceedence of the PEL (315 ug/g). The sources of these metals may be diffuse pollution from the urban environment, or they may include point sources.

Follow-Up Sampling in West Corbett Creek

The Ecosystem Health Division of Environment Canada conducted additional sampling in Corbett Creek in 2003 to follow up on previous results that showed elevated PCBs and chromium concentrations (EHD-OR, unpublished data). Three sites, including one immediately upstream of the 2002 site, were sampled. PCBs were much lower, ranging from 20 to 40 ng/g. These PCB values are consistent with those observed in many other urban tributaries to the lower Great Lakes. The chromium concentrations at the three additional West Corbett Creek sites sampled in 2003, ranging from 18 to 29 ug/g, were much lower than the concentration observed in 2002 (311 ug/g), and were all below federal sediment quality guidelines.

It is possible that the higher PCB and chromium concentrations observed in 2002 were not representative of the concentrations observed in West Corbett Creek. For example, laboratory error could have contributed to the elevated concentrations, or a portion of the sample could have contained anomalously high concentrations of these parameters and contributed to the overall apparent contamination at the site. Alternatively, the 2002 observed concentrations could be real, and the change of sampling locations between 2002 and 2003 could account for the differences observed over time. In 2002, the sample at Thickson Road and Wentworth was taken at the southeast corner (i.e., downstream) of the intersection; in 2003, the sample was taken at the northwest corner (i.e., upstream) of the intersection. It is possible that a source of these compounds enters the creek at or beneath the intersection. Any subsequent sampling should be undertaken downstream of the intersection to confirm or refute the 2002 results.

Sediment Quality Index

The sediment quality index was calculated using all parameters for which sediment quality guidelines and data were available. The wetland outflow sites sampled by CLOCA and GRCA were excluded from the SQI analysis, since no organics (i.e., organochlorine and PAH) analyses were performed for these sites.

A total of 15 locations (33 percent) had "excellent" sediment quality; 19 locations (42 percent) had "good" sediment quality; five locations (11percent) were classified each as "fair" or "marginal", and one location had "poor" sediment quality. Because of the lower concentrations of PAHs and some organochlorines observed at the TRCA sites, the SQI values calculated for sites sampled by TRCA tend to indicate better sediment quality compared to the other sites.

Table 2.1.3-4. Summary of Sediment Quality Index (SQI) scores for Durham Region coastal wetlands and their tributaries in 2002.

Site	Sampled By	Site Type	SQI	Category
Westside Creek	EHD-OR	Tributary	100.0	Excellent
Rouge River Marsh-5	TRCA	Wetland	100.0	Excellent
Rouge River Marsh-4	TRCA	Wetland	100.0	Excellent
Rouge River Marsh-3	TRCA	Wetland	100.0	Excellent
Rouge River Marsh-2	TRCA	Wetland	100.0	Excellent
Rouge River Marsh-1	TRCA	Wetland	100.0	Excellent
Duffins Creek Marsh-4	TRCA	Wetland	100.0	Excellent
Duffins Creek Marsh-3	TRCA	Wetland	100.0	Excellent
Duffins Creek Marsh-2	TRCA	Wetland	100.0	Excellent
Duffins Creek Marsh-1	TRCA	Wetland	100.0	Excellent
Carruthers Creek Marsh-2	TRCA	Wetland	100.0	Excellent
Carruthers Creek Marsh-1	TRCA	Wetland	100.0	Excellent
Frenchman's Bay Marsh-1	TRCA	Wetland	98.1	Excellent
Frenchman's Bay Marsh-2	TRCA	Wetland	96.3	Excellent
Carruthers Creek	EHD-OR	Tributary	95.5	Excellent
Wilmot Creek	EHD-OR	Tributary	93.4	Good
Foster Creek	EHD-OR	Tributary	93.4	Good
Graham Creek	EHD-OR	Tributary	91.6	Good
West Lynde Creek	EHD-OR	Tributary	90.8	Good
Wilmot Rivermouth Marsh	GRCA	Wetland	90.4	Good
Bowmanville Marsh	CLOCA	Wetland	90.4	Good
Westside Beach Marsh	CLOCA	Wetland	89.7	Good
Hydro Marsh-2	TRCA	Wetland	89.7	Good
McLaughlin Bay Marsh	CLOCA	Wetland	89.7	Good
Corbett Creek Mouth Marsh	CLOCA	Wetland	89.3	Good
Hydro Marsh-1	TRCA	Wetland	88.9	Good
Rouge River	EHD-OR	Tributary	88.1	Good
Hydro Marsh-3	TRCA	Wetland	86.5	Good
Cranberry Marsh	CLOCA	Wetland	86.4	Good
Lynde Creek Marsh	CLOCA	Wetland	85.3	Good
Port Newcastle Wetland	GRCA	Wetland	84.7	Good
Duffins Creek	EHD-OR	Tributary	83.1	Good
Bowmanville Creek	EHD-OR	Tributary	82.6	Good
Soper Creek	EHD-OR	Tributary	82.3	Good
East Lynde Creek	EHD-OR	Tributary	78.8	Fair
Radom	EHD-OR	Tributary	72.7	Fair
East Corbett Creek	EHD-OR	Tributary	67.7	Fair
Harmony Creek	EHD-OR	Tributary	65.8	Fair
West Corbett Creek	EHD-OR	Tributary	65.2	Fair
Bayly	EHD-OR	Tributary	58.4	Marginal
Oshawa Second Marsh	CLOCA	Wetland	57.0	Marginal
Amberlea Creek	EHD-OR	Tributary	55.7	Marginal
Farewell Creek	EHD-OR	Tributary	55.5	Marginal
Hydro	EHD-OR	Tributary	46.4	Marginal
Pumphouse Marsh	CLOCA	Wetland	40.8	Poor

Discussion

The parameters examined in this study can have various effects on unicellular, plant, fish, bird, invertebrate, and mammalian communities (EC, DFO, and HWC 1991; Carey *et al.* 1998). Table 2.1.3-5 describes generalized effects that selected parameters may have on biota. Sediment quality guidelines for each parameter are established through empirical toxicity testing. The tests describe the concentrations of the parameter that cause adverse effects on the study organism and/or the LD_{50}. As such, parameter concentrations above the recommended guidelines compromise biotic communities and, presumably, multiple high level parameters could have detrimental additive or synergistic effects on wetland life.

Table 2.1.3-5. Effects of various substances present in Durham Region coastal wetland sediments.

Parameter	Potential Effects
Mercury[1]	• Non-specific toxicity • Neurotoxicity • Behavioural effects • Nephrotoxicity • Fetotoxicity
Lead[1]	• Non-specific toxicity • Neurotoxicity
Cadmium[1]	• Non-specific toxicity • Neurotoxicity
PAHs[1]	Various effects depending on specific compound • Decreased longevity • Reproductive problems • May cause skin and respiratory tract tumours
PCBs[1,2]	• Decreased longevity • Hepatic toxicity • Developmental toxicity • Reproductive toxicity • Cancer • Endocrine toxicity • Immuno-toxicity
Pesticides (DDT)[1,2]	• Hepatic toxicity • Immuno-toxicity • Neurological effects • Reproductive effects • Cancer • Endocrine toxicity

Source: [1]EC, DFO, & HWC (1991); [2]Carey *et al.* (1998)

Three wetlands, Rouge River, Duffins Creek, and Carruthers Creek marshes, did not have any parameters that exceeded the federal or provincial sediment quality guidelines. Many other sites in the Toronto region also appeared to have sediment quality categorized as “excellent” by the Sediment Quality Index. Although these results appear to reflect high sediment quality, the absence of exceeded parameters at these sites is conspicuous considering the proximity of these wetlands to the urban Toronto environment. The PAH and PCB data appear to be lower for sites sampled and analyzed by the TRCA compared to the other sites. Interlaboratory variation appears to account for these differences; errors in data entry and manipulation have been ruled out. A recommendation with steps to permit laboratory comparisons in the future is made in the methodology evaluation below.

In general, the sediments analyzed from the wetland and tributary sites were of high quality. A full 77 percent of sites had sediment quality that was categorized as "excellent" or "good" when all parameters with sediment quality guidelines were considered. A comparative analysis of sediment quality measured in 131 tributaries to Lake Ontario (Dove *et al.* 2003) in 2002 and 101 tributaries to Lake Erie in 2001 (Dove *et al.* 2002) has shown that only 22 percent of tributaries to Lake Ontario and 57 percent of tributaries to Lake Erie were classified as "excellent" or "good" using the SQI (unpublished analysis). These results show that the Durham Region wetlands and tributaries rank favourably with respect to other tributary sites in the lower Great Lakes region.

The site with the poorest sediment quality measured in the current study was Pumphouse Marsh. The site was found to contain relatively high levels of PAHs as well as lead and, to a lesser degree, copper and zinc. Follow up sampling in 2003 found that the area of PAHs contamination is likely limited. The marsh is primarily storm sewer fed; therefore, no quantification of any inputs was made. It is possible that the marsh receives discharge effluent from area facilities; these should be reviewed (if any) and audited for compliance with appropriate regulations.

The spatial trends in sediment quality (Figure 2.1.3-1) showed that sediment quality was generally poorest at tributary (i.e., inflow) sites and highest at wetland sites. This indicates that sediment quality improves with distance downstream in the wetlands. As the flow velocities slow and solids are settling out, wetlands are acting as cleansers, trapping poorer quality sediment near their inflows or in the deepest portions of the basin. This cleansing function is useful in preventing contamination from entering the lake; however, organisms inhabiting the wetlands may be exposed to higher concentrations of contaminants. The preferred situation is, obviously, control at source, and prevention of contaminated sediment from entering the wetlands.

Although the level of several substances was higher than the federal guidelines, the biological toxicity of these contaminants is highly dependent on the total organic carbon and grain size characteristics of the sediment. Contaminants adhere to these particles, often with strong affinities that may sequester the substances from biological uptake. Sediment sample collection was targeted at areas with organic deposition. Therefore, it is possible that the biological toxicity of sediments may be less than expected.

Methodology Evaluation

The methodology for sediment collection was developed by the USGS (Sheldon and Capel 1994) and has been adopted by EHD-OR. Screening level surveys have been conducted by EHD-OR in tributaries to the lower Great Lakes since 2001 at approximately 330 sites. The use of a consistent methodology here permits a comparison with these other stream sites.

The methodology is considered to be suitable for the DRCWMP. Sediment quality is not anticipated to change quickly with time; therefore, a sampling frequency of once every five years is considered to be adequate. In the future, efforts should be taken to utilize the same laboratory across all sites. If this cannot be accomplished for all sites, then a series of split samples should be taken to assess interlaboratory variability.

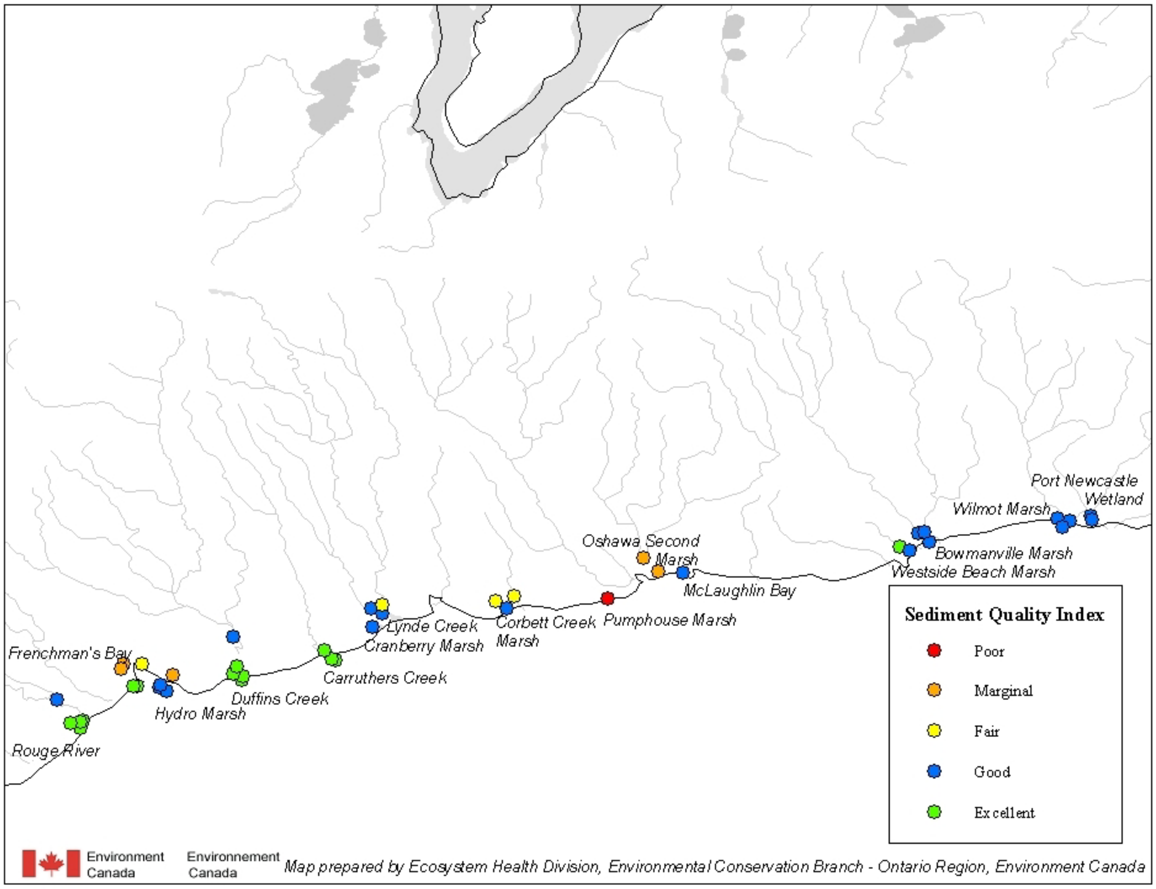

Figure 2.1.3-1. Sediment Quality Index at various Durham Region Coastal wetlands and their tributaries.

Data Analysis

The tools for data analysis used here included comparison with sediment quality guidelines and the calculation of a sediment quality index. The sediment quality guidelines provide useful benchmarks for the identification of contaminants that may be impairing conditions at a given site. Calculation of the sediment quality index involves a comparison of sediment quality with all available guidelines and provides an integrated score to indicate the overall contaminant status of sediments at the site. The SQI is anticipated to be formally adopted by the Canadian Council of Ministers of the Environment and, as such, is recommended for the DRCWMP.

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2.1.4 Wetland Bathymetry

Objective

To assess and monitor wetland bathymetry in Durham Region coastal wetlands.

Methodology – Update

The use of Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) was evaluated by the International Joint Commission (IJC) for its ability to provide bathymetric data on Great Lakes coastal wetlands. If the data were found to be suitable, the DRCWMP would take steps toward implementing this methodology. Although there has been no formal report discussing the efficacy of using SHOALS on Great Lakes coastal wetlands, it was apparent that turbid waters would greatly reduce the effectiveness of this technology.

In the past, TRCA has used boat-borne water depth and GPS equipment to determine the bathymetry of several areas along the Toronto waterfront. In 2002, TRCA used this technology to map the bathymetry of the Corner Marsh basin of Duffins Creek Marsh as a pilot. Methodological and data processing details will be reported if the methodology is determined to suit the needs of the DRCWMP.

In addition, the IJC has completed a similar method of site-level bathymetry data collection. The bathymetry data were corrected to the Lake Ontario (IGLD) water level for the date of the survey and converted to Canadian Geodetic Datum 28 (CGD28). As well, current orthorectified digital terrain models (DTMs), available as topography in CGD28 for Durham Region were used (Accuracy: ±5 m horizontal and ± 2.5 m vertical). Using a GIS, the bathymetry and topography were merged and 0.5-m contours were created to provide an example of the product for Lynde Creek Marsh.

Results – Preliminary

The pilot data allowed the bathymetry of the Corner Marsh and Lynde Creek Marsh basins to be mapped at 0.1-m contours (not shown). The detail of both maps appears to be representative of the basin. The Corner Marsh data have been field checked and deemed accurate, while the Lynde Creek Marsh data still require field checking. An example of the Lynde Creek mapping at 0.5-m contours (Figure 2.1.4-1) and an inset with additional detail at 0.1-m contours (Figure 2.1.4-2) are provided. These products are better viewed on larger media (e.g., via plotter), and are provided here for example only.

Discussion

Both products of bathymetry mapping appear to be effective. In 2003, TRCA began to employ the methodology full scale on one or two Durham Region coastal wetlands but staffing problems prevented the completion of the task. The possibility of completing this task in 2004 is being investigated.

The bathymetry mapping currently available at a usable scale for monitoring wetland changes is selective. To create bathymetric maps of additional Durham Region coastal wetlands, specific hydrographic surveys are required. These site-specific surveys can provide enough data to complete a bathymetry model with reasonable accuracy. LIDAR continues to be investigated as an efficient and comprehensive modeling tool for wetland elevations on a mass scale but advancements need to occur in data collection of near-shore and turbid environments.

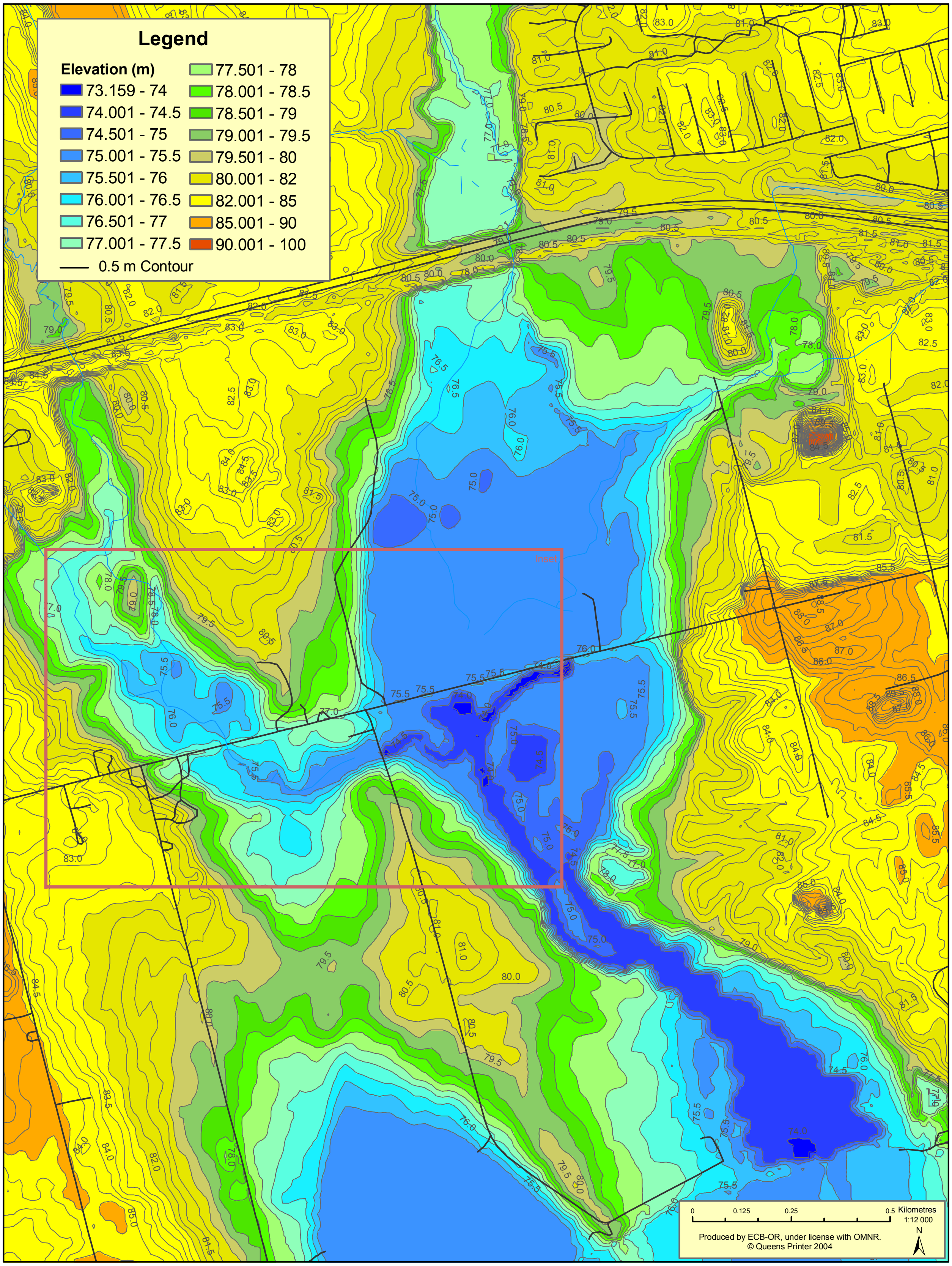

Figure 2.1.4-1. Lynde Creek Marsh basin bathymetry and upland topography at 0.5-m contours.

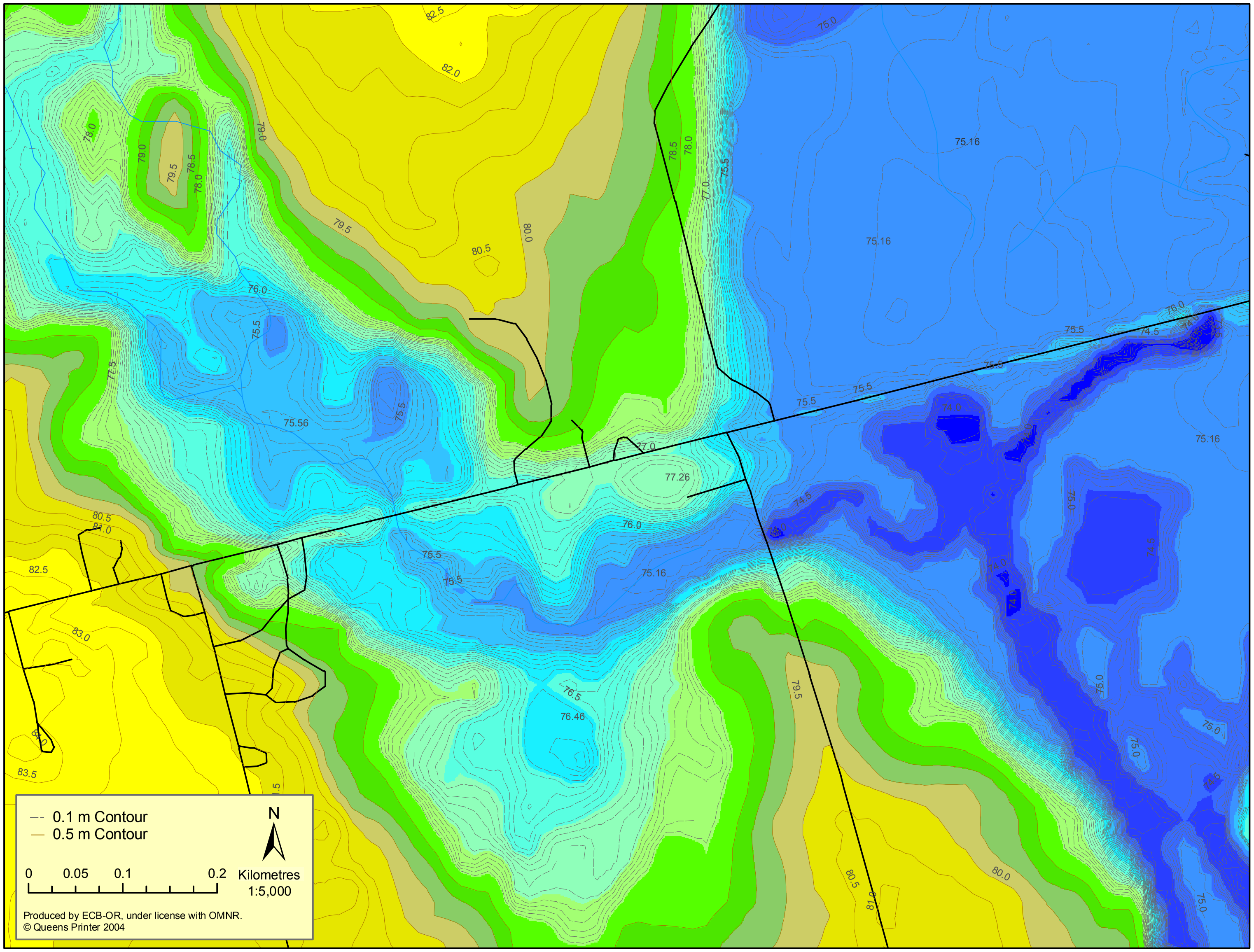

Figure 2.1.4-2. Inset of Lynde Creek Marsh basin bathymetry and upland topography at 0.1-m contours.

2.1.5 Wetland Water Quality

Objective

To assess and monitor water quality in Durham Region coastal wetlands.

Method Summary

Wetland water quality assessment is a new task that has been added to the DRCWMP. As such, the methodology does not yet appear in the most recent approximation of the DRCWMP Methodology Handbook (Environment Canada and Central Lake Ontario Conservation Authority 2003). Therefore, the method summary in this section includes extended, but not thorough, methodology descriptions.

Water samples were collected and analyzed from the 15 Durham Region wetlands and the 16 non-Durham wetlands during July 2003. At each study site, three replicate locations were selected in each of the open water and emergent vegetation zones. Emergent vegetation sampling locations were selected randomly to represent the areal extent of the wetlands. Where applicable, unique plant communities were sampled; however *Typha* sp. was the dominant vegetation in 82 percent of sampling sites. Open water sites were sampled by moving approximately 30 meters perpendicular to the shoreline from the emergent sampling locations. Where a 30-metre distance did not occur, samples were taken as far from emergent vegetation as possible. Sampling locations were approached by boat and care was taken to avoid disturbing the sediment while sample collection took place.

A Quanta Hydrolab unit was used to measure dissolved oxygen (mg L^{-1}), pH, water temperature (ºC), conductivity (µS cm^{-1}), redox potential (mΩ), and turbidity (NTU). The meter probe was positioned at mid-depth in the water column. A propeller fixed to the unit was turned on to ensure ambient water continually circulated over the sensors. Water depth (m) and Secchi depth (m) measurements were collected at each replicate location using a calibrated Secchi disk. Alkalinity was estimated using a Hach test strip designed to generate an alkalinity estimate within a range of 20 mg L^{-1}.

Water samples for ammonia nitrogen (NH_4) and nitrate nitrogen (NO_3) were collected from the surface in clean, deionized-rinsed, plastic centrifuge tubes. Nitrite nitrogen (NO_2) samples were collected using a sterilized 60-millilitre plastic syringe, triple-rinsed with sample water prior to collecting the sample, filtered through 0.45-µm sterile filter and stored in plastic centrifuge containers. Samples were analyzed for NO_3, NO_2, and NH_4 using a DR890 colorimeter. The Hach reagents used meet USEPA protocols for the analysis of surface water as they are generated from Standard Methods. A cadmium reduction method was used for the analysis of nitrate nitrogen, salicylate for ammonia, and diazotization for nitrite. Samples were stored in the dark at 4ºC until analysis. The storage period for the samples did not exceed 48 hours and generally, the samples were analyzed within 12 hours of collection.

Water samples for analysis of total phosphorus (TP) were collected in 125-mL flint glass bottles that had been filled with 0.5 percent H_2SO_4 for three days and triple-rinsed with both deionized water and sample water prior to collection. These samples were preserved with one mL of 30 percent H_2SO_4, stored in the dark, and sent to the National

Laboratory of Environmental Testing (NLET) in Burlington, Ontario for analysis. Chlorophyll *a* samples were collected at all locations. Using a one-litre polypropylene bottle, a sample of 200-1,000 mL of water was collected and filtered through a 0.45-µm glass fibre filter. These filters were stored in plastic petri dishes, wrapped in aluminum foil and stored below 0ºC until analysis at NLET.

To meet quality control requirements, ten percent of the samples were collected and analyzed in duplicate. Field and method blanks were run with each batch of water samples collected from the wetlands. The results from these quality control samples were analyzed to determine the potential for sample contamination and reproducibility of data. Laboratory certified standards were run periodically to ensure the field colorimeter was operating accurately.

Information on the location and surrounding vegetation was collected at each replicate location within the vegetation zone. The dominant vegetation was recorded for each sampling location, along with observations of incidental species within three metres of the sampling location. A Magellan GPS 320 global positioning system was used to record each sampling location.

Data Analysis

The mean values of each water quality parameter were compared between the open water and emergent vegetation communities using paired t-tests.

Results

Paired t-tests showed that there was no significant difference between open water and emergent vegetation communities for any of the water quality parameters. Therefore, the overall mean of all six sampling locations in the wetlands was used in the disturbance values for this study. Table 2.1.5-1 shows the mean wetland values for all water quality parameters.

Although concerted attempts were made to fully assess the water quality at each Durham Region coastal wetland, total phosphorus (TP) measurements for Oshawa Second and McLaughlin Bay marshes were unavailable. In the disturbance assessment of the sites (section 3.1), TP for these sites was estimated from values published by Crosbie and Chow-Fraser (1999) and the mean TP from all other Durham Region coastal wetlands.

Discussion

The main purpose of collecting water quality data was for use in assessing disturbance at Durham Region and other Lake Ontario coastal wetlands (see section 3.1).

The water quality estimates used in this section are from one-time measurements. Although resampling water quality throughout the growing season would be preferable, the current results are consistent with expectations; sites in more urbanized watersheds had poorer water quality. Water quality sampling involves moderate time and equipment costs, but the value of repeated and temporally variable water quality assessments is high and should be considered for implementation in this project.

Table 2.1.5-1. Water quality parameters for Durham Region (bold) and other Lake Ontario coastal wetlands.

	Ammonia		**Total Phosphorus**		**Nitrate**		**Nitrite**		**Chlorophyll *a***		**Conductivity**	
Wetland Name	Mean ($mg\ L^{-1}$)	SD	Mean ($mg\ L^{-1}$)	SD	Mean ($mg\ L^{-1}$)	SD	Mean ($mg\ L^{-1}$)	SD	Mean ($\mu g\ L^{-1}$)	SD	Mean ($mS\ cm^{-1}$)	SD
Bayfield Bay	0.014	0.010	0.132	0.122	2.12	0.98	0	0	4.22	1.50	0.253	0.008
Big Sand Bay	0.017	0.023	0.055	0.017	2.13	0.49	0	0	3.90	2.60	0.273	0.035
Bowmanville Marsh	0.146	0.095	0.181	0.066	2.01	1.54	0.028	0.007	61.20	39.51	0.489	0.056
Button Bay	0.058	0.040	0.145	0.105	0.22	0.16	0.016	0.006	ND	ND	0.401	0.153
Carruthers Creek Marsh	0.167	0.109	0.103	0.021	3.31	1.12	0.009	0.012	7.70	2.25	0.681	0.079
Corbett Creek Marsh	0.031	0.018	0.086	0.040	2.95	0.80	0.002	0.002	3.53	1.55	1.712	0.226
Cranberry Marsh	0.216	0.227	0.444	0.190	3.78	1.73	0.017	0.012	4.42	3.85	0.442	0.011
Duffins Creek Marsh	0.240	0.082	0.102	0.066	3.79	0.55	0.013	0.018	24.10	0	0.630	0.021
Frenchman's Bay Marsh	0.251	0.335	0.137	0.122	0.65	0.57	0.015	0.021	17.55	8.13	0.603	0.216
Hay Bay North	0.047	0.045	0.061	0.020	0.33	0.08	0.017	0.012	4.70	2.60	0.317	0.077
Hay Bay South	0.041	0.024	0.060	0.037	0.35	0.05	0.011	0.003	2.70	1.65	0.238	0.013
Huyck's Bay	0.036	0.055	0.041	0.024	1.26	0.50	0.116	0.262	0.63	0.39	0.206	0.095
Hydro Marsh	0.080	0.093	0.224	0.116	0.45	0.49	0.019	0.027	3.66	3.71	0.334	0.023
Jordan Station Marsh	0.170	0.045	0.177	0.030	0.80	0.14	0.01	0.013	34.74	19.59	0.908	0.123
Little Cataraqui Creek	0.087	0.084	0.085	0.021	0.34	0.32	0.023	0.006	9.10	3.66	0.528	0.160
Lynde Creek Marsh	0.304	0.120	0.133	0.031	4.82	0.64	0.007	0.007	3.60	4.26	0.566	0.270
McLaughlin Bay Marsh	0.063	0.033	ND	ND	0.18	0.15	0	0	15.43	13.58	0.702	0.095
Oshawa Second Marsh	0.250	0.365	ND	ND	0.14	0.28	0	0	5.54	3.30	1.515	0.010
Parrot's Bay	0.048	0.045	0.042	0.023	1.40	0.18	0	0	10.22	22.37	1.090	0.904
Port Britain	0.183	0.197	0.068	0.026	0.60	0.06	0.074	0.066	1.25	0.99	0.391	0.039
Port Newcastle Wetland	0.114	0.072	0.126	0.055	3.04	0.53	0.039	0.043	2.20	0.99	0.448	0.017
Presqu'ile Bay	0.016	0.019	0.017	0.004	0.68	0.20	0	0	5.55	0.35	0.545	0.030
Pumphouse Marsh	0.078	0.025	0.095	0.015	2.12	0.35	0.007	0.017	1.50	0.00	0.316	0.011
Robinson's Cove	0.016	0.027	0.043	0.019	1.17	0.32	0.003	0.003	19.97	13.90	0.890	0.032
Rouge River Marsh	0.141	0.085	0.067	0.036	3.93	0.71	0.138	0.315	2.78	2.04	0.253	0.014
South Bay	0.015	0.015	0.034	0.037	1.01	0.56	0	0	8.94	5.88	0.900	0.072
Westside Marsh	0.237	0.218	0.124	0.031	1.42	1.13	0.032	0.023	1.18	1.64	0.300	0.006
Wilmot Creek Marsh	0.116	0.035	0.083	0.056	0.93	0.23	0.046	0.067	11.45	10.82	0.946	0.049

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2.2 WATERSHED

2.2.1 Watershed Ecological Land Classification

Objective

To assess and monitor changes in watershed land cover of Durham Region coastal wetlands.

Method Summary

Each watershed associated with a coastal wetland in Durham Region has been mapped according to the Ecological Land Classification (ELC) system (Lee *et al.* 1998) and will be monitored for change.

Current land cover within a watershed was identified and delineated through air photo interpretation. While natural areas were classified to the Community Series level in the ELC (e.g., deciduous forest, coniferous forest), the ELC does not yet have a complete cultural (e.g., residential, industrial) land cover classification system, resulting in white space on the map where land cover is not classified. Cultural classifications under the ELC system are currently under development and will be incorporated when available.

Results

The total watershed areas and percentage of ELC polygon areas within them vary considerably (Table 2.2.1-1; Figure 2.2.1-1 to 2.2.1-15; see Table 2.2.1-3 for ELC definitions). Two of the smaller watersheds, Cranberry Marsh and McLaughlin Bay, have a considerable amount of the land area in natural vegetation (41 percent and 70 percent, respectively). Of the large watersheds, the Port Newcastle Wetland, Duffins Creek Marsh, and the Wilmot Creek Marsh watersheds have fairly high percentages (44 percent, 37 percent and 35 percent, respectively) of land area in ELC polygons. Pumphouse Marsh has an extremely small watershed (54 ha) which is almost entirely storm sewer-fed (J.D. Barnes Ltd. 1973).

According to guidelines for the rehabilitation of Great Lakes Areas of Concern (AOCs), wetland and forest should cover a certain minimum percentage (Table 2.2.1-2) of a watershed to maintain the existence of healthy ecosystems (Environment Canada 2004). "Forest" includes both natural coniferous, deciduous, and mixed forests, as well as swamps and plantations. The "wetland" percentage includes marshes, fens, and swamps. Since both the forest and wetland categories include swamp polygons, there is overlap in these percentages (Environment Canada 2004).

None of the Durham Region coastal wetland watersheds currently meet the minimum forest cover objectives (Table 2.2.1-2), although the easternmost watersheds (i.e., Bowmanville Marsh, Wilmot Creek Marsh and Port Newcastle Wetland) and the Duffins Creek watershed all have more than 20 percent forested cover. Four watersheds have less than five percent forest cover: Hydro Marsh, Corbett Creek Marsh, Pumphouse Marsh, and Westside Marsh. Of these, Westside has the lowest forested cover with a very poor one percent.

Table 2.2.1-1. Total and ELC areas in Durham Region coastal wetland watersheds and percentage of each watershed in natural and cultural vegetation and ELC land cover.

Watershed	Total ELC (ha)	Watershed area (ha)	% Natural	% Cultural	% of watershed in ELC polygons*
Rouge River Marsh	8,017	33,289	N/A	N/A	24
Frenchman's Bay Marsh	513	1,652	N/A	N/A	31
Hydro Marsh	313	1,061	N/A	N/A	30
Duffins Creek Marsh	10,745	28,654	N/A	N/A	37
Carruthers Creek Marsh	1,059	3,813	N/A	N/A	28
Cranberry Marsh	67	161	27	14	41
Lynde Creek Marsh	3,126	13,194	14	9	23
Corbett Creek Marsh	265	1,463	7	11	18
Pumphouse Marsh	13	54	17	7	24
Oshawa Second Marsh	2,061	10,705	15	4	19
McLaughlin Bay Marsh	154	209	27	43	70
Westside Marsh	164	573	10	19	29
Bowmanville Marsh	4,951	16,590	21	8	29
Wilmot Creek Marsh	3,481	9,882	20	15	35
Port Newcastle Wetland	3,444	7,815	28	16	44

* All ELC polygons are either "natural" or "cultural"; these percentages sum to the total ELC polygon percentage in each watershed.

The three smallest watersheds (i.e., Cranberry Marsh, Pumphouse Marsh, and McLaughlin Bay Marsh) meet the objective for percent of wetland (>10 percent; Table 2.2.1-2). This is a function of the wetlands themselves taking up a large proportion of these tiny watersheds. Of the larger watersheds, only Port Newcastle Wetland reaches the minimum target percentage with 10 percent wetland, with Oshawa Second Marsh (i.e., the Black, Harmony, and Farewell watersheds) not far behind at eight percent. The smallest percentages of wetland are in the Frenchman's Bay Marsh and Wilmot Creek Marsh watersheds (only two percent).

Table 2.2.1-2. Percentages of wetland and forest in Durham Region coastal wetland watersheds and recommended minimum guidelines.

Watershed	% Forest	% Wetland
Rouge River Marsh	12	3
Frenchman's Bay Marsh	14	2
Hydro Marsh	4	5
Duffins Creek Marsh	25	4
Carruthers Creek Marsh	15	5
Cranberry Marsh	14	26
Lynde Creek Marsh	14	5
Corbett Creek Marsh	4	4
Pumphouse Marsh	3	14
Oshawa Second Marsh	13	8
McLaughlin Bay Marsh	7	25
Westside Marsh	1	9
Bowmanville Marsh	23	6
Wilmot Creek Marsh	23	2
Port Newcastle Wetland	27	10
AOC Guideline[1]	**>30**	**>10**

[1] Environment Canada (2004)

NOTE: TRCA forest percentages include only forest and swamp values; however, there are still "unknown wetlands" that need to be defined as either marsh or swamp: this will likely increase the total forested percentage.

ELC polygons are categorized as either "Natural" or "Cultural" (Table 2.2.1-1). "Cultural", as defined in the ELC manual (Lee *et al.* 1998), refers to a community that results from or is maintained by human-based disturbances. These are vegetation communities such as Cultural Meadows (CUM), Thickets (CUT), Savannahs (CUS), Woodlands (CUW), or Plantations (CUP).

The watersheds of Lynde Creek, Corbett Creek, Pumphouse, Oshawa Second and Westside marshes all had less than 20 percent land area as "natural vegetation", while the watersheds of Cranberry, McLaughlin Bay, Bowmanville, Wilmot Creek, and Port Newcastle marshes had at least 20 percent natural cover in their watersheds. The Corbett Creek Marsh, McLaughlin Bay Marsh, and Westside Marsh watersheds had a greater percentage of land cover as cultural ELC polygons as opposed to natural ones. All of these watersheds are fairly small (i.e., less than 300 ha) and do not extend north into more pristine areas of the Oak Ridges Moraine. The high cultural percentages are indicative of the agricultural land-use that was prevalent throughout the southern portion of Durham Region in the recent past.

TRCA wetland watersheds are not yet classified to the Community Series level of resolution, but Community Class total areas and percentages are available (Table 2.2.1-4). Three of the TRCA watersheds have their greatest proportion of lands as forested areas: Rouge – 11 percent, Duffins – 23 percent and Carruthers – 12 percent.

The total area of each ELC Community Series was calculated for ten watersheds in Durham Region (Table 2.2.1-5). Corbett Creek Marsh, McLaughlin Bay, Westside Marsh and Port Newcastle Wetlands watershed have Cultural Meadow (CUM) as their largest ELC Community Series.

Currently, Oshawa Second Marsh is isolated from its former watershed due to the construction of the berm along the west side, which diverted the creek straight to Lake Ontario. Thus, its temporary watershed is actually quite small. However, since the diversion is temporary, the former watershed area will be used in this report.

Discussion

This information facilitates decision-making regarding rehabilitation within Durham Region coastal wetland watersheds and may partially explain the results of other monitoring activities (e.g., turbidity). For example, Crosbie and Chow-Fraser (1999) found that land-use in various Great Lakes wetland watersheds negatively impacted both water quality (i.e., higher turbidity, phosphorus, and nitrogen levels) and submerged aquatic plant species diversity.

Watershed land-use effects have been found to vary according to the existence of a hydrological linkage to the Great Lakes. Wetlands that did not have input from the Great Lakes were determined to be more impacted, in terms of water and sediment quality, by land-use in the watershed than those that experienced mixing of the wetland and lake waters (Lougheed *et al.* 2001). A few of the Durham coastal wetlands (i.e., Cranberry, Pumphouse, and McLaughlin Bay marshes) have been isolated from lake-water influence for a number of years. While these watersheds are very small (approximately 200 ha or less), they may have a sizable impact on the health of the wetlands.

Comparing current percentages of forest and wetland cover to the recommended Environment Canada guidelines serves as a starting point for assessing the relative condition of each watershed (Environment Canada 2004). These guidelines are intended as *minimum* ecological requirements and, ideally, the reference point for restoration should be the pre-settlement landscape. Obviously, that level of natural cover is unattainable in today's settled landscape but if a watershed contains more habitat than the guideline (e.g., 35 percent forest cover), it should be maintained. In some cases, the guidelines may exceed historical values (at least with respect to wetlands) and in such cases the target percentages would be lower (Environment Canada 2004).

It is important to note that the numbers illustrated in this section are approximations. For the majority of each watershed, the ELC mapping has been done only from air photo interpretation, which can result in underestimation of wetland areas. In particular, swamps may be difficult to distinguish from forests, depending on the time of year that the photos were taken. As well, an update of the original ELC work is currently being undertaken by CLOCA using 2002 digital orthophotos. The original ELC mapping was done using hardcopy air photos, which was subsequently digitized to create a GIS layer. With the advent of digital orthophotos, it is now possible to accurately define polygon boundaries and determine ELC designations. As a result of this updating process, while the percentages of some ELC Community Series may change in the future, these changes may reflect the results of these refinements and not necessarily actual changes in the landscape.

Future Considerations

Partner conservation authorities have either already produced Watershed Management Plans for some of these watersheds or are in the process of doing so. For example, TRCA, in conjunction with task forces comprised of residents, elected officials, and representatives of environmental groups and government agencies, has developed plans for both the Duffins Creek and Carruthers Creek watersheds. A committee is currently working towards implementing recommendations from the management plans. One objective is to increase natural cover in both watersheds: Duffins Creek – from 37 to 49 percent and Carruthers Creek – from 28 to 30 percent (TRCA 2003).

Table 2.2.1-3. Ecological land classification code definitions.

CODE	ELC Community Units
BBO	Open Beach / Bar
BBS	Shrub Beach / Bar
BBT	Treed Beach / Bar
BLO	Open Bluff
BLS	Shrub Bluff
BLT	Treed Bluff
FOC	Coniferous Forest
FOM	Mixed Forest
FOD	Deciduous Forest
CUP	Plantation
CUM	Cultural Meadow
CUT	Cultural Thicket
CUS	Cultural Savannah
CUW	Cultural Woodland
SWC	Coniferous Swamp
SWM	Mixed Swamp
SWD	Deciduous Swamp
SWT	Thicket Swamp
FEO	Open Fen
MAM	Meadow Marsh
MAS	Shallow Marsh
OAO	Open Aquatic
SAS	Submerged Shallow Aquatic
SAM	Mixed Shallow Aquatic
SAF	Floating-leaved Shallow Aquatic

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Toronto and Region Conservation Authority (TRCA). 2003. A Watershed Plan for Duffins Creek and Carruthers Creek. August 2003. Toronto and Region Conservation.

Table 2.2.1-4. Ecological Land Classification (ELC) Community Class areas and percentages for five Durham Region coastal wetland watersheds.

	Rouge River		Frenchman's Bay		Hydro Marsh		Duffins Creek		Carruthers Creek	
Vegetation Communities	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**
Beach/Bluff	2		4		8	1			1	
Forest	3,818	11	219	13	30	3	6,689	23	455	12
Meadow	3,009	9	233	14	217	20	2,451	9	362	9
Successional	257	1	20	1	0		369	1	60	2
Unknown	9				0		5		0	
Wetland	114		5		15	1	286	1	29	1
Wetland, Bog	5						3			
Wetland, Fen	1									
Wetland, Marsh	143		15	1	21	2	107		41	1
Wetland, Open Water	35		8	1	4		16		5	
Wetland, Other	316	1					345	1		
Wetland, Swamp	310	1	8	1	18	2	429	1	107	3
Total Watershed	33,289	24	1,652	31	1,061	30	28,654	37	3,813	28

Note: Shading indicates vegetation community with largest area in each watershed.

Table 2.2.1-5. Ecological Land Classification (ELC) Community Series areas and percentages for 10 Durham Region coastal wetland watersheds.

	Cranberry		Lynde Creek		Corbett Creek		Pumphouse		Second Marsh	
ELC Community Series	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**	**Area (ha)**	**% of Total Watershed**
BBO	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
BBS			<1	<1					<1	<1
BBT	<1	<1	<1	<1			<1	<1	<1	<1
BLO										
BLS										
BLT										
CUM	5	3	481	4	122	8	2	3	235	2
CUP	13	8	170	1					13	<1
CUS			21	<1						
CUT	5	3	295	2	33	2	2	3	93	<1
CUW			258	2	3	<1	<1	1	65	<1
FEO			<1	<1						
FOC			252	2	3	<1			174	2
FOD	<1	<1	676	5	33	2	<1	1	410	4
FOM			363	3	7	<1			187	2
MAM	8	5	70	1	18	1	<1	<1	101	1
MAS	19	12	41	<1	30	2	3	5	36	<1
OAO	5	3	54	<1	3	<1			11	<1
SAF			<1	<1					4	<1
SAM			6	<1						
SAS			9	<1	4	<1	3	6	45	<1
SWC			20	<1					51	<1
SWD	8	5	259	2	9	<1	<1	<1	265	2
SWM			72	1					298	3
SWT	2	1	76	1			1	2	71	1
Total Watershed	161	42	13,194	24	1,463	18	55	23	10,705	19

Note: Shading indicates community series with largest area in each watershed.

Table 2.2.1-5. Cont'd

ELC Community Series	McLaughlin Bay		Westside		Bowmanville		Wilmot Creek		Port Newcastle	
	Area (ha)	% of Total Watershed	Area (ha)	% of Total Watershed	Area (ha)	% of Total Watershed	Area (ha)	% of Total Watershed	Area (ha)	% of Total Watershed
BBO	1	<1					<1	<1		
BBS	3	1								
BBT										
BLO							1	<1	3	<1
BLS									3	<1
BLT									2	<1
CUM	56	27	80	14	334	2	704	7	723	9
CUP	8	4			422	3	435	4	131	2
CUS							64	1	93	1
CUT	11	5	26	5	260	2	231	2	247	3
CUW	14	7	2	<1	371	2	83	1	49	1
FEO										
FOC					456	3	736	7	696	9
FOD	1	1	3	<1	875	5	506	5	300	4
FOM			<1	<1	1,292	8	564	6	456	6
MAM	5	3	9	2	35	<1	27	<1	30	<1
MAS	1	1	24	4	26	<1	22	<1	14	<1
OAO	38	18	13	2	49	<1	10	<1	33	<1
SAF					5	<1			2	<1
SAM										
SAS					2	<1	22	<1	32	<1
SWC					92	1	20	<1	379	5
SWD	6	3	1	<1	236	1	25	<1	34	<1
SWM					425	3	15	<1	138	2
SWT	1	1	5	1	71	<1	14	<1	82	1
Total Watershed	209	70	573	29	16,590	30	9,882	35	7,815	44

Note: Shading indicates community series with largest area in each watershed.

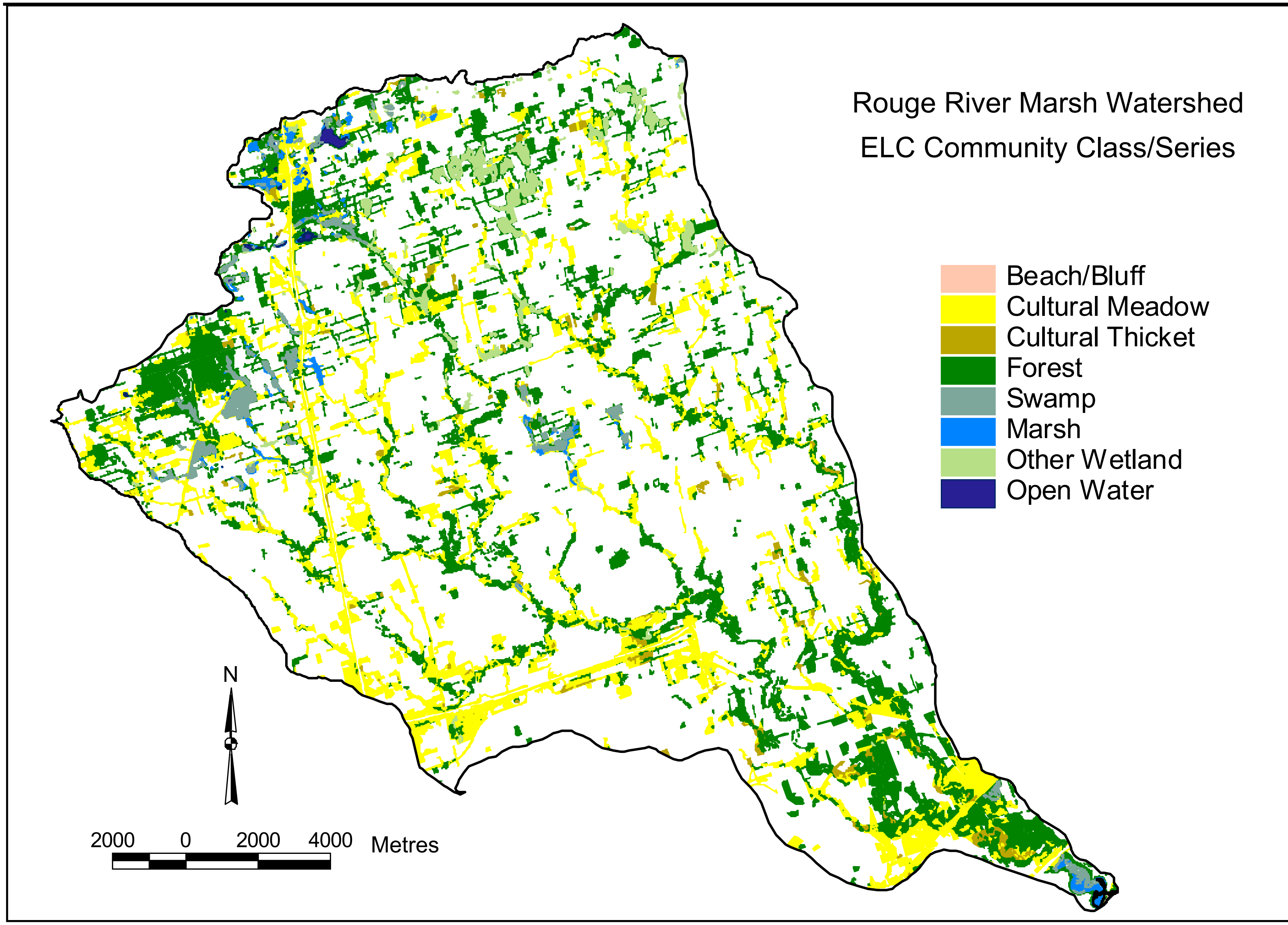

Figure 2.2.1-1. Rouge River Marsh watershed Ecological Land Classification (ELC) Community Class/Series designations.

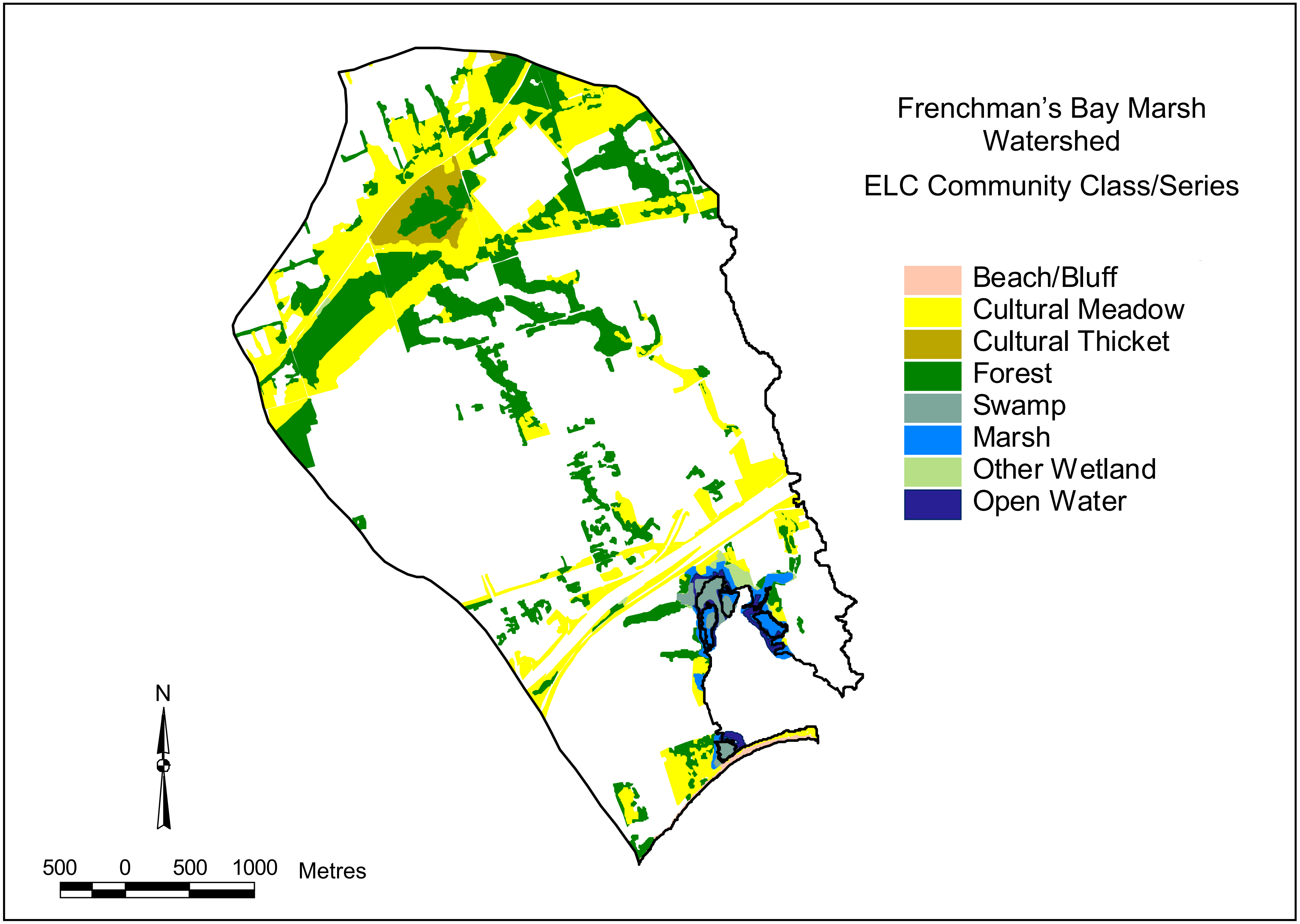

Figure 2.2.1-2. Frenchman's Bay Marsh watershed Ecological Land Classification (ELC) Community Class/Series designations.

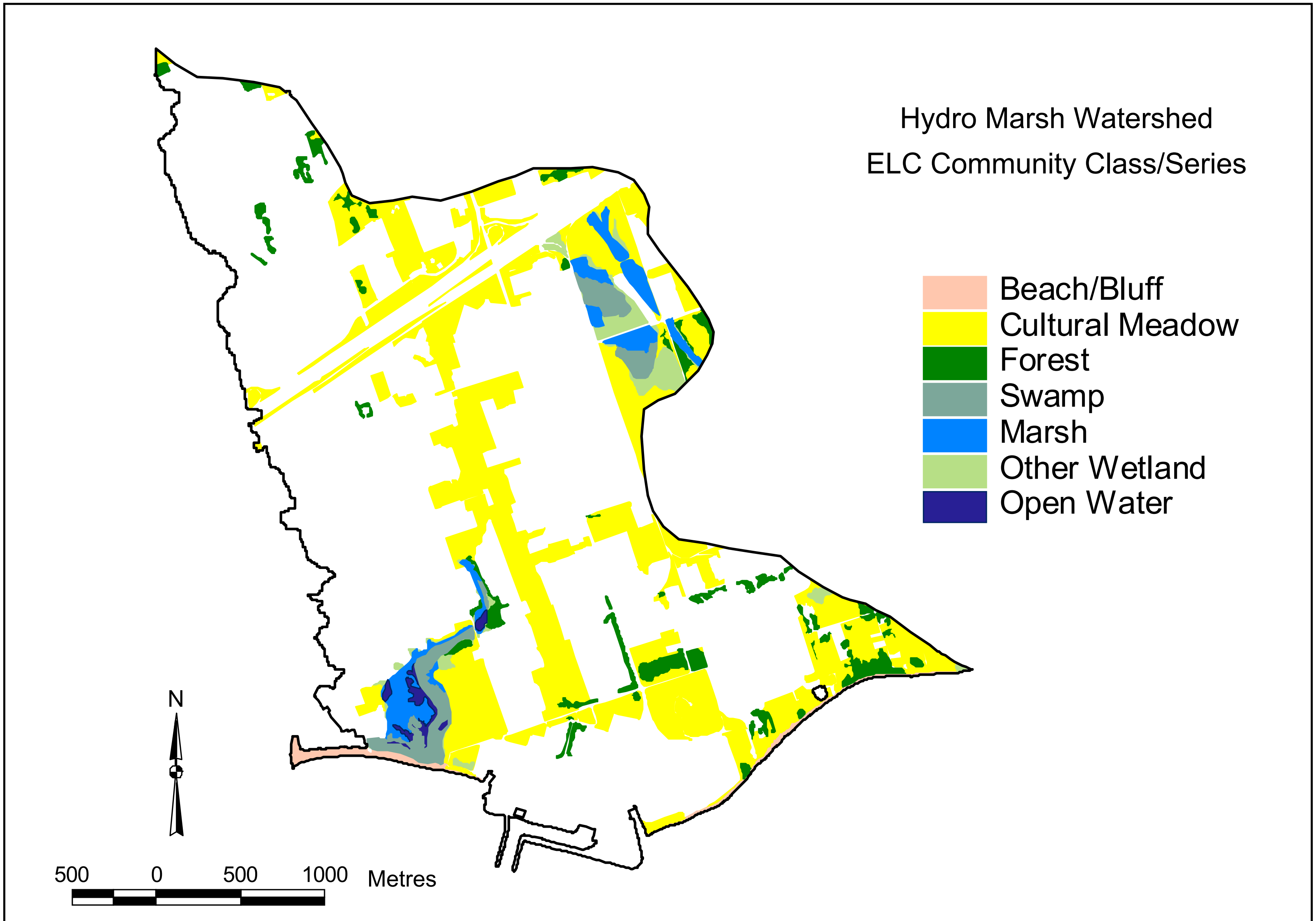

Figure 2.2.1-3. Hydro Marsh watershed Ecological Land Classification (ELC) Community Class/Series designations.

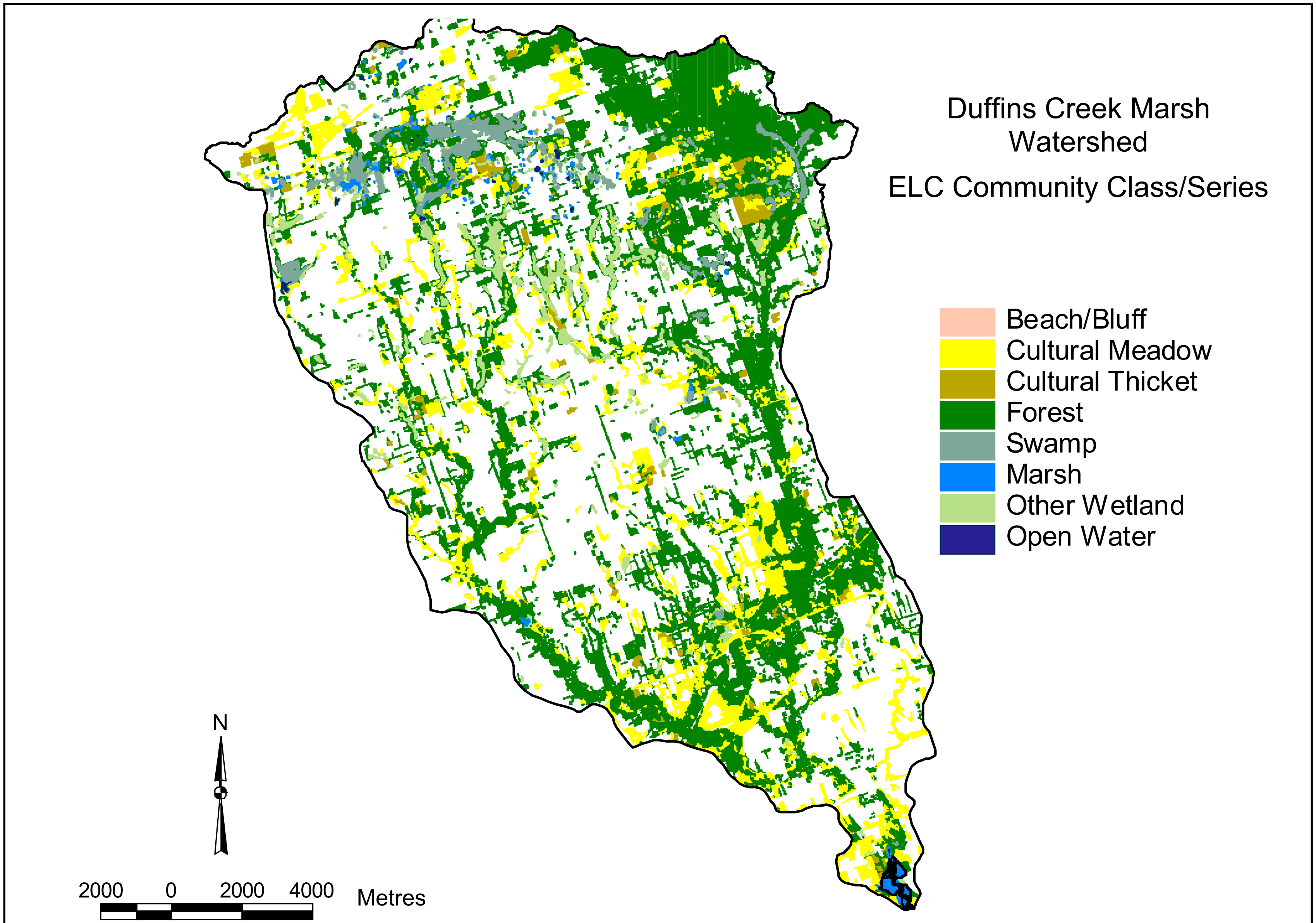

Figure 2.2.1-4. Duffins Creek Marsh watershed Ecological Land Classification (ELC) Community Class/Series designations.

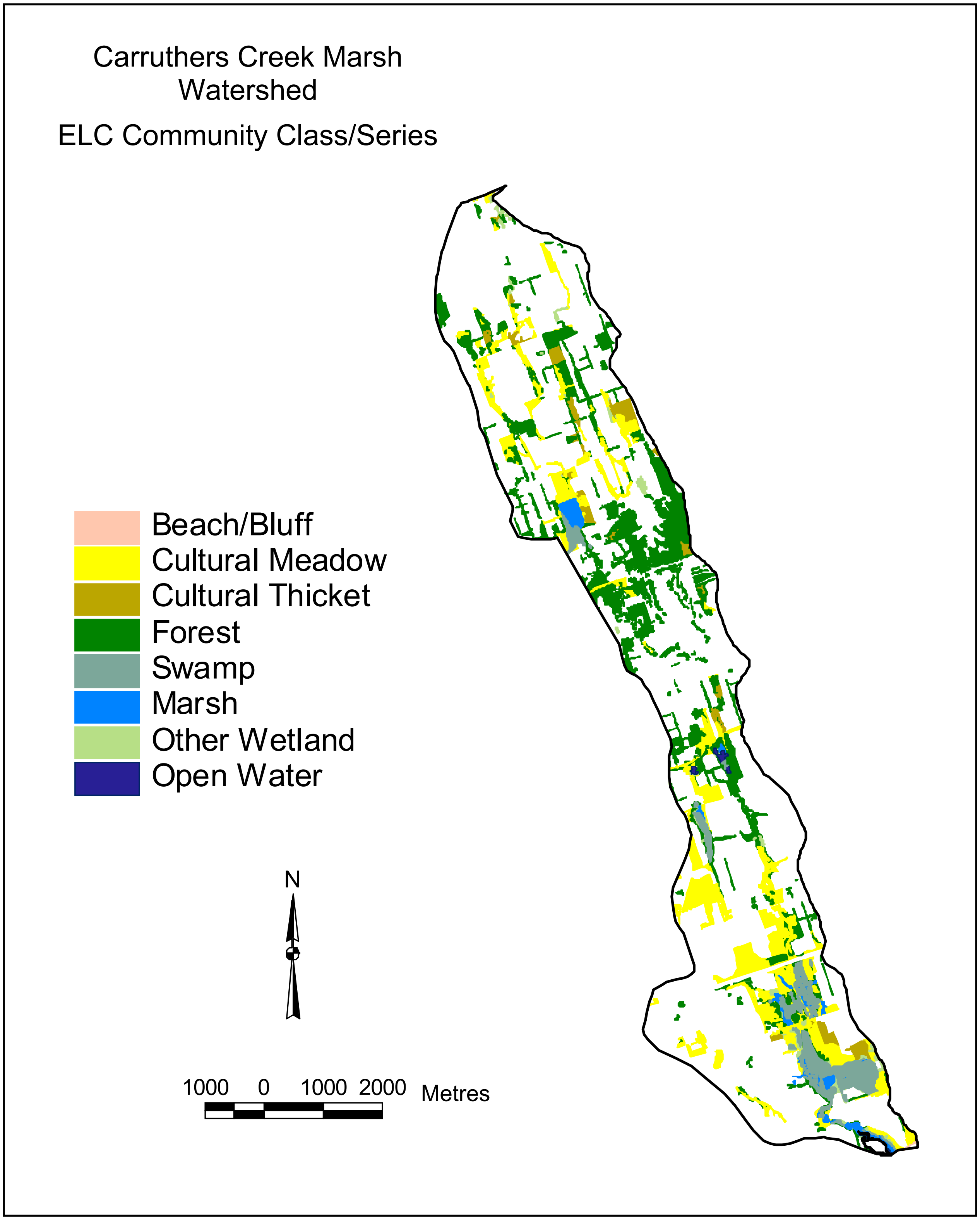

Figure 2.2.1-5. Carruthers Creek Marsh watershed Ecological Land Classification (ELC) Community Class/Series designations.

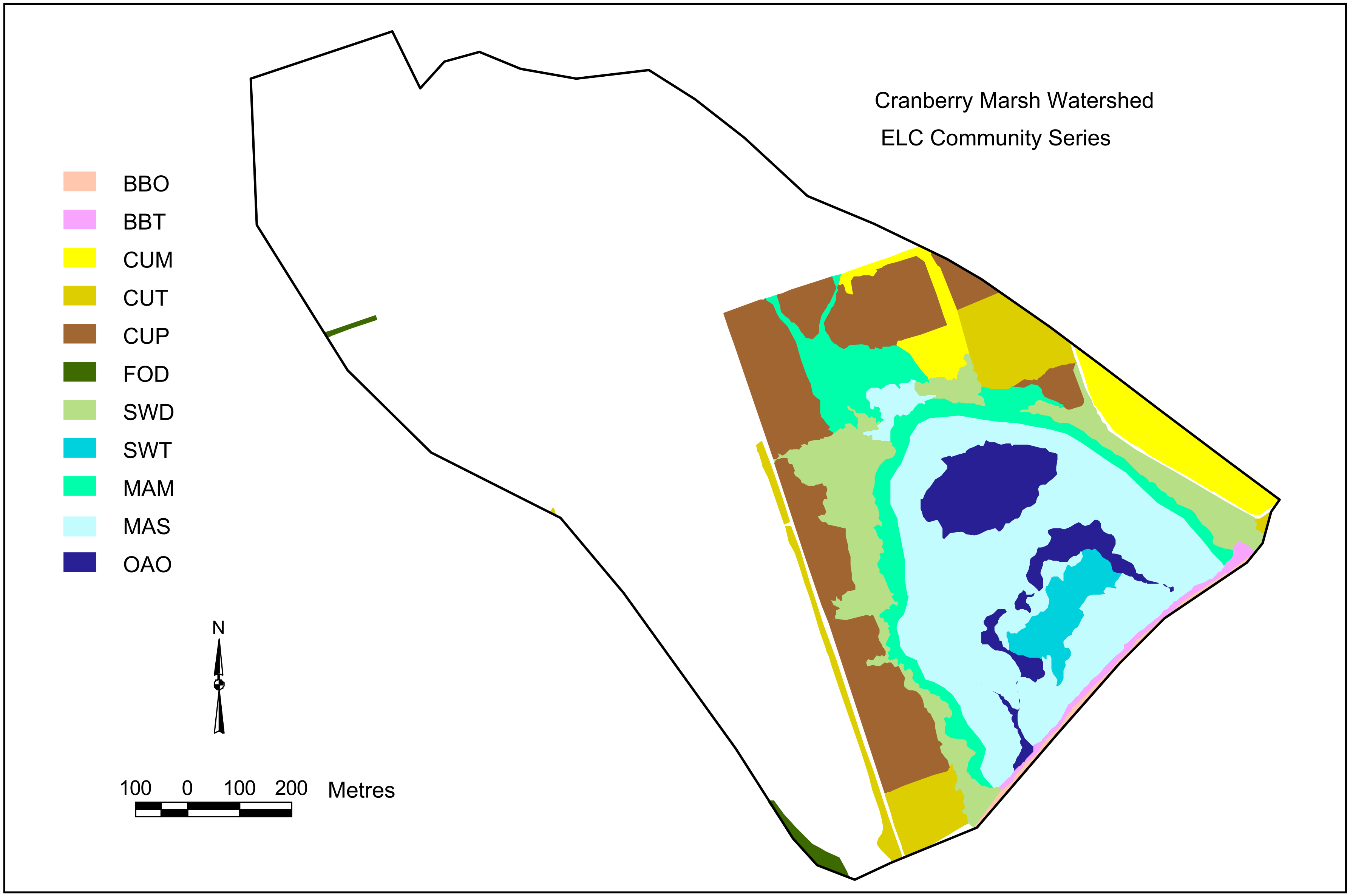

Figure 2.2.1-6. Cranberry Marsh watershed Ecological Land Classification (ELC) Community Series designations.

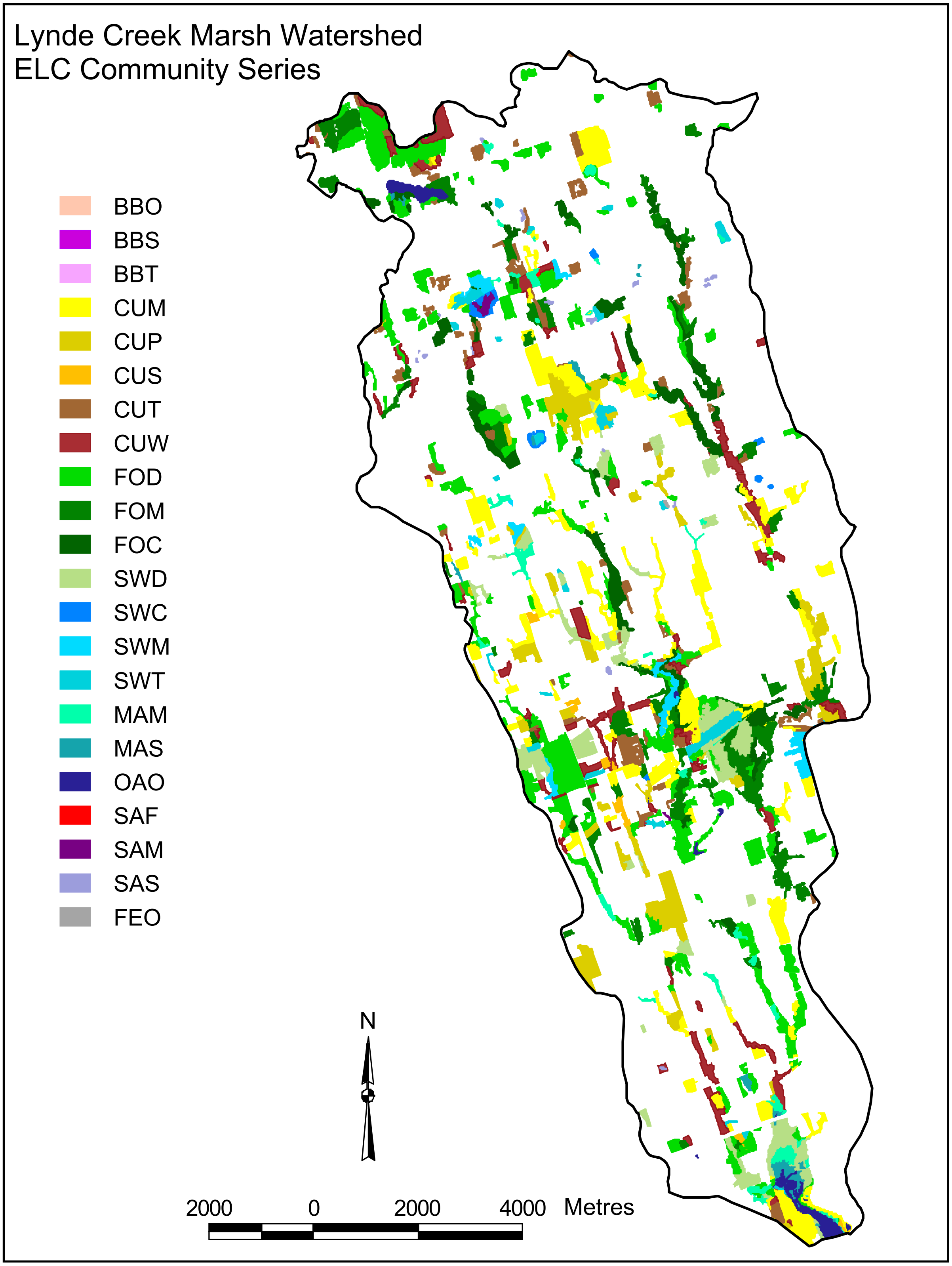

Figure 2.2.1-7. Lynde Creek Marsh watershed Ecological Land Classification (ELC) Community Series designations.

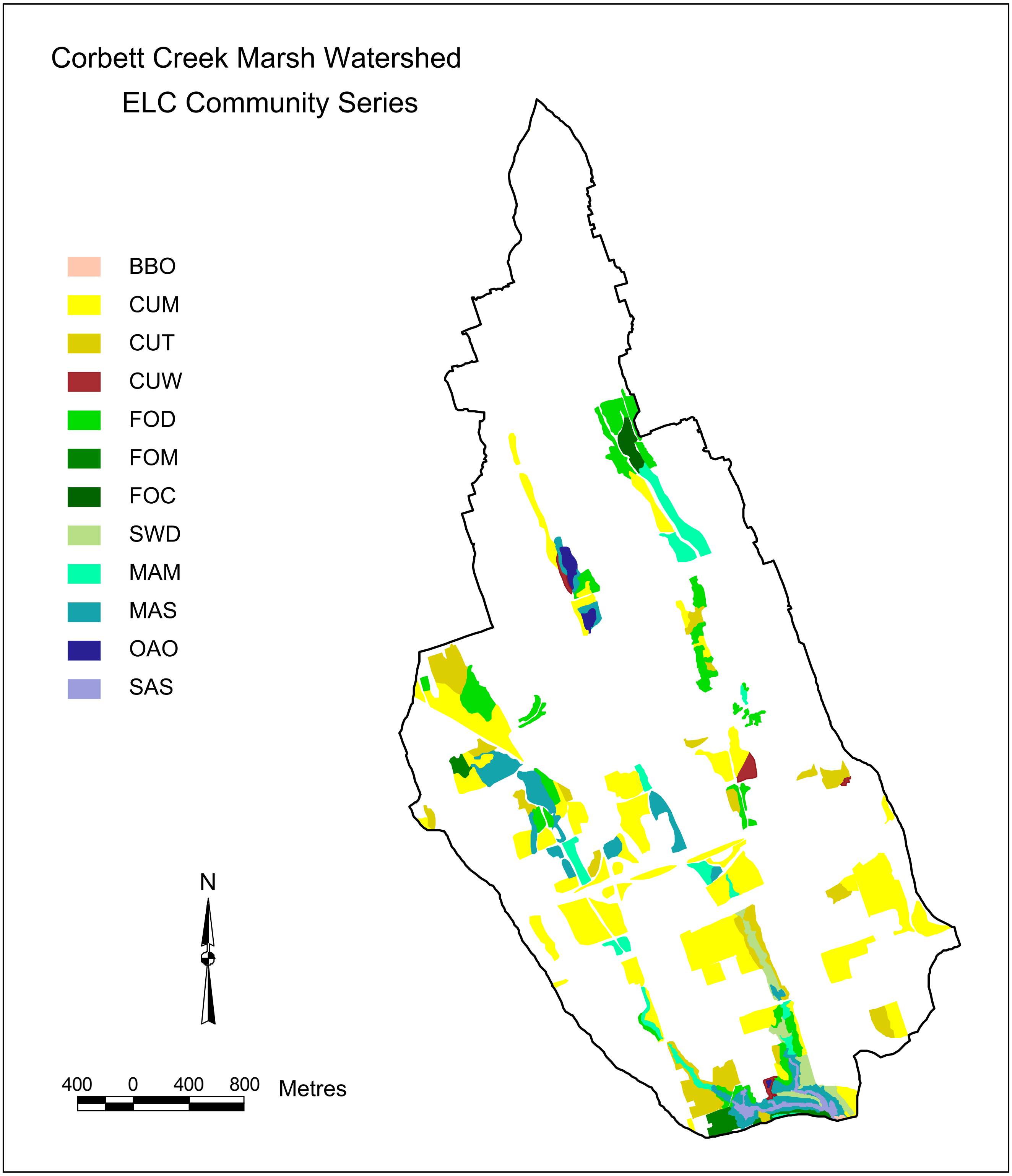

Figure 2.2.1-8. Corbett Creek Marsh watershed Ecological Land Classification (ELC) Community Series designations.

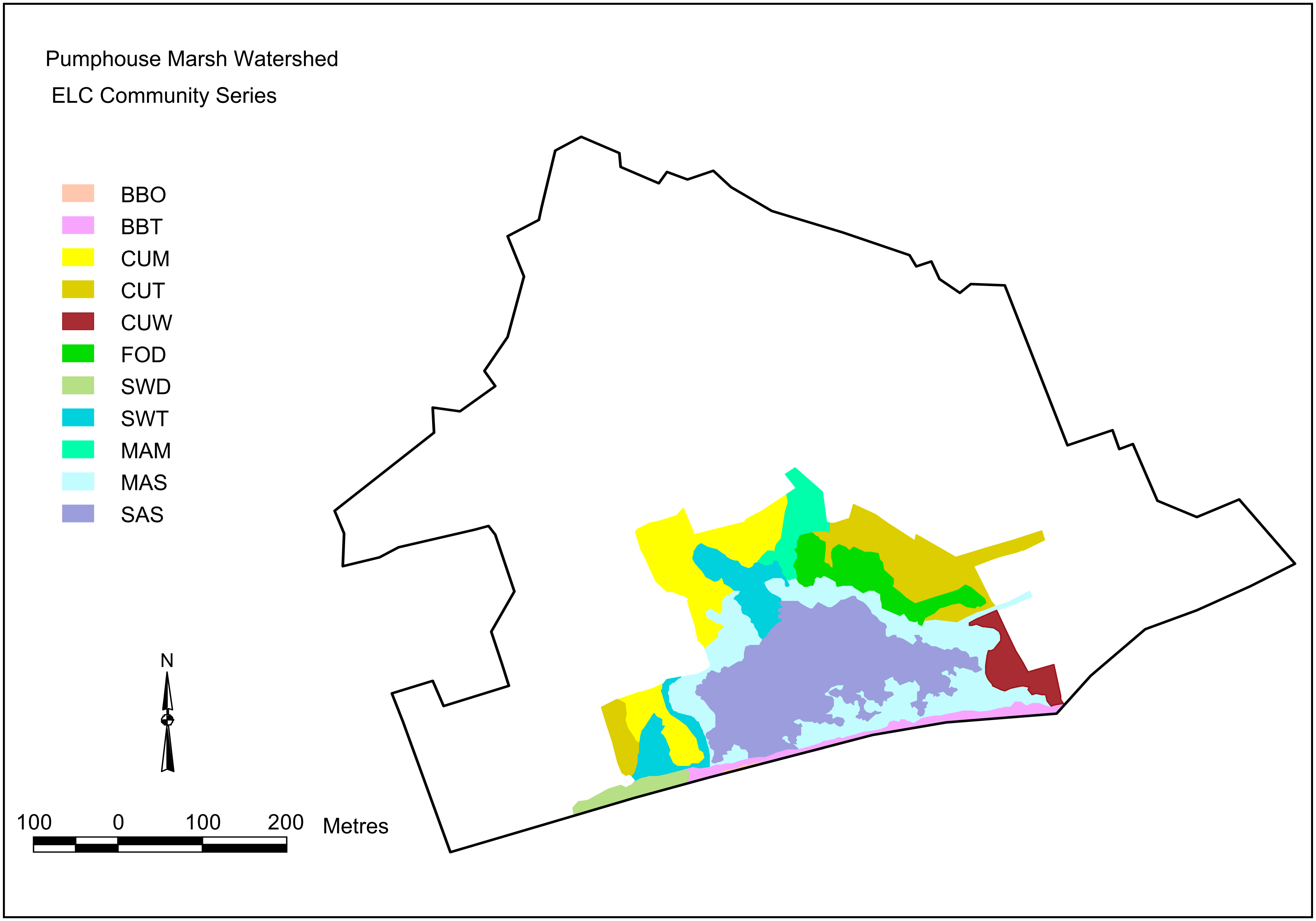

Figure 2.2.1-9. Pumphouse Marsh watershed Ecological Land Classification (ELC) Community Series designations.

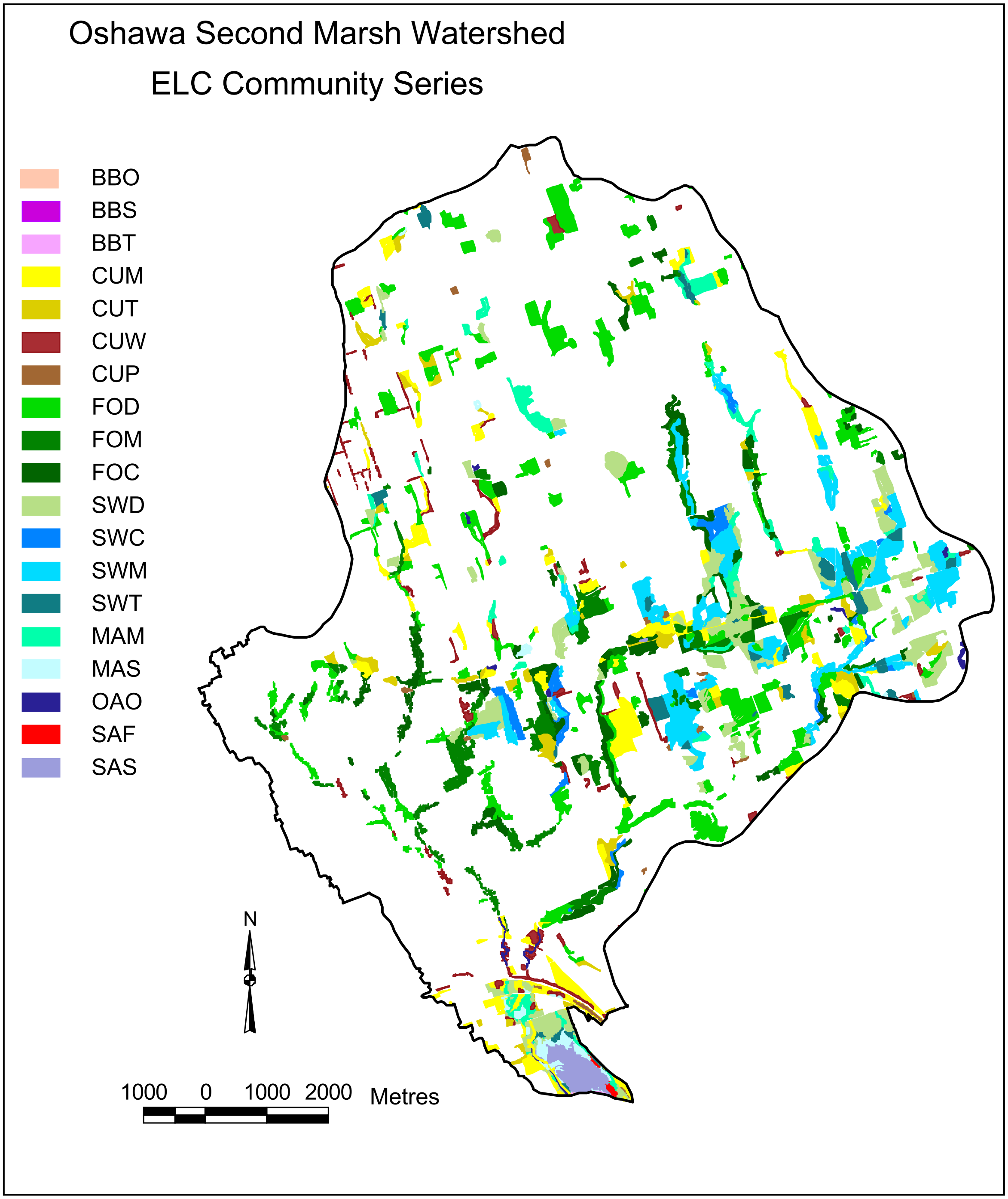

Figure 2.2.1-10. Oshawa Second Marsh watershed Ecological Land Classification (ELC) Community Series designations.

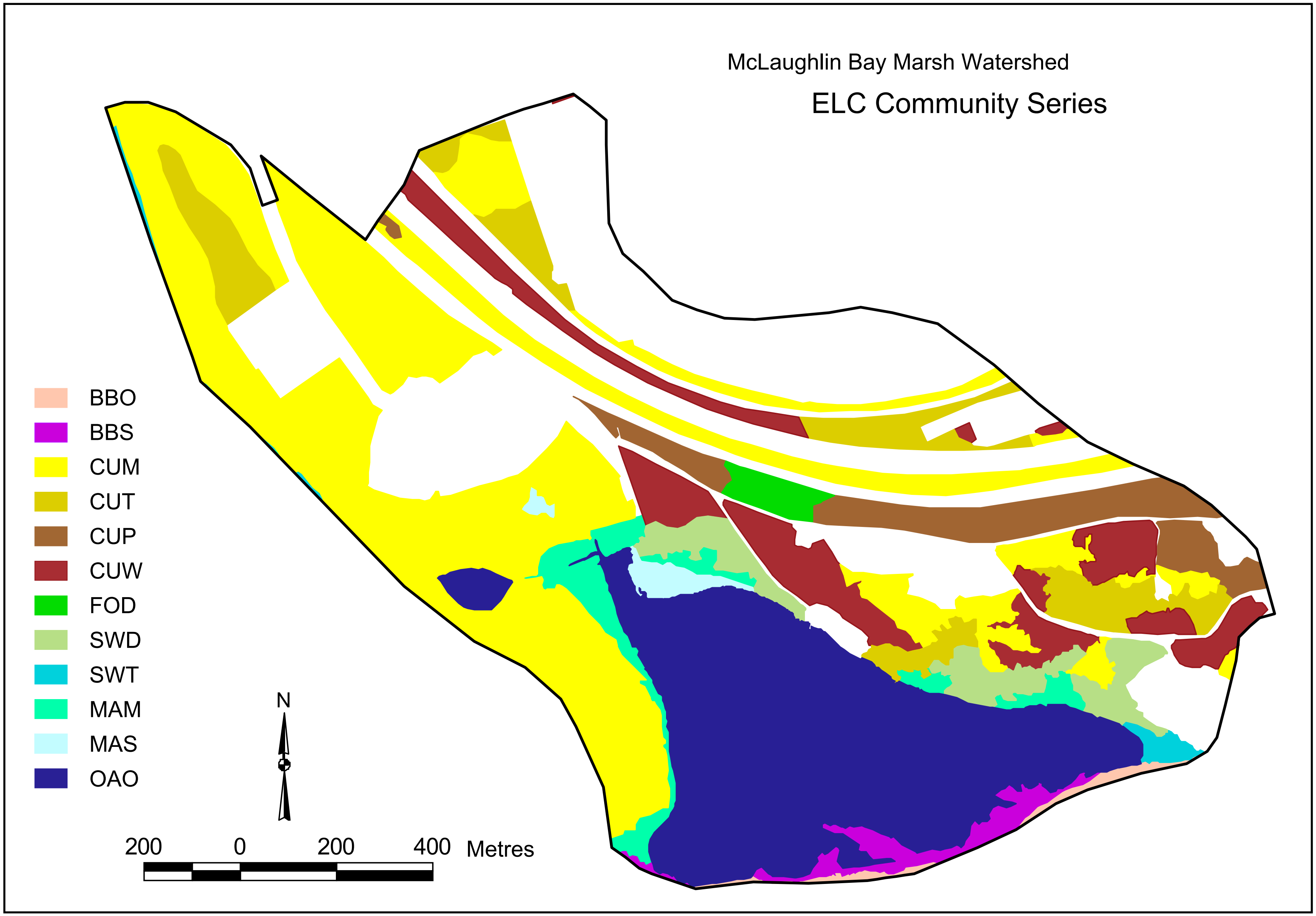

Figure 2.2.1-11. McLaughlin Bay Marsh watershed Ecological Land Classification (ELC) Community Series designations.

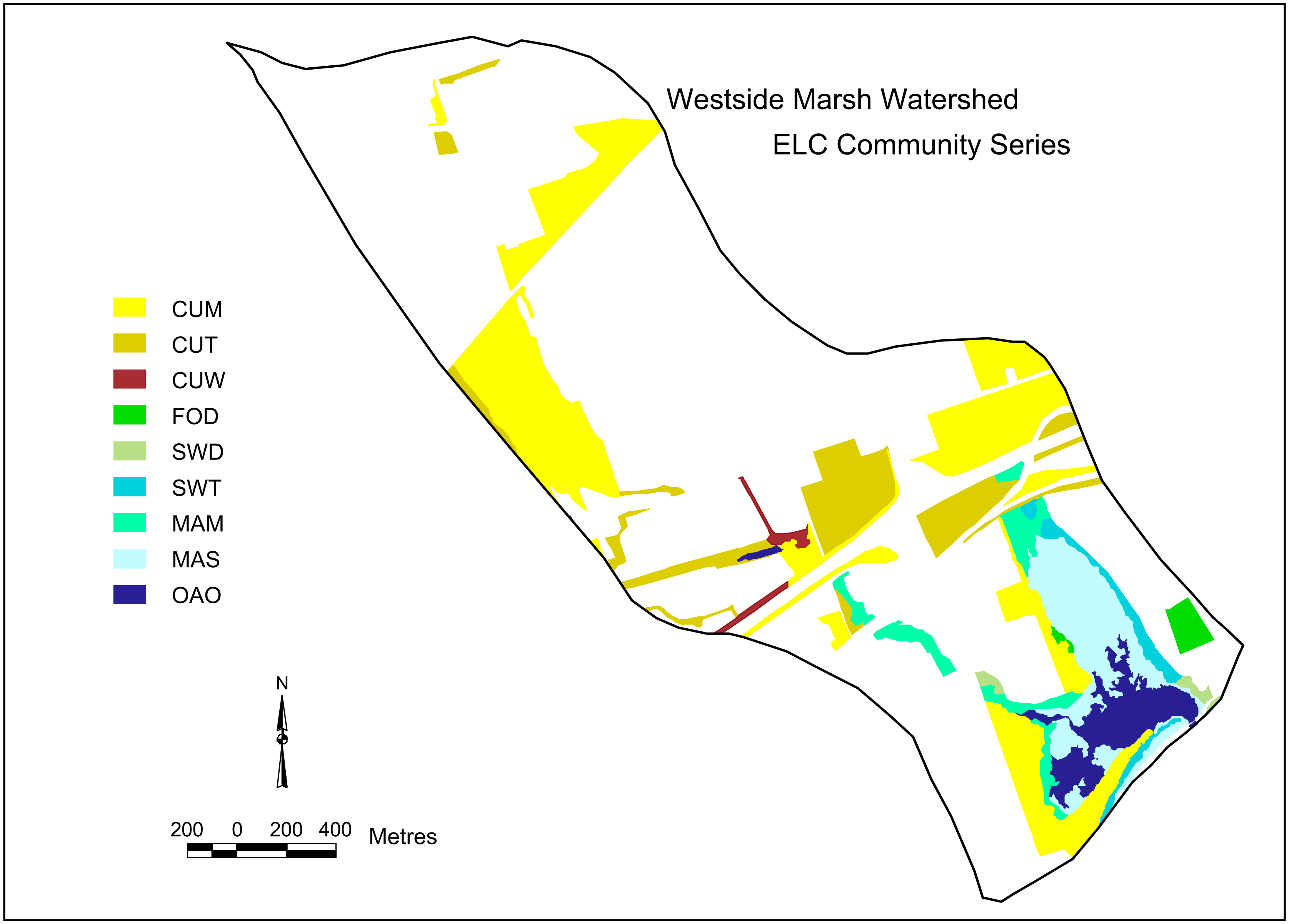

Figure 2.2.1-12. Westside Marsh watershed Ecological Land Classification (ELC) Community Series designations.

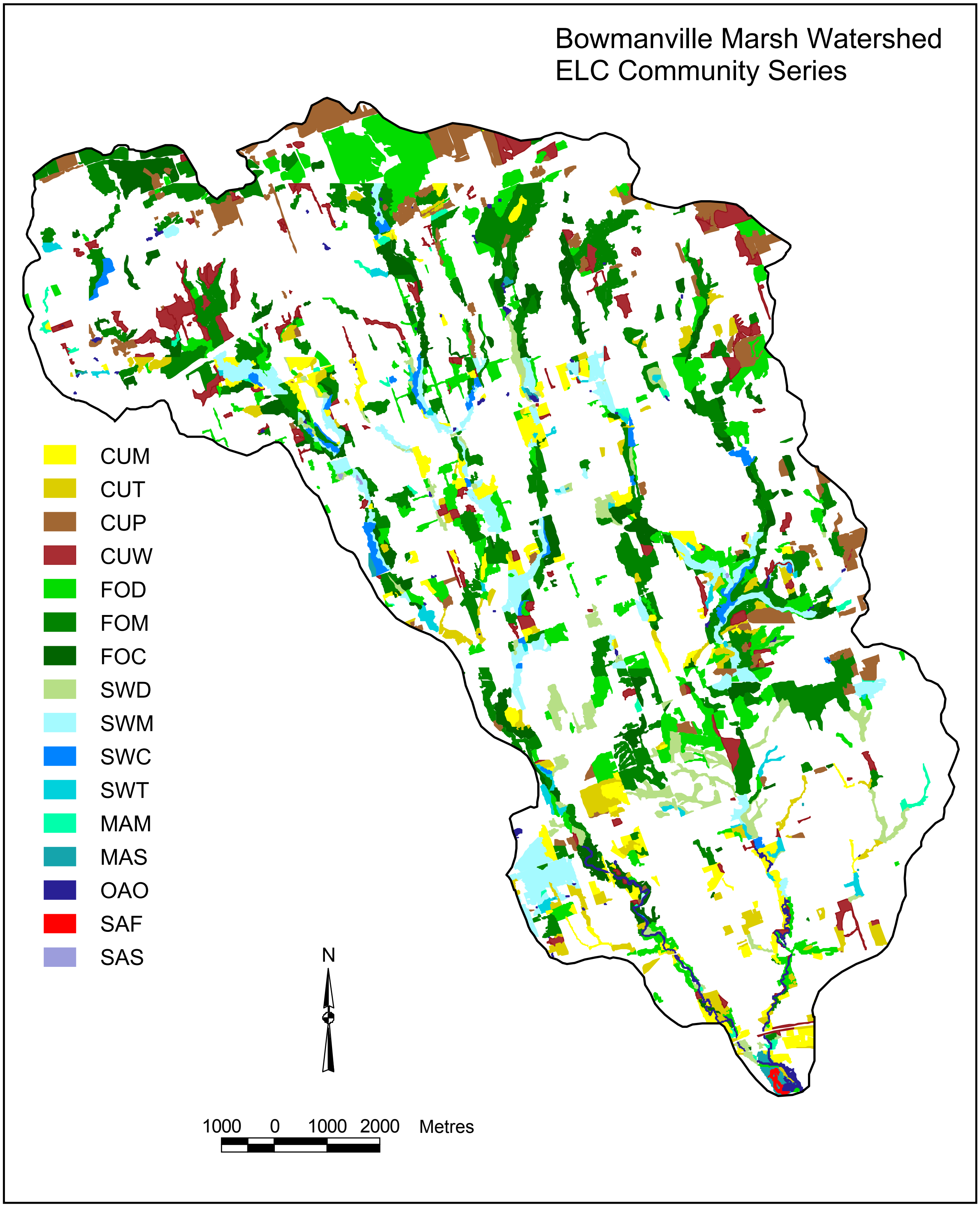

Figure 2.2.1-13. Bowmanville Marsh watershed Ecological Land Classification (ELC) Community Series designations.

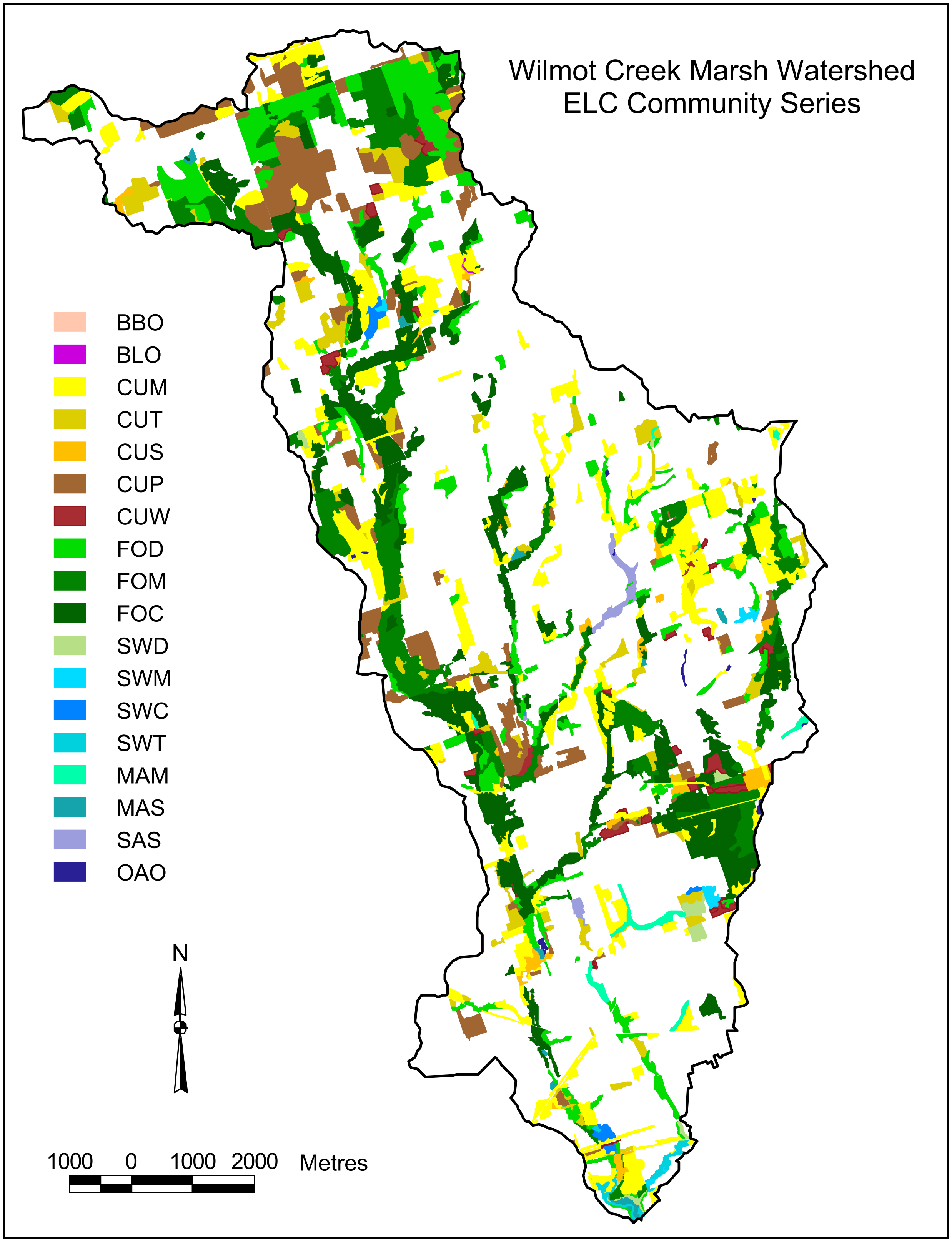

Figure 2.2.1-14. Wilmot Creek Marsh watershed Ecological Land Classification (ELC) Community Series designations.

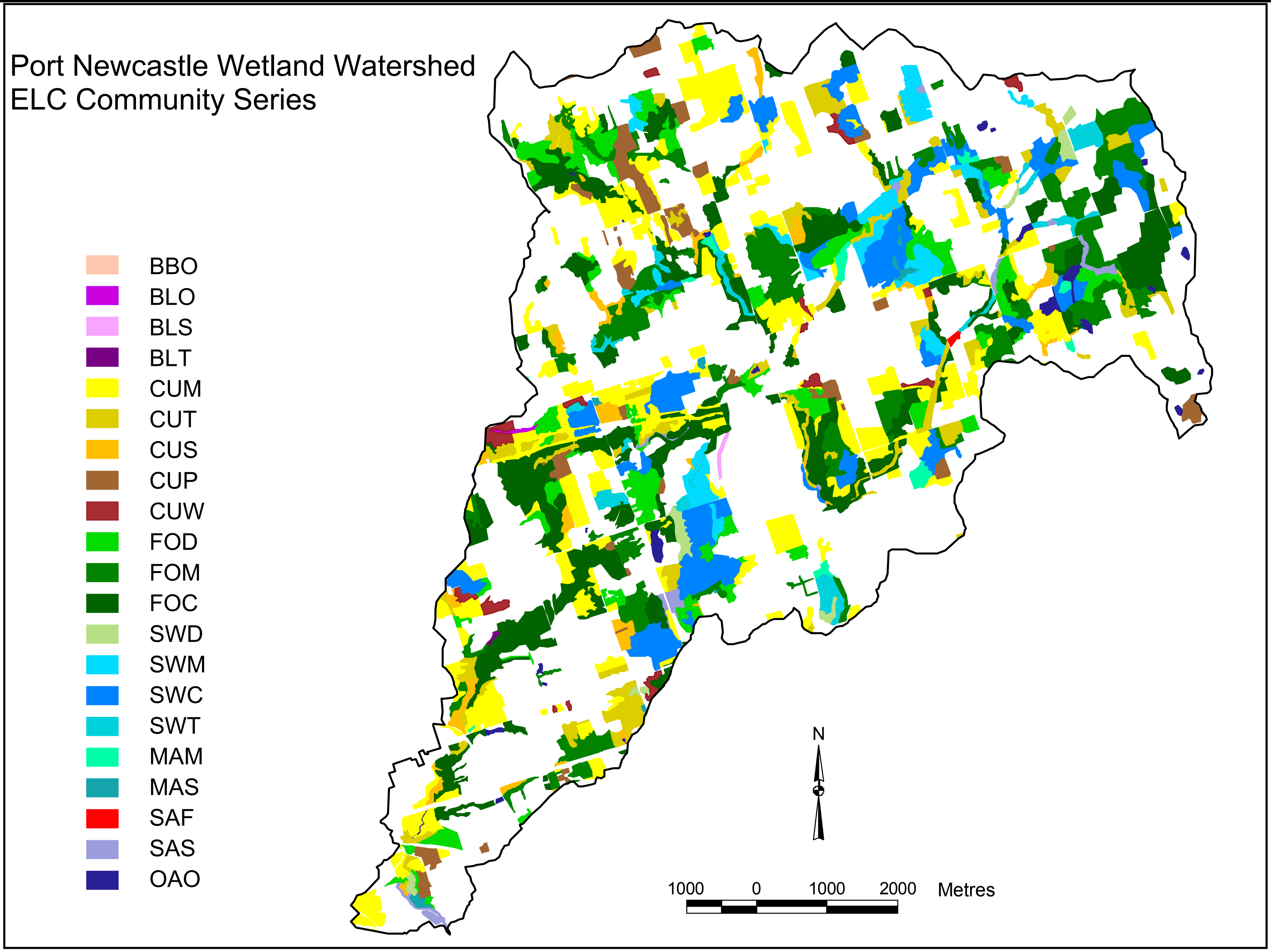

Figure 2.2.1-15. Port Newcastle Wetland watershed Ecological Land Classification (ELC) Community Series designations

2.2.2 Land-use Change in Adjacent Uplands

Objective

To assess and monitor anticipated land-use change on lands adjacent to Durham Region coastal wetlands.

Method Summary

Existing Land-use

Current land-use within 1,000 metres of the wetland boundary was identified and delineated through air photo interpretation. For the purpose of this monitoring activity, land-use was classified as follows:

- **Residential**
- **Non-residential Development**:
    - **Industrial**
    - **Commercial**
    - **Institutional**
- **Utility and Transportation Corridor**
- **Crop and Improved** (including manicured parks, athletic fields, golf courses, crop fields, sod farms, nurseries, and orchards)
- **Pasture** (including grazing lands, fallow fields, and Ecological Land Classification (ELC) designations CUM, CUW and CUT)
- **Woodlot and Forest** (including ELC designations FOD, FOC, FOM, and CUP)
- **Wetland** (including ELC designations SWD, SWC, SWM, SWT, FEO, FES, FET, MAM, MAS, SAS, SAM, and SAF)

Potential Change in Land-use

Using either Regional or Municipal Official Plans (OPs), future land-use can be delineated as a GIS layer. The Municipal OPs are more detailed than the Regional OPs and will give a more accurate estimation of the actual future landscape. To obtain even greater detail, the Municipal Zoning By-laws can be consulted.

For the CLOCA jurisdiction, the Durham Region OP in digital format is currently undergoing revision and is therefore unavailable. However, for this fairly small area (i.e., 1,000 m around the wetland boundary), it was most efficient for experienced and knowledgeable CA staff to denote any changes that are likely to occur based on designations in the appropriate Municipal OP (J. McColl, CLOCA, pers. comm., March 2004). If an area had the potential for a variety of land-use, the Municipal Zoning By-law was referenced.

Because detailed knowledge of these 1,000-m buffers was available, the same land-use designations could be maintained as used for the existing conditions. Any changes were made on the current conditions layer in the GIS to create a new “future” layer.

In certain areas, the OPs were not followed when mapping the potential future change. For example, residential areas currently exist to the south of both Westside and

Bowmanville marshes, but in the Clarington OP these areas are called "Waterfront Greenway" (Municipality of Clarington 1996). While the long-term goal of the municipality may be to acquire many of these properties and create a park instead, it is unlikely to happen in the near future (i.e., within 10 years).

Data Analysis

Using GIS queries, areas (ha) for each classification in the current land-use layer, the future land-use layer, and their percentage change were calculated. The Lake Ontario area within the 1,000-m buffer was excluded from both current and future calculations and any non-lake "open water" was included within the "Wetland" category.

Results

Current land-use within the 1,000-m buffers is, in most cases, heavily altered by human use (Table 2.2.2-1 and Figures 2.2.2-1 to 2.2.2-29). Even much of the "natural" vegetation is mostly human-influenced (i.e., "cultural" according to ELC designations).

Future land-use will change within the 1,000-metre buffer of most wetlands (Table 2.2.2-1). Only the Pumphouse Marsh buffer will likely remain unchanged, since it is already heavily developed. In most instances, there will be a decrease in the percentage of naturally vegetated areas, while developed land-uses will increase. The TRCA wetlands may all experience a potentially large increase in the amount of development within 1000 m (from 10 percent for Rouge River Marsh and Frenchman's Bay Marsh to 30 percent for Carruthers Creek Marsh). In the CLOCA jurisdiction, the Corbett Creek Marsh buffer will potentially have an increase of 15 percent increase in non-residential development (Table 2.2.2-1 and Figures 2.2.2-15 and 2.2.2-16).

While most of the potential future land-use changes impact negatively on natural vegetation communities, one positive change is the potential increase of almost eight percent in "Woodlot and Forest" area in the 1,000-m buffer surrounding Cranberry Marsh (Table 2.2.2-1). This is a result of change from crop production to a recently-treed lot (with small seedlings). In addition, both the Westside and Bowmanville marsh buffers may see small increases in the percentage of woodlot and forest, since a parcel currently designated as "Crop and Improved" has been conveyed to CLOCA, which plans to reforest this property (P. Sisson, CLOCA, pers. comm., March 2004).

Discussion

Natural habitat adjacent to a wetland can be vital for maintaining wetland functions and attributes. While these adjacent lands are often referred to as buffers, they can be an intrinsic part of the wetland ecosystem, providing a variety of habitat functions for some wetland-associated fauna (Environment Canada 2004). These lands could better be described as Critical Function Zones (CFZs) (see sidebar below for definition; Environment Canada 2004).

At least until CFZs are determined for Durham Region coastal wetlands, tracking the current and future adjacent land-use will assist in determining whether human-created disturbances will potentially increase or decrease in the future, thereby impacting wetland condition. Impacts of land-use on amphibian populations in wetlands have been found to exist even as far as 2,000-3,000 m (Houlahan and Findlay 2003).

Difficulties arose in determining whether land-use designated as “Agricultural” should then be mapped as “Crop and Improved” in the future (assuming a worst-case scenario in terms of loss of natural cover) or as pasture or left as the current vegetation communities and assume no change. This should be clarified in the Methodology Handbook (Environment Canada and Central Lake Ontario Conservation Authority 2003). For this iteration, vegetation cover was left as is in agricultural zones.

The future land-use categories suggested in the Methodology Handbook (Environment Canada and Central Lake Ontario Conservation Authority 2003) were:

- Open Space (includes all natural areas)
- Agriculture
- Urban (high-density residential and industrial uses)

However, at this small scale it was possible to designate changes according to the same land-use classifications as were used for existing conditions. Grouping into the broader categories listed above can easily be accomplished through GIS queries, so it may be preferable to start with as much detail as possible. The level of detail achievable may vary among the CAs.

The potential future changes in land-use are based on broad OP designations and as such do not mean that the mapped changes will necessarily ever occur. It is impossible to accurately predict all future change, but by using OP mapping, these potential changes are considered a best estimate.

Critical Function Zone defined:

The term Critical Function Zone (or CFZ) describes non-wetland areas within which biophysical functions or attributes directly related to the wetland of interest occur. This could, for example, be adjacent upland grassland nesting habitat for waterfowl (that use the wetland to raise their broods). It could also be upland turtle nesting habitat for turtles that otherwise occupy the wetland; foraging areas for Leopard Frog and dragonflies; or nesting habitat for birds that use both the wetland-upland ecozone (e.g., Yellow Warbler). A groundwater recharge area that is important for the function of an adjacent wetland could also be considered a CFZ.

Effectively, the CFZ is a functional extension of the wetland into the upland. Once identified, the CFZ (with the wetland itself) needs to be protected by a Protection Zone (PZ) from adverse effects that originate from outside the wetland and its CFZ. This zone could range in scope from a simple fence (i.e., to dissuade human access) to a vegetated area for intercepting storm water run-off or providing physical separation from a stressor. Effectively, the PZ is aimed at reducing upland impacts on wetland functions.

The combined CFZ and its PZ may range in total width from a few metres to hundreds of metres.

Environment Canada (2004)

Future Considerations

Effects of adjacent land-use have been found on amphibians even within a two to three km buffer (Houlahan and Findlay 2003), but many other studies have looked at watershed land-use as a factor having more of a direct impact on wetland health through decreased water quality (e.g., Crosbie and Chow-Fraser 1999, Lougheed *et al.* 2001).

While watershed land-use is important to monitor for its effects on water quality/quantity, examining land-use immediately adjacent to each wetland (whether that land is within the watershed or not) should also continue. Much work has been done on habitat fragmentation and landscape effects in various ecosystems. These previous studies show that for metapopulation dynamics and habitat connectivity, the landscape surrounding a particular natural heritage feature, such as a wetland, is of vital importance to the health of various wildlife populations.

Currently the total areas and percentages of land-use include the wetland itself, but it may be more appropriate to subtract the area within the delineated wetland boundary habitats, so that the numbers more accurately reflect adjacent land-use.

Determining Critical Function Zones for the Durham coastal wetlands would be an important next step in evaluating appropriate levels of development on adjacent lands.

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Table 2.2.2-1. Existing and potential land-use change in the 1000-metre buffer surrounding 15 Durham Region coastal wetlands.

Current Land-use	Rouge River Marsh	Frenchman's Bay Marsh	Hydro Marsh	Duffins Creek Marsh	Carruthers Creek Marsh
Wetland	11.0	7.2	6.5	12.6	14.1
Woodlot and Forest	20.8	5.4	1.5	10.6	6.1
Pasture and Idle Field	7.9	11.2	19.3	26.6	25.0
Crop and Improved	6.2	1.4	6.1	8.0	9.7
Residential	42.9	54.1	27.3	14.8	36.3
Non-residential	4.6	10.8	36.9	23.4	4.3
Utility and Transportation	6.5	9.9	2.5	3.9	4.5
Future Land-use					
Wetland	7.3	6.9	6.5	11.9	12.9
Woodlot and Forest	19.0	2.1	0.8	8.9	3.3
Pasture and Idle Field	3.5	5.2	6.0	13.0	6.9
Crop and Improved	7.8	0.6	2.3	5.7	1.2
Residential	50.9	64.8	30.3	16.0	54.7
Non-residential	5.7	10.3	51.5	40.4	16.5
Utility and Transportation	5.8	10.1	2.6	4.1	4.5
Change in Land-use					
Wetland	-3.7	-0.3	-0.1	-0.7	-1.2
Woodlot and Forest	-1.9	-3.3	-0.7	-1.7	-2.8
Pasture and Idle Field	-4.4	-6.0	-13.2	-13.6	-18.1
Crop and Improved	1.6	-0.8	-3.7	-2.3	-8.5
Residential	8.0	10.7	3.0	1.2	18.4
Non-residential	1.1	-0.6	14.6	17.0	12.1
Utility and Transportation	-0.7	0.2	0.1	0.2	0.0

Table 2.2.2-1. Continued.

Current Land-use	Cranberry Marsh	Lynde Creek Marsh	Corbett Creek Marsh	Pump-house Marsh	Oshawa Second Marsh	McLaughlin Bay Marsh	Westside Marsh	Bowman-ville Marsh	Wilmot Creek Marsh	Port Newcastle Wetland
Beach/Bluff	0.4	0.1	0.8	0.9	0.9	2.2	0.5	0.6	0.9	0.6
Wetland	27.4	18.5	6.3	12.8	24.5	25.4	18.1	40.7	4.8	3.4
Woodlot and Forest	7.9	5.4	6.4	6.9	2.5	6.8	2.1	2.4	12.0	10.6
Pasture and Idle Field	15.2	9.7	14.0	1.7	20.6	25.9	16.0	14.4	19.2	19.0
Crop and Improved	37.1	29.5	9.9	18.8	11.5	27.2	12.0	12.8	24.0	29.1
Residential	9.1	18.3	1.3	43.7	14.0	1.1	10.4	9.4	30.1	27.4
Non-residential	0.9	13.1	54.2	5.4	17.1	3.6	33.0	13.1	2.7	2.8
Utility and Transportation	2.0	5.3	7.1	9.7	9.0	7.8	7.9	6.6	6.4	7.1
Future Land-use										
Beach/Bluff	0.4	0.1	0.8	0.9	0.9	2.2	0.5	0.6	0.9	0.6
Wetland	27.4	18.1	6.3	12.8	24.5	25.4	13.3	37.6	4.8	3.4
Woodlot and Forest	15.5	4.8	2.4	6.9	2.5	6.8	5.2	5.2	12.0	10.6
Pasture and Idle Field	15.2	8.6	9.6	1.7	14.7	22.4	11.4	9.1	17.7	17.3
Crop and Improved	29.6	25.2	2.7	18.8	6.2	13.0	4.4	4.9	17.1	23.0
Residential	9.1	23.1	1.3	43.7	15.2	2.1	10.4	13.1	33.8	28.8
Non-residential	0.9	11.6	69.6	5.4	27.1	20.0	46.7	24.1	7.2	11.3
Utility and Transportation	2.0	8.6	7.2	9.7	9.0	7.8	7.7	6.6	6.5	7.4
Change in Land-use										
Beach/Bluff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wetland	0.0	-0.4	0.0	0.0	0.0	0.0	-4.8	-3.1	0.0	0.0
Woodlot and Forest	7.6	-0.7	-4.0	0.0	0.0	0.0	3.1	2.8	0.0	0.0
Pasture and Idle Field	0.0	-1.1	-4.4	0.0	-5.9	-3.4	-4.6	-5.3	-1.5	-1.7
Crop and Improved	-7.6	-4.3	-7.1	0.0	-5.3	-14.2	-7.6	-7.8	-6.9	-6.1
Residential	0.0	4.8	0.0	0.0	1.2	1.0	0.0	3.7	3.7	1.4
Non-residential	0.0	-1.5	15.4	0.0	10.0	16.5	13.7	11.0	4.5	8.5
Utility and Transportation	0.0	3.3	0.1	0.0	0.0	0.0	-0.3	0.0	0.2	0.3

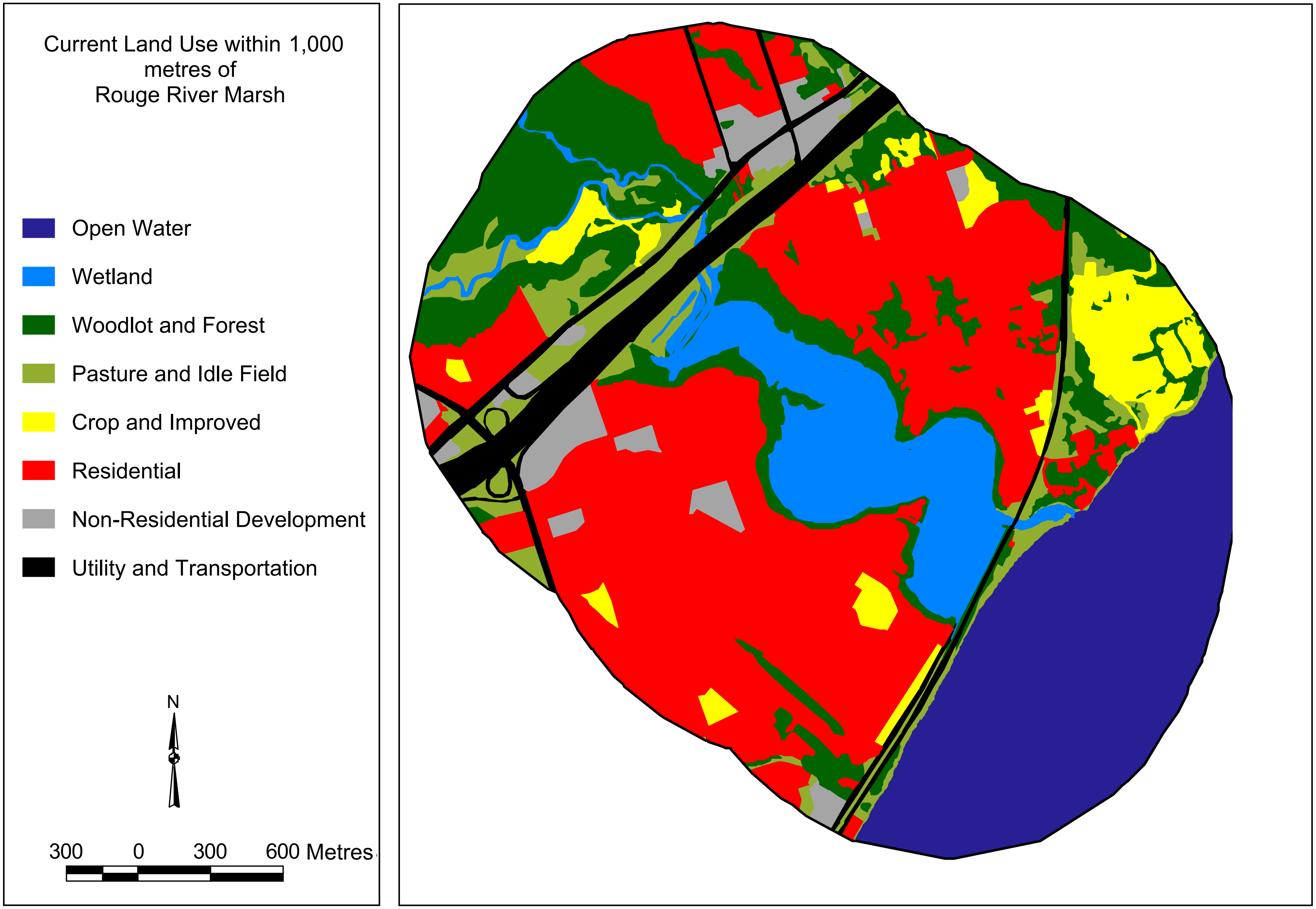

Figure 2.2.2-1. Current land-use at Rouge River Marsh and within a 1,000-metre buffer around its boundary.

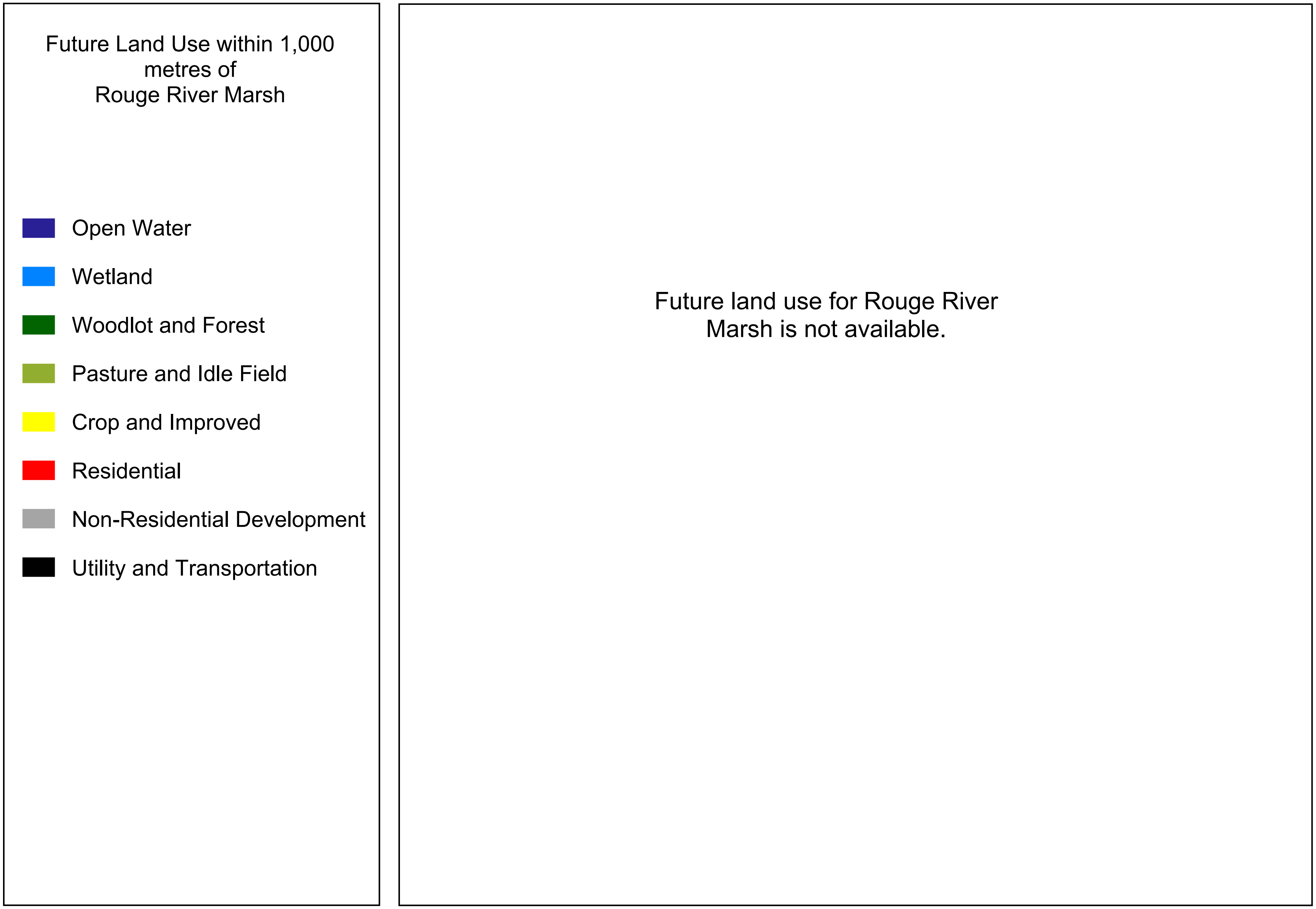

Figure 2.2.2-2. Future land-use at Rouge River Marsh and within a 1,000-metre buffer around its boundary.

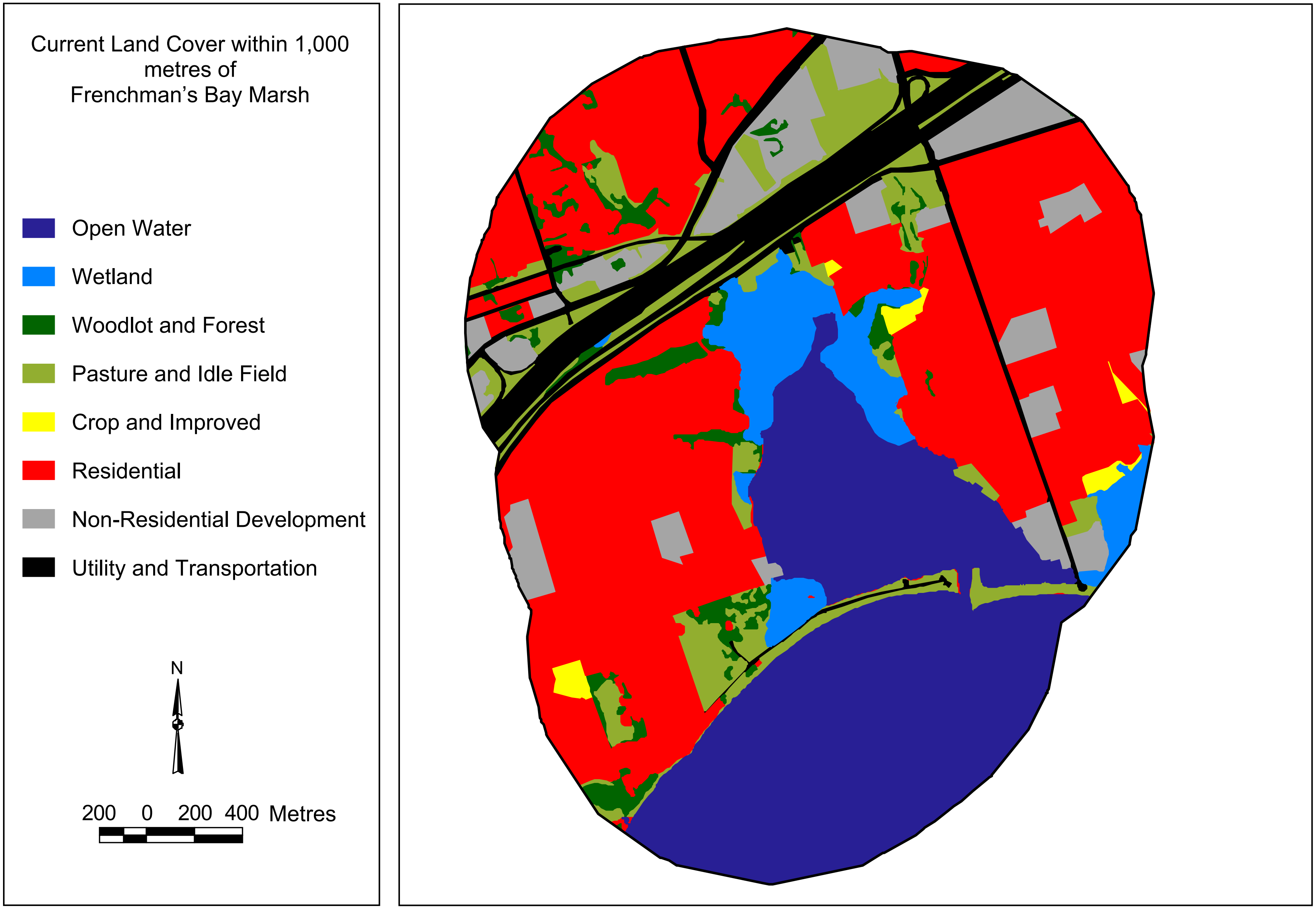

Figure 2.2.2-3. Current land-use at Frenchman's Bay Marsh and within a 1,000-metre buffer around its boundary.

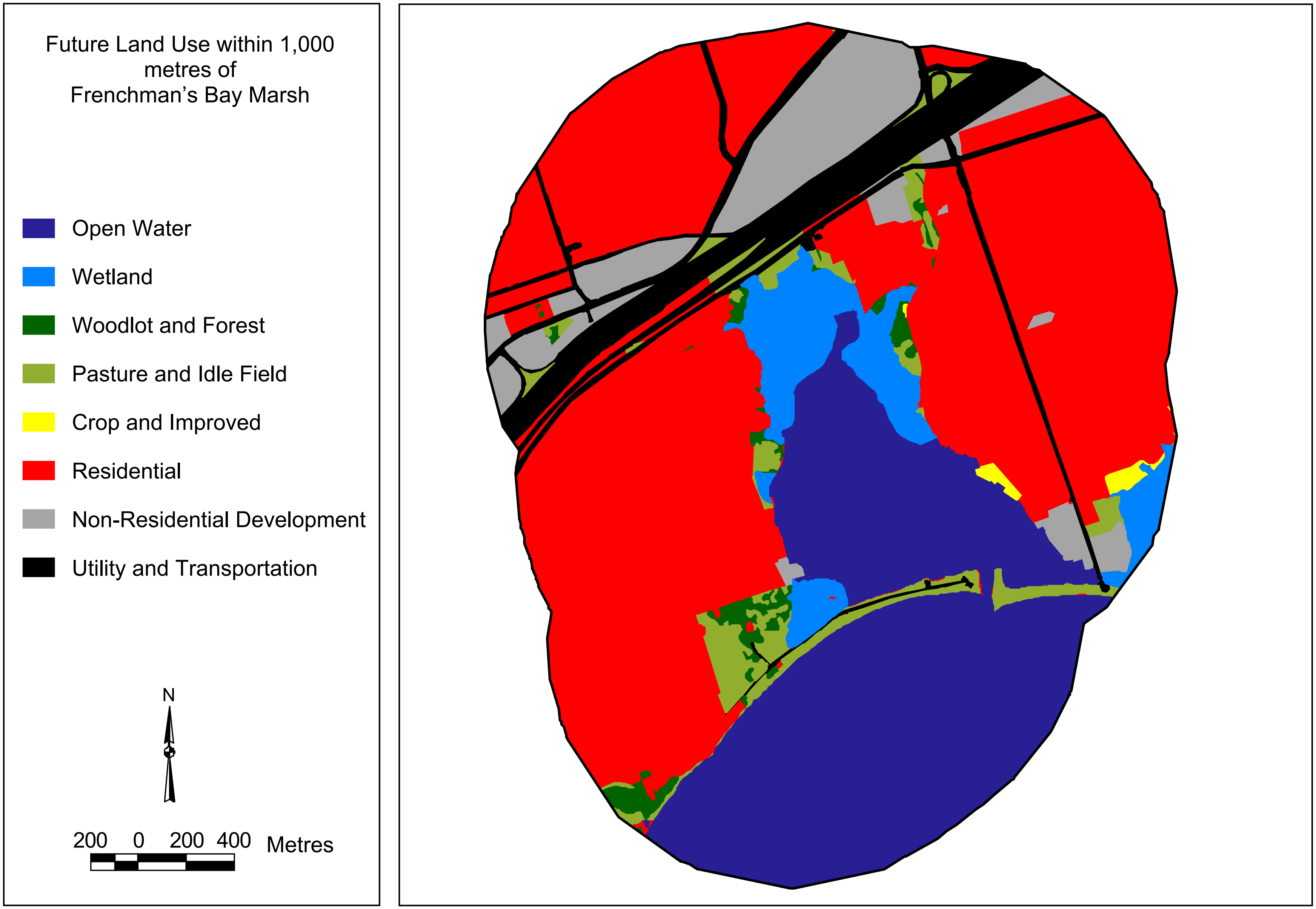

Figure 2.2.2-4. Future land-use at Frenchman's Bay Marsh and within a 1,000-metre buffer around its boundary.

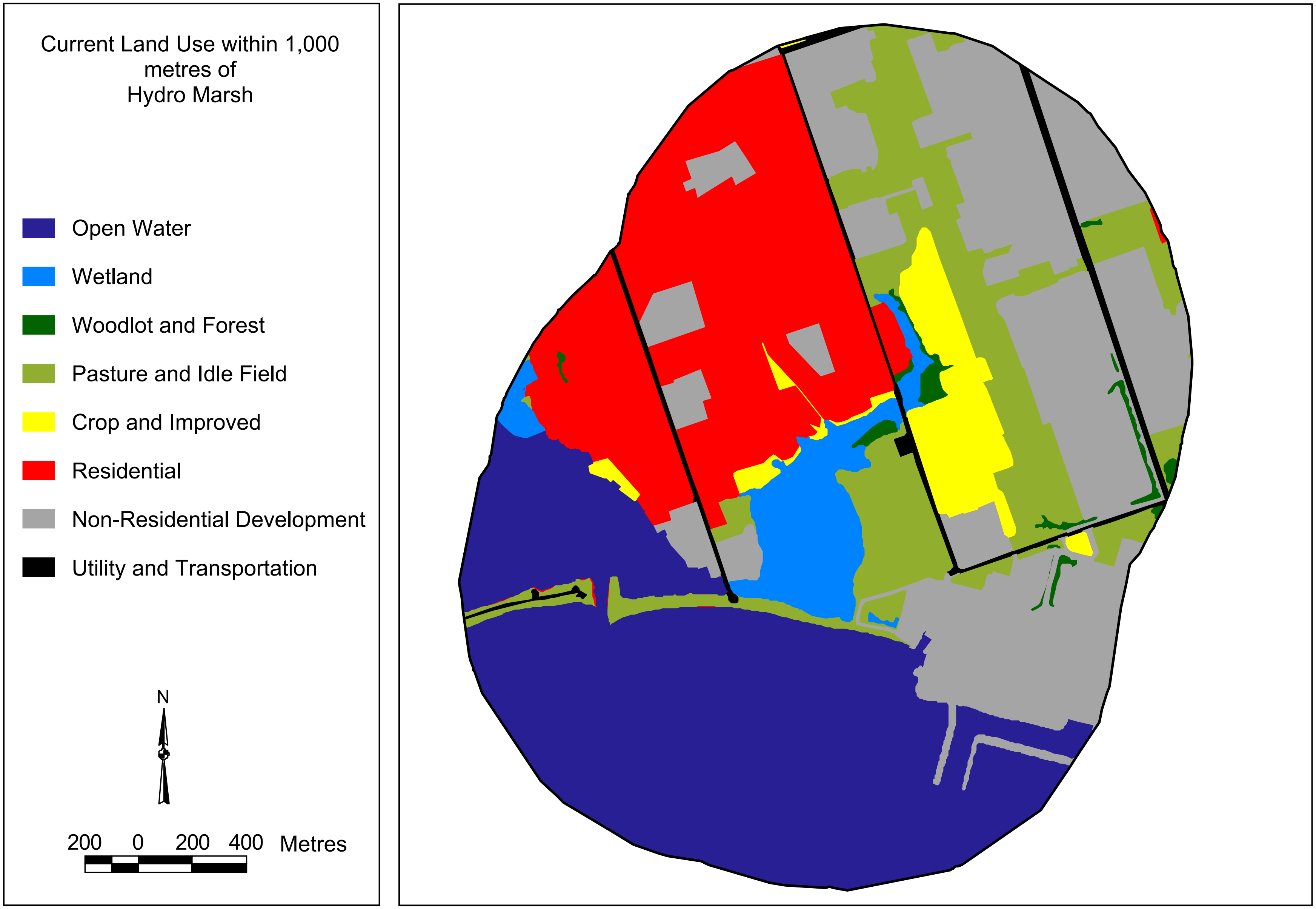

Figure 2.2.2-5. Current land-use at Hydro Marsh and within a 1,000-metre buffer around its boundary.

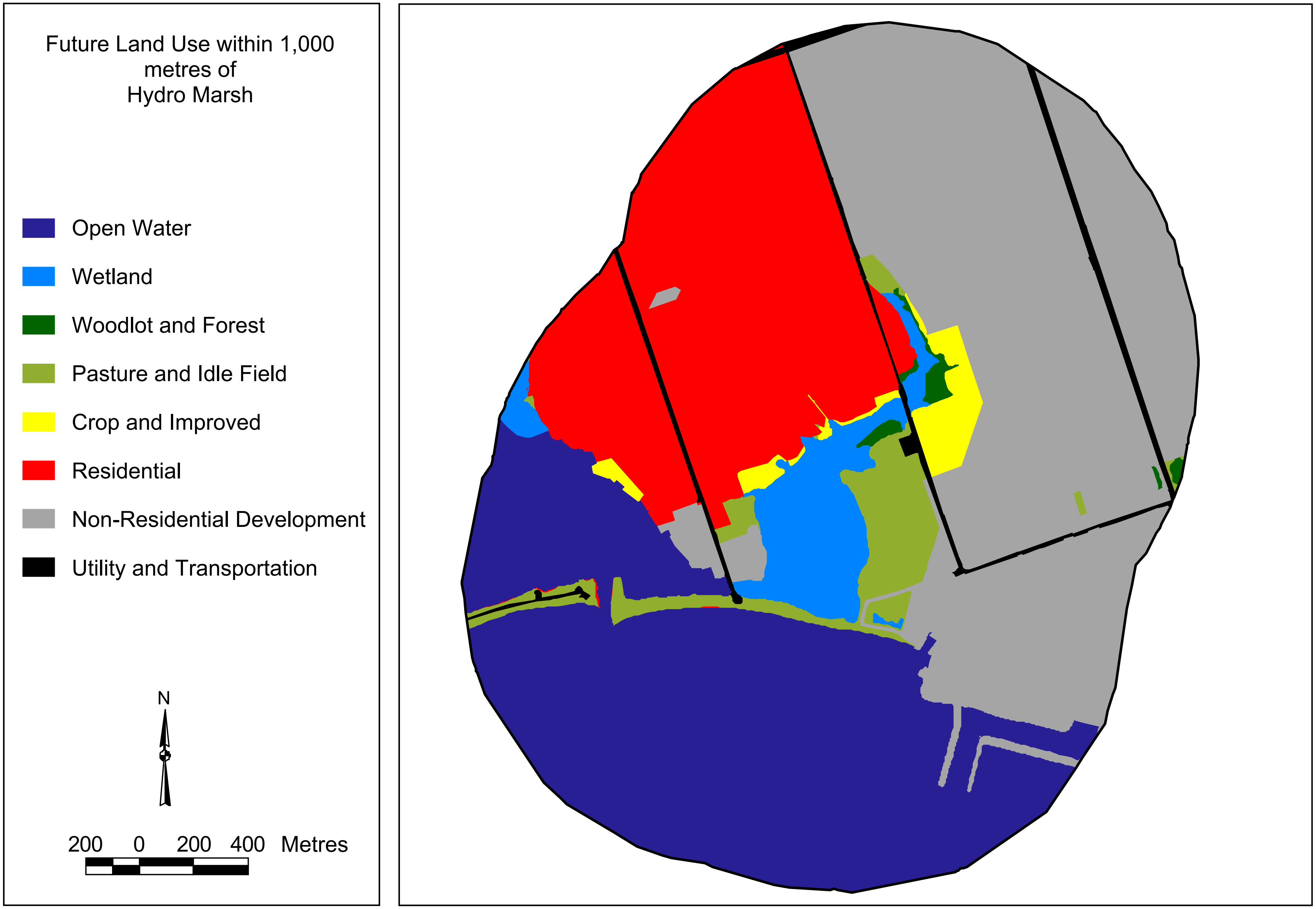

Figure 2.2.2-6. Future land-use at Hydro Marsh and within a 1,000-metre buffer around its boundary.

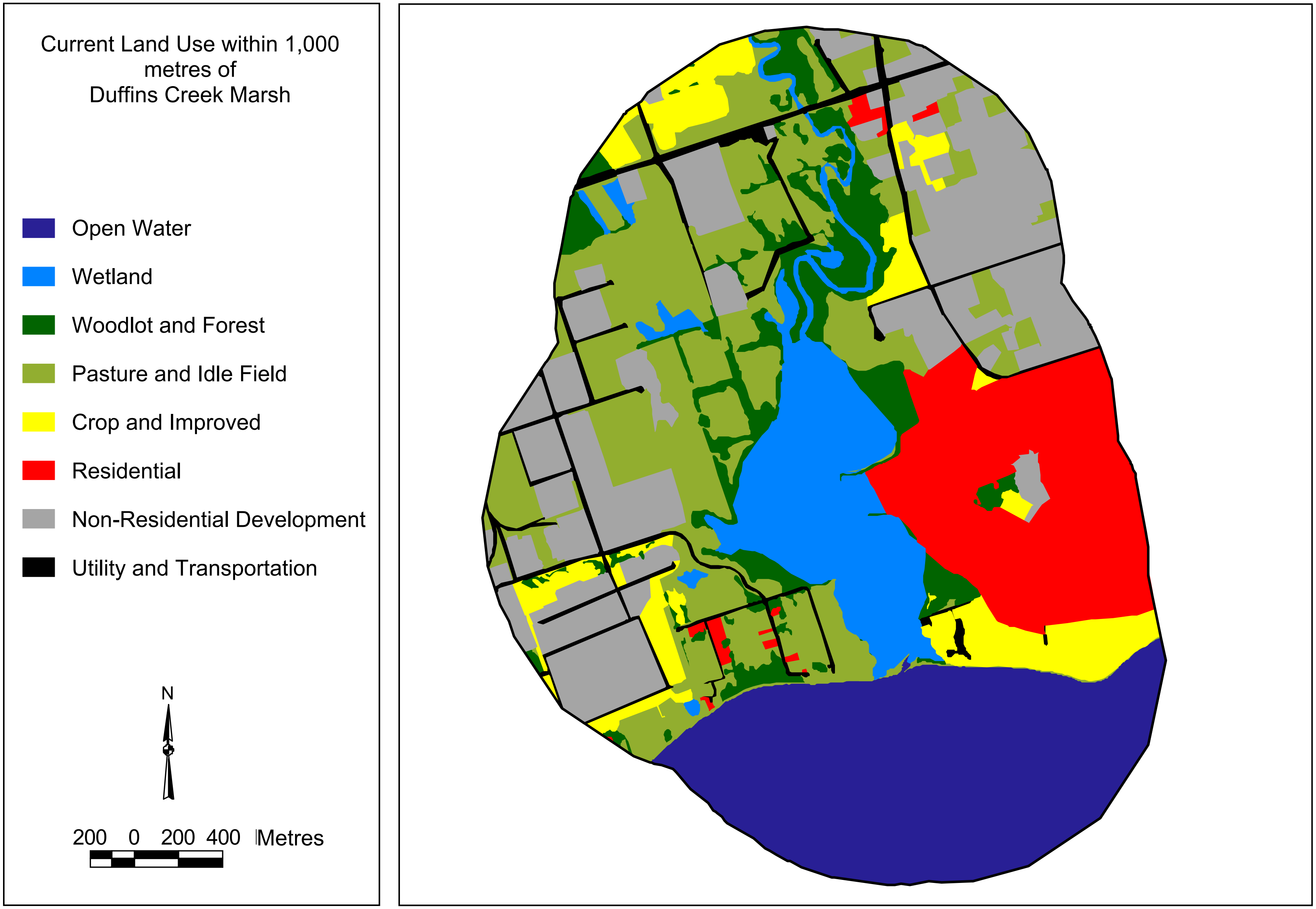

Figure 2.2.2-7. Current land-use at Duffins Creek Marsh and within a 1,000-metre buffer around its boundary.

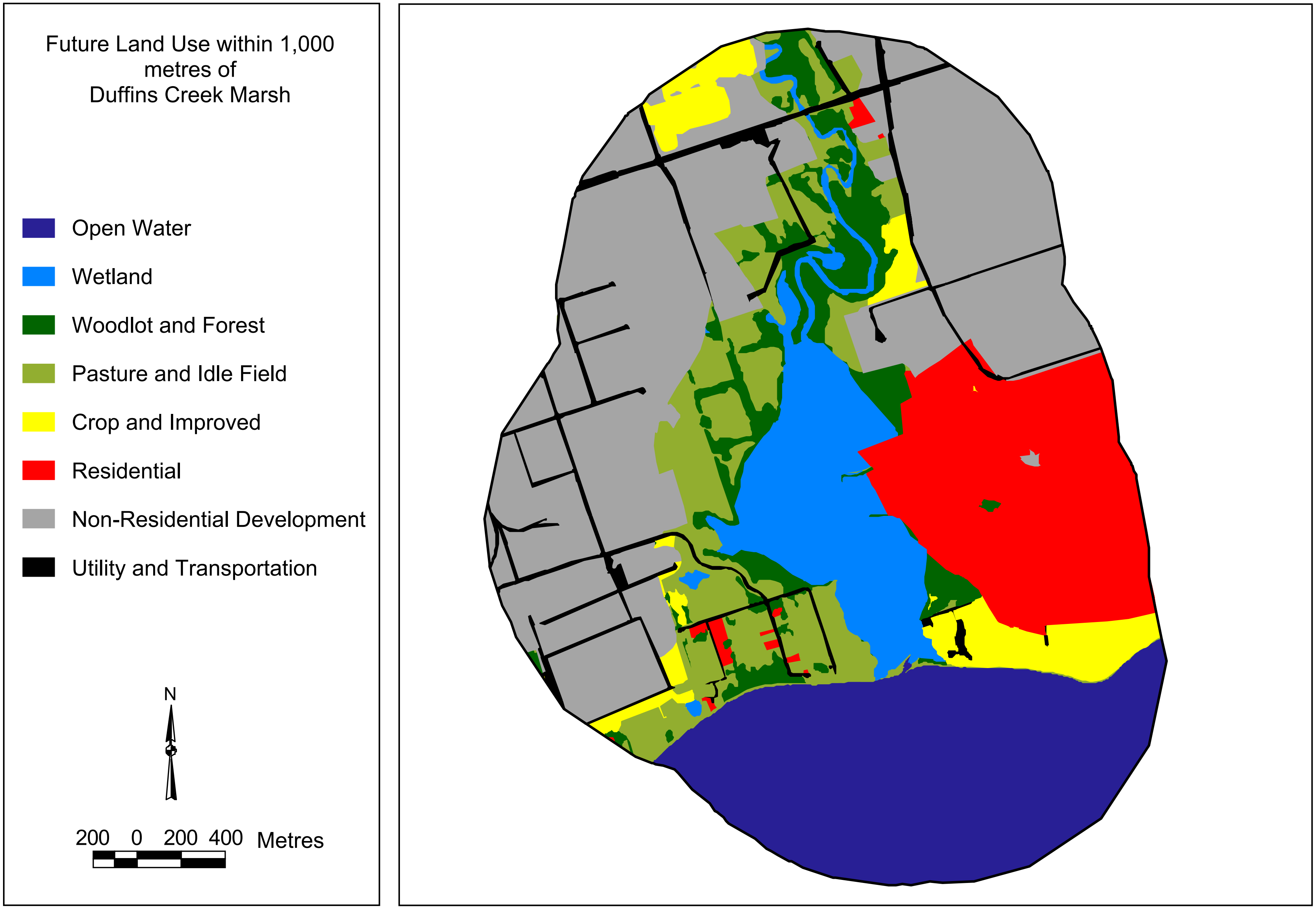

Figure 2.2.2-8. Future land-use at Duffins Creek Marsh and within a 1,000-metre buffer around its boundary.

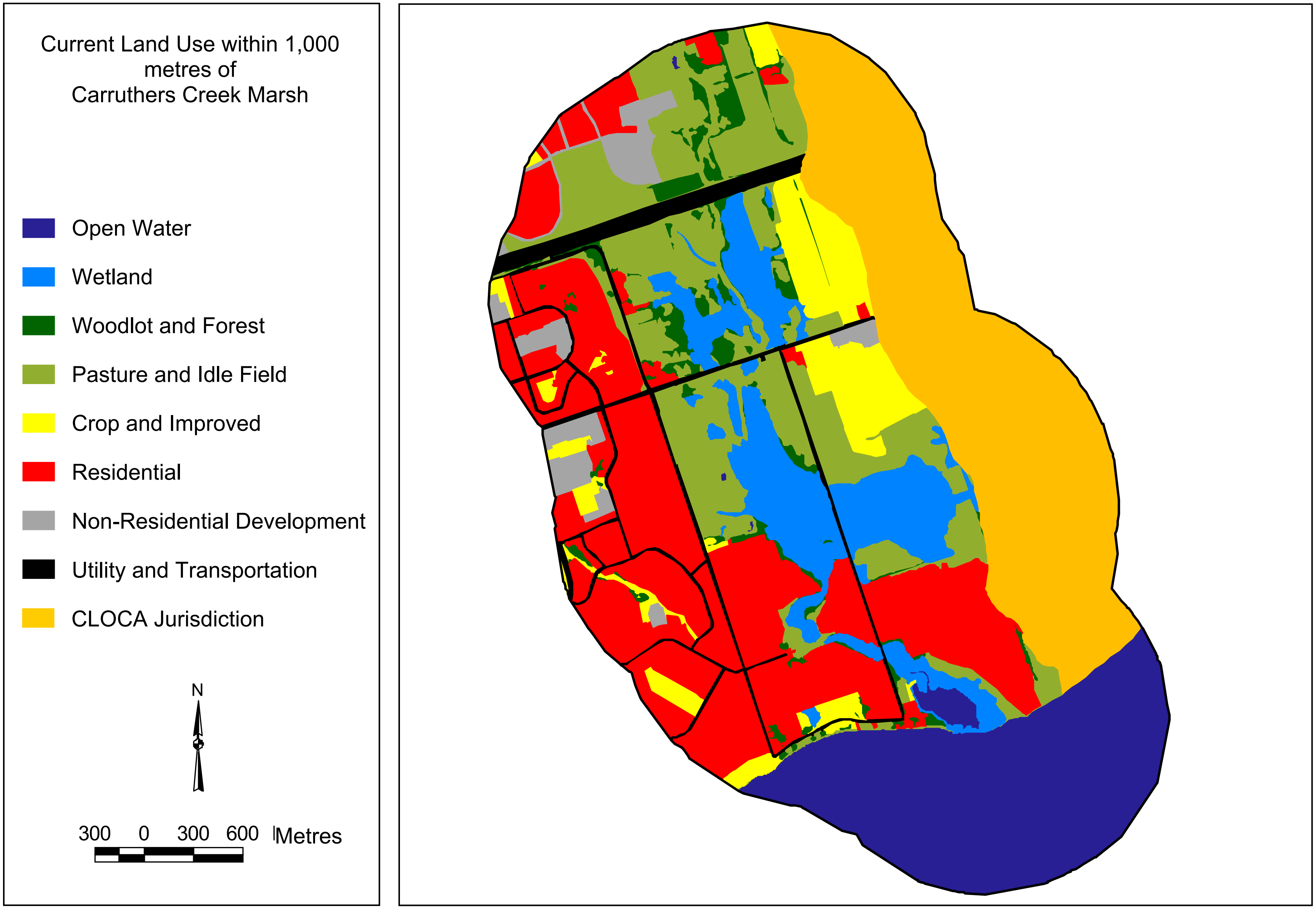

Figure 2.2.2-9. Current land-use at Carruthers Creek Marsh and within a 1,000-metre buffer around its boundary.

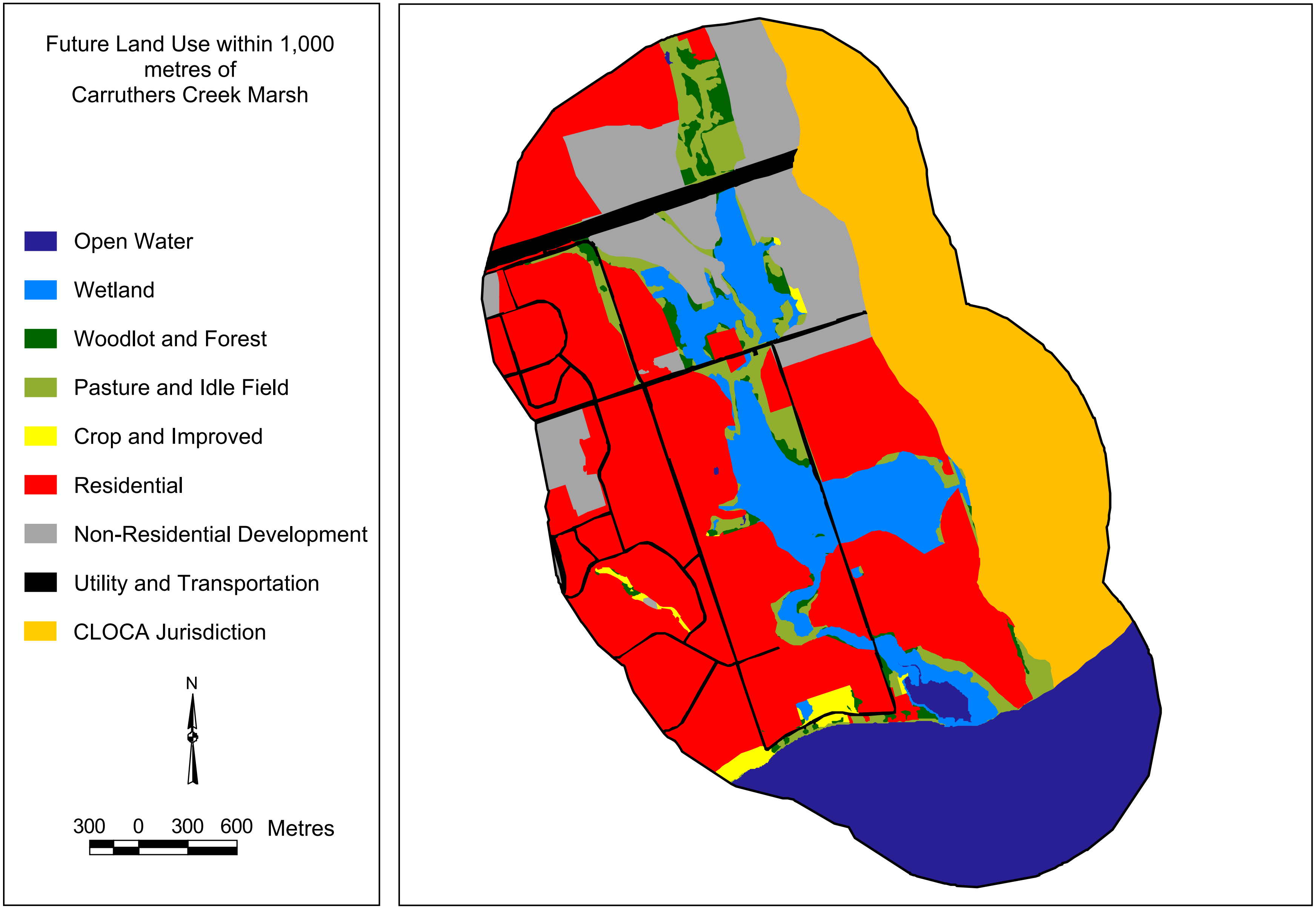

Figure 2.2.2-10. Future land-use at Carruthers Creek Marsh and within a 1,000-metre buffer around its boundary.

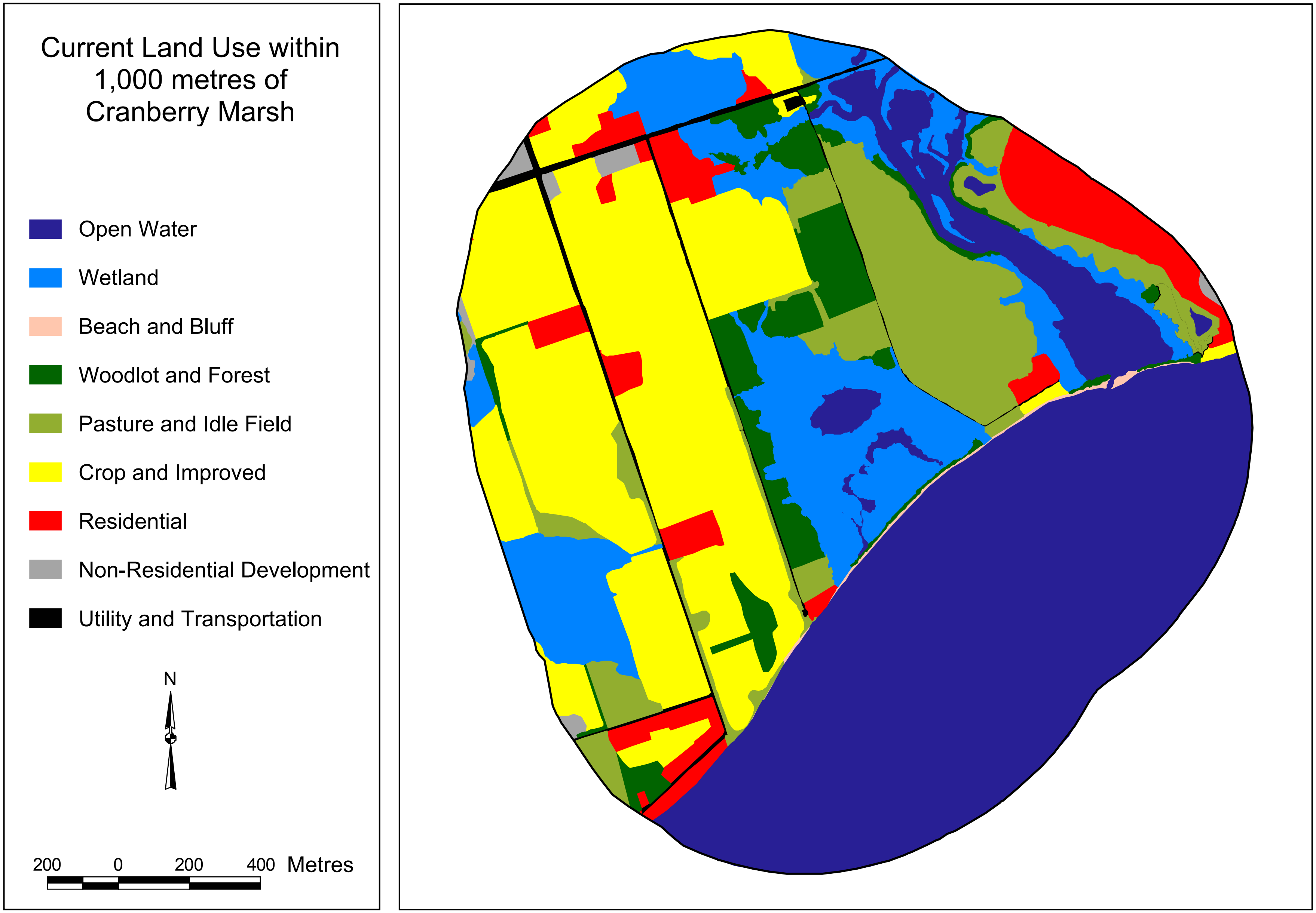

Figure 2.2.2-11. Current land-use at Cranberry Marsh and within a 1,000-metre buffer around its boundary.

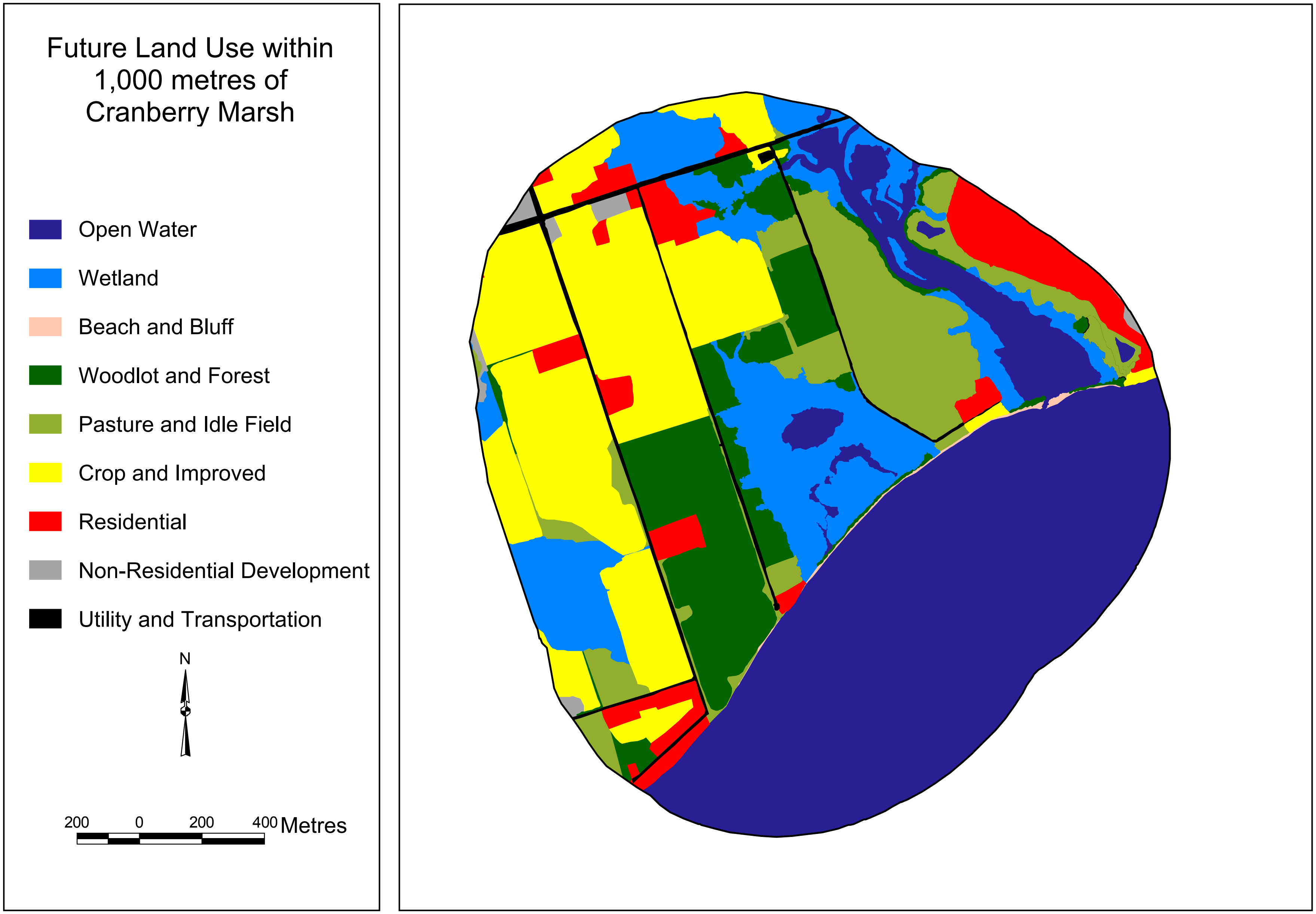

Figure 2.2.2-12. Future land-use at Cranberry Marsh and within a 1,000-metre buffer around its boundary.

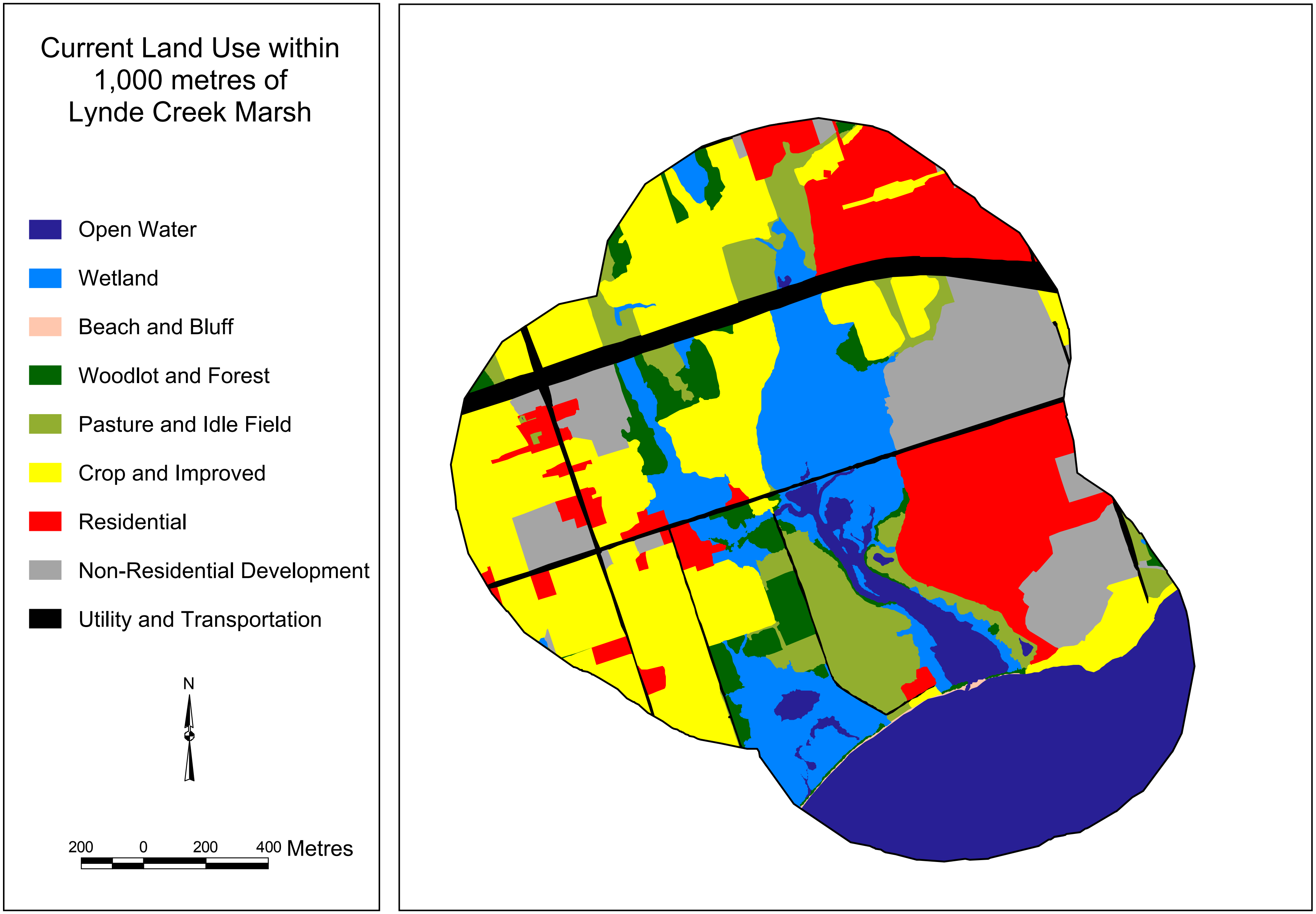

Figure 2.2.2-13. Current land-use at Lynde Creek Marsh and within a 1,000-metre buffer around its boundary.

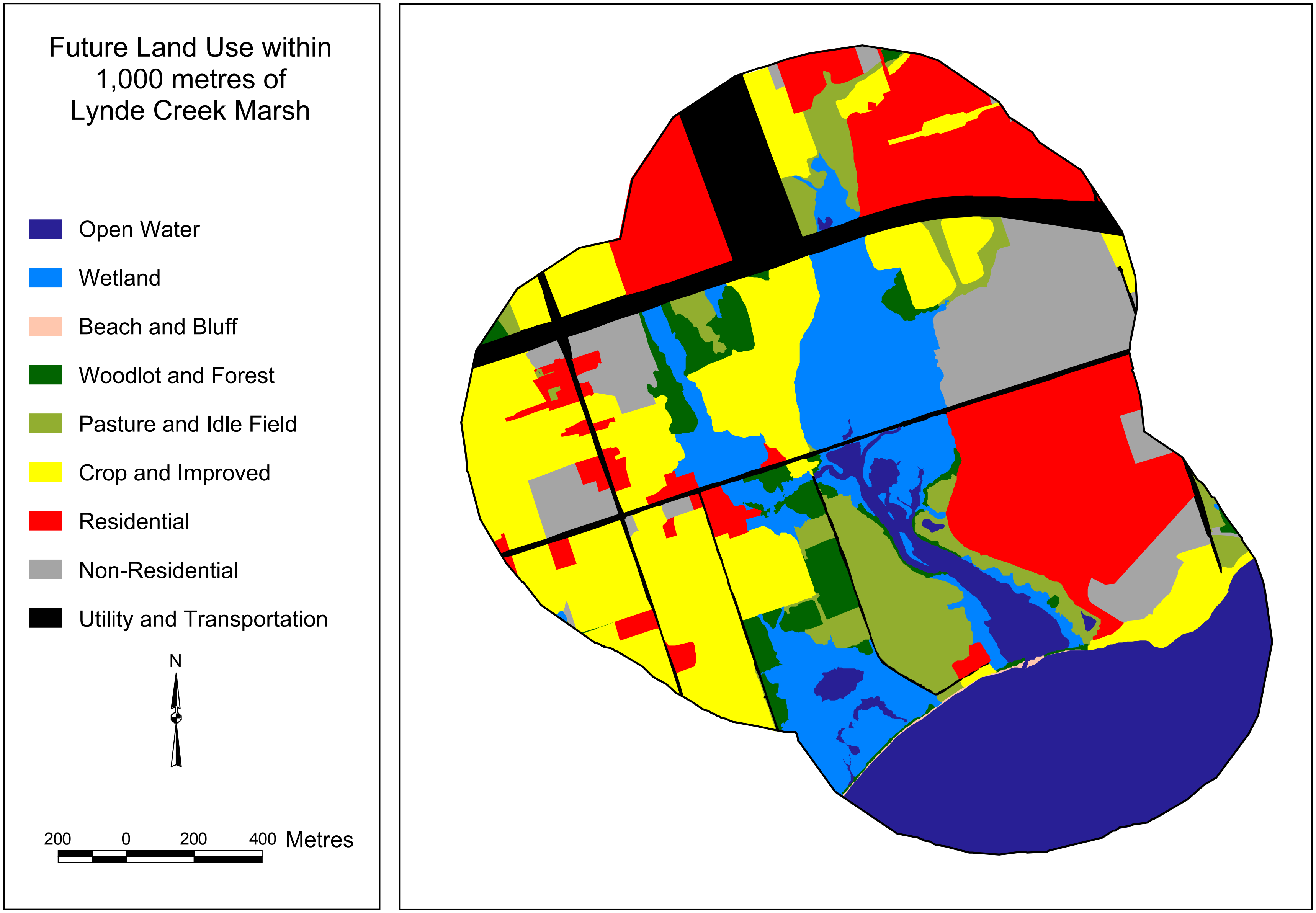

Figure 2.2.2-14. Future land-use at Lynde Creek Marsh and within a 1,000-metre buffer around its boundary.

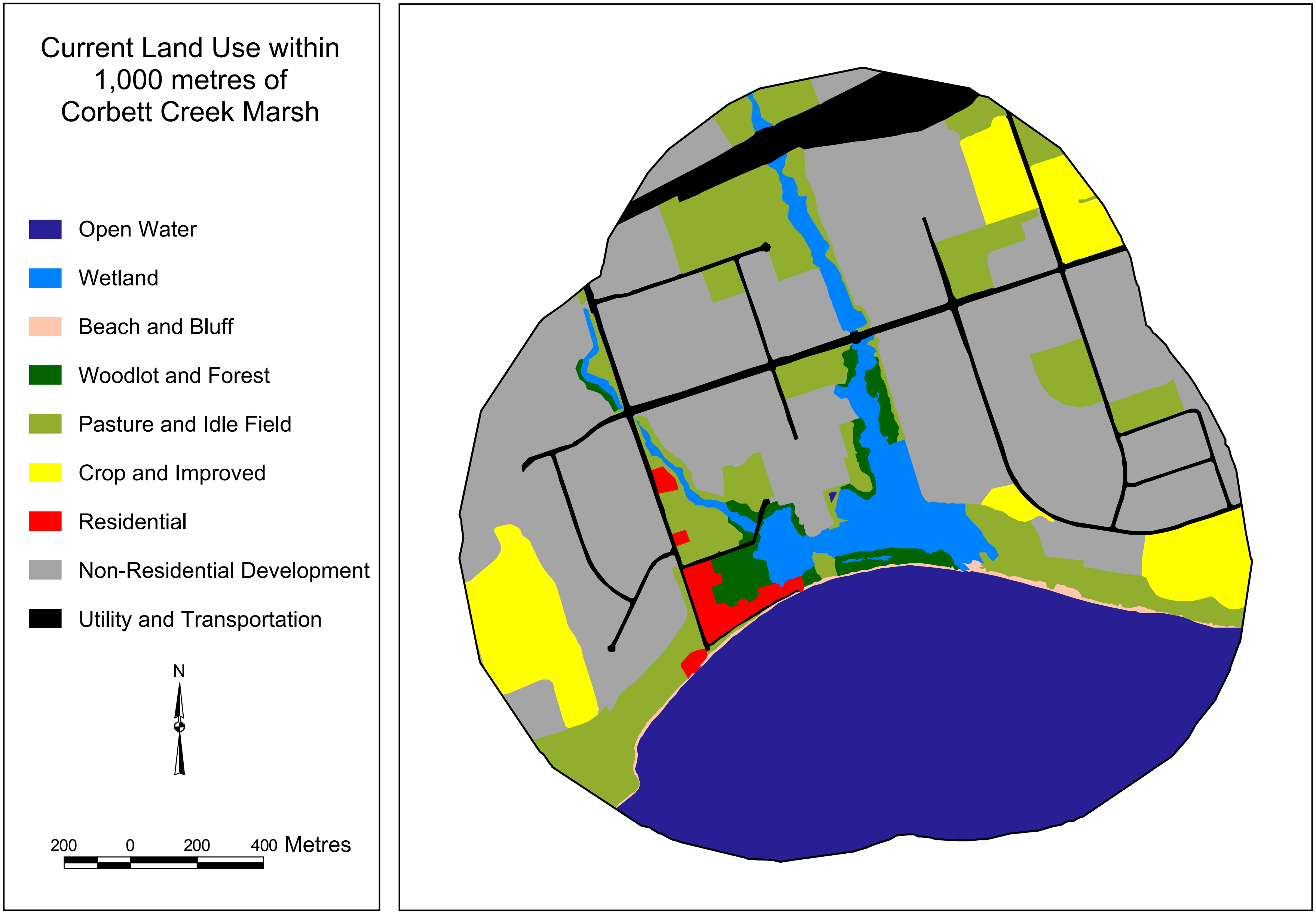

Figure 2.2.2-15. Current land-use at Corbett Creek Marsh and within a 1,000-metre buffer around its boundary.

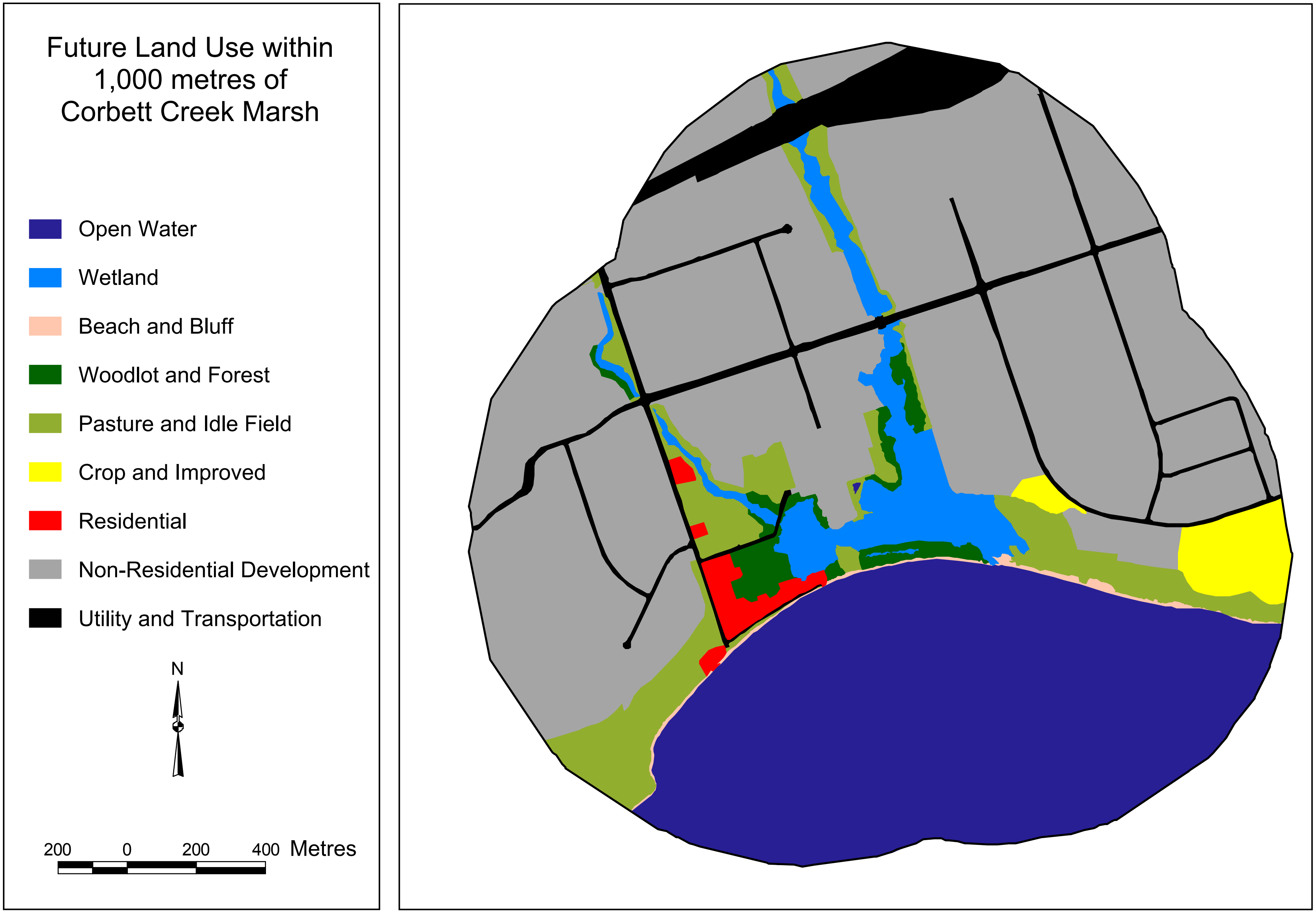

Figure 2.2.2-16. Future land-use at Corbett Creek Marsh and within a 1,000-metre buffer around its boundary.

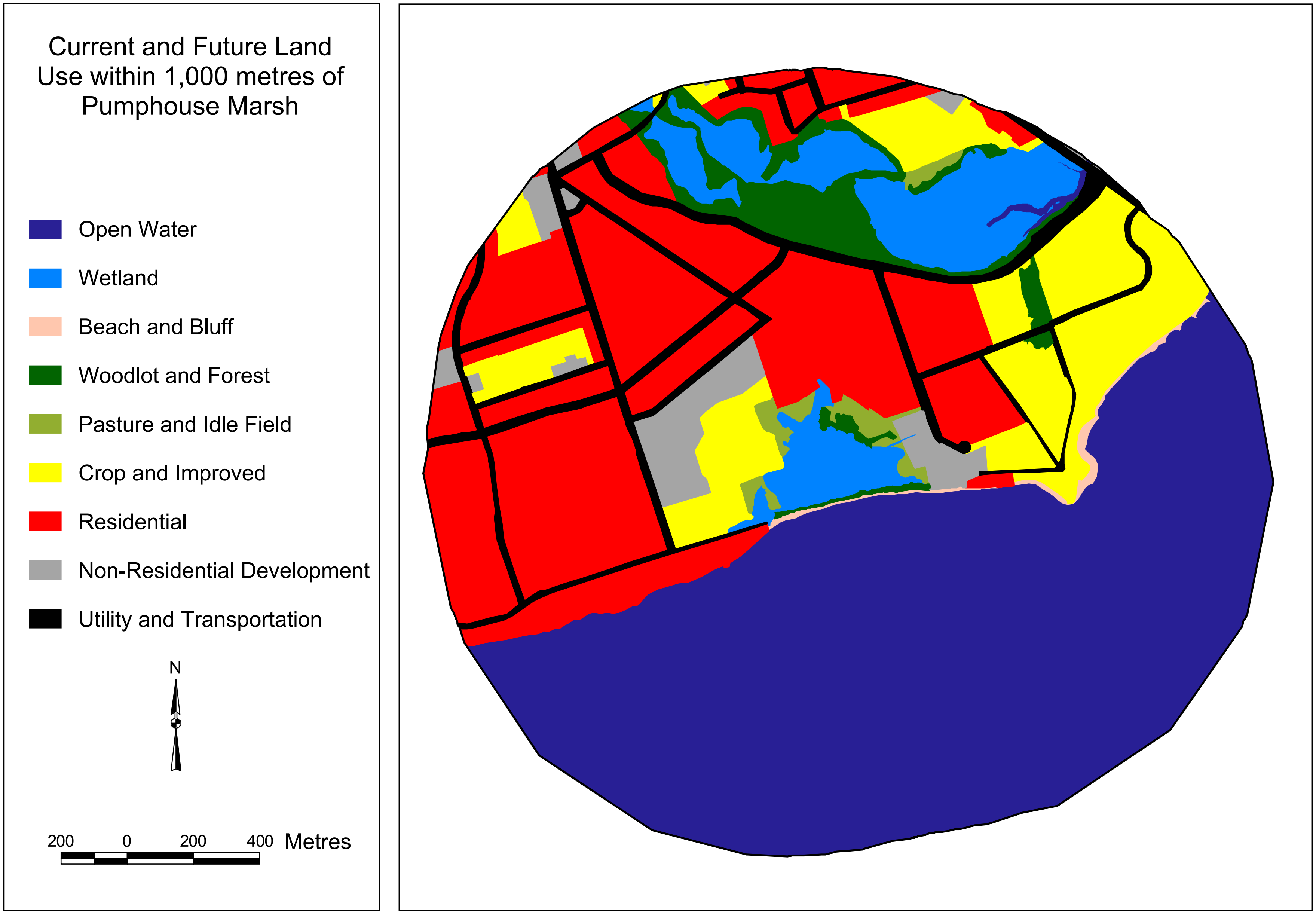

Figure 2.2.2-17. Current and future land-use at Pumphouse Marsh and within a 1,000-metre buffer around its boundary.

Note: Predictable future land-use at Pumphouse Marsh is expected to be the same as current land-use (See Figure 2.2.2-17).

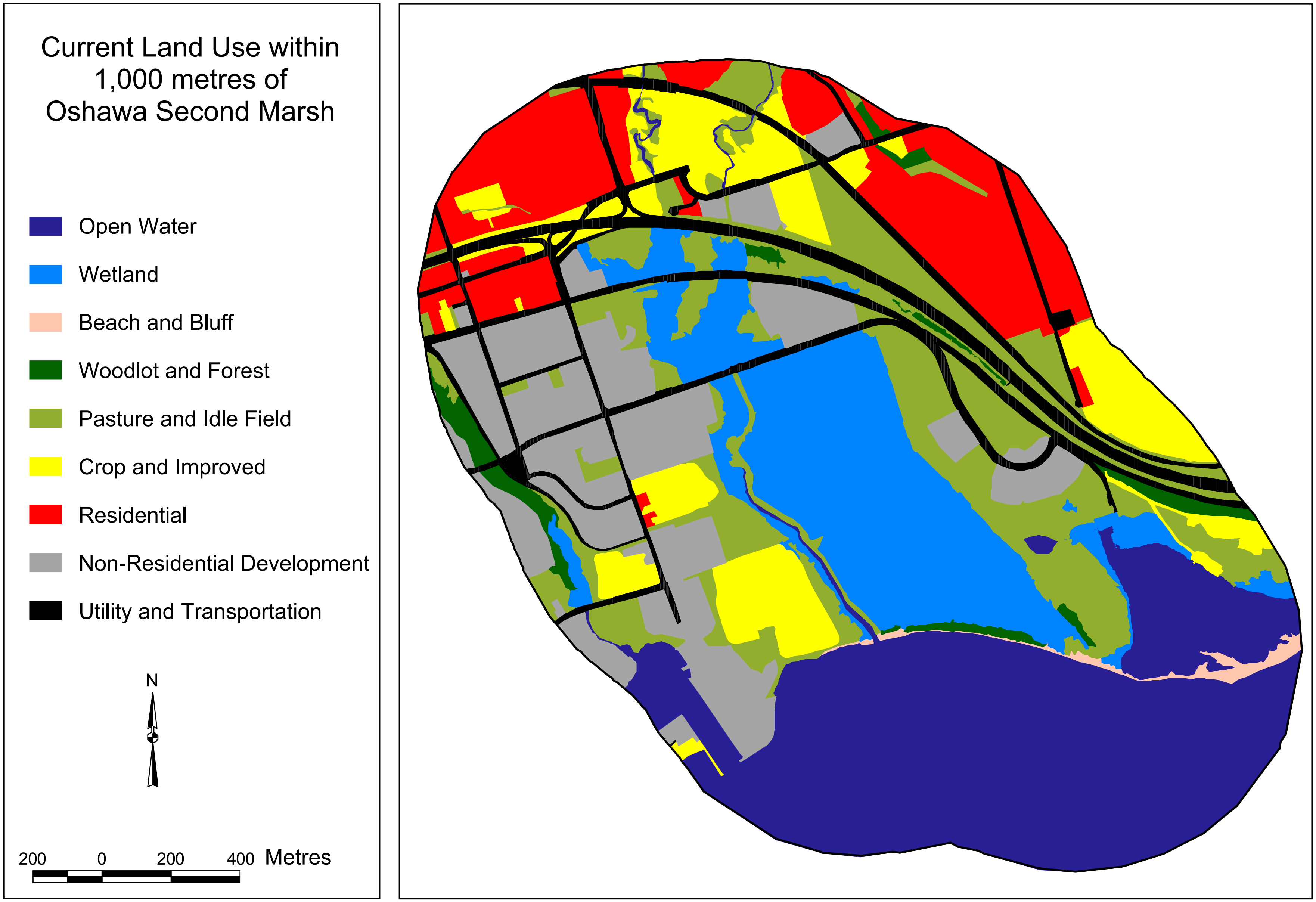

Figure 2.2.2-18. Current land-use at Oshawa Second Marsh and within a 1,000-metre buffer around its boundary.

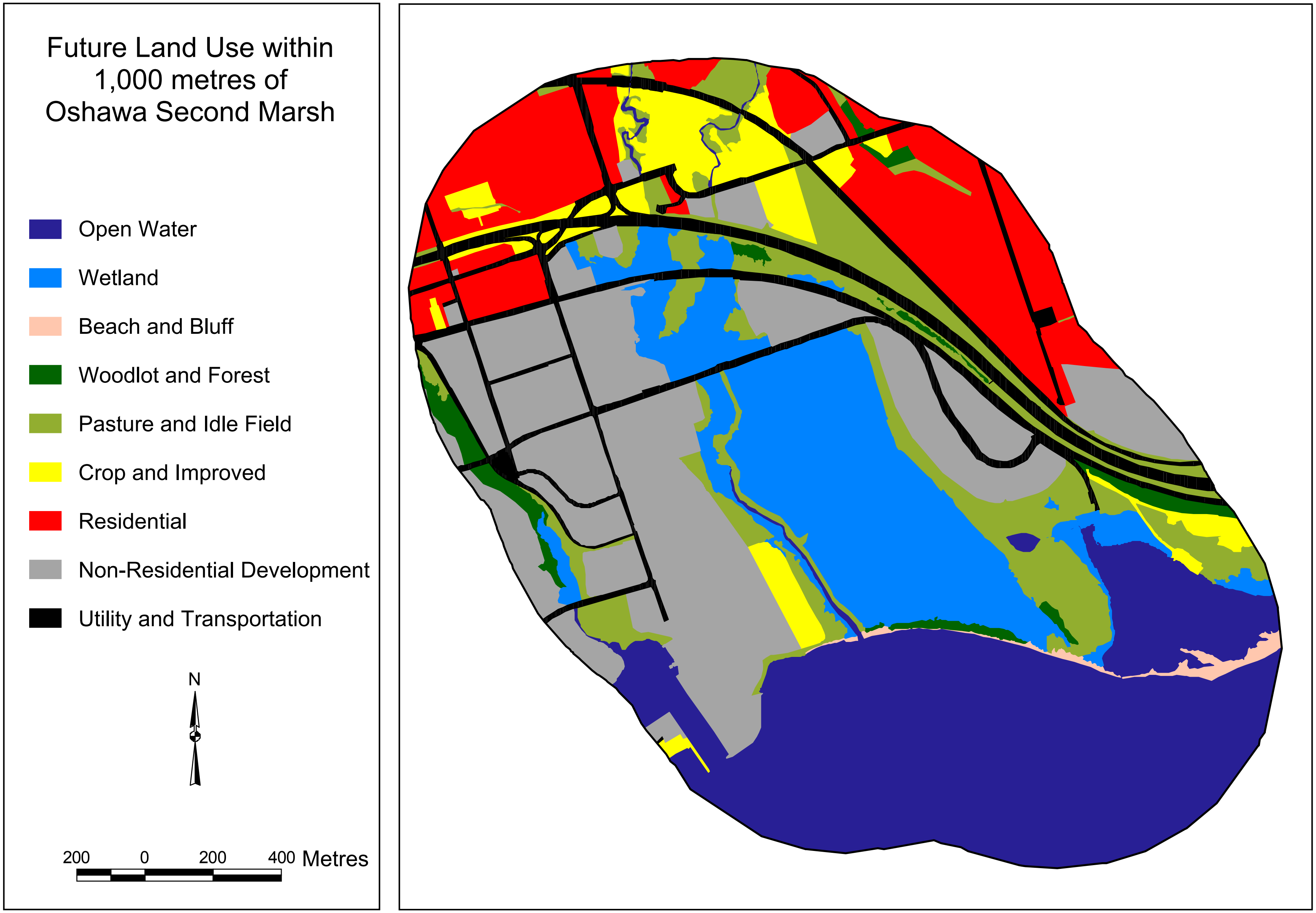

Figure 2.2.2-19. Future land-use at Oshawa Second Marsh and within a 1,000-metre buffer around its boundary.

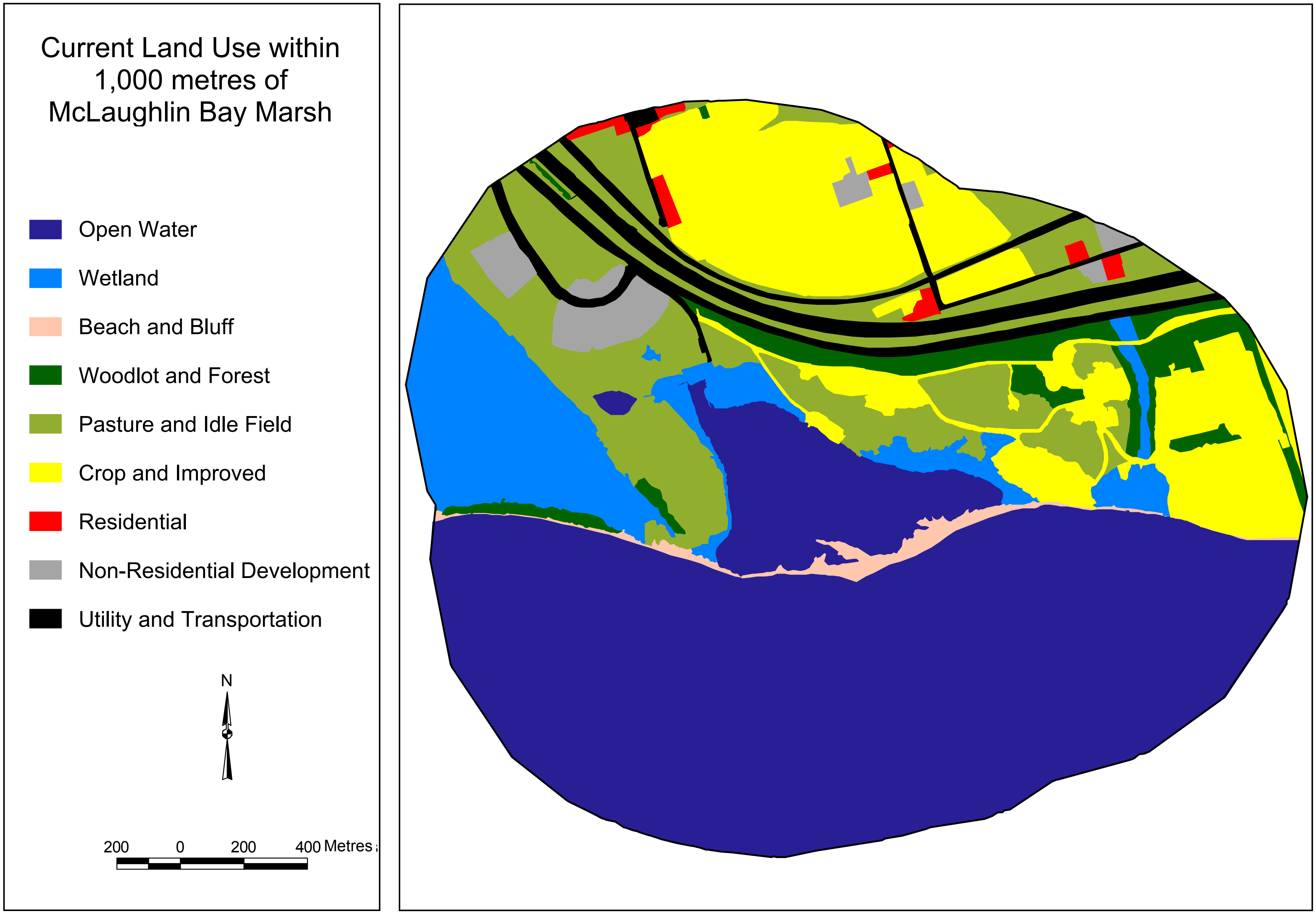

Figure 2.2.2-20. Current land-use at McLaughlin Bay Marsh and within a 1,000-metre buffer around its boundary.

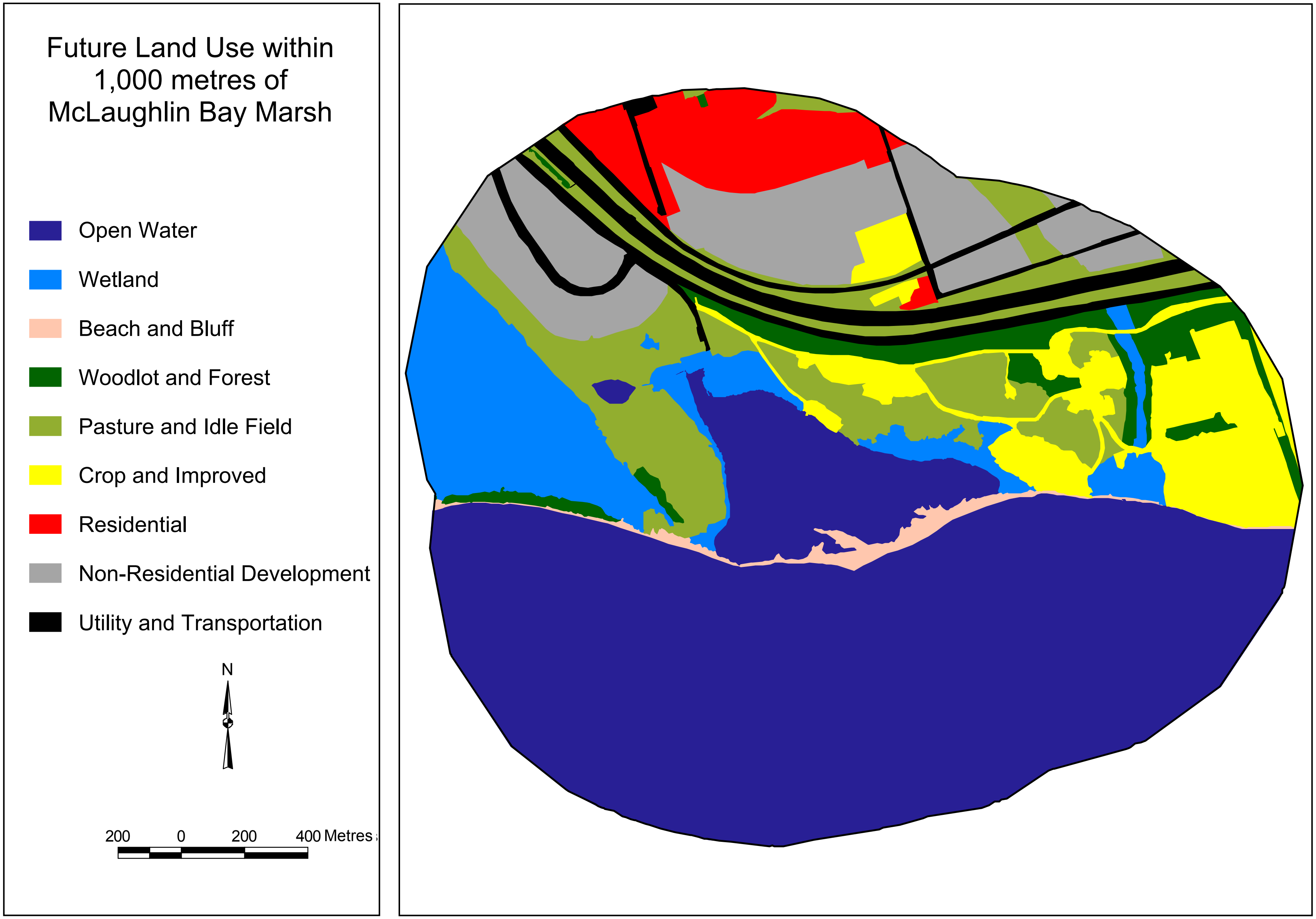

Figure 2.2.2-21. Future land-use at McLaughlin Bay Marsh and within a 1,000-metre buffer around its boundary.

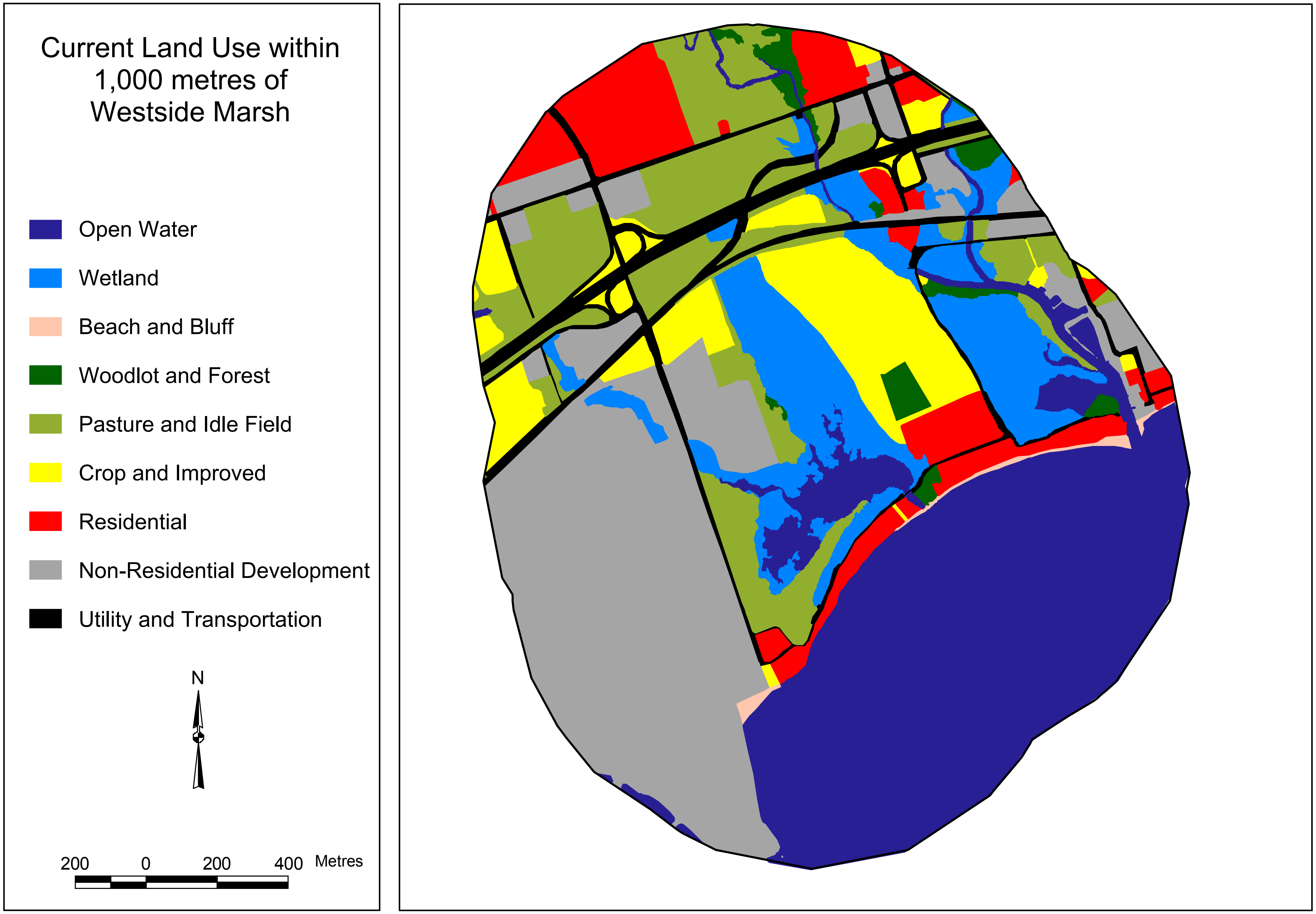

Figure 2.2.2-22. Current land-use at Westside Marsh and within a 1,000-metre buffer around its boundary.

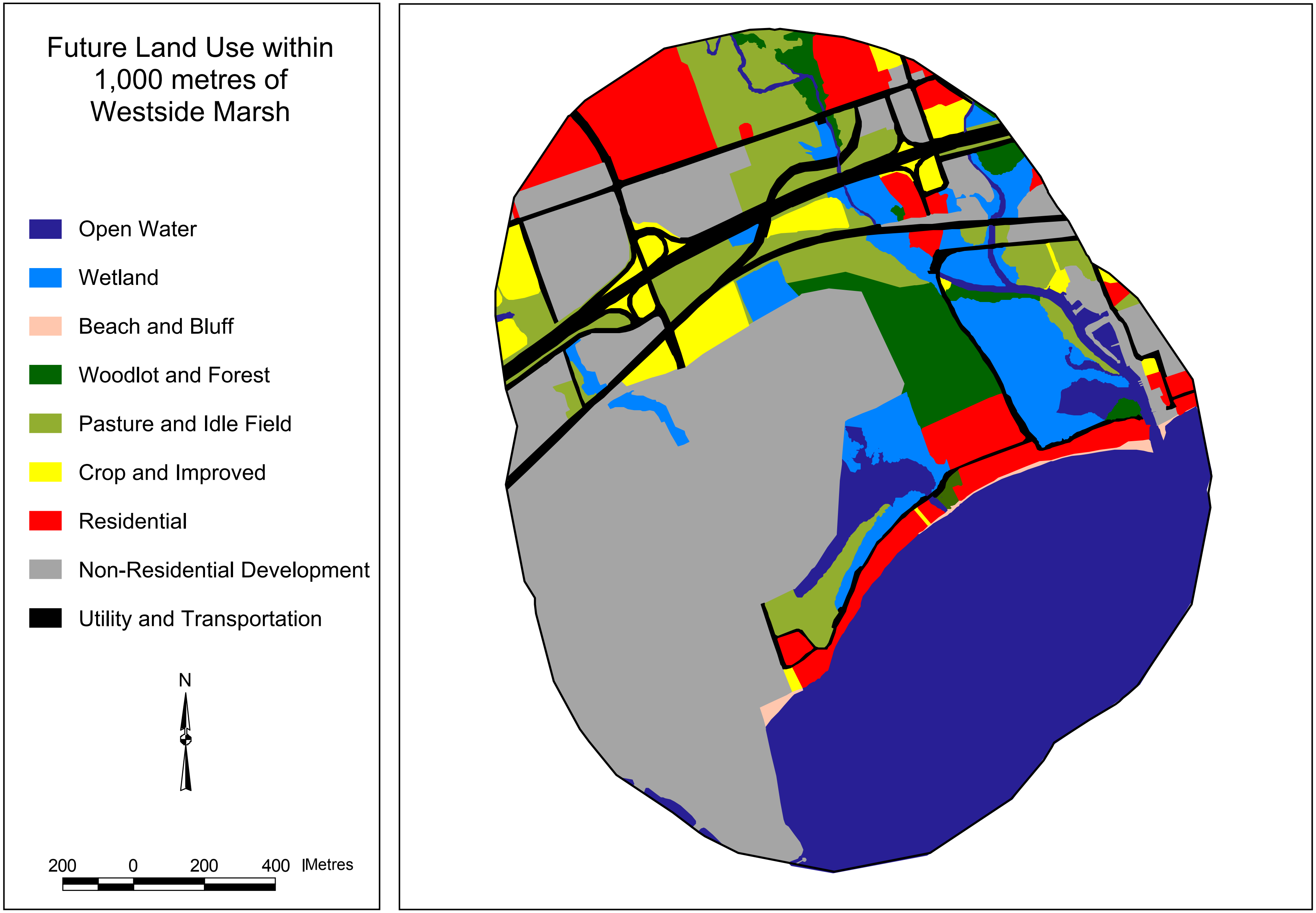

Figure 2.2.2-23. Future land-use at Westside Marsh and within a 1,000-metre buffer around its boundary.

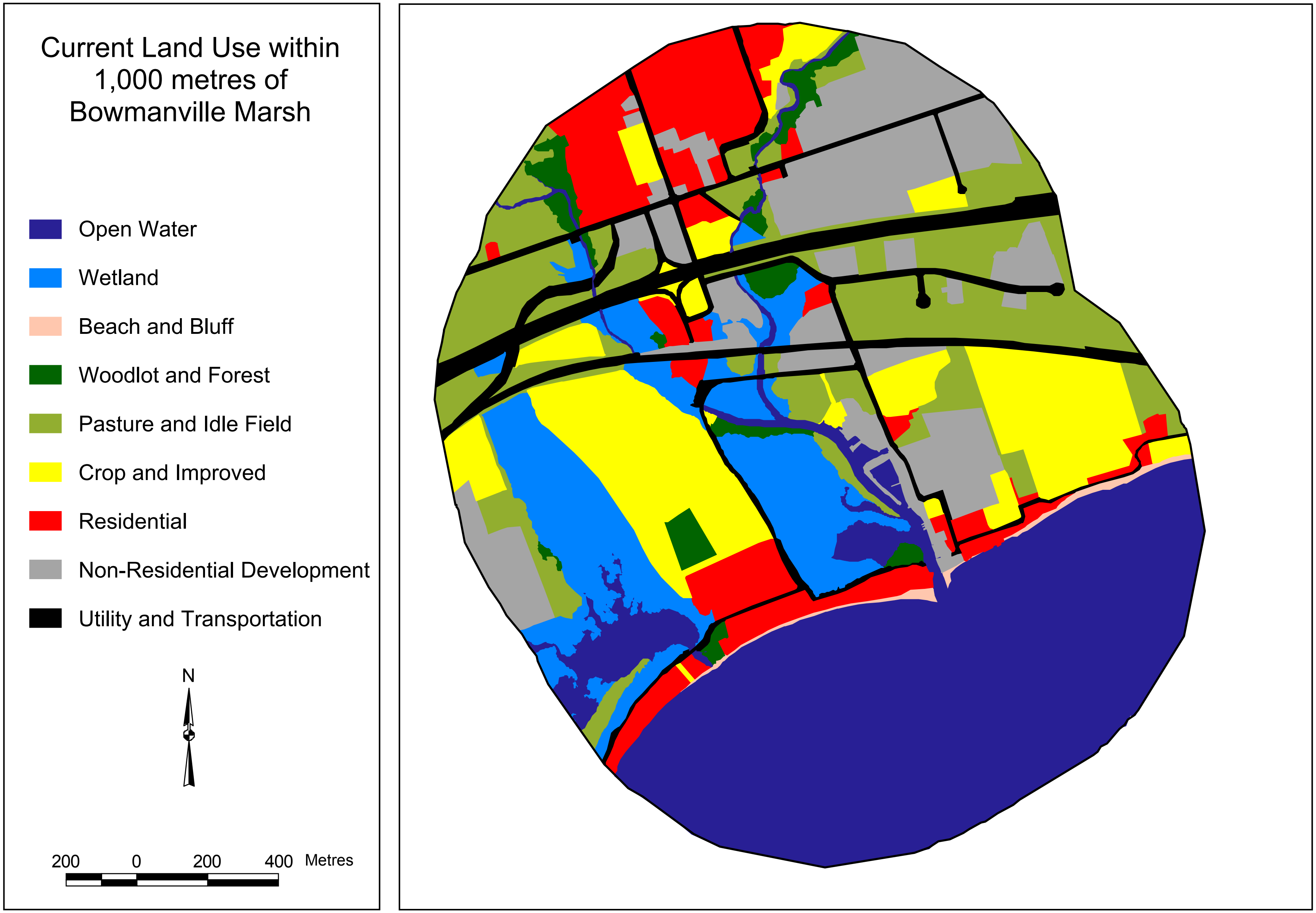

Figure 2.2.2-24. Current land-use at Bowmanville Marsh and within a 1,000-metre buffer around its boundary.

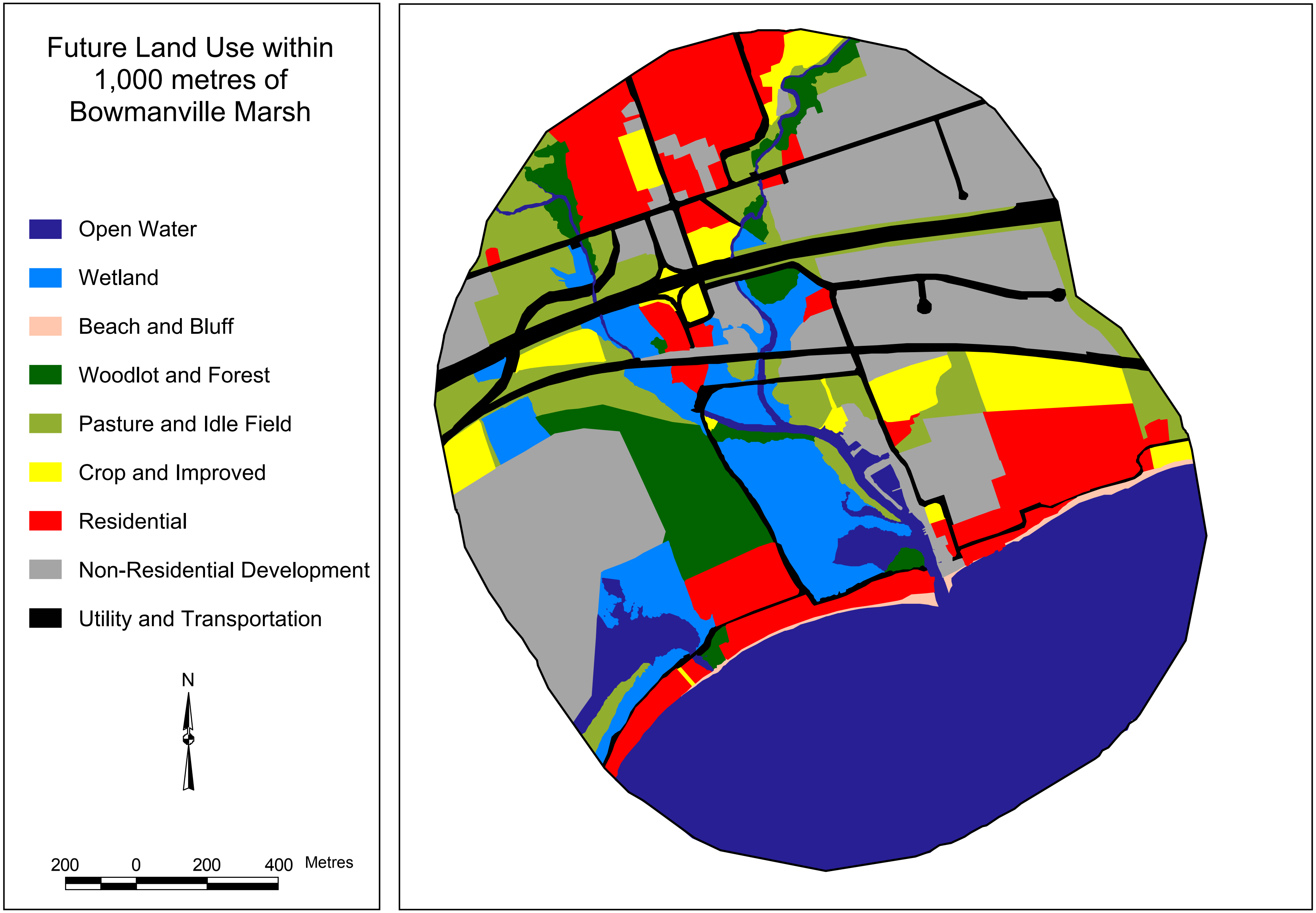

Figure 2.2.2-25. Future land-use at Bowmanville Marsh and within a 1,000-metre buffer around its boundary.

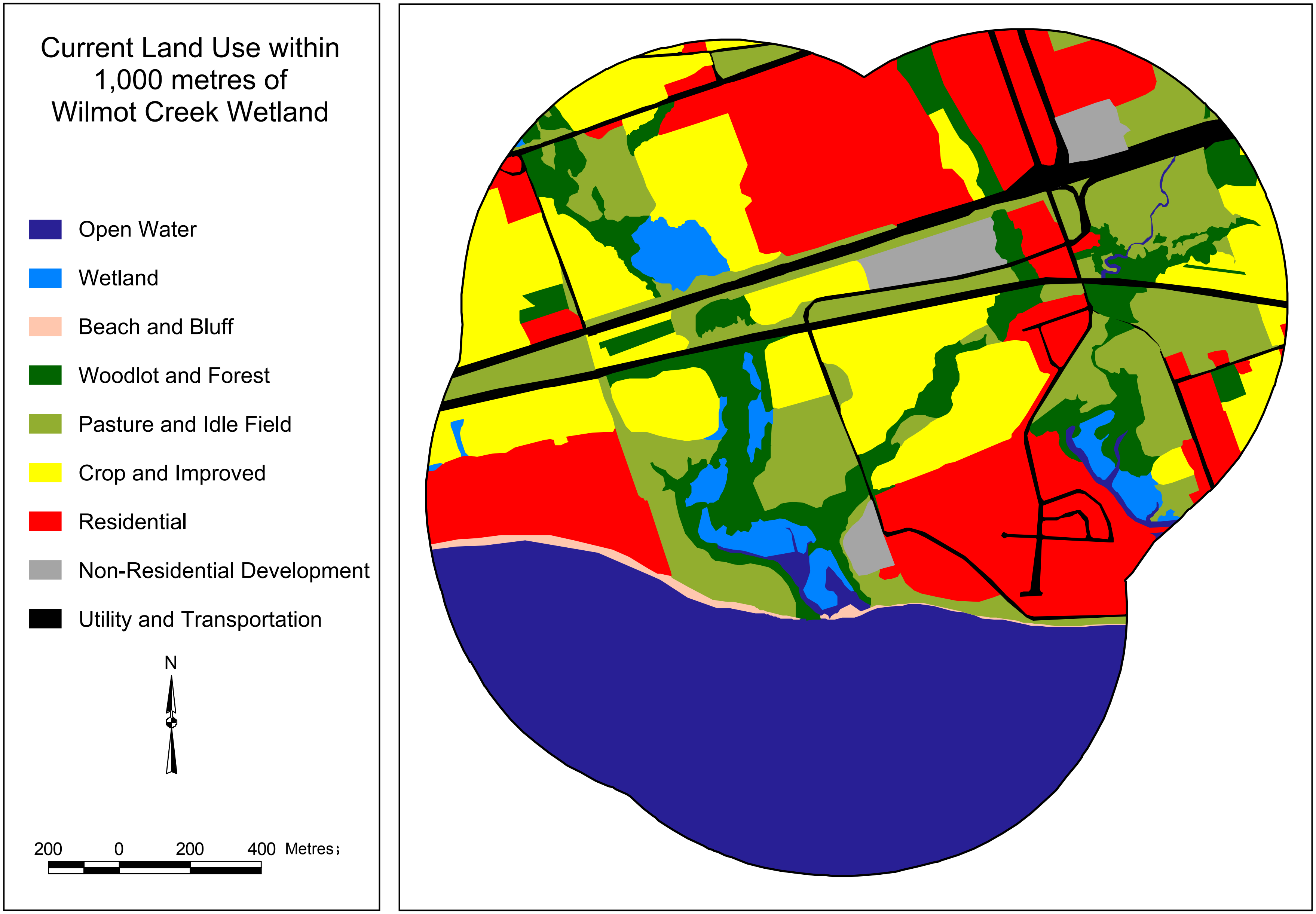

Figure 2.2.2-26. Current land-use at Wilmot Creek Marsh and within a 1,000-metre buffer around its boundary.

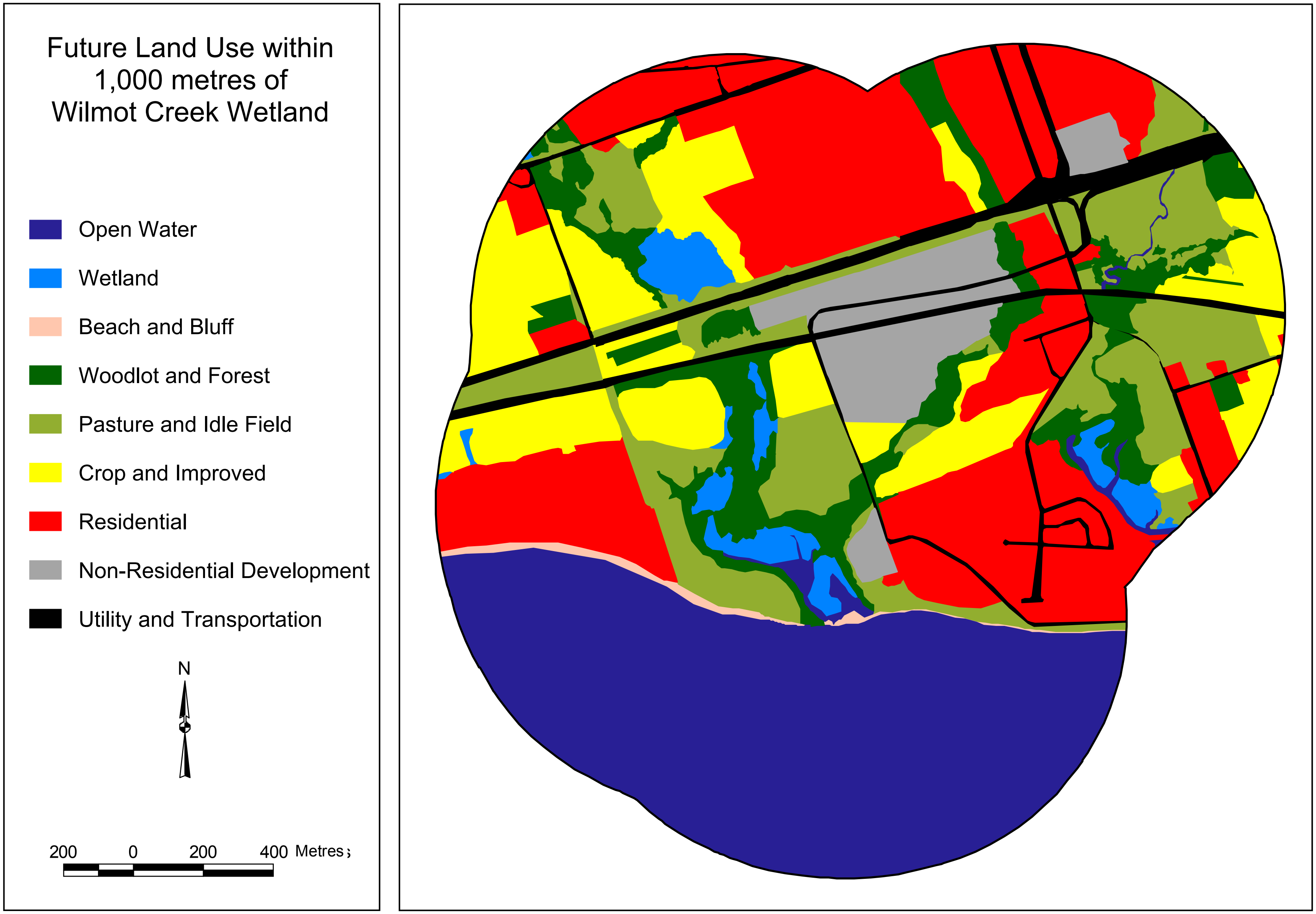

Figure 2.2.2-27. Future land-use at Wilmot Creek Marsh and within a 1,000-metre buffer around its boundary.

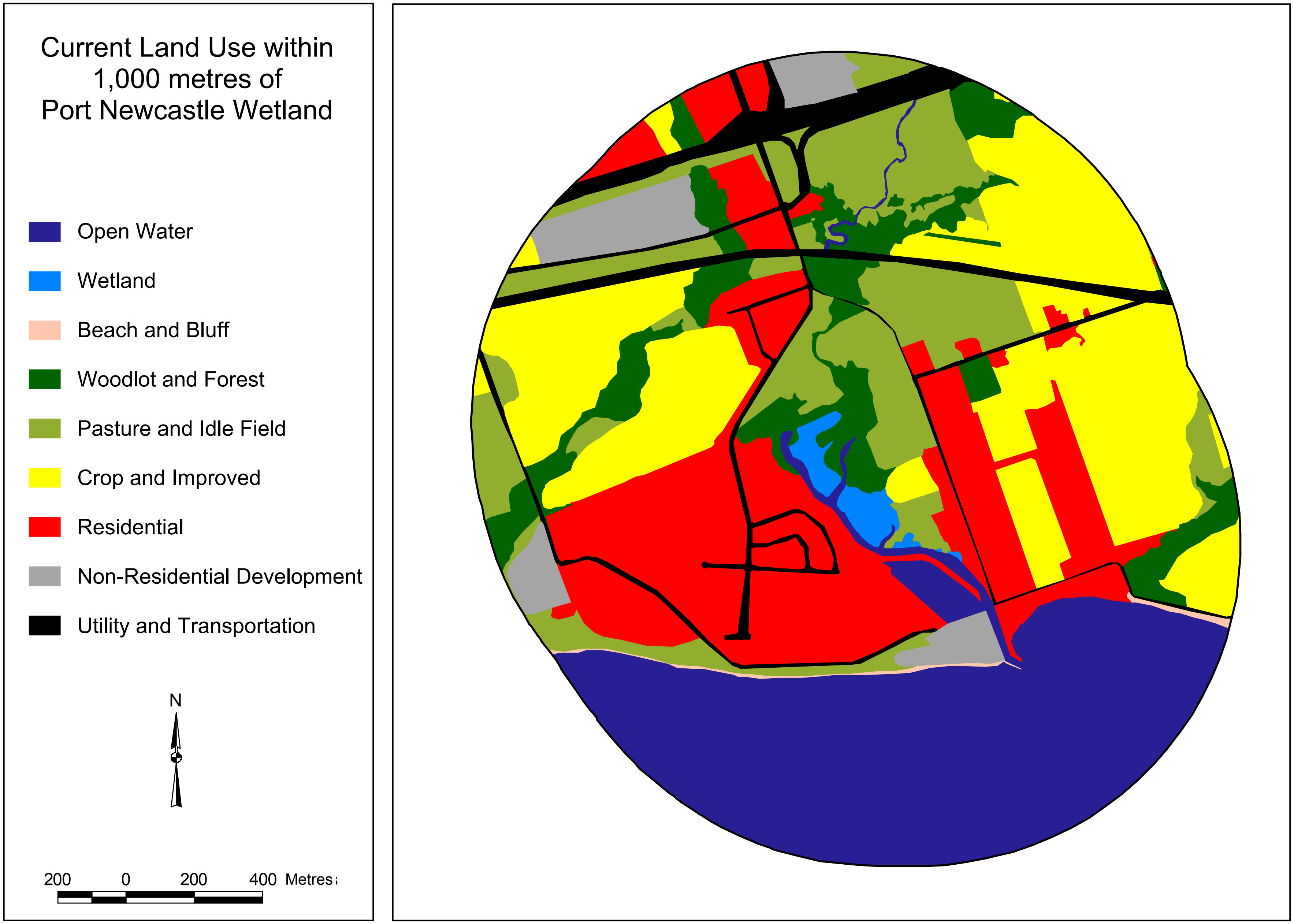

Figure 2.2.2-28. Current land-use at Port Newcastle Wetland and within a 1,000-metre buffer around its boundary.

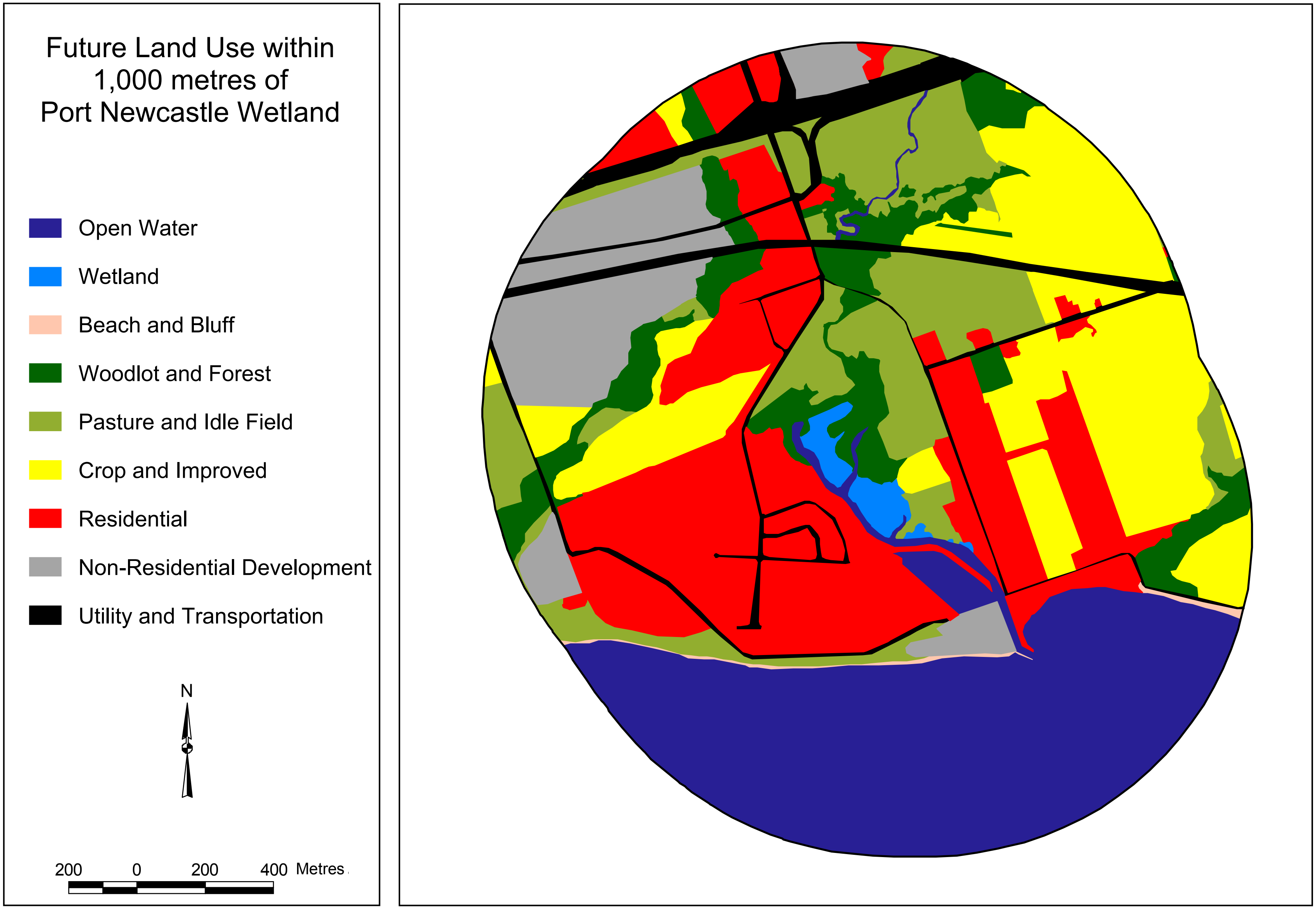

Figure 2.2.2-29. Future land-use at Port Newcastle Wetland and within a 1,000-metre buffer around its boundary.

2.2.3 Land-use Change in Watershed

Objective

To assess and monitor the anticipated land-use change within each watershed of Durham Region coastal wetlands.

Method Summary

This task is essentially an Ecological Land Classification (ELC) and land-use polygon delineation task on a watershed scale. Although partner CAs have completed ELC delineation to the Community Series scale for their watersheds, the land-use mapping is still in progress.

As stated in the Methodology Handbook for this project (Environment Canada and Central Lake Ontario Conservation Authority 2003), the completion of this objective will coincide with the appropriate Conservation Authority Watershed Management Plan review. Some Management Plans are currently in preparation: for example, CLOCA is now working on the Lynde Creek Watershed Management Plan, which will provide the existing and future land-use for this watershed.

Literature Cited

Environment Canada and Central Lake Ontario Conservation Authority. 2003. Durham Region Coastal Wetland Monitoring Project: Methodology Handbook – Second Approximation. Environment Canada/Central Lake Ontario Conservation Authority. May 2003.

2.2.4 Extent of Public Ownership of Watershed Lands

Objective

To identify and monitor the amount and distribution of public land in the watersheds of Durham Region coastal wetlands.

Method Summary

Using Terranet data, which includes property ownership information and a GIS layer of georeferenced land parcels, a set of records of publicly-owned property was created.

However, Terranet data are not yet available to the conservation authorities for all municipalities and the completion of this task manually (by searching the tax rolls) would be prohibitively time-consuming. Currently, CLOCA and GRCA have the Municipality of Clarington's land-parcel data so the four wetland watersheds within this municipality have had areas of public ownership mapped and calculated.

Results

Since the land-parcel ownership information was available only in the Municipality of Clarington, the extent of public ownership could only be determined for four coastal wetlands: Westside Marsh, Bowmanville Marsh, Wilmot Creek Marsh and Port Newcastle Wetland.

Of the possible public landowners, the conservation authorities, Management Board Secretariat, Ministry of Natural Resources (MNR), Ministry of Transportation, and Municipality of Clarington were owners of vacant land in the four watersheds (Figures 2.2.4-1 and 2.2.4-2). Durham Regional Municipality is a property owner, but its lands were not in natural land cover and currently are being used as public works yards or water treatment facilities.

The Management Board Secretariat is the provincial government ministry responsible for advising the Management Board of Cabinet and carrying out its directions with respect to the government's workforce, money, technology, and real estate. It owns parts of the middle reaches of the Wilmot Creek watershed (Figure 2.2.4-2). This area is part of the former Orono Tree Nursery. Following the closure of this MNR operation in 1996, 145 hectares of the property were subsequently sold, with the remaining 425 hectares retained as Crown land (Environmental Commissioner of Ontario 2002). In 2000, a partnership between MNR and the community-based Orono Forest Crown Land Trust was established enabling cooperative management of this site adjacent to Wilmot Creek.

The percentage of publicly-held lands in the watersheds varies substantially (Table 2.2.4-1). While the comparatively tiny Westside Marsh watershed is currently 12 percent in public hands, less than one percent of the Port Newcastle Wetland watershed is publicly owned.

Table 2.2.4-1. Areas and percentages of publicly owned lands in four Durham Region coastal wetland watersheds.

Watershed	Area of public lands (ha)	Total watershed area (ha)	% of watershed in public ownership
Westside Marsh	69	573	12
Bowmanville Marsh	982	16,590	6
Wilmot Creek Marsh	526	9,882	5
Port Newcastle Wetland	39	7,815	<1

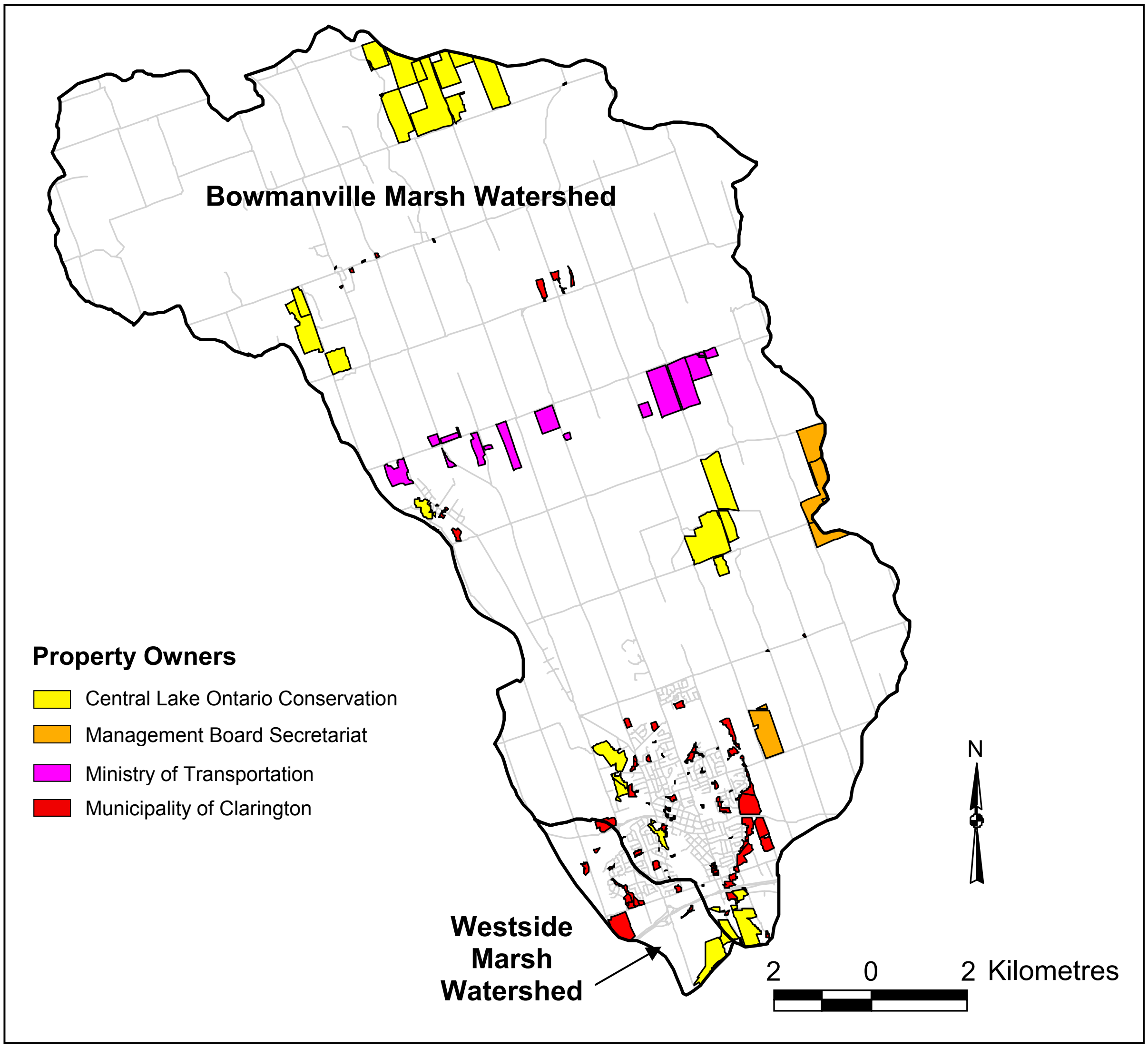

Figure 2.2.4-1. Publicly-owned lands in the Westside Marsh and Bowmanville Marsh watersheds.

Discussion

The goal of this objective is to determine the extent of publicly-owned land that could potentially be used for restoration/rehabilitation of critical watershed area. In addition, if land is in public ownership, it may be possible to influence the owner to retain the land rather than selling it for development purposes, particularly if it is significant to watershed and wetland health.

In the Bowmanville Marsh watershed, it is unlikely that the Ministry of Transportation's property will become available for restoration/rehabilitation as the land is being held in anticipation of the proposed extension of Highway 407.

It is important to note that while these data are the most current available at the conservation authorities, they may not be entirely up-to-date.

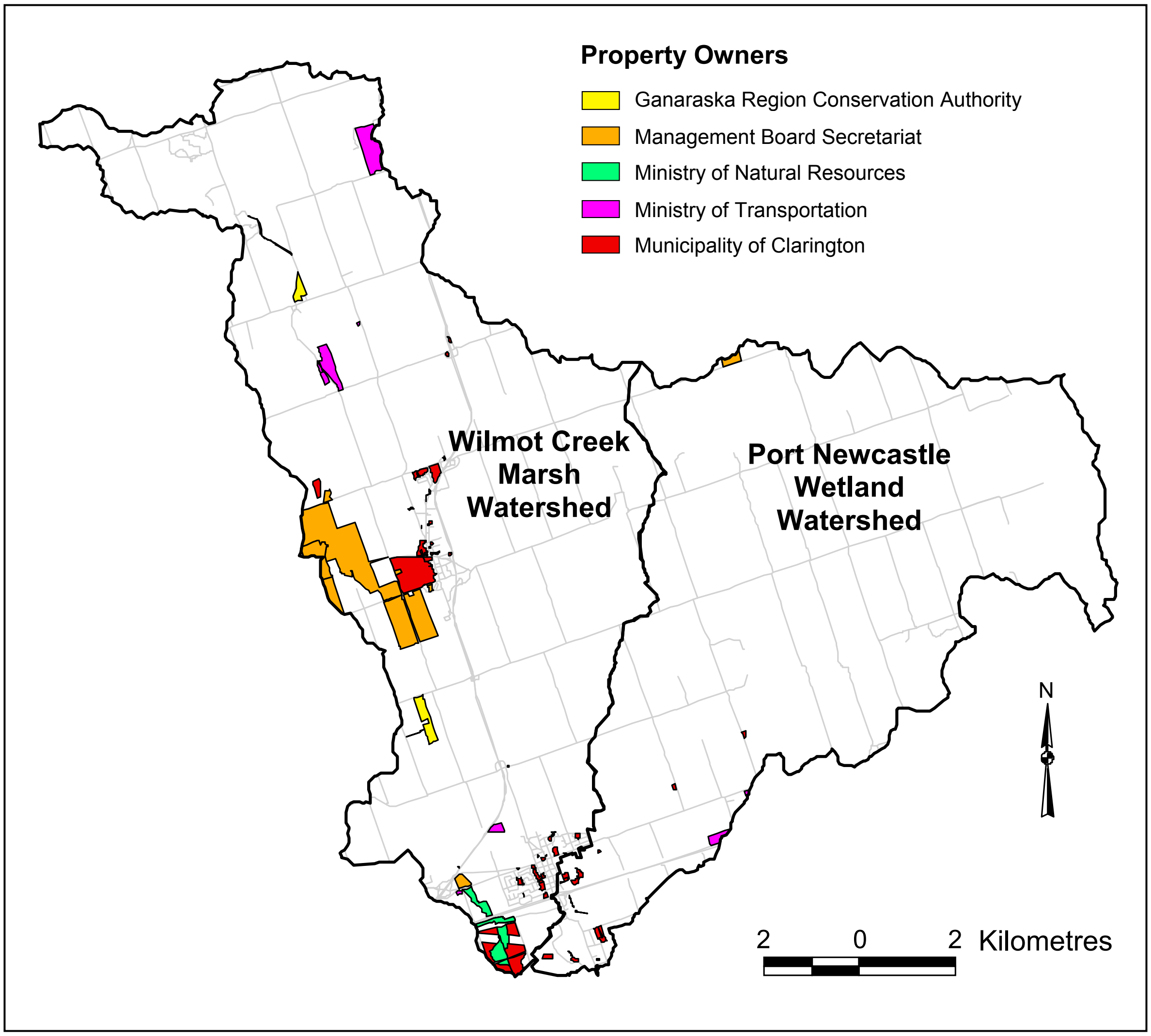

Figure 2.2.4-2. Publicly-owned lands in the Wilmot Creek Marsh and Port Newcastle Wetland watersheds.

Future Considerations

The future of this monitoring objective will rest on the availability of land ownership data for all municipalities that contain coastal wetland watersheds. Due to the high cost of these data, there is a strong possibility that not all the conservation authorities will be able to purchase current ownership information.

Literature Cited

Environmental Commissioner of Ontario. 2002. Supplement to the 2001-2002 Annual Report – Developing Sustainability. Office of the Environmental Commissioner of Ontario.

2.2.5 Sediment and Nutrient Loading

Objective

To assess and monitor a relative estimate of how much sediment and nutrients are being deposited from the watershed into Durham Region coastal wetlands.

Status of Methodology Development

The feasibility and effectiveness of field sampling for sediment loading was investigated and it was determined that computer modeling would be a better method for obtaining this information. TRCA has experience in this type of modeling and it may be applicable to this project.

The current availability of the necessary digital base data for the watersheds of interest, watershed model completion, and GIS capacity are limited to a few watersheds within the TRCA jurisdiction. CLOCA anticipates receipt of a Digital Elevation Model (DEM) of their jurisdiction (expected in May 2003, but not delivered to date). CLOCA and GRCA must make a statement regarding the applicability, suitability and feasibility of this modeling under their watershed management plan and for use in monitoring their coastal wetlands in the Durham Region.

3. WETLAND ASSESSMENT METHODS

3.1 ASSESSING THE LEVEL OF DISTURBANCE WITHIN WETLANDS

Determining the disturbance experienced by a biotic community serves two purposes. First, it allows for the assessment of potential metrics by plotting raw metric values against disturbance to evaluate the metric's suitability in an Index of Biotic Integrity (IBI) (Figure 1-3). Second, the various factors contributing to the disturbance (e.g., turbidity, surrounding development) can be examined to reveal their relative magnitude and impact on the community.

The overall level of disturbance in each wetland was derived statistically using the method described by Hughes *et al.* (1998). Using this method, physical and chemical data from Durham Region and a range of other Lake Ontario coastal wetlands (Figure 1-5) are analyzed using a multivariate principal components analysis (PCA; Table 3.1-1).

In this report, two different disturbance matrices were used depending on the biotic community examined. For fish, bird, and amphibian communities, variables listed in Matrix A were used (Table 3.1-2). These disturbance estimates included submerged aquatic vegetation (SAV) cover as a physical variable because presence and abundance of SAV was considered to be important to these communities. SAV coverage was not used as a variable for aquatic macroinvertebrate communities because the samples were taken from emergent vegetation stands. Habitat variables in Matrix B were used to calculate the relative disturbance experienced by submerged aquatic vegetation and macroinvertebrate communities.

Using the parameters in Matrix A, a case score graph from the PCA is plotted (Figure 3.1-1) on the first two principal components. This helps to visualize the differences between sites. From the location and clustering of points across PC-1, it is clear that Durham Region sites (red) are different from the other Lake Ontario sites (blue).

To determine how the sites are different, physical variables that contribute to the spread along PC-1 must be examined. To do this, a variable score graph is plotted (Figure 3.1-2) using the same two principal components as Figure 3.1-1 (See Table 3.1-2 for eigenvectors and accountable variances). This variable score graph indicates that sites on the left side of the Figure 3.1-1, mainly Durham Region sites, are characterized by parameters on the left side of Figure 3.1-2 – high turbidity, chlorophyll *a*, conductivity, ammonium, total phosphorus, and nitrate. The opposite scenario also holds. Sites on the right side of Figure 3.1-1 have higher SAV coverage and more natural (woodlot) and semi-natural (pasture and idle field) areas surrounding them. With more disturbed sites on the left and less disturbed sites on the right, PC-1 in the case score plot (Figure 3.1-1) represents a gradient of disturbance. Therefore, to quantify disturbance at these sites, case (site) scores for PC-1 were used.

Table 3.1-1. Description of disturbance variables used to rank the level of disturbance experienced by various Lake Ontario coastal wetland biotic communities.

Disturbance Variable	Description
SAV Coverage	The mean percent cover of submerged aquatic vegetation in the wetlands as described in section 4.1.3 of this report.
Woodlot	The percent cover of woodlot or forest within 1-km of the wetland as described in section 2.2.2 of this report.
Pasture and Idle Field	The combined percent cover of pasture and idle field within 1-km of the wetland as described in section 2.2.2 of this report.
Total Phosphorus *	The concentration ($mg \cdot L^{-1}$) of all forms of phosphorus dissolved in the sample. This is an important indicator of enrichment in surface waters.
Ammonia *	The concentration ($mg \cdot L^{-1}$) of ammonia nitrogen in the sample. Ammonia can be toxic to aquatic organisms and is released into waterways by many industries, primarily municipal wastewater treatment plants.
Nitrate *	The concentration of nitrate nitrogen ($mg \cdot L^{-1}$) in the sample. The greatest sources of nitrates in the environment are sewage, fertilizer, and manure.
Nitrite *	The concentration of nitrite nitrogen ($mg \cdot L^{-1}$) in the sample. Concentrations in aquatic environments are generally low due to its ready conversion to nitrate.
Turbidity	A measure of the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles as described in section 2.1.1. Measured in Nephelometric Turbidity Units (NTU).
Chlorophyll *a* *	A measurable parameter for all phytoplanktonic production. On average, 1.5 percent of algal organic matter is chlorophyll-*a*. Thus, if chlorophyll-*a* levels are known, the phytoplankton biomass in the water body can be estimated.
Conductivity *	A measure of the dissolved ions in water measured in milliseimens per centimetre ($mS \cdot cm^{-1}$). Conductivity is a good indicator of urban run-off.

* As described in section 2.1.5

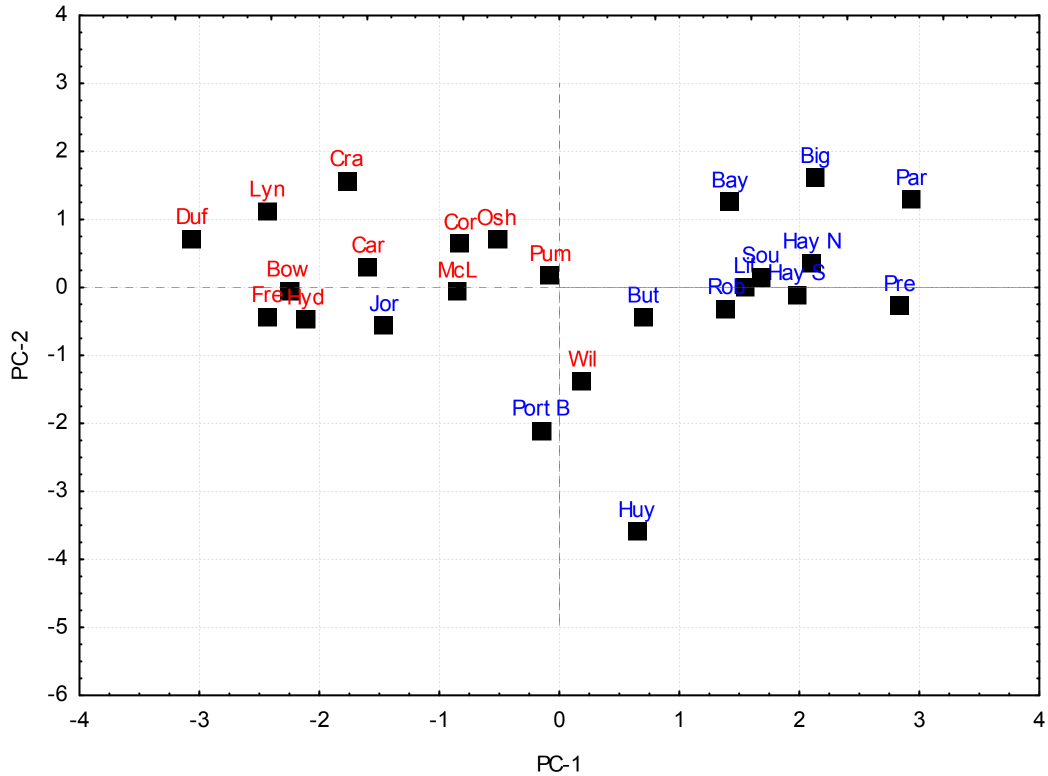

Figure 3.1-1. The case (site) score graph from the PCA using the first two principal components. Site acronyms are in the first column of Table 3.1-3. Durham sites are in red; other Lake Ontario sites are in blue.

Table 3.1-2. Eigenvectors and accountable variances of the first two principal components using physical and chemical disturbance data.

	Disturbance Matrix A		Disturbance Matrix B	
Disturbance Variable	**PC-1**	**PC-2**	**PC-1**	**PC-2**
Woodlot	0.529	0.013	0.490	-0.427
Pasture and Idle Field	0.482	0.462	0.482	0.497
SAV Coverage	0.790	0.283	not used	not used
Total Phosphorus	-0.577	0.288	-0.616	0.313
Ammonia	-0.769	0.104	-0.844	-0.055
Nitrate	-0.456	0.456	-0.521	-0.272
Nitrite	-0.068	-0.840	-0.136	-0.815
Turbidity	-0.686	-0.018	-0.837	-0.052
Chlorophyll *a*	-0.603	0.034	-0.624	0.227
Conductivity	-0.464	0.103	-0.376	0.103
Percent variation explained	33	13	39	16

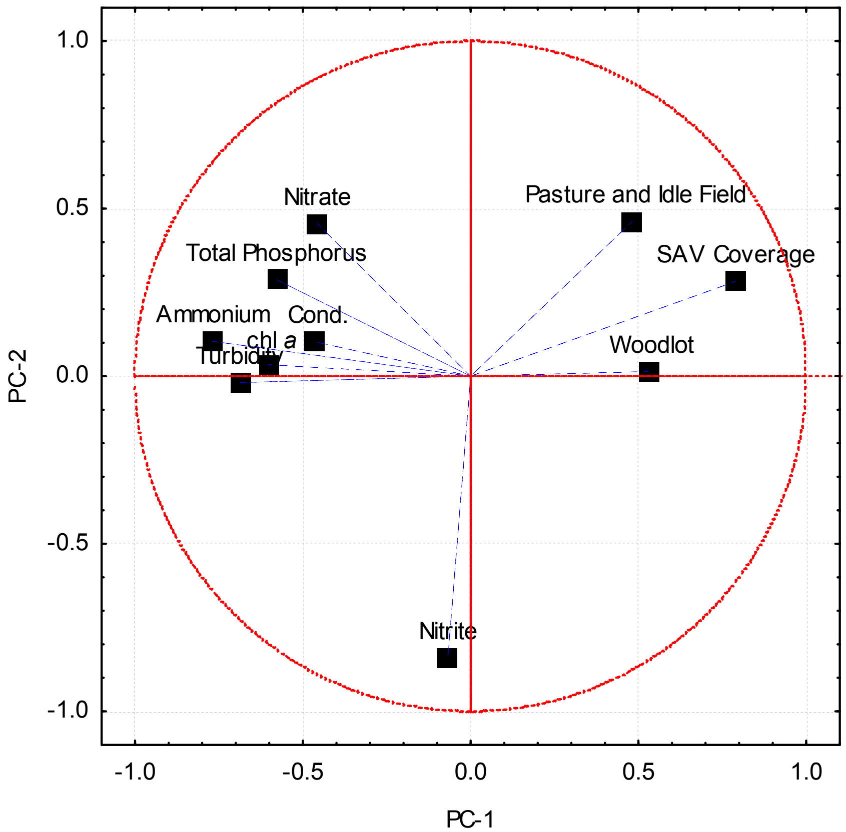

Figure 3.1-2. The variable score graph from the PCA using the first two principal components.

To calculate relative disturbance, the PC-1 values were multiplied by -1, to give a more easily interpreted disturbance estimate where highly disturbed sites had higher values (Table 3.1-3). Note that Rouge River, Westside, and Port Newcastle marshes do not have relative disturbance estimates generated from disturbance Matrix A because SAV sampling was not completed at these wetlands. This procedure was repeated to get disturbance values using physical parameters in Matrix B.

In general, the disturbance estimates generated through PCA appear to be representative of the level of disturbance experience by the wetlands. Wetlands that were suspected to be highly impacted by human activity (e.g., Frenchman's Bay) showed high disturbance scores. Conversely, wetlands that were protected (e.g., Presqu'ile Provincial Park, Parrott's Bay Conservation Area) were the least disturbed.

The current surrounding land-use data were very important in estimating the level of disturbance experience by a wetland. In particular, the amount of natural (woodlot) and semi-natural (idle field and pasture) within a 1,000-metre distance of the provincially assessed (Ontario Ministry of Natural Resources) wetland boundary was used. In most cases, the use of these parameters effectively contributed to the estimate of disturbance at the site. One exception may be Carruthers Creek Marsh because the marsh is associated with extensive tracts of swamp that are included in the provincial assessment of the wetland complex. Of the 141-hectare assessed wetland area, 105 hectares are wooded swamp and 36 hectares are lacustrine marsh.

The 1,000-metre buffer surrounding land-use was assessed beyond the marsh and swamp wetland boundary. As such, approximately six percent of the 1,000-metre buffer was forested area. However, the assessment of biotic communities in this project focused exclusively on the lacustrine wetland. Thus, excluding the wooded swamp from the coastal wetland estimate and including it in the surrounding land-use buffer may be warranted and should be investigated further. This adjustment would increase the forested area in the 1,000-metre buffer to 18 percent which would result in a marginally decreased wetland disturbance estimate.

Oshawa Second, Lynde Creek, and Rouge River marshes also support greater than 25 percent swamp and would also show decreased disturbance estimates if these areas were included as surrounding lands and not wetland. The use of swamp areas in surrounding land-use buffers and disturbance estimates requires further attention.

Table 3.1-3. Relative habitat disturbance experienced by Durham Region (bold) and other Lake Ontario coastal wetlands based on case score PC-1 of physical and water chemistry disturbance data. Site acronyms follow site names in first column.

Matrix A		**Matrix B**	
Wetland Name	**Relative Disturbance**	**Wetland Name**	**Relative Disturbance**
Parrott's Bay (Par)	-2.936	Presqu'ile Bay	-2.975
Presqu'ile Bay (Pre)	-2.836	Parrott's Bay	-2.662
Big Sand Bay (Big)	-2.132	Hay Bay North	-2.092
Hay Bay North (Hay N)	-2.102	Hay Bay South	-2.033
Hay Bay South (Hay S)	-1.977	Big Sand Bay	-1.977
South Bay (Sou)	-1.679	South Bay	-1.889
Little Cataraqui Creek (Lit)	-1.542	Robinson's Cove	-1.392
Bayfield Bay (Bay)	-1.425	Bayfield Bay	-1.365
Robinson's Cove (Rob)	-1.390	Little Cataraqui Creek	-1.279
Button Bay (But)	-0.699	Button Bay	-0.840
Huyck's Bay (Huy)	-0.647	Huyck's Bay	-0.812
Wilmot Creek Marsh (Wil)	-0.191	**Wilmot Creek Marsh**	**-0.796**
Pumphouse Marsh (Pum)	0.084	**McLaughlin Bay Marsh**	**-0.511**
Port Britain (Port B)	0.154	Port Britain	0.020
Oshawa Second Marsh (Osh)	0.521	**Corbett Creek Marsh**	**0.087**
Corbett Creek Marsh (Cor)	0.825	**Port Newcastle Wetland**	**0.106**
McLaughlin Bay Marsh (McL)	0.850	**Pumphouse Marsh**	**0.406**
Jordan Station Marsh (Jor)	1.460	**Carruthers Creek Marsh**	**0.830**
Carruthers Creek Marsh (Car)	1.593	**Oshawa Second Marsh**	**0.976**
Cranberry Marsh (Cra)	1.774	**Rouge River Marsh**	**1.038**
Hydro Marsh (Hyd)	2.116	Jordan Station Marsh	1.079
Bowmanville Marsh (Bow)	2.250	**Hydro Marsh**	**1.383**
Frenchman's Bay Marsh (Fre)	2.434	**Westside Marsh**	**1.612**
Lynde Creek (Lyn)	2.435	**Frenchman's Bay Marsh**	**2.058**
Duffins Creek Marsh (Duf)	3.058	**Cranberry Marsh**	**2.359**
Port Newcastle Wetland (port N)	-	**Duffins Creek Marsh**	**2.590**
Rouge River Marsh (Rou)	-	**Bowmanville Marsh**	**2.729**
Westside Marsh (Wes)	**-**	**Lynde Creek**	**3.349**

3.2 USING METRICS TO ASSESS THE CONDITION OF BIOTIC COMMUNITIES

The multimetric approach combines several metrics to create an Index of Biotic Integrity (IBI) for the biotic community being studied. The first step is to identify suitable metrics, within a specific biotic community, to include in an index. Potential metrics can be determined through literature searches, reporting from such initiatives as the previously mentioned GLCWC project and expert advice. Metrics describing biological communities fall into three different categories: species richness, trophic composition, and abundance and condition. With candidate metrics identified, additional metric data from appropriate sites (i.e., other Lake Ontario coastal wetlands; Figure 1-5) must be obtained to develop regionally suitable metric scores. To determine the suitability of metrics, the metric was plotted against site disturbance as described in section 3.1.

A metric was determined to be suitable if the probability statistic (p-value) of the correlation coefficient (r) between the metric and disturbance was less than 0.20. Although the convention in statistics dictates that p-values greater than 0.05 do not represent significant trends, a p-value of less than 0.20 indicates a significant enough relationship to be considered in the IBI. This means that the certainty of detecting a significant trend between disturbance and the raw metric is 80 percent instead of 95 percent. The IBI achieves increased accuracy to describe the condition of biological communities from the incorporation of several metrics. This synergy of metrics exemplifies the underlying principle of IBI for describing biotic communities. As a result, an IBI comprised of marginally significant and/or significant metrics will show a strong, significant positive relationship with site disturbance.

Once it was determined that a metric responded to disturbance, the values of the metric were transformed into a measure of integrity. The June 2003, DRCWMP: Interim Report described a method using trisection on box plots to assign ordinal scoring of metrics. After reconsidering this process, it was decided that the data would be more accurately represented by using a continuous scoring method as in Minns *et al.* (1994) and Hughes *et al.* (1998). This method uses a linear function to transform raw metric data into standardized metrics with a minimum value of zero and a maximum value of 10, as in Minns *et al.* (1994). For all IBIs, the following equation and conditions were used to define the standardized metric:

$$M_S = A + BM_R,$$
$$\text{If } M_S < M_{MIN}, \text{ then } M_S = M_{MIN}$$
$$\text{If } M_S > M_{MAX}, \text{ then } M_S = M_{MAX}$$

Where B defines the slope between the standardized metric (M_S) and the raw metric (M_R) and A is the intercept. The minimum and maximum thresholds (M_{MIN} and M_{MAX}) provide upper and lower limits to the standardized metric. For metrics that decrease with increasing disturbance (e.g., native species richness), a lower limit (M_{MIN}) of zero is used, indicating an absence of biota. The upper limit (M_{MAX}) for these metrics was based on the 95th percentile of metrics from the Durham Region and other Lake Ontario coastal wetlands. For metrics that increase with disturbance (e.g., exotic species richness), the slope of the above function is negative, indicating that as the raw metric decreases, the standardized metric increases. In these cases, M_S=0 for the sites with M_R above the 95th

percentile (highest exotic species richness) and M_S=10 for sites with M_R=0 (no exotic species richness). Any exceptions to this procedure are noted in the relevant sections.

The standardized metrics were then added, multiplied by 10, and divided by the total number of metrics to create an Index of Biotic Integrity (IBI) with scores between 0 and 100. Higher scores indicate biotic communities in better condition. IBIs were developed and reported for five biotic communities: plant, aquatic macroinvertebrate, fish, breeding bird, and amphibian (sections 4.1.3, 4.2.1, 4.2.2, 4.2.3, and 4.2.4, respectively).

3.3 STATISTICAL PROPERTIES OF IBI

The use of IBIs in scientific reporting provides easily interpreted results to non-technical audiences. However, error terms are not often reported with IBI values, so their reliability and robustness are often not known. In each section where IBIs are used, the statistical properties of the IBIs are examined in the same manner described in Fore *et al.* (1994). This method involves creating a measure of variance in the IBI by randomly resampling (bootstrapping) the data. Based on the means and variances generated through resampling, a model assuming three replicates per site and the statistical standard of $\propto$=0.05 as the risk of type I error (rejecting the null hypothesis when it is true) is used to create a standard power curve. A power of 80 percent (commonly accepted statistical standard) is used to determine the minimum detectable difference between the means. Then the range of IBI scores is divided by the minimum detectable difference to determine the number of classes that the IBI can distinguish.

For example, the minimum detectable difference at 80 percent power was found to be 7.5 IBI units. If the empirical range of IBIs for a community was 28-85 then the range is the difference, 57. The maximum number of classes that the IBI can distinguish between is 57 ÷ 7.5 = 7.6. So the IBI range would be separated into at a maximum of seven classes (e.g., very poor, poor, fair, good, very good, excellent, pristine). This method was used to determine statistical properties of plant, fish, bird, and amphibian IBIs (sections 4.1.3, 4.2.2, 4.2.3, and 4.2.4, respectively).

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4. BIOLOGICAL CONDITION

4.1 PLANT COMMUNITY CONDITION

4.1.1 Wetland and Adjacent Upland Ecological Land Classification

Objective

To assess and monitor change in vegetation communities within Durham Region coastal wetlands and adjacent upland areas.

Method Summary

Ecological Land Classification (ELC), as described in Lee *et al.* (1998), was completed for most vegetation polygons at coastal wetlands and uplands within 500 m from the edge of the delineated wetland to the Vegetation Type level (the finest resolution of the ELC). The resulting polygons were digitized to produce a GIS layer or an already-existing ELC Community Series layer was adjusted to allow classification to the Vegetation Type level.

Results

As ELC Vegetation Type evaluation is a time-consuming process, some polygons still need to be classified to this level. ELC polygons within the 500-m buffer that are not contiguous with wetland vegetation communities (i.e., are isolated from them by human-related development) were initially not intended to be classified to this level of detail. However, in the Second Approximation of the Methodology Handbook for this project (Environment Canada and Central Lake Ontario Conservation Authority 2003), this protocol was altered to include all vegetation communities within 500 m of the wetland boundary. In some cases, this substantially increased the number of polygons that needed detailed fieldwork and resulted in a delay in completing this objective. Those polygons that have not yet been classified to Vegetation Type are shown with their appropriate Community Series designation.

The Bowmanville Marsh ELC was completed as part of the Westside/Bowmanville Marshes Environmental Management Plan (Niblett Environmental Associates 2003). The Westside Marsh ELC information was obtained using a combination of the Westside Marsh Fish Habitat Compensation Report (Dillon Consulting 1997) and orthophoto interpretation. The Westside Marsh ELC was expected to be completed by Niblett Environmental Associates during 2001/2002 as part of the Westside/Bowmanville Marshes Environmental Management Plan. The results of the ELC work are presented here, but not to the resolution required by this project. By 2003, the berm construction and restoration works at Westside Marsh were well underway, precluding field work at that time.

To simplify reporting, the ELC data are summarized at the Community Series level rather than at the more detailed Vegetation Type scale (Table 4.1.1-1). Half of the wetlands had a cultural vegetation community (either Cultural Meadow or Woodland) as the largest by area, while the other half had a wetland community as the largest. All wetlands, with the exception of Cranberry Marsh and Port Newcastle Wetland, had a larger percentage of area in natural as compared to cultural vegetation communities. Pumphouse Marsh, which is generally surrounded by residential and educational development, had by far the smallest percentage (10.8 percent) of wetland and buffer area in ELC polygons (Table 4.1.1-1). However, none of the wetlands had more than 55 percent of the buffer and wetland as naturally vegetated communities and most had less than 50 percent.

In general, ELC Vegetation Type designations are shown for Durham Region wetlands (Figures 4.1.1-1 to 4.1.1-10; see Table 4.1.1-2 for ELC definitions). Polygons that show less resolution (Community Series or Ecosite) are awaiting Vegetation Type classification or there are currently no appropriate designations at this level. Appropriate Vegetation Type classifications were lacking for many Cultural Woodland (CUW) polygons.

Discussion

This monitoring task is largely GIS and map-oriented, and reveals the location of vegetation communities as a result of geophysical features and anthropogenic disturbance. Specific discussion regarding the results and future goals of this monitoring should occur within the DRCWMP.

In general, vegetation in Durham Region coastal wetlands may change as a result of disturbance (e.g., invasive plants, turbidity, agriculture) and natural variability (e.g., change in water levels, succession). It is critical to monitor vegetation patterns to determine if management, restoration, invasive species removal or other activities are required to maintain or enhance wetland health. In addition, the ELC process will allow wetland vegetation health assessments to be made (e.g., floristic quality).

As water levels fluctuate in wetlands, the various vegetation communities will shift to conform to their zones of tolerance. With higher water levels, the emergent, submerged and open water habitats will increase and the meadow marsh and shrub thickets will migrate landward (Mortsch 1998). This ongoing shifting will maintain high habitat diversity and may alter the wildlife communities which can inhabit each vegetation zone/type (see Identification of Key Habitats, section 4.1.2). The geomorphology of the wetland basin will affect how water level changes alter vegetation communities. If the gradient is steep, the area of wetland will decrease as water levels increase, because the emergent and meadow marsh communities will have only a small area of appropriate water depth (Mortsch 1998). Also, if the wetland is surrounded by development, the vegetation communities will not be able to shift according to changes in water level (Whillans 1985).

The most prominent trend observed in Durham Region coastal wetlands reflects that, in the past, many of the wetlands were abutted by intensive agricultural activities that have since been stopped. As a result, succession has occurred in the abandoned fields, and there are substantial areas of cultural vegetation types within 500 m. Around Cranberry Marsh and McLaughlin Bay Marsh, in particular, there have been extensive plantings of coniferous trees on the former agricultural lands, resulting in large areas of Cultural Plantation (CUP).

The relatively low levels of natural vegetation (i.e., non-manicured) in the 500 m around most wetlands suggests that connectivity with other natural areas is generally low. Much work has been done on the subject of habitat fragmentation and its impacts on various wildlife communities (Martin and Finch 1995). While the size of a wetland is important in terms of the numbers of individuals and diversity of species that it can support, the degree of isolation of wetlands from other wetlands is also important (Brown and Dinsmore 1985; Houlahan and Findlay 2003).

Future Considerations

As new orthophotos become available, the ELC mapping iterations should be completed. It is unrealistic to expect all ELC polygons at and within 500 m of the wetlands to be classified to Vegetation Type in one field season; in the future, some ELC work should be conducted each field season (following the arrival of updated orthophotos and revised polygon boundaries).

A number of coastal wetlands in Durham Region are undergoing restoration/ rehabilitation/construction work of some sort (i.e., Rouge River, Frenchman's Bay, Duffins Creek, Cranberry, Oshawa Second and Westside marshes). For these wetlands, it is particularly important to continue monitoring any vegetation community changes.

Using some of the non-Durham wetlands that are considered to be less impacted (e.g., Huyck's Bay, Parrott's Bay, etc.) for comparison could provide insight into the relative state of the Durham coastal wetlands in terms of adjacent land-use.

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Table 4.1.1-1. Percentages of ELC Community Series in Durham Region coastal wetlands and within 500 m of their boundaries.

ELC Community Series	Cranberry Marsh	Lynde Creek Marsh	Corbett Creek Marsh	Pumphouse Marsh	Oshawa Second Marsh	McLaughlin Bay Marsh	Westside Marsh	Bowmanville Marsh	Wilmot Creek Marsh	Port Newcastle Wetland
BBO	0.4	0.2	0.7	0.5	0.5	1.4	0.3	0.9	0.9	0.5
BBS					0.1	1.4	0.3			
BBT	0.4	0.2		0.5	0.5	0.2	0.3	0.4		
BLO	0.1		0.1							
BLS			0.2	0.6				0.2		
BLT			0.1							
CUM	12.2	9.6	7.5	1.1	17.9	12.9	9.8	4.1	16.3	8.0
CUP	6.8	1.9			0.7	3.5			0.6	0.8
CUS	0.2	0.4								
CUT	2.0	1.0	4.8	1.1	2.7	2.1	2.6	1.6	0.4	0.4
CUW	1.3	1.5	0.4	0.3	1.7	5.4			1.3	9.6
FOC									0.2	
FOD	1.1	3.8	1.9	0.8		0.8	1.1	2.4	10.1	9.1
FOM		0.2	2.4	0.4				0.1	2.4	0.4
MAM	3.0	3.8	0.9	0.3	3.6	2.8	2.7	1.2	1.2	3.0
MAS	7.1	5.1	4.7	1.8	5.7	1.2	9.1	8.7	1.8	
OAO	2.4	4.8	0.3		3.4	13.6	4.4	5.9	1.0	5.4
SAF					0.7	1.0	0.8	2.4		
SAS			1.4	2.4	8.7	0.4				
SWC									1.7	
SWD	4.0	10.0	3.1	0.2	8.0	3.6	1.9	2.5		
SWT	1.0	0.3		0.7	1.3	0.3	1.5	0.9	0.2	
% Natural	19.5	28.4	15.6	8.2	32.5	26.6	22.3	25.8	19.5	18.4
% Cultural	22.5	14.4	12.7	2.5	22.9	23.9	12.4	5.7	18.5	18.8
% Total ELC	42.1	42.8	28.3	10.8	55.4	50.5	34.7	31.4	38.1	37.1

Note: Shading denotes ELC Community Series with highest percentage for each wetland.

Table 4.1.1-2. Definitions of ELC codes.

CODE	*Nested ELC Community Units*
BBO1	Mineral Open Beach / Bar Ecosite
BBO1-1	Sea Rocket Sand Open Beach Type
BBS1	Mineral Shrub Beach / Bar Ecosite
BBS1-2	Willow Gravel Shrub Beach Type
BBT1	Mineral Treed Beach / Bar Ecosite
BLO1	Mineral Open Bluff Ecosite
BLS1	Mineral Shrub Bluff Ecosite
BLT1	Mineral Treed Bluff Ecosite
FOC	Coniferous Forest
FOM	Mixed Forest
FOM2-2	Dry - Fresh White Pine - Sugar Maple Mixed Forest Type
FOM4-2	Dry - Fresh White Cedar - Poplar Mixed Forest Type
FOM6-1	Fresh - Moist Sugar Maple - Hemlock Mixed Forest Type
FOD	Deciduous Forest
FOD2-4	Dry - Fresh Oak - Hardwood Deciduous Forest Type
FOD3-2	Dry - Fresh White Birch Deciduous Forest Type
FOD4	Dry - Fresh Deciduous Forest Ecosite
FOD4-2	Dry - Fresh White Ash Deciduous Forest Type
FOD5-2	Dry - Fresh Sugar Maple - Beech Decidous Forest Type
FOD5-9	Dry - Fresh Sugar Maple - Red Maple Deciduous Forest Type
FOD6	Fresh - Moist Sugar Maple Deciduous Forest Ecosite
FOD6-1	Fresh - Moist Sugar Maple - Lowland Ash Deciduous Forest Type
FOD7-2	Fresh - Moist Ash Lowland Deciduous Forest Type
FOD7-3	Fresh - Moist Willow Lowland Deciduous Forest Type
FOD8-1	Fresh - Moist Poplar Deciduous Forest Type
FOD9-1	Fresh - Moist Oak - Sugar Maple Deciduous Forest Type
FOD9-2	Fresh - Moist Oak - Maple Deciduous Forest Type
CUP	Plantation
CUP1	Deciduous Plantations
CUP1-5	Silver Maple Deciduous Plantation Type
CUP2	Mixed Plantations
CUP2-1	Black Walnut - White Pine Mixed Plantation Type
CUP3	Coniferous Plantations
CUP3-2	White Pine Coniferous Plantation Type
CUP3-3	Scotch Pine Coniferous Plantation Type
CUP3-5	Tamarack - European Larch Coniferous Plantation Type
CUP3-6	European Larch Coniferous Plantation Type
CUP3-8	White Spruce - European Larch Coniferous Plantation Type
CUM1-1	Dry - Moist Old Field Meadow Type
CUT	Cultural Thicket
CUT1	Mineral Cultural Thicket Ecosite
CUT1-3	Chokecherry Cultural Thicket Type
CUS1-1	Hawthorn Cultural Savannah Type
CUW	Cultural Woodland
CUW1	Mineral Cultural Woodland Ecosite
SWC	Coniferous Swamp
SWD	Deciduous Swamp

Table 4.1.1-2. Continued.

CODE	*Nested ELC Community Units*
SWD2-2	Green Ash Mineral Deciduous Swamp Type
SWD3-2	Silver Maple Mineral Deciduous Swamp Type
SWD3-4	Manitoba Maple Mineral Deciduous Swamp Type
SWD4-1	Willow Mineral Deciduous Swamp Type
SWD4-3	White Birch – Poplar Mineral Deciduous Swamp Type
SWT	Thicket Swamp
SWT2-1	Alder Mineral Thicket Swamp Type
SWT2-2	Willow Mineral Thicket Swamp Type
SWT2-5	Red-osier Mineral Thicket Swamp Type
SWT2-6	Meadowsweet Mineral Thicket Swamp Type
SWT2-10	Nannyberry Mineral Thicket Swamp Type
MAM	Meadow Marsh
MAM2	Mineral Meadow Marsh Ecosite
MAM2-1	Bluejoint Mineral Meadow Marsh Type
MAM2-2	Reed-canary Grass Mineral Meadow Marsh Type
MAM2-5	Narrow-leaved Sedge Mineral Meadow Marsh
MAM2-6	Broad-leaved Sedge Mineral Meadow Marsh Type
MAM2-10	Forb Mineral Meadow Marsh Type
MAM3-1	Bluejoint Organic Meadow Marsh Type
MAM5-1	Mineral Fen Meadow Marsh Type
MAS	Shallow Marsh
MAS2-1	Cattail Mineral Shallow Marsh Type
MAS2-9	Forb Mineral Shallow Marsh Type
MAS3-1	Cattail Organic Shallow Marsh Type
MAS3-6	Spike Rush Organic Shallow Marsh Type
MAS3-10	Forb Organic Shallow Marsh Type
MAS3-12	Water Willow Organic Shallow Marsh Type
OAO	Open Aquatic
SAS1	Submerged Shallow Aquatic Ecosite
SAS1-1	Pondweed Submerged Shallow Aquatic Type
SAF1-1	Water Lily - Bullhead Lily Floating-leaved Shallow Aquatic Type

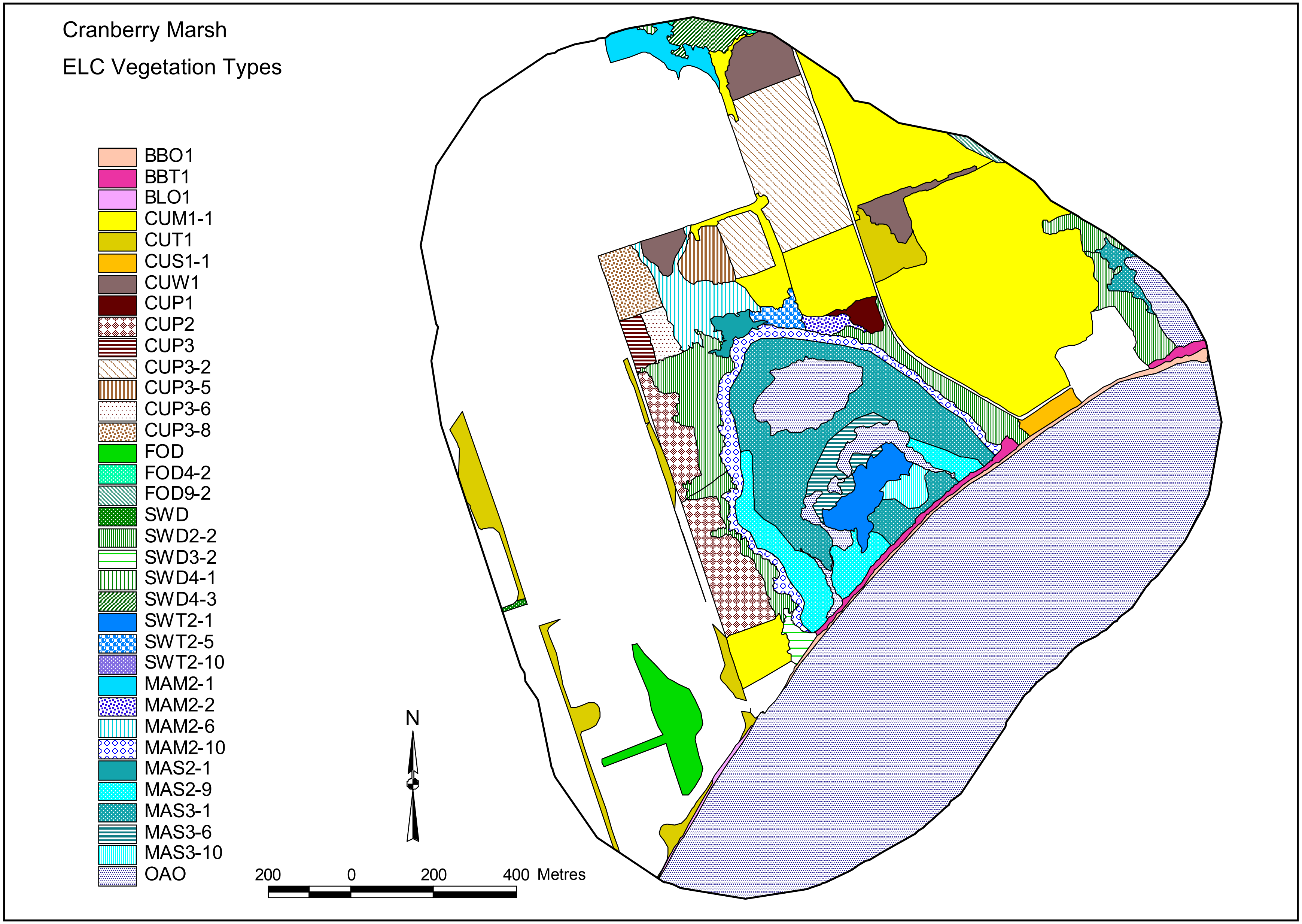

Figure 4.1.1-1. Ecological Land Classification (ELC) Vegetation Types at Cranberry Marsh and within 500 m of its boundary.

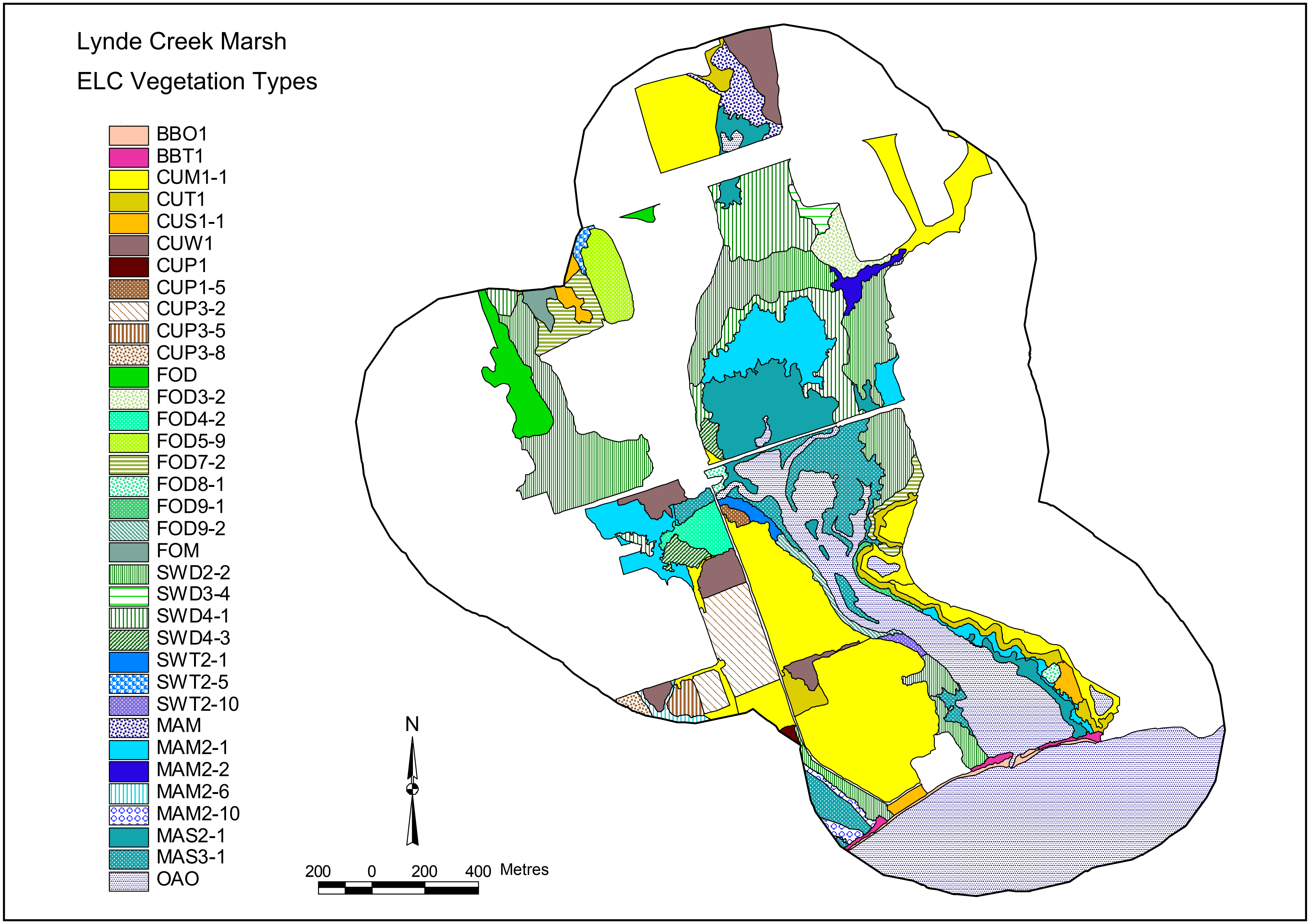

Figure 4.1.1-2. Ecological Land Classification (ELC) Vegetation Types at Lynde Creek Marsh and within 500 m of its boundary.

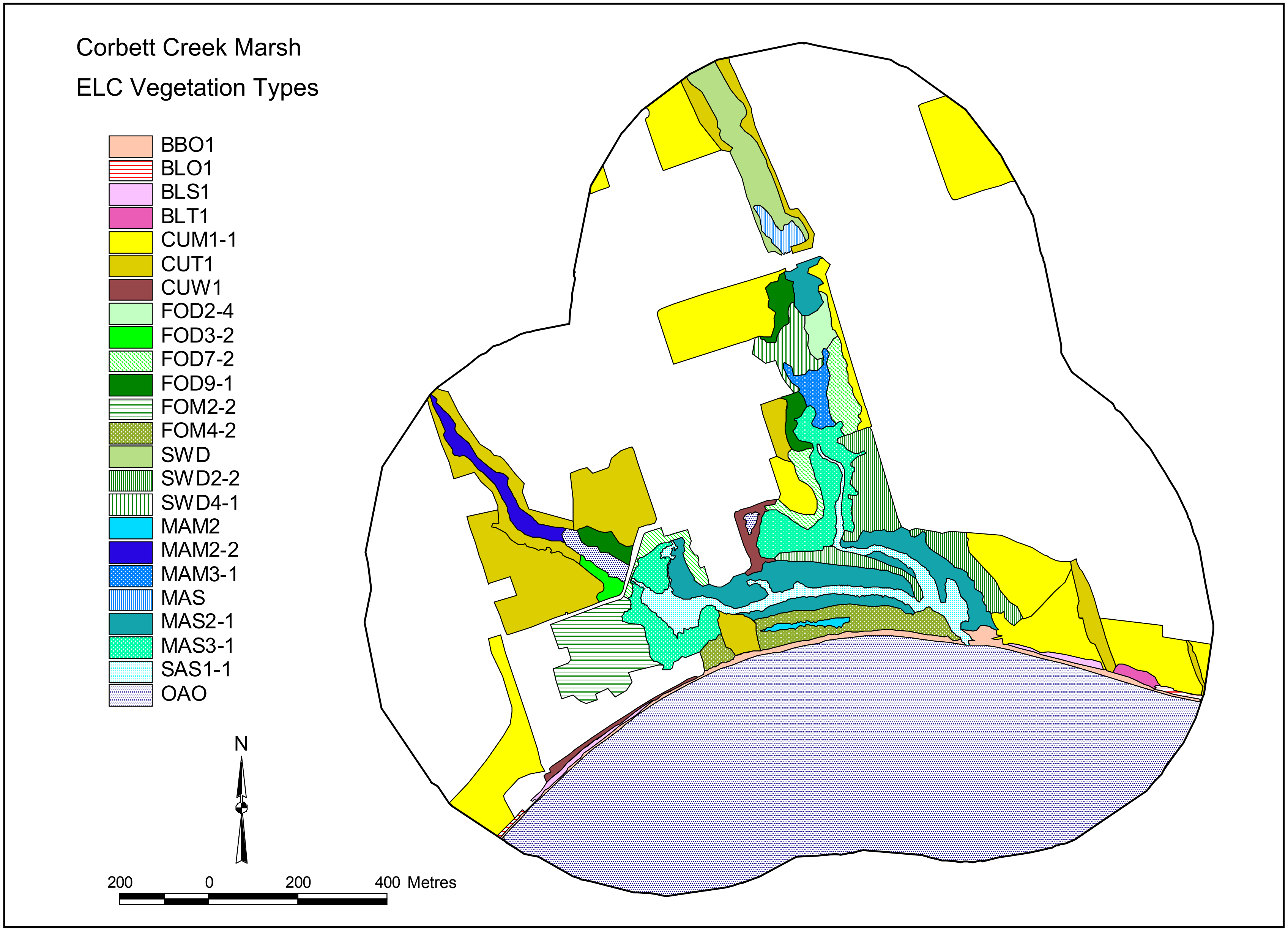

Figure 4.1.1-3. Ecological Land Classification (ELC) Vegetation Types at Corbett Creek Marsh and within 500 m of its boundary.

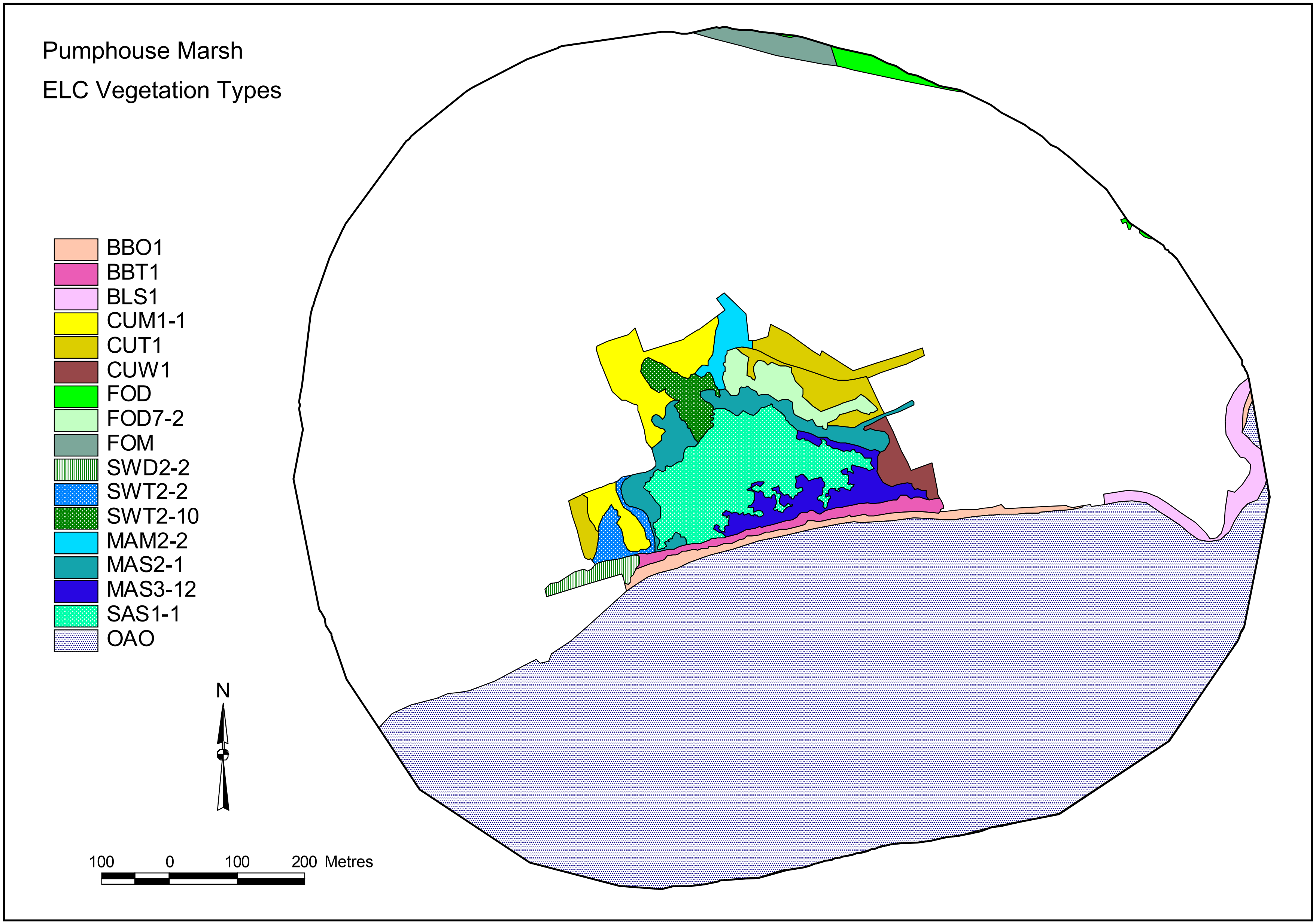

Figure 4.1.1-4. Ecological Land Classification (ELC) Vegetation Types at Pumphouse Marsh and within 500 m of its boundary.

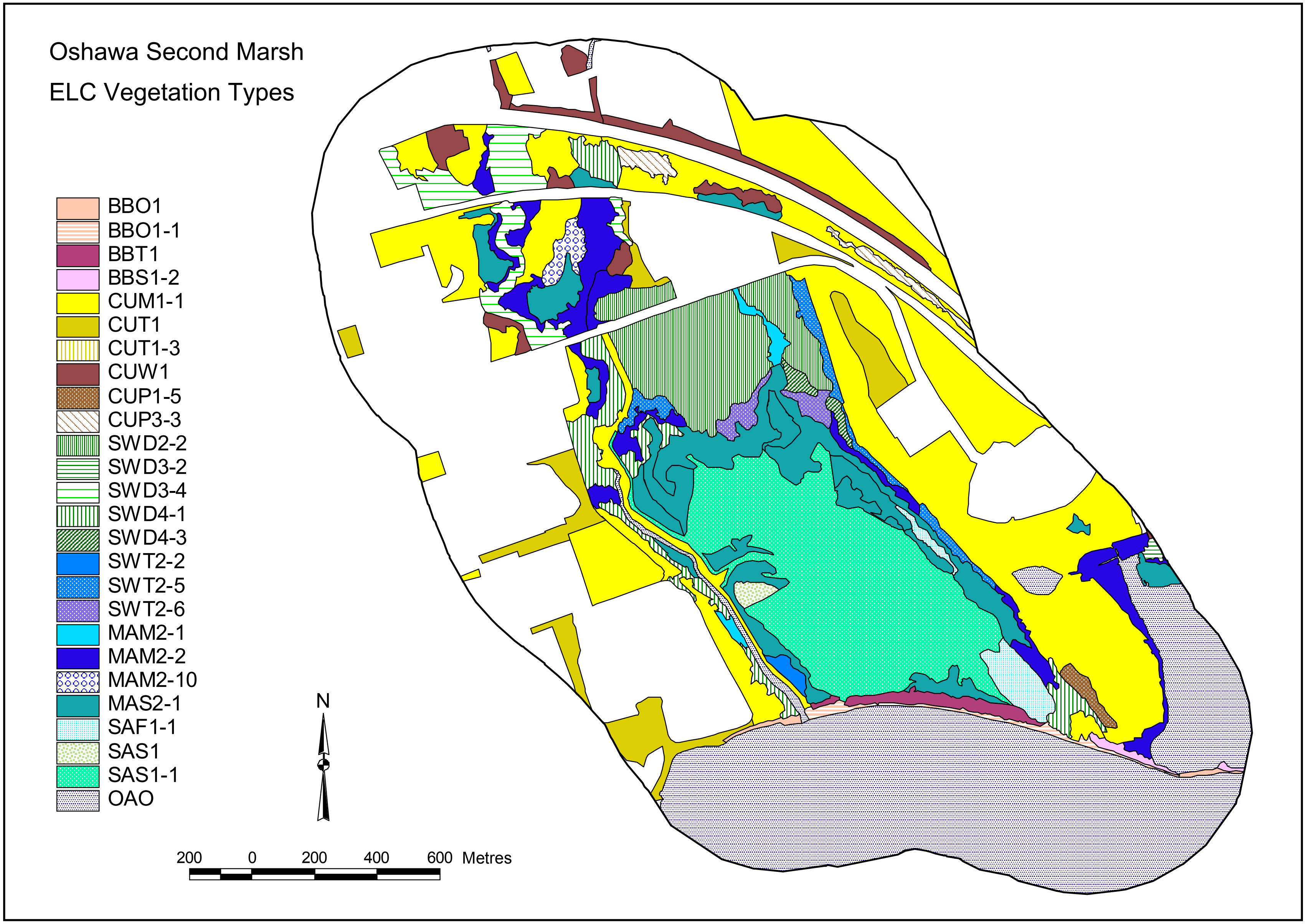

Figure 4.1.1-5. Ecological Land Classification (ELC) Vegetation Types at Oshawa Second Marsh and within 500 m of its boundary.

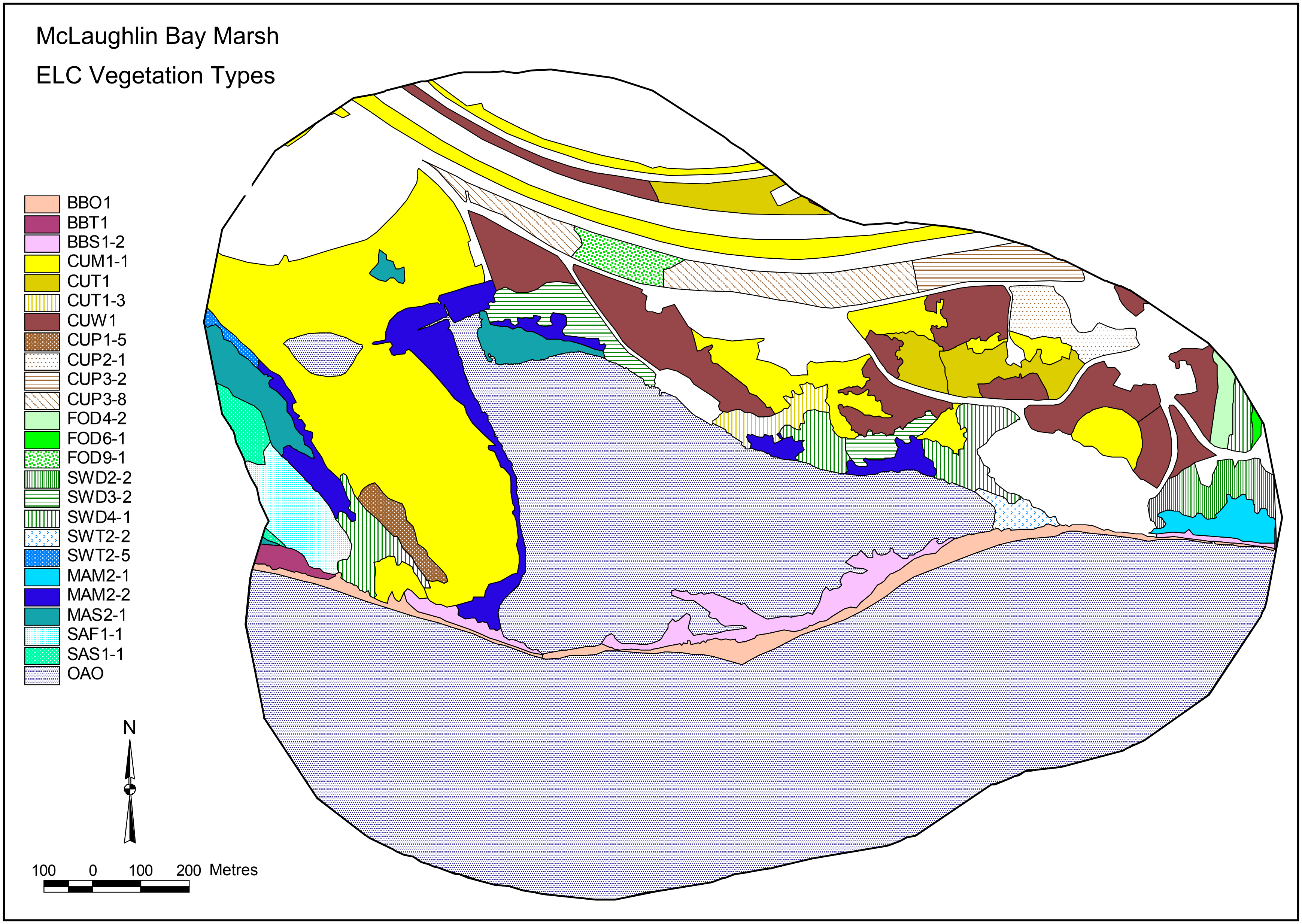

Figure 4.1.1-6. Ecological Land Classification (ELC) Vegetation Types at McLaughlin Bay Marsh and within 500 m of its boundary.

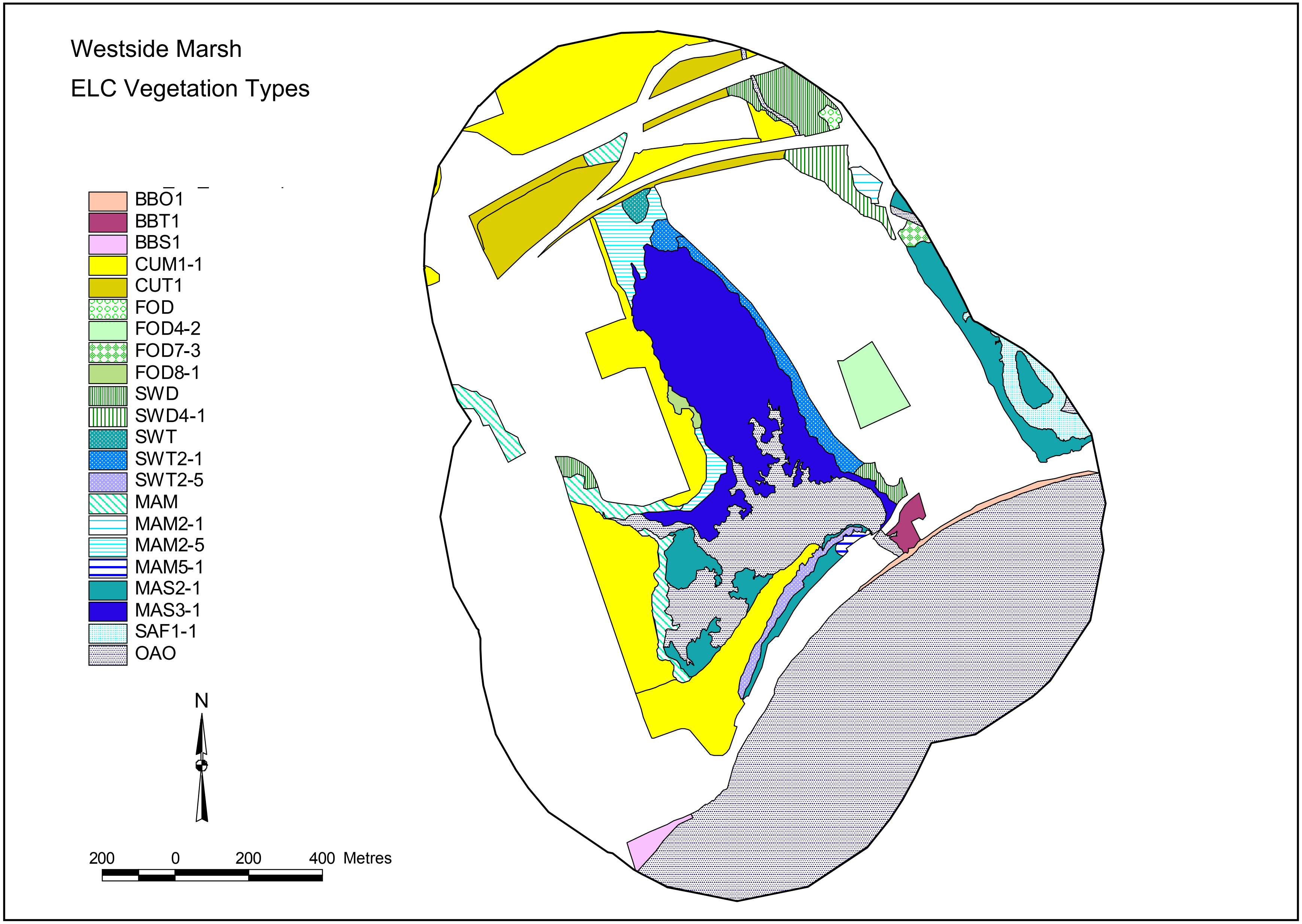

Figure 4.1.1-7. Ecological Land Classification (ELC) Vegetation Types at Westside Marsh and within 500 m of its boundary.

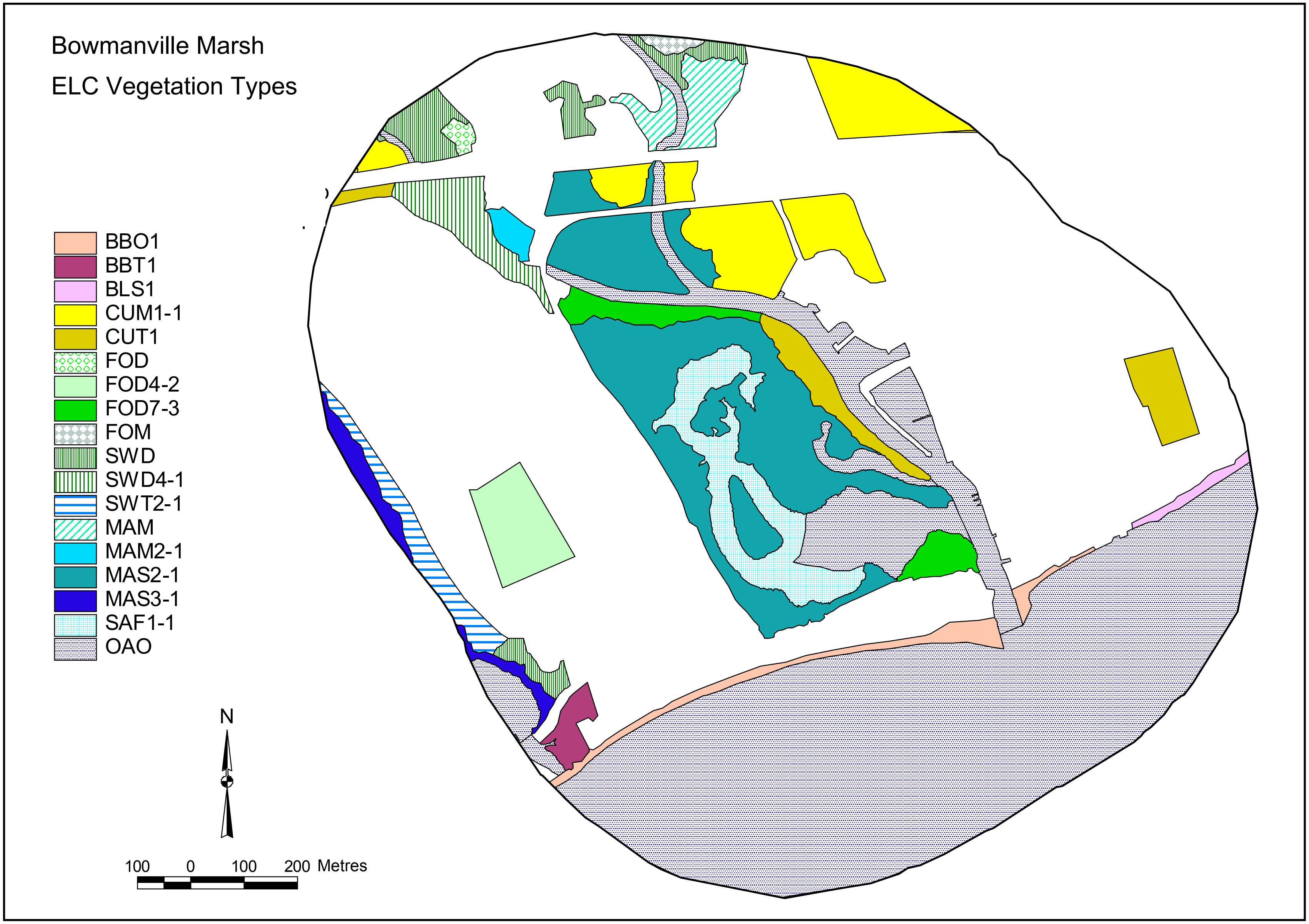

Figure 4.1.1-8. Ecological Land Classification (ELC) Vegetation Types at Bowmanville Marsh and within 500 m of its boundary.

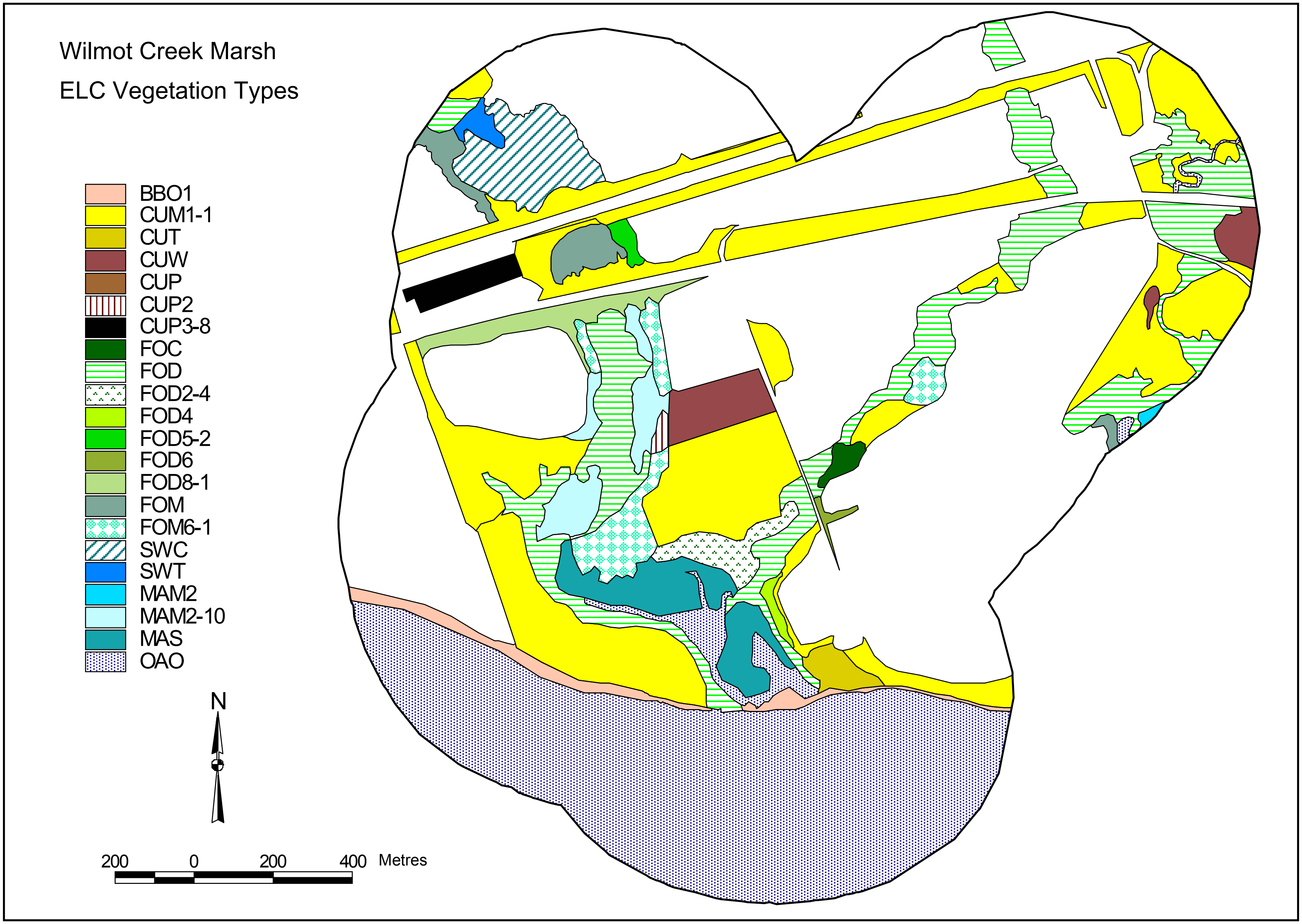

Figure 4.1.1-9. Ecological Land Classification (ELC) Vegetation Types at Wilmot Creek Marsh and within 500 m of its boundary.

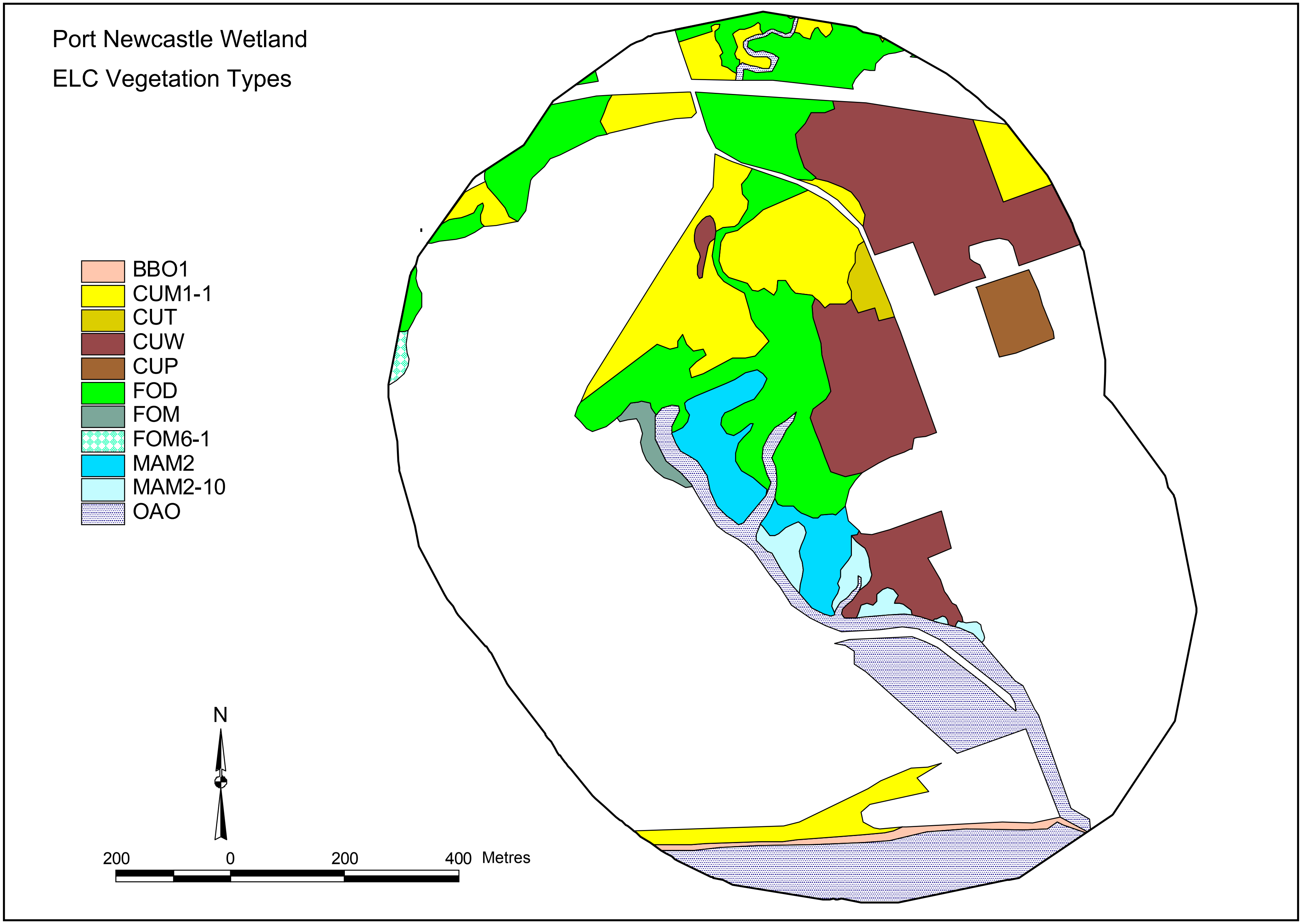

Figure 4.1.1-10. Ecological Land Classification (ELC) Vegetation Types at Port Newcastle Wetland and within 500 m of its boundary.

4.1.2 Identification of Key Habitats

Objective

To assess and monitor the shape, size and composition of key habitats within each Durham Region coastal wetland and within a 500-m wetland buffer.

Method Summary

Key habitats are those that recently (i.e., within the past three years) supported species that are at risk in Ontario (either through federal or provincial designations). "Support" refers to the provision of food, shelter, spawning, staging, migratory stopover or breeding areas for fauna. In addition, any habitats where plant species at risk are found will be considered key habitats. Species information is acquired through a literature search, interviewing knowledgeable people, and the fieldwork conducted for other monitoring activities for this project.

Data Analysis

Where a species at risk was identified, the habitat type (Ecological Land Classification – Vegetation Type) that the species was using was flagged as a "key habitat" and the area of this habitat was calculated. For example, if a marsh-nesting bird species at risk was identified as using "Cattail Mineral Shallow Marsh Type" (MAS2-1), then all polygons of that Vegetation Type would be classified as "key habitat" and the area of this type will be tracked.

Results

To date, species at risk and their associated key habitats have only been identified at wetlands within the CLOCA jurisdiction (Table 4.1.2-1). As well, an example of the mapping product has been included (Figure 4.1.2-1). This figure depicts the Shallow Marsh Community Series at Oshawa Second Marsh, which is a key habitat for a species at risk.

GRCA does not have any records of species at risk using either Wilmot Creek Marsh or Port Newcastle Wetland (M. Desjardins, pers. comm. 2003). Information has not yet available from TRCA.

Discussion

This monitoring activity is a two-part process: initially the species at risk using the wetlands have to be identified and then the habitats must be flagged and tracked over time. Although the results of this protocol will be presented on a three-year review basis, the task is essentially ongoing. As new species at risk sightings are made, they will be incorporated into the database and the key habitats identified.

The monitoring of key habitats can be advantageous, but possibly harmful with respect to the well-being of species at risk. Therefore, great care must be taken with ongoing monitoring of these species and associated habitats. This type of monitoring is of paramount importance for guiding conservation and restoration practices. The knowledge and documentation of key habitats will create a tool to allow proponents of wetland conservation to defend against the alteration or destruction of these habitats through development. In addition, restoration biologists are provided with a tool to aid in decisions regarding undertakings of habitat enhancement or creation in Durham Region wetlands.

Table 4.1.2-1. Species at risk observed at Durham Region coastal wetlands (CLOCA jurisdiction) from 2000 to 2003.

Wetland — Genus and species	Common Name	Year
Corbett Creek Marsh		
Melanerpes erythrocephalus[1]	Red-headed Woodpecker	2000
Buteo lineatus[2]	Red-shouldered Hawk	2002
Dendroica cerulea[2]	Cerulean Warbler	2002
Falco peregrinus[2]	Peregrine Falcon	2002
Ixobrychus exilis[2]	Least Bittern	2002
Wilsonia citrina[2]	Hooded Warbler	2002
Cranberry Marsh		
Aquila chrysaetos[4]	Golden Eagle	2000
Chlidonias niger[3]	Black Tern	2000
Falco peregrinus[4]	Peregrine Falcon	2000
Falco peregrinus[5]	Peregrine Falcon	2001
Falco peregrinus[6]	Peregrine Falcon	2003
Haliaeatus leucocephalus[5]	Bald Eagle	2001
Haliaeatus leucocephalus[7]	Bald Eagle	2002
Ixobrychus exilis[8]	Least Bittern	2002
Lynde Creek Marsh		
Chlidonias niger[9]	Black Tern	2000
Chlidonias niger[10]	Black Tern	2001
Haliaeatus leucocephalus[11]	Bald Eagle	2003
Oshawa Second Marsh		
Aquila chrysaetos[12]	Golden Eagle	2000
Asio flammeus[13]	Short-eared Owl	2003
Chlidonias niger[14]	Black Tern	2000
Chlidonias niger[14]	Black Tern	2001
Chlidonias niger[14]	Black Tern	2002
Chlidonias niger[18]	Black Tern	2003
Falco peregrinus[8]	Peregrine Falcon	2002
Ixobrychus exilis[14]	Least Bittern	2000
Ixobrychus exilis[14]	Least Bittern	2001
Ixobrychus exilis[15]	Least Bittern	2002
Ixobrychus exilis[18]	Least Bittern	2003
Pumphouse Marsh		
Chlidonias niger[14,16]	Black Tern	2000
Chlidonias niger[8]	Black Tern	2002
Bowmanville Marsh		
Chlidonias niger	Black Tern	2002

Note: Superscript numbers indicate source report listed in Literature Cited section.

Figure 4.1.2-1. Shallow Marsh (MAS) identified as key habitat at Oshawa Second Marsh.

A drawback of identifying key habitats is that the reporting of this information provides general knowledge of species at risk locations. For many naturalists, and birders in particular, the sighting of a rare species is often sought. With general knowledge of a species location, the concern is that sensitive key habitats may experience a harmful influx of human visitors. Although the intention of the visitors is noble, unnecessary stress through habitat disturbance may result. The Natural Heritage Information Centre (NHIC) manages much of the dissemination of species at risk information for Ontario and they suggest that for general reporting purposes only the wetland name should be provided, rather than the habitat type (D. Sutherland, pers. comm. 2003). A table with the full Vegetation Type classification for each species at risk is listed in a separate appendix, which will be provided on a restricted basis.

Monarch butterfly (*Danaus plexippus)* is designated as a species of Special Concern (COSEWIC) and individuals were seen feeding and/or resting in many polygons, particularly during migration. However, their habitat use will not be tracked in the same way as other species at risk. In other cases, the habitat (ELC Vegetation Type) used by the species may not be known or it may be using the entire wetland for foraging (e.g., Peregrine Falcon). In these cases, the areas that the species is expected to be using (based on its known behaviour) are flagged as "key habitat".

Future Considerations

Local naturalists are likely one of the best sources of current species at risk sightings and efforts should be made to encourage their participation in this project.

Literature Cited

Source for species at risk sightings documentation listed in Table 4.2.1-1.

1. Lockrey, D. 2000. Ontario Birds Rare Sightings Report. May 21, 2000.
2. Barry, D. (compiler) 2002. Thickson's Woods 2002 Species Sightings List – unpublished data.
3. Walsh, J. 2000. Ontario Birds Rare Sightings Report. July 22, 2000.
4. Lockrey, D. 2000. Cranberry Marsh Raptor Watch 2000.
5. Lockrey, D. 2001. Cranberry Marsh Raptor Watch 2001.
6. Lockrey, D. 2003. Cranberry Marsh Raptor Watch 2003.
7. Lockrey, D. 2002. Cranberry Marsh Raptor Watch 2002.
8. The Durham Region Coastal Wetland Monitoring Project – CLOCA – unpublished data collected during 2002 field season.
9. Niblett Environmental Associates. 2001. Lynde Shores Wildlife Monitoring Program – 2000 Report. March 2001.
10. Niblett Environmental Associates. 2002. Lynde Shores Wildlife Monitoring Program – 2001 Report. March 2002.
11. The Durham Region Coastal Wetland Monitoring Project – CLOCA – unpublished data collected during 2002 field season.
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13. Various. 2003. Ontario Birds Rare Sightings Report. February to March 2003.
14. Henshaw, B., and J. Kamstra. 2002. Oshawa Second Marsh Breeding Bird and Amphibian Monitoring – 2001 Annual Report and Multi-year Summary. February 2002.

15. Environment Canada. 2002. Unpublished breeding bird survey data collected from Oshawa Second Marsh.

16. Pinilla, F. 2000. Ontario Birds Rare Sightings Report. May 24, 2000.

17. Niblett Environmental Associates. 2002. Environmental Management Plan for Westside/Bowmanville Marshes – Natural Heritage Component.

18. Hoar, T. 2003. Unpublished bird observations – personal communication.

4.1.3 Submerged Aquatic Plant Community

Objective

To assess and monitor submerged aquatic vegetation (SAV) community condition.

Method Summary

Sampling was completed using 20 randomly placed 1-m x 1-m quadrats in the open water basin of each wetland. Within each quadrat, the percent coverage of each submerged and floating-leaved species was recorded (See Table A-1 in Appendix A for plant species presence). Submerged aquatic vegetation community sampling did not occur at Rouge River, Westside, and Port Newcastle marshes.

Data Analysis
Methods of determining SAV community disturbance, metric suitability, and final IBI score are detailed in section 3.

Selection of Metrics

Twelve metrics were tested for suitability in Lake Ontario coastal wetlands (Table 4.1.3-1). Eight of the metrics are based on suggestions by Albert and Minc (in press) and the other four were identified as potential metrics through Great Lakes Coastal Wetlands Consortium work (Environment Canada 2003). Raw metric values tested against disturbance were means per wetland (i.e., a quadrat was the sampling unit). SAV species were grouped into various water quality guilds (turbidity tolerant, turbidity intolerant and nutrient responsive) according to Albert and Minc (in press) (Table A-2 in Appendix A).

Results

Metric Suitability

Of the 12 metrics evaluated (see Appendix A), five were retained for use in the IBI. All suitable metrics showed a highly significant response ($p<0.005$) to disturbance (Table 4.1.3-1).

Two metrics, richness of turbidity tolerant SAV (STUR) and percent non-native cover (PNNA) had acceptable p-values (<0.20). However, these were not deemed as suitable metrics because the correlation coefficients were low (0.40 and 0.28, respectively). This indicates that disturbance only accounts for a small amount of the variation observed in the metric. Therefore, these metrics are poor predictors of disturbance and were not used in the IBI.

STUR showed a significant response to disturbance ($p=0.04$), but the trend was opposite to what was expected (as disturbance increased, the metric decreased). This result suggests that other sources of disturbance affecting turbidity-tolerant species richness at disturbed sites shadow the effect of turbidity alone.

Table 4.1.3-1. Submerged aquatic vegetation community metric codes, descriptions, and expected and empirical response to disturbance. For metrics used in the IBI, the linear model coefficients, intercept (A) and slope (B) for standardizing raw metric (M_R) with the upper and lower M_R limits of the standardized metrics (M_S) are shown. Correlation coefficients and p-values for all metrics are with graphs in Appendix A.

		Expected Response	Metric Response		Metric coefficients		Values of M_R where	
Code	**Metric Description**		**r**	**p**	**A**	**B**	**M_S=0**	**M_S=10**
Species richness								
SINT	Number of turbidity-intolerant species*	↓	-0.75	<0.001	0	8.06	0	1.24
STUR	Number of turbidity-tolerant species*	↑	-0.40	0.04				
SRES	Number of nutrient-responsive species*	↑	-0.04	0.83				
SNAT	Total number of native species	↓	-0.62	0.001	0	2.88	0	3.47
Floristic quality								
FQI	Floristic Quality Index **	↓	-0.56	0.003	0	3.18	0	3.14
Abundance								
PINT	Relative % cover of turbidity-intolerant species*	↓	-0.66	<0.001	0	0.19	0	52.2
PTUR	Relative % cover of turbidity-tolerant species*	↑	-0.11	0.57				
PRES	Relative % cover of nutrient-responsive species*	↑	0.09	0.66				
RNNA	Relative % cover of non-native species	↑	-0.06	0.76				
PNNA	% cover of non-native species	↑	-0.28	0.16				
PCOV	Total coverage*	↓	-0.69	<0.001	0	0.10	0	100
PALG	Percent cover of filamentous algae*	↑	0.13	0.53				

* Metrics suggested by Albert and Minc (in press)
** FQI calculated according to Oldham *et al.* (1995)

Calculating the IBI

Metrics were standardized as described in section 3 (Table 4.1.3-1).

When the metrics were standardized and integrated, wetland IBI scores (Table 4.1.3-2) were strongly associated with wetland disturbance (n=26, r=-0.76, p<0.001). All additional wetlands east of Durham Region, except Port Britain, scored higher than Durham Region wetlands. The highest scoring Durham Region wetland was Pumphouse Marsh at 50.62 while several wetlands shared near zero scores. Most Durham Region wetlands scored poorly in metrics measuring turbidity-intolerant SAV.

Table 4.1.3-2. Standardized SAV community metrics and IBIs for Lake Ontario coastal wetlands. Sites in bold indicate Durham Region wetlands. Note *Lynde Creek 2003 a* and *b* represent replicate within-year samples.

Wetland Name	SINT	SNAT	FQI	PINT	PCOV	IBI
Bayfield Bay	10	9.22	10	10	8.71	95.8
Robinson's Cove	8.47	7.78	9.69	9.83	8.24	88.0
Hay Bay South	10	7.20	8.32	9.71	8.14	86.7
Button Bay	8.06	6.34	9.84	10	6.60	81.6
Hay Bay North	9.27	7.35	6.14	8.31	8.50	79.1
Little Cataraqui Creek	6.05	7.20	8.53	5.40	9.88	74.1
South Bay	6.05	6.34	10	7.08	7.21	73.3
Parrott's Bay	4.44	10	8.38	1.51	10	68.6
Presqu'ile Bay	7.66	8.50	6.14	4.62	7.41	68.6
Big Sand Bay	2.42	7.78	6.92	2.70	10	59.6
Huyck's Bay	5.24	6.77	6.10	2.61	5.47	52.4
Pumphouse Marsh	**1.21**	**10**	**4.81**	**0.32**	**8.97**	**50.6**
Oshawa Second Marsh 2003	**0**	**6.05**	**4.38**	**0**	**8.98**	**38.8**
Oshawa Second Marsh 2002	**0**	**4.50**	**7.06**	**0**	**5.71**	**34.5**
Cranberry Marsh	**0.40**	**6.20**	**4.51**	**0.01**	**6.10**	**34.4**
Corbett Creek Marsh	**0**	**6.92**	**7.04**	**0**	**2.40**	**32.7**
Lynde Creek Marsh 2003a	**0**	**4.32**	**7.59**	**0**	**4.04**	**31.9**
Bowmanville Marsh 2002	**0.81**	**4.23**	**5.88**	**0.67**	**3.11**	**29.4**
Port Britain	0	2.88	6.51	0	3.12	25.0
Jordan Station	0	2.74	7.17	0	2.43	24.6
Wilmot Creek Marsh	**0**	**2.16**	**5.71**	**0**	**2.35**	**20.4**
Lynde Creek Marsh 2003b	**0**	**3.89**	**4.69**	**0**	**1.54**	**20.2**
Frenchman's Bay Marsh	**0.27**	**2.31**	**5.55**	**0.21**	**1.70**	**20.0**
Lynde Creek Marsh 2002	**0**	**2.70**	**4.21**	**0**	**1.22**	**16.2**
Bowmanville Marsh 2003	**0**	**2.88**	**3.37**	**0**	**1.79**	**16.0**
Duffins Creek Marsh	**0**	**0.20**	**0.66**	**0**	**0.01**	**1.7**
Hydro Marsh	**0**	**0.10**	**0.42**	**0**	**0.01**	**1.0**
McLaughlin Bay Marsh	**0**	**0**	**0**	**0**	**0**	**0**
Carruthers Creek	**0**	**0**	**0**	**0**	**0**	**0**
Rouge River Marsh	**-**	**-**	**-**	**-**	**-**	**NS**
Port Newcastle Wetland	**-**	**-**	**-**	**-**	**-**	**NS**
Westside Marsh	**-**	**-**	**-**	**-**	**-**	**NS**

Statistical Properties of the IBI

Resampling of SAV community IBI metrics consisted of recalculating the mean metric values for each wetland by bootstrapping the field-collected data through 100 iterations (Figure 4.1.3-1).

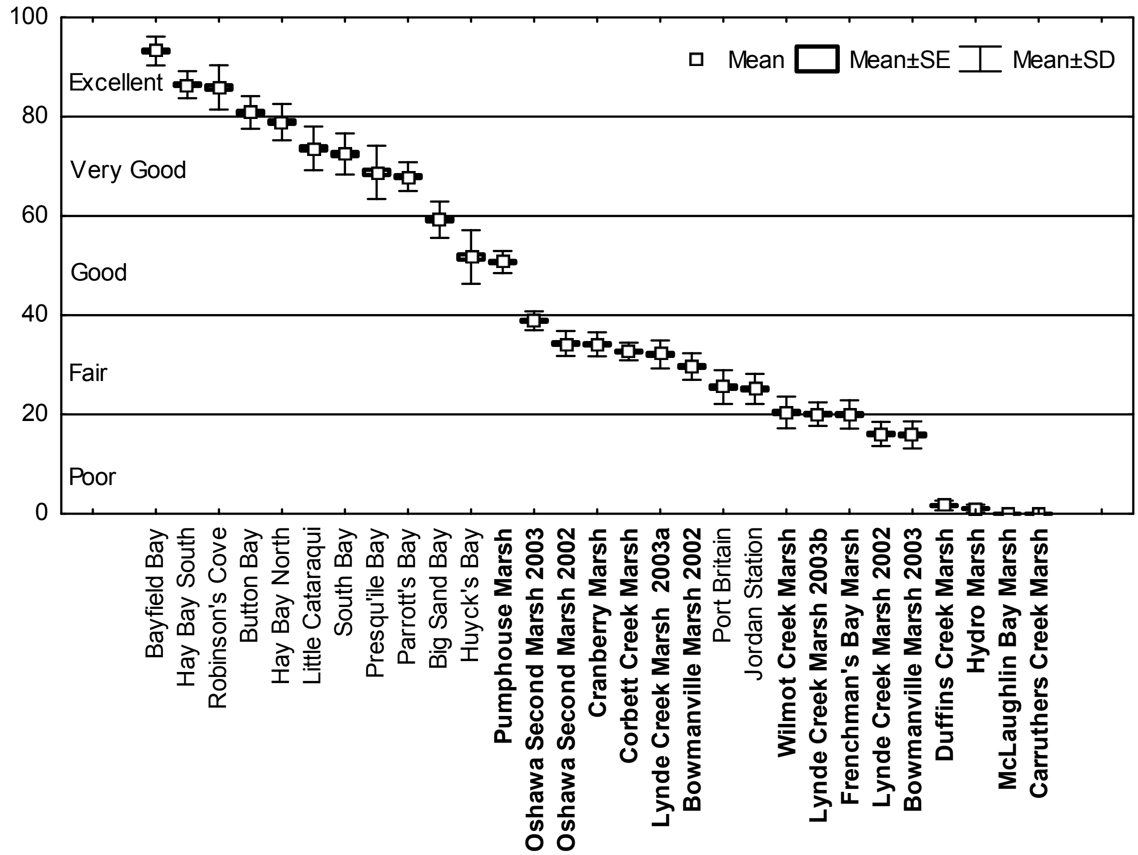

Figure 4.1.3-1. Box and whisker plots of the resampled IBIs for each site showing five IBI category rankings.

IBI classes were established by using the method described by Fore *et al.* (1994). A power curve was constructed by determining the power of all pairwise (n=78) comparisons in theoretical three-sample t-tests ($\propto = 0.05$). The power of each test was then plotted against the difference between means (Figure 4.1.3-2). At the statistical standard of 80 percent power, the minimum detectible difference in IBI means is 11 IBI units. Taking the range of IBIs (Table 4.1.3-2) and dividing it by the minimum detectable difference [(96-0) ÷ 11] equals 8.72. This means that the range of IBIs can be split into as many as eight classes. For simplicity, five IBI classes were identified (poor, fair, good, very good, and excellent) With this classification, the majority of Durham Region coastal wetlands had scores in the fair and poor category while one site, Pumphouse Marsh, was in the good category.

Discussion

Metrics

All Durham Region sites received very low or zero metric scores for metrics involving turbidity-intolerant species (SINT and PINT). Of the Durham sites that scored above zero in these metrics, three of them, Pumphouse, Cranberry, and Bowmanville (2002) marshes, had means below the high-turbidity (30 NTU) threshold (section 2.1.1). Corbett Creek, Oshawa Second, Port Newcastle, and Wilmot Creek marshes were also identified as below the high turbidity threshold, but no turbidity-intolerant species were found at these wetlands. This may be due to limitations in the sampling regime, but is more likely due to periodic high-turbidity events that restrict the establishment of these species. This is supported by the fact that all sites east of the Durham Region (except Port Britain which is adjacent to the Region) had low turbidities (<20 NTU) and scored well on the SINT and PINT metrics.

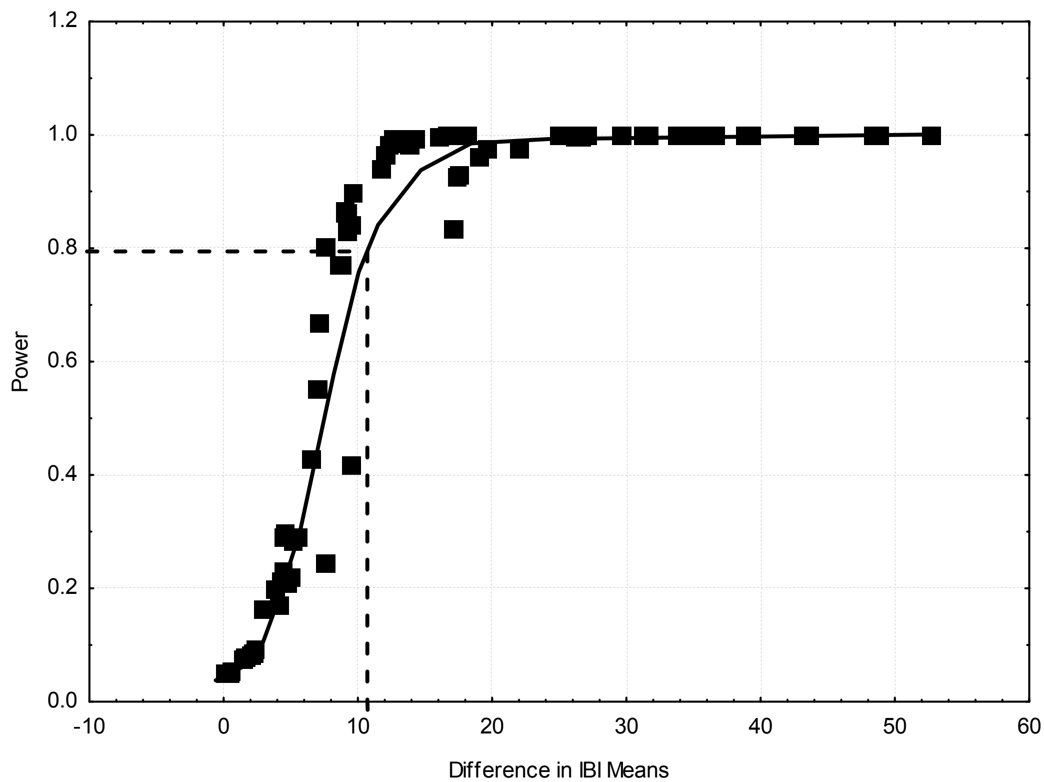

Figure 4.1.3-2. Power curve for IBIs estimated at 13 locations sampled three times. All points shown are for ∝ = 0.05.

Lopez and Fennessy (2002) found that human disturbance negatively influenced the FQI of depressional wetlands in Ohio, and Wilcox *et al.* (2002) found the same trend in Lake Michigan drowned river-mouth and Lake Superior barrier beach coastal wetlands. This trend also appears in Lake Ontario coastal wetlands and Durham Region in particular.

In these studies, FQIs were calculated using coefficients of conservatism that are region-specific. Similarly, this study used a system that was devised for southern Ontario. For FQIs to be useful metrics in the development of basin-wide SAV community IBIs, consistent bi-national, basin-wide coefficients of conservatism for wetland plants require development.

IBI Scores and Ranking

Oshawa Second, Bowmanville, and Lynde Creek marshes were sampled in 2002 and in 2003. Based on the resampling model and within-year minimum detectable difference, the Oshawa Second Marsh SAV community did not change significantly between years. The 2002 Lynde Creek Marsh SAV community was more than 11 IBI points lower than one 2003 sample but not the other. This suggests that the SAV community at Lynde Creek Marsh may have been marginally better in 2003 than in 2002, but because the two 2003 samples were within the minimum detectable difference, it is unlikely that there was a significant annual change in SAV community condition.

Conversely, the Bowmanville Marsh IBI estimate decreased 13 points from 2002 to 2003. According to the power analysis, this represents significant decrease in SAV community wetland condition. By inspecting the individual metric scores, it appears that this change is largely due to a decrease in overall SAV coverage in the marsh. This change coincides with general field observations.

Pumphouse Marsh had the highest SAV community IBI of the Durham Region sites. This result appeared to be driven in part by the presence of a turbidity intolerant species, slender naiad (*Najas flexilis*), and more strongly by the high overall SAV cover at the site.

Resampling SAV quadrat data within each site provided estimates of error (SD and SE) in the IBIs. Because the SD around an IBI mean could span more than one category, the status of a site is best described within the context of this error. For example, the SAV community at Wilmot Creek Marsh (Table 4.1.3-3) would be ranked as Fair-Poor, because the mean is in the fair range but the SD error bar extends into the poor range.

Table 4.1.3-3. SAV community rankings for Durham Region coastal wetlands based on error estimates of observed IBIs.

Wetland Name	SAV Community Ranking
Pumphouse Marsh	Good
Oshawa Second Marsh	Fair-Good
Cranberry Marsh	Fair
Corbett Creek Marsh	Fair
Lynde Creek Marsh	Fair-Poor
Wilmot Creek Marsh	Fair-Poor
Frenchman's Bay Marsh	Fair-Poor
Bowmanville Marsh	Poor
Duffins Creek Marsh	Poor
Hydro Marsh	Poor
McLaughlin Bay Marsh	Poor-Non existent
Carruthers Creek Marsh	Poor-Non existent
Port Newcastle Wetland	N/A
Rouge River Marsh	N/A
Westside Marsh	N/A

The strong association between disturbance rankings and IBI suggests this IBI is suitable for SAV community condition monitoring in Durham Region coastal wetlands. Although resampling indicates the minimum detectable difference between IBI scores, this should be re-examined after determining empirical within-site variation.

Future Considerations

The Lynde Creek Marsh SAV community was sampled twice in 2003. The two IBI estimates were barely within the minimum detectable difference determined through the power analysis and cannot be considered significantly different. Although replicate IBIs were expected to be closer, this variation may reveal the extent of within-site sampling error (e.g., due to turbidity, observer identification skills, observer bias). In future years, additional within-site replicates should be taken across several of the study sites to further examine this variability.

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4.2 FISH AND WILDLIFE COMMUNITY CONDITION

4.2.1 Wetland Macroinvertebrates

Objective

To assess and monitor wetland macroinvertebrate community condition.

Method Summary

Methods were based on Burton *et al.* (1999). For each wetland, three replicate sub-samples of approximately 150 aquatic macroinvertebrates were taken by sweep-netting through the water column in the cattail (*Typha* spp.) dominated emergent communities. Macroinvertebrates were identified to the lowest taxonomic group possible.

Data Analysis

Methods of determining SAV community disturbance, metric suitability, and final IBI score are similar for all biotic communities in this project and are detailed in section 3.

Selection of Metrics

Twenty-two potential metrics were tested for suitability in Lake Ontario coastal wetlands (Table 4.2.1-1). Metrics were based on those tested in Table 3 of Burton *et al.* (1999). Raw metric values tested against disturbance were means from the three samples per wetland.

Results

Metric Suitability

A summary of aquatic macroinvertebrate species found in Durham region coastal wetlands is in Appendix B (Table B-1). Of the 22 metrics evaluated (See Appendix B), 11 were retained for use in the IBI. All suitable metrics showed a highly significant response ($p<0.01$) to disturbance (Table 4.2.1-1). All retained metrics decreased with disturbance except the percent Diptera (PDIP) and Chironomidae (PCHI) as was expected.

Several of the tested metrics showed strong significant associations with disturbance but were not retained for use in the IBI. The number of Ephemeroptera (NEPH) and Trichoptera (NTRI) were not used because they were combined in the NETG metric. Percent Chironomidae (PCHI) was not used because it was the main influence on the percent Diptera (PDIP; Chironomidae is a family in the order Diptera). The number of families (NFAM) and number of genera (NGEN) appeared to be redundant so the broader taxonomic unit (PFAM) was retained.

Three additional metrics that showed marginal significance, percent Tanytarsini (PTAN), percent Sphaeriidae (PSHP) and Simpson Index (SIMP) were not retained because several other metrics showed more significant responses to disturbance (p-values of these metrics were 0.15, 0.09, and 0.15, respectively).

Table 4.2.1-1. Aquatic macroinvertebrate community metric codes, descriptions, and expected and empirical response to disturbance. For metrics used in the IBI, the linear model coefficients, intercept (A) and slope (B) for standardizing raw metric (M_R) with the upper and lower M_R limits of the standardized metrics (M_S) are shown. Correlation coefficients and p-values for all metrics are with graphs in Appendix B.

		Expected response	Metric Response		Metric coefficients		Values of M_R where	
Code	Metric Description		r	p	A	B	M_S=0	M_S=10
Richness of Measures		↓						
NCMG	No. of Crustacea* + Mollusca genera	↓	-0.66	<0.0001	0	1.08	0	9.21
NETG	No. of Ephemeroptera + Trichoptera genera	↓	-0.63	<0.0001	0	3.61	0	2.76
NEPH	No. of Ephemeroptera genera	↓	-0.44	0.02				
NODO	No. of Odonata genera	↓	-0.37	0.05	0	3.75	0	2.66
NTRI	No. of Trichoptera genera	↓	-0.62	0.0003				
NGEN	Total no. of genera	↓	-0.58	0.001				
NFAM	Total no. of families	↓	-0.59	0.001	0	0.54	0	18.31
Relative Abundances								
PAMP	% Amphipoda	↓	-0.55	0.002	0	0.19	0	53.78
PCHI	% Chironomidae	↑	0.61	0.0005				
PCRM	% Crustacea* + Mollusca	↓	-0.61	0.001	0	0.12	0	83.46
PEPH	% Ephemeroptera	↓	-0.45	0.016	0	1.25	0	7.98
PGAS	% Gastropoda	↓	-0.04	0.83				
PISO	% Isopoda	↓	-0.45	0.02	0	0.87	0	11.49
PODO	% Odonata	↓	0.11	0.56				
PSPH	% Sphaeriidae	↓	-0.32	0.09				
PTAN	% Tanytarsini	↓	-0.27	0.16				
PTRI	% Trichoptera	↓	-0.54	0.003	0	4.05	0	2.49
PDIP	% Diptera	↑	0.62	<0.001	15.7	-0.35	43.73	15.90
PCRU	% Crustacea*	↓	-0.61	0.001	0	0.16	0	59.59
Diversity Indices								
EVEN	Evenness (J')	↓	-0.11	0.57				
SHAN	Shannon index (H')	↓	-0.11	0.57				
SIMP	Simpson index (D)	↓	0.27	0.15				

*not including microcrustaceans (see Burton *et al.* 1999)

Calculating the IBI

Metrics were standardized as described in section 3.2 (Table 4.2.1-1). When the metrics were standardized and scored, wetland IBI scores (Table 4.2.1-3) were strongly associated with wetland disturbance ($r=-0.81$, $p<0.001$, $n=28$). The highest scoring Durham Region wetland was Port Newcastle Wetland, which showed the sixth highest IBI of all sites in the analysis. Wilmot Creek and Pumphouse marshes also scored relatively high compared to other Durham Region wetlands. Although some Durham Region coastal wetlands scored high aquatic macroinvertebrate IBIs, Durham sites were most frequently among the lower scoring wetlands.

Resampling Metrics

To resample aquatic macroinvertebrate community IBI metrics, mean values would be recalculated for each wetland by bootstrapping the field collected data through 100 iterations. The sample collection protocol used in this study was based on methodology developed by Burton *et al.* (1999) and required the collection of three replicate samples at *Typha* spp. stands within each wetland. However, effective bootstrap resampling requires more initial samples to estimate the variability within a wetland. If resampling were done for these wetlands, the variability would be estimated from three samples instead of 7-12 (fish) or 20-30 (SAV). The result would be a deceptively low within-site variance. As a result, aquatic macroinvertebrate data were not resampled.

However, a preliminary IBI classification with a broad range (35 IBI units) that incorporated natural breaks in the range of IBI estimates has been used to describe the condition of the aquatic macroinvertebrate communities (Figure 4.2.1-1).

Discussion

Metrics

Trichopterans (caddisflies) are known to be sensitive to disturbance (Resh and Jackson 1993). This is demonstrated by the abundance of low and zero PTRI scores for many of the sites. Additionally, sites that scored well in this metric had high overall IBI scores.

The percent of Diptera metric (PDIP) was the only raw metric used in the IBI that showed an increase with disturbance. This was expected because, in general, Diptera tolerate a large range of environmental conditions (Merritt and Cummins 1996).

The raw metric, percent Chironomidae (PCHI), also showed a significant increase with disturbance but was not used in the IBI formulation. Chironomidae is a family in the order Diptera and, after closer inspection of the data, it was clear that the percent Diptera (PDIP) was driven by the number of Chironomidae in the sample. The advantage of retaining PDIP as a metric and not PCHI lies in the sample classification step. Identifying aquatic macroinvertebrate samples is very time consuming and if individuals of Diptera only need to be identified to Order and not family, time is saved.

Burton *et al.* (1999) developed a preliminary aquatic macroinvertebrate IBI for Lake Huron coastal wetlands. They developed the IBI within four vegetation zones: wet meadow, *Typha* stands, inner *Scirpus*, and outer *Scirpus.* The IBI developed in this project only considered the *Typha* vegetation zone. This is because sufficient *Scirpus* stands and meadow marsh areas do not exist in most Durham Region coastal wetlands.

Furthermore, wet meadows were generally not flooded, which made sweep net sampling impossible.

Within the *Typha* stands Burton *et al.* (1999) retained seven of the metrics described in Table 4.2.1-1. Their criteria for retaining metrics for IBI were not based on the linear regression response of the metric to disturbance as in this study. Instead, two groups of Lake Huron sites were examined; impacted (Saginaw Bay sites) and less impacted (northern Lake Huron sites). Impacted sites had heavy agricultural, urban, and industrial land-uses whereas the less impacted sites had catchments that were primarily forested. Metrics that showed clear differences between impacted and less impacted sites were deemed suitable for the IBI.

The response of metrics to disturbance was consistent between studies except for the percent amphipods. Burton *et al.* (1999) found that the proportion of amphipods increased (Table 4.2.1-2) at more disturbed sites whereas this study found a significant decrease (r=-0.55, p=0.002). The reasons for this discrepancy are not clear and require further investigation.

Table 4.2.1-2. Comparison of metric responses used by Burton *et al.* (1999).

		Response to Disturbance	
Code	**Metric**	**DRCWMP**	**Burton *et al.* (1999)**
NODO	No. of Odonata genera	↓	↓
PODO	% Odonata	↓*	↓
NCMG	No. of Crustacea + Mollusca genera	↓	↓
NGEN	Total no. of genera	↓**	↓
PGAS	% Gastropoda	↓*	↓
PSPH	% Sphaeriidae	↓**	↓
PAMP	% Amphipoda	↓	↑

* No significant relationship between metric and disturbance
** Significant relationship between metric and disturbance but not used (see text)

Table 4.2.1-3. Standardized aquatic macroinvertebrate community metrics and IBIs for Lake Ontario coastal wetlands. Sites in bold indicate Durham Region sites.

Site	NCMG	NETG	NODO	NFAM	PAMP	PCRM	PEPH	PISO	PTRI	PDIP	PCRU	IBI
Hay Bay South	9.76	10	10	10	9.89	8.90	3.79	1.87	10	10	9.28	84.9
Robinson's Cove	10	7.23	8.75	7.28	9.02	10	1.97	10	7.49	10	10	83.4
Little Cataraqui Creek	7.96	10	8.75	8.19	8.75	7.96	6.86	4.10	9.89	10	8.69	82.8
Hay Bay North	9.40	8.43	7.50	9.65	10	8.42	5.85	1.33	7.52	10	9.32	79.4
Bayfield Bay	6.15	4.82	3.75	5.64	10	9.28	9.90	5.27	9.08	10	10	76.2
Port Newcastle Wetland	**8.32**	**6.02**	**8.75**	**8.01**	**4.78**	**6.53**	**3.29**	**8.61**	**7.64**	**6.29**	**5.97**	**67.4**
South Bay	10	8.43	2.50	7.83	4.23	10	1.65	4.16	10	10	4.62	66.7
Presqu'ile Bay	7.96	4.82	5.00	9.10	3.70	6.29	10	7.72	2.14	10	4.83	65.0
Wilmot Creek Marsh	**6.51**	**2.41**	**5.00**	**8.19**	**7.85**	**7.52**	**2.85**	**10**	**0**	**9.26**	**9.60**	**62.9**
Parrott's Bay	6.87	4.82	8.75	9.10	8.04	7.67	4.44	0.63	1.69	9.69	7.37	62.7
Pumphouse Marsh	**8.68**	**3.61**	**6.25**	**9.65**	**9.06**	**7.87**	**1.80**	**0.51**	**0**	**10**	**8.28**	**59.7**
Huyck's Bay	7.59	1.20	6.25	7.28	9.92	9.58	0.30	0.41	0	10	9.03	55.9
Button Bay	9.04	1.08	1.25	7.46	9.73	9.27	0	0.95	0.85	10	8.96	53.2
Corbett Creek Marsh	**6.51**	**2.41**	**10**	**9.46**	**7.33**	**5.69**	**1.21**	**4.16**	**0**	**3.87**	**6.61**	**52.0**
Big Sand Bay	8.32	4.82	0	10	3.75	5.50	4.29	1.96	0.87	10	3.76	48.4
Port Britain	4.70	0	10	8.92	6.53	4.81	0	2.07	0	6.09	6.29	44.9
Westside Beach Marsh	**4.70**	**1.20**	**3.75**	**6.37**	**6.97**	**5.14**	**2.56**	**1.90**	**0**	**9.33**	**6.65**	**44.1**
Rouge River Marsh	**6.15**	**8.43**	**5.00**	**8.55**	**0.38**	**2.09**	**10**	**0**	**4.01**	**1.22**	**0.38**	**42.0**
Oshawa Second Marsh	**5.79**	**1.20**	**2.50**	**8.19**	**3.41**	**9.22**	**0**	**0.41**	**1.03**	**10**	**3.16**	**40.8**
McLaughlin Bay Marsh	**5.06**	**2.41**	**2.50**	**4.37**	**3.45**	**4.75**	**5.31**	**0**	**3.81**	**10**	**3.11**	**40.6**
Carruthers Creek Marsh	**6.87**	**1.20**	**3.75**	**7.64**	**5.08**	**5.99**	**1.23**	**0.93**	**0**	**7.38**	**4.58**	**40.6**
Cranberry Marsh	**4.70**	**0**	**5.00**	**5.82**	**5.43**	**7.72**	**0**	**0**	**0**	**10**	**4.90**	**39.6**
Jordan Station	4.34	3.61	5.00	4.91	3.38	4.01	1.17	0	2.94	1.91	3.05	31.2
Lynde Creek Marsh	**7.59**	**0**	**5.00**	**7.10**	**3.32**	**3.53**	**0**	**0.41**	**0**	**2.23**	**3.08**	**29.3**
Bowmanville Marsh	**6.15**	**1.20**	**2.50**	**7.28**	**1.43**	**2.04**	**2.85**	**0.25**	**0**	**3.93**	**1.34**	**26.3**
Frenchman's Bay	**3.25**	**1.20**	**0**	**4.37**	**3.71**	**4.43**	**0.45**	**0**	**0**	**4.99**	**3.35**	**23.4**
Duffins Creek Marsh	**4.70**	**1.20**	**1.25**	**5.46**	**1.49**	**3.96**	**1.06**	**0.24**	**0**	**0**	**1.39**	**18.8**
Hydro Marsh	**3.98**	**0**	**1.25**	**4.91**	**0.51**	**1.29**	**1.05**	**0**	**0**	**0**	**0.46**	**12.2**

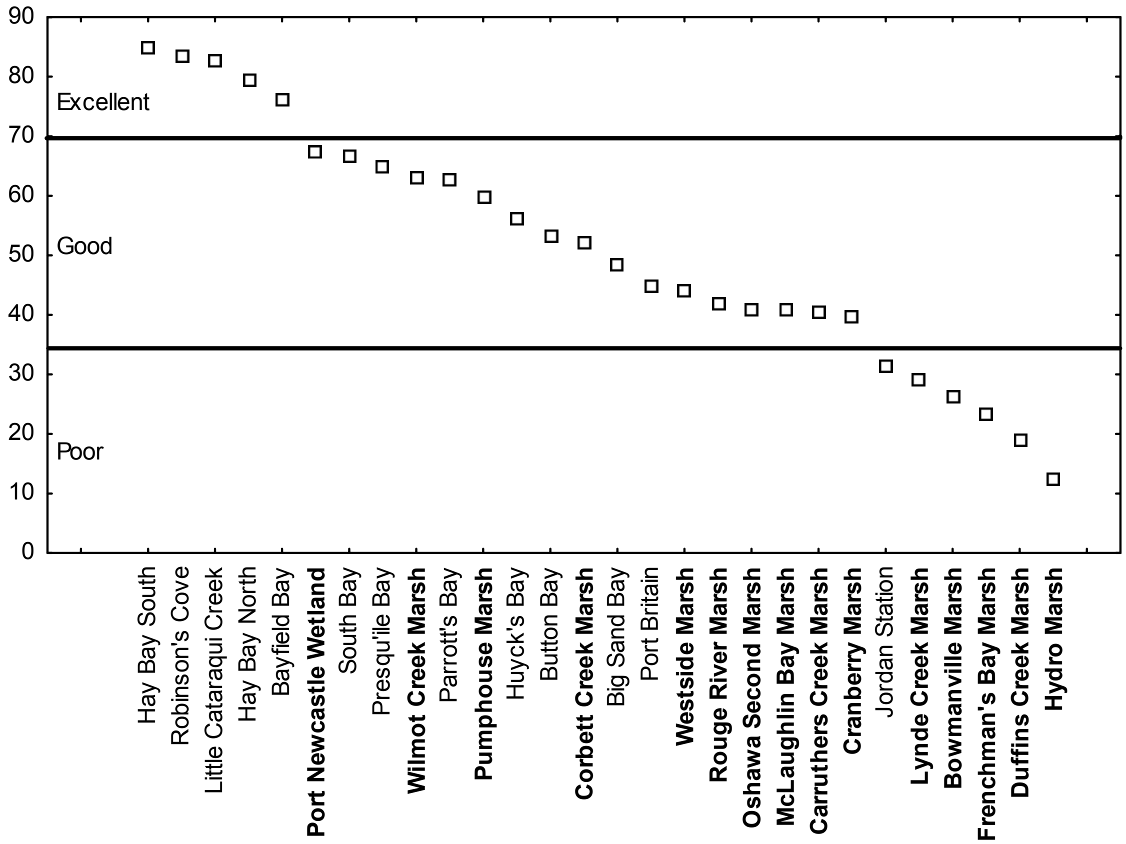

Figure 4.2.1-1. Plot of IBIs for Durham Region (bold) and other Lake Ontario coastal wetlands showing three IBI category rankings.

Similarly, the identification of suitable metrics also identifies the taxonomic resolution required for IBI calculation. If the macroinvertebrate identifier is aware of the specific taxonomic groups that require identification, much time can be saved by focusing on taxa relevant to the IBI. This may allow additional samples to be processed at the same cost, thus increasing the sample size.

IBI Scores and Ranking

The strong association between the aquatic macroinvertebrate IBI and disturbance indicates that the IBI is a good tool for describing aquatic macroinvertebrate community condition in Durham Region coastal wetlands. At this time, an estimate of the difference in IBI that represents a significant difference in community condition is not available.

For the purposes of this report a broad IBI classification has been created. In this classification, the condition of the aquatic macroinvertebrate community is more definitive (no error) and assumed to be accurate due to the strong relationship between IBI and community disturbance (Table 4.2.1-4).

Table 4.2.1-4. Macroinvertebrate community condition rankings for Durham Region coastal wetlands based on comparisons with other Lake Ontario wetlands.

Wetland Name	Aquatic Macroinvertebrate Community Ranking
Port Newcastle Wetland	Good
Wilmot Creek Marsh	Good
Pumphouse Marsh	Good
Corbett Creek Marsh	Good
Westside Marsh	Good
Rouge River Marsh	Good
Oshawa Second Marsh	Good
McLaughlin Bay Marsh	Good
Carruthers Creek Marsh	Good
Cranberry Marsh	Good
Lynde Creek Marsh	Poor
Bowmanville Marsh	Poor
Frenchman's Bay Marsh	Poor
Duffins Creek Marsh	Poor
Hydro Marsh	Poor

Future Considerations

At present, there is no means to provide error estimates for the calculated IBI. For future monitoring, it is recommended that at least six replicate samples per wetland be collected and analyzed. The variance among site-specific samples may then be used to better classify aquatic macroinvertebrate condition in Durham Region coastal wetlands.

Literature Cited

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Merritt, R.W. and K. W. Cummins (Eds.). 1996. An Introduction to the Aquatic Insects of North America, Third Edition. Kendall/Hunt, Dubuque, IA, USA.

Resh, V.H., and J.K. Jackson. 1993. Rapid Assessment approaches to biomonitoring using benthic macroinvertebrates. In: Rosenberg, D.M. and V.H. Resh (Eds.), Freshwater Biomonitoring and benthic Macroinvertebrates. Chapman and Hall, London, pp. 195-223.

4.2.2 Fish Sampling

Objective

To assess and monitor fish community condition.

Method Summary

Fish were captured by electrofishing six points along 44-m transects, which were stratified by habitat types (i.e., emergent marsh, submerged aquatic vegetation, open water) within each wetland. Fork length and weight measurements were taken on all fish. When large numbers of conspecific fish were captured, 10 randomly chosen individuals in each of two age classes (i.e., young-of-year and juvenile/adult) were weighed and measured; then the remainder of each cohort was counted and batch weighed. Sampling occurred during August.

Fish sampling was completed at all Durham Region coastal wetlands in 2002 or 2003, except Cranberry and Westside marshes. Cranberry Marsh was not sampled because the electrofishing boat could not be launched due to low water levels. Ten minnow traps were set in the marsh in a 24-hour set, but no minnows were caught.

Westside Marsh was not sampled because the site was not accessible due to quarry expansion and large-scale restoration. In addition, two other Lake Ontario wetlands, Parrott's Bay and Huyck's Bay, were sampled. These wetlands were chosen using two criteria: 1) the sites are expected to be less disturbed and thus provide data regarding healthier fish communities; and 2) the sites were of similar geomorphic type as the barrier beach and drowned river-mouth coastal wetlands of the Durham Region.

Data Analysis

Methods of determining fish community disturbance, metric suitability, and final IBI score are similar for all biotic communities in this project and are detailed in section 3.

Relative disturbances experienced by fish communities (Table 3.1-3; Matrix A) are represented by the site level PC-1. Note that relative disturbances do not appear for Rouge River Marsh, Port of Newcastle Wetland, and Pumphouse Marsh because sufficient data were not available for habitat quality analysis. Although these sites were not included in the metric suitability analysis, fish sampling did occur at these sites and IBIs for the fish community at these sites were calculated.

Selection of Metrics

Thirteen metrics were tested for suitability in Durham Region coastal wetlands and two other Lake Ontario coastal wetlands (Table 4.2.2-1). Twelve of these metrics were used in an IBI designed for Great Lakes littoral habitats (Minns *et al.* 1994); the thirteenth metric (BYPE) was suggested for use by Tÿs Theÿsmeÿer, Royal Botanical Gardens (pers. comm. 2003).

Raw metric values that were tested against disturbance were site means with a transect as the sampling unit. Before the suitability of a metric was determined, the relationship between metric values and marsh size, number of transects and number of habitats sampled was examined. If there was a relationship between metric values and any of

Table 4.2.2-1. Fish community metric codes, descriptions, and expected and empirical response to disturbance. For metrics used in the IBI, the linear model coefficients, intercept (A) and slope (B) for standardizing raw metric (M_R) with the upper and lower M_R limits of the standardized metrics (M_S) are shown. Correlation coefficients and p-values for all metrics are with graphs in Appendix C.

		Expected Response	Metric Response		Metric coefficients		Values of M_R where	
Code	Metric Description		r	p	A	B	M_S=0	M_S=10
Species richness								
SNAT	Number of native species	↓	-0.56	0.07	0	2.39	0	4.17
SCEN	Number of centrarchid species	↓	-0.69	0.02	0	7.36	0	1.35
SINT	Number of turbidity-intolerant species	↓	0.25	0.45				
SNIN	Number of non-indigenous species *	↑	0.13	0.70				
SCYP	Number of native cyprinid species *	↓	0.39	0.24				
Trophic structure								
PPIS	% piscivore biomass	↓	-0.42	0.19	0	0.70	0	14.33
PGEN	% generalist biomass	↑	0.33	0.32				
PSPE	% specialist biomass	↓	-0.14	0.67				
Abundance and condition								
NNAT	Number of native individuals *	↓	-0.70	0.02	0	0.27	0	21.7 **
BNAT	Biomass of native fish	↓	-0.34	0.31				
PNNI	% non-indigenous numbers	↑	0.30	0.38				
PBNI	% non-indigenous biomass *	↑	0.52	0.09	10	-0.32	30.6	0
BYPE	Biomass (g) of yellow perch	↓	-0.72	0.01	0	0.18	0	57.06

* Metric was corrected for site-specific interaction.
** Upper values from Pumphouse Marsh were not considered because extremely high number of native cyprinids skewed results.

these variables, the metrics were corrected for the interaction of the variable (i.e., residual metric values were assessed against disturbance).

Results

Metric Suitability

Four metrics had moderate or strong relationships with site-specific variables. SCYP and NNAT had marginally significant relationships with the number of transects sampled per wetland (n=11, r=0.51, p=0.07), and marsh size (n=11, r=0.47, p=0.10), respectively. SNIN and PBNI had strong significant relationships with the number of habitat types sampled at the wetland (SNIN: n=11, r=0.62, p=0.02; PBNI: n=11, r=0.76, p=0.02). These interactions were corrected by plotting the residual values of the metric: site-specific variable interaction against disturbance.

Of the 13 metrics evaluated (see Appendix C), six were retained for use in the IBI. Three metrics showed a significant response (p<0.05) and three showed moderate responses (p<0.20) to disturbance (Table 4.2.2-1). The remaining metrics that were tested, except SCYP, showed weak but expected (positive or negative) trends against disturbance.

Calculating the IBI

Metrics were standardized as described in section 3.2 (Table 4.2.2-1). Although all the metrics did not respond significantly (p<0.05) to wetland disturbance, when the metrics were standardized and integrated, wetland IBIs (Table 4.2.2-2) were strongly associated with wetland disturbance (n=11, r=-0.72, p=0.01).

Table 4.2.2-2. Standardized metrics and IBIs for Durham Region coastal wetlands and two additional (bold) Lake Ontario coastal wetlands.

Wetland Name	SNAT	SCEN	PPIS	NNAT	PBNI	BYPE	IBI
Parrott's Bay	**10**	**10**	**7.05**	**8.56**	**9.13**	**10**	**91.2**
Huyck's Bay	**8.77**	**9.82**	**8.20**	**6.96**	**10**	**3.41**	**78.6**
Wilmot Creek Marsh	6.65	4.91	10	3.99	6.50	4.26	60.5
Frenchman's Bay Marsh	5.87	8.04	8.40	5.15	0.67	0.81	48.2
Bowmanville Marsh	4.79	4.30	0	2.84	9.95	5.85	46.2
Lynde Creek Marsh	4.79	4.69	3.91	4.94	8.12	0	44.0
Oshawa Second Marsh	4.44	0	0	10	3.94	7.97	43.9
McLaughlin Bay Marsh	3.76	6.32	0	2.70	6.36	2.37	35.8
Rouge River Marsh	5.26	3.68	0	4.33	6.52	0.90	34.5
Carruthers Creek Marsh	4.79	5.73	0	4.66	4.34	0	32.5
Corbett Creek Marsh	3.29	3.68	0	2.07	8.02	0	28.4
Duffins Creek Marsh	7.45	4.09	0	3.58	1.20	0.60	28.2
Port Newcastle Wetland	2.66	4.09	0	1.64	6.38	2.12	28.1
Pumphouse Marsh	5.98	0	0	10	0	0	26.6
Hydro Marsh	2.79	2.46	0	3.80	2.74	0	19.6
Cranberry Marsh	-	-	-	-	-	-	See text
Westside Marsh	-	-	-	-	-	-	See text

The two non-Durham wetlands scored the highest IBIs. The highest scoring Durham Region wetland was Wilmot Creek Marsh at 60.5. This marsh was also the only marsh to receive a 10 in the PPIS metric. Frenchman's Bay and Bowmanville marshes scored the next highest at 48.2 and 46.2 out of 100, respectively. The remainder of the wetlands scored quite low compared to the non-Durham wetlands.

Resampling Metrics

Resampling of fish community IBI metrics consisted of recalculating the mean metric values for each wetland by bootstrapping the field-collected data through 100 iterations (Figure 4.2.2-1) to yield estimates of error around the means. In all cases, bootstrapped means were very close to empirical IBI values.

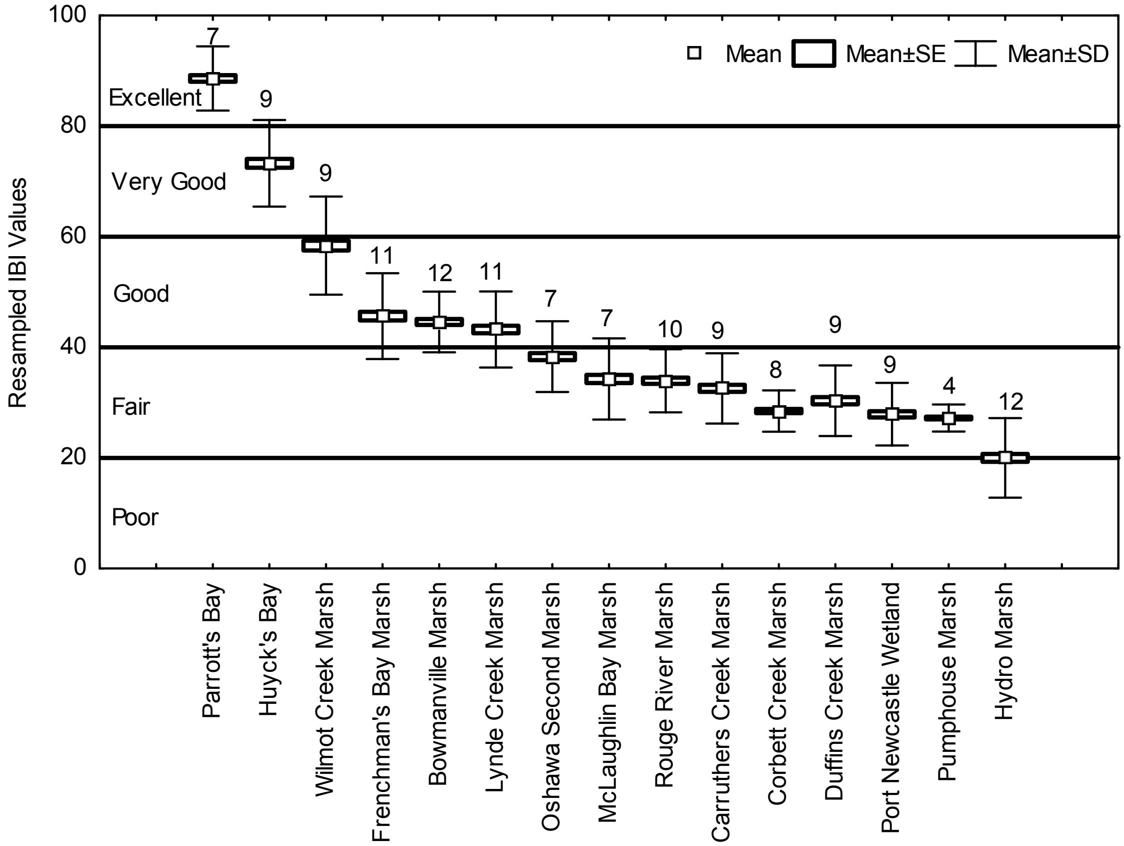

Figure 4.2.2-1. Box and whisker plots of the resampled IBIs for each site showing five separate IBI category rankings. Number of transects sampled per site are located above each box and whisker plot.

IBI classes were established by the method described by Fore *et al.* (1994). A power curve was constructed by determining the power of all pairwise (n=105) comparisons in theoretical three sample t-tests ($\propto = 0.05$). The power of each test was then plotted against the difference between means (Figure 4.2.2-2). At the statistical standard of 80 percent power, the minimum detectible difference in IBI means is 20 IBI units. Taking the range of IBIs (Table 4.2.2-2) and dividing it by the minimum detectable difference [(91-20)÷20] equals 3.55. This means that the range of IBIs can be split into three classes (fair, good, very good). Note that additional classes (poor and excellent) have been added outside of the divided range. With this classification, the majority of Durham

Region coastal wetlands had means in the fair category while four sites were in the good category.

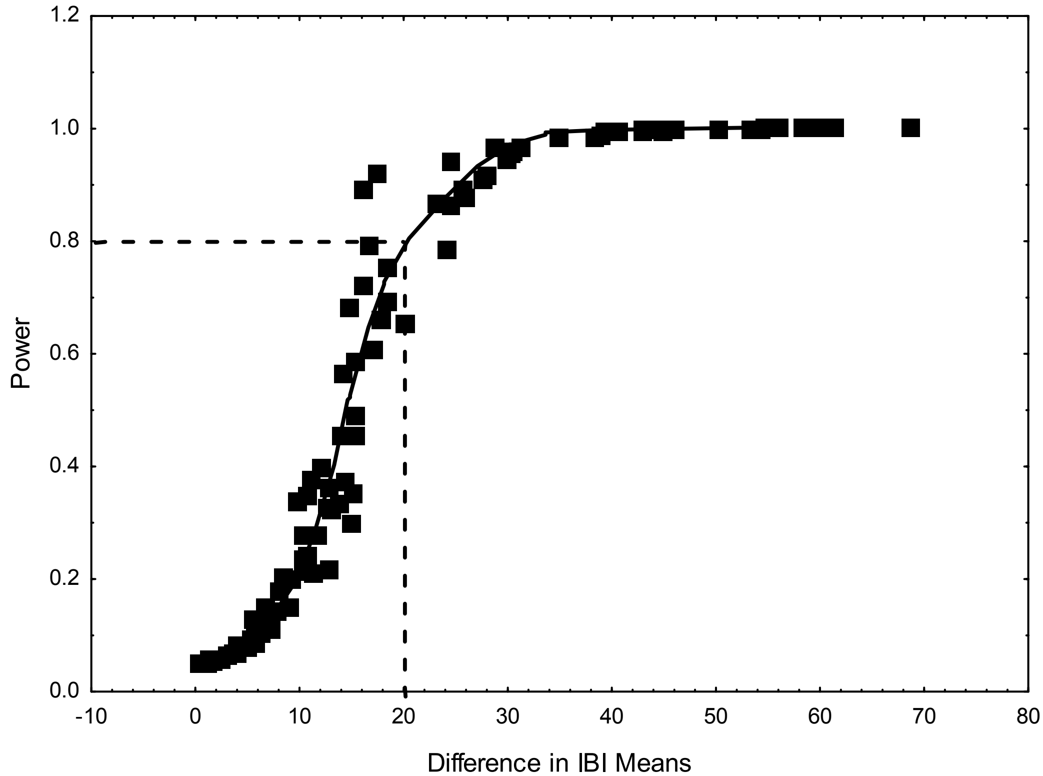

Figure 4.2.2-2. Power curve for IBIs estimated at 15 locations sampled three times. All points shown are for ∝ = 0.05.

Discussion

Metrics

Highly disturbed sites generally scored low on the percent piscivore biomass (PPIS), indicating that these sites lack healthy piscivore communities. In addition, disturbed sites often had low biomass of yellow perch (BYPE) scores, although the two metrics were not significantly associated (n=11, r=0.34, p=0.23).

Oshawa Second and Pumphouse marshes were the only wetlands to score 10 on the number of native individuals (NNAT). These were also the only two sites that scored zero on the PPIS metric. Although the data do not support an explanation for this fact, the lack of centrarchids and the abundance of native minnows (mainly cyprinids) occurs at the two sites that were isolated from Lake Ontario for an extended period of time. Pumphouse Marsh has a permanent barrier closing it off from the lake and Oshawa Second Marsh (sampled in 2002) has a fishway between the marsh and creek to facilitate fish passage of desirable species and to exclude large carp. Although the fishway was installed in 2001, it was not operational in 2002 which isolated the marsh from Farewell Creek and Lake Ontario.

Similarly, Cranberry Marsh is generally isolated from the lake. Electrofishing could not be completed in this wetland and minnow traps did not yield a catch, but many cyprinids were observed in the wetland (I. Kelsey, CLOCA, pers. comm.). The fish assemblage at these wetlands would likely be different if a more frequent direct connection to the lake existed. These results also call into question the suitability of wetlands with a very limited hydrological connection (mainly seepage) with Lake Ontario to be considered as coastal wetlands in the context of fish habitat.

IBI Scores and Ranking

The strong, significant association between IBIs and the statistically-derived disturbance ranking indicates that the index is suitable for use in describing fish communities in Lake Ontario coastal wetlands. This relationship was also observed by Hughes *et al.* (1998) for IBI development for stream fish communities. In addition, as expected, the non-Durham Region wetlands scored high IBIs compared to Durham Region coastal wetlands.

Using less impacted non-Durham Region wetlands provides a good indication of the state of Durham Region coastal wetlands. These comparisons provide an empirically-based tool for monitoring the effectiveness of restoration and rehabilitation activities. Furthermore, the PC-1 values of the variable score plot (Table 3.1-3; Matrix A) provide insight into what habitat variables are most important for healthy Lake Ontario coastal wetland fish communities (i.e., high total SAV cover and low turbidity, total phosphorus, and ammonium).

Statistically resampling fish transect data within each site provided estimates of error (SD and SE) in the IBIs. Because the error around an IBI mean could span more than one category, the status of a site is best described within the context of this error. For example, the fish community at Oshawa Second Marsh (Table 4.2.2-3) would be described as Fair-Good, because the mean is in the fair range but the SD error bar extends into the good range.

Table 4.2.2-3 Fish community condition rankings for Durham Region coastal wetlands based on error estimates of observed IBIs.

Wetland Name	Fish Community Ranking
Wilmot Creek Marsh	Good-Very Good
Frenchman's Bay Marsh	Fair-Good
Bowmanville Marsh	Fair-Good
Lynde Creek Marsh	Fair-Good
Oshawa Second Marsh	Fair-Good
McLaughlin Bay Marsh	Fair-Good
Rouge River Marsh	Fair-Good
Carruthers Creek Marsh	Fair
Corbett Creek Marsh	Fair
Duffins Creek Marsh	Fair
Port Newcastle Wetland	Fair
Pumphouse Marsh	Fair
Hydro Marsh	Fair-Poor
Cranberry Marsh	N/A
Westside Marsh	N/A

Future Considerations

Overall, the fish community IBI appears to reflect the true status of fish communities in Durham Region coastal wetlands as indicated by the strong association between habitat disturbance and IBI. Although marsh size, available habitat types, and sampling effort were accounted for in this report, other impacts such as overall watershed land-use, watershed size and stream inlet presence/absence should be examined and incorporated into the IBI, if necessary.

Although statistically-based error estimates were generated in this report, field-based error measurements should also be calculated. For future monitoring, a subset of Durham Region sites should be resampled within the sampling window so that within-site variance can be calculated.

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4.2.3 Breeding Bird Community Condition

Objective

To assess and monitor marsh breeding bird community condition.

Method Summary

The Marsh Monitoring Program (MMP), administered by Bird Studies Canada (BSC), was used to survey bird communities within various Durham Region coastal wetlands. Although the data for some sites span several years, this report focuses on the current condition (2002-2003) of the breeding bird communities. Data were collected by volunteers and, in the absence of volunteers, conservation authority and Environment Canada – Ontario Region (EC-OR) staff. The goal was to survey all Durham Region project sites in 2002 and/or 2003.

Carruthers Creek, Pumphouse, McLaughlin Bay and Port Newcastle marshes were not sampled in either year. Although the wetland associated with Carruthers Creek is large (141 ha), the wetland consists mostly of swamp. The marsh portion of the wetland is too small to fit the MMP methodology requirements and cannot be sampled. In contrast, Pumphouse, McLaughlin Bay and Port Newcastle marshes were to be sampled by volunteers, but the data were not collected or not submitted.

Data Analysis

Methods for determining breeding bird community disturbance, metric suitability, and final IBI score are similar for all biotic communities in this project and are detailed in section 3.

Selection of Metrics

To date, few quantitative metrics suitable for describing bird community condition have been developed. The MMP has identified a list of bird species that are indicators of high quality marsh habitat (Table 4.2.3.-1). This list was used as a starting point to identify specific guilds of marsh bird species for use as metrics. In general, the list identifies species that are marsh-nesting obligates.

Other guilds of species that may respond to disturbance in Lake Ontario coastal wetlands are:

- Area-sensitive nesters – require minimum area of suitable marsh habitat for nesting;
- Marsh users – often use marshes for feeding, breeding activities, and cover but may also use other upland or open water habitat (e.g., Red-winged Blackbirds, gulls, most waterfowl); and
- All users – any bird species that was seen in the wetland, including incidental visitors and fly-throughs.

In all, eight breeding bird community metrics were tested for suitability in Lake Ontario coastal wetlands (Table 4.2.3-2). A list of marsh-nesting obligates, marsh users and upland/generalists was compiled using all species recorded for MMP surveys in Durham Region and other Lake Ontario coastal wetlands (see Appendix D). The species guild identification for marsh users and marsh-nesting obligates was performed through EC-OR staff using *The Birds of North America* (Poole and Gill 1992-ongoing) series as a primary reference. Marsh area-sensitive species were identified by Naugle *et al.* (2000; Black Tern), Riffle *et al.* (2001; American Bittern, Virginia Rail, Sora, Swamp Sparrow) and Brown and Dinsmore (1986; Black Tern, Swamp Sparrow, Pied-billed Grebe, and Least Bittern).

Table 4.2.3-1. Bird species that are indicators of high quality marsh habitat as identified by the Marsh Monitoring Program.

Common Name	Latin Name	Species Code
Least Bittern	*Ixobrychus exilis*	LEBI
Black Tern	*Chlidonias niger*	BLTE
Virginia Rail	*Rallus limicola*	VIRA
Sora	*Porzana carolina*	SORA
Marsh Wren	*Cistothorus palustris*	MAWR
Pied-billed Grebe	*Podilymbus podiceps*	PBGR
American Bittern	*Botaurus lentiginosus*	AMBI
Blue-winged Teal	*Anas discors*	BWTE
American Coot	*Fulica americana*	AMCO
Common Moorhen	*Gallinula chloropus*	COMO
Common Snipe	*Gallinago gallinago*	COSN
Common Moorhen/American Coot *	*Gallinula chloropus/Fulica americana*	MOOT

* Differentiating the calls of the American Coot and Common Moorhen can be difficult, hence the combined code (MOOT).

Species richness and abundance estimates were calculated using the maximum value between the two site visits. Raw metric values tested against disturbance were site means (i.e., survey station was the sampling unit) for sites surveyed in 2002. The IBI model was developed with 2002 data because more sites were surveyed in that year, thus increasing the ability to detect associations between disturbance and breeding bird community metrics.

Before the suitability of a metric was determined, the relationship between metric values and marsh size, and number of stations sampled per wetland was examined.

Results

Metric Suitability

Although Timmermans and Craigie (2003) found effects of site size and effort on overall bird species richness and abundance metrics in Lake Erie coastal wetlands (Long Point), these effects were not observed in the current data which use site means.

Of the eight metrics evaluated (see Appendix D), four were retained for use in the IBI. Two metrics showed a significant response ($p<0.05$), one showed a moderately significant response ($p=0.06$), and one showed a marginally significant response ($p<0.20$) to disturbance (Table 4.2.3-2). The remaining metrics that were tested showed weak but expected trends against disturbance.

Table 4.2.3-2. Marsh breeding bird community metric codes, descriptions, and expected and empirical response to disturbance. For metrics used in the IBI, the linear model coefficients, intercept (A) and slope (B) for standardizing raw metric (M_R) with the upper and lower M_R limits of the standardized metrics (M_S) are shown. Correlation coefficients and p-values for all metrics are with graphs in Appendix D.

Code	Metric Description	Expected Response	Metric Response		Metric coefficients		Values of M_R where	
			r	p	A	B	M_S=0	M_S=10
Species richness								
SMNO	Marsh-nesting obligate species richness	↓	-0.12	0.63				
SMUS	Marsh-user species richness	↓	0.31	0.23				
SMAS	Marsh area-sensitive species richness	↓	-0.47	0.056	0	5	0	2
STOT	Total species richness	↓	0.05	0.84				
Abundance								
PMNO	Relative % marsh-nesting obligates	↓	-0.38	0.130	0	0.29	0	34.8
PMUS	Relative % marsh-users	↓	-0.57	0.016	0	0.11	0	87.5
PMAS	Relative % marsh area-sensitive	↓	-0.54	0.025	0	0.48	0	20.6
PTOT	Total abundance	↓	0.10	0.69				

Calculating the IBI

Metrics were standardized as described in section 3.2. When the metrics from 2002 were standardized and integrated, wetland IBIs (Table 4.2.3-3) were significantly associated with wetland disturbance (r=-0.64, p=0.01, n=17). To further validate the IBI response to disturbance, IBIs for 2003 were plotted against disturbance. Despite only having data from a few sites, the relationship was significant and strong (r=-0.89, p=0.01, n=6).

Marsh breeding bird community IBIs showed a large range 11.21-89.22. Westside Marsh consistently scored the highest IBIs and was also one of two sites to score a 10 in the area-sensitive species richness (SMAS) metric. Other Durham Region sites that scored well were Wilmot Creek, Oshawa Second and Cranberry marshes.

Table 4.2.3-3. Standardized breeding bird community metrics and IBIs for Durham Region coastal wetlands (bold) and other Lake Ontario coastal wetlands.

Wetland Name	SMAS	PMNO	PMUS	PMAS	IBI
Westside Marsh (2002)	**10**	**10**	**6.70**	**8.99**	**89.2**
Westside Marsh (2003)	**10**	**9.32**	**5.86**	**9.49**	**86.6**
Parrott's Bay (2002)	7.50	5.98	10	8.57	80.1
Button Bay (2002)	7.50	8.11	9.60	6.81	80.0
Wilmot Creek Marsh (2003)	**5.00**	**6.79**	**9.61**	**10**	**78.5**
Oshawa Second Marsh (2003) *	**5.83**	**7.45**	**7.70**	**10**	**77.4**
Huyck's Bay (2002)	10	5.64	7.29	6.96	74.7
Cranberry Marsh (2003) *	**5.71**	**10**	**8.22**	**4.92**	**72.1**
Bayfield Bay 2002	8.33	7.78	7.30	4.66	70.1
Oshawa Second Marsh (2002) *	**6.67**	**6.59**	**4.90**	**7.96**	**65.2**
Robinson's Cove (2002)	5.00	4.88	7.17	8.23	63.1
Hay Bay South (2002)	5.00	4.21	7.92	7.09	60.5
Port Newcastle (2003)	**5.00**	**3.38**	**9.41**	**5.69**	**58.7**
Lynde Creek Marsh (2002) *	**5.00**	**4.15**	**9.30**	**4.73**	**57.9**
Corbett Creek Marsh (2002)	**5.00**	**4.31**	**7.55**	**5.06**	**54.7**
Presqu'ile Bay (2002) *	3.57	3.34	10	3.71	51.5
Cranberry Marsh (2002) *	**5.71**	**5.46**	**6.07**	**2.52**	**49.4**
South Bay (2002)	5.00	2.81	5.26	3.84	42.2
Port Britain (2002)	5.00	1.99	7.01	2.69	41.7
Bowmanville Marsh (2003) *	**2.50**	**1.44**	**9.91**	**2.42**	**40.6**
Lynde Creek Marsh (2003) *	**1.82**	**1.86**	**8.80**	**2.35**	**37.0**
Bowmanville Marsh (2002) *	**4.17**	**2.55**	**2.05**	**4.30**	**32.7**
Wilmot Creek Marsh (2002)	**5.00**	**2.26**	**2.65**	**1.31**	**28.0**
Rouge River (2003)	**0**	**0**	**8.11**	**0**	**20.2**
Duffins Creek Marsh (2003)	**2.50**	**0.83**	**2.62**	**1.40**	**18.3**
Hydro Marsh (2002)	**0**	**0.96**	**4.69**	**0**	**14.1**
Robinson's Cove (2003)	0	0	4.71	0	11.7
Frenchman's Bay Marsh (2002)	**0**	**1.44**	**3.05**	**0**	**11.2**

* - indicates sites used for statistical resampling

Resampling Metrics

Resampling of marsh breeding bird community IBI metrics consisted of recalculating the mean metric values for selected wetlands (see Table 4.2.3-3) by bootstrapping the field-collected data through 100 iterations (Figure 4.2.3-1). These sites were chosen because they had five or more replicates (survey stations) per route, thus providing a more accurate estimate of error.

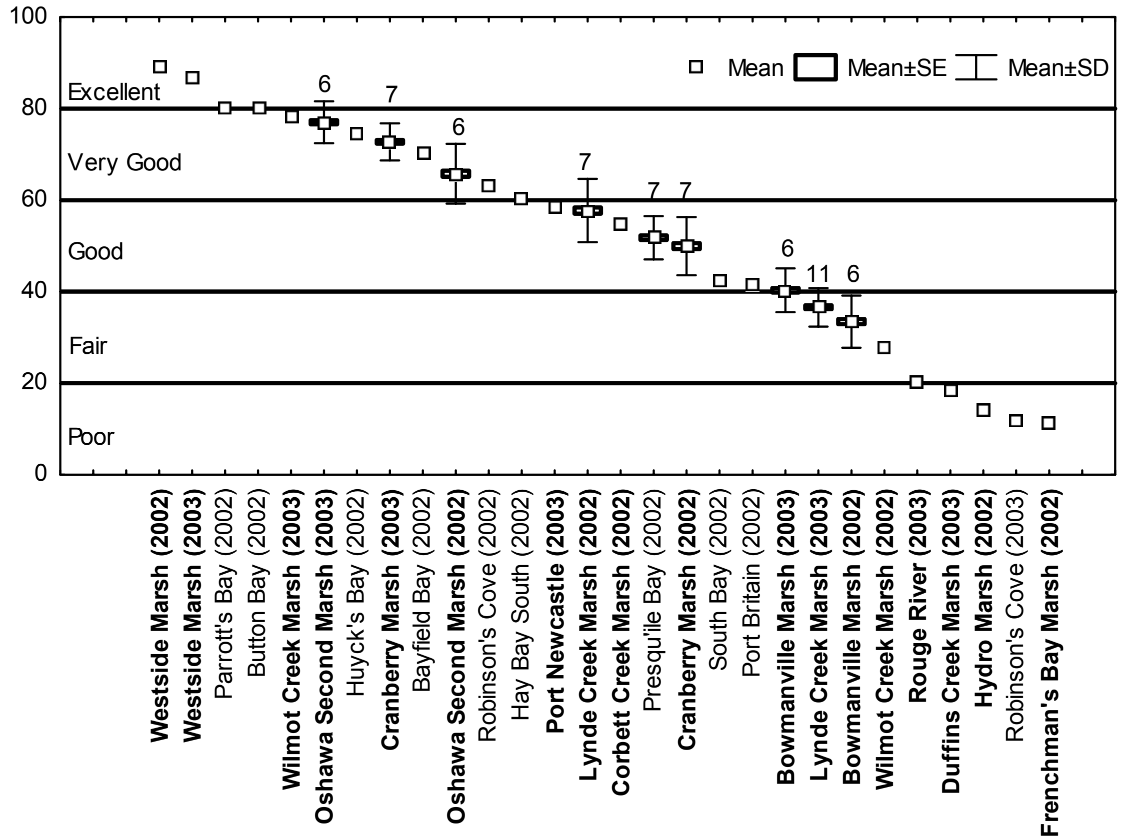

Figure 4.2.3-1. Box and whisker plots of the resampled marsh breeding bird IBIs for selected sites showing five separate IBI category rankings. Empirical IBI scores for all other sites (box only) are also shown for comparison. Number of stations sampled per site is located above each box and whisker plot.

IBI classes were established by the method described by Fore *et al.* (1994). A power curve was constructed by determining the power of all pairwise (n=36) comparisons in theoretical three sample t-tests ($\propto$ = 0.05). The power of each test was then plotted against the difference between means (Figure 4.2.3-2). At the statistical standard of 80 percent power, the minimum detectible difference in IBI means is 17 IBI units. Taking the range of IBIs (Table 4.2.3-3) and dividing it by the minimum detectable difference [(89-11)÷17] equals 4.5, which means that the range of IBIs can be split into five classes (poor, fair, good, very good, and excellent). With this classification, Durham Region coastal wetland breeding bird communities occupy the full range of categories.

Discussion

Metrics

Marsh area-sensitive metrics (SMAS and PMAS) respond to disturbance but not total wetland size. Although the lack of response to wetland size appears erroneous, it is likely that area-sensitive species are responding to the area of suitable breeding habitat within the wetland and that this area decreases with increasing disturbance at the site.

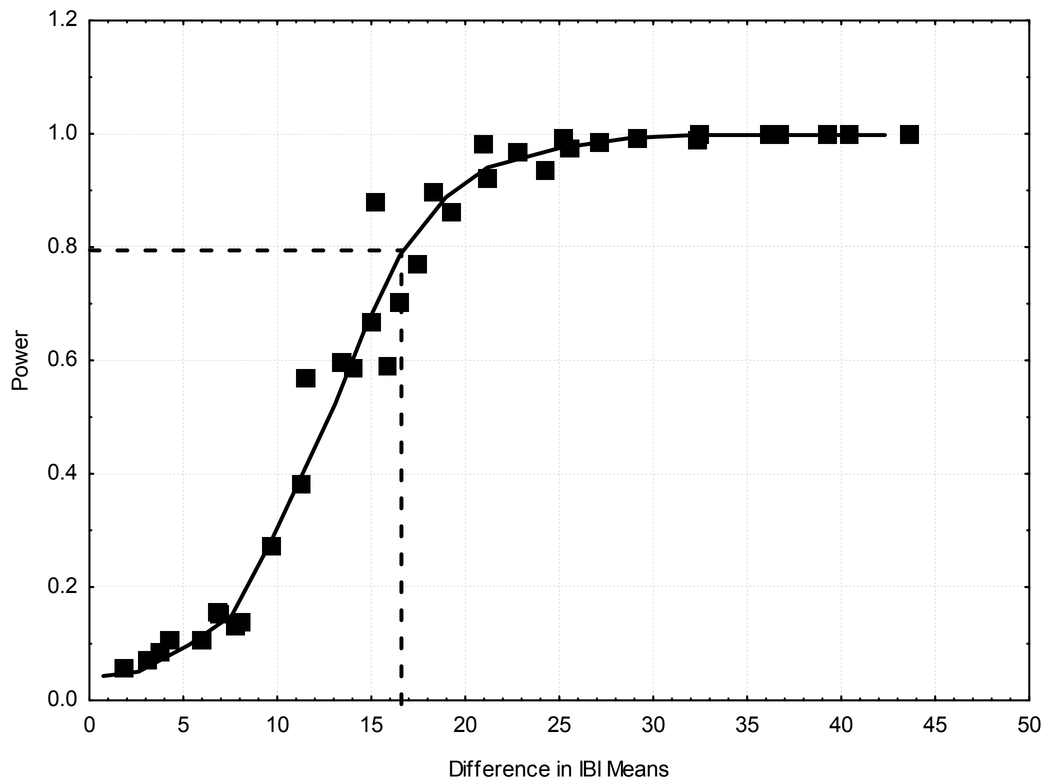

Figure 4.2.3-2. Power curve for nine breeding bird IBIs sampled three times. All points shown are for ∝ = 0.05.

High SMAS and PMAS metric scores at Westside Marsh were due to the consistent presence of Virginia Rails (*Rallus limicola*) and Swamp Sparrows (*Melospiza georgiana*) and the occasional presence of Soras (*Porzana carolina*) at the three survey stations. Other wetlands (Wilmot Creek, Cranberry and Presqu'ile Bay marshes) had the same species richness of area-sensitive birds, but they were not found consistently at all stations.

The presence and abundance of particular bird species (e.g., Black Tern (*Chlidonias niger*); Least Bittern (*Ixobrychus exilis*)) in Durham Region coastal wetlands is often of general interest to biologists and naturalists. A table summarizing the presence and abundance of all marsh users is in Appendix D.

IBI Scores and Classes

The relationship between disturbance and IBIs from 2002 is statistically significant and moderately strong (r=-0.64). Limited validation due to a small sample size is provided from plotting the 2003 IBIs against disturbance (r=-0.89). This suggests the condition of the breeding bird communities in Lake Ontario coastal wetland marshes are affected by disturbance as defined by the case score plot PC-1 (see section 3.1). Because three of the four IBI metrics evaluate the suitability of the wetland for marsh nesters, the estimated disturbance at the site may be more accurate if variables indicating the extent of suitable marsh habitat (percent interspersion, emergent vegetation diversity/dominance) were used in the disturbance PCA. These variables should be included from a landscape level (air photograph interpretation) and survey station (from MMP habitat evaluation) level.

Some breeding bird community IBIs varied considerably between years (Robinson's Cove -51.43, Lynde Creek -20.85, Cranberry Marsh +27.72). These changes are larger than the calculated minimum detectable difference of 17 and should represent a significant change in breeding bird community condition. However, the error estimate generated from resampling is likely lower than the real error because the resampling error is based on recorded observations and does not account for observation error. It is unclear how much of the observed difference in IBI is due to real change and how much is due to sampling error.

Given the potential within-site variability of breeding bird IBIs, results (Table 4.2.3-3) and IBI classes assigned to sites (Table 4.2.3-4) should be interpreted and acted upon cautiously until a better understanding of site-level variability is available.

Table 4.2.3-4. Marsh breeding bird community condition rankings for Durham Region coastal wetlands based on observed IBIs.

Wetland Name	Breeding Bird Community Ranking
Westside Marsh (2002)	Excellent
Westside Marsh (2003)	Excellent
Wilmot Creek Marsh (2003)	Very Good
Oshawa Second Marsh (2003)	Very Good
Cranberry Marsh (2003)	Very Good
Oshawa Second Marsh (2002)	Very Good
Port Newcastle (2003)	Good
Lynde Creek Marsh (2002)	Good
Corbett Creek Marsh (2002)	Good
Cranberry Marsh (2002)	Good
Bowmanville Marsh (2003)	Fair
Lynde Creek Marsh (2003)	Fair
Bowmanville Marsh (2002)	Fair
Wilmot Creek Marsh (2002)	Fair
Rouge River (2003)	Fair
Duffins Creek Marsh (2003)	Poor
Hydro Marsh (2002)	Poor
Frenchman's Bay Marsh (2002)	Poor

Future Considerations

An important next step for bird community monitoring is to determine the levels error in bird community IBIs. Substantial levels of within-site variation can be due to observer error and site variability.

Sources of observer error in point count and call-back surveys are numerous and will not be discussed here, but are thoroughly documented in a series of 22 papers culminated by Ralph *et al.* (1995) and reviewed by Anderson (1997). In general, sources of error that are constant among sites and visits (e.g., detectability) will not affect the IBI, but observer error can have a substantial influence in the survey results. For example, Tozer (2002) found that the mean percent (±SE) agreement on species composition within MMP survey stations was 68.2% ± 3.1 between surveyors of different experience (20 and 7 years) and 75.7% ± 3.1 between surveyors of similar experience (10 and 7 years). More striking is the fact that there were consistently significant differences between the relative abundance of Swamp Sparrows (*Melospiza georgiana*) recorded by different observers in the same station at the same time. Because relative abundance of Swamp Sparrows is included in the calculation of the IBI, this variation could substantially affect the within-site error in IBI. For example, a difference in mean relative abundance of observed Swamp Sparrows of 10 percent (reported by Tozer 2002) could result in a difference in IBI of 12 points.

To generate estimates of observer error, the approach that Tozer (2002) used is recommended. Selected Durham Region MMP routes should be surveyed by at least two different observers at the same time. Differences in survey results can be used to generate estimates of observer error.

To calculate estimates of site variability, selected sites should be re-surveyed by the same observer over a short period. For example, if a site is surveyed on two consecutive days (during similar weather conditions) by the same observer, the results of the survey are expected to be very similar. Any difference in the survey results can be attributed to site variability (whether the variability is due to differences in daily detectability or true short term changes in the bird assemblage).

In addition to observer and within-year site variability, there is also a natural, annual variability in the breeding bird assemblage within wetlands. Administrators of the MMP recognize this, and assert that these data are most applicable to monitoring long-term regional trends in marsh-breeding birds (Weeber and Vallianatos 2000). In the DRCWMP, data are being used to assess the annual condition of the breeding bird community at a site level. However, if observer error, within-year site variability, and annual variability are too high to make reliable annual assessments of breeding bird community condition, then longer-term Durham Region trends will be the only feasible method of reporting.

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4.2.4 Amphibian Community Condition

Objective

To assess and monitor amphibian community condition.

Method Summary

The Marsh Monitoring Program (MMP), administered by Bird Studies Canada (BSC), was used to survey amphibian (anuran) communities within various Durham Region coastal wetlands. Although the data for some sites span several years, this report focuses on the current condition (2002-2003) of the amphibian communities. Data were collected by volunteers and, in the absence of volunteers, conservation authority and Environment Canada – Ontario Region (EC – OR) staff. The goal was to sample all breeding amphibian communities in 2002 and/or 2003. Carruthers Creek Marsh was to be sampled by volunteers, but the data were not collected or not submitted.

Data Analysis

Methods of determining breeding amphibian community disturbance, metric suitability, and final IBI score are similar for all biotic communities in this project and are detailed in section 3.

Selection of Metrics

Timmermans and Craigie (2003) did not identify any significant associations between amphibian community metrics and disturbance across a limited range of coastal wetlands in and around Long Point, Lake Erie. Some of the metrics that showed promise are tested here.

In all, four amphibian community metrics were tested for suitability in Durham Region and other Lake Ontario coastal wetlands (Table 4.2.4-1). Species that are identified by the MMP as being indicators of high quality marshes include: Bullfrog (*Rana catesbeiana*; BULL), Northern Leopard Frog (*Rana pipiens*; NLFR), Chorus Frog (*Pseudacris triseriata* or *P. maculata*; CHFR), Spring Peeper (*Pseudacris crucifer*; SPPE), and Mink Frog (*Rana septentrionalis*; MIFR). The Ontario Herpetofaunal Summary indicates that the species range of Mink Frog does not include the Durham Region (Ministry of Natural Resources 2001). Therefore, only the incidence of the four other amphibian species will be monitored in this project.

Species richness and abundance estimates were calculated by using the maximum value among the three site visits. According to MMP protocol, abundance of each species is estimated per survey station. In the cases where a species of amphibian is calling in full chorus, abundance estimates are impossible due to the sheer numbers of individuals creating the chorus. For these few cases, a dummy value of five individuals was used. Although more than five individuals were present (or it would not be considered a chorus), this value allows the data to be analyzed statistically. Although this data addition method is not ideal, it does not bias the results toward finding a trend between disturbance and abundance; rather it reduces the possibility. Raw metric values tested against disturbance were site means (survey station as the sampling unit) for sites surveyed in 2002. The IBI model was developed with 2002 data because more sites were surveyed in that year, thus increasing the ability to detect associations between disturbance and amphibian community metrics.

Results

Metric Suitability

All four metrics evaluated (see Appendix E) responded to increasing disturbance as expected and were retained for use in the IBI, showing highly significant responses ($p<0.01$; Table 4.2.4-1). In general, metric scores within a site were consistent (i.e., if a site scored high in one metric, the others were high as well). Notable exceptions to this trend were McLaughlin Bay (2003), which scored a 10 on the PIND metric but low on the others; and McLaughlin Bay (2002), which scored a high NTOT metric but low on all others. In 2003, the 10 on the PIND was due solely to the detection of five Spring Peepers and the high NTOT score in 2002 was due to relatively high numbers of Wood Frogs (*Rana sylvatica;* 12) and Green Frogs (*Rana clamitans*; nine).

Calculating the IBI

Metrics were standardized as described in section 3.2 (Table 4.2.4-1). When the metrics from 2002 were standardized and integrated, wetland IBIs (Table 4.2.4-2) were significantly associated with wetland disturbance ($r=-0.72$, $p<0.001$, $n=19$). In addition, the association between disturbance and IBI for 2003 data, which were not used to develop the IBI model, was strong ($r=-0.68$, $p=0.02$, $n=11$).

Amphibian community IBIs showed a large range: 0-98.92. Bayfield Bay scored nearly perfect scores and was followed by another Wolfe Island coastal wetland, Button Bay, and then by other non-Durham wetlands. Port of Newcastle Wetland scored low, albeit the highest IBI within Durham Region, followed by McLaughlin Bay and Pumphouse marshes.

Table 4.2.4-1. Breeding amphibian community metric codes, descriptions, and empirical response to disturbance. For metrics used in the IBI, the linear model coefficients, intercept (A) and slope (B) for standardizing raw metric (M_R) with the upper and lower M_R limits of the standardized metrics (M_S) are shown. Correlation coefficients and p-values for all metrics are with graphs in Appendix E.

		Metric Response*		Metric coefficients		Values of M_R where	
Code	**Metric Description**	**r**	**p**	**A**	**B**	**M_S=0**	**M_S=10**
Species richness							
SIND	Indicator species richness	-0.73	<0.001	0	2.85	0	2.85
STOT	Total species richness	-0.74	<0.001	0	1.91	0	5.22
Abundance							
PIND	Relative % indicator species abundance	-0.68	0.001	0	0.12	0	82.83
NTOT	Total abundance	-0.56	0.012	0	0.41	0	24.03

* All metrics decreased with increasing disturbance as expected.

Table 4.2.4-2. Standardized breeding amphibian community metrics and IBIs for Durham Region coastal wetlands (bold) and other Lake Ontario coastal wetlands.

Wetland Name	STOT	NTOT	SIND	PIND	IBI
Bayfield Bay (2002)	9.57	10	10	10	98.9
Button Bay (2002)	8.61	10	10	8.55	92.9
Hay Bay South (2002)	10	9.78	8.57	6.95	88.2
Parrott's Bay (2002) *	9.09	6.97	10	8.59	86.6
South Bay (2002)	10	7.91	8.57	7.01	83.7
Parrott's Bay (2003) *	6.70	8.01	6.43	9.57	76.7
Presqu'ile Bay (2002)	8.37	7.18	6.79	7.03	73.4
Port Britain (2002)	6.70	8.53	4.29	7.34	67.1
Huyck's Bay (2002)	7.66	4.16	5.71	6.04	58.9
Port Newcastle Wetland (2003)	**5.74**	**5.41**	**2.86**	**5.57**	**48.9**
McLaughlin Bay Marsh (2003)	**1.91**	**2.08**	**2.86**	**10**	**42.1**
Pumphouse Marsh (2003)	**5.74**	**5.83**	**2.86**	**0.86**	**38.2**
Robinson's Cove (2003)	3.83	2.91	2.86	5.17	36.9
Duffins Creek Marsh (2003)	**3.19**	**0.83**	**2.86**	**7.38**	**35.6**
Wilmot Creek Marsh (2002)	**5.74**	**2.91**	**2.86**	**1.72**	**33.0**
McLaughlin Bay Marsh (2002)	**3.83**	**8.74**	**0**	**0**	**31.4**
Duffins Creek Marsh (2002)	**3.83**	**2.91**	**1.90**	**1.95**	**26.5**
Frenchman's Bay Marsh (2002)	**1.91**	**3.12**	**2.86**	**2.19**	**25.2**
Cranberry Marsh (2003) *	**3.83**	**2.08**	**1.43**	**1.84**	**22.9**
Cranberry Marsh (2002) *	**2.55**	**1.39**	**0.95**	**3.22**	**20.2**
Rouge River Marsh (2003)	**3.83**	**3.33**	**0**	**0**	**17.8**
Hydro Marsh (2002)	**1.91**	**0.83**	**0.95**	**2.41**	**15.2**
Wilmot Creek Marsh (2003)	**2.55**	**1.53**	**0**	**0**	**10.2**
Oshawa Second Marsh (2002) *	**1.09**	**0.59**	**0.41**	**1.72**	**9.5**
Oshawa Second Marsh (2003) *	**1.59**	**1.80**	**0**	**0**	**8.5**
Corbett Creek Marsh (2002)	**1.91**	**0.97**	**0**	**0**	**7.2**
Westside Marsh (2003)	**1.91**	**0.83**	**0**	**0**	**6.8**
Bowmanville Marsh (2002)	**0.64**	**0.28**	**0.95**	**0**	**4.6**
Lynde Creek Marsh (2002)	**0.64**	**0.55**	**0**	**0**	**2.9**
Bowmanville Marsh (2003)	**0.64**	**0.28**	**0**	**0**	**2.2**
Lynde Creek Marsh (2003)	**0**	**0**	**0**	**0**	**0**
Robinson's Cove (2002)	0	0	0	0	0

* - indicates sites used for statistical resampling

Resampling Metrics

Resampling of marsh amphibian community IBI metrics consisted of recalculating the mean metric values for selected wetlands (Table 4.2.4-2) by bootstrapping the field-collected data through 100 iterations (Figure 4.2.4-1). These sites were chosen because they had four or more replicates (survey stations) per route.

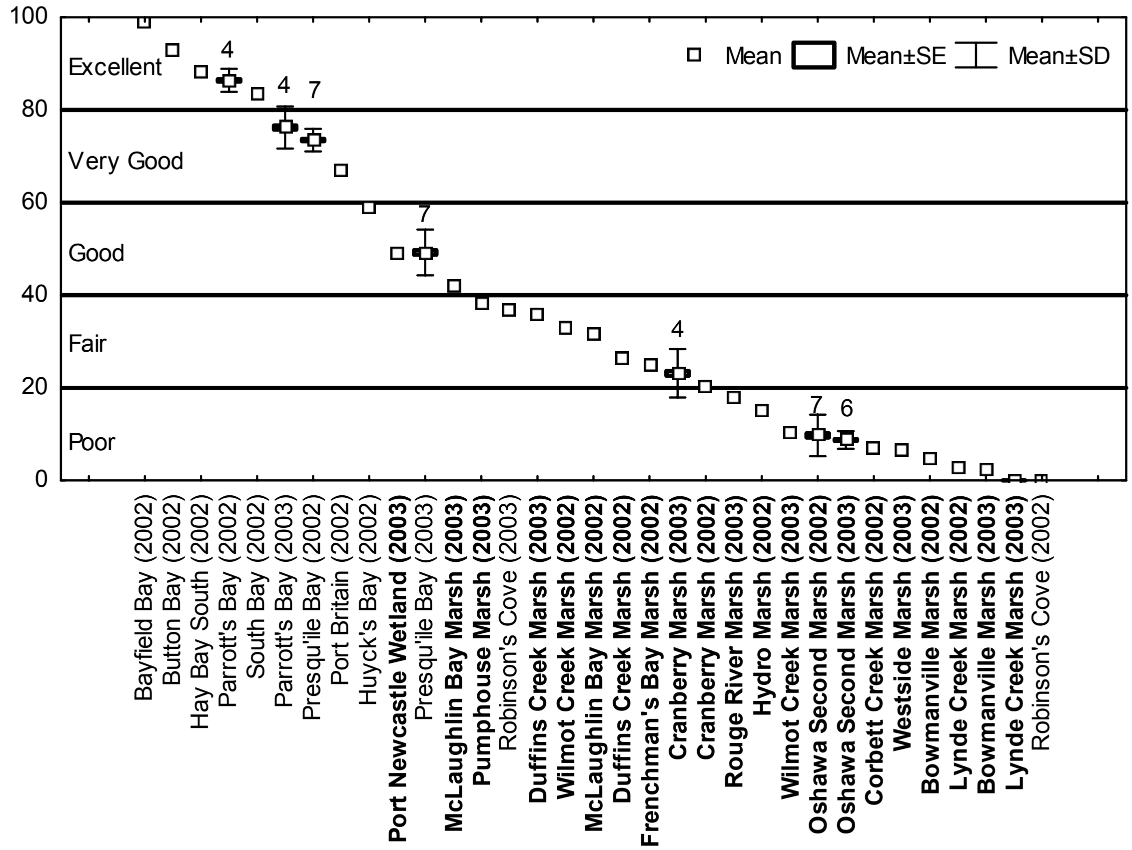


Figure 4.2.4-1. Box and whisker plots of the resampled amphibian IBIs for selected sites showing five separate IBI category rankings. Empirical IBI scores for all other sites (box only) are also shown for comparison. Number of stations sampled per site for resampled data is located above each box and whisker plot.

IBI classes were established by the method described by Fore *et al.* (1994). A power curve was constructed by determining the power of all pairwise (n=21) comparisons in theoretical three sample t-tests ($\propto$ = 0.05). The power of each test was then plotted against the difference between means (Figure 4.2.4-2). At the statistical standard of 80 percent power, the minimum detectible difference in IBI means is 12 IBI units. Taking the range of IBIs (Table 4.2.4-2) and dividing it by the minimum detectable difference [(98-0)÷12] equals 8.1. This means that the range of IBIs can be split into eight classes. For simplicity, five IBI classes were identified (poor, fair, good, very good and excellent). Durham Region coastal wetland breeding amphibian communities occupy the full range of classes.

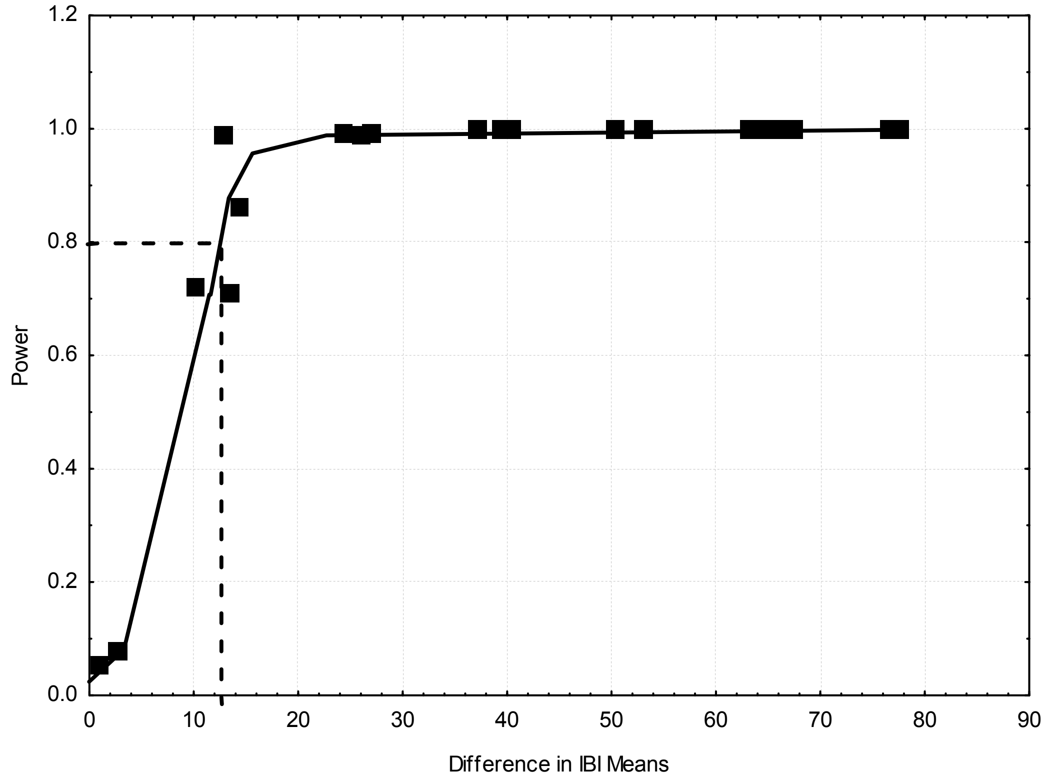


Figure 4.2.4-2. Power curve for seven amphibian IBIs sampled three times. All points shown are for ∝ = 0.05.

Discussion

Metrics

The high strength and significance of all metric associations with disturbance provides an excellent foundation for breeding amphibian IBI development in Lake Ontario coastal wetlands. Although total abundance decreased with increasing wetland disturbance, the fact that the indicator species relative abundance also responded negatively to disturbance is of particular interest. The nature of the relative abundance response to disturbance indicates that the abundance of indicator species decreases disproportionately more to disturbance than overall abundance. This trend validates the assumption that these species are indeed indicator species.

IBI Scores and Classes

The strong significant association between the IBIs calculated from the developed model and disturbance (r=-0.72) suggests that this IBI is a good measure of breeding amphibian community condition. Furthermore, the strong response of IBIs (2003) that were not used in the model development to disturbance (r=-0.68) indicates that the IBI is robust to annual variability within survey sites.

The inter-annual agreement of the IBI response to disturbance is facilitated by similar within-site IBIs. The obvious exception to this is the Robinson's Cove site. The IBI at this site differed far more than the minimum detectable difference of 12-13 IBI points (+36.93). At Robinson's Cove, amphibians were not detected in the first or second visit of either year. The third visit in 2002 still did not yield any amphibians, whereas in the third visit in 2003, three Bull Frogs and six Green Frogs were detected. The presence of these frogs in 2003 was responsible for the IBI score. Although this change appears to be real, Robinson's Cove is a small wetland and had only one sample station. This wetland may require additional survey stations to gain a more accurate representation of the amphibian community.

Overall, this IBI appears to reflect the condition of breeding amphibian communities at Durham Region coastal wetlands (Table 4.2.4-3). However, precautions should be taken to ensure that sufficient field data (i.e., maximize the number of stations) are collected to characterize the community.

Table 4.2.4-3. Marsh breeding bird community condition rankings for Durham Region coastal wetlands based on observed IBIs.

Wetland Name	Breeding Amphibian Community Condition
Port Newcastle Wetland (2003)	Good
McLaughlin Bay Marsh (2003)	Good
Pumphouse Marsh (2003)	Fair
Duffins Creek Marsh (2003)	Fair
Wilmot Creek Marsh (2002)	Fair
McLaughlin Bay Marsh (2002)	Fair
Duffins Creek Marsh (2002)	Fair
Frenchman's Bay Marsh (2002)	Fair
Cranberry Marsh (2003)	Fair
Cranberry Marsh (2002)	Fair
Rouge River Marsh (2003)	Poor
Hydro Marsh (2002)	Poor
Wilmot Creek Marsh (2003)	Poor
Oshawa Second Marsh (2002)	Poor
Oshawa Second Marsh (2003)	Poor
Corbett Creek Marsh (2002)	Poor
Westside Marsh (2003)	Poor
Bowmanville Marsh (2002)	Poor
Lynde Creek Marsh (2002)	Poor
Bowmanville Marsh (2003)	Poor
Lynde Creek Marsh (2003)	Poor

Future Considerations

The data collection methods for amphibian communities are very similar to the methods used for the bird community. As such, the same error and site variability issues exist for both communities. The recommendations under *Future Considerations* in the bird community monitoring section should also be extended to monitoring the amphibian community.

Literature Cited

Timmermans, S.T.A., and E.G. Craigie. 2003. Great Lakes Coastal Wetlands Consortium Year-One Pilot Project Indicator Research Activities: A Technical Report by Bird Studies Canada. Marsh Monitoring Program, Bird Studies Canada. April 2003.

Ministry of Natural Resources. 2001. Mink Frog (*Rana septentrionalis*) species range map in Ontario. Map prepared by the Natural Heritage Information Centre. (www.mnr.gov.on.ca/MNR/nhic/herps/frogs.html)

Weeber, R.C. and M. Vallianatos (Eds.) 2000. The Marsh Monitoring Program 1995 - 1999: Monitoring Great Lakes Wetlands and Their Amphibian Inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. (www.bsc-eoc.org/mmpreport.html)

4.2.5 Measurement of Wildlife Species Richness

Objective

To assess and monitor marsh bird and amphibian species richness.

Method Summary

Species richness is defined as the number of bird and amphibian species residing within a biological community. For the purpose of this project, the community included the wetland and the area within 500 metres of the delineated wetland boundaries.

Species lists of birds and amphibians were compiled from reports and records from experienced naturalists of sightings made from January 2000 to December 2002. Additionally, all species observed during fieldwork undertaken for other monitoring activities of this project were included in the appropriate list.

To supplement records from other sources, a checklist of birds and amphibians that could be seen in Durham Region was prepared and distributed to local naturalists.

Results

The number of species seen during this three-year period is quite variable across the wetlands (Table 4.2.5-1). At some wetlands, extensive checklists were maintained by experienced birdwatchers (e.g., Corbett Creek Marsh), while at others, very little information was available (e.g., McLaughlin Bay Marsh).

A few checklists were returned and did help to supplement the existing data. However, the variability among marshes (and likely among years in the future) is so great that the species richness numbers are inconclusive. A major drawback is the difficulty in quantifying the effort expended in collecting this information, which would allow the species richness numbers to be standardized; e.g., by using total person-hours spent at each wetland.

Table 4.2.5. Species richness at Durham Region Coastal wetlands (Jan. 2000 to Dec. 2002)

Wetland	Bird and Amphibian Species Richness
Rouge River Marsh	63
Cranberry Marsh	65
Lynde Creek Marsh	102
Corbett Creek Marsh	232
Pumphouse Marsh	21
Oshawa Second Marsh	111
McLaughlin Bay Marsh	6
Westside Marsh	16
Bowmanville Marsh	83
Wilmot Creek Marsh	70
Port Newcastle Wetland	75

Discussion

Based on the results to date, it was decided that this monitoring activity will be discontinued in the future. A standardized bird and amphibian survey, the Marsh Monitoring Program (MMP), is already part of this project. It was designed to monitor populations at a variety of spatial scales (Weeber and Vallianatos 2000) and, unlike the species richness numbers, the MMP data should be comparable among years and wetlands.

Although species richness will not be reported on in the future, it is still valuable to obtain species observation records from naturalists and published reports. This information will be helpful in completing the Identification of Key Habitats protocol (section 4.1.2) by potentially providing species at risk observations from the Durham Region coastal wetlands.

Literature Cited

Weeber, R.C. and M. Vallianatos (Eds.) 2000. The Marsh Monitoring Program 1995 - 1999: Monitoring Great Lakes Wetlands and Their Amphibian Inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. (www.bsc-eoc.org/mmpreport.html)

5. SUMMARY

This project was designed to monitor biological and physical conditions within 15 Durham Region coastal wetlands. Eight monitoring methodologies focused on assessing the condition of plant, fish, aquatic macroinvertebrate, and wildlife communities and 10 methodologies assessed the geophysical condition of the wetlands and their associated watersheds.

The wetland and watershed attributes being monitored were identified by drawing largely on coastal wetland indicator development from the State of the Lakes Ecosystem Conferences (SOLEC) and Bird Studies Canada's Marsh Monitoring Program.

The project used a multivariate approach to create relative disturbance estimates experienced by various biotic communities by incorporating physical variables such as surrounding land-use and water quality. The disturbance estimates were used to determine if various community-specific attributes responded to the level of disturbance. Attributes that responded to disturbance (called metrics) were combined to create a multi-metric index of biotic integrity (IBI) for each biotic community. Throughout this process, additional Lake Ontario coastal wetlands were used to formulate IBIs and present results in a broad context.

The results indicate that Durham Region coastal wetlands are among some of the most disturbed coastal wetlands on the Canadian side of Lake Ontario. Within the Region, easterly wetlands generally experience less disturbance than wetlands closer to Toronto.

The condition of the biotic communities within these wetlands reflects the level of disturbance experienced by the wetland (Table 6.1). As such, Durham Region coastal wetlands generally show biotic communities that are impaired and rank in poor to good condition. Biotic communities at some sites, such as fish at Wilmot Creek Marsh and breeding birds at Westside, Oshawa Second and Cranberry marshes, are examples of communities in very good and excellent condition (Table 6.1).

Scientific monitoring is an iterative approach. This report provides a preliminary assessment of Durham Region coastal wetlands. To maintain an effective monitoring project, successive years of data collection are required.

There is also a need to better understand the limitations of reporting results through IBIs. In particular, additional data collection is important to create estimates of error about IBI values. Knowing the confidence limits of IBIs will help provide an understanding of long-term trends and aid in restoration decisions. As confidence in the results improves, additional analyses of monitoring data can be performed to identify site specific goals and possible reasons for biological impairment. This information can then be used to direct conservation and restoration activities.

This report allows the DRCWMP Implementation and Methodology Committees to assess the progress and make recommendations regarding the direction and priorities of the project.

Table 6.1. A summary of physical and biotic assessments made in this project. Disturbance estimates were created through multivariate analysis of physical habitat variables including surrounding land-use, water quality and submerged aquatic vegetation (SAV) cover. Disturbance experienced by biotic communities was based on one of two matrices, A or B. Disturbance values are relative – higher numbers indicate higher disturbance. SQI and IBI values are out of 100.

		Disturbance		Sediment		Natural Cover
	Site Name	Matrix A	Matrix B	SQI	Ranking	in Watershed (%)
West	Rouge River Marsh	-	1.038	100.0	Excellent	24
	Frenchman's Bay Marsh	2.434	2.058	98.1	Excellent	31
	Hydro Marsh	2.116	1.383	88.9	Good	30
	Duffins Creek Marsh	3.058	2.590	100.0	Excellent	37
	Carruthers Creek Marsh	1.593	0.830	100.0	Excellent	28
	Cranberry Marsh	1.774	2.359	86.4	Good	41
	Lynde Creek	2.435	3.349	85.3	Good	23
	Corbett Creek Marsh	0.825	0.087	89.3	Good	18
	Pumphouse Marsh	0.084	0.406	40.8	Poor	24
	Oshawa Second Marsh	0.521	0.976	57.0	Marginal	19
	McLaughlin Bay Marsh	0.850	-0.510	89.7	Good	70
	Westside Marsh	-	1.612	89.7	Good	29
	Bowmanville Marsh	2.250	2.729	90.4	Good	29
	Wilmot Creek Marsh	-0.190	-0.800	90.4	Good	35
East	Port Newcastle Wetland	-	0.106	84.7	Good	44

Table 6.1 Continued.

		SAV		Invertebrates		Fish		Birds		Amphibians	
	Site Name	IBI	Ranking	IBI	Ranking	IBI	Ranking	IBI	Ranking	IBI	Ranking
West	Rouge River Marsh	–	–	42.0	Good	34.5	Fair – Good	20.2	Fair	17.8	Poor
	Frenchman's Bay Marsh	20.0	Fair – Poor	23.4	Poor	48.2	Fair – Good	11.2	Poor	25.2	Fair
	Hydro Marsh	1.0	Poor	12.2	Poor	19.6	Fair – Poor	14.1	Poor	15.2	Poor
	Duffins Creek Marsh	1.7	Poor	18.8	Poor	28.2	Fair	18.3	Poor	35.6	Fair
	Carruthers Creek Marsh	0.0	Poor	40.6	Good	32.5	Fair	–	–	–	–
	Cranberry Marsh	34.4	Fair	39.6	Good	–	–	72.1	Very Good	22.9	Fair
	Lynde Creek Marsh	31.9	Fair – Poor	29.3	Poor	44.0	Fair – Good	37.0	Fair	2.9	Poor
	Corbett Creek Marsh	32.7	Fair	52.0	Good	28.4	Fair	54.7	Good	7.2	Poor
	Pumphouse Marsh	50.6	Good	59.7	Good	26.6	Fair	–	–	38.2	Fair
	Oshawa Second Marsh	38.8	Fair – Good	40.8	Good	43.9	Fair – Good	77.4	Very Good	9.5	Poor
	McLaughlin Bay Marsh	0.0	Poor	40.6	Good	35.8	Fair – Good	–	–	42.1	Good
	Westside Marsh	–	–	44.1	Good	–	–	86.6	Excellent	6.8	Poor
	Bowmanville Marsh	16.0	Poor	26.3	Poor	46.2	Fair – Good	40.6	Fair	4.6	Poor
	Wilmot Creek Marsh	20.4	Fair – Poor	62.9	Good	60.5	Good – Very Good	78.5	Very Good	33	Fair
East	Port Newcastle Wetland	–	–	67.4	Good	28.1	Fair	58.7	Good	48.9	Good

APPENDIX A

Table A-1. Submerged aquatic plant species presence in Durham Region coastal wetlands.

Genus and species	Bowmanville Marsh 2002	Bowmanville Marsh 2003	Carruthers Creek Marsh 2002	Corbett Creek Marsh 2002	Cranberry Marsh 2003	Duffins Creek Marsh 2002	Frenchman's Bay Marsh 2002	Hydro Marsh 2002
Algae sp.	X	X		X	X	X		
Ceratophyllum demersum	X	X		X				
Chara sp.					X			
Elodea canadensis	X						X	X
Heteranthera dubia								
Hydrocharis morsus-ranae	X			X				
Lemna minor	X	X		X	X	X		
Lemna triscula								
Myriophyllum sibiricum					X			
Myriophyllum spicatum				X	X		X	
Najas flexilis	X							
Nuphar variegatum		X						
Nymphaea odorata	X	X		X				
Potamogeton amplifolius								
Potamogeton crispus								
Potamogeton foliosus				X	X			
Potamogeton gramineus								
Potamogeton natans								
Potamogeton pectinatus	X			X	X	X		
Potamogeton pusillus	X						X	
Potamogeton richardsonii							X	
Potamogeton robbinsii								
Potamogeton zosteriformis	X							
Ranunculus longirostris								
Riccia fluitans		X		X	X			
Ricciocarpos natans	X				X			
Spirodela polyrhiza	X	X		X	X			
Utricularia vulgaris								
Vallisneria americana							X	

Table A-1 Continued.

Genus and species	Lynde Creek Marsh 2002	Lynde Creek Marsh 2003	McLaughlin Bay Marsh 2003	Oshawa Second Marsh 2002	Oshawa Second Marsh 2003	Pumphouse Marsh 2003	Wilmot Creek Marsh 2003
Algae sp.	X	X	X	X	X	X	X
Ceratophyllum demersum	X	X				X	X
Chara sp.				X	X	X	
Elodea canadensis				X	X	X	X
Heteranthera dubia							
Hydrocharis morsus-ranae		X					X
Lemna minor	X	X		X	X	X	X
Lemna triscula							
Myriophyllum sibiricum							
Myriophyllum spicatum	X				X		
Najas flexilis						X	
Nuphar variegatum							
Nymphaea odorata	X	X					
Potamogeton amplifolius							
Potamogeton crispus			X	X			X
Potamogeton foliosus		X			X	X	
Potamogeton gramineus							
Potamogeton natans							
Potamogeton pectinatus	X	X		X	X	X	X
Potamogeton pusillus	X			X			
Potamogeton richardsonii							
Potamogeton robbinsii							
Potamogeton zosteriformis							
Ranunculus longirostris							
Riccia fluitans	X	X					
Ricciocarpos natans							
Spirodela polyrhiza	X	X			X	X	
Utricularia vulgaris							
Vallisneria americana							

Table A-2. Wetland SAV species responses to stress[1]

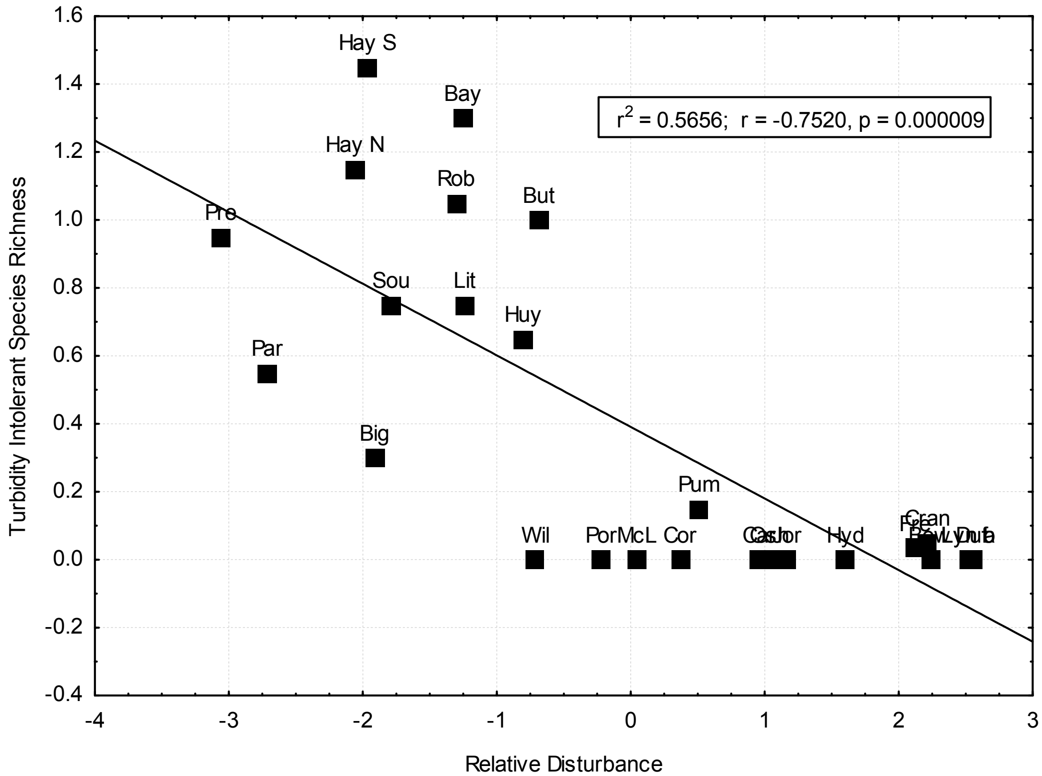
Stress	Responsive species[1]
Nutrient Enrichment	*Myriophyllum spicatum* (++) *Potamogeton crispus* (++) *Potamogeton pectinatus* (++) *Elodea canadensis* (++) *Ceratophyllum demersum* (++) *Lemna minor* (++) Filamentous algae (++)
Sedimentation and Increased Turbidity	*Megalodonta beckii* (-) *Myriophyllum exalbescens* (-) *Najas flexilis* (-) *Potamogeton amplifolius* (-) *P. robbinsii* (-) *P. zosteriformis* (-) *P. friesii* (-) *Vallisneria americana* (-) *Potamogeton pectinatus* (+) *P. crispus* (+) *P. foliosus* (+) *P. pusillus* (+) *Ceratophyllum demersum* (+) *Elodea canadensis* (+) *Heteranthera dubia* (+) *Ranunculus longirostris* (+) *Myriophyllum spicatum* (+)

[1] Species responses are coded as: - Intolerant of stress; + Tolerant of stress; ++ Positive response to stress. Albert, D.A., and Minc, L.D. 2003. Plants as indicators for Great Lakes coastal wetland health. Aquat. Ecosys. Health Manag. (accepted Sept. 2003).

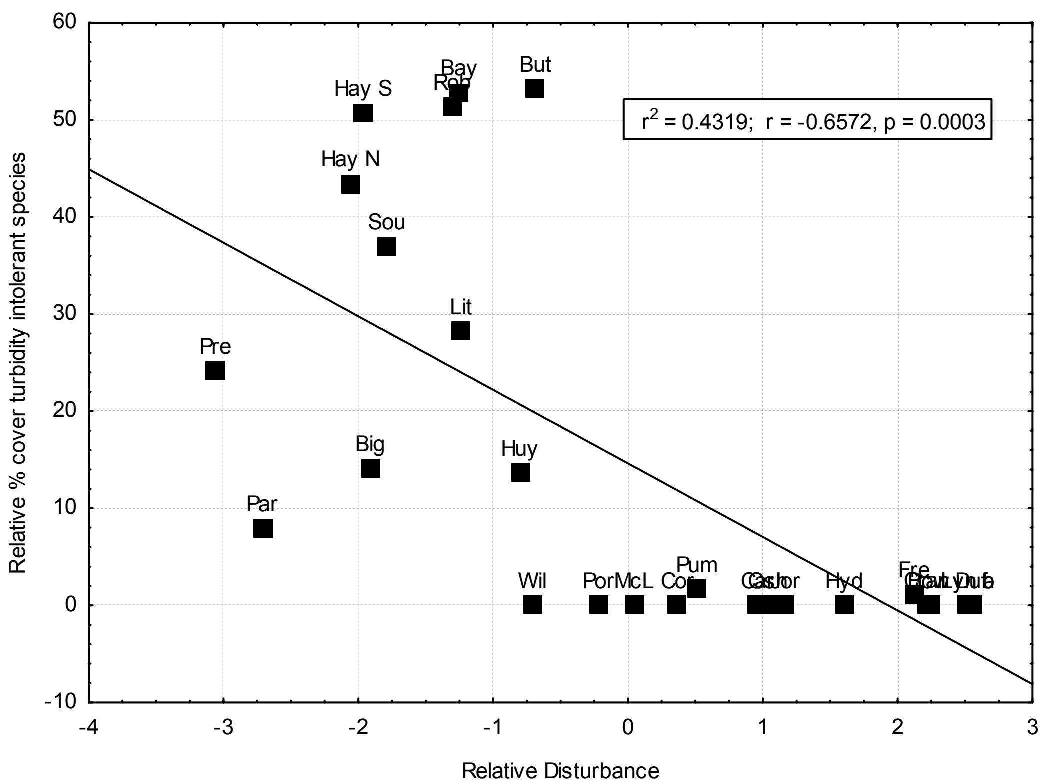
Table A-2. Sites names and acronyms used in disturbance vs. metric data graphs.

Site Acronym	Wetland Name
Bay	Bayfield Bay
Big	Big Sand Bay
Bow	Bowmanville Marsh
But	Button Bay
Car	Carruthers Creek
Cor	Corbett Creek Marsh
Cran	Cranberry Marsh
Duf	Duffins Creek Marsh
Fre	Frenchman's Bay Marsh
Hay N	Hay Bay North
Hay S	Hay Bay South
Huy	Huyck's Bay
Hyd	Hydro Marsh
Jor	Jordan Station
Lit	Little Cataraqui
Lyn a	Lynde Creek Marsh 2003a
Lyn b	Lynde Creek Marsh 2003b
McL	McLaughlin Bay Marsh
Osh	Oshawa Second Marsh
Par	Parrott's Bay
Por	Port Britain
Pre	Presqu'ile Bay
Pum	Pumphouse Marsh
Rob	Robinson's Cove
Sou	South Bay
Wil	Wilmot Rivermouth Wetland

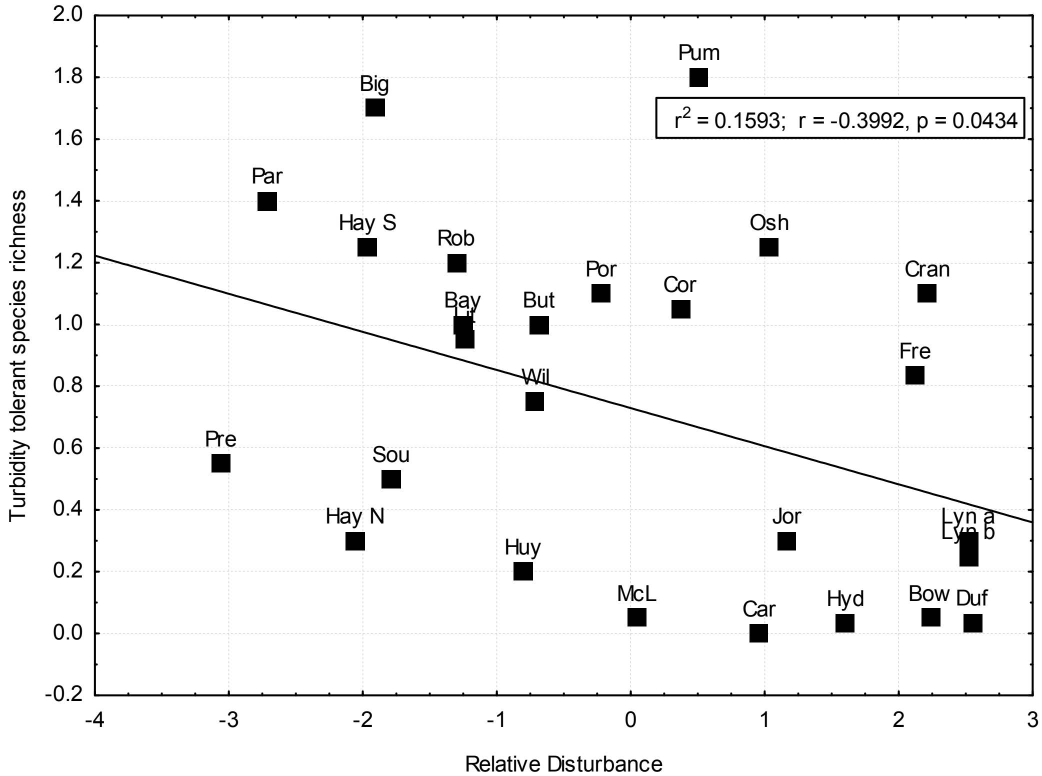
The following graphs represent all SAV community metrics assessed against wetland disturbance

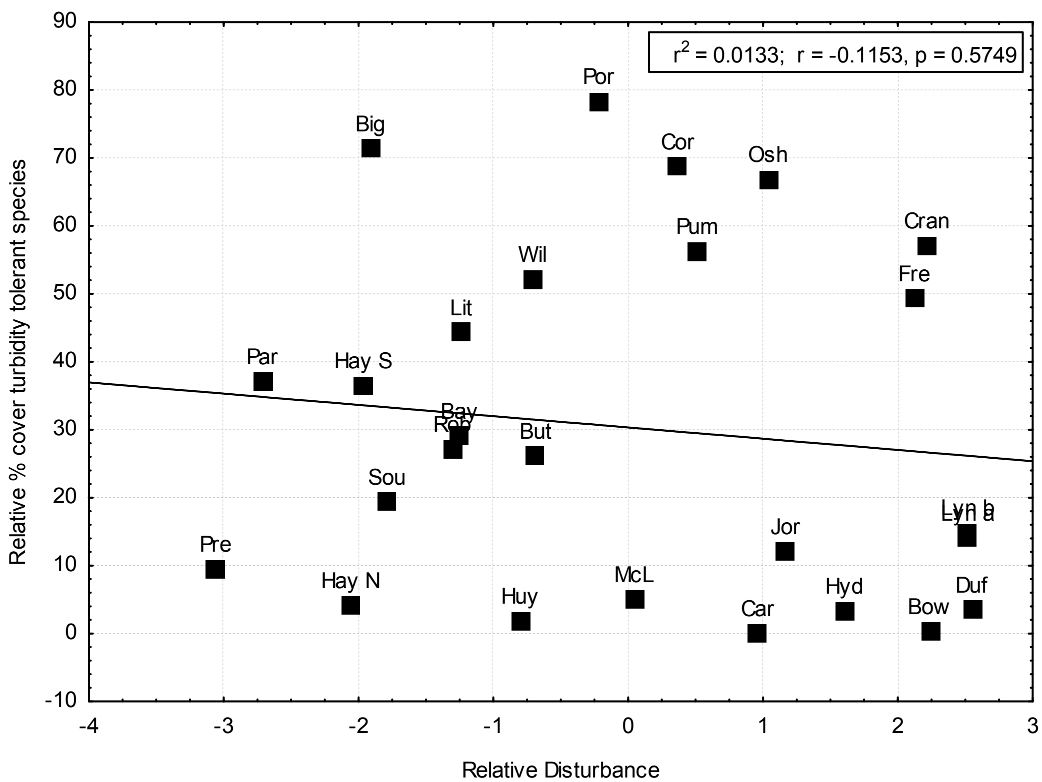


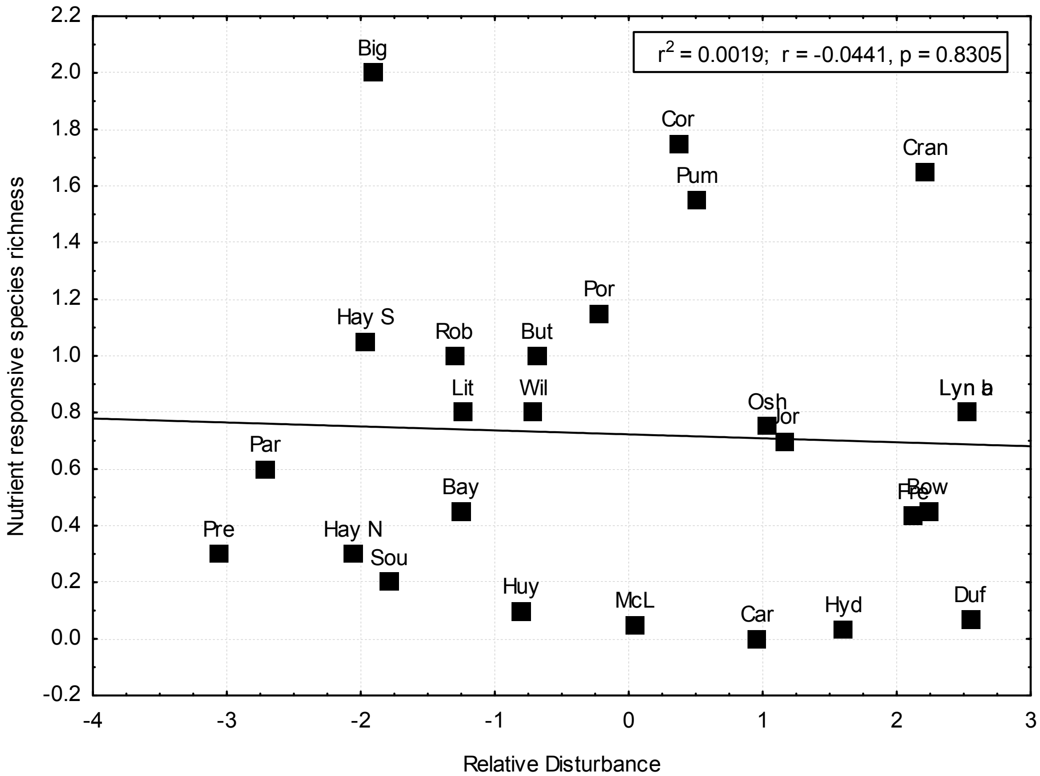
Turbidity Intolerant Species Richness
Relative Disturbance
$r^2 = 0.5656$; r = -0.7520, p = 0.000009
Hay S
Bay
Hay N
Rob
But
Pre
Sou
Lit
Huy
Par
Big
Pum
Wil
Por
McL
Cor
Hyd
Cran
Fre

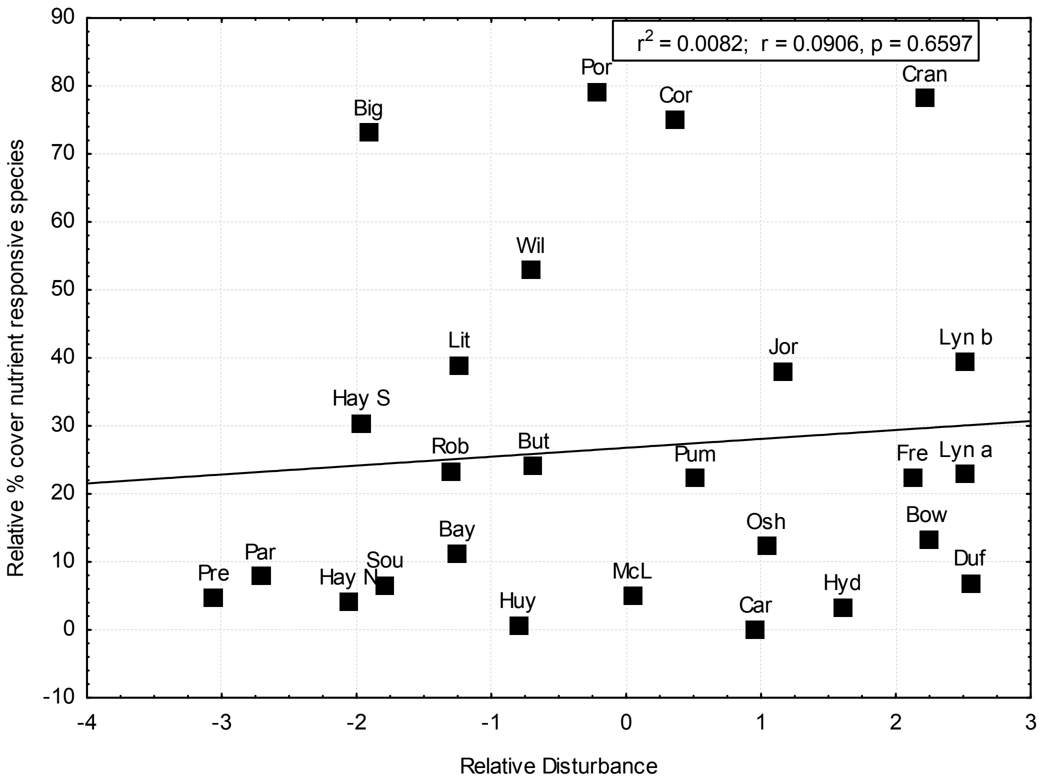


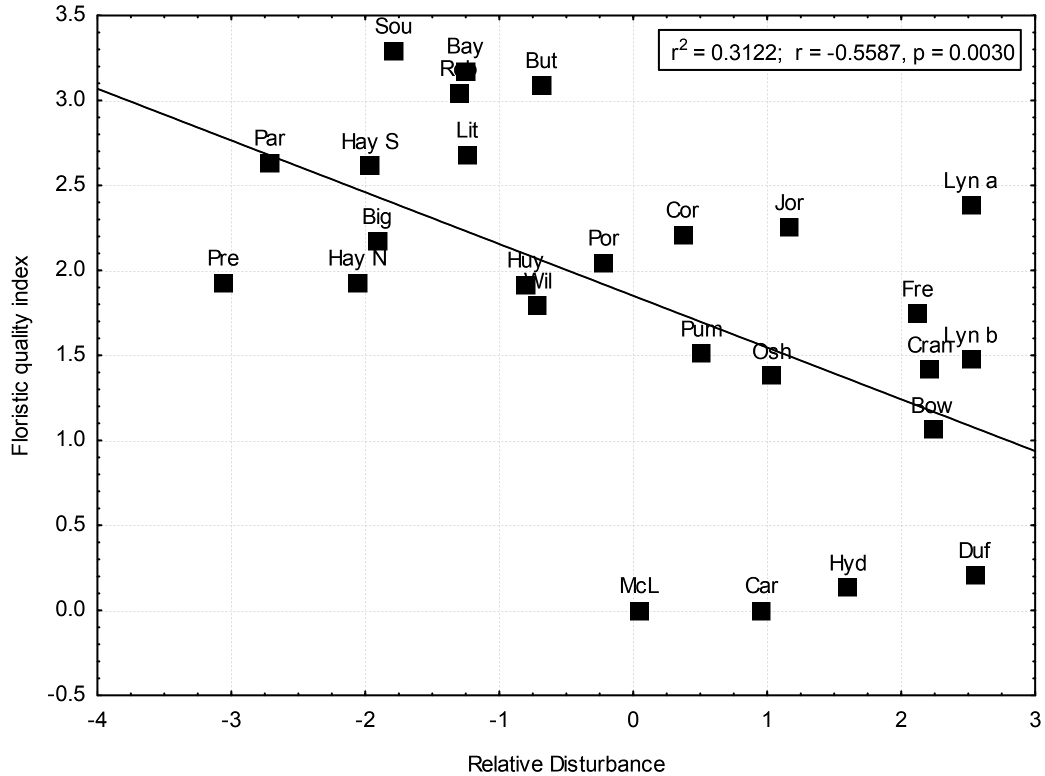
Relative % cover turbidity intolerant species
Relative Disturbance
$r^2 = 0.4319$; r = -0.6572, p = 0.0003
Bay
But
Rob
Hay S
Hay N
Sou
Lit
Pre
Big
Huy
Par
Pum
Wil
Por
McL
Cor
Hyd
Fre

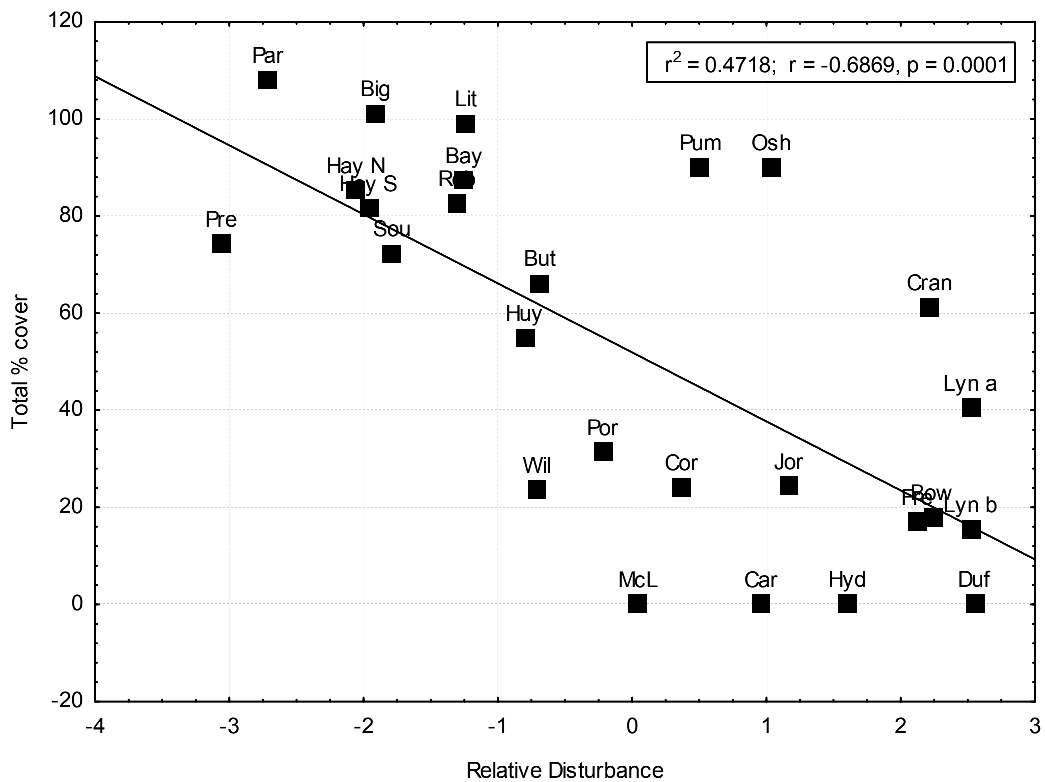

r² = 0.1593; r = -0.3992, p = 0.0434
Turbidity tolerant species richness
Relative Disturbance
Pum
Big
Par
Hay S
Rob
Osh
Por
Cor
Cran
Bay
Lit
But
Fre
Wil
Pre
Sou
Hay N
Jor
Lyn a
Lyn b
Huy
McL
Car
Hyd
Bow
Duf

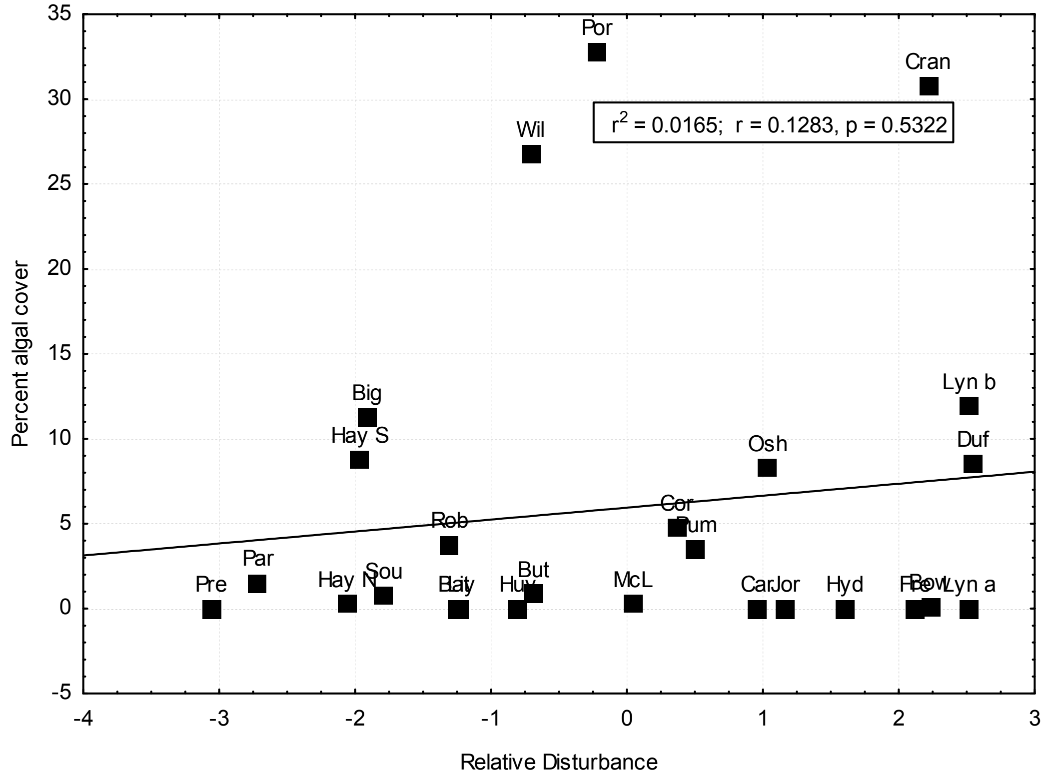

r² = 0.0133; r = -0.1153, p = 0.5749
Relative % cover turbidity tolerant species
Relative Disturbance
Por
Big
Cor
Osh
Pum
Cran
Wil
Fre
Lit
Par
Hay S
Bay
Rob
But
Sou
Lyn b
Lyn a
Jor
Pre
Hay N
Huy
McL
Car
Hyd
Bow
Duf


r² = 0.0019; r = -0.0441, p = 0.8305
Nutrient responsive species richness
Relative Disturbance
Big
Cor
Cran
Pum
Por
Hay S
Rob
But
Lit
Wil
Osh
Jor
Lyn a
Lyn b
Par
Bay
Fre
Bow
Pre
Hay N
Sou
Huy
McL
Car
Hyd
Duf

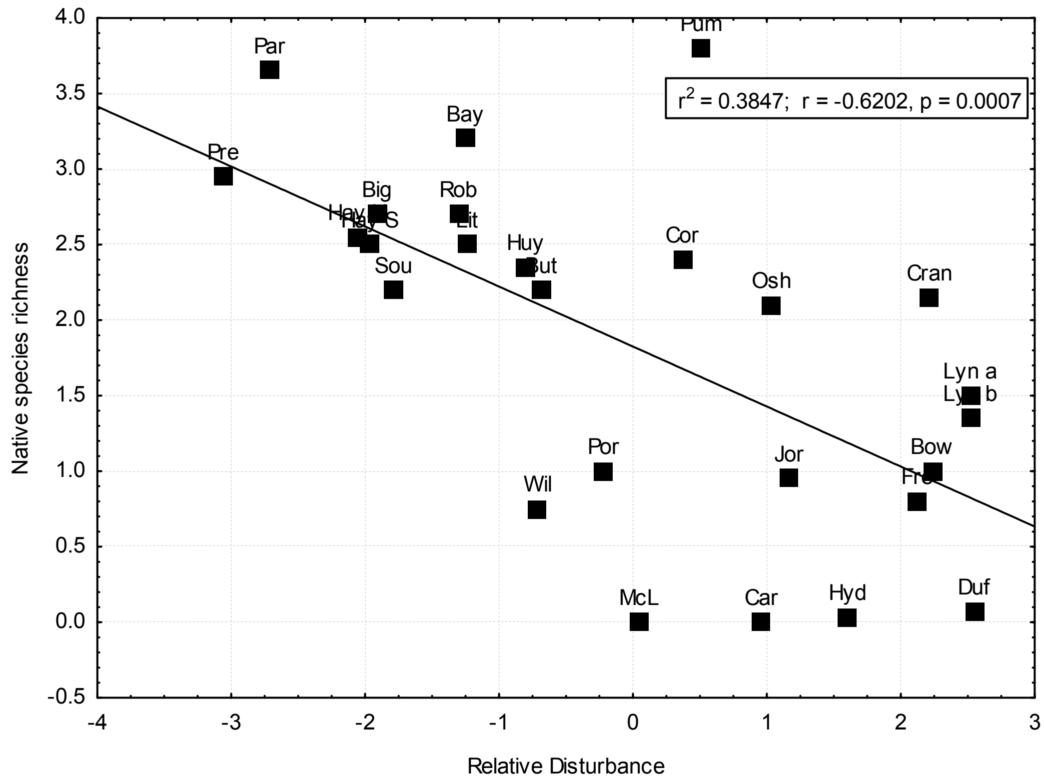

r² = 0.0082; r = 0.0906, p = 0.6597
Relative % cover nutrient responsive species
Relative Disturbance
Por
Cran
Big
Cor
Wil
Lit
Jor
Lyn b
Hay S
Rob
But
Pum
Fre
Lyn a
Bay
Osh
Bow
Pre
Par
Hay N
Sou
McL
Duf
Huy
Car
Hyd


r² = 0.3122; r = -0.5587, p = 0.0030
Floristic quality index
Relative Disturbance
Sou
Bay
But
Par
Hay S
Lit
Lyn a
Big
Cor
Jor
Pre
Hay N
Huy
Wil
Por
Fre
Pum
Osh
Cran
Lyn b
Bow
Duf
Hyd
McL
Car

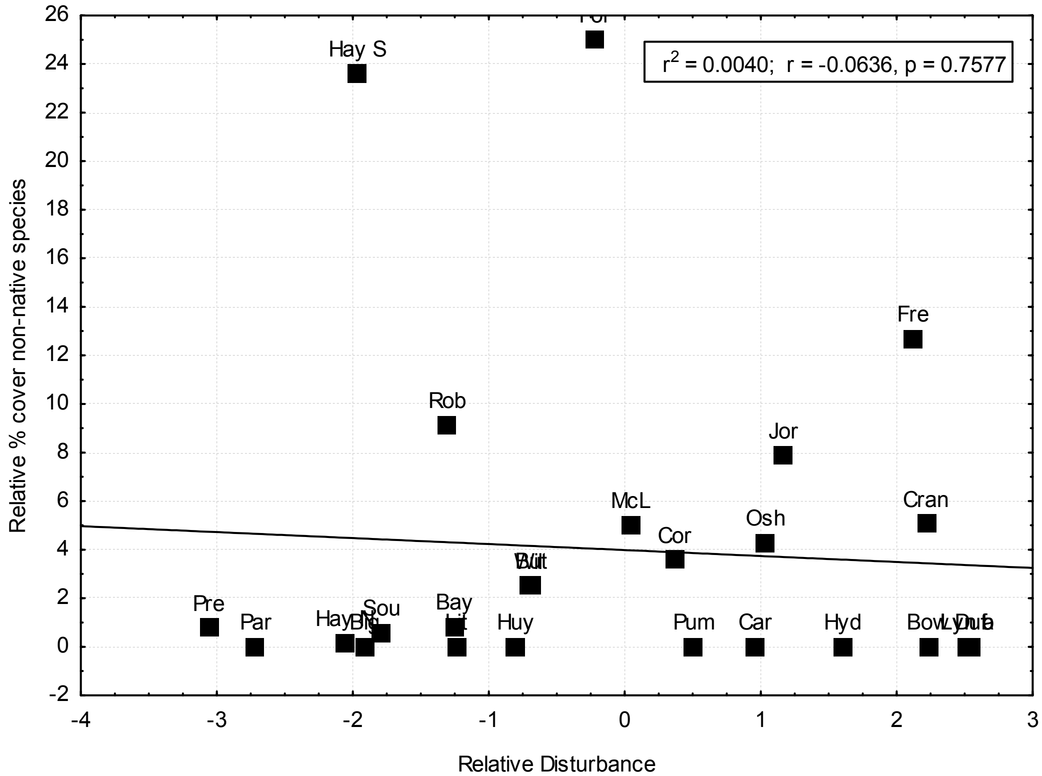

r² = 0.4718; r = -0.6869, p = 0.0001
Total % cover
Relative Disturbance
Par
Big
Lit
Bay
Hay N
Pum
Osh
Pre
Sou
But
Cran
Huy
Lyn a
Por
Wil
Cor
Jor
Bow
Lyn b
McL
Car
Hyd
Duf

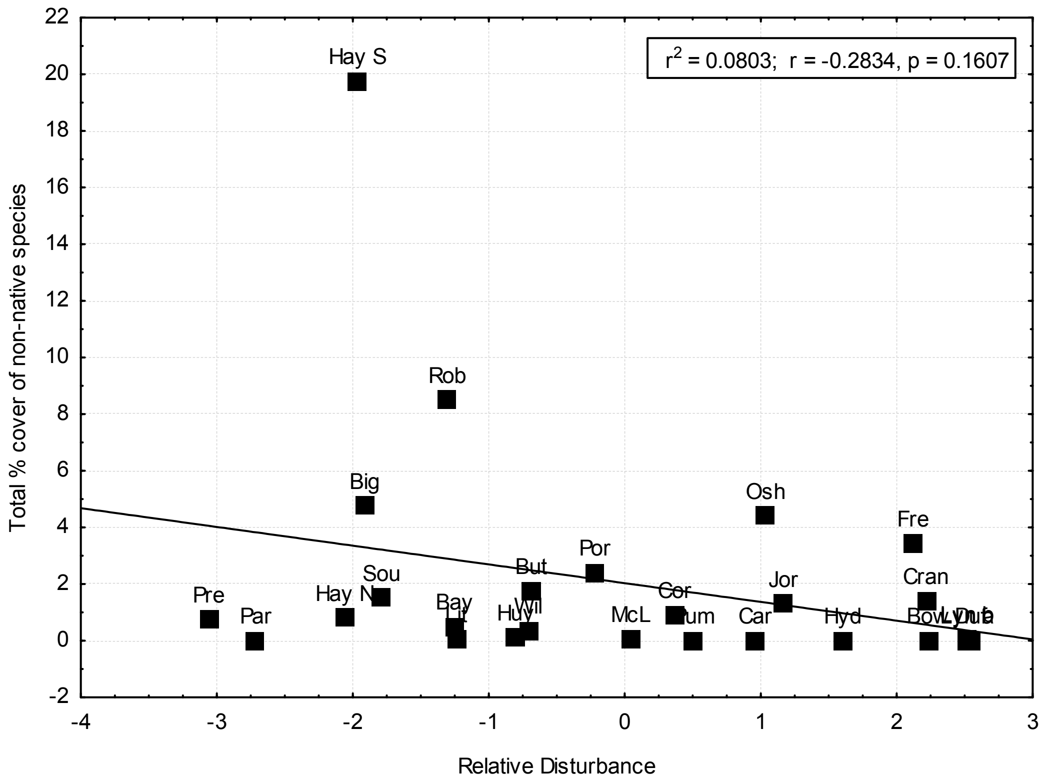


r² = 0.0165; r = 0.1283, p = 0.5322
Percent algal cover
Relative Disturbance
Por
Cran
Wil
Big
Hay S
Lyn b
Duf
Osh
Rob
Cor
Pum
Par
Pre
Hay N
Sou
Lit
Huy
But
McL
Car
Jor
Hyd
Bow
Lyn a



r² = 0.3847; r = -0.6202, p = 0.0007
Native species richness
Relative Disturbance
Pum
Par
Bay
Pre
Big
Rob
Hay S
Lit
Huy
Cor
Sou
Osh
Cran
Lyn a
Por
Jor
Bow
Wil
McL
Car
Hyd
Duf


r2 = 0.0040; r = -0.0636, p = 0.7577
Relative % cover non-native species
Relative Disturbance
Hay S
Fre
Rob
Jor
McL
Cor
Osh
Cran
Pre
Par
Sou
Bay
Huy
Pum
Car
Hyd


r2 = 0.0803; r = -0.2834, p = 0.1607
Total % cover of non-native species
Relative Disturbance
Hay S
Rob
Big
Osh
Fre
Por
Sou
But
Cor
Jor
Cran
Pre
Par
Hay N
Bay
McL
Car
Hyd

APPENDIX B

Table B-1 Presence and total abundance of aquatic macroinvertebrate species at Durham Region coastal wetlands.

Wetland Name	Class	Order	Family	Genus/Species	Total
Bowmanville Marsh	Crustacea	Amphipoda	Crangonyctidae	*Crangonyx*	11
			Gammaridae	*Gammarus pseudolimnaeus*	9
			Hyalellidae	*Hyalella azteca*	2
		Isopoda	Asellidae	*Caecidotea*	1
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	2
				Stagnicola elodes	2
			Physidae	*Physella gyrina*	2
			Planorbidae	*Gyraulus*	17
				Heliosoma anceps	1
				Promenetus exacuous	1
	Insecta	Coleoptera	Dytiscidae	*Ilybius*	1
				Laccornis	1
			Helophoridae	*Helophorus*	1
			Hydrophilidae	*Hydrobius*	1
				Tropisternus	1
		Diptera	Chironomidae	*Chironomini*	77
				Orthocladinae	30
			Stratiomyidae	*Odontomyia*	1
		Ephemeroptera	Baetidae	*Callibaetis*	7
		Hemiptera	Corixidae	*Palmacorixa*	25
			Mesoveliidae	*Mesovelia*	2
			Pleidae	*Neoplea striola*	1
		Odonata	Lestidae	*Lestes*	11
			Libellulidae	*Leucorrhinia frigida*	4
Carruther's Creek Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	58
			Hyalellidae	*Hyalella azteca*	10
		Isopoda	Asellidae	*Caecidotea*	3
	Gastropoda	Limnophila	Lymnaeidae	*Pseudosuccinea columella*	1
				Stagnicola elodes	5
			Physidae	*Physella gyrina*	14
			Planorbidae	*Gyraulus*	37
				Promenetus exacuous	2
	Insecta	Coleoptera	Halipidae	*Halipus*	5
			Helophoridae	*Helophorus*	1
			Hydrophilidae	*Berosus*	3
				Enochrus	2
				Hydrobius	1
				Paracymus	1
				Tropisternus	2
		Collembola	Poduridae	*Podura*	1
		Diptera	Chironomidae	*Chironomini*	69
				Orthocladinae	4

Table B-1 Continued.

			Stratiomyidae	*Odontomyia*	3
		Ephemeroptera	Baetidae	*Callibaetis*	3
		Hemiptera	Belostomatidae	*Belostoma*	1
			Corixidae	*Palmacorixa*	3
			Mesoveliidae	*Microvelia*	1
			Notonectidae	*Notonecta*	2
		Odonata	Aeshinidae	*Anax junius*	1
			Coenagrionidae	*Enallagma*	2
Corbett Creek Marsh	Bivalvia	Veneroida	Sphaeriidae	*Musculium*	1
	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	90
			Hyalellidae	*Hyalella azteca*	58
		Isopoda	Asellidae	*Caecidotea*	20
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	3
				Pseudosuccinea columella	1
			Physidae	*Physella gyrina*	12
			Planorbidae	*Gyraulus*	16
				Heliosoma anceps	1
	Insecta	Coleoptera	Dytiscidae	*Hydroporus*	3
				Hydrovatus pusillus	1
				Ilybius	4
			Halipidae	*Peltodytes*	1
			Hydrophilidae	*Berosus*	1
				Tropisternus	2
		Collembola	Poduridae	*Podura*	5
		Diptera	Chironomidae	*Chironomini*	89
				Orthocladinae	34
				Tanypodinae	2
			Stratiomyidae	*Odontomyia*	15
		Ephemeroptera	Baetidae	*Callibaetis*	4
		Hemiptera	Belostomatidae	*Belostoma*	2
			Corixidae	*Palmacorixa*	1
			Gerridae	*Gerris*	2
			Mesoveliidae	*Mesovelia*	7
			Notonectidae	*Notonecta*	1
			Veliidae	*Microvelia*	1
		Odonata	Aeshinidae	*Anax junius*	4
			Coenagrionidae	*Ishnura verticalis*	16
			Lestidae	*Lestes*	11
			Libellulidae	*Leucorrhinia frigida*	2

Table B-1 Continued.

Cranberry Marsh	Crustacea	Amphipoda	Hyalellidae	*Hyalella azteca*	106
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	1
				Pseudosuccinea columella	4
				Stagnicola elodes	4
			Physidae	*Physella gyrina*	5
			Planorbidae	*Gyraulus*	26
				Promenetus exacuous	3
	Insecta	Coleoptera	Dytiscidae	*Hydroporus*	8
				Laccornis	3
			Hydrophilidae	*Enochrus*	2
		Diptera	Ceratopogonidae	*Bezzia*	1
			Chironomidae	*Chironomini*	12
				Orthocladinae	7
				Tanypodinae	4
			Sciomyzidae	*Sepedon*	1
			Stratiomyidae	*Odontomyia*	1
		Hemiptera	Notonectidae	*Notonecta*	1
		Odonata	Aeshinidae	*Anax junius*	12
			Libellulidae	*Leucorrhinia frigida*	2
Duffin's Creek Marsh	Crustacea	Amphipoda	Crangonyctidae	*Crangonyx*	21
			Hyalellidae	*Hyalella azteca*	2
		Isopoda	Asellidae	*Caecidotea*	1
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	35
			Physidae	*Physella gyrina*	3
			Planorbidae	*Gyraulus*	36
				Heliosoma anceps	2
				Promenetus exacuous	1
	Insecta	Coleoptera	Halipidae	*Peltodytes*	2
			Hydrophilidae	*Berosus*	3
				Tropisternus	3
		Collembola	Poduridae	*Podura*	3
		Diptera	Chironomidae	*Chironomini*	76
				Orthocladinae	29
				Tanypodinae	11
			Sciomyzidae	*Sepedon*	1
		Ephemeroptera	Baetidae	*Callibaetis*	3
		Hemiptera	Belostomatidae	*Belostoma*	5
			Notonectidae	*Notonecta*	1
		Odonata	Lestidae	*Lestes*	1

Table B-1 Continued.

Frenchman's Bay Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	75
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	7
			Physidae	*Physella gyrina*	10
			Planorbidae	*Gyraulus*	54
	Insecta	Coleoptera	Hydrophilidae	*Hydrobius*	1
		Diptera	Chironomidae	*Chironomini*	72
				Orthocladinae	31
				Tanypodinae	4
				Tanytarsini	2
			Stratiomyidae	*Odontomyia*	3
		Ephemeroptera	Baetidae	*Callibaetis*	1
		Hemiptera	Mesoveliidae	*Mesovelia*	3
Hydro Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	12
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	2
				Pseudosuccinea columella	3
			Physidae	*Physella gyrina*	2
			Planorbidae	*Gyraulus*	17
	Insecta	Coleoptera	Hydrophilidae	*Berosus*	2
				Hydrobius	1
		Collembola	Poduridae	*Podura*	2
		Diptera	Chironomidae	*Chironomini*	53
				Orthocladinae	149
			Stratiomyidae	*Odontomyia*	2
		Hemiptera	Belostomatidae	*Belostoma*	3
			Corixidae	*Palmacorixa*	5
			Mesoveliidae	*Mesovelia*	2
			Notonectidae	*Notonecta*	1
		Odonata	Aeshinidae	*Anax junius*	1
Lynde Creek Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	88
			Hyalellidae	*Hyalella azteca*	1
		Isopoda	Asellidae	*Caecidotea*	2
	Gastropoda	Limnophila	Lymnaeidae	*Pseudosuccinea columella*	2
				Stagnicola elodes	2
			Physidae	*Physella gyrina*	1
			Planorbidae	*Gyraulus*	21
				Promenetus exacuous	5
		Mesogastropoda	Bithynidae	*Bithynia tentaculata*	3
			Hydrobiidae	*Amnicola limosa*	16
			Valvatidae	*Valvata sincera*	4

Table B-1 Continued.

	Insecta	Coleoptera	Hydrophilidae	*Paracymus*	1
				Tropisternus	1
		Diptera	Chironomidae	*Chironomini*	157
				Orthocladinae	1
				Tanytarsini	4
			Stratiomyidae	*Odontomyia*	4
		Hemiptera	Belostomatidae	*Belostoma*	1
			Corixidae	*Palmacorixa*	2
			Mesoveliidae	*Mesovelia*	3
			Pleidae	*Neoplea striola*	1
		Odonata	Coenagrionidae	*Ishnura verticalis*	3
			Lestidae	*Lestes*	3
McLaughlin Bay Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	7
			Hyalellidae	*Hyalella azteca*	12
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	2
			Physidae	*Physella gyrina*	7
			Planorbidae	*Gyraulus*	23
				Menetus cristata	1
	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	1
		Diptera	Chironomidae	*Chironomini*	17
				Orthocladinae	9
				Tanypodinae	1
		Ephemeroptera	Baetidae	*Callibaetis*	1
		Lepidoptera	Pyralidae	*Acentria*	2
		Odonata	Coenagrionidae	*Ishnura verticalis*	1
			Lestidae	*Lestes*	2
		Trichoptera	Leptoceridae	*Oecetis*	2
Oshawa Second Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	19
			Hyalellidae	*Hyalella azteca*	61
		Isopoda	Asellidae	*Caecidotea*	2
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	113
				Lymnaea stagnalis	1
				Pseudosuccinea columella	31
				Stagnicola elodes	8
			Physidae	*Physella gyrina*	65
			Planorbidae	*Gyraulus*	49
		Mesogastropoda	Valvatidae	*Valvata sincera*	1
	Insecta	Coleoptera	Dytiscidae	*Coptotomus*	1
				Hydroporus	4
				Hydrovatus pusillus	7
				Ilybius	1
				Laccophilus	5
			Halipidae	*Halipus*	1
				Peltodytes	5

Table B-1 Continued.

			Hydrophilidae	*Berosus*	2
				Enochrus	1
		Diptera	Ceratopogonidae	*Bezzia*	5
			Chironomidae	*Chironomini*	6
				Orthocladinae	11
			Sciomyzidae	*Sepedon*	1
		Hemiptera	Corixidae	*Palmacorixa*	1
			Gerridae	*Gerris*	2
			Mesoveliidae	*Mesovelia*	2
		Lepidoptera	Pyralidae	*Acentria*	35
		Odonata	Lestidae	*Lestes*	1
			Libellulidae	*Leucorrhinia frigida*	1
		Trichoptera	Leptoceridae	*Oecetis*	2
Port Newcastle Wetland	Bivalvia	Veneroida	Sphaeriidae	*Musculium*	14
	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	99
			Hyalellidae	*Hyalella azteca*	18
		Isopoda	Asellidae	*Caecidotea*	50
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	12
				Pseudosuccinea columella	1
				Stagnicola elodes	9
			Physidae	*Physella gyrina*	1
			Planorbidae	*Gyraulus*	14
				Promenetus exacuous	11
		Mesogastropoda	Valvatidae	*Valvata sincera*	23
	Insecta	Coleoptera	Elmidae	*Stenelmis*	1
			Gyrinidae	*Gyrinus*	1
			Helophoridae	*Helophorus*	1
			Hydrochidae	*Hydrochus*	1
			Hydrophilidae	*Enochrus*	1
				Hydrobius	1
		Diptera	Chironomidae	*Chironomini*	57
				Orthocladinae	29
				Tanypodinae	2
				Tanytarsini	32
		Ephemeroptera	Baetidae	*Callibaetis*	12
		Hemiptera	Corixidae	*Palmacorixa*	2
		Odonata	Aeshinidae	*Anax junius*	5
			Corduliidae	*Somatochlora*	9
			Lestidae	*Lestes*	38
		Trichoptera	Hydroptilidae	*Ochrotrichia*	3
			Leptoceridae	*Nectopsyche*	6

Table B-1 Continued.

Pumphouse Marsh	Bivalvia	Veneroida	Sphaeriidae	*Musculium*	10
				Pisidium	5
	Crustacea	Amphipoda	Hyalellidae	*Hyalella azteca*	257
		Isopoda	Asellidae	*Caecidotea*	3
	Gastropoda	Limnophila	Lymnaeidae	*Lymnaea stagnalis*	2
				Pseudosuccinea columella	1
				Stagnicola elodes	1
			Physidae	*Physella gyrina*	23
			Planorbidae	*Gyraulus*	21
				Heliosoma anceps	5
				Menetus cristata	2
				Physella gyrina	4
				Promenetus exacuous	12
	Insecta	Coleoptera	Dytiscidae	*Hydrovatus pusillus*	3
				Ilybius	1
				Laccornis	6
			Hydrophilidae	*Paracymus*	1
				Tropisternus	2
			Scirtidae	*Cyphon*	20
		Diptera	Chironomidae	*Chironomini*	21
				Orthocladinae	1
				Tanypodinae	1
			Sciomyzidae	*Sepedon*	1
		Ephemeroptera	Baetidae	*Callibaetis*	2
			Caenidae	*Caenis*	5
		Hemiptera	Belostomatidae	*Belostoma*	2
			Corixidae	*Palmacorixa*	17
			Gerridae	*Aquarius*	1
				Gerris	10
			Mesoveliidae	*Mesovelia*	3
			Notonectidae	*Notonecta*	1
			Veliidae	*Microvelia*	7
		Megaloptera	Corydalidae	*Chauliodes rastricornis*	2
		Odonata	Aeshinidae	*Anax junius*	1
			Coenagrionidae	*Enallagma*	2
				Ishnura verticalis	1
			Lestidae	*Lestes*	2
Rouge River Marsh	Bivalvia	Veneroida	Sphaeriidae	*Musculium*	3
				Pisidium	1
	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	5
			Hyalellidae	*Hyalella azteca*	3
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	9
				Lymnaea stagnalis	1
				Stagnicola elodes	2

Table B-1 Continued.

			Physidae	*Physella gyrina*	3
			Planorbidae	*Gyraulus*	33
				Menetus cristata	2
				Promenetus exacuous	10
	Insecta	Coleoptera	Dytiscidae	*Laccophilus*	1
				Liodessus	1
			Elmidae	*Stenelmis*	3
			Gyrinidae	*Gyrinus*	2
			Halipidae	*Halipus*	2
				Peltodytes	1
			Hydrophilidae	*Berosus*	12
				Tropisternus	4
		Collembola	Poduridae	*Podura*	1
		Diptera	Chironomidae	*Chironomini*	149
				Orthocladinae	14
				Tanypodinae	4
				Tanytarsini	6
		Ephemeroptera	Baetidae	*Callibaetis*	16
			Caenidae	*Caenis*	27
		Hemiptera	Belostomatidae	*Belostoma*	8
			Corixidae	*Palmacorixa*	11
			Gerridae	*Aquarius*	1
			Mesoveliidae	*Mesovelia*	1
			Pleidae	*Neoplea striola*	12
			Veliidae	*Microvelia*	3
		Odonata	Aeshinidae	*Anax junius*	1
			Corduliidae	*Somatochlora*	1
			Lestidae	*Lestes*	3
		Trichoptera	Hydroptilidae	*Hydroptila*	1
			Leptoceridae	*Nectopsyche*	3
West Side Beach Marsh	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	18
			Hyalellidae	*Hyalella azteca*	125
		Isopoda	Asellidae	*Caecidotea*	8
	Gastropoda	Limnophila	Lymnaeidae	*Fossaria exigua*	2
			Physidae	*Physella gyrina*	6
			Planorbidae	*Gyraulus*	4
	Insecta	Coleoptera	Dytiscidae	*Hydrovatus pusillus*	2
				Laccornis	1
			Hydrophilidae	*Hydrobius*	1
			Scirtidae	*Cyphon*	2
		Collembola	Poduridae	*Podura*	2
		Diptera	Chironomidae	*Chironomini*	48
				Orthocladinae	13
			Stratiomyidae	*Odontomyia*	3
		Ephemeroptera	Caenidae	*Caenis*	6

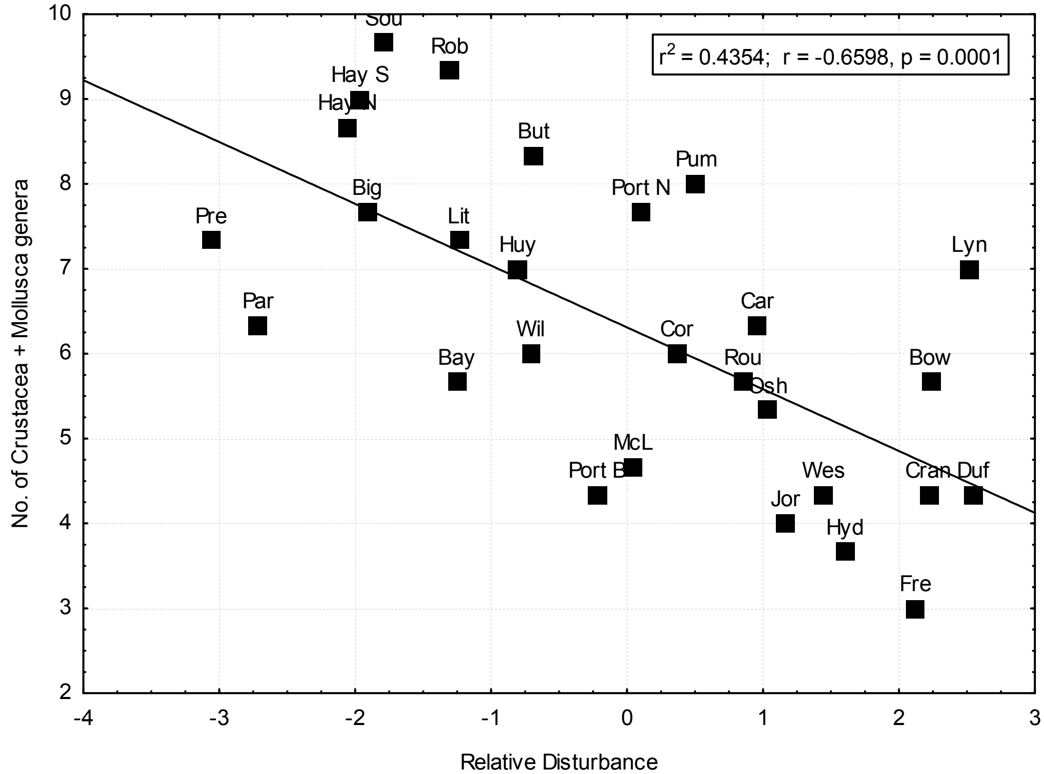
Table B-1 Continued.

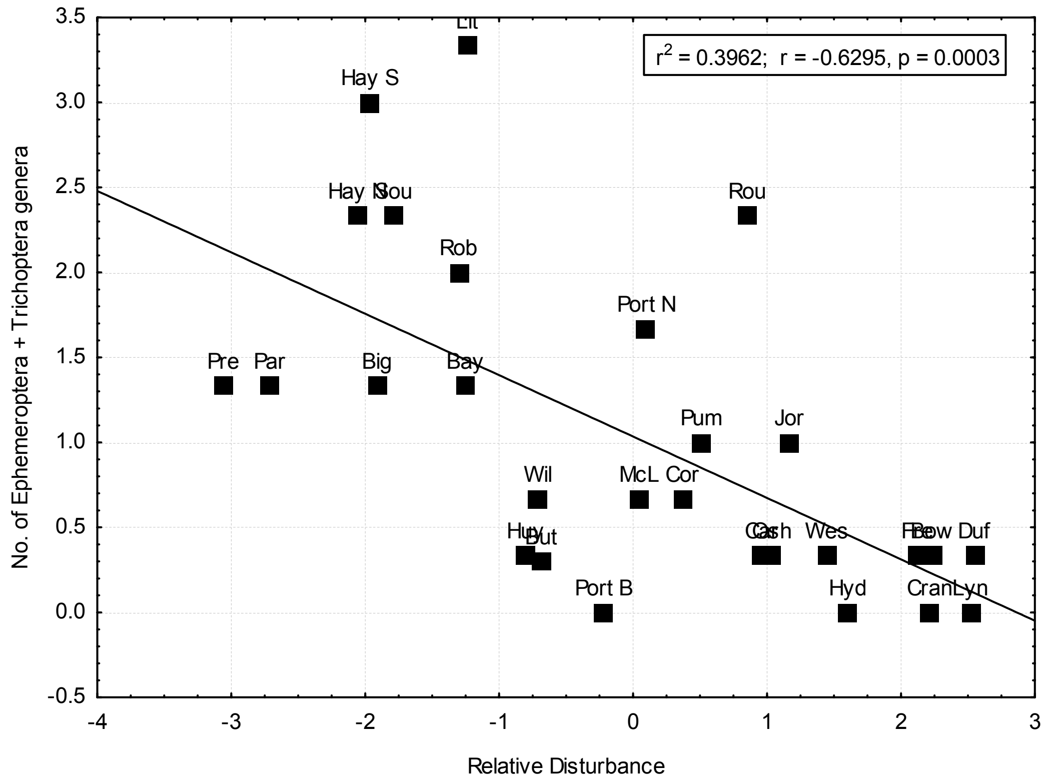
		Hemiptera	Corixidae	*Palmacorixa*	3
			Mesoveliidae	*Mesovelia*	2
			Notonectidae	*Buenoa*	1
			Pleidae	*Neoplea striola*	1
			Veliidae	*Microvelia*	5
		Odonata	Coenagrionidae	*Enallagma*	1
				Ishnura verticalis	9
Wilmot Rivermouth Wetland	Bivalvia	Veneroida	Sphaeriidae	*Musculium*	4
	Crustacea	Amphipoda	Gammaridae	*Gammarus pseudolimnaeus*	29
			Hyalellidae	*Hyalella azteca*	141
		Isopoda	Asellidae	*Caecidotea*	64
	Gastropoda	Limnophila	Physidae	*Physella gyrina*	6
			Planorbidae	*Gyraulus*	5
				Promenetus exacuous	1
		Mesogastropoda	Hydrobiidae	*Amnicola limosa*	3
			Valvatidae	*Valvata sincera*	3
	Insecta	Coleoptera	Halipidae	*Halipus*	9
		Diptera	Chironomidae	*Chironomini*	50
				Orthocladinae	30
		Ephemeroptera	Baetidae	*Callibaetis*	5
			Caenidae	*Caenis*	2
		Hemiptera	Corixidae	*Palmacorixa*	5
			Mesoveliidae	*Mesovelia*	4
			Nepidae	*Ranatra*	1
			Notonectidae	*Buenoa*	1
			Veliidae	*Microvelia*	1
		Megaloptera	Corydalidae	*Chauliodes rastricornis*	1
		Odonata	Coenagrionidae	*Enallagma*	1
				Ishnura verticalis	2
			Lestidae	*Lestes*	4

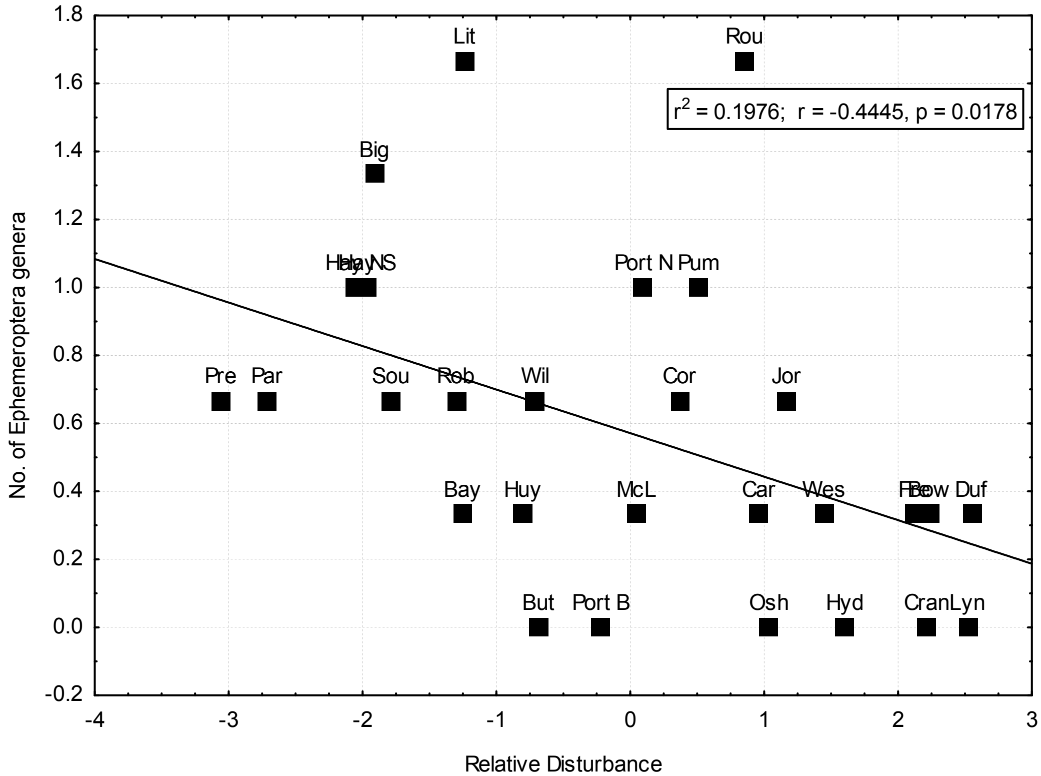
Table B-2. Site codes for wetlands used in disturbance vs. aquatic macroinvertebrate metric plots.

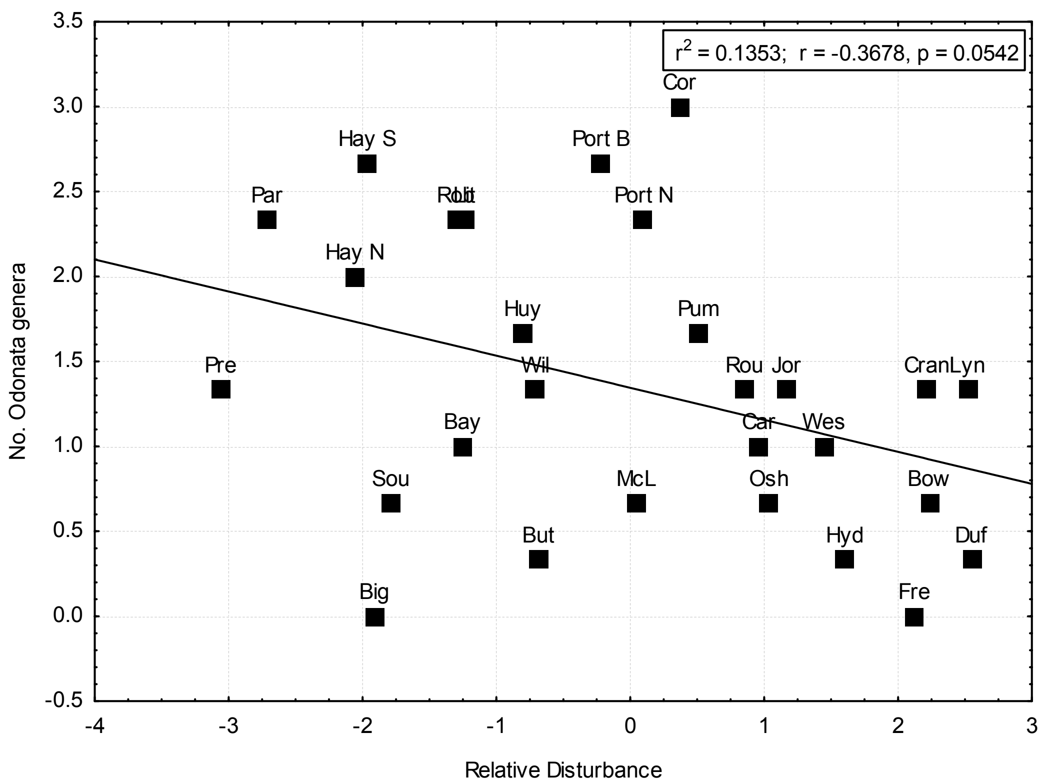
Site Code	Wetland Name
Bay	Bayfield Bay
Big	Big Sand Bay
Bow	Bowmanville Marsh
But	Button Bay
Car	Carruthers Creek Marsh
Cor	Corbett Creek Marsh
Cran	Cranberry Marsh
Duf	Duffins Creek Marsh
Fre	Frenchman's Bay
Hay N	Hay Bay North
Hay S	Hay Bay South
Huy	Huyck's Bay
Hyd	Hydro Marsh
Jor	Jordan Station
Lit	Little Catarqui Creek
Lyn	Lynde Creek Marsh
McL	McLaughlin Bay Marsh
Osh	Oshawa Second Marsh
Par	Parrott's Bay
Port B	Port Britain
Port N	Port Newcastle Wetland
Pre	Presqu'ile Bay
Pum	Pumphouse Marsh
Rob	Robinson's Cove
Rou	Rouge River Marsh
Sou	South Bay
Wes	West Side Beach Marsh

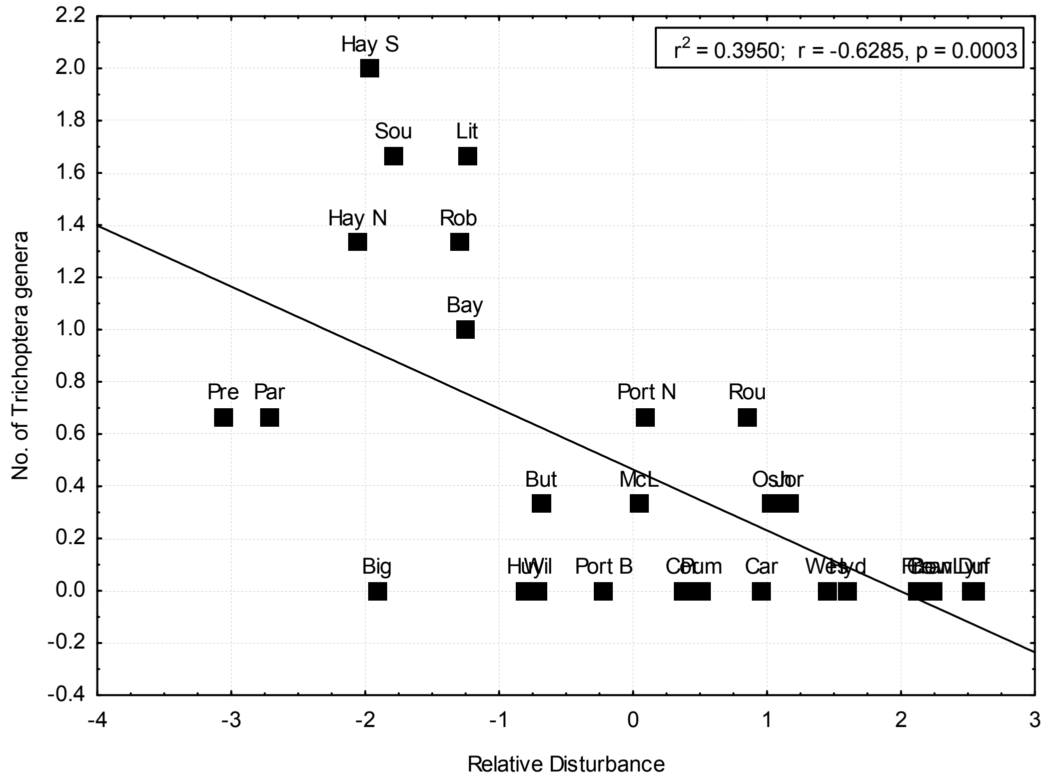
The following graphs are all aquatic macroinvertebrate community metrics assessed against wetland disturbance.

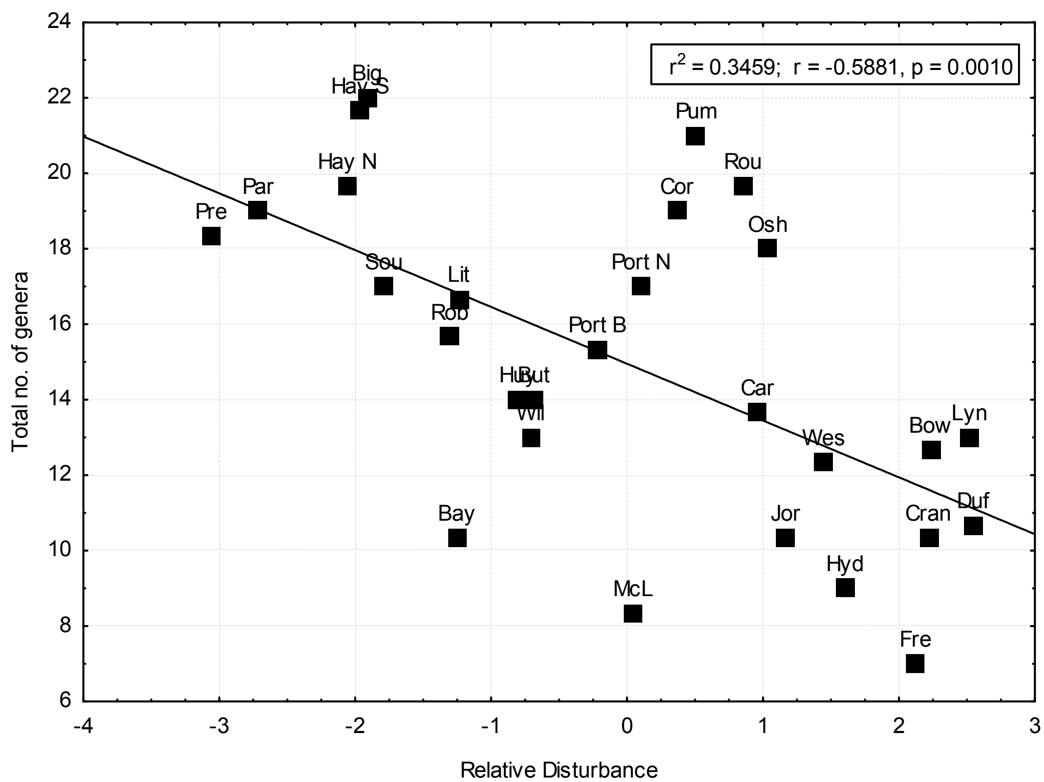

r² = 0.4354; r = -0.6598, p = 0.0001
No. of Crustacea + Mollusca genera
Relative Disturbance
Sou
Rob
Hay S
Hay N
But
Pum
Port N
Big
Pre
Lit
Huy
Lyn
Par
Car
Wil
Cor
Bay
Rou
Bow
Osh
McL
Port B
Wes
Cran
Duf
Jor
Hyd
Fre

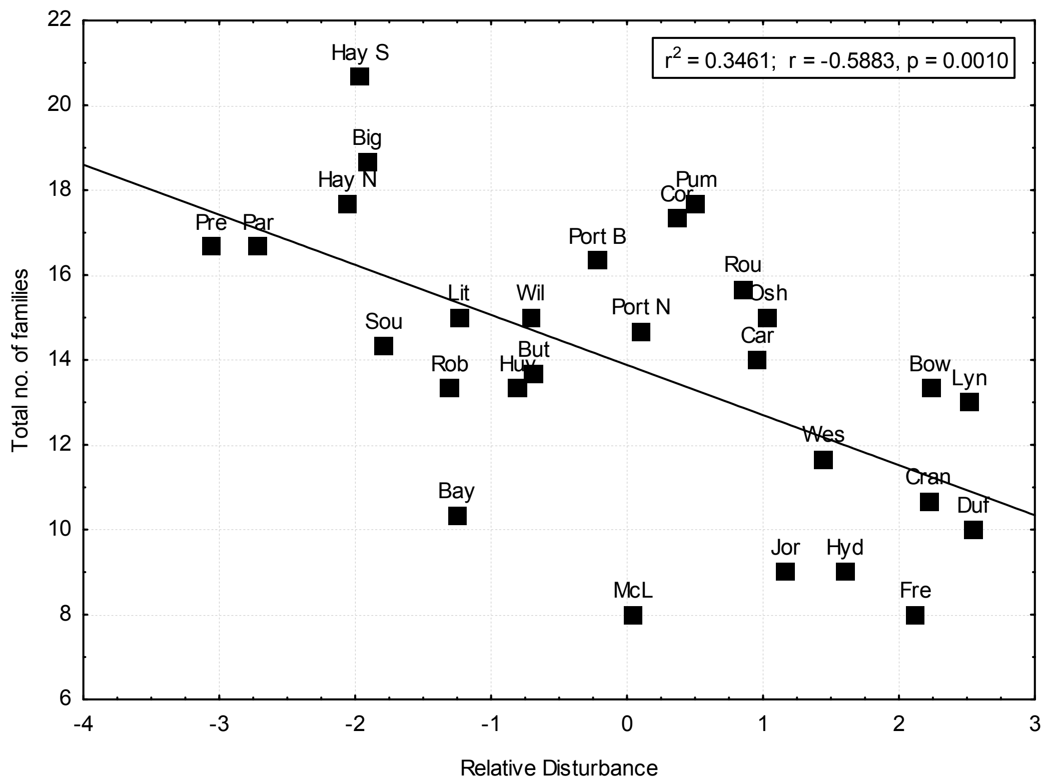

r² = 0.3962; r = -0.6295, p = 0.0003
No. of Ephemeroptera + Trichoptera genera
Relative Disturbance
Lit
Hay S
Hay N
Sou
Rou
Rob
Port N
Pre
Par
Big
Bay
Pum
Jor
Wil
McL
Cor
Huy
But
Car
Osh
Wes
Fre
Bow
Duf
Port B
Hyd
Cran
Lyn

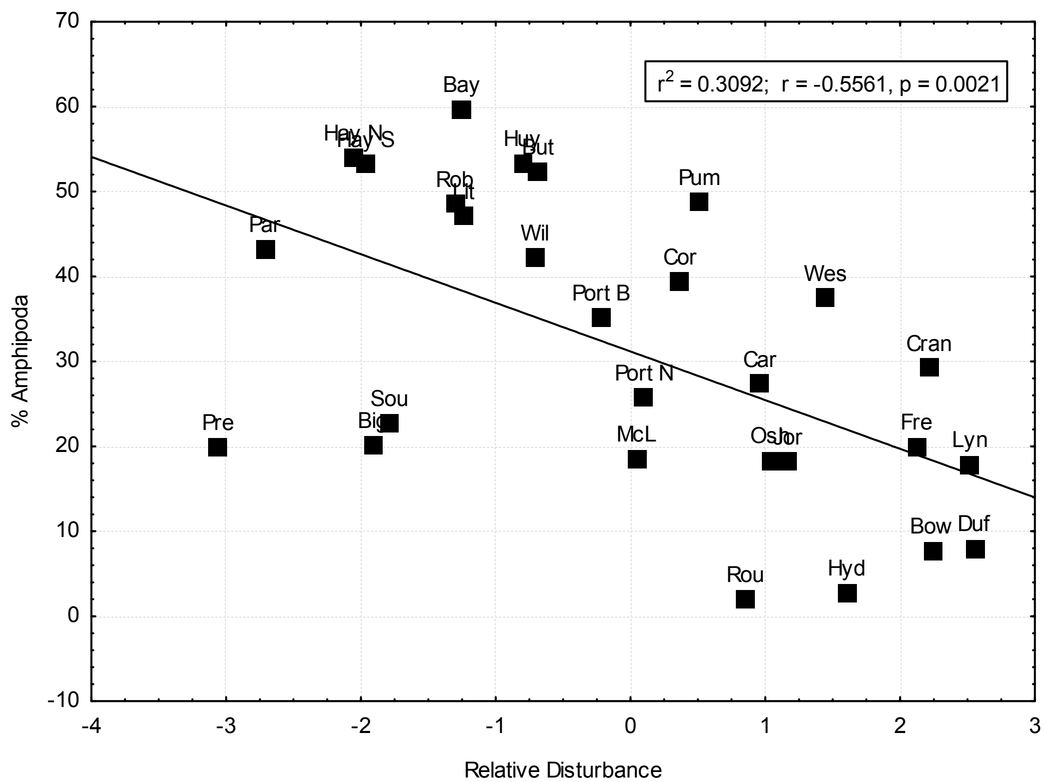

r² = 0.1976; r = -0.4445, p = 0.0178
No. of Ephemeroptera genera
Relative Disturbance
Lit
Rou
Big
Port N
Pum
Pre
Par
Sou
Rob
Wil
Cor
Jor
Bay
Huy
McL
Car
Wes
Duf
But
Port B
Osh
Hyd
CranLyn

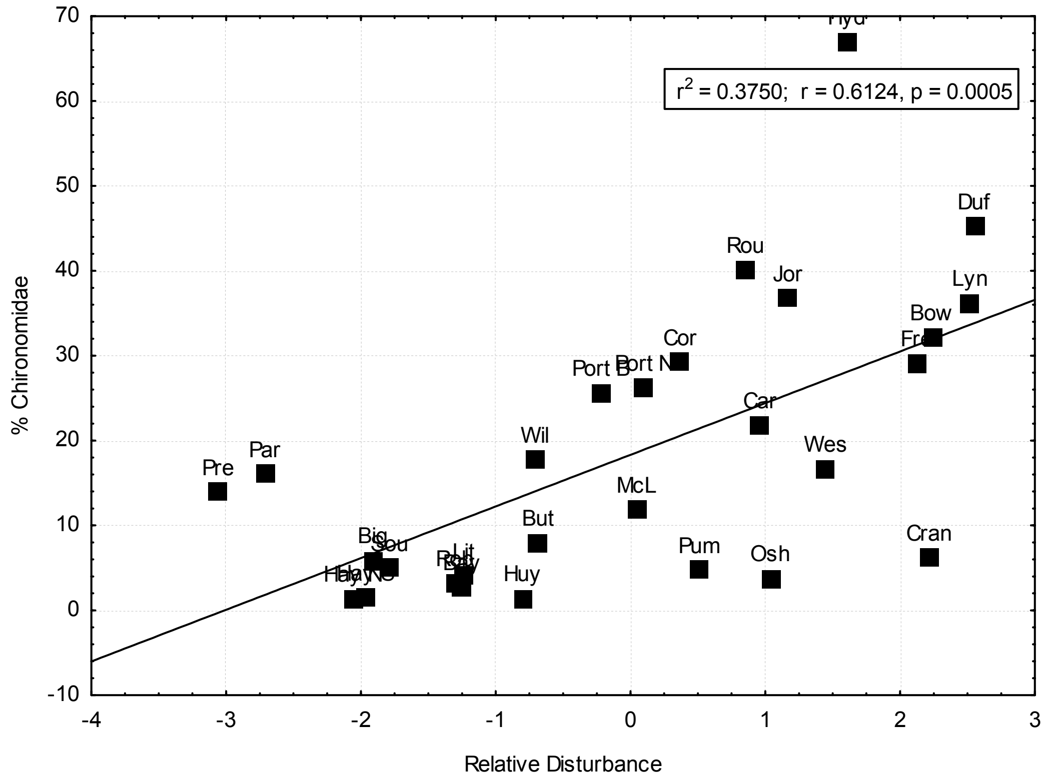

r² = 0.1353; r = -0.3678, p = 0.0542
No. Odonata genera
Relative Disturbance
Cor
Hay S
Port B
Par
Port N
Hay N
Huy
Pum
Pre
Wil
Rou
Jor
CranLyn
Bay
Car
Wes
Sou
McL
Osh
Bow
But
Hyd
Duf
Big
Fre


r^2 = 0.3950; r = -0.6285, p = 0.0003
No. of Trichoptera genera
Relative Disturbance
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-4
-3
-2
-1
0
1
2
3
Hay S
Sou
Lit
Hay N
Rob
Bay
Pre
Par
Port N
Rou
But
McL
Big
Port B
Car

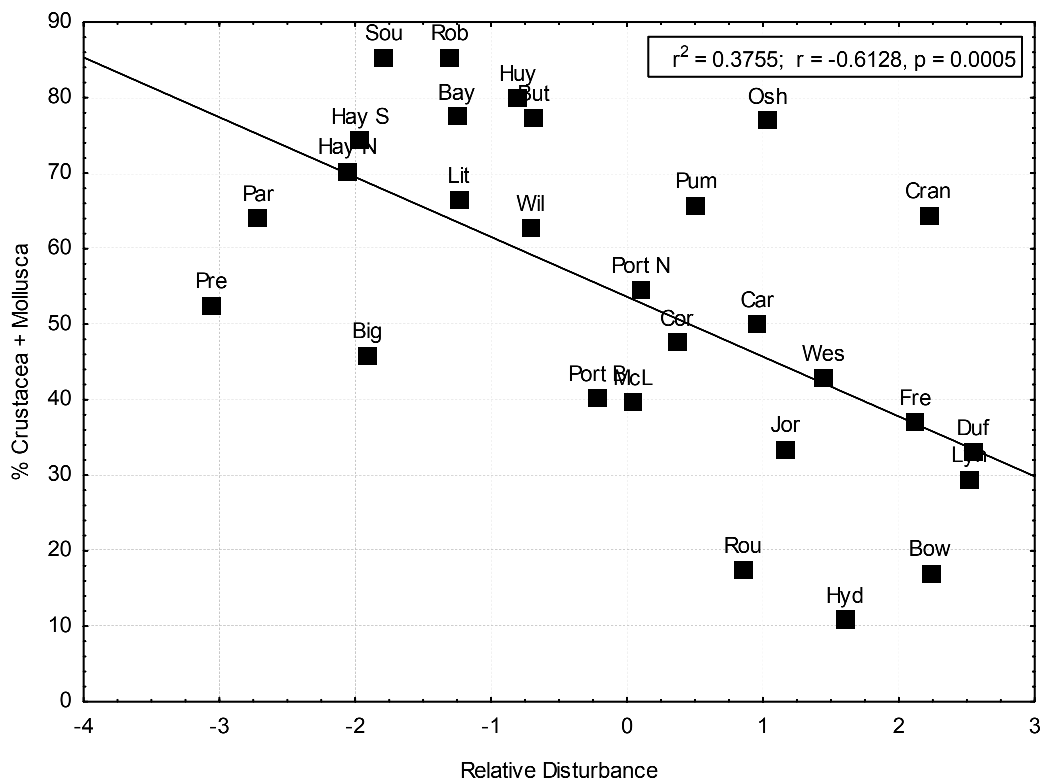

r^2 = 0.3459; r = -0.5881, p = 0.0010
Total no. of genera
Relative Disturbance
24
22
20
18
16
14
12
10
8
6
-4
-3
-2
-1
0
1
2
3
Big
Hay S
Pum
Hay N
Rou
Par
Cor
Pre
Osh
Sou
Lit
Port N
Rob
Port B
Wil
Car
Lyn
Bow
Wes
Bay
Jor
Cran
Duf
Hyd
McL
Fre


r² = 0.3461; r = -0.5883, p = 0.0010
Total no. of families
Relative Disturbance
Hay S
Big
Hay N
Pre
Par
Pum
Cor
Port B
Rou
Osh
Lit
Wil
Port N
Sou
Car
But
Rob
Huy
Bow
Lyn
Wes
Cran
Duf
Bay
Jor
Hyd
McL
Fre

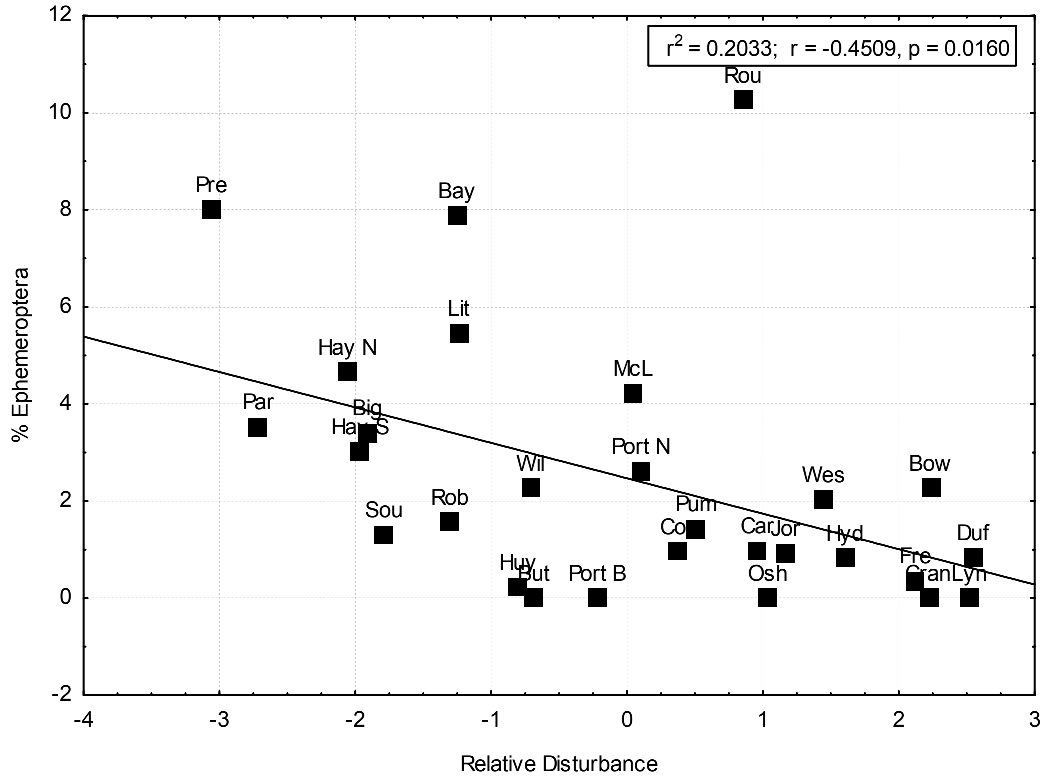

r² = 0.3092; r = -0.5561, p = 0.0021
% Amphipoda
Relative Disturbance
Bay
Hay N
Hay S
Huy
But
Rob
Lit
Pum
Par
Wil
Cor
Wes
Port B
Cran
Car
Port N
Sou
Pre
Big
McL
Osh
Jor
Fre
Lyn
Bow
Duf
Rou
Hyd



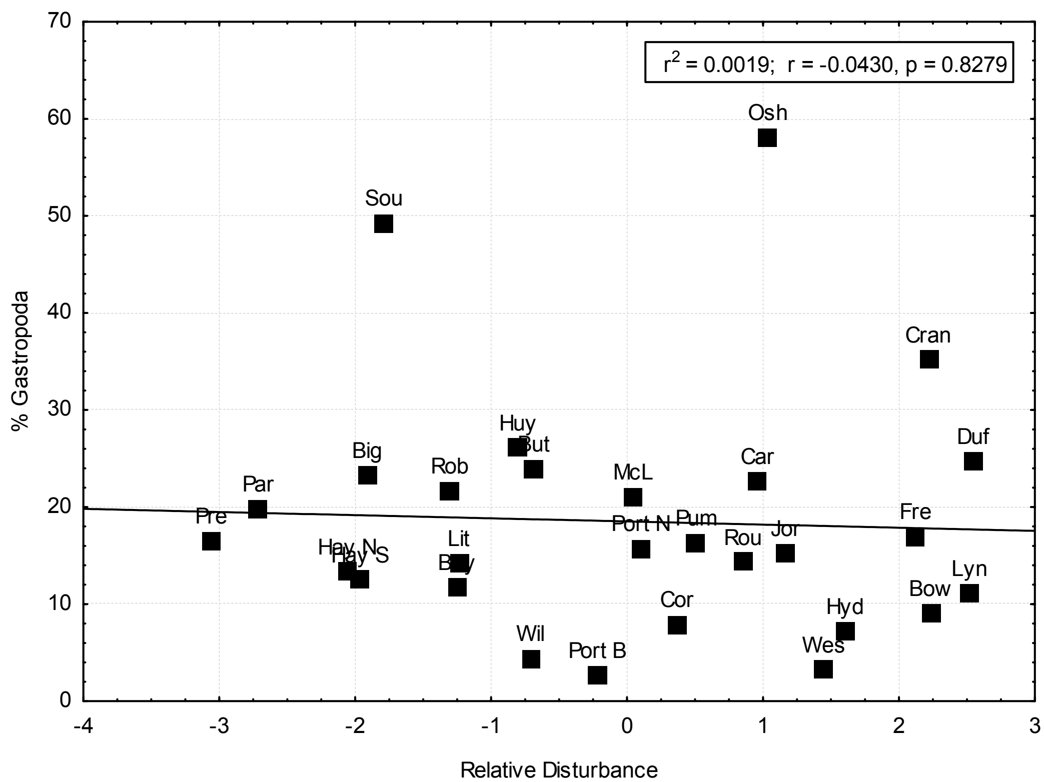
r² = 0.3750; r = 0.6124, p = 0.0005
% Chironomidae
Relative Disturbance
Hyd
Duf
Rou
Jor
Lyn
Bow
Fre
Cor
Port B
Port N
Car
Wil
Wes
Pre
Par
McL
But
Cran
Big
Sou
Pum
Osh
Huy



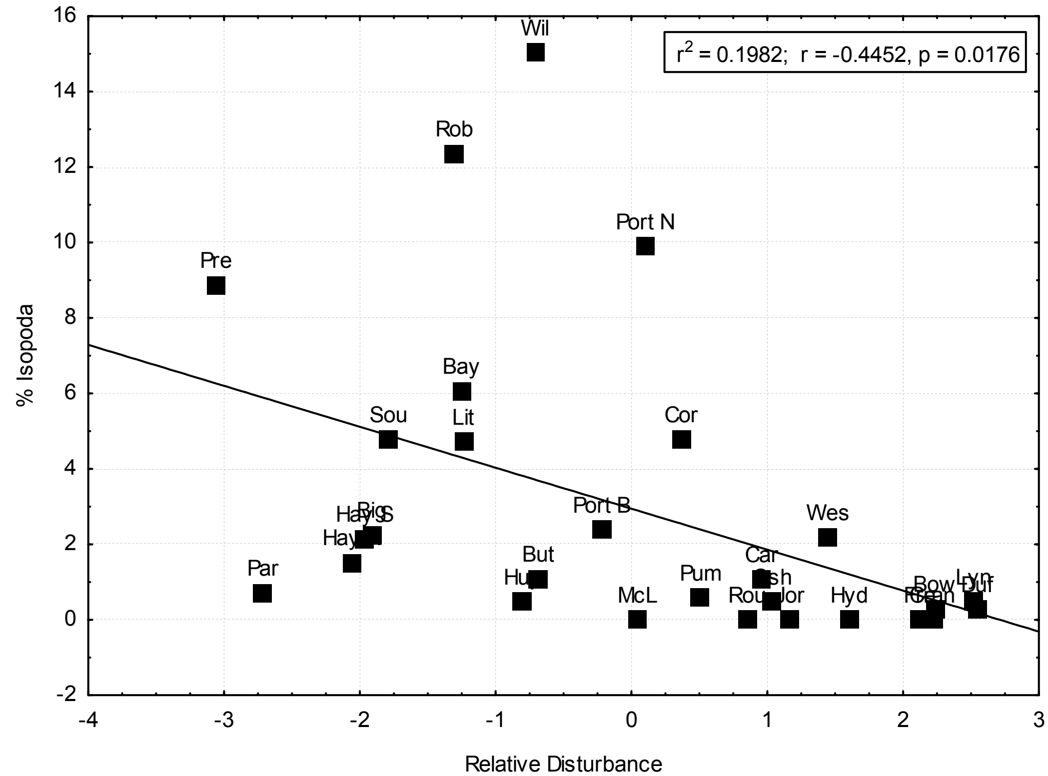
r² = 0.3755; r = -0.6128, p = 0.0005
% Crustacea + Mollusca
Relative Disturbance
Sou
Rob
Huy
Bay
But
Osh
Hay S
Hay N
Lit
Pum
Cran
Par
Wil
Port N
Pre
Car
Cor
Big
Wes
Port B
McL
Fre
Jor
Duf
Rou
Bow
Hyd



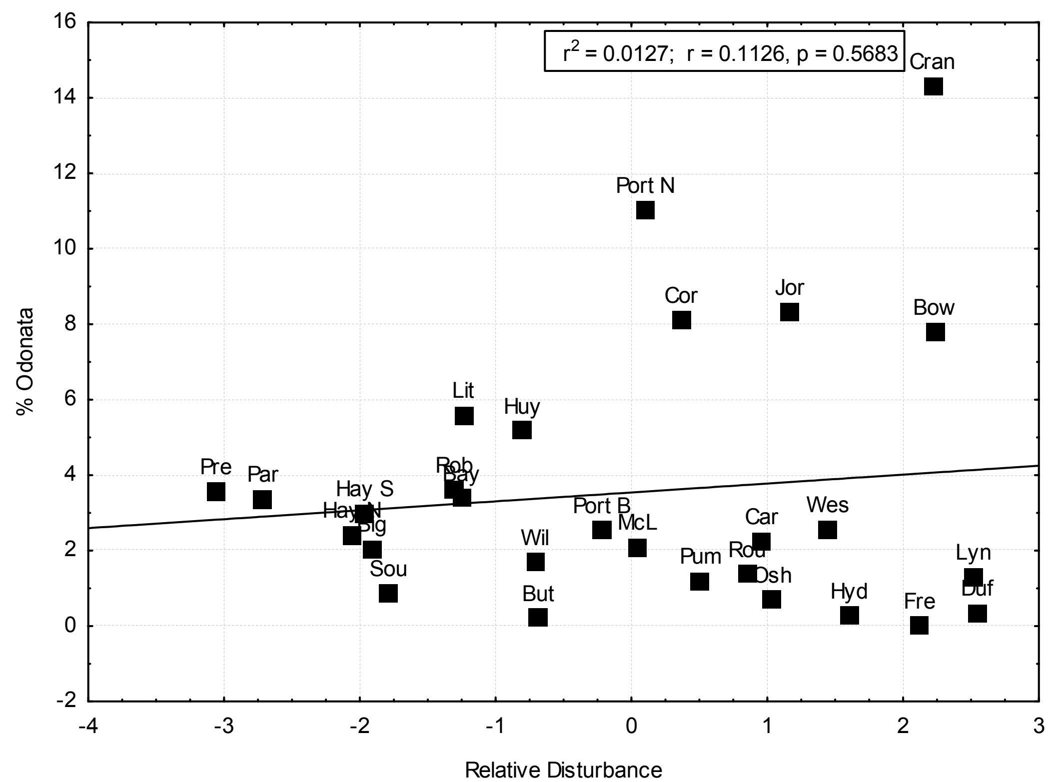
r^2 = 0.2033; r = -0.4509, p = 0.0160
% Ephemeroptera
Relative Disturbance
Rou
Pre
Bay
Lit
Hay N
McL
Par
Big
Hay S
Port N
Wil
Wes
Bow
Rob
Sou
Pum
Cor
Car
Jor
Hyd
Duf
Fre
Huy
But
Port B
Osh
Cran
Lyn



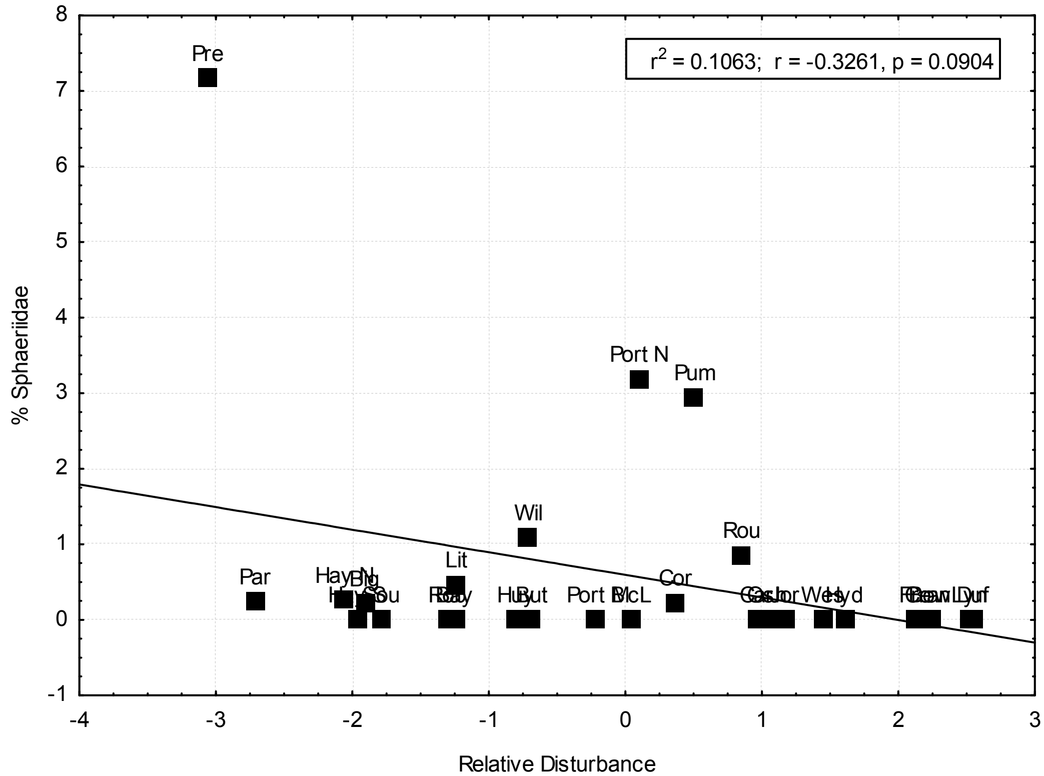
r^2 = 0.0019; r = -0.0430, p = 0.8279
% Gastropoda
Relative Disturbance
Osh
Sou
Cran
Huy
But
Big
Rob
McL
Car
Duf
Par
Pre
Port N
Pum
Fre
Hay N
Hay S
Lit
Bay
Rou
Jor
Lyn
Cor
Hyd
Bow
Wil
Port B
Wes

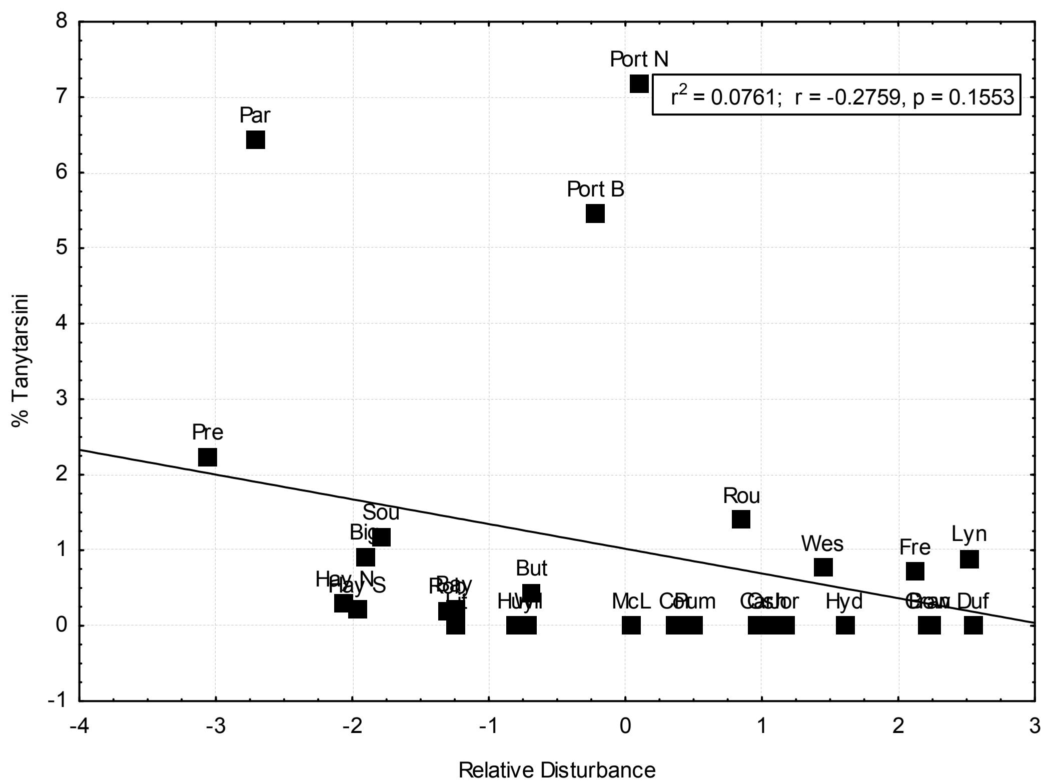


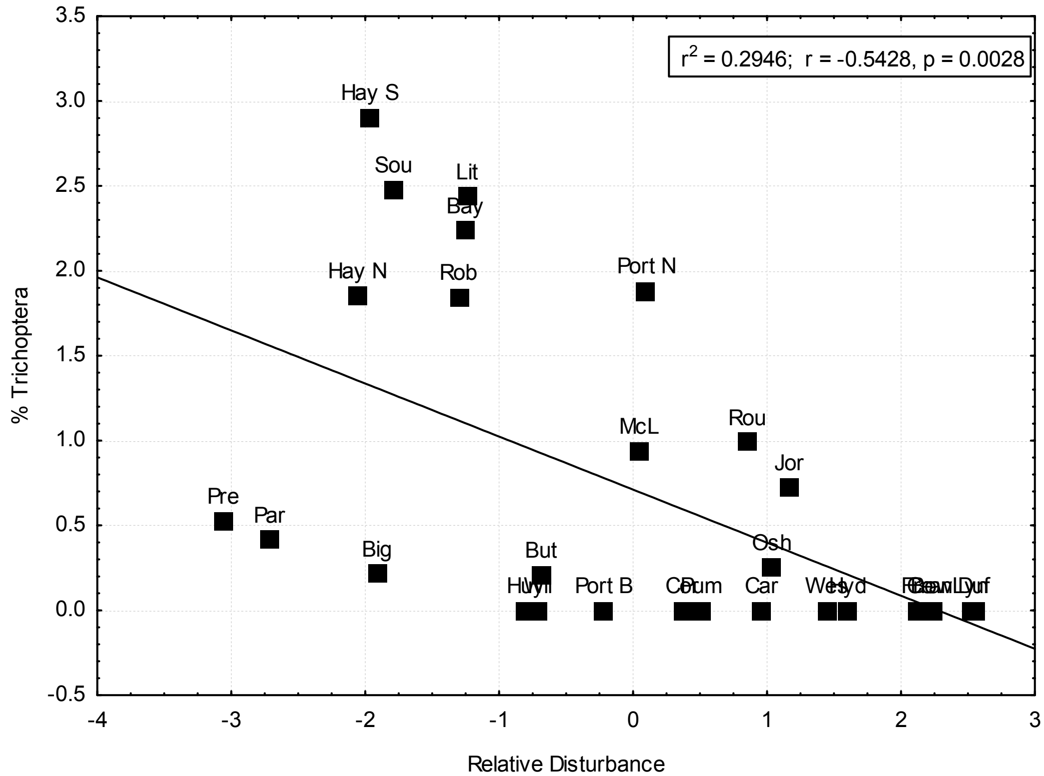
r2 = 0.1982; r = -0.4452, p = 0.0176
% Isopoda
Relative Disturbance
Wil
Rob
Port N
Pre
Bay
Sou
Lit
Cor
Port B
Wes
But
Par
Pum
McL
Car
Hyd
Bow
Lyn
Duf

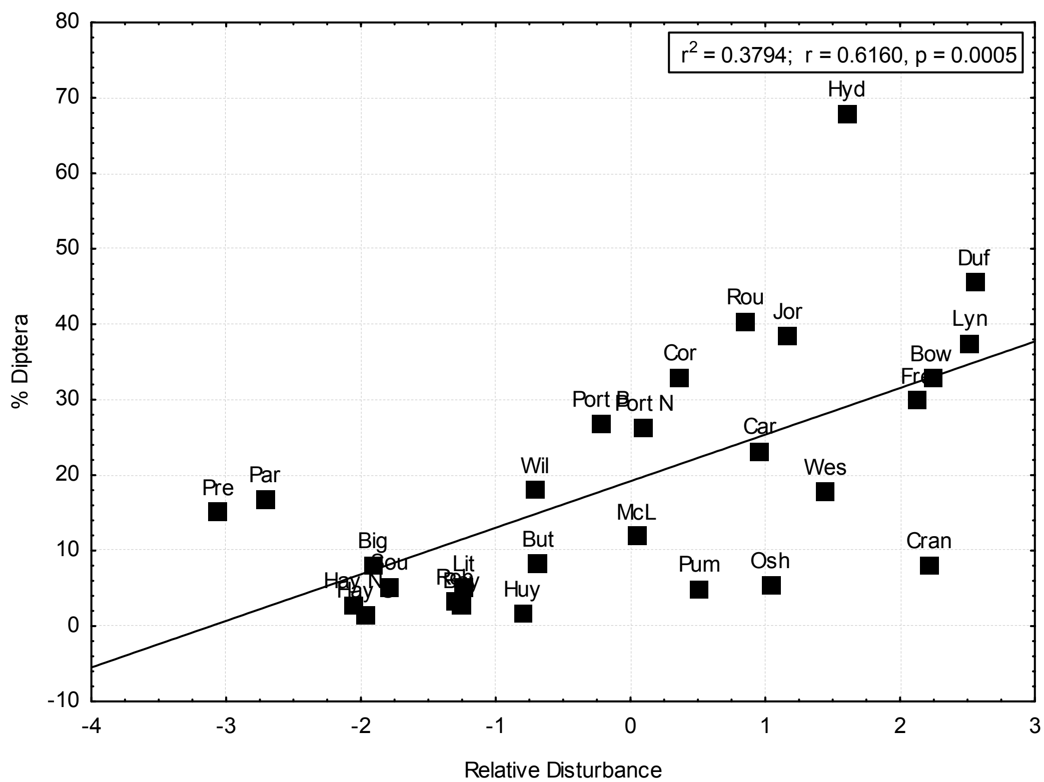


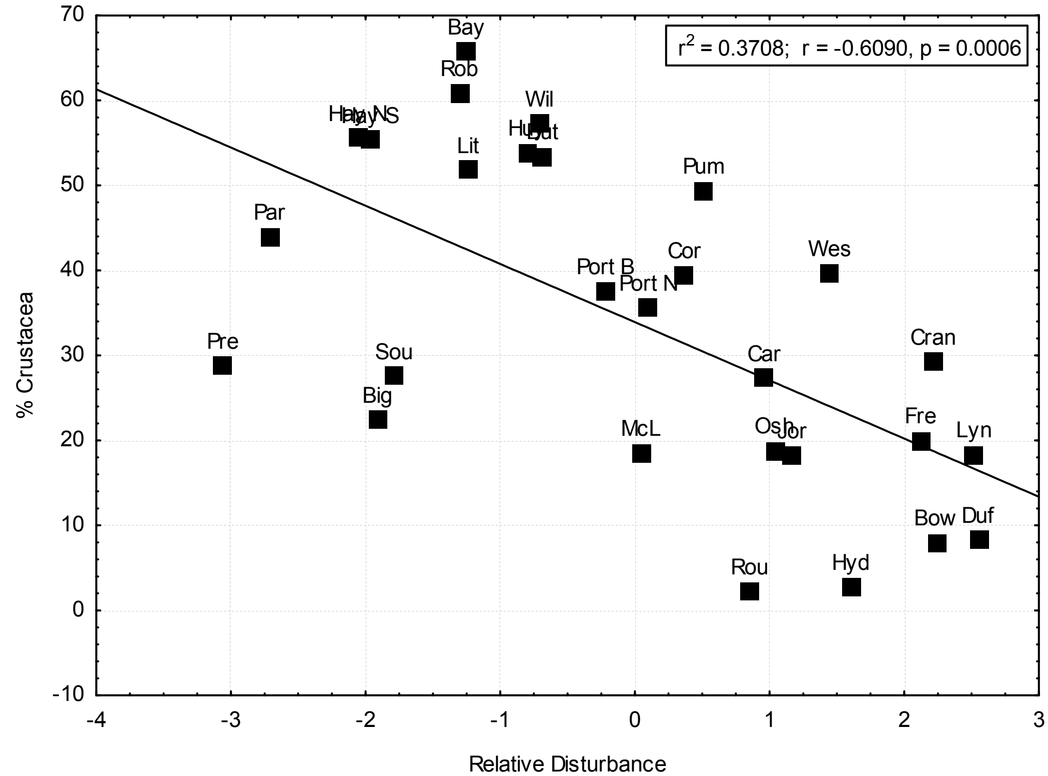
r2 = 0.0127; r = 0.1126, p = 0.5683
% Odonata
Relative Disturbance
Cran
Port N
Cor
Jor
Bow
Lit
Huy
Pre
Par
Hay S
Port B
McL
Wes
Car
Wil
Pum
Sou
But
Hyd
Fre
Lyn
Duf

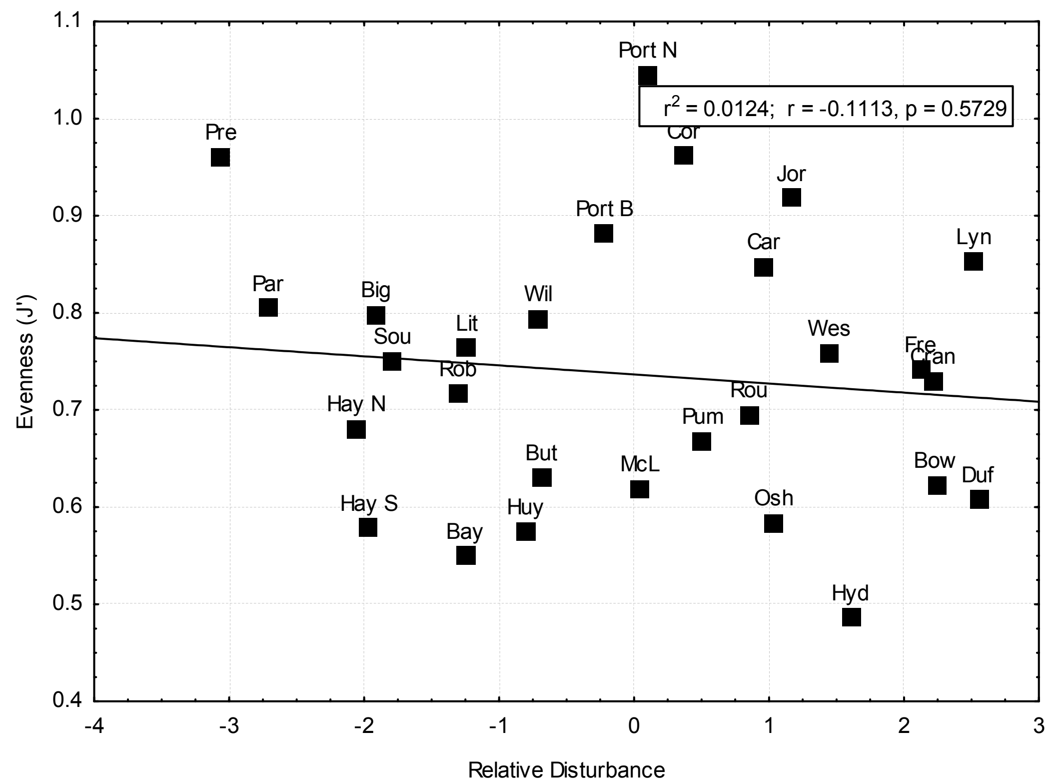

r2 = 0.1063; r = -0.3261, p = 0.0904
% Sphaeriidae
Relative Disturbance
Pre
Port N
Pum
Wil
Rou
Par
Lit
Cor
Hyd
Duf

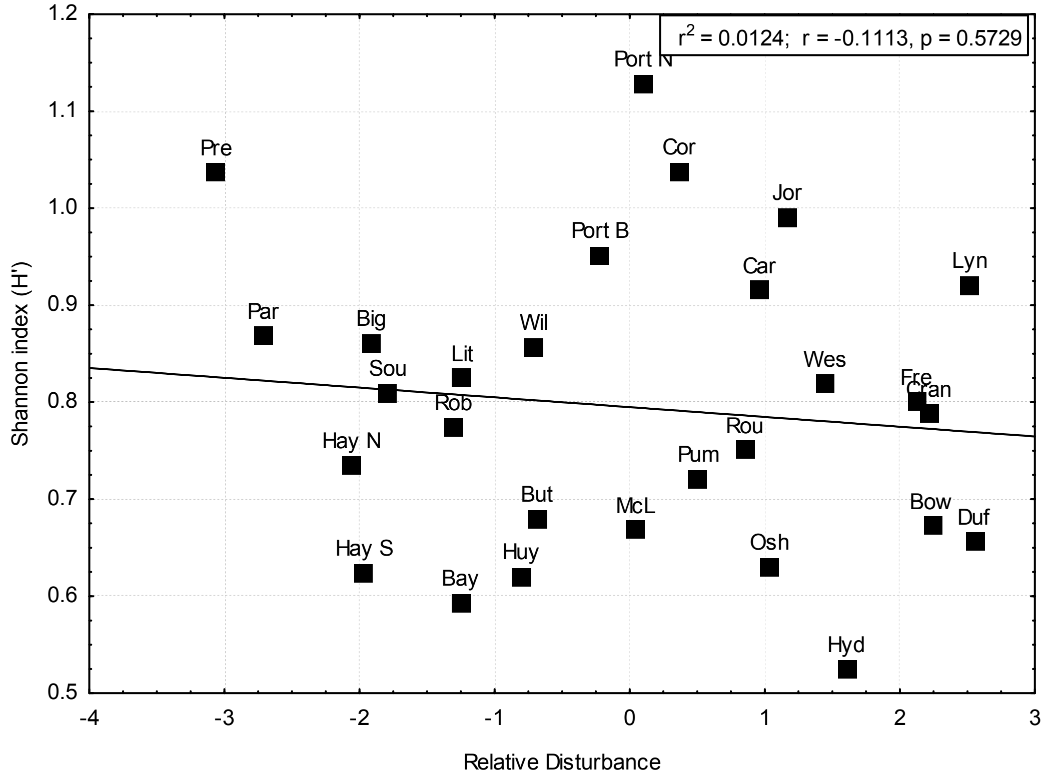

r2 = 0.0761; r = -0.2759, p = 0.1553
% Tanytarsini
Relative Disturbance
Port N
Par
Port B
Pre
Rou
Sou
Wes
Fre
Lyn
But
McL
Hyd
Duf


r² = 0.2946; r = -0.5428, p = 0.0028
% Trichoptera
Relative Disturbance
Hay S
Sou
Lit
Bay
Hay N
Rob
Port N
McL
Rou
Jor
Pre
Par
Big
But
Osh
Huy
Wil
Port B
Cor
Pum
Car
Wes
Hyd
Duf

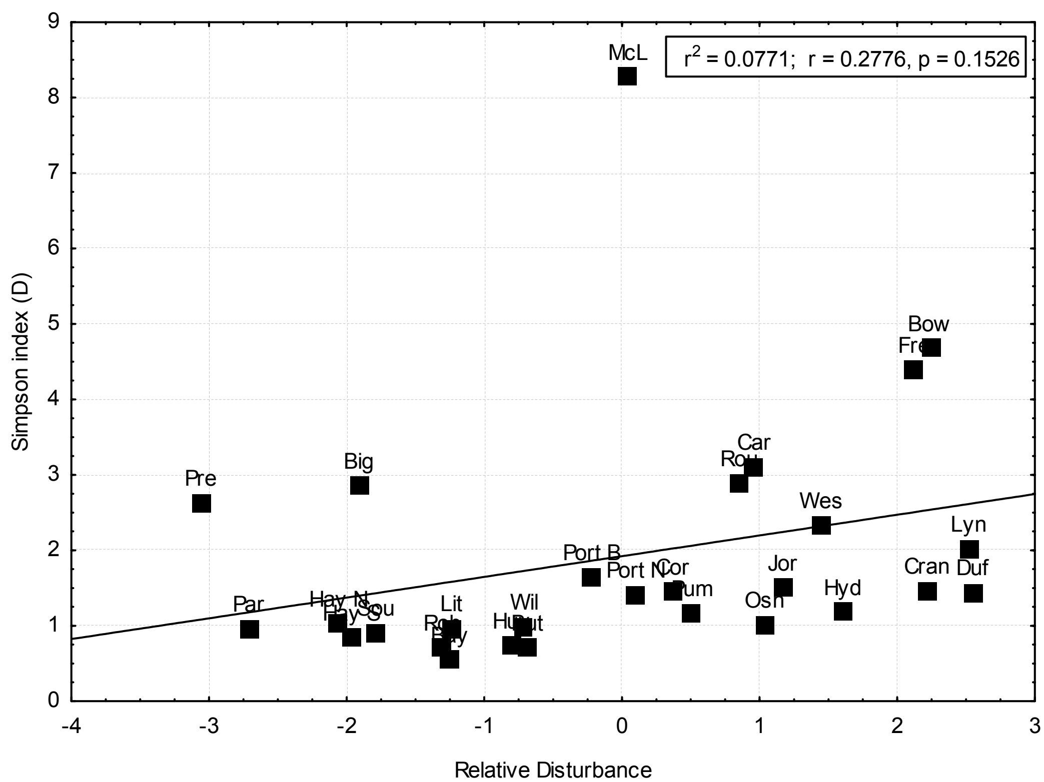

r² = 0.3794; r = 0.6160, p = 0.0005
% Diptera
Relative Disturbance
Hyd
Duf
Rou
Jor
Lyn
Cor
Bow
Port B
Port N
Car
Pre
Par
Wil
Wes
McL
Big
But
Cran
Lit
Hay N
Huy
Pum
Osh


r² = 0.3708; r = -0.6090, p = 0.0006
% Crustacea
Relative Disturbance
Bay
Rob
Wil
Hay N
Hay S
Huy
But
Lit
Pum
Par
Port B
Port N
Cor
Wes
Pre
Sou
Big
Car
Cran
McL
Osh
Jor
Fre
Lyn
Bow
Duf
Rou
Hyd


r² = 0.0124; r = -0.1113, p = 0.5729
Evenness (J')
Relative Disturbance
Port N
Pre
Cor
Jor
Port B
Car
Lyn
Par
Big
Wil
Lit
Sou
Wes
Fre
Cran
Rob
Rou
Hay N
Pum
But
McL
Bow
Duf
Osh
Hay S
Huy
Bay
Hyd



$r^2 = 0.0124$; $r = -0.1113$, $p = 0.5729$
Shannon index (H')
Relative Disturbance
Port N
Pre
Cor
Jor
Port B
Car
Lyn
Par
Big
Wil
Lit
Sou
Wes
Fre
Cran
Rob
Rou
Hay N
Pum
But
McL
Bow
Duf
Hay S
Osh
Huy
Bay
Hyd



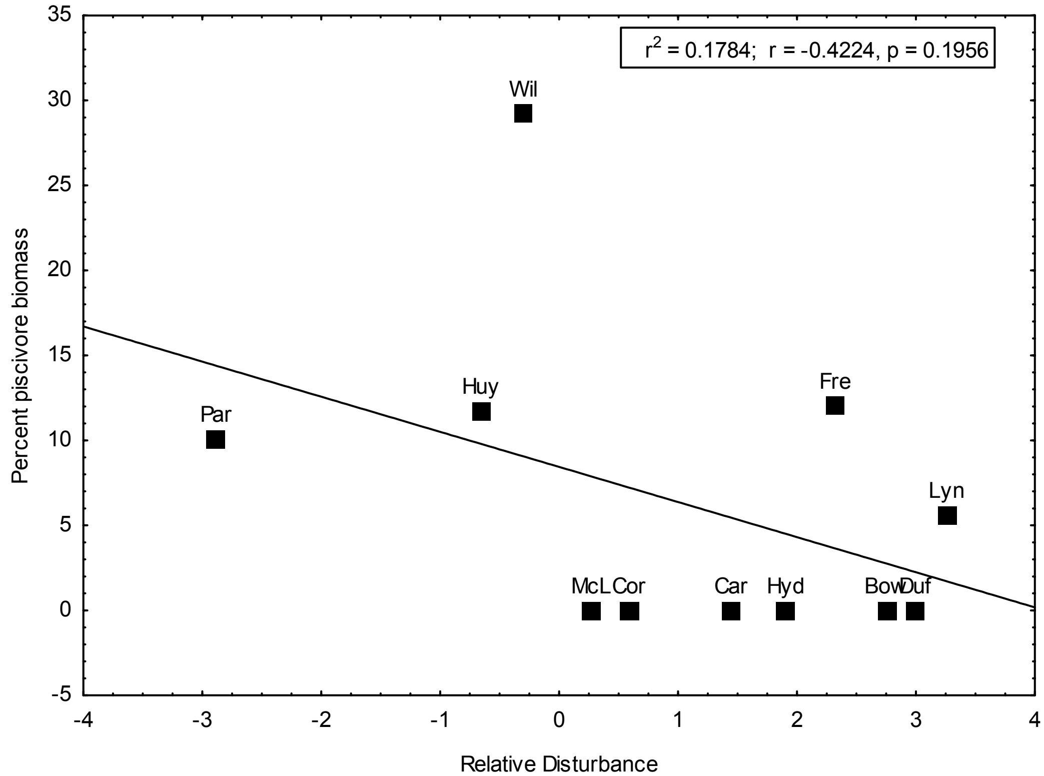
$r^2 = 0.0771$; $r = 0.2776$, $p = 0.1526$
Simpson index (D)
Relative Disturbance
McL
Bow
Car
Big
Pre
Wes
Lyn
Port B
Port N
Cor
Jor
Cran
Duf
Par
Hay N
Sou
Lit
Wil
Osh
Hyd

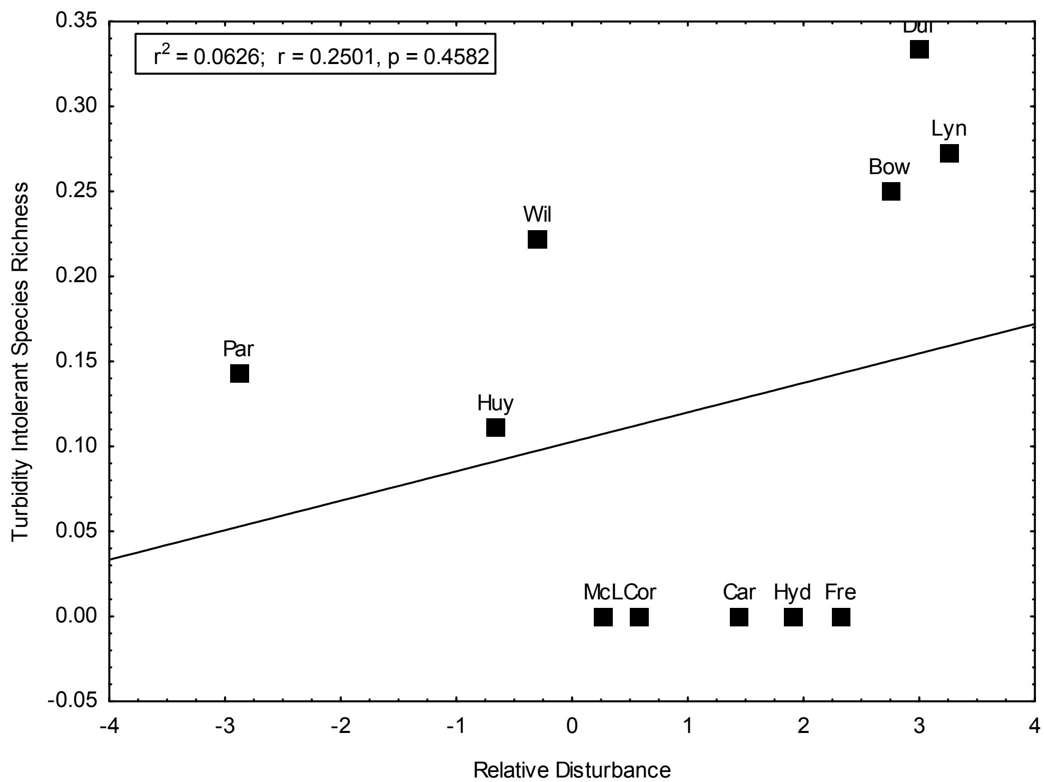
APPENDIX C

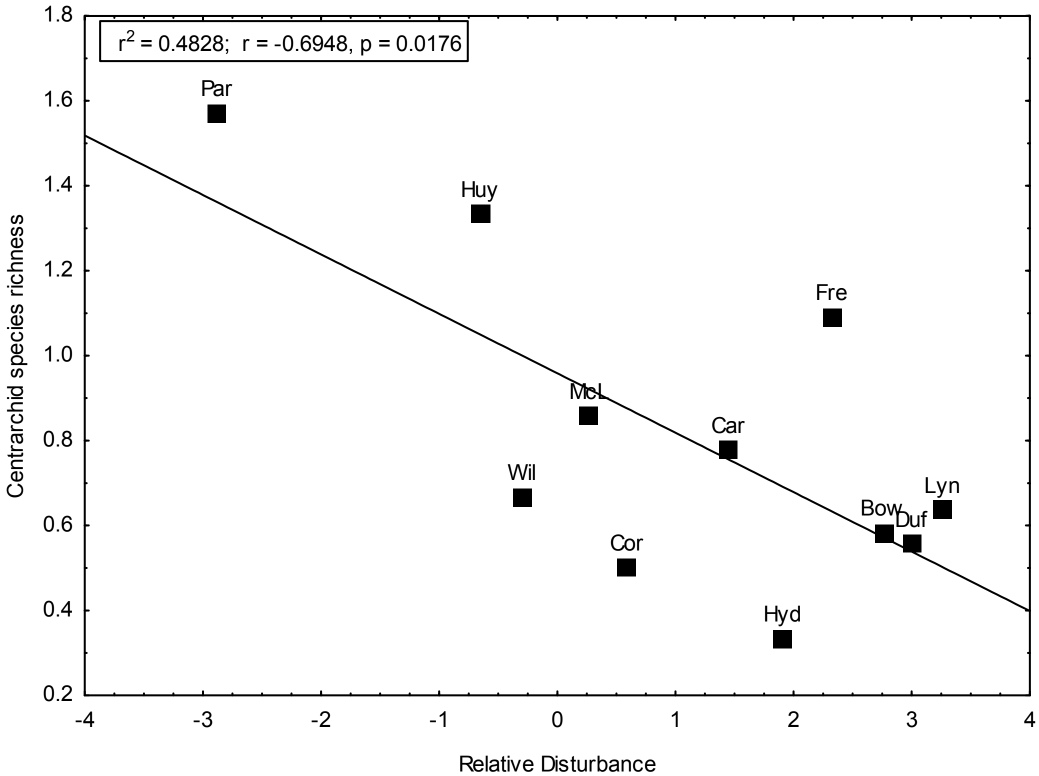
Table C-1 Site acronyms of names used in fish community metrics vs. habitat disturbance.

Site Acronym	Wetland Name
Bow	Bowmanville Marsh
Car	Carruthers Creek Marsh
Cor	Corbett Creek Marsh
Duf	Duffins Creek Marsh
Fre	Frenchman's Bay Marsh
Huy	Huyck's Bay
Hyd	Hydro Marsh
Lyn	Lynde Creek Marsh
McL	McLaughlin Bay Marsh
Par	Parrott's Bay
Wil	Wilmot Creek Marsh

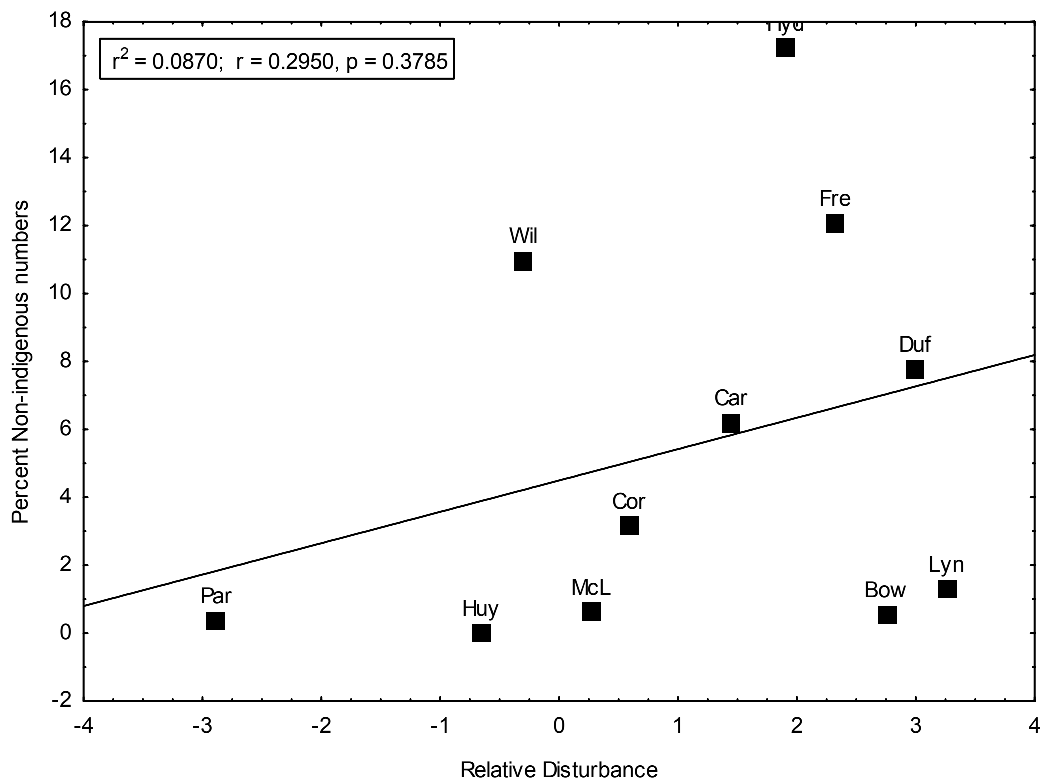
The following graphs represent all fish community metrics assessed against wetland disturbance.


r² = 0.1784; r = -0.4224, p = 0.1956
Percent piscivore biomass
Relative Disturbance
Wil
Huy
Par
Fre
Lyn
McL
Cor
Car
Hyd
Bow
Duf
35
30
25
20
15
10
5
0
-5
-4
-3
-2
-1
0
1
2
3
4

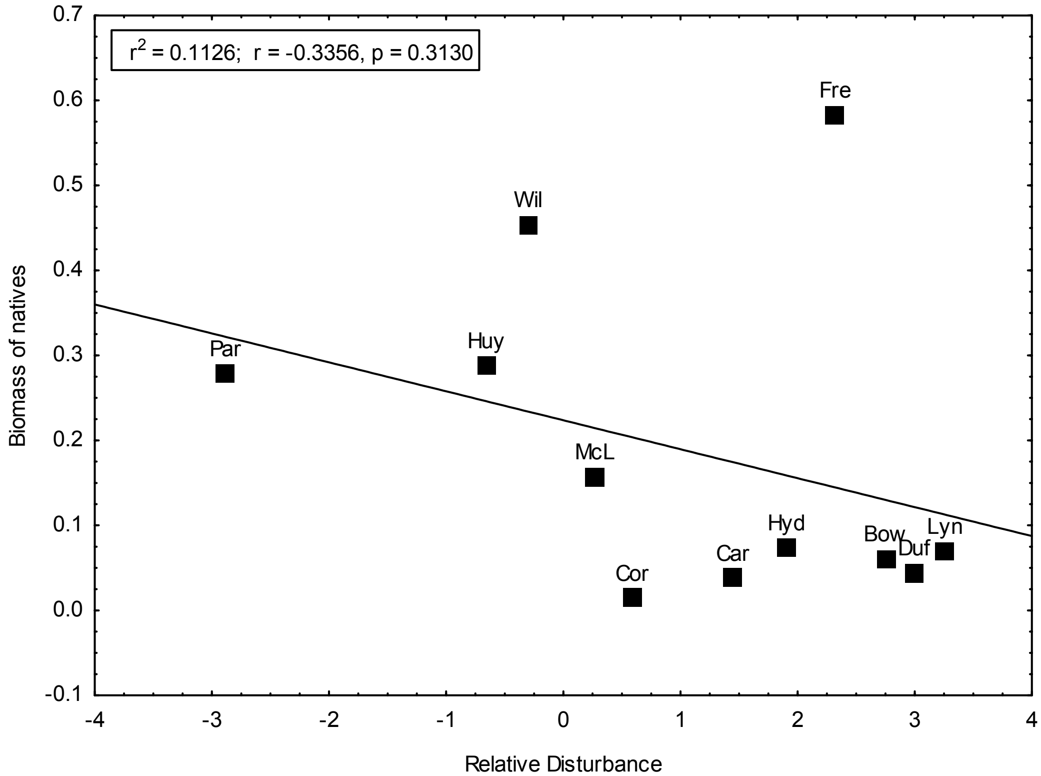

r² = 0.0626; r = 0.2501, p = 0.4582
Turbidity Intolerant Species Richness
Relative Disturbance
Lyn
Bow
Wil
Par
Huy
McL
Cor
Car
Hyd
Fre
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-4
-3
-2
-1
0
1
2
3
4

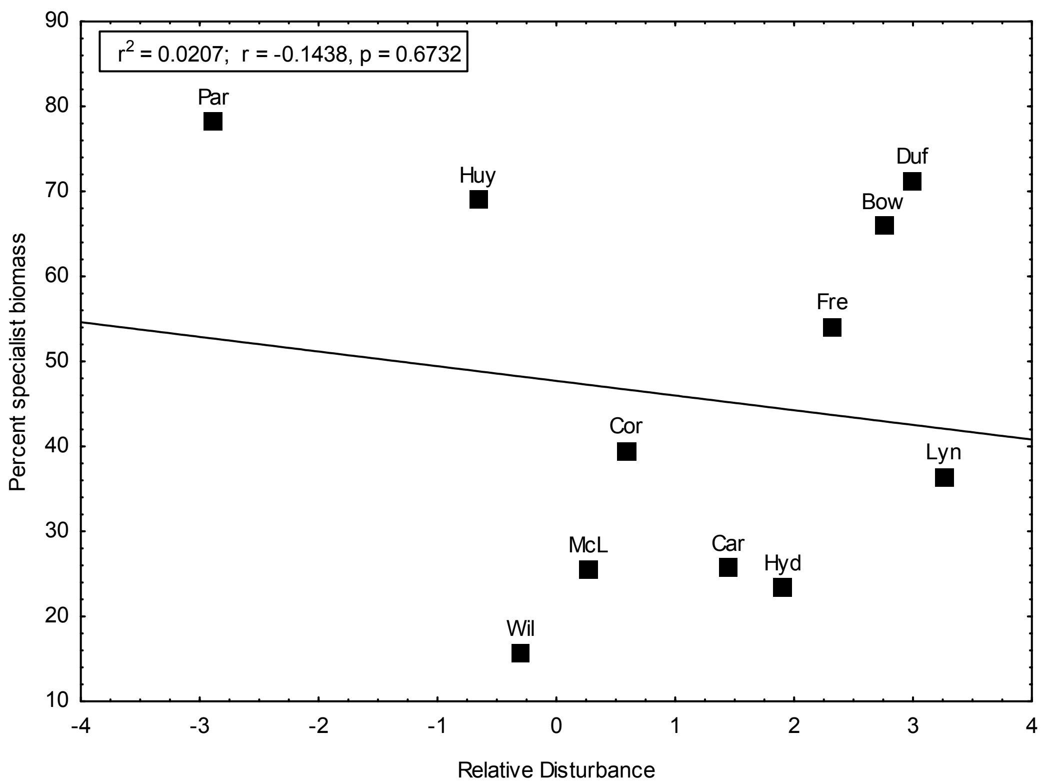


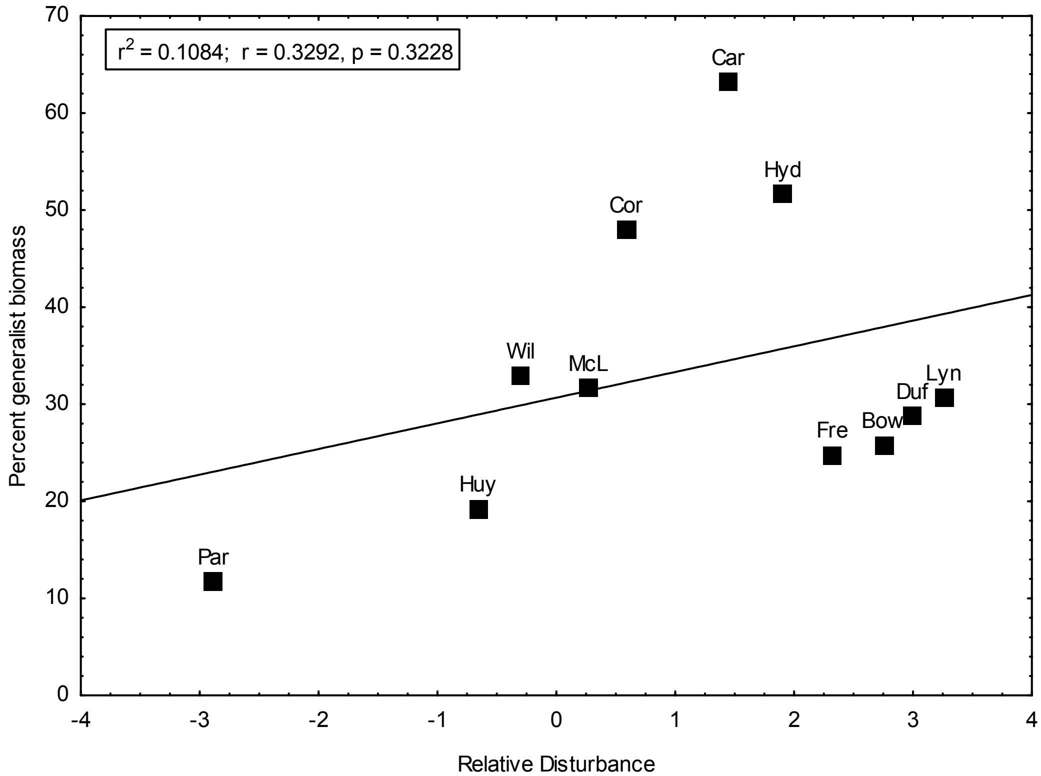
r2 = 0.4828; r = -0.6948, p = 0.0176
Centrarchid species richness
Relative Disturbance
Par
Huy
Fre
McL
Car
Wil
Lyn
Bow
Duf
Cor
Hyd
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-4
-3
-2
-1
0
1
2
3
4

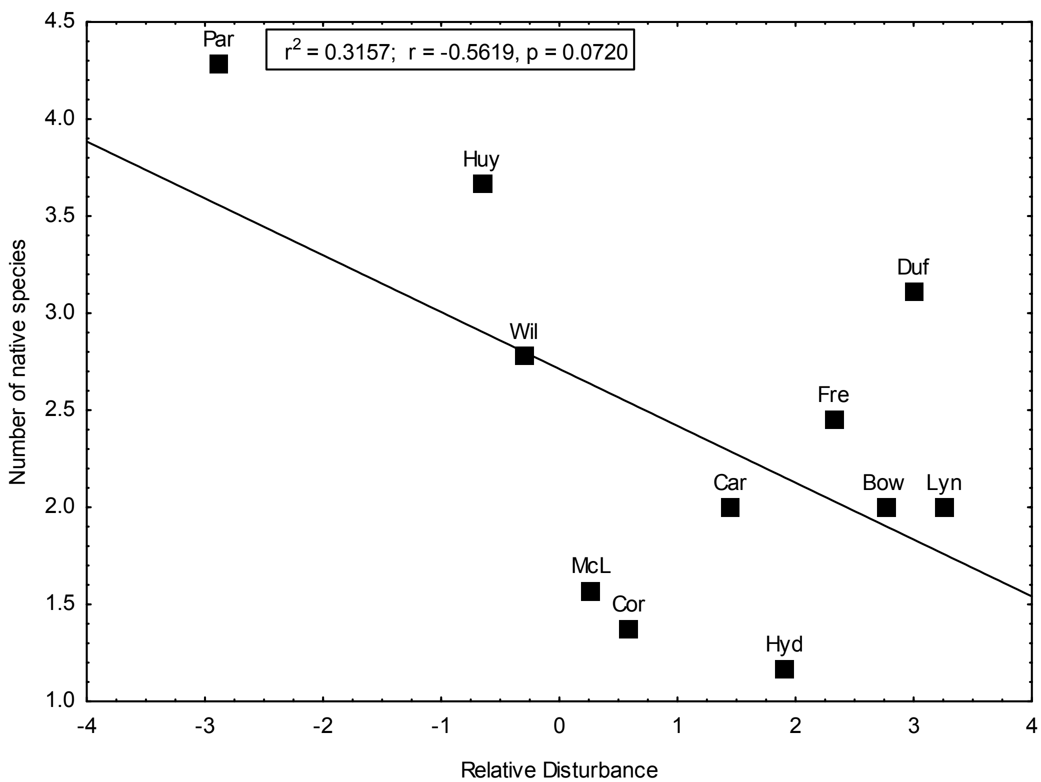


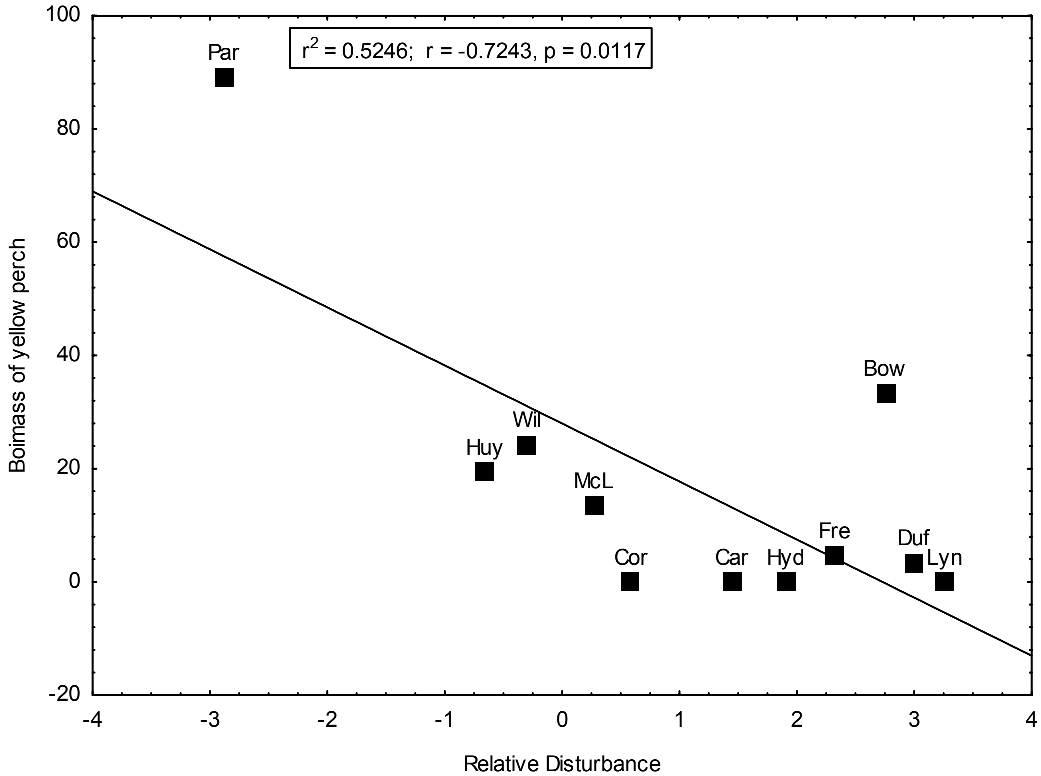
r2 = 0.0870; r = 0.2950, p = 0.3785
Percent Non-indigenous numbers
Relative Disturbance
Fre
Wil
Duf
Car
Cor
Lyn
Par
McL
Bow
Huy
18
16
14
12
10
8
6
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
4

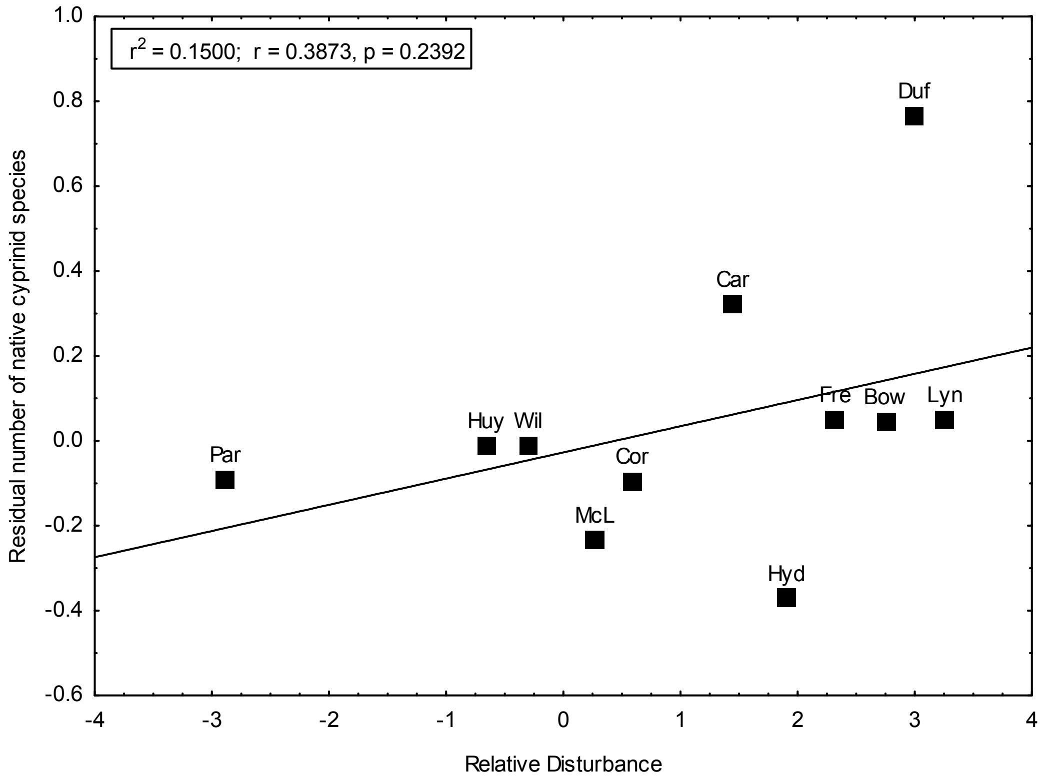

r2 = 0.1126; r = -0.3356, p = 0.3130
Biomass of natives
Relative Disturbance
Fre
Wil
Huy
Par
McL
Hyd
Bow
Lyn
Duf
Car
Cor
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-4
-3
-2
-1
0
1
2
3
4

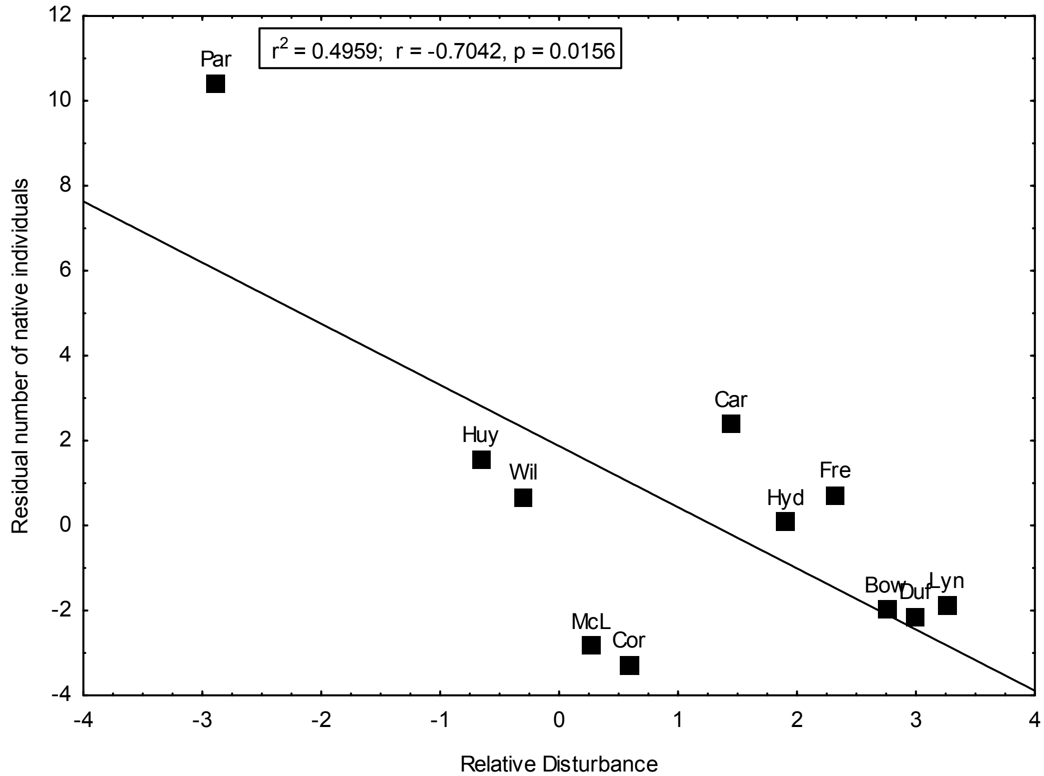

r2 = 0.0207; r = -0.1438, p = 0.6732
Percent specialist biomass
Relative Disturbance
Par
Huy
Duf
Bow
Fre
Cor
Lyn
McL
Car
Hyd
Wil
90
80
70
60
50
40
30
20
10
-4
-3
-2
-1
0
1
2
3
4


r² = 0.1084; r = 0.3292, p = 0.3228
Percent generalist biomass
Relative Disturbance
70
60
50
40
30
20
10
0
-4
-3
-2
-1
0
1
2
3
4
Car
Hyd
Cor
Wil
McL
Lyn
Duf
Bow
Fre
Huy
Par

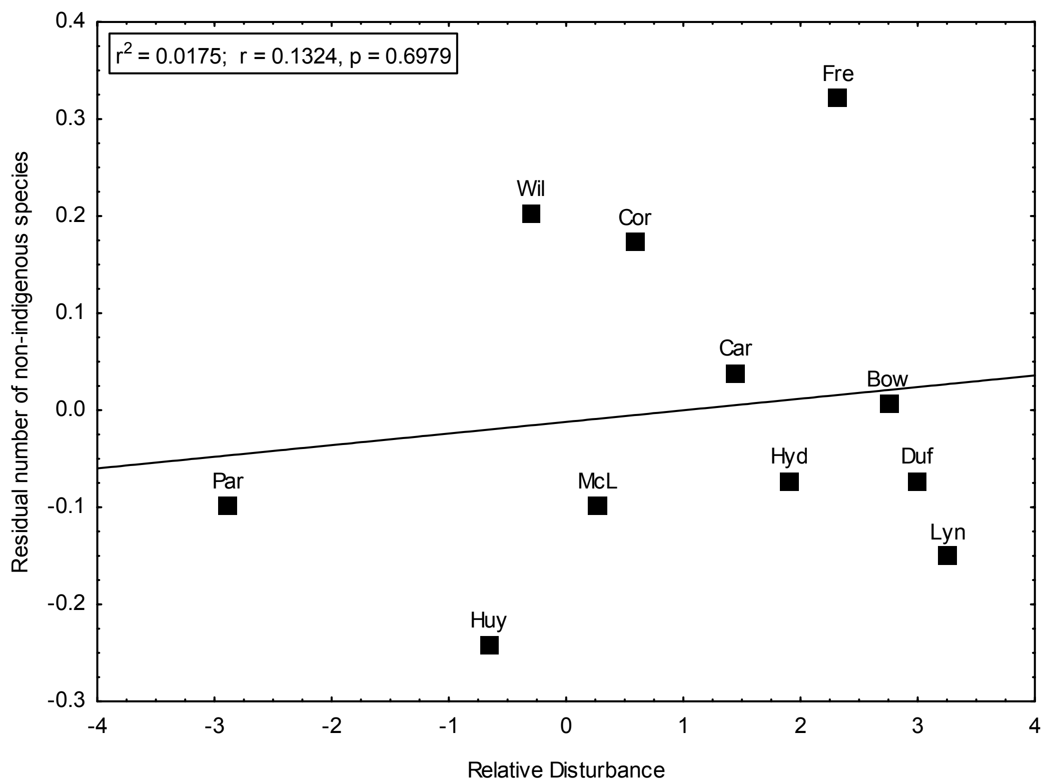

r² = 0.3157; r = -0.5619, p = 0.0720
Number of native species
Relative Disturbance
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
-4
-3
-2
-1
0
1
2
3
4
Par
Huy
Duf
Wil
Fre
Car
Bow
Lyn
McL
Cor
Hyd


r² = 0.5246; r = -0.7243, p = 0.0117
Par
Huy
Wil
McL
Cor
Car
Hyd
Fre
Bow
Duf
Lyn
Boimass of yellow perch
Relative Disturbance
100
80
60
40
20
0
-20
-4
-3
-2
-1
0
1
2
3
4


r² = 0.1500; r = 0.3873, p = 0.2392
Duf
Car
Fre
Bow
Lyn
Huy
Wil
Par
Cor
McL
Hyd
Residual number of native cyprinid species
Relative Disturbance
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-4
-3
-2
-1
0
1
2
3
4



r² = 0.4959; r = -0.7042, p = 0.0156
Residual number of native individuals
Relative Disturbance
Par
Huy
Wil
McL
Cor
Car
Hyd
Fre
Bow
Duf
Lyn
12
10
8
6
4
2
0
-2
-4
-4
-3
-2
-1
0
1
2
3
4



r² = 0.0175; r = 0.1324, p = 0.6979
Residual number of non-indigenous species
Relative Disturbance
Fre
Wil
Cor
Car
Bow
Hyd
Duf
Par
McL
Lyn
Huy
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-4
-3
-2
-1
0
1
2
3
4

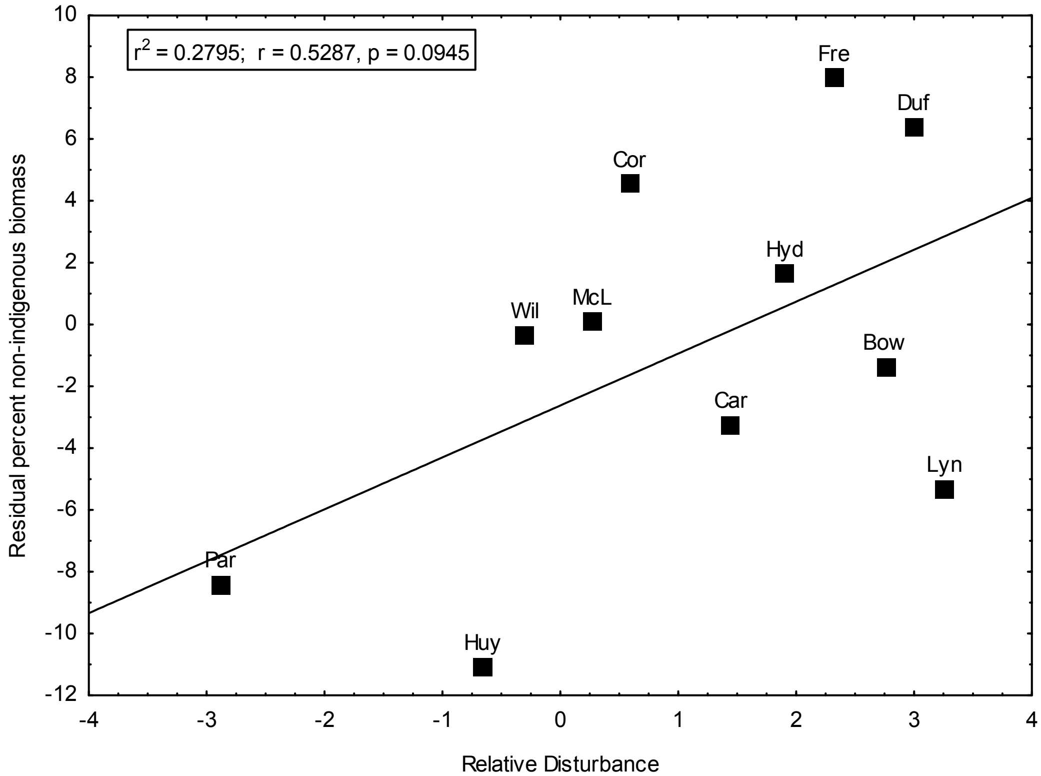

r2 = 0.2795; r = 0.5287, p = 0.0945
Residual percent non-indigenous biomass
Relative Disturbance
Fre
Duf
Cor
Hyd
McL
Wil
Bow
Car
Lyn
Par
Huy
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-4
-3
-2
-1
0
1
2
3
4

Table C-1. The number and species of fish caught in Lake Ontario coastal wetlands

Wetland Name	Common Name	*Genus species*	
Bowmanville Marsh	Alewife	*Alosa pseudoharengus*	1
Bowmanville Marsh	Golden Shiner	*Notemigonus crysoleucas*	16
Bowmanville Marsh	Spottail Shiner	*Notropis hudsonius*	7
Bowmanville Marsh	Bluntnose Minnow	*Pimephales notatus*	4
Bowmanville Marsh	Brown Bullhead	*Ameiurus nebulosus*	13
Bowmanville Marsh	Pumpkinseed	*Lepomis gibbosus*	28
Bowmanville Marsh	Yellow Perch	*Perca flavescens*	5
Bowmanville Marsh	Johnny Darter	*Etheostoma nigrum*	1
Carruthers Creek Marsh	Gizzard Shad	*Dorosoma cepedianum*	6
Carruthers Creek Marsh	Common Carp	*Cyprinus carpio*	7
Carruthers Creek Marsh	Emerald Shiner	*Notropis atherinoides*	1
Carruthers Creek Marsh	Bluntnose Minnow	*Pimephales notatus*	6
Carruthers Creek Marsh	Fathead Minnow	*Pimephales promelas*	37
Carruthers Creek Marsh	Brown Bullhead	*Ameiurus nebulosus*	8
Carruthers Creek Marsh	Pumpkinseed	*Lepomis gibbosus*	31
Carruthers Creek Marsh	Bluegill	*Lepomis macrochirus*	2
Corbett Creek Marsh	Common Carp	*Cyprinus carpio*	3
Corbett Creek Marsh	Fathead Minnow	*Pimephales promelas*	21
Corbett Creek Marsh	Brown Bullhead	*Ameiurus nebulosus*	6
Corbett Creek Marsh	Banded Killifish	*Fundulus diaphanus*	1
Corbett Creek Marsh	Pumpkinseed	*Lepomis gibbosus*	8
Duffins Creek Marsh	Gizzard Shad	*Dorosoma cepedianum*	12
Duffins Creek Marsh	White Sucker	*Catostomus commersoni*	1
Duffins Creek Marsh	Common Carp	*Cyprinus carpio*	3
Duffins Creek Marsh	Emerald Shiner	*Notropis atherinoides*	1
Duffins Creek Marsh	Common Shiner	*Luxilis cornutus*	14
Duffins Creek Marsh	Spottail Shiner	*Notropis hudsonius*	2
Duffins Creek Marsh	Bluntnose Minnow	*Pimephales notatus*	6
Duffins Creek Marsh	Fathead Minnow	*Pimephales promelas*	13
Duffins Creek Marsh	Brown Bullhead	*Ameiurus nebulosus*	1
Duffins Creek Marsh	Rock Bass	*Ambloplites rupestris*	1
Duffins Creek Marsh	Pumpkinseed	*Lepomis gibbosus*	8
Duffins Creek Marsh	Yellow Perch	*Perca flavescens*	5
Duffins Creek Marsh	Johnny Darter	*Etheostoma nigrum*	1
Duffins Creek Marsh	Logperch	*Percina caprodes*	5
Hydro Marsh	Alewife	*Alosa pseudoharengus*	4
Hydro Marsh	Gizzard Shad	*Dorosoma cepedianum*	1
Hydro Marsh	Common Carp	*Cyprinus carpio*	3
Hydro Marsh	Golden Shiner	*Notemigonus crysoleucas*	5
Hydro Marsh	Fathead Minnow	*Pimephales promelas*	22
Hydro Marsh	Brown Bullhead	*Ameiurus nebulosus*	66
Hydro Marsh	Pumpkinseed	*Lepomis gibbosus*	4
Hydro Marsh	Black Crappie	*Pomoxis nigromaculatus*	1

Table C-1 Continued.

Wetland Name	Common Name	*Genus species*	
Frenchman's Bay Marsh	Alewife	*Alosa pseudoharengus*	11
Frenchman's Bay Marsh	Gizzard Shad	*Dorosoma cepedianum*	1
Frenchman's Bay Marsh	White Sucker	*Catostomus commersoni*	1
Frenchman's Bay Marsh	Common Carp	*Cyprinus carpio*	5
Frenchman's Bay Marsh	Emerald Shiner	*Notropis atherinoides*	35
Frenchman's Bay Marsh	Spotfin Shiner	*Cyprinella spiloptera*	5
Frenchman's Bay Marsh	Bluntnose Minnow	*Pimephales notatus*	7
Frenchman's Bay Marsh	Brown Bullhead	*Ameiurus nebulosus*	2
Frenchman's Bay Marsh	Pumpkinseed	*Lepomis gibbosus*	57
Frenchman's Bay Marsh	Bluegill	*Lepomis macrochirus*	4
Frenchman's Bay Marsh	Smallmouth Bass	*Micropterus dolomieui*	2
Frenchman's Bay Marsh	Largemouth Bass	*Micropterus salmoides*	5
Frenchman's Bay Marsh	Yellow Perch	*Perca flavescens*	2
Frenchman's Bay Marsh	Johnny Darter	*Etheostoma nigrum*	1
Frenchman's Bay Marsh	Freshwater Drum	*Aplodinotus grunniens*	1
Huyck's Bay	Northern Pike	*Esox lucius*	1
Huyck's Bay	Central Mudminnow	*Umbra limi*	9
Huyck's Bay	Golden Shiner	*Notemigonus crysoleucas*	7
Huyck's Bay	Blackchin Shiner	*Notropis heterodon*	1
Huyck's Bay	Sand Shiner	*Notropis stramineus*	4
Huyck's Bay	Brown Bullhead	*Ameiurus nebulosus*	2
Huyck's Bay	Banded Killifish	*Fundulus diaphanus*	1
Huyck's Bay	Pumpkinseed	*Lepomis gibbosus*	15
Huyck's Bay	Bluegill	*Lepomis macrochirus*	1
Huyck's Bay	Largemouth Bass	*Micropterus salmoides*	4
Huyck's Bay	Yellow Perch	*Perca flavescens*	89
Huyck's Bay	Iowa Darter	*Etheostoma exile*	1
Huyck's Bay	Johnny Darter	*Etheostoma nigrum*	1
Lynde Creek Marsh	Alewife	*Alosa pseudoharengus*	1
Lynde Creek Marsh	Gizzard Shad	*Dorosoma cepedianum*	10
Lynde Creek Marsh	Golden Shiner	*Notemigonus crysoleucas*	6
Lynde Creek Marsh	Spottail Shiner	*Notropis hudsonius*	18
Lynde Creek Marsh	Bluntnose Minnow	*Pimephales notatus*	3
Lynde Creek Marsh	Fathead Minnow	*Pimephales promelas*	24
Lynde Creek Marsh	Brown Bullhead	*Ameiurus nebulosus*	18
Lynde Creek Marsh	Pumpkinseed	*Lepomis gibbosus*	38
Lynde Creek Marsh	Walleye (Yellow Pickerel)	*Stizostedion vitreum vitreum*	1
McLaughlin Bay Marsh	Common Carp	*Cyprinus carpio*	1
McLaughlin Bay Marsh	Brown Bullhead	*Ameiurus nebulosus*	17
McLaughlin Bay Marsh	Pumpkinseed	*Lepomis gibbosus*	5
McLaughlin Bay Marsh	Black Crappie	*Pomoxis nigromaculatus*	15
McLaughlin Bay Marsh	Yellow Perch	*Perca flavescens*	4

Table C-1 Continued.

Wetland Name	Common Name	Fish species name	
Oshawa Second Marsh	Goldfish	*Carassius auratus*	10
Oshawa Second Marsh	Fathead Minnow	*Pimephales promelas*	58
Oshawa Second Marsh	Brown Bullhead	*Ameiurus nebulosus*	3
Oshawa Second Marsh	Yellow Perch	*Perca flavescens*	20
Parrott's Bay	Northern Pike	*Esox lucius*	1
Parrott's Bay	Central Mudminnow	*Umbra limi*	2
Parrott's Bay	Golden Shiner	*Notemigonus crysoleucas*	18
Parrott's Bay	Brown Bullhead	*Ameiurus nebulosus*	4
Parrott's Bay	Banded Killifish	*Fundulus diaphanus*	3
Parrott's Bay	Rock Bass	*Ambloplites rupestris*	1
Parrott's Bay	Pumpkinseed	*Lepomis gibbosus*	15
Parrott's Bay	Largemouth Bass	*Micropterus salmoides*	5
Parrott's Bay	Black Crappie	*Pomoxis nigromaculatus*	1
Parrott's Bay	Yellow Perch	*Perca flavescens*	77
Parrott's Bay	Johnny Darter	*Etheostoma nigrum*	3
Parrott's Bay	Round Goby	*Neogobius melanostomus*	1
Port Newcastle Wetland	White Sucker	*Catostomus commersoni*	1
Port Newcastle Wetland	Common Carp	*Cyprinus carpio*	1
Port Newcastle Wetland	Pumpkinseed	*Lepomis gibbosus*	24
Port Newcastle Wetland	Yellow Perch	*Perca flavescens*	3
Port Newcastle Wetland	Johnny Darter	*Etheostoma nigrum*	4
Pumphouse Marsh	Central Mudminnow	*Umbra limi*	32
Pumphouse Marsh	Goldfish	*Carassius auratus*	37
Pumphouse Marsh	Fathead Minnow	*Pimephales promelas*	484
Pumphouse Marsh	Brown Bullhead	*Ameiurus nebulosus*	5
Rouge River Marsh	Gizzard Shad	*Dorosoma cepedianum*	3
Rouge River Marsh	Common Carp	*Cyprinus carpio*	3
Rouge River Marsh	Emerald Shiner	*Notropis atherinoides*	5
Rouge River Marsh	Common Shiner	*Luxilis cornutus*	1
Rouge River Marsh	Bluntnose Minnow	*Pimephales notatus*	2
Rouge River Marsh	Fathead Minnow	*Pimephales promelas*	2
Rouge River Marsh	Brown Bullhead	*Ameiurus nebulosus*	64
Rouge River Marsh	Pumpkinseed	*Lepomis gibbosus*	8
Rouge River Marsh	Yellow Perch	*Perca flavescens*	9
Wilmot Creek Marsh	Sea Lamprey	*Petromyzon marinus*	1
Wilmot Creek Marsh	Rainbow Trout	*Oncorhynchus mykiss*	1
Wilmot Creek Marsh	Northern Pike	*Esox lucius*	4
Wilmot Creek Marsh	White Sucker	*Catostomus commersoni*	2
Wilmot Creek Marsh	Common Carp	*Cyprinus carpio*	5
Wilmot Creek Marsh	Golden Shiner	*Notemigonus crysoleucas*	2
Wilmot Creek Marsh	Spottail Shiner	*Notropis hudsonius*	1
Wilmot Creek Marsh	Bluntnose Minnow	*Pimephales notatus*	2
Wilmot Creek Marsh	Brown Bullhead	*Ameiurus nebulosus*	12
Wilmot Creek Marsh	Rock Bass	*Ambloplites rupestris*	1
Wilmot Creek Marsh	Pumpkinseed	*Lepomis gibbosus*	31
Wilmot Creek Marsh	Largemouth Bass	*Micropterus salmoides*	1
Wilmot Creek Marsh	Yellow Perch	*Perca flavescens*	3
Wilmot Creek Marsh	Johnny Darter	*Etheostoma nigrum*	19

APPENDIX D

Table D-1. A categorization of all bird species observed in MMP stations in Durham Region and other Lake Ontario coastal wetlands.

Common Name	Species CODE	Marsh Nesting Obligate	Marsh User	Upland/ Generalist
American Black Duck	ABDU		X	
Alder Flycatcher	ALFL			
American Bittern	AMBI	X	X	
American Coot	AMCO	X	X	
American Crow	AMCR			X
American Goldfinch	AMGO			X
American Robin	AMRO			X
American Woodcock	AMWO		X	
Bald Eagle	BAEA		X	
Bank Swallow	BANS			
Barn Swallow	BARS			
Black-billed Cuckoo	BBCU			X
Black-capped Chickadee	BCCH			X
Black-crowned Night-heron	BCNH		X	
Belted Kingfisher	BEKI		X	
Blue-gray Gnatcatcher	BGGN			X
Brown-headed Cowbird	BHCO			X
Blue Jay	BLJA			X
Black Tern	BLTE	X	X	
Bobolink	BOBO			X
Bonaparte's Gull	BOGU		X	
Blue-winged Teal	BWTE		X	
Canada Goose	CAGO		X	
Carolina Wren	CARW			X
Caspian Tern	CATE		X	
Cedar Waxwing	CEDW			X
Cerulean Warbler	CERW			X
Chipping Sparrow	CHSP			X
Chimney Swift	CHSW			
Cliff Swallow	CLSW			
Common Grackle	COGR		X	
Cooper's Hawk	COHA			X
Common Loon	COLO		X	
Common Merganser	COME		X	
Common Moorhen	COMO	X	X	
Common Nighthawk	CONI			
Common Snipe	COSN	X	X	
Common Tern	COTE		X	
Common Yellowthroat	COYE			X
Chestnut-sided warbler	CSWA			X
Double-crested Cormorant	DCCO		X	
Downy Woodpecker	DOWO			X
Dunlin	DUNL		X	
Eastern Kingbird	EAKI			
Eastern Meadowlark	EAME			X
European Starling	EUST			X
Eastern Wood-Pewee	EWPE			X
Forster's Tern	FOTE	X	X	
Gadwall	GADW		X	
Great Black-backed Gull	GBBG		X	
Great Crested Flycatcher	GCFL			

Table D-1 Continued.

Common Name	Species CODE	Marsh Nesting Obligate	Marsh User	Upland/ Generalist
Great Horned Owl	GHOW			X
Gray Catbird	GRCA			X
Great Egret	GREG		X	
Green Heron	GRHE		X	
Great Blue Heron	GBHE		X	
Green-winged Teal	GWTE		X	
Herring Gull	HERG		X	
House Finch	HOFI			X
House Wren	HOWR			X
Indigo Bunting	INBU			X
Killdeer	KILL		X	
Least Bittern	LEBI	X	X	
Least Flycatcher	LEFL			
Lesser Scaup	LESC		X	
Lesser Yellowlegs	LEYE		X	
Little Gull	LIGU		X	
Mallard	MALL		X	
Magnolia Warbler	MAWA			X
Marsh Wren	MAWR	X	X	
Morning Dove	MODO			X
Moorhen/Coot spp.	MOOT	X	X	
Mute Swan	MUSW		X	
Northern Cardinal	NOCA			X
Northern Flicker	NOFL			X
Northern Harrier	NOHA		X	
Northern Shoveler	NSHO		X	
Osprey	OSPR		X	
Ovenbird	OVEN			X
Pied-billed Grebe	PBGR	X	X	
Purple Martin	PUMA			
Rose-breasted Grosbeak	RBGR			X
Ring-billed Gull	RBGU		X	
Red-eyed Vireo	REVI			X
Ring-necked Pheasant	RINP			X
Ring-necked Duck	RNDU		X	
Rock Dove	RODO			X
Red-tailed Hawk	RTHA			X
Ruby-throated Hummingbird	RTHU			X
Ruddy Duck	RUDU		X	
Red-winged Blackbird	RWBL		X	
Sandhill Crane	SACR		X	
Savannah Sparrow	SAVS			X
Sedge Wren	SEWR		X	
Sora	SORA	X	X	
Song Sparrow	SOSP			X
Spotted Sandpiper	SPSA		X	
Sharp-shinned Hawk	SSHA			X
Sharp-tailed Sparrow	STSP			X
Swamp Sparrow	SWSP	X	X	
Tree Swallow	TRES			
Trumpeter Swan	TRUS		X	

Table D-1 Continued.

Common Name	Species CODE	Marsh Nesting Obligate	Marsh User	Upland/ Generalist
Warbling Vireo	WAVI			X
Turkey Vulture	TUVU			X
Virginia Rail	VIRA	X	X	
Willow Flycatcher	WIFL			
Wood Duck	WODU		X	
Wood Thrush	WOTH			X
Yellow-breasted Chat	YBCH			X
Yellow Warbler	YWAR			X

Table D-2.Bird species (4 letter MMP codes) found in MMP stations in Lake Ontario coastal wetlands.

	Bayfield Bay	Bowmanville Marsh		Button Bay	Corbett Creek Marsh	Cranberry Marsh		Duffins Creek Marsh	Frenchman's Bay Marsh
Species	2002	2002	2003	2002	2002	2002	2003	2003	2002
AMBI	1	0	0	1	0	0	0	0	0
AMCO	0	0	0	0	0	18	6	0	0
AMWO	0	0	0	0	0	0	0	0	0
BCNH	0	0	0	0	0	0	9	0	2
BEKI	0	0	0	0	2	0	1	0	0
BLTE	0	0	0	1	0	0	0	0	0
BOGU	0	0	0	0	0	0	0	0	0
BWTE	0	0	0	2	0	4	2	0	0
CAGO	1	0	0	0	0	1	0	0	3
CATE	0	0	0	8	0	0	0	0	0
COGR	1	0	0	0	1	0	4	1	0
COLO	0	0	0	0	0	0	0	0	0
COME	0	0	0	0	0	0	0	0	0
COMO	0	0	0	0	0	2	4	0	0
COTE	0	2	0	0	0	0	0	0	0
DCCO	0	0	0	0	0	0	0	0	0
DUNL	0	0	0	0	1	0	0	0	0
GADW	0	0	0	0	0	5	1	0	0
GRCA	0	0	0	0	0	0	1	0	0
GREG	0	0	0	0	0	0	1	0	0
GRHE	0	0	0	0	2	1	0	0	0
GBHE	0	0	2	1	0	0	0	0	0
GWTE	0	0	0	0	0	2	0	0	0
HERG	0	0	0	0	0	0	0	0	0
KILL	0	0	0	0	0	0	0	0	0
LEBI	0	1	0	0	0	0	0	0	0
MALL	3	1	8	0	2	22	0	0	0
MAWA	0	0	0	0	0	0	0	0	0
MAWR	17	0	0	6	2	7	14	0	7
MOOT	0	0	0	0	0	0	10	0	0
MUSW	0	0	3	0	0	1	2	0	0
NOHA	1	0	0	0	0	0	0	0	0
NRWS	0	0	13	0	0	0	0	11	0
NSHO	0	0	0	0	0	3	0	0	0
OSPR	0	0	0	0	0	0	0	0	0
PBGR	0	0	0	0	0	0	0	0	0
RBGU	0	0	0	0	0	0	0	0	0
RNDU	0	0	0	0	0	0	1	0	0
RUDU	0	0	0	0	0	0	0	0	0
RWBL	33	62	149	26	22	24	26	3	28
SORA	0	0	0	0	0	2	0	0	0
SPSA	0	0	0	0	0	0	1	0	0
SWSP	11	6	4	0	2	3	3	3	0
TRUS	0	0	0	0	0	0	0	0	0
VIRA	2	1	1	4	2	4	9	0	0
WODU	0	0	0	2	0	0	2	0	0

Table D-2 Continued

	Hay Bay South	Huyck's Bay	Port Newcastle	Hydro Marsh	Lynde Creek Marsh		Oshawa Second Marsh		Parrott's Bay	Port Britain
Species	2002	2002	2003	2002	2002	2003	2002	2003	2002	2002
AMBI	0	1	0	0	0	0	0	0	0	0
AMCO	0	0	0	0	0	0	0	0	0	0
AMWO	0	0	0	0	1	0	0	0	0	0
BCNH	0	0	2	6	0	0	1	0	0	0
BEKI	0	0	0	0	4	0	0	0	0	0
BLTE	0	0	0	0	0	0	0	0	0	0
BOGU	0	0	0	0	0	0	0	0	0	0
BWTE	0	0	0	0	0	1	0	0	0	0
CAGO	0	0	0	1	3	12	2	2	0	0
CATE	0	0	0	0	0	0	0	1	0	0
COGR	3	0	0	0	6	7	1	0	0	0
COLO	0	0	0	0	0	0	0	0	0	0
COME	0	0	0	0	0	0	2	0	0	0
COMO	0	0	0	0	0	0	0	0	0	2
COTE	0	0	0	0	0	0	6	0	0	0
DCCO	0	0	0	0	0	0	0	0	1	0
DUNL	0	0	0	0	0	0	0	0	0	0
GADW	0	0	0	0	0	0	2	0	0	0
GRCA	0	0	0	0	0	0	3	6	0	0
GREG	0	0	1	0	0	0	0	0	0	0
GRHE	0	0	0	0	1	0	0	0	0	0
GBHE	0	0	1	0	0	1	0	1	0	0
GWTE	0	0	0	0	0	0	0	0	0	1
HERG	0	0	0	0	0	0	0	0	0	0
KILL	0	0	0	0	0	0	3	0	0	0
LEBI	0	0	0	0	0	0	0	0	0	0
MALL	0	0	0	0	0	0	1	2	2	4
MAWA	0	0	0	0	1	0	0	0	0	0
MAWR	0	3	0	3	9	3	13	8	0	0
MOOT	0	0	0	0	0	0	0	0	0	0
MUSW	0	0	0	0	2	1	1	0	0	0
NOHA	0	0	0	0	0	0	0	0	0	0
NRWS	0	0	0	0	0	1	2	2	0	0
NSHO	0	0	0	0	0	0	0	0	0	0
OSPR	0	0	0	0	0	0	0	0	1	0
PBGR	0	0	0	0	0	0	0	0	0	0
RBGU	0	0	0	0	13	0	0	0	0	0
RNDU	0	0	0	0	0	0	0	0	0	0
RUDU	0	0	0	0	0	0	0	2	0	0
RWBL	50	22	4	23	55	55	49	61	35	124
SORA	0	0	0	0	1	0	0	0	0	0
SPSA	0	0	0	0	0	0	3	3	0	0
SWSP	12	3	2	0	11	6	35	44	7	2
TRUS	0	0	0	0	0	0	0	0	0	0
VIRA	0	1	0	0	2	1	3	1	1	3
WODU	0	0	0	0	0	0	5	0	0	0

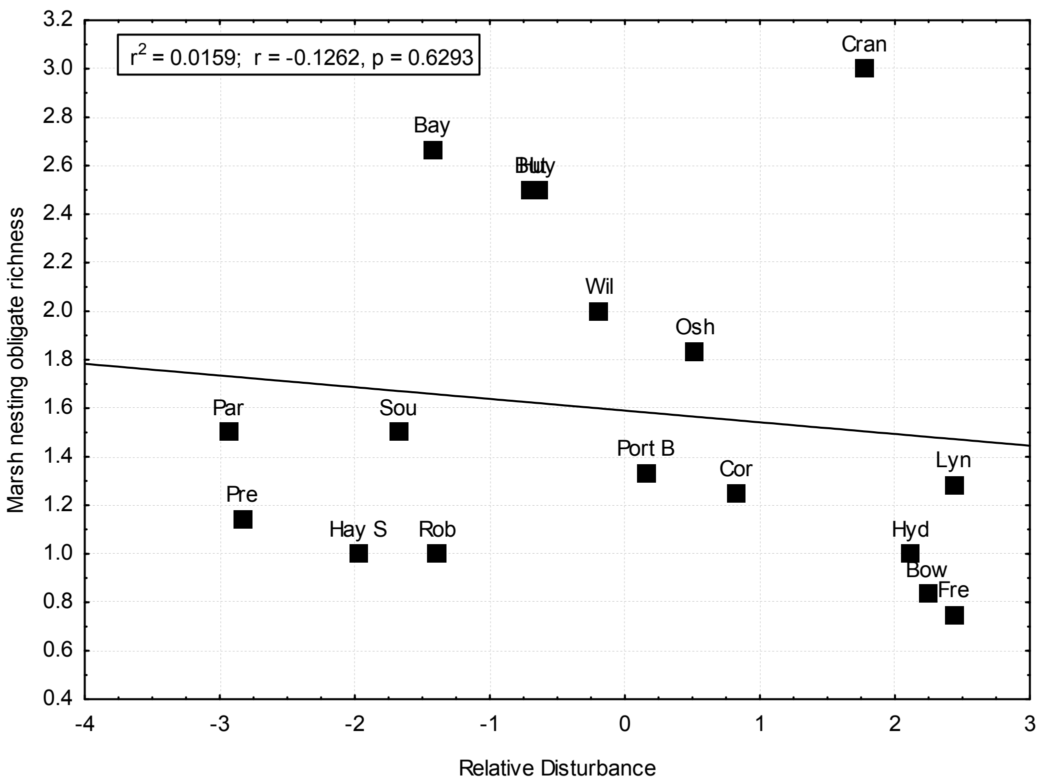
Table D-2 Continued

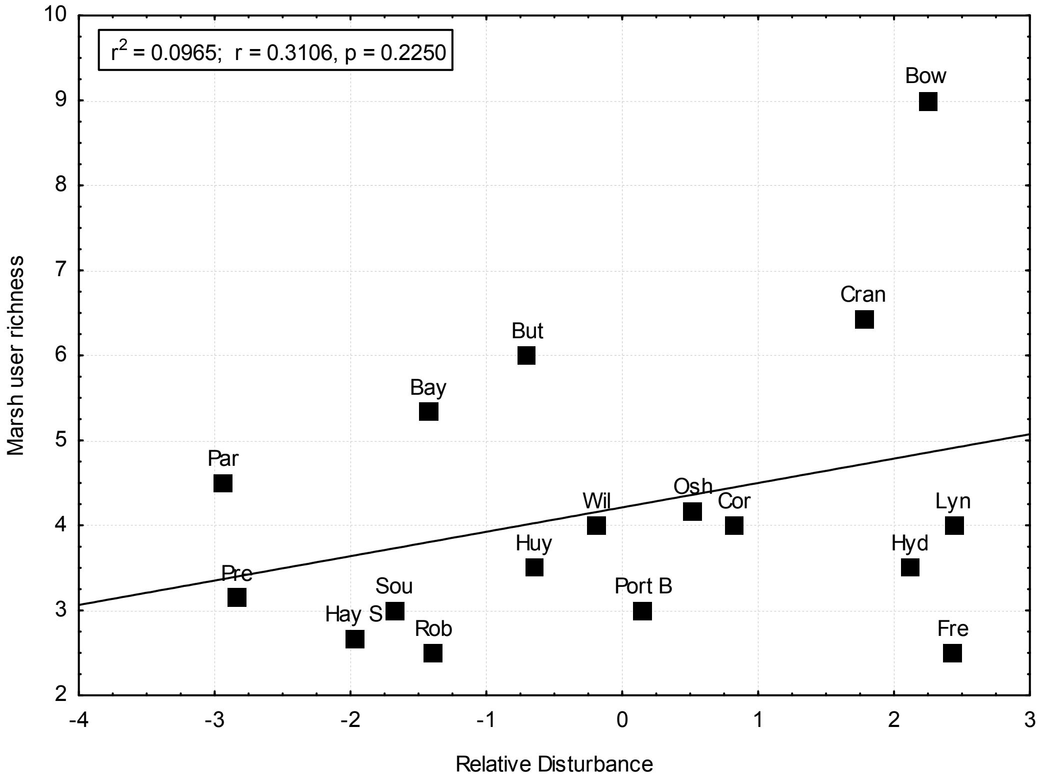
	Presqu'ile Bay	Robinson's Cove		South Bay	Westside Marsh		Wilmot Creek Marsh		Rouge River Marsh
Species	2002	2002	2003	2002	2002	2003	2002	2003	2003
AMBI	1	0	0	0	0	0	0	0	0
AMCO	0	0	0	0	0	0	0	0	0
AMWO	0	0	0	0	0	0	0	0	0
BCNH	0	0	0	0	0	0	0	0	0
BEKI	0	0	0	0	0	0	0	1	0
BLTE	0	0	0	0	0	0	0	0	0
BOGU	0	0	0	0	0	0	0	0	0
BWTE	0	0	0	0	0	0	0	0	0
CAGO	2	0	0	0	0	0	0	0	0
CATE	1	0	3	0	0	0	0	0	0
COGR	2	1	1	0	0	0	0	0	2
COLO	0	0	0	0	0	0	0	0	0
COME	0	0	0	0	0	0	0	0	0
COMO	2	0	0	0	0	0	0	0	0
COTE	0	0	0	2	0	0	0	0	0
DCCO	0	0	0	0	0	0	0	0	0
DUNL	0	0	0	0	0	0	0	0	0
GADW	0	0	0	0	0	0	0	0	0
GRCA	0	0	0	0	0	0	0	0	0
GREG	0	0	0	0	0	0	0	0	0
GRHE	0	0	0	0	0	0	0	0	0
GBHE	2	0	0	0	0	0	0	0	0
GWTE	0	0	0	0	0	0	0	0	0
HERG	0	0	0	0	0	0	0	0	0
KILL	0	0	0	0	0	0	0	0	0
LEBI	0	0	0	0	0	0	0	0	0
MALL	2	0	0	0	0	0	2	0	0
MAWA	0	0	0	0	0	0	0	0	0
MAWR	1	0	0	1	21	16	0	0	0
MOOT	0	0	0	0	0	0	6	0	0
MUSW	4	0	0	0	0	0	0	0	0
NOHA	0	0	0	0	0	0	0	0	0
NRWS	0	0	0	0	0	0	0	0	0
NSHO	0	0	0	0	0	0	0	0	0
OSPR	0	0	0	0	0	0	0	0	0
PBGR	3	0	0	0	0	0	0	0	0
RBGU	0	0	0	0	0	0	0	0	0
RNDU	0	0	0	0	0	0	0	0	0
RUDU	0	0	0	0	0	0	0	0	0
RWBL	52	20	13	25	29	20	23	12	10
SORA	1	0	0	0	2	0	2	0	0
SPSA	0	0	0	0	0	1	0	0	0
SWSP	0	4	0	6	11	12	0	7	0
TRUS	0	0	0	0	0	0	0	0	0
VIRA	1	0	0	0	6	9	4	0	0
WODU	0	0	0	0	0	0	0	0	0

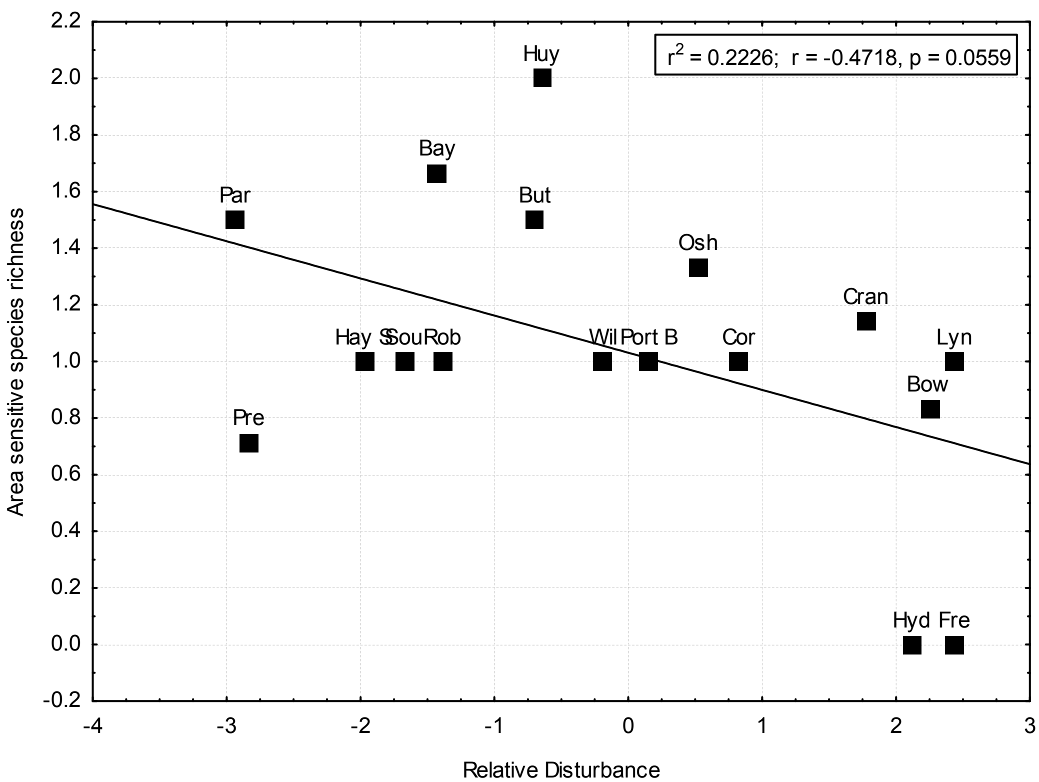
Table D-3 Site codes for wetlands used in disturbance vs. bird metric plots.

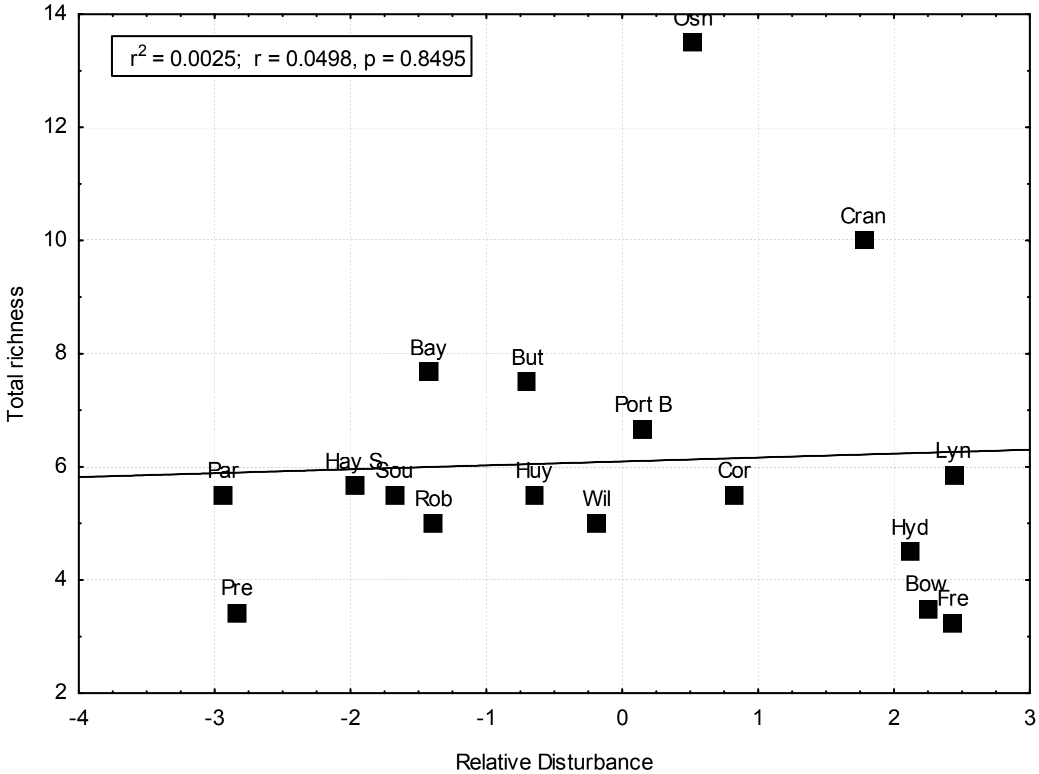
Site Code	Wetland Name
Bay	Bayfield Bay
Bow	Bowmanville Marsh
But	Button Bay
Cor	Corbett Creek Marsh
Cran	Cranberry Marsh
Fre	Frenchman's Bay Marsh
Hay S	Hay Bay South
Huy	Huyck's Bay
Hyd	Hydro Marsh
Lyn	Lynde Creek Marsh
Osh	Oshawa Second Marsh
Par	Parrott's Bay
Port B	Port Britain
Pre	Presqu'ile Bay
Rob	Robinson's Cove
Sou	South Bay
Wes	Westside Marsh
Wil	Wilmot Creek Marsh

The following graphs represent all breeding bird community metrics assessed against wetland disturbance.

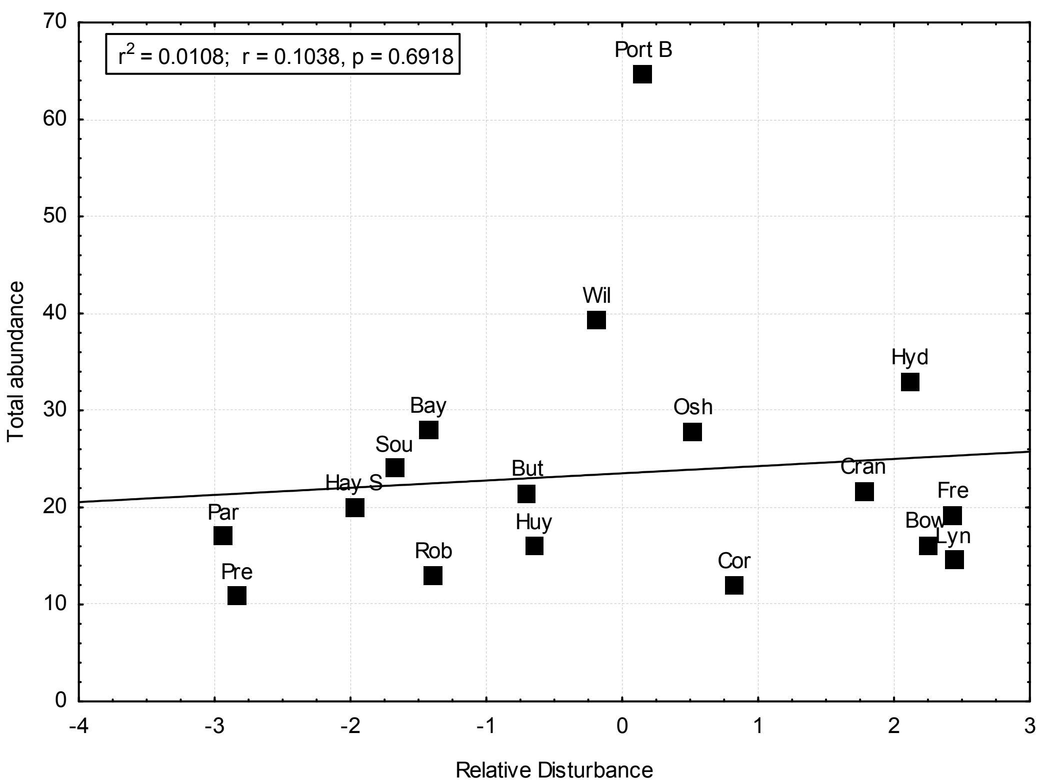



r^2 = 0.0965; r = 0.3106, p = 0.2250
Marsh user richness
Relative Disturbance
Bow
Cran
But
Bay
Par
Wil
Osh
Cor
Lyn
Huy
Hyd
Pre
Sou
Port B
Hay S
Rob
Fre

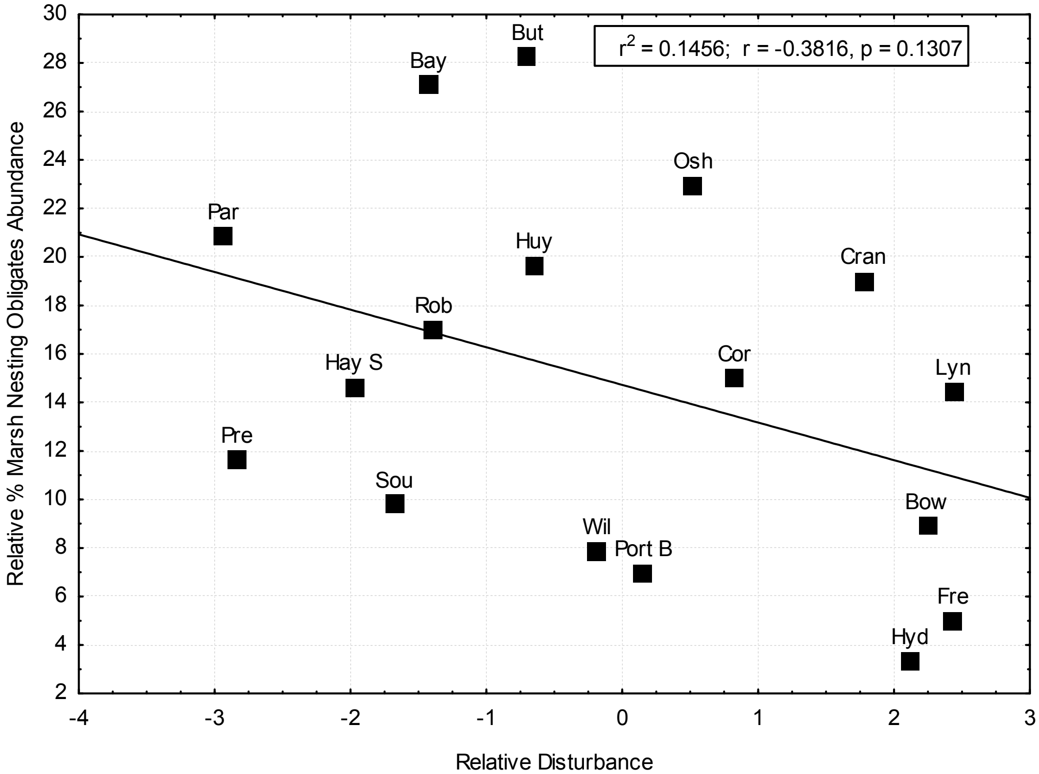

r^2 = 0.2226; r = -0.4718, p = 0.0559
Area sensitive species richness
Relative Disturbance
Huy
Bay
Par
But
Osh
Cran
Hay S
Sou
Rob
Wil
Port B
Cor
Lyn
Bow
Pre
Hyd
Fre

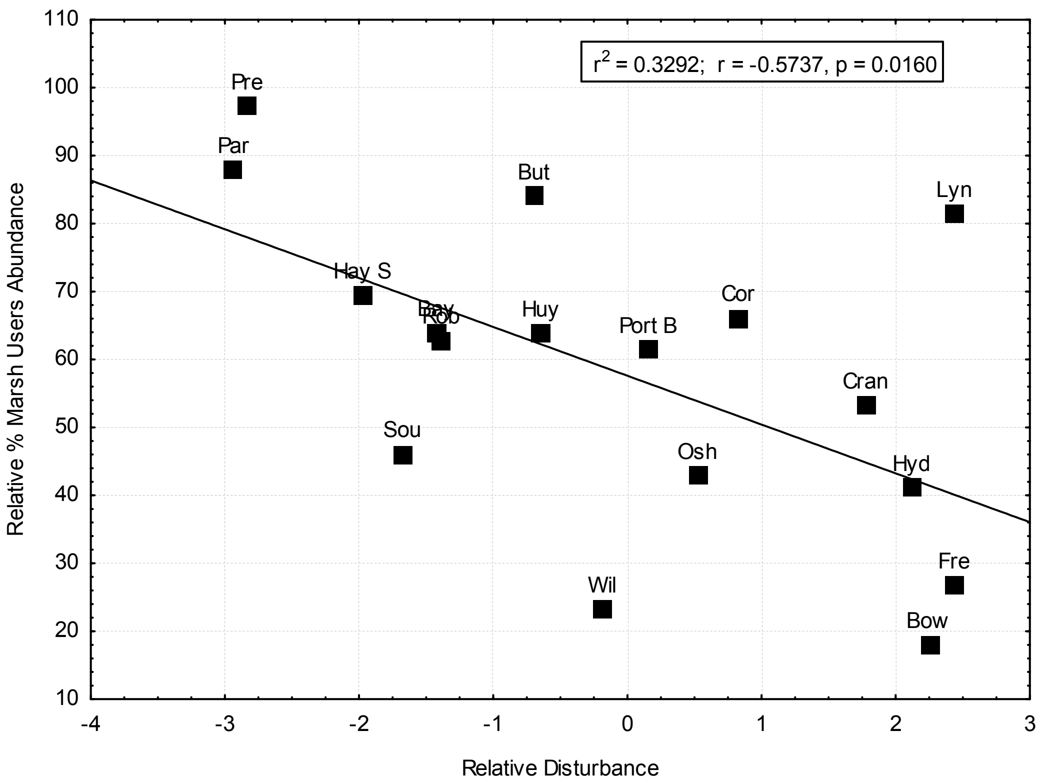


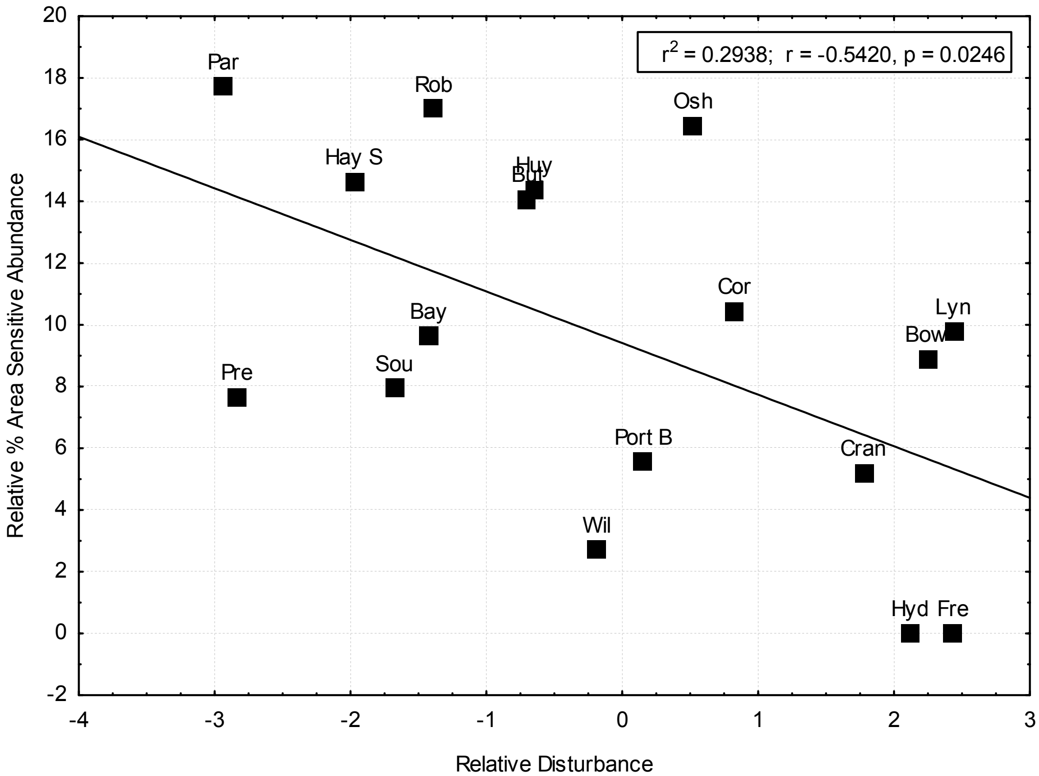
r^2 = 0.0025; r = 0.0498, p = 0.8495
Osh
Cran
Bay
But
Port B
Par
Hay S
Sou
Rob
Huy
Wil
Cor
Lyn
Hyd
Pre
Bow
Fre
Total richness
Relative Disturbance
14
12
10
8
6
4
2
-4
-3
-2
-1
0
1
2
3



r^2 = 0.0108; r = 0.1038, p = 0.6918
Port B
Wil
Hyd
Bay
Osh
Sou
But
Cran
Hay S
Fre
Par
Huy
Bow
Lyn
Rob
Cor
Pre
Total abundance
Relative Disturbance
70
60
50
40
30
20
10
0
-4
-3
-2
-1
0
1
2
3


r² = 0.1456; r = -0.3816, p = 0.1307
Relative % Marsh Nesting Obligates Abundance
Relative Disturbance
But
Bay
Osh
Par
Huy
Cran
Rob
Cor
Hay S
Lyn
Pre
Sou
Bow
Wil
Port B
Fre
Hyd


r² = 0.3292; r = -0.5737, p = 0.0160
Relative % Marsh Users Abundance
Relative Disturbance
Pre
Par
But
Lyn
Hay S
Cor
Bay
Rob
Huy
Port B
Cran
Sou
Osh
Hyd
Fre
Wil
Bow



r2 = 0.2938; r = -0.5420, p = 0.0246
Par
Rob
Osh
Hay S
Huy
Bul
Cor
Lyn
Bow
Bay
Pre
Sou
Port B
Cran
Wil
Hyd
Fre
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
Relative % Area Sensitive Abundance
Relative Disturbance

APPENDIX E

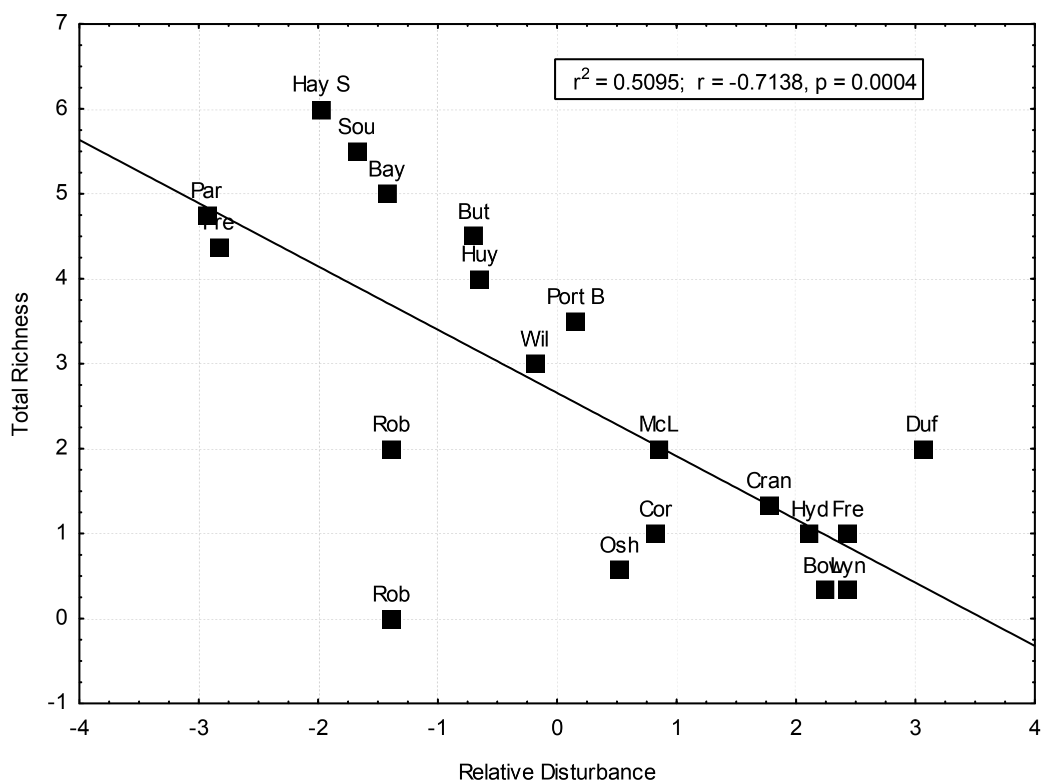
Table E-1. Amphibian species (four-letter MMP codes) found in Lake Ontario coastal wetlands.

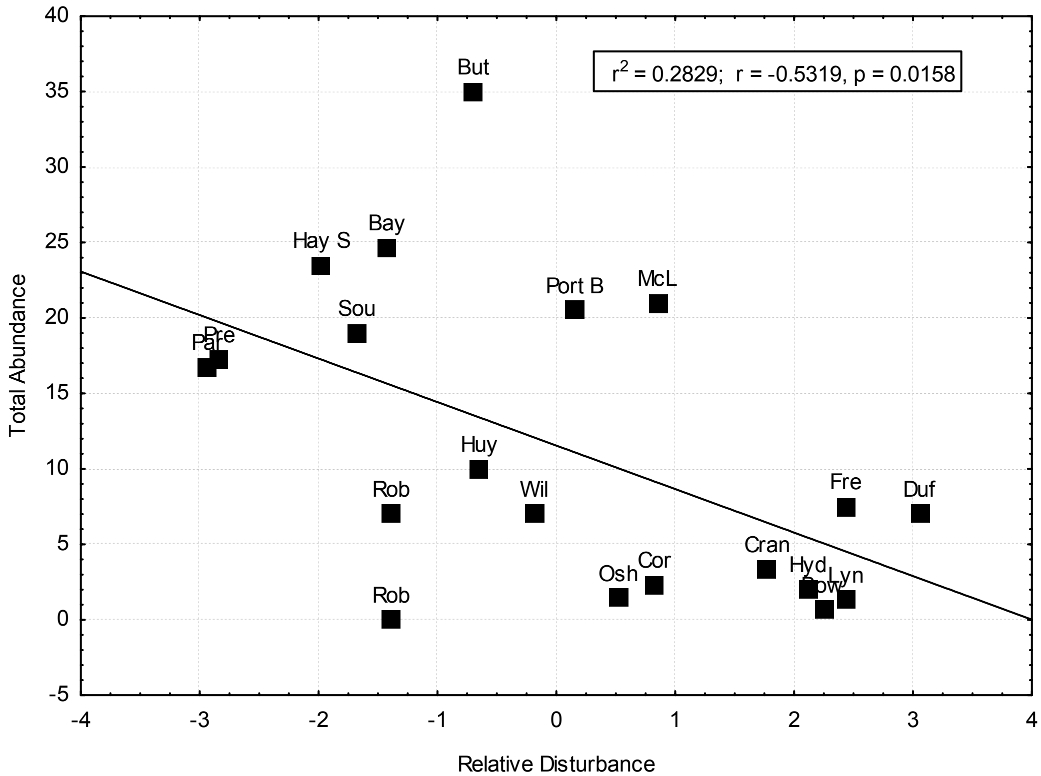
	AMTO		BULL		CHFR		GRFR		GRTR		NLFR		SPPE		WOFR	
Wetland Name	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Bayfield Bay	4	0	13	0	8	0	2	0	0	0	12	0	4	0	0	0
Bowmanville Marsh	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Button Bay	6	0	2	0	18	0	0	0	0	0	5	0	11	0	0	0
Corbett Creek Marsh	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Cranberry Marsh	2	3	0	0	0	0	3	1	0	0	4	1	0	1	0	5
Duffins Creek Marsh	6	1	0	0	0	0	4	2	0	0	2	1	0	0	0	0
Frenchman's Bay Marsh	5	0	0	0	0	0	2	0	0	0	2	0	2	0	0	0
Hay Bay South	2	0	8	0	0	0	3	0	6	0	1	0	6	0	0	0
Huyck's Bay	0	0	3	0	2	0	1	0	0	0	0	0	0	0	4	0
Hydro Marsh	1	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0
Lynde Creek Marsh	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
McLaughlin Bay Marsh	0	0	0	0	0	0	9	0	0	0	0	0	0	5	12	0
Oshawa Second Marsh	4	8	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Parrott's Bay	5	0	3	4	9	0	3	4	0	0	3	3	5	30	0	3
Port Britain	6	0	0	0	0	0	4	0	0	0	1	0	15	0	0	0
Port Newcastle Wetland	0	1	0	0	0	0	0	6	0	0	0	6	0	0	0	0
Presqu'ile Beach	1	2	9	0	2	5	6	0	9	6	0	3	6	5	0	0
Pumphouse Marsh	0	9	0	0	0	0	0	4	0	0	0	1	0	0	0	0
Robinson's Cove	0	0	0	3	0	0	0	4	0	0	0	0	0	0	0	0
Rouge River Marsh	0	6	0	0	0	0	0	2	0	0	0	0	0	0	0	0
South Bay	2	0	1	0	4	0	2	0	5	0	5	0	5	0	0	0
Wilmot Creek Marsh	2	4	0	0	0	0	4	0	0	0	0	0	1	0	0	3

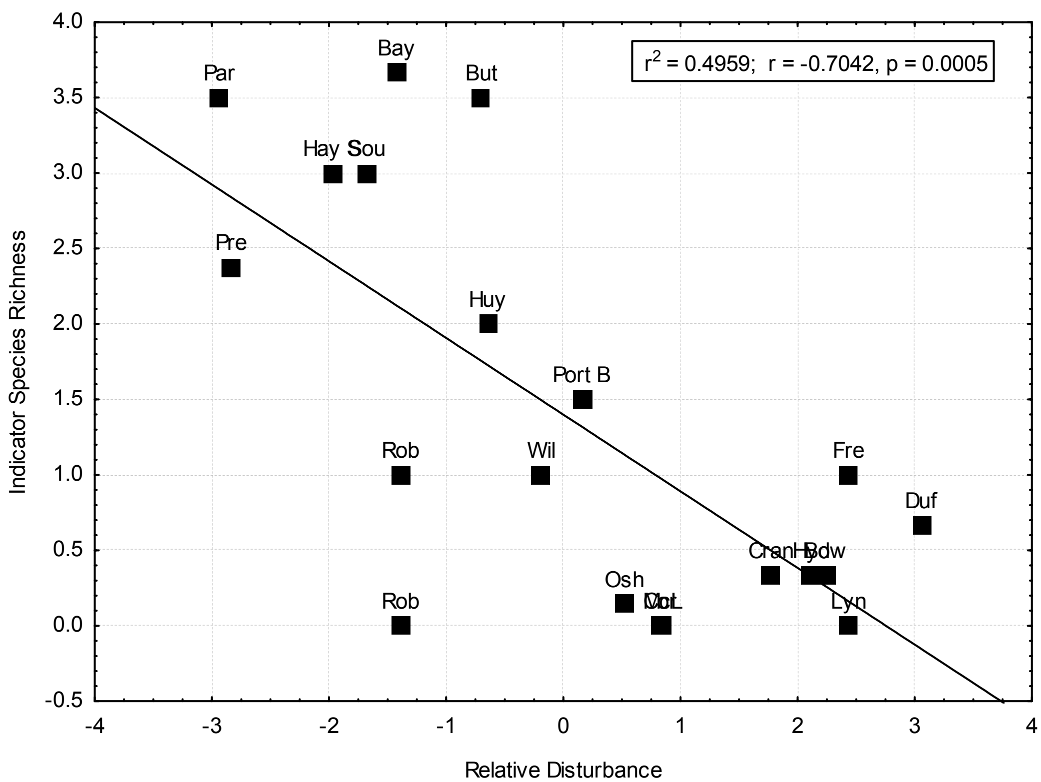
Table E-2. Site codes for wetlands used in disturbance vs. metric plots.

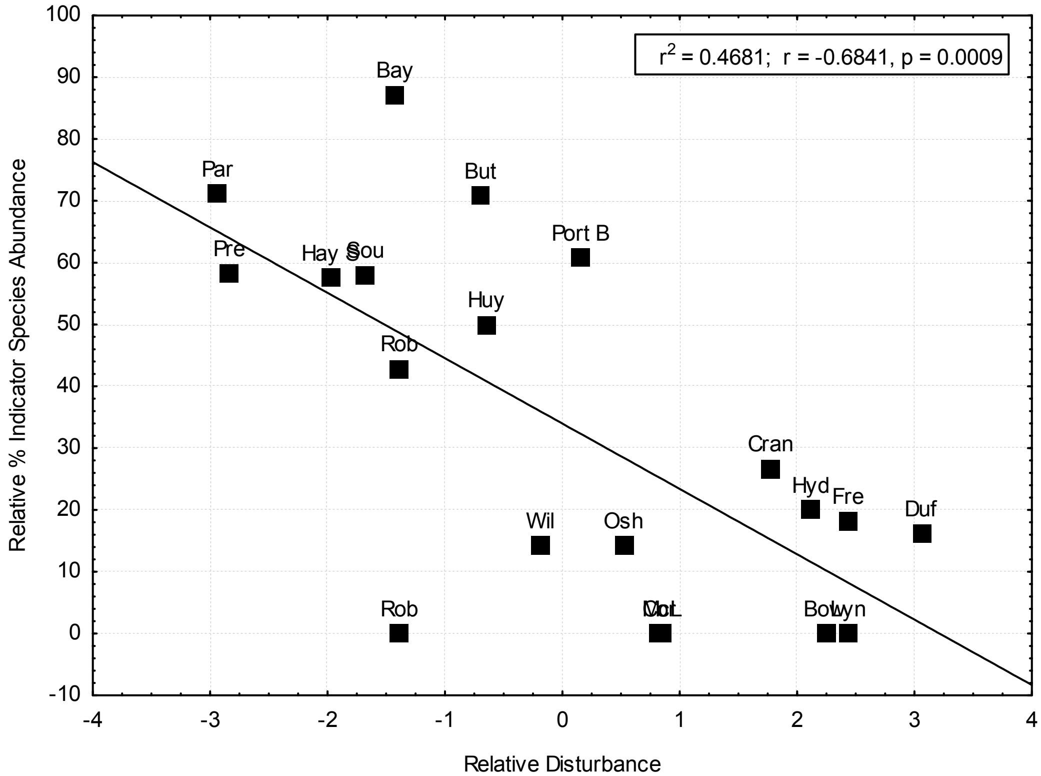
Site Code	Wetland Name
Bay	Bayfield Bay
Bow	Bowmanville Marsh
But	Button Bay
Cor	Corbett Creek Marsh
Cran	Cranberry Marsh
Duf	Duffins Creek Marsh
Fre	Frenchman's Bay Marsh
Hay S	Hay Bay South
Huy	Huyck's Bay
Hyd	Hydro Marsh
Lyn	Lynde Creek Marsh
McL	McLaughlin Bay Marsh
Osh	Oshawa Second Marsh
Par	Parrott's Bay
Port B	Port Britain
Pre	Presqu'ile Bay
Rob	Robinson's Cove
Sou	South Bay
Wil	Wilmot Creek Marsh

The following graphs represent all breeding amphibian community metrics assessed against wetland disturbance




r2 = 0.2829; r = -0.5319, p = 0.0158
Total Abundance
Relative Disturbance
But
Hay S
Bay
Sou
Port B
McL
Par
Pre
Huy
Rob
Wil
Fre
Duf
Cran
Osh
Cor
Hyd
Bow
Lyn
Rob


r2 = 0.4959; r = -0.7042, p = 0.0005
Indicator Species Richness
Relative Disturbance
Par
Bay
But
Hay S
Sou
Pre
Huy
Port B
Rob
Wil
Fre
Duf
Cran
Hyd
Bow
Osh
Cor
McL
Rob
Lyn


r2 = 0.4681; r = -0.6841, p = 0.0009
Relative % Indicator Species Abundance
Relative Disturbance
Bay
Par
But
Port B
Pre
Hay S
Sou
Huy
Rob
Cran
Hyd
Fre
Duf
Wil
Osh
Rob
Bow
Lyn
100
90
80
70
60
50
40
30
20
10
0
-10
-4
-3
-2
-1
0
1
2
3
4

APPENDIX F

Sediment Sampling and Analysis Methodology

Targeted compounds include those that are typically associated with sediment, such as organochlorines (including DDT and PCBs), metals, and polycyclic aromatic hydrocarbons (PAHs). Targeting these compounds is appropriate for sediment quality investigations since there is increased probability of detecting these compounds, compared with water quality measurements, if they exist at the site.

Sediment sampling was performed by the conservation authorities in Durham Region in collaboration with a larger, screening-level assessment of sediment quality in Canadian tributaries to the Great Lakes conducted by the Ecosystem Health Division – Ontario Region, Environment Canada (EHD-OR)(Figure 2.1.3-1). As such, the sampling methodology employed by EHD-OR, (based on U.S. Geological Survey protocols [Shelton and Capel 1994]), was adopted by the DRCWMP. According to this methodology, one sediment sample, consisting of many subsamples, was taken from each site in a manner that was representative of the overall sediment quality at that site. Only the very fine-grained surface deposits, to a maximum depth of approximately one or two cm, depending on the site, were collected. These surface sediments better represent relatively recent rather than historic deposition.

The sampled sites are shown in Figure F-1. In general, surface sediments were collected from depositional areas at three or more zones for each wetland: 1) from each tributary upstream of the wetland, if present; 2) the open water basin of the wetland, and 3) the outlet of the wetland. All tributaries (i.e., wetland inflows) were sampled by EHD-OR. A total of 21 tributary sites were sampled for this project.

Wetlands and outflow sites were sampled by the respective conservation authority. Eight wetlands and eight wetland outflows were sampled by the Central Lake Ontario Conservation Authority (CLOCA); two wetlands and two wetland outflows were sampled by the Ganaraska Region Conservation Authority (GRCA); and 16 wetland sites (in five wetlands) were sampled by the Toronto and Region Conservation Authority (TRCA). CLOCA and GRCA followed the sampling methodology adopted by EHD-OR. The TRCA field methods differed slightly in that the top five cm of sediments were collected from each wetland.

Laboratory Methods – Environment Canada and Central Lake Ontario and Ganaraska Region Conservation Authorities

Sediments collected from all tributary and wetland sites were screened for a suite of parameters including metals, organochlorines and polycyclic aromatic hydrocarbons (PAHs). Physical properties of the sediments (organic carbon content and grain size fractions) were also determined. Wetland outflow sites were analyzed for metals and physical properties only.

Analysis of organochlorines and PAHs was performed by Maxxam Analytics Inc., Mississauga, Ontario. Organochlorines were analyzed by gas chromatography/dual column electron capture detector (GC/ECD) after accelerated solvent extraction following the SW846 EPA 3545 protocol. Samples for PAH analysis were extracted using a sonication method. The extracts were then concentrated and analyzed by mass spectrometry (GC/MS). Sample results were reported on a dry weight basis.

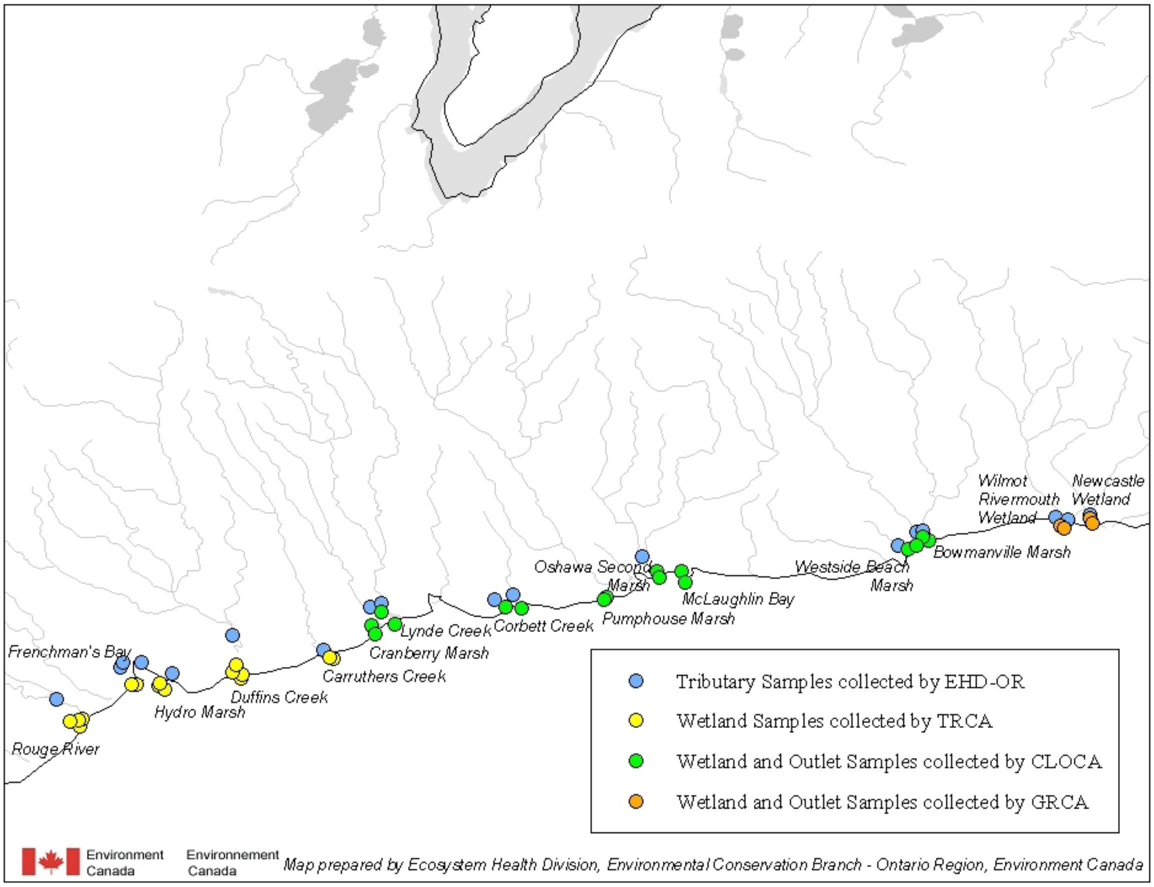


Figure F-1. The locations and samplers for sediments in Durham Region Coastal wetlands.

The samples for metals, carbon content, and grain size analysis were freeze-dried by Natural Resources Canada (NRCAN) in Ottawa prior to analysis. NRCAN analyzed carbon content by Leco Cr-412 and grain-size fractions using a Lecotrac Particle Size Analyzer LT100.

Caduceon Enterprises Inc., located in Ottawa, performed the metals analysis (including mercury) using aqua regia digestion methods. Sample results were reported on a dry weight basis.

Laboratory Methods – Toronto and Region Conservation Authority

AMEC Earth and Environmental, located in Mississauga, Ontario, performed all analyses for samples collected by TRCA. The list of analytes was similar to that for the other sites, with the exception that two DDT metabolites (o,p'-DDD and o,p'-DDE) were not analyzed. Additional analyses (chromium VI, conductivity, loss on ignition, oil and grease, pH and Total Kjeldahl Nitrogen) were performed on TRCA-collected samples that were not performed by the other laboratories.

TRCA Sediment Sampling Locations:

ID	Sample #	UTM Northing	UTM Easting	Notes
Duffins Creek Marsh	1	4853349	657987	North basin
Duffins Creek Marsh	2	4853578	658024	Second basin from north (large basin)
Duffins Creek Marsh	3	4853721	657603	3rd basin from north
Duffins Creek Marsh	4	4854138	657740	Basin closest to lake
Rouge River Marsh	1	4850466	651121	West basin
Rouge River Marsh	2	4850384	651116	
Rouge River Marsh	3	4850783	651237	South basin
Rouge River Marsh	4	4850735	651100	South basin
Rouge River Marsh	5	4850607	650731	East basin
Carruthers Creek Marsh	1	4854641	661940	North sample
Carruthers Creek Marsh	2	4854710	661782	South sample
Frenchman's Bay Marsh	1	4852871	653520	South sample
Frenchman's Bay Marsh	2	4852871	653324	North sample
Hydro Marsh	1	4852839	654462	North sample
Hydro Marsh	2	4852652	654753	Sampled on Nov. 8
Hydro Marsh	3	4852962	654498	Sampled on Nov. 8

Date & Sampling Method:

Wetland	Date	Start Time	End Time	Sampler
Duffins Creek Marsh	11/6/2002			Ponar dredge
Rouge River Marsh	11/7/2002			Ponar dredge
Carruthers Creek Marsh	11/6/2002			Ponar dredge
Frenchman's Bay Marsh	11/5/2002			Ponar dredge
Hydro Marsh	11/5/2002			Ponar dredge

TRCA Metals Results•

Parameter	MDL	Duffins Creek Marsh-1	Duffins Creek Marsh-2	Duffins Creek Marsh-3	Duffins Creek Marsh-4	Rouge River Marsh-1	Rouge River Marsh-2	Rouge River Marsh-3	Rouge River Marsh-4
Antimony (ug/g)	0.1	0	0	0	0	0	0	0	0
Arsenic (ug/g)	0.1	0.9	0.9	1	1.1	1.2	1.3	0.8	0.8
Barium (ug/g)	0.5	57	69	73	62	70	84	53	63
Beryllium (ug/g)	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2
Cadmium (ug/g)	0.5	0	0	0	0	0	0	0	0
Chromium (ug/g)	1	12	16	14	9	16	19	11	13
Cobalt (ug/g)	1	4	4	5	4	5	6	4	5
Copper (ug/g)	1	12	16	15	12	17	21	14	15
Iron (%)	0.0005	1.33	1.48	1.7	1.26	1.63	1.7	1.11	1.32
Lead (ug/g)	2	9	11	11	9	10	15	7	9
Manganese (ug/g)	2	280	389	438	373	430	417	334	360
Mercury (ug/g)	0.01	0.03	0.05	0.04	0.02	0.01	0.02	0.03	0.02
Molybdenum (ug/g)	2	0	0	0	0	0	0	0	0
Nickel (ug/g)	2	8	11	10	8	11	13	7	9
Phosphorus (ug/g)	5	698	693	753	755	723	886	680	738
Selenium (ug/g)	0.1	0.1	0.1	0.1	0	0	0.1	0	0
Silver (ug/g)	0.5	0	0	0	0	0	0	0	0
Vanadium (ug/g)	5	16	13	17	12	19	21	14	15
Zinc (ug/g)	2	41	48	49	41	53	62	44	40

TRCA Metals Results[•]

Parameter	Rouge River Marsh-5	Carruthers Creek Marsh-1	Carruthers Creek Marsh-2	Frenchman's Bay Marsh-1	Frenchman's Bay Marsh-2	Hydro Marsh-1	Hydro Marsh-2	Hydro Marsh-3
Antimony	0	0	0	0	0.1	0	0.3	0.3
Arsenic	0.8	0.9	0.6	2.4	2.4	2.2	1.5	1.4
Barium (ug/g)	46	84	23	83	91	107	103	93
Beryllium	0.2	0.4	0	0.3	0.4	0.5	0.5	0.4
Cadmium	0	0	0	0	0.6	1.2	1.2	0.8
Chromium	10	18	6	14	18	29	32	21
Cobalt (ug/g)	4	6	3	4	6	6	7	7
Copper (ug/g)	11	18	5	37	40	94	67	37
Iron (%)	0.95	1.36	0.54	1.21	1.6	1.79	1.88	1.68
Lead (ug/g)	8	20	5	24	35	46	71	68
Manganese	256	249	85	384	423	340	365	300
Mercury	0.03	0.04	0.01	0.06	0.03	0.13	0.19	0.1
Molybdenum	0	0	0	2	0	2	2	0
Nickel (ug/g)	8	12	5	12	15	19	20	17
Phosphorus	804	829	668	605	813	6680	1120	923
Selenium	0	0.2	0	0.3	0.3	0.5	0.4	0.3
Silver (ug/g)	0	0	0	0	0	0	0	0
Vanadium	13	12	8	15	20	25	30	28
Zinc (ug/g)	32	72	24	86	125	389	305	190

[•] Lab: AMEC Earth & Environmental, Mississauga (905-890-0785)

TRCA Organics Results•

Parameter	MDL	Duffins Creek Marsh-1	Duffins Creek Marsh-2	Duffins Creek Marsh-3	Duffins Creek Marsh-4	Rouge River Marsh-1	Rouge River Marsh-2	Rouge River Marsh-3	Rouge River Marsh-4	Rouge River Marsh-5
a-BHC (ug/g)	0.003	0	0	0	0	0	0	0	0	0
a-Chlordane (ug/g)	0.003	0	0	0	0	0	0	0	0	0
Aldrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0
b-BHC (ug/g)	0.003	0	0	0	0	0	0	0	0	0
d-BHC (ug/g)	0.004	0	0	0	0	0	0	0	0	0
Dieldrin (ug/g)	0.000	0	0	0	0	0	0	0	0	0
Endosulfan I (ug/g)	0.004	0	0	0	0	0	0	0	0	0
Endosulfan II	0.004	0	0	0	0	0	0	0	0	0
Endosulfan sulfate	0.006	0	0	0	0	0	0	0	0	0
Endrin (ug/g)	0.000	0	0	0	0	0	0	0	0	0
g-BHC (ug/g)	0.000	0	0	0	0	0	0	0	0	0
g-Chlordane (ug/g)	0.004	0	0	0	0	0	0	0	0	0
Heptachlor (ug/g)	0.000	0	0	0	0	0	0	0	0	0
Heptachlor epoxide	0.002	0	0	0	0	0	0	0	0	0
Hexachlorobenzen	0.004	0	0	0	0	0	0	0	0	0
Methoxychlor	0.005	0	0	0	0	0	0	0	0	0
Mirex (ug/g)	0.001	0	0	0	0	0	0	0	0	0
o,p'-DDT (ug/g)	0.003	0	0	0	0	0	0	0	0	0
p,p'-DDD (ug/g)	0.003	0	0	0	0	0	0	0	0	0
p,p'-DDE (ug/g)	0.003	0	0	0	0	0	0	0	0	0
p,p'-DDT (ug/g)	0.003	0	0	0	0	0	0	0	0	0
Total PCB (ug/g)	0.005	0	0	0	0	0	0	0	0	0

• Lab: AMEC Earth & Environmental, Mississauga (905-890-0785)

TRCA Organics Results[•]

Parameter	Carruthers Creek Marsh-1	Carruthers Creek Marsh-2	Frenchman's Bay Marsh-1	Frenchman's Bay Marsh-2	Hydro Marsh -1	Hydro Marsh -2	Hydro Marsh -3
a-BHC (ug/g)	0	0	0	0	0	0	0
a-Chlordane	0	0	0	0	0	0	0
Aldrin (ug/g)	0	0	0	0	0	0	0
b-BHC (ug/g)	0	0	0	0	0	0	0
d-BHC (ug/g)	0	0	0	0	0	0	0
Dieldrin (ug/g)	0	0	0	0	0	0	0
Endosulfan I	0	0	0	0	0	0	0
Endosulfan II	0	0	0	0	0	0	0
Endosulfan	0	0	0	0	0	0	0
Endrin (ug/g)	0	0	0	0	0	0	0
g-BHC (ug/g)	0	0	0	0	0	0	0
g-Chlordane	0	0	0	0	0	0	0
Heptachlor (ug/g)	0	0	0	0	0	0	0
Heptachlor	0	0	0	0	0	0	0
Hexachlorobenze	0	0	0	0	0	0	0
Methoxychlor	0	0	0	0	0	0	0
Mirex (ug/g)	0	0	0	0	0	0	0
o,p'-DDT (ug/g)	0	0	0	0	0	0	0
p,p'-DDD (ug/g)	0	0	0	0	0	0	0
p,p'-DDE (ug/g)	0	0	0	0	0	0	0
p,p'-DDT (ug/g)	0	0	0	0	0	0	0
Total PCB (ug/g)	0	0	0	0	0	0	0

[•] Lab: AMEC Earth & Environmental, Mississauga (905-890-0785)

TRCA PAH, Physical Parameters and Other Results•

Parameter	MDL	Duffins Creek Marsh-1	Duffins Creek Marsh-2	Duffins Creek Marsh-3	Duffins Creek Marsh-4	Rouge River Marsh-1	Rouge River Marsh-2	Rouge River Marsh-3	Rouge River Marsh-4	Rouge River Marsh-5
Acenaphthene (ug/kg)	2	0	0	0	0	0	0	0	0	0
Acenaphthylene (ug/kg)	1	0	0	0	0	0	0	0	0	0
Anthracene (ug/kg)	1	0	0	0	0	0	0	0	0	0
Benzo(a)anthracene (ug/kg)	1	0		0	0	0	0	0	0	0
Benzo(a)pyrene (ug/kg)	3	0	0	0	0	0	0	0	0	0
Benzo(b)fluoranthene (ug/kg)	4	19	0	0	0	0	0	0	0	0
Benzo(ghi)perylene (ug/kg)	2	0	0	0	0	0	0	0	0	0
Benzo(k)fluoranthene (ug/kg)	4	14	0	0	0	0	0	0	0	0
Chrysene (ug/kg)	1	0	0	0	0	0	0	0	0	0
Dibenzo(a,h)anthracene (ug/kg)	4	0	0	0	0	0	0	0	0	0
Fluoranthene (ug/kg)	1	3	0	4	12	5	0	21	2	0
Fluorene (ug/kg)	1	0	0	0	0	0	0	0	0	0
Indeno(1,2,3-cd)pyrene (ug/kg)	3	0	0	0	0	0	0	0	0	0
Naphthalene (ug/kg)	2	0	0	0	0	0	0	0	0	0
Phenanthrene (ug/kg)	1	0	0	0	0	0	0	0	0	0
Pyrene (ug/kg)	3	3	0	2	10	3	0	16	3	0
Grain size - sand (%)		15.8	8.85	11.6	12.8	14.7	26.7	21.3	15.7	42.8
Grain size - silt/clay (%)		84.2	91.2	88.4	87.2	85.3	73.3	78.7	84.3	57.2
Total Organic Carbon (%)*	0.05	1.72	1.92	1.78	1.82	1.92	2.73	1.27	2.17	2.43
Chromium VI (ug/g)	0.2	0	0	0	0	0	0	0	0	0
Conductivity (us/cm)	10	600	524	585	557	635	786	472	857	790
LOI (%)	0.1	4.4	5	4.9	4.6	4.7	7	3.5	5.9	6
Oil & Grease (ug/g)	100	200	240	250	240	270	270	330	240	190
pH		7.8	7.7	7.7	7.7	7.7	7.6	7.7	7.6	7.6
TKN (ug/g)	60	1400	1790	1620	1000	1790	2290	1060	2290	2350

• Lab: AMEC Earth & Environmental, Mississauga (905-890-0785)

TRCA PAH, Physical Parameters and Other Results[•]

Parameter	Carruthers Creek Marsh-1	Carruthers Creek Marsh-2	Frenchman's Bay Marsh-1	Frenchman's Bay Marsh-2	Hydro Marsh-1	Hydro Marsh-2	Hydro Marsh-3
Acenaphthene (ug/kg)	0	0	0	0	0	0	0
Acenaphthylene (ug/kg)	0	0	0	0	0	0	0
Anthracene (ug/kg)	0	0	0	0	0	0	0
Benzo(a)anthracene (ug/kg)	0	0	0	0	0	0	0
Benzo(a)pyrene (ug/kg)	0	0	0	0	0	0	0
Benzo(b)fluoranthene (ug/kg)	0	0	0	0	0	0	0
Benzo(ghi)perylene (ug/kg)	0	0	0	0	0	0	0
Benzo(k)fluoranthene (ug/kg)	0	0	0	0	0	0	0
Chrysene (ug/kg)	0	0	0	0	0	0	0
Dibenzo(a,h)anthracene	0	0	0	0	0	0	0
Fluoranthene (ug/kg)	0	1	0	6	17	52	204
Fluorene (ug/kg)	0	0	0	0	0	0	0
Indeno(1,2,3-cd)pyrene	0	0	0	0	0	0	0
Naphthalene (ug/kg)	0	0	0	0	0	0	0
Phenanthrene (ug/kg)	0	0	0	0	0	0	0
Pyrene (ug/kg)	0	0	0	5	18	49	159
Grain size - sand (%)	26.6	80.6	24.2	25.6	41.8	44.9	54.6
Grain size - silt/clay (%)	73.4	19	75.8	74.4	58.2	55.1	45.4
Total Organic Carbon (%)*	3.79	1.23	6.98	7.61	10.7	15.1	9.27
Chromium VI (ug/g)	0	0	0	0	0	0	0
Conductivity (us/cm)	730	520	810	843	1690	1560	1450
LOI (%)	9.7	4.1	17.3	18.2	22.7	21	21
Oil & Grease (ug/g)	280	160	580	820	2340	3360	1460
pH	7.6	7.6	7.8	7.6	7.3	7.4	7.3
TKN (ug/g)	3240	952	6380	6600	4480	7330	3970

[•] Lab: AMEC Earth & Environmental, Mississauga (905-890-0785)

CLOCA and GRCA Sediment Sampling Locations

Location:

Wetland	Sample #	UTM - Northing	UTM - Easting	Notes
Bowmanville Marsh	1	4862291	687228	middle
Corbett Creek	1	4857853	669245	middle
Cranberry Marsh	1	4856616	663485	inlet
Lynde Creek Marsh	1	4857452	663891	middle
McLaughlin Bay Marsh	1	4860195	676718	inlet
Oshawa Second Marsh	1	4860178	675652	middle
Port Newcastle Wetland	1	4863807	694140	middle
Pumphouse Marsh	1	4858557	673539	near inlet
West Side Beach Marsh	1	4861762	686370	middle
Wilmot Rivermouth Wetland	1	4863345	692860	middle
Bowmanville Marsh	2	4862510	686984	north end
Corbett Creek	2	4857809	669936	near outlet
Cranberry Marsh	2	4856116	663657	"outlet"
Lynde Creek Marsh	2	4856748	664521	outlet
McLaughlin Bay Marsh	2	4859553	676898	"outlet"
Oshawa Second Marsh	2	4859804	675748	"outlet"
Port Newcastle Wetland	2	4863498	694250	outlet
Pumphouse Marsh	2	4858382	673446	"outlet"
West Side Beach Marsh	2	4861948	686716	outlet
Wilmot Rivermouth Wetland	2	4863202	693048	outlet

CLOCA and GRCA Sediment Sampling Locations
Date & Sampling Method:

Wetland	Date	Start Time	End Time	Sampler
Corbett Creek Marsh	9/13/2002	11:10:00 AM	12:00:00 PM	spoon
Pumphouse Marsh	9/16/2002	9:35:00 AM	11:45:00 AM	spoon
Bowmanville Marsh	9/17/2002	2:50:00 PM	3:45:00 PM	spoon
West Side Beach Marsh	9/18/2002	10:15:00 AM	11:57:00 AM	Ekman mini-dredge
Oshawa Second Marsh	9/24/2002	1:30:00 PM	2:35:00 PM	spoon
McLaughlin Bay Marsh	9/24/2002	4:25:00 PM	5:35:00 PM	Ekman mini-dredge
Lynde Creek Marsh	9/26/2002	11:10:00 AM	12:43:00 PM	spoon
Cranberry Marsh	9/30/2002	9:00:00 AM	11:00:00 AM	spoon
Port Newcastle Wetland	9/25/2002	12:30:00 PM	2:15:00 PM	spoon
Wilmot Rivermouth Wetland	9/25/2002	9:30:00 AM	11:50:00 AM	spoon

CLOCA and GRCA Metals and Physical Parameters Results♦

Parameter	MDL	Corbett Creek-1	Corbett Creek-2	Pumphouse Marsh-1	Pumphouse Marsh-2	Bowmanville Marsh-1	Bowmanville Marsh-2	West Side Beach Marsh-1
Aluminum (%)	0.01	0.9	0.98	1.3	1.35	0.61	0.65	1.62
Arsenic (ug/g)	5	0	0	0	0	0	0	0
Barium (ug/g)	1	106	121	175	140	111	106	146
Beryllium (ug/g)	0.2	0.3	0.4	0.5	0.5	0.3	0.3	0.5
Bismuth (ug/g)	5	0	0	0	0	0	0	0
Cadmium (ug/g)	1	0	0	1	2	0	0	0
Calcium (%)	0.01	9.19	13.4	9.43	4.5	10.8	8.54	8.52
Chromium (ug/g)	1	36	28	28	24	12	11	26
Cobalt (ug/g)	1	6	8	10	11	4	6	13
Copper (ug/g)	1	32	37	51	34	17	16	25
Iron (%)	0.01	1.54	1.69	1.95	2.03	1.19	1.17	2.23
Lead (ug/g)	5	35	33	105	75	15	20	30
Lithium (ug/g)	1	10	12	15	12	9	9	18
Magnesium (%)	0.01	0.63	0.78	0.75	0.67	0.59	0.62	0.77
Manganese	1	587	598	475	577	388	388	516
Mercury (ug/g)	0.005	0.042	0.045	0.117	0.117	0.05	0.026	0.069
Molybdenum	1	4	4	3	3	2	1	5
Nickel (ug/g)	1	16	10	24	20	8	5	23
Potassium (%)	0.05	0.14	0.19	0.22	0.19	0.08	0.06	0.26
Silver (ug/g)	0.5	0	0	0	0	0	0	0
Sodium (%)	0.01	0.1	0.11	0.11	0.24	0.02	0.03	0.08
Strontium (ug/g)	1	162	240	167	95	164	130	146
Tin (ug/g)	20	0	0	0	0	0	0	0
Titanium (ug/g)	1	476	465	587	514	256	230	871
Vanadium (ug/g)	1	24	23	29	32	14	14	36
Yttrium (ug/g)	1	9	10	11	11	9	8	14
Zinc (ug/g)	1	206	202	240	281	53	61	99
TOC %				7.1	12.2	8.2	7.2	6.3
Sand %				11.4	20.5	19.4	10.8	30.5
Silt %				74.0	71.5	52.2	63.6	55.6
Clay %				14.6	7.9	28.4	25.5	13.9

♦ Metals Analyses by Caduceon Enterprises, Ottawa; Physical Parameters by Activation Labs, Ancaster (905-648-9611)

CLOCA and GRCA Metals and Physical Parameters Results♦

Parameter	West Side Beach Marsh-2	Oshawa Second Marsh-1	Oshawa Second Marsh-2	McLaughlin Bay Marsh-1	McLaughlin Bay Marsh-2	Lynde Creek Marsh-1	Lynde Creek Marsh-2
Aluminum	1.35	0.52	0.78	1.43	0.36	0.63	1.09
Arsenic	0	0	0	0	0	0	0
Barium (ug/g)	125	65	94	152	46	77	121
Beryllium	0.5	0	0.3	0.5	0	0.3	0.4
Bismuth	0	0	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0
Calcium (%)	7.06	9.41	12.4	4.28	0.81	8.74	10.8
Chromium	22	23	54	31	17	12	20
Cobalt (ug/g)	11	5	4	13	6	8	9
Copper	22	19	28	29	14	16	27
Iron (%)	1.9	1.1	1.4	2.06	0.79	1.27	1.98
Lead (ug/g)	25	20	30	20	15	15	20
Lithium	14	7	12	14	6	8	14
Magnesium	0.62	0.57	0.7	0.7	0.46	0.56	0.71
Manganese	514	280	358	408	215	328	493
Mercury	0.074	0.04	0.069	0.076	0.045	0.026	0.084
Molybdenum	0	2	1	1	2	3	4
Nickel (ug/g)	11	22	41	25	24	12	16
Potassium	0.17	0.09	0.14	0.22	0	0.07	0.15
Silver (ug/g)	0	0	0	0	0	0	0
Sodium (%)	0.07	0.05	0.07	0.1	0.06	0.02	0.04
Strontium	128	150	190	81	137	137	170
Tin (ug/g)	0	0	0	0	0	0	0
Titanium	713	330	379	750	238	326	434
Vanadium	32	16	20	30	12	17	23
Yttrium (ug/g)	13	8	10	14	7	9	12
Zinc (ug/g)	94	87	123	100	52	53	88
TOC %	8.4	1.8	2.2	4.5	2.4	1.8	3.8
Sand %	25.8	9.0	2.6	15.5	15.3	7.5	18.4
Silt %	61.2	62.9	61.5	65.0	77.4	63.7	55.4
Clay %	13.0	28.2	35.8	19.4	7.3	28.8	26.2

♦ Metals Analyses by Caduceon Enterprises, Ottawa; Physical Parameters by Activation Labs, Ancaster (905-648-9611)

CLOCA and GRCA Metals and Physical Parameters Results♦

Parameter	Cranberry Marsh-1	Cranberry Marsh-2	Port Newcastle Wetland-1 (Graham Creek)	Port Newcastle Wetland-2 (Graham Creek)	Wilmot Rivermouth Wetland-1	Wilmot Rivermouth Wetland-2
Aluminum (%)	2.05	0.76	0.69	0.58	0.48	0.4
Arsenic (ug/g)	0	0	0	0	0	0
Barium (ug/g)	229	104	95	84	101	138
Beryllium (ug/g)	0.6	0.3	0.2	0.2	0	0
Bismuth (ug/g)	0	0	0	0	0	0
Cadmium (ug/g)	1	1	0	0	0	0
Calcium (%)	3.09	4.54	0.88	0.81	10.6	14
Chromium (ug/g)	32	14	13	11	11	8
Cobalt (ug/g)	14	7	8	8	5	0
Copper (ug/g)	27	22	11	11	11	9
Iron (%)	2.45	1.3	1.26	1.1	1.04	0.74
Lead (ug/g)	40	30	10	10	10	0
Lithium (ug/g)	18	8	8	9	7	7
Magnesium (%)	0.81	0.41	0.59	0.55	0.46	0.4
Manganese	516	420	585	502	346	213
Mercury (ug/g)	0.062	0.047	0.024	0.017	0.042	0.024
Molybdenum	2	0	1	3	2	2
Nickel (ug/g)	22	9	11	8	7	0
Potassium (%)	0.25	0.07	0.13	0.06	0.06	0.1
Silver (ug/g)	0	0	0	0	0	0
Sodium (%)	0.03	0.02	0.03	0.02	0.03	0.04
Strontium (ug/g)	73	91	123	116	126	160
Tin (ug/g)	0	0	0	0	0	0
Titanium (ug/g)	838	327	479	370	273	280
Vanadium (ug/g)	38	18	19	15	13	11
Yttrium (ug/g)	12	6	9	8	7	6
Zinc (ug/g)	131	82	41	39	39	29
TOC %	10.2	19.3	1.8	1.9	2.6	1.7
Sand %	15.6	19.8	18.7	13.1	3.3	8.1
Silt %	69.5	73.5	63.2	65.3	67.5	68.4
Clay %	14.9	6.6	18.1	21.6	29.2	23.5

♦ Metals Analyses by Caduceon Enterprises, Ottawa; Physical Parameters by Activation Labs, Ancaster (905-648-9611)

CLOCA and GRCA Organics Results°

Parameter	MDL	Lynde Cree	McLaughlin Bay Marsh	Wilmot Rivermouth Wetland	Pumphouse Marsh	Corbett Creek	Cranberry Marsh	Westside Beach Marsh	Bowman-ville Marsh	Port Newcastle	Oshawa Secon
Moisture %		61	80	76	87	70	91	85	89	82	65
Hexachlorobenzene (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
o,p'-DDD (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Endrin Aldehyde (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
o,p'-DDT (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Octachlorostyrene (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Toxaphene (ug/g)	0.08	0	0	0	0	0	0	0	0	0	0
o,p'-DDE (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aldrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
a-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
b-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
d-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Lindane (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
a-Chlordane (ug/g)	0.002	0	0	0	0.004	0	0	0	0	0	0
g-Chlordane (ug/g)	0.002	0	0	0	0.006	0	0	0	0	0	0
p,p'-DDD (ug/g)	0.002	0.002	0	0	0	0	0	0.002	0.003	0.02	0
p,p'-DDE (ug/g)	0.002	0.007	0.005	0.01	0.006	0.005	0.009	0.009	0.01	0.01	0.003
p,p'-DDT (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Dieldrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Endosulfan I (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Endosulfan II (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Endosulfan sulfate (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Endrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Heptachlor (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Heptachlor epoxide (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Methoxychlor (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Mirex (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor1262 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor1016 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor 1221 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor 1232 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor 1242 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Aroclor 1248 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0

° Laboratory Analysis by Maxxam Analytics 1-800-563-6266

CLOCA and GRCA Organics Results°

Parameter	MDL	Lynde Creek Marsh	McLaughlin Bay Marsh	Wilmot Rivermouth Wetland	Pumphouse Marsh	Corbett Creek Marsh	Cranberry Marsh	Westside Beach Marsh	Bowman-ville Marsh	Port Newcastle Wetland	Oshawa Second Marsh
Aroclor 1254 (ug/g)	0.002	0.01	0.04	0	0.02	0.03	0	0	0	0	0.01
Aroclor 1260 (ug/g)	0.002	0	0.02	0	0.02	0.05	0	0.01	0.01	0	0.01
Aroclor 1268 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0
Total PCB (ug/g)	0.002	0.01	0.06	0	0.04	0.08	0	0.01	0.01	0	0.02
Naphthalene (ug/kg)	5	0	0	0	0	0	0	0	0	0	6
Acenaphthylene (ug/kg)	5	0	0	0	0	0	0	0	0	0	9
Acenaphthene (ug/kg)	10	0	0	0	17	0	0	0	0	0	0
Fluorene (ug/kg)	5	0	0	0	28.1	0	0	0	0	0	12.9
Phenanthrene (ug/kg)	5	36.1	25.1	9	476	22.5	0	25.3	17.5	20.5	225
Anthracene (ug/kg)	5	0	0	0	59.8	0	0	0	0	0	31.3
Fluoranthene (ug/kg)	5	113	41.6	20.7	2110	50.5	33	45	24.8	52.4	882
Pyrene (ug/kg)	5	93	35.6	16	1810	65.6	25.8	42.6	20.8	42	776
Benzo(a)anthracene (ug/kg)	10	42	42	15	788	27	39	35	27	30	339
Chrysene (ug/kg)	10	69	18	0	1060	36	0	26	0	26	404
Benzo(b)fluoranthene (ug/kg)	10	62	33	12	1220	34	22	30	0	23	417
Benzo(k)fluoranthene (ug/kg)	10	41	13	0	781	16	0	17	0	15	251
Benzo(a)pyrene (ug/kg)	5	62.3	56.9	9	1460	29	0	33	0	26.3	483
Indeno(1,2,3-cd)pyrene (ug/kg)	20	39	25	0	835	23	0	33	0	0	235
Dibenzo(a,h)anthracene (ug/kg)	20	0	0	0	260	0	0	0	0	0	77
Benzo(ghi)perylene (ug/kg)	20	52	32	0	975	40	40	53	0	0	278
Total PAH (ug/kg)		609	322	82	11,880	344	160	340	90	235	4,426

° Laboratory Analysis by Maxxam Analytics 1-800-563-6266

EHD-OR Sediment Sampling Locations

Tributary	Tributary to:	Sampling Date	Latitude	Longitude
Amberlea Creek	Frenchman's Bay	16-Jul-02	43.82203	-79.09969
Bayly	Frenchman's Bay	16-Jul-02	43.82477	-79.09836
Bowmanville Creek	Bowmanville Marsh	17-Sep-02	43.89442	-78.67536
Carruthers Creek	Carruthers Creek Marsh	16-Jul-02	43.83179	-78.99141
Duffins Creek	Duffins Creek Marsh	16-Jul-02	43.83942	-79.04008
East Corbett Creek	Corbett Creek Marsh	18-Jul-02	43.86125	-78.89026
East Lynde Creek	Lynde Creek Marsh	16-Jul-02	43.85662	-78.96081
Farewell Creek	Oshawa Second Marsh	28-Aug-02	43.88112	-78.8216
Foster Creek	Wilmot Rivermouth Wetland	18-Sep-02	43.90086	-78.59479
Graham Creek	Port Newcastle Wetland	18-Sep-02	43.90386	-78.58314
Harmony Creek	Oshawa Second Marsh	28-Aug-02	43.88104	-78.82186
Hydro	Hydro Marsh	16-Jul-02	43.81919	-79.07228
Radom	Frenchman's Bay	16-Jul-02	43.82513	-79.08846
Rouge River	Rouge River Marsh	16-Jul-02	43.80556	-79.13402
Soper Creek	Bowmanville Marsh	17-Sep-02	43.89519	-78.67218
West Corbett Creek	Corbett Creek Marsh	18-Jul-02	43.85854	-78.90038
West Lynde Creek	Lynde Creek Marsh	16-Jul-02	43.85436	-78.96639
Westside Creek	Westside Beach Marsh	17-Sep-02	43.88724	-78.6852
Wilmot Creek	Wilmot Rivermouth Wetland	18-Sep-02	43.90212	-78.60104

EHD-OR Organics Results°

Tributary	MDL	Amberlea Creek	Bayly	Bowmanville Creek	Carruthers Creek	Duffins Creek	East Corbett Creek	East Lynde Creek	Farewell Creek	Foster Creek	Graham Creek	Harmony Creek
Moisture (%)		41	40	61	45	45	46	55	48	46	57	48
Hexachlorobenzene(ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
o,p'-DDD (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Endrin Aldehyde (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
O,p'-DDT (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Octachlorostyrene(ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Toxaphene (ug/g)	0.08	0	0	0	0	0	0	0	0	0	0	0
O,p'-DDE (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aldrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
a-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
b-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
d-BHC (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Lindane (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
a-Chlordane (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
g-Chlordane (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
P,p'-DDD (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0.002	0
P,p'-DDE (ug/g)	0.002	0.002	0.003	0	0	0	0.002	0.006	0	0.004	0.007	0
P,p'-DDT (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0.002	0.002
Dieldrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Endosulfan I (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Endosulfan II (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Endosulfan sulfate (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Endrin (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Heptachlor (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Heptachlor epoxide (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Methoxychlor (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Mirex (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor1262 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor1016 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor 1221 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor 1232 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor 1242 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Aroclor 1248 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0

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EHD-OR Organics Results°

Tributary	Hydro	Radom	Rouge River	Soper Creek	West Corbett Creek	West Lynde Creek	Westside Creek	Wilmot Creek
Moisture (%)	49	50	41	63	48	57	48	52
Hexachlorobenzene(ug/g)	0	0	0	0	0	0	0	0
o,p'-DDD (ug/g)	0	0	0	0	0	0	0	0
Endrin Aldehyde (ug/g)	0	0	0	0	0	0	0	0
O,p'-DDT (ug/g)	0	0	0	0	0	0	0	0
Octachlorostyrene(ug/g)	0	0	0	0	0	0	0	0
Toxaphene (ug/g)	0	0	0	0	0	0	0	0
O,p'-DDE (ug/g)	0	0	0	0	0	0	0	0
Aldrin (ug/g)	0	0	0	0	0	0	0	0
a-BHC (ug/g)	0	0	0	0	0	0	0	0
b-BHC (ug/g)	0	0	0	0	0	0	0	0
d-BHC (ug/g)	0	0	0	0	0	0	0	0
Lindane (ug/g)	0	0	0	0	0	0	0	0
a-Chlordane (ug/g)	0	0	0	0	0	0	0	0
g-Chlordane (ug/g)	0	0	0	0	0	0	0	0
P,p'-DDD (ug/g)	0	0	0	0.003	0	0.002	0	0
P,p'-DDE (ug/g)	0.002	0	0	0.01	0	0.008	0	0.005
P,p'-DDT (ug/g)	0	0	0	0	0	0	0	0.002
Dieldrin (ug/g)	0	0	0	0	0	0	0	0
Endosulfan I (ug/g)	0	0	0	0	0	0	0	0
Endosulfan II (ug/g)	0	0	0	0	0	0	0	0
Endosulfan sulfate (ug/g)	0	0	0	0	0	0	0	0
Endrin (ug/g)	0	0	0	0	0	0	0	0
Heptachlor (ug/g)	0	0	0	0	0	0	0	0
Heptachlor epoxide (ug/g)	0	0	0	0	0	0	0	0
Methoxychlor (ug/g)	0	0	0	0	0	0	0	0
Mirex (ug/g)	0	0	0	0	0	0	0	0
Aroclor1262 (ug/g)	0	0	0	0	0	0	0	0
Aroclor1016 (ug/g)	0	0	0	0	0	0	0	0
Aroclor 1221 (ug/g)	0	0	0	0	0	0	0	0
Aroclor 1232 (ug/g)	0	0	0	0	0	0	0	0
Aroclor 1242 (ug/g)	0	0	0	0	0	0	0	0
Aroclor 1248 (ug/g)	0	0	0	0	0	0	0	0

° Laboratory Analysis by Maxxam Analytics 1-800-563-6266

EHD-OR Organics Results[°]

Tributary	MDL	Amberlea Creek	Bayly	Bowmanville Creek	Carruthers Creek	Duffins Creek	East Corbett Creek	East Lynde Creek	Farewell Creek	Foster Creek	Graham Creek	Harmony Creek
Aroclor 1254 (ug/g)	0.002	0	0.01	0	0.06	0	0.02	0.02	0	0	0	0.007
Aroclor 1260 (ug/g)	0.002	0	0.01	0	0	0	0	0	0	0	0	0.004
Aroclor 1268 (ug/g)	0.002	0	0	0	0	0	0	0	0	0	0	0
Total PCB (ug/g)	0.002	0	0.02	0	0.06	0	0.02	0.02	0	0	0	0.01
Naphthalene (ug/kg)	5	13.4	18.5	0	0	0	15	0	7	0	0	7
Acenaphthylene (ug/kg)	5	8	15.5	0	0	0	9	0	8	0	0	7
Acenaphthene (ug/kg)	10	14	0	0	0	0	12	0	17	0	0	0
Fluorene (ug/kg)	5	22.6	19.6	0	0	0	20.4	0	22.4	0	0	11.9
Phenanthrene (ug/kg)	5	377	335	123	36.1	89.4	190	85.1	396	29.6	10	194
Anthracene (ug/kg)	5	50	85.1	11.3	0	11.3	44.9	16.5	66.4	0	0	45.7
Fluoranthene (ug/kg)	5	779	544	177	64.6	218	336	240	1000	80.3	22.4	505
Pyrene (ug/kg)	5	573	389	156	49.4	169	275	181	759	62.5	17.6	380
Benzo(a)anthracene (ug/kg)	10	123	95	65	27	41	73	48	202	18	0	89
Chrysene (ug/kg)	10	476	337	107	35	119	185	122	484	49	0	332
Benzo(b)fluoranthene (ug/kg)	10	151	174	38	26	46	94	45	172	28	0	155
Benzo(k)fluoranthene (ug/kg)	10	185	97	39	12	59	84	56	234	24	0	160
Benzo(a)pyrene (ug/kg)	5	233	167	52.8	23.4	54.4	95.9	56.2	243	25	0	181
Indeno(1,2,3-cd)pyrene (ug/kg)	20	207	121	42	0	62	99	60	262	24	0	155
Dibenzo(a,h)anthracene (ug/kg)	20	54	28	0	0	0	24	0	65	0	0	34
Benzo(ghi)perylene (ug/kg)	20	218	141	53	0	67	122	64	268	28	0	168
Total PAH (ug/kg)		3484	2567	864	274	936	1679	974	4206	368	50	2425

[°] Laboratory Analysis by Maxxam Analytics 1-800-563-6266

EHD-OR Organics Results°

Tributary	Hydro	Radom	Rouge River	Soper Creek	West Corbett Creek	West Lynde Creek	Westside Creek	Wilmot Creek
Aroclor 1254 (ug/g)	0.01	0	0	0.007	0.05	0	0	0
Aroclor 1260 (ug/g)	0.01	0	0	0.005	0.06	0	0	0
Aroclor 1268 (ug/g)	0	0	0	0	0	0	0	0
Total PCB (ug/g)	0.02	0	0	0.01	0.21	0	0	0
Naphthalene (ug/kg)	11.3	0	0	0	12.7	0	0	0
Acenaphthylene (ug/kg)	10.6	0	0	0	6	0	0	0
Acenaphthene (ug/kg)	35	0	0	0	0	0	0	0
Fluorene (ug/kg)	53.5	9	0	0	11.3	0	0	0
Phenanthrene (ug/kg)	703	145	51.7	54.3	94.4	0	8	0
Anthracene (ug/kg)	116	27.7	6	9	21.8	0	0	0
Fluoranthene (ug/kg)	1340	402	131	118	165	15	17.2	17.8
Pyrene (ug/kg)	999	300	94.3	82.9	174	10.8	16.6	15.6
Benzo(a)anthracene	263	67	36	42	54	0	0	0
Chrysene (ug/kg)	769	245	76	66	127	0	14	13
Benzo(b)fluoranthene	307	89	47	34	50	0	0	0
Benzo(k)fluoranthene	362	118	23	16	55	0	0	0
Benzo(a)pyrene (ug/kg)	462	108	27	23	69.7	0	8	0
Indeno(1,2,3-cd)pyrene	397	124	41	36	55	0	0	0
Dibenzo(a,h)anthracene	108	26	0	0	0	0	0	0
Benzo(ghi)perylene	378	128	45	39	91	0	0	0
Total PAH (ug/kg)	6314	1789	578	520	987	26	64	46

° Laboratory Analysis by Maxxam Analytics 1-800-563-6266

EHD-OR Metals and Physical Parameters Results$^{\nabla}$

Tributary	Amberlea Creek	Bayly	Bowmanville Creek	Carruthers Creek	Duffins Creek	East Corbett Creek	East Lynde	Farewell Creek	Foster Creek	Graham Creek	Harmony Creek
Silver (ug/g)	0	1	0	1	1	1	1.5	0	0	0	0.5
Aluminum (%)	0.62	0.38	0.71	0.48	0.31	0.54	0.77	0.53	0.63	0.59	0.52
Arsenic (ug/g)	0	1	0	0	0	0	0	0	6	0	0
Barium (ug/g)	63	79	126	44	50	68	86	74	59	83	55
Beryllium (ug/g)	0.3	0.2	0.3	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2
Bismuth (ug/g)	0	0	0	0	0	0	0	0	0	0	0
Calcium (%)	8	9	12	5	11	10	10	11	4	12	11
Cadmium (ug/g)	1	1	1	1	1	1	1	1	0	0	1
Cobalt (ug/g)	3	7	4	5	8	10	10	4	8	3	5
Chromium (ug/g)	17	65	15	10	25	22	16	11	11	12	13
Copper (ug/g)	26	83	16	10	13	20	17	12	8	7	15
Iron (%)	1.53	1.76	1.31	0.95	1.03	1.24	1.55	1.13	1.13	1.18	1.05
Potassium (%)	0.09	0.06	0.18	0	0.07	0.09	0.11	0.14	0.13	0.18	0.15
Lithium (ug/g)	13	10	9	9	8	10	12	7	8	9	8
Magnesium (%)	0.58	0.78	0.64	0.33	0.63	0.52	0.56	0.49	0.33	0.53	0.46
Manganese (ug/g)	519	460	539	253	412	483	437	415	316	421	484
Molybdenum (ug/g)	0	1	0	1	0	0	0	0	0	0	0
Sodium (%)	0.07	0.07	0.04	0.04	0.04	0.06	0.05	0.04	0.04	0.05	0.05
Nickel (ug/g)	9	6	9	7	6	1	3	5	10	6	6
Lead (ug/g)	23	31	9	12	11	22	15	7	7	0	26
Tin (ug/g)	0	0	0	0	0	0	0	0	0	0	0
Strontium (ug/g)	104	116	163	64	133	134	126	146	64	161	145
Titanium (ug/g)	232	194	395	222	201	332	337	443	582	464	411
Vanadium (ug/g)	24	21	20	16	19	23	25	17	20	19	18
Yttrium (ug/g)	8	6	9	6	6	7	10	9	9	7	8
Zinc (ug/g)	132	318	64	55	56	178	76	65	51	28	79
Mercury (ug/g)	0.034	0.026	0.03	0.024	0.024	0.049	0.044	0.014	0.084	0.009	0.022
Total Carbon (%)	5.9	5.1	9.1	3.4	5.1	5.4	6.2	4.9	3.1	6.4	5.4
Inorganic C (%)	2.9	3.1	4.6	1.3	3.3	3.1	3.0	3.1	1.5	4.2	3.6
Organic C (%)	3.0	2.0	4.5	2.1	1.8	2.3	3.2	1.8	1.6	2.2	1.8
Loss On Ignition (%)	6.3	3.8	11.3	5.4	3.7	5.0	8.2	4.5	4.1	5.9	4.0
Sand (%)	35.7	37.9	25.7	47.0	41.5	37.3	23.9	41.5	41.7	21.1	45.3
Silt (%)	63.5	61.8	74.3	52.7	58.2	62.3	75.1	58.5	57.9	78.6	53.9
Clay (%)	0.8	0.3	0.0	0.3	0.3	0.4	1.0	0.0	0.4	0.3	0.8

$^{\nabla}$ Metals Analyses by Caduceon Enterprises; Physical Parameters by Natural Resources Canada, Ottawa

EHD-OR Metals and Physical Parameters Results[∇]

Tributary	Hydro	Radom	Rouge River	Soper Creek	West Corbett Creek	West Lynde Creek	Westside Creek	Wilmot Creek
Silver (ug/g)	0	0	0	0	0.5	0	0	0
Aluminum (%)	0.65	0.53	0.37	0.92	0.45	0.7	1.15	0.47
Arsenic (ug/g)	0	0	0	0	0	0	0	0
Barium (ug/g)	67	54	51	113	93	70	90	81
Beryllium (ug/g)	0.3	0.2	0.2	0.3	0.2	0.3	0.4	0.2
Bismuth (ug/g)	0	0	0	0	0	0	0	0
Calcium (%)	9	8	10	10	11	9	5	12
Cadmium (ug/g)	1	1	1	1	2	1	0	0
Cobalt (ug/g)	11	11	9	7	7	9	10	0
Chromium (ug/g)	26	17	14	15	311	21	18	8
Copper (ug/g)	37	20	13	14	56	15	12	8
Iron (%)	1.26	1.26	0.99	1.46	2.25	1.22	1.62	1.07
Potassium (%)	0.09	0.07	0.07	0.2	0.08	0.11	0.21	0.13
Lithium (ug/g)	11	13	9	11	7	10	12	8
Magnesium (%)	0.59	0.44	0.68	0.6	0.57	0.36	0.52	0.43
Manganese (ug/g)	257	441	363	506	1865	334	423	358
Molybdenum (ug/g)	0	2	0	0	0	0	0	0
Sodium (%)	0.05	0.07	0.04	0.04	0.06	0.05	0.05	0.04
Nickel (ug/g)	6	4	8	9	13	9	9	2
Lead (ug/g)	54	23	6	9	46	14	7	0
Tin (ug/g)	0	0	0	0	0	0	0	0
Strontium (ug/g)	118	102	120	141	169	109	75	157
Titanium (ug/g)	318	224	235	500	267	353	795	376
Vanadium (ug/g)	24	19	19	23	38	25	30	15
Yttrium (ug/g)	8	7	7	10	6	9	12	7
Zinc (ug/g)	183	121	52	62	229	65	60	34
Mercury (ug/g)	0.073	0.036	0.024	0.043	0.071	0.05	0.014	0.014
Total Carbon (%)	5.9	4.6	3.7	7.9	6.4	7.2	3.4	6.3
Inorganic Carbon (%)	2.9	2.4	2.8	3.7	3.8	2.8	1.5	3.8
Organic Carbon (%)	3.0	2.2	0.9	4.2	2.6	4.4	1.9	2.5
Loss On Ignition (%)	8.7	2.1	0.9	10.8	10.1	10.7	4.6	6.3
Sand (%)	47.0	33.3	43.6	25.3	44.9	45.7	33.3	37.6
Clay (%)	0.3	0.6	0.4	0.3	0.0	0.0	1.3	0.0
Silt (%)	52.7	66.1	56.0	74.4	55.1	54.3	65.4	62.4

[∇] Metals Analyses by Caduceon Enterprises; Physical Parameters by Natural Resources Canada, Ottawa