Wetland bird response to water level changes in the Lake Ontario - St. Lawrence River hydrosystem

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Final report to the International Joint Commission made in conjunction with the International Lake Ontario – St. Lawrence River Water Regulation Review Study (2000-2005)

by the Canadian Wildlife Service, Québec and Ontario Regions, Environment Conservation Branch, Environment Canada.

Photo : John Mitchell

March 2005

Recommended citation:

DesGranges, J.-L., J. Ingram, B. Drolet, C. Savage, J. Morin, and D. Borcard. 2005. *Wetland bird response to water level changes in the Lake Ontario - St. Lawrence River hydrosystem*. Final report to the International Joint Commission in support of the International Lake Ontario – St. Lawrence River Water Regulation Review Study. Canadian Wildlife Service, Québec and Ontario Regions. Environment Canada. Unpublished report xiv + 132 pp. (including 4 enclosures and 14 appendices).

ACKNOWLEDGEMENTS

The project was funded primarily by the International Joint Commission and Environment Canada (Canadian Wildlife Service), in support of the Lake Ontario-St. Lawrence River water regulation review study.

Thanks to Aaron Brees, Steeve Fournier, Stéphanie Gagnon, Kate Gee, John Gorniak, Yves Grégoire, Krista Holmes, Ludovic Jolicoeur, Suzanne Maillé, Mario Paquin, and Carrie Sadowski for their help during fieldwork and data compilation. Guy Létourneau of the Centre Saint-Laurent classified the MEIS and IKONOS images and provided invaluable support in remote sensing, while Greg Grabas, Maggie Galloway, Barb Crosbie, and Lenny Shirose completed wetland plant community mapping, ground truthing, GIS support and survey site development for Lake Ontario and Upper St. Lawrence River study sites. We are very grateful to Olivier Champoux, Sylvain Martin and Katerine Turgeon of the Canadian Meteorological Service, Québec Region, for their valuable comments on hydrology and habitat, as well as, to O. Champoux and S. Martin for performance indicator coding in the 2D and the 1D hydrological model for the Lower St. Lawrence River and its counterpart in the Integrated Environnemental Response Model (IERM). Todd Redder and Joe DePinto of Limno-Tech Inc. completed performance indicator coding for the Lake Ontario and Upper St. Lawrence River section in the IERM. Thank you to Sylvain Giguère with whom we developed the Least Bittern performance indicator. Pierre Gagnon of the Centre Saint-Laurent and Marc Mingelbier of "ministère des Resources naturelles et de la Faune du Québec" helped with statistical analysis of performance indicators sensitivity to the various water regulation plans.

Thanks also to Karl Lévesque and Denis Lepage of Bird Studies Canada who completed during the course of this research a pilot study for the eventual implementation of the Marsh Monitoring Program for future monitoring of Lake Ontario-St. Lawrence wetland bird communities (Lévesque *et al.* 2004).

Partners

International Joint Commission / Commission mixte internationale (IJC-CMI), Ottawa & Washington DC.;
Limno-Tech Inc., Ann Arbor, MI, U.S.A.
Centre Saint-Laurent, Environnement Canada, Montréal;
Fondation Les Oiseleurs du Québec, Lévis;
Bird Studies Canada / Études d'oiseaux Canada, Port Rowan, Ontario

ABSTRACT

Lake Ontario and St. Lawrence River (LOSL) wetland bird abundance and diversity are greatly influenced by lake and river hydrology. Multi-year (2000-2003) bird surveys captured bird distribution and density in wetland habitats under varying degrees of water inundation, depth and fluctuation. Analysis of this multi-year bird and habitat database has revealed strong associations between estimated breeding pair densities and plant communities, water depth, as well as, degree of water level fluctuation during the breeding season for a suite of wetland bird species using marsh, wet meadow, shrub swamp and treed swamp habitats. These quantitative associations were used to develop wetland bird performance indicators for use in a LOSL water regulation review study. Several of the bird species also nest at or near the water surface and are thus vulnerable to nest flooding and/or stranding. Changes to the seasonal hydrology of Lake Ontario and St. Lawrence River that result in an increased frequency or magnitude of these nest failure events may have a significant impact on regional population sustainability. Long-term nest record databases were analyzed to create nesting flooding and stranding probability equations based on water level increases and decreases during the breeding season. These species-specific nesting relationships were incorporated into a reproduction index.

This study documents that many breeding bird species are strongly associated with specific wetland plant communities. Predicted habitat suitability, as measured by estimated breeding pair density, can also change significantly within a specific wetland plant community based solely on changes in water depth during the breeding season (e. g. without any actual predicted change in the distribution and abundance of the plant community). In addition, obligate marsh breeding bird species richness is responsive to water level fluctuations. Three indicator species, Black Tern, Least Bittern and Virginia Rail, were selected for use as key environmental performance indicators for alternate regulation plan comparisons.

Water regulation criteria should be such that the long-term diversity and abundance of wetland plant communities, and the frequency of spring flooding in marsh habitats during breeding are not reduced. The magnitude and frequency of water level change during the nesting season (May–July) can also adversely affect the reproductive success of many wetland bird species. As such, regulation criteria that increase the magnitude and frequency of water level change during the breeding season may be detrimental to the long-term viability of certain regional breeding bird populations.

Keywords: Wetlands, Birds, Indicators, Water regulation, Lake Ontario, St. Lawrence River

RÉSUMÉ

L'abondance et la diversité des oiseaux palustres (de milieux humides) du lac Ontario et du fleuve Saint-Laurent sont grandement influencées par les conditions hydrologiques de cet hydrosystème. Une base de données des relevés d'oiseaux nicheurs et de leurs habitats menés sur plusieurs années (2000-2003) a permis d'établir la répartition et la densité des oiseaux dans des milieux humides présentant divers degrés d'inondation, de profondeurs d'eau et de fluctuations des niveaux d'eau. L'analyse de cette base de données a révélé des liens étroits entre la densité estimée des couples nicheurs, la profondeur de l'eau et le degré de fluctuation des niveaux d'eau pendant la saison de reproduction de certaines espèces d'oiseaux palustres vivant dans des marais, des prés humides et des marécages arbustifs et arborescents. On a utilisé ces associations quantitatives pour élaborer des indicateurs de performance de la reproduction des oiseaux palustres aux fins d'une étude sur la régularisation des niveaux d'eau du lac Ontario et du Saint-Laurent d'eau douce. Ces espèces indicatrices nichent à la surface de l'eau ou à proximité; leurs nids sont donc vulnérables aux effets de l'eau, qui peut les inonder ou les rendre plus accessibles aux prédateurs terrestres. Les conditions hydrologiques changeantes du lac Ontario et du Saint-Laurent qui font augmenter la fréquence ou l'ampleur des échecs de nidification peuvent considérablement influer sur la viabilité des populations aviaires régionales. On a analysé des bases de données sur la nidification à long terme pour formuler des équations de probabilité d'inondation et d'assèchement des sites de nids, équations fondées sur les hausses et les baisses des niveaux d'eau pendant la saison de reproduction. Ces relations avec la nidification propres à ces espèces ont été intégrées dans un indice de reproduction.

Cette étude montre que de nombreuses espèces d'oiseaux nicheurs sont fortement associées à certaines communautés végétales palustres. La qualité prévue des habitats (telle qu'elle est mesurée par la densité estimée des couples nicheurs) peut aussi changer significativement au sein d'une communauté végétale palustre du simple fait de changements dans la profondeur de l'eau pendant la saison de reproduction (par exemple, sans qu'il y ait réellement de changement dans la répartition et l'abondance de la communauté végétale). De plus, la richesse des espèces aviaires nichant obligatoirement en milieux humides dépend aussi des fluctuations des niveaux d'eau. Trois oiseaux, la Guifette noire, le Petit Blongios et le Râle de Virginie, ont été sélectionnés comme espèces indicatrices clés de performance environnementale à des fins de comparaison de futurs plans de régularisation des niveaux d'eau du Lac Ontario et du fleuve Saint-Laurent.

Les critères de régularisation des niveaux d'eau doivent être établis de manière à ne pas diminuer la diversité et l'abondance à long terme des communautés végétales, ni à réduire la fréquence des crues printanières dans les marais. L'ampleur et la fréquence des fluctuations des niveaux d'eau pendant la saison de nidification (mai-juillet) peuvent également nuire au succès de reproduction de nombreuses espèces d'oiseaux palustres. Par conséquent, une hausse de l'ampleur et de la fréquence de ces fluctuations sera à long terme nuisible à certaines populations d'oiseaux nicheurs.

Mots-clés : Milieux humides, Oiseaux, Indicateurs, Régularisation des niveaux d'eau, Lac Ontario, Saint-Laurent.

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1. Introduction

1.1. Ecohydraulic issues

Coastal and shoreline wetlands of Lake Ontario and St. Lawrence River (LOSL) play a vital role in the life cycle of hundreds of wildlife species. Many of these species are birds that utilize the diversity of wetland habitats for breeding and migration (DesGranges and Tardif 1995; James et al. 2002; DesGranges and Jobin 2003). Daily, seasonal and annual variations in water levels and flows drive important ecological processes that maintain a diversity of wetlands and associated biodiversity (Keough et al. 1999; Frochot and Roché 2000; Weller 2001; Keddy 2002; Turgeon et al. 2004). Changes in the hydrologic regime, due to management or climate change, can result in changes in the distribution and abundance of different wetland types. This can in turn have significant repercussions on many bird populations frequenting freshwater habitats within the LOSL, particularly during the breeding season (Craigie et al. 2003; Griese et al. 1980; Greenberg 1988; Manci and Rusch 1988; Mazzocchi et al. 1997; Gilbert 2001).

All coastal or riparian wetland plant communities in the LOSL system have one or more bird habitats influenced by water depths and flood duration (Savage et al. in prep.). The main influence being inter and intra-annual variation in water depth, which affects the total wetland area, the physiognomic composition of habitats and the risk of nest loss due to flooding or stranding (Weller 1951; Glover 1953; Robertson 1971; Griese et al. 1980; Leonard and Pickman 1987; Mowbray 1997; Gilbert 2001; Steen and Gibbs 2002).

The International Joint Commission (IJC) is the agency responsible for discharge regulation of the LOSL system. The main control structure is the Moses-Saunders Power Dam located near Cornwall, Ontario. The plan and criteria currently used for regulation was developed in the late 1950's, and is known as the Plan 1958DD. Since that time, the regulation plan has been modified slightly and deviations from criteria within the plan occur on a regular basis. Regulation has moderated the "natural" water level fluctuations within Lake Ontario, reduced discharge in the St. Lawrence during spring, and increased it during fall (Morin and Leclerc 1998).

1.2. Wetland bird study objectives

An assessment of the current water regulation plan (Plan 1958D with deviations, or Plan 1958DD) is being completed to evaluate how current regulation criteria affect the multitude of stakeholder interests within the system. The main study objective is to develop a new plan that would address past environmental impacts and future sustainability, and better accommodate current and future stakeholder interests. An Environment Technical Working Group (ETWG) was formed to study and predict the response of selected environmental attributes to a variety of water supply scenarios and regulation plans. The overarching ETWG goals were to ensure the maintenance of hydrologically sensitive ecosystems, with a focus on wetland quality and quantity, and access of fauna to suitable wetlands as required for completing their life cycles. Within these goals, the wetland bird study presented here had two objectives:

1) Identify wetland breeding bird associations with plant communities, and hydrological variation in the LOSL region. Use the identified correlations to develop predictive models of wetland breeding bird populations and communities, and associated performance indicators (PI) that are applicable to the entire area of study.

2) Apply the wetland breeding bird performance indicators to hydrological and wetland plant community outputs based on alternate water regulation plans. Use the outputs of the wetland bird models to assess the relative ability of various water regulation plans to support wetland breeding birds and maintain diversity within LOSL system.

2. Methodology

The study used an interdisciplinary, ecosystem approach, blending avian and plant ecology, ecohydraulic, statistical ecology and modelling to predict the impact of water level fluctuations on indicator species representative of the composition of wetland breeding bird assemblages in the entire LOSL freshwater system.

To help with this task, an Integrated Ecological Response Model (IERM) was developed by the ETWG to bring together the diversity of models and environmental performance indicators created for the study. The IERM enabled an integrated evaluation of different regulation plans, and a linkage to the overall multi-interest Shared Vision Model [SVM] used to select the best plan overall.

2.1. Hydrological context

Evolution of flow discharge - from pristine to present state: Riparian habitats that border large rivers such as the St. Lawrence are very much affected by water flow fluctuations, which are themselves under the main influence of climate (Vincent and Dodson 1999). In the Great Lakes – St. Lawrence River System, climate variations are seen as driving a 20 to 35 years cycle in water levels and flows (Chanut et al. 1988; Morin and Leclerc 1998). Some researchers predict that the actual climate warming episode the planet is experiencing could cause a 40% decrease in the St. Lawrence water flow over the present century (Mortsch and Quinn 1996; Quinn 1997).

Before regulation, the Galop Rapids acted as a control section for the Lake Ontario outflow waters. With the construction of various dams, Lake St. Lawrence has been created, and more than 70 km of river sections are controlled from Cornwall to Iroquois. Since 1958, the Moses-Saunders power plant is the main structure controlling Lake Ontario outflow.

St. Lawrence River flows at Cornwall have small seasonal variations due to the natural regulatory effect of the Great Lakes. Under natural conditions, prior to 1958, the average maximum flow occurred during June, whereas low flow appeared in February. The flow clearly increases during the spring thaw, and a slight increase is observable during fall (Morin and Leclerc 1998). Artificial regulation of the flow since 1958 has reduced the average maximum flow in summer and increased the minimum flow in winter (Fig. 2.1.1). The average maximum flow now occurs in July and the minimum in January. There is also a deliberate sharp reduction in flow at the end of December to induce the formation of ice cover upstream from the power dams.

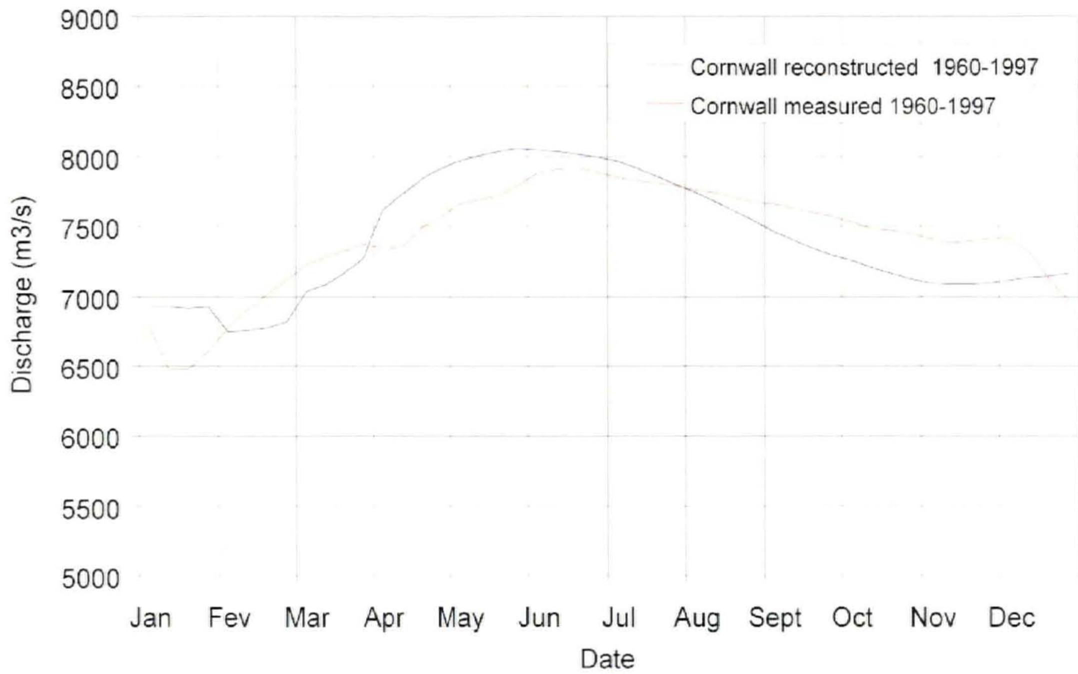


Figure 2.1.1 Changes in the St. Lawrence flow discharge by regulation, as shown by inter-annual monthly average of the simulated (natural) and measured (regulated) flow at Cornwall (1963-1995) (modified from Morin and Bouchard 2000)

Operation limits and dam specifications were set by the International Joint Commission (IJC) in the 1952 Order of Approval and the 1956 Supplementary Order. These orders of approval contain ten criteria for flow regulation to satisfy four main objectives: reduction of extreme water levels in Lake Ontario, reduction of the risk of flooding in the Montréal area, sufficient depth for navigation, and sufficient flow for power generation. Moreover, there is an eleventh criterion that allows divergence from the plan in the event that flows are outside the range of those observed prior to 1954 (Yee 1995). As a result, the active flooding and dewatering elevation range on Lake Ontario has been compressed to approximately half of what it was prior to regulation or would have been without regulation. The compression of water levels is specifically obvious during the summer (Fig. 2.1.2).

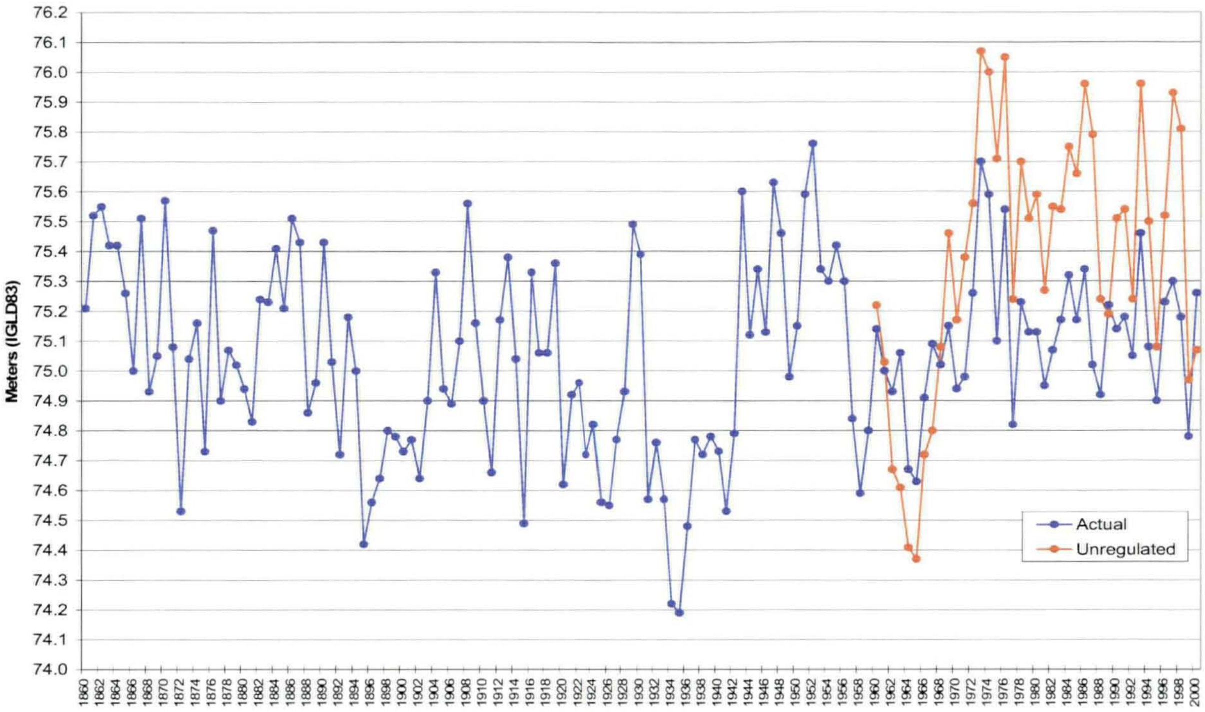


Figure 2.1.2 Changes in Lake Ontario water levels due to regulation, as shown by measured (Actual) interannual average August water levels and estimated natural (Unregulated) water levels since regulation (1960) in Lake Ontario (1860-2001).

Present water regulation plan (1958DD): The International Board of Control is responsible for the application of the IJC rules on an operational basis. The 1958D regulation plan, currently in use, was developed and tested using historical data on Lake Ontario outflows and water levels from 1860 to 1954. Adjustments of the flow are generally calculated every week based upon Lake Ontario water level and actual water supplies to the lake. Several flow limitations are imposed in order to reach the objectives of the orders of approval, and numerous issues are addressed by flow control, particularly in critical situations such as ice formation, ice break up, and flooding. Lake Saint-François itself is regulated by the Beauharnois power dam and Coteau works within a small range of level variations of about 15 cm at Coteau. The IJC water regulation review considers several interests and regions, but does not take into account the environmental impacts of water level management in Lake Saint-Francois.

Long-term flow discharge variations: The analysis of the evolution of monthly flow average reveals that the St. Lawrence River shows important flow fluctuations. These fluctuations are related to pluviometric variations over the hydrographic basin. As confirmed by spectral analysis, a cyclic signal of 20–35 years can be observed in the sequence. The cycles correspond to wet and dry periods. The lowest monthly flow was recorded in January 1935 at 4500 m3/s. The highest monthly average flow of 10 012 m3/s was measured in May 1993 (Fig. 2.1.3).

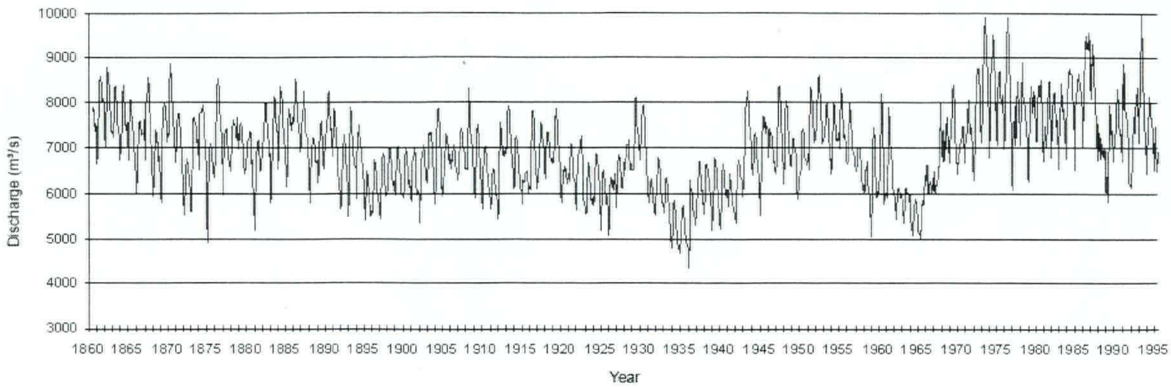


Figure 2.1.3 Long-term fluctuations in St. Lawrence River flow discharge (modified from Morin & Leclerc 1998).

An analysis of reconstructed discharge series for the St. Lawrence River and its major tributaries between 1932 and 1998 indicates that regulation has resulted primarily in a flow reduction in the spring and a flow increase in the fall in the Sorel area..

Effect of tides: The semi-diurnal tide has a period of 12 hrs 25 min and its impact on the water level is mostly obscured below Trois-Rivières. The semi-lunar signal has a period of 14 days and its effect is maximum at full moon and to a lesser extent, at new moon. Because of small amplitudes in the semi-diurnal signal above Trois-Rivières and of the very large period of the semi-lunar signal, the impact on velocities in Lake Saint-Pierre is relatively small. The effect of tides was not considered in this study. However, the lunar can affect water level of approximately 30 cm in Lake Saint-Pierre to near 15 cm in the port of Montreal (Morin and Bouchard 2000)

Impacts on wetlands: It is recognized that wetland dynamics in the Great Lakes – St. Lawrence system involves short- and long-term cycles of flooding and drought (IJC 1993). This dynamic allows plant species to complete one or several reproductive cycles and ensure their preservation in the local seed bank (Keddy and Reznicek 1986; Wilcox 1988; Turgeon et al. 2004). The Lake Saint-François wetlands have been maintained artificially by annual burning. This practice was stopped in 1978; since then, important internal modifications have been observed in the wetlands (Jean and Bouchard 1991). Loss of water level fluctuations, as has occurred in Lake Saint-François, has also favoured the growth of trees and shrubs.

2.2. Sampling sites

Bird and habitat sampling sites were selected according to three main criteria: accessibility, ecological representation, and landscape heterogeneity. Major wetland plant communities that are ecologically representative of the region include: marshes, wet meadows, shrub swamps, and treed swamps. The combination of thematic maps derived from the reclassification of MEIS and IKONOS remote sensing imagery and vegetation maps from interpreted aerial photographs were used to select wetland sampling sites within LOSL River.

From 2000 to 2002, breeding bird and habitat communities were sampled within circular survey plots measuring 1.8 ha (75 m in radius). In 2003, the size of the survey plots was increased to improved the probability of detecting all of the bird species present within a specific habitat type, including species that are rare, those with larger breeding territories, and species that infrequently vocalize. Survey plots in 2003 included polygons of various shapes, enclosing specific habitats and ranging in area from 3 to 5 hectares on average. In addition, since birds are particularly sensitive to the landscape characteristics of the habitats surrounding their breeding territory (Saab 1999; Whited et al. 2000; Riffell et al. 2001; Riffell et al. 2003), we also characterized the environment within 350 m of the sampling sites in 2002 to develop a typology of landscape types.

Over the four years, we censused birds and vegetation at 475 survey sites constituting 1187 ha of habitat (Appendix A). The sampling effort was divided among six hydrozones, from Lake Ontario in the west, to Lake Saint-Pierre in the east. Slightly less than one third of the sites were upstream of the Moses Sanders Dam (Fig. 2.2.1).

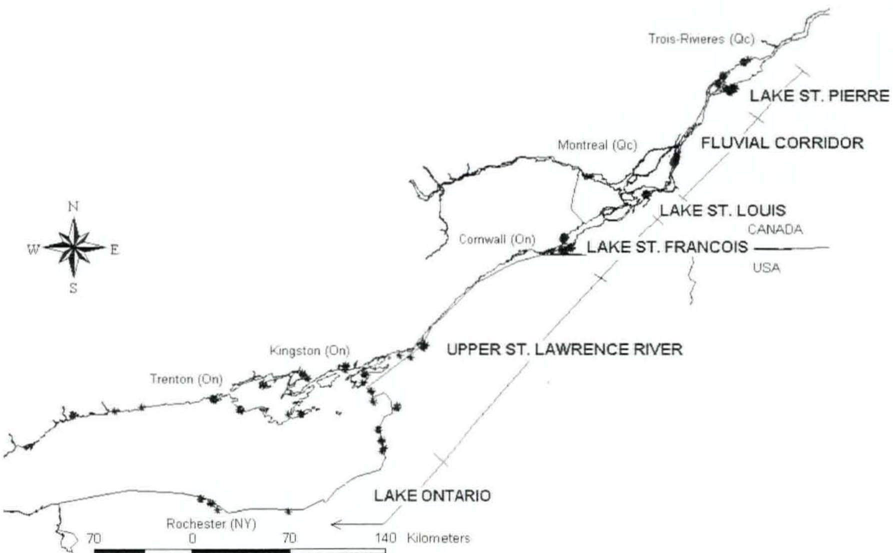


Figure 2.2.1 Map of the Lake Ontario – St. Lawrence system showing location of sampling sites (Hydrozones in capital letters).

2.3. Environmental variables

Vegetation and bird habitat description: Several types of environmental variables were measured at the survey sites: landscape types, degrees of disturbance, structure classes and vegetation classes. The presence and percentage of open water area (with or without submerged vegetation) was noted for each class, as was the mean water depth (estimated visually) within the vegetation classes. Sketches were completed at each of the sites to characterize the heterogeneity of the habitats. Vertical heterogeneity was estimated by the number of vertical strata of shrubs and trees and their respective average heights. Horizontal heterogeneity was estimated by counting the number of wetland habitat classes in the plot. In addition, the three dominant plant species (in percent cover) were noted in each stratum (i.e. tree, shrub, or herbaceous species). Landscapes were characterized mathematically using classified remote sensing imagery (MEIS in year 2000 and IKONOS in year 2002) and aerial photo interpreted land cover maps. The spatial data was compiled using Patch Analyst landscape fragmentation software (Rempel and Carr 2003). Landscape metrics are as follows: area of each wetland class (class area, CA), total landscape area (TLA), mean patch size (MPS), number of patches (NUMP), edge density (ED) and mean perimeter-to-area ratio (MPAR). These variables were calculated for each class individually (water, marsh, wet meadow, etc.), as well as globally (all of the classes of a given site (landscape)). Additional details of the various botanical and landscape measurements are provided in Appendix B and Savage *et al.* (in prep.).

Bird density: Plots were visited once, in the morning, between 4:30 am and 9:30 am (EST), on a calm day without strong winds or continuous rain. From 2000 to 2002, all birds seen or heard during a 30 minute period within a radius of 50 m (in 2000) and 75 m (in 2001 and 2002) were recorded to estimate both species richness and the abundance of individual species. Birds outside the 75-m radius were also recorded, but not taken into account in the analyses. In 2003, we increased the size of the plots sampled as well as the duration of the bird surveys, while maintaining a sampling effort per site that was comparable (on average) from one habitat to another both in duration (80 - 92 minutes) and in surface area (4.2 - 4.8 ha). The purpose was to improve detection of rare and cryptic species and species that utilize large territories. Observers also moved around the plot during the observation period to improve detection of cryptic species (e.g., rails and bitterns) and species that do not vocalize much (some sparrows). Territorial males were identified (and recorded directly on the field sheets) by the frequency of their singing and/or repeated chases of rival males nesting in the area immediately around their territory. The singing males were tracked during census in order to exclude odd males that could be attracted in the plot. Birds observed in flight above the plot were not included in the abundance estimate unless they were clearly showing foraging or courtship display behaviour within the plot. Many non-territorial species, and those that nest very early in spring were removed from the list of analysed species. This group included several duck, raptor, wader, swallow and Fringillidae species. In all, 72 species were retained for the analyses. The complete list of species surveyed is provided in Appendix C.

When compiling data, the estimated abundance of a species (expressed as density, or the number of breeding pairs per 10 ha), only took into account the estimated number of territorial males observed in each plot. All relevant data collected during the four years of the study were calibrated so that data from surveys of different surface areas, could be used for statistical analyses (Appendix D). The effect of census surface area on bird density diminishes with increasing quadrat size (Figure D1). We used bird densities from survey plots of 6 ha and over, as reference for calibration of density from smaller plot sizes. A specific ratio was calculated per species and the mean of all specific ratios was used in the case of species with insufficient data (Table D2). Thus, the calibrated density should be surface area independent (Figure D1).

Nest success: Nest success is a critical component of reproductive success for birds. Although wetland breeding bird populations have adapted to annual fluctuations in reproductive success, population sustainability can be threatened if there are increases in the frequency or severity of nest flooding and stranding events due to water level regulation. Some wetland breeding bird species construct nests on or near the water surface within or adjacent to wetland habitats. Due to the proximity of the nests relative to water, these nests are at risk of flooding or stranding due to water level changes during the egg laying and incubation period (25–35 days) (Weller 1999). By quantifying the magnitude and frequency of water level change during nesting (late May–early July) and species specific distributions of nest height above the water surface and water depth below the nest, probabilities of nest loss due to flooding or stranding were calculated and relative estimates of nest success generated.

A combination of nest record data, published literature and bird habitat model results were used to obtain information necessary in the development of nest success models that are species specific. Ontario nest record data was compiled from the Ontario Nest Record Scheme (ONRS), a long-term nest record database located at the Royal Ontario Museum. Québec nest record data were obtained from the « Suivi de l'occupation des stations de populations d'oiseaux en péril du Québec » (SOSPOP 2003). Nesting vegetation type, nest height above water, water depth below the nest, and nest initiation dates were summarized. Nest initiation dates were estimated using nest records that contained repeated visits documenting the egg-laying phase, or were considered to represent nests in an egg-laying phase based upon a clutch size below the average for each species. Backdating to initiation of egg laying was calculated by subtracting one day per egg observed in the nest. Cumulative distributions of nest height above the water and water depth below the nest data were used to develop nest flooding and stranding probabilities and identify the temporal nesting exposure period. Published literature was used to confirm nest record calculations and improve estimates for species that had limited nest record data (Peck and James 1983, 1987; Cadman et al. 1987; Gauthier and Aubry 1995; Poole and Gill, multi-years). Renesting rates were also incorporated to generate an estimate of the probability that a breeding female would successfully hatch a nest during the breeding season. Appendix F provides some natural traits of several wetland bird study species.

2.4. Data analysis

Databases: Dependent variables for the bird assemblages are abundance of various obligate and facultative wetland species, species richness, and the composition and structure of the bird assemblages. The environmental (hydrological and vegetation) variables likely to affect bird habitat selection come from the following sources: ecological modelling (n= 36), field work (n= 29), spatial analysis (n= 17), and geographic context (n= 3)(see Appendices B, E & H). However, the number and quality of the environmental data vary. Some portions of the study area are not covered by certain categories of descriptors. All of the data is managed within an Access database, with several tables corresponding to different variable types: general information, physical environment, biological environment, spatial structure, disturbances, photos and taxa.

Bird habitat classification: Analyses of data on vegetation composition and structure, as well as, hydrological variables were used to define a typology of wetland bird habitats, including ecocomplexes that are heterogeneous habitats consisting of semi-open wetlands with varying proportions of herbaceous species (grasses and emergent plants), shrubs and trees (Appendices B & G). Figure 2.4.1 illustrates the typology of wetland bird habitats in the LOSL system. This typology consists of 10 wetland habitat classes that are utilized by wetland breeding birds.

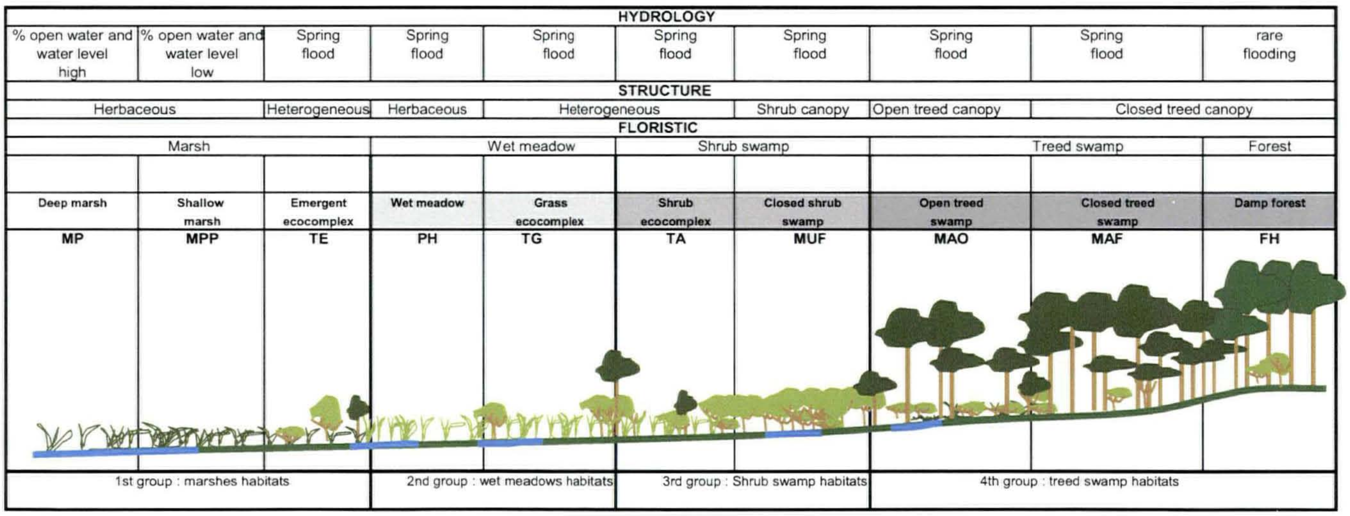


Figure 2.4.1 Typology of wetland bird habitats.

The lowest part of the gradient is a wetland plant community that is typically flooded for most of the breeding season. This region constitutes the first group of bird habitats, marsh habitats that can be further subdivided into deep and shallow marsh, and emergent ecocomplex. Both deep and shallow marshes are relatively homogeneous herbaceous environments with no trees or shrubs. Deeper and more open water distinguish deep marsh from shallow marsh. Emergent ecocomplexes are also herbaceous environments, but are more heterogeneous, with less than 30% shrubs and up to 10% trees. Emergent ecocomplexes are often found where the surface is heterogeneous with microtopographic features such as ridges and mounds or where dikes are present and water levels are being manipulated independent of the LOSL.

The second group of wetlands moving up the gradient are known as wet meadow habitats. They may be flooded in spring, but usually contain no standing water for most of the breeding season, and are dominated by grasses and sedges. This group consists of both wet meadow and grass ecocomplex. A wet meadow is a homogeneous herbaceous environment with no trees or shrubs. A grass ecocomplex is a heterogeneous herbaceous environment with less than 30% shrubs and up to 20% trees.

Shrub swamp habitats are considered the next group along the hydrologic gradient. These habitats, consist of shrub ecocomplex and closed shrub swamp. Hydrological conditions in this group vary, depending on whether the habitat is diked. A shrub ecocomplex is a heterogeneous open environment containing herbs, shrubs (30 to 60%) and up to 30% trees. A closed shrub swamp is more homogeneous and has over 60% shrub cover.

Along the upper part of the gradient, we find the last group, the treed swamp habitats, which are dominated by trees. Treed swamps are distinguished from damp forests by their wetland components, due to spring flooding. Treed swamps are subdivided into open and closed categories according to the degree of openness of the canopy. Open treed swamps have a cover of 30 to 80%; thus contain many openings that are colonized either by herbaceous species or shrubs. These swamps are characterized by a greater number of tree and shrub strata. Closed treed swamps have canopies that are over 80% closed. Damp forests are closed treed environments with a cover exceeding 80%, but contain some terrestrial components, notably among the co-dominant tree species.

The linkages between wetland bird density and nest success were modeled considering the four major habitat types: marsh (deep and shallow marshes and emergent ecocomplex), wet meadow (wet meadow and grass ecocomplex), shrub swamp (shrub ecocomplex and closed shrub swamps) and treed swamp (treed swamps and damp forests). The predicted surface area of these wetland habitat types were modeled in the LSL using water depth, speed of current, flooding occurrence, percent of the growing season flooded, waves and slope (Morin et al. 2005) and in LO, using topography, flood and dewater history and wetland geomorphology (Wilcox et al. 2005).

Wetland bird indicator species: Indicator bird species were chosen according to their ecological affinity for one of the four major wetland habitat types (marshes, wet meadows, shrub swamps and treed swamps), their sensitivity to hydrological conditions (depth of surface water or water table and fluctuations of water level) and their nesting strategy (that is, on the ground near the shoreline, on floating vegetation, or attached to vegetation above the water or on the ground) (Appendix F). For study purposes, we were restricted to a limited selection of indicator species distributed according to the four major wetland habitat types, the vulnerability of their nests and the nature of the statistical relationship with the hydrological variables.

Wetland breeding bird performance indicators: The ETWG developed an Integrated Ecological Response Model (IERM) that brings together the diversity of models and environmental performance indicators created for the study. The IERM enabled an integrated evaluation of different regulation plans, and a linkage to the overall multi-interest Shared Vision Model [SVM] used to select the best plan overall. The IERM uses biotic performance indicators (PIs) to compare alternative regulation plans with the one currently in effect (Plan 1958DD). The bird PIs are thus biotic response models used to assess the relative differences among various hydrological situations either prospectively or retrospectively, rather than to predict the state (absolute size and population dynamic) of a bird population. Moreover, because the PIs' response is calculated for each year independently of the preceding ones, there are no temporal linkages among the calculated values, which of course is not the case in population dynamics models.

PIs evaluated for use within a wetland breeding bird performance indicator include:

- *Species richness:* This metric is a relative estimate of the number of species within a specific area and may be expressed as per sample or per wetland. Wetland breeding bird species richness is affected by changes in habitat availability and quality. Many wetland birds can be grouped within guilds or assemblages that are known to breed in specific wetland plant communities (i.e. marsh, wet meadow, shrub swamp and treed swamp). Thus, the bird species richness of a wetland will increase as the number of plant communities within the wetland increases (Frochot and Roché 2000). The suitability of wetland habitats for many bird species assemblages is also influenced by habitat patch size, the presence of standing water and/or the vertical and horizontal heterogeneity of the habitat (e.g. emergents interspersed with open water, shrubs within a wet meadow). As more species–specific preferences occur within a wetland, the overall potential species richness also increases. For each node of the hydrological model (see Appendix E) included in our patches of habitat (see Morin et al. 2005), a linear regression model, based on the water level fluctuation index, was used to estimate the approximate number of species likely to nest in the various habitat patches we surveyed.

- *Indicator species reproductive index:* An index was developed to represent a crude estimate of the number of clutches likely to be raised successfully each year, according to species specific habitat availability and the various hydrological conditions that may affect the breeding effort. This reproductive index combines a relative estimate of the number of breeding pairs a specific area can support with an estimate of breeding pair nest success. The reproductive index of a specific species is affected by the amount and quality of habitat that is available, and the probability a pair can successfully hatch a clutch. Many species of breeding birds are territorial and pairs will distribute somewhat evenly across a specific habitat. Based on bird surveys of a known area, breeding pair densities can be estimated and expressed as breeding pairs per hectare of habitat. Once the total area of suitable habitat is determined for a wetland or wetlands, the potential breeding population can be estimated. This index is calculated for each indicator species in the following four steps:

1) For each node in the hydrological (LSL) or geomorphic (LO-USL) model (Figure 2.4.2, and hydrological model described in Appendix E (succinctly) and Morin *et al.* 2005), a density of pairs of each species associated with the habitat at the node is estimated from a non-linear regression model (Proc NLin, SAS 2001). Relating surveyed density to the modeled average water depth (or of water table) at the sub-set of nodes sampled in the field (see Morin et al. 2005).

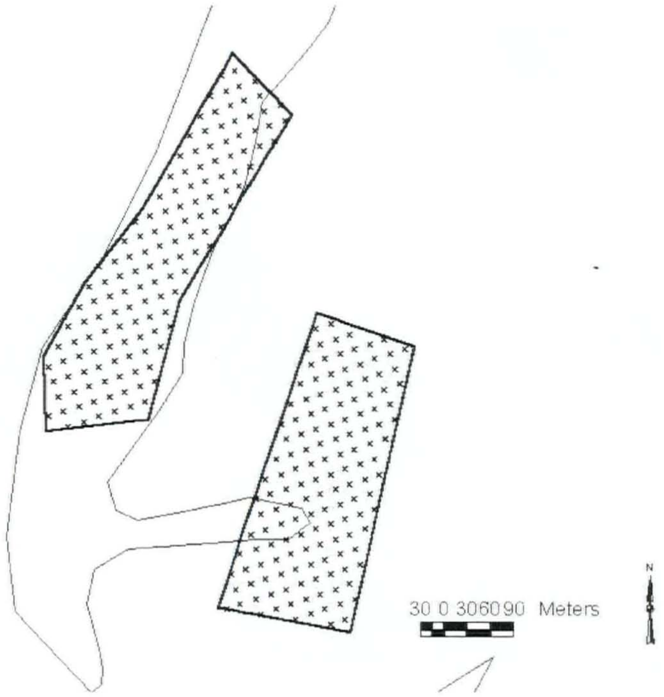


Figure 2.4.2 Sub-set of nodes samples in the field for hydrological and biotic modelization.

2) The estimated density of nesting pairs is adjusted based upon the degree of water-level fluctuation during the breeding season. Like density, the correction factors have been determined from a non-linear regression model, that relates surveyed density of nesting pairs to an index value for magnitude of rise and/or fall in water level from the third week (quarter-month in fact) of May to the week of field observations. The index for degree of water level change represents a *persistency rate* or an estimate of the probability that a pair of birds will continue nesting at their initial breeding location, given the variations in water level that they experience (as forecasted using various hydrological scenarios) (see Tables in enclosures I and II). The index values range from 0 (continued presence of the pair) to 1 (representing loss of the pair) according to: the type of wetland in question, the magnitude of water level change, presence of open water in the habitats, and depth of water remaining after a fall in water level. The magnitude of water level change is classified into four ranges: 0-20, 21-50, 51-70 and > 70 cm. The persistency rate also decreased when marsh habitats become dry, or when wet meadows and swamps become flooded. Decreases in water level did not affect

nesting pair density in marshes, as long as at least 40 cm of water remained in the habitat. Persistency rates were set to and remained at 0 in unflooded treed swamps, provided rising water levels did not reach the surface of these habitats. The persistency rate was set to 1 in marshes that became unflooded during the breeding season due to a drop in water level. Dry emergent habitats do not provide the nesting conditions required by certain species.

3) The weighted density index for nesting pairs underwent a second adjustment to account for an estimated nest success rate. This correction factor represents the probability that a nesting pair will successfully hatch a nest during the breeding season, given the water-level fluctuations to which the nest is subjected. The calculation of this probability takes into account the risks of drowning eggs or nestlings according to nest heights relative to the water or ground level, and the increased risk of predation or abandonment when the nest location becomes unflooded.

4) Lastly, the reproductive index is a relative estimate of successful nesting pairs of each indicator species within the LOSL region, based upon a summation of the total suitable surface area (this surface area is calculated based upon the number of nodes situated within the preferred habitat type).

PIs metrics developed for plan comparisons: In order to evaluate alternate water regulation plans, the study adopted an approach of creating regulation plan specific, theoretical 100 year water-level and flow scenarios with which relative comparisons could be made. The plan specific water level scenarios were created by applying each plan's criteria to a 100 water supply scenario. For the purpose of comparing the water level regulation plans evaluated in the IERM, we use two metrics calculated from annual estimates of the wetland bird PI responses over a 100-year water level scenario. First, a two year moving average calculation was used to aggregate PI output time series Then relative plan comparisons were made by comparing the number of years the PI value exceeded the first quartile PI value from Plan 1958DD. PI scores below the Plan 1958DD first quartile value are considered to represent poor breeding conditions. Alternate regulation plans that reduce the number of poor breeding years relative to Plan 1958DD, are considered to represent better regulation plans for wetland birds that are represented by that PI. Finally, regulation plan comparisons are expressed as a ratio, alternate plan divided by base plan. A ratio greater than 1 represents an alternate plan that is better than base plan.

3. Ecological modeling results

3.1. Composition of avian assemblages

In total, 129 species were observed over the four years of field work. Of this total, 8 species occurred at more than 40% of the survey sites, and the following species were documented at approximately 70% or more plots: the Red-winged Blackbird (91%), the Swamp Sparrow (72%), the Yellow Warbler (71%) and the Song Sparrow (69%). Table 3.1.1 summarizes the abundance per habitat for each of the 9 indicator species retained for the study of water regulation impacts on birds. Appendix I provides a list of the 72 wetland bird species (obligate and non obligate) found along the wetland hydrosphere, and data on their abundance (density and occurrence). Data on species composition and abundance of nesting pairs of various types of bird assemblages are provided in Appendix J.

Table 3.1.1 Abundance (# of pairs per 10 ha of each wetland habitat type) of 9 indicator species retained for the study of water regulation impacts on birds.

		Marsh habitat		Wet meadow habitat		Shrub swamp habitat		Treed swamp habitat	
Species	Prefered habitat	Moy	SD	Moy	SD	Moy	SD	Moy	SD
American Bittern	Marsh habitat	**0,11**	**0,11**	0,04	0,09	0,00	0,02	0,00	0,03
Black Tern	Marsh habitat	**0,30**	**0,28**	0,06	0,13	0,04	0,15	0,02	0,06
Common Moorhen	Marsh habitat	**0,19**	**0,24**	0,02	0,09	0,01	0,06		
Least Bittern	Marsh habitat	**0,01**	**0,02**	0,00	0,02				
Marsh Wren	Marsh habitat	**0,53**	**0,51**	0,22	0,40	0,05	0,16		
Virginia Rail	Marsh habitat	**0,16**	**0,12**	0,02	0,06	0,01	0,06		
Swamp Sparrow	Wet meadow habitat	0,60	0,56	**0,74**	**0,49**	0,41	0,45	0,09	0,16
Song Sparrow	Shrub swamp habitat	0,11	0,31	0,28	0,27	**0,45**	**0,33**	0,34	0,29
Veery	Treed swamp habitat	0,00	0,00	0,01	0,03	0,07	0,13	**0,15**	**0,18**

3.2. Bird/habitat relationships

Associations between birds and habitats were described using cluster and canonical ordination analyses, allowing the development of a wetland breeding bird habitat typology (Fig. 2.4.1).

In the clustering approach, the environmental variables included vegetation structure, floristics, and landscape characteristics of the survey sites and immediate surroundings, as well as the hydrological context (from modelled outputs; Morin et al. (2005) and field evaluation) (Appendix H). This approach revealed three groups of environmental variables significantly associated with wetland bird species occurrence. Tree canopy openness, more specifically the density of tree cover, was the most significant criterion for bird occurrence, followed by hydrological context and degree of heterogeneity of riparian landscapes. The various combinations of these variables within the cluster analyses identified twelve avian assemblages from 478 sampling sites (details in Appendix G, Fig. G.1.3). Further refinements of these results as well as the analysis of the vegetation data finally yielded 10 bird habitats, that became the basis upon which the rest of the analyses were conducted.

Figure 3.2.1 shows an ordination (RDA) of the bird assemblages constrained by the typology of 10 habitats as well as the major environmental variables explaining their distribution. The main bird assemblages are described below.

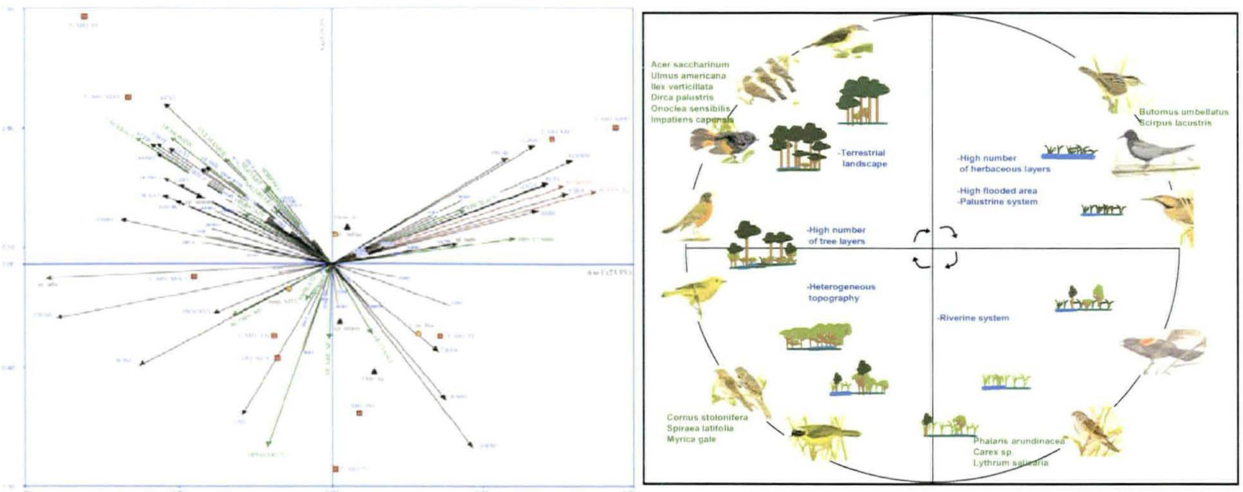


Figure 3.2.1 RDA showing the environmental variables most correlated with bird species abundances in avian habitat types.

The first avian assemblage group (top right corner in Fig. 3.2.1) was characteristic of treeless (less than 10%) wetland habitats: deep marsh, shallow marsh, and emergent ecocomplex. Such habitats are typically subject to flooding for a relatively long duration during the breeding season. Marsh Wren was particularly abundant in the most flooded sites, while Black Tern (currently declining in the study region) appeared to be more common in marshes with reduced water level fluctuation. These habitats were dominated by herbaceous vegetation and depending on the local micro-topography, may have a relatively high spatial heterogeneity. Marsh habitat that contained open water areas that remained throughout the breeding season, more commonly contained species such as American Coot, Common Moorhen, Sora, Virginia Rail, Least Bittern and American Bittern.

A second avian assemblage group (bottom right of Figure 3.2.1), was dominated by Redwing Blackbird and Swamp Sparrow , species typically associated with semi-open habitats made up of wet meadow and grass ecocomplex.

A third group (bottom left of Figure 3.2.1) was characteristic of shrub ecocomplexes and closed shrub swamp. The most common species documented in shrub thickets on the edge of forests included, Yellow Warbler and Song Sparrow. This type of landscape, was typically a mosaic of habitats, with a high degree of spatial heterogeneity, sometimes including permanent ponds. Such ponds provide good habitat for dabbling ducks (American Widgeon, Northern Shoveller and Mallard), Green Heron, and Common Yellowthroat.

A fourth group (top left of Fig.3.2.1) of avian assemblage frequents treed habitats: open treed swamp, closed treed swamp and damp forest. The canopy can be open or closed, and is periodically subjected to spring flooding. At the lower end of this vegetation toposequence, stands are more open and often contain standing water in the spring. Wood Duck and Tree Swallow occurrence was typically higher within this habitat. In some places, artificial structures have been built to retain water and maintain deeper ponds surrounded by dead trees and shrubs. These impoundments appeared to favour the Wood Duck, Wilson's Snipe, Tree Swallow, Alder Flycatcher, and Willow Flycatcher. As the tree canopy became more closed, species associated with trees such as Warbling Vireo and Baltimore Oriole were more common. At the upper end of the toposequence, flooding is rare and short-lived. Here, the avifauna was more typical of assemblages found in poorly drained deciduous forests. Forest species such as White-breasted Nuthatch, Eastern Wood-Pewee, Red-eyed Vireo and American Redstart were very characteristic of this ecotone between swampy forests per se and deciduous forests growing on fairly dry sites.

3.3. Wetland bird performance indicators

Wetland obligate bird species richness in marshes: This indicator is limited to wetland obligate bird species that build their nest either on a floating platform over water, on the ground near the water edge or in robust vegetation slightly above water. In our study area, the nests of some species are susceptible to flooding due to storm events and rapid water level rises (>20 cm) during the breeding season (Ward et al. 1999; Stapanian et al. 2004). Among all the indicators that we calculated to describe the structure of the bird assemblages, the wetland obligate bird species richness was the only assemblage indicator that showed significant links with hydrological conditions in marsh habitats (Figure 3.3.1). Being easily understandable, this PI can be used to insure public opinion is sensitive to the environmental consequences of water regulation. The rate and degree of water level increase will affect different subsets of marsh species depending on the number of nesting strata that happen to be flooded during the nesting season. Therefore, it has a direct effect on the potential number of wetland bird species (i.e. species richness) that can successfully breed in a particular marsh. This same statistical association was not observed between obligate wetland species richness and water level decrease.

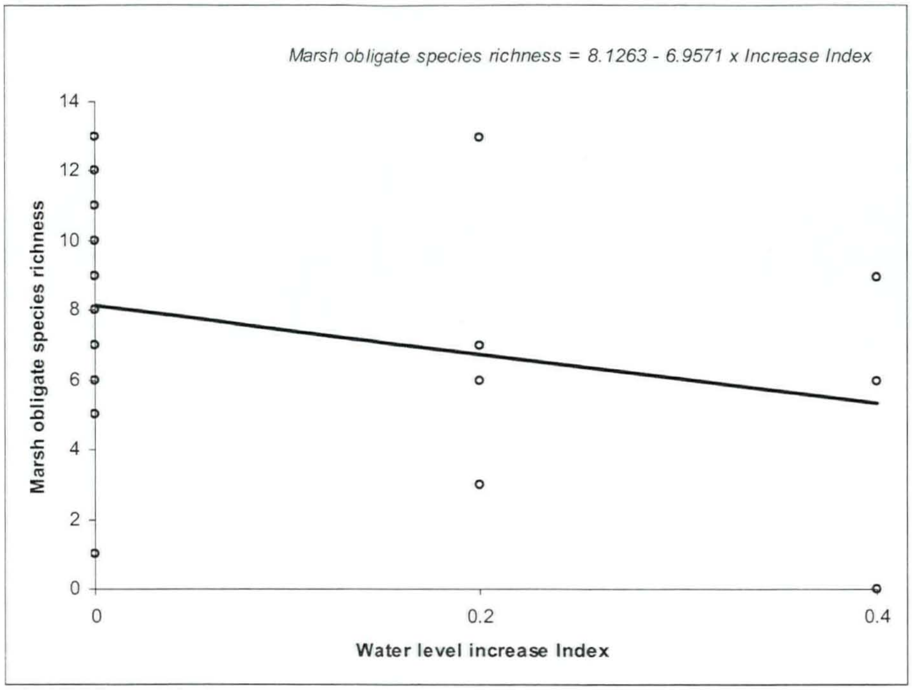


Figure 3.3.1 Predicted wetland obligate species richness according to water level increase index in marshes.

3.4. Indicator species response models

Wetland breeding bird density index: Mean density comparison (Kruskal-Walis Test) indicated that among the 72 wetland bird species surveyed in the field, 50 displayed wetland preferences. The relationship between breeding bird density and water depth (WD), water level increase index (IN) and water level decrease index (DE) were determined by performing linear and non-linear regressions (Appendices K & L). The regression equation (predicted data) that "best fits" the field data from a statistical and biological standpoint was selected for modelling purposes. It was not possible to incorporate multiple variables and their interactions in a non-linear procedure. Instead, the water depth model was used as the base algorithm, and calculated weighting factors to take into account effect of water level fluctuations. These factors were derived directly from the water increase/decrease models. The water increase/decrease indices were determined using:

- the highest/lowest increase/decrease of water level (in metres) between two quarter-month during the breeding periods.
- the wetland transition (wet-dry, dry-wet, wet-wet, dry-dry) before and after fluctuation and;
- in marshes, the water depth after water level decrease.

Based on expert opinion and on literature, some relationships that explained only a small portion of data variability (r^2) and/or were not statistically significant to a probability of 0.10 ($0.10 < p < 0.40$) were still considered for development of the PIs because the models were logical and fit known ecological thresholds and amplitude. These statistical thresholds were justified from a strict scientific selection process by the decision making process of this study. In fact, environmental relationships are complex and variable, this is often the case for wildlife data, which can fail to be statistically significant when evaluating a single environmental variable. "*And yet, especially when experiments are difficult or management actions needed, we may not have the luxury of obtaining statistical significance before needing to act on our hypotheses*" (Hilborn and Mangel 1997). Non-statistically significant relationships in our study ($p > 0.1$), should be seen as hypotheses, that are further supported by published literature and expert opinion, and are considered to be the best available quantitative information that when incorporated into PIs and the IERM, give the IJC, the best information available in their decision making process.

Hydrological effect on breeding bird density: For marshes, we focused on the following indicator species that showed statistically significant ($p < 0.10$), if not suggestive ($0.10 < p < 0.40$) and biologically meaningful variations in density according to hydrological conditions:

- Black Tern (*Chlidonias niger)*, which builds a crude, typically floating nest platform of dead aquatic vegetation (Dunn and Agro 1995);
- Common Moorhen (*Gallinula chloropus)*, which typically builds a larger and more sturdy nest over water that is attached to emergent vegetation (Bannor and Kiviat 2002);
- Virginia Rail (*Rallus limicola)*, which builds its nest with plant materials in emergent vegetation that is shallowly flooded or has moist soil (Conway 1995);
- Least Bittern (*Ixobrychus exilis)*, a species currently considered at risk in the study area; it weaves its nest from leaves, typically 20 to 80 cm above standing water, in robust emergent vegetation (Giguère *et al.* 2005). Field data were insufficient to determined statistical relationships between density and hydrological variables. Instead, the habitat quality model from Giguère et al. (2005) was used to calculated the reproduction index PI;
- Marsh Wren (*Cistothorus palustris)*, which also builds its nest from leaves in robust emergent vegetation, but in a variety of water depths and usually more than 60 cm above water level (Kroodsma and Verner 1997); and
- American Bittern (*Botaurus lentiginosus)*, which nests on the ground, usually a very short distance (<15 cm) away from water, either on the riverbank or on small islands (Gibbs et al. 1992).

Except for American Bittern, the density of the four remaining species showed a non linear regression relationship (Gauss-Newton, SAS 2001) with water depth. Black Tern densities increased with water depth, while the other species mainly frequent shallow marshes (optimal water depth: from 0.3 to 0.8 m). Based on predicted data, emergent marsh habitats without positive water depths during the breeding season will not support breeding pairs for at least 4 of the 6 indicator species. We did not have enough data to draw any firm conclusions for the two species of bittern, but the density of Least Bittern breeding pairs based upon nest habitat preferences and published literature should also react negatively to dry marsh habitats (Giguère et al. 2005).

The density of all five analysed species were negatively correlated with increases in the water level index. Predicted densities dropped rapidly with increases of 0.2 m and more between two quarter month periods. Except for American Bittern, all other correlations were non linear. Virginia Rail was the only species with densities that correlated with both increases and decreases in the water level index.

The observed and predicted breeding bird density in relation to water depth and water level change are shown for two species, Black Tern (Fig. 3.4.2 a & b) and Virginia Rail (Fig. 3.4.3 a, b & c). The predicted breeding bird density curves for all analysed species are presented in Appendix K.

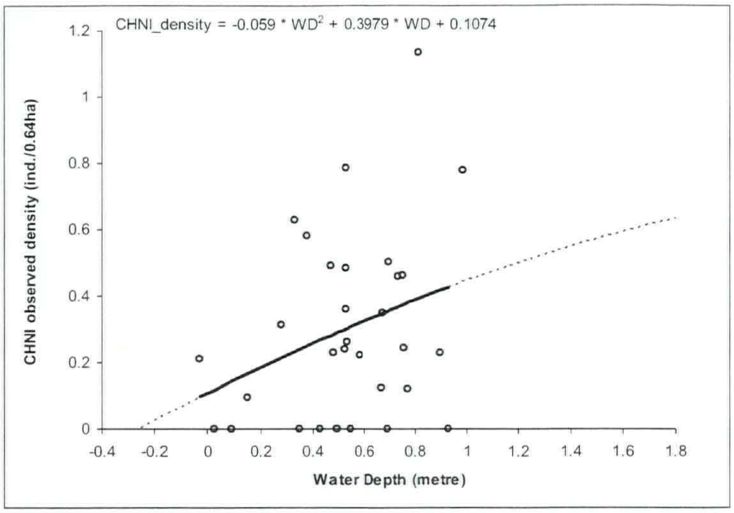


Figure 3.4.1a Relationship between water depth (WD) in metres and Black Tern breeding pair density (CHNI_density/0.64ha). Circle represents observed data from 31 field sites, and solid line, the predicted relationship based on field data and doted lines indicate extrapolation and water depth lower and upper limits considered in the algorithm. The formula gives the density algorithm without water level fluctuations (IN=0; DE=0). Negative water depth values indicate water table depth below the ground surface.

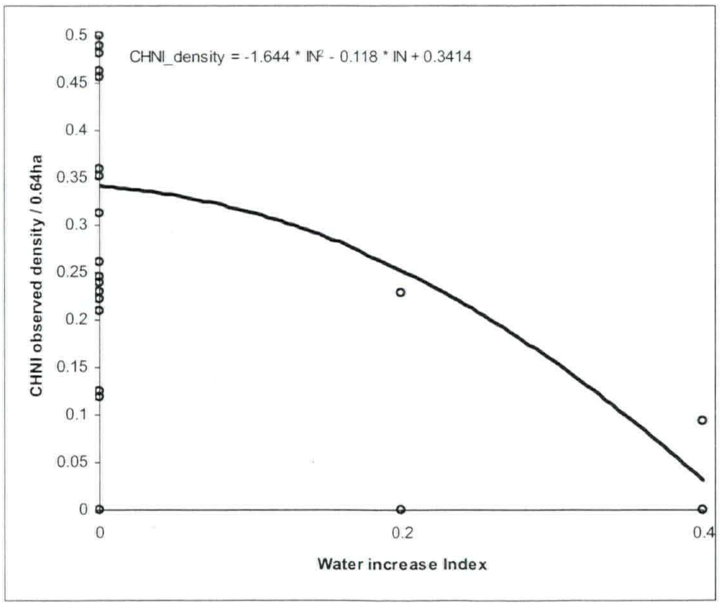


Figure 3.4.1b Relationship between water increase index (IN) and Black Tern breeding pair density (CHNI_density / 0.64ha). Circle represents observed data from 31 field sites, and solid line, the predicted relationship. The weighting factors included in density algorithm were derived from the formula equation. The relationship with water decrease was not significant.

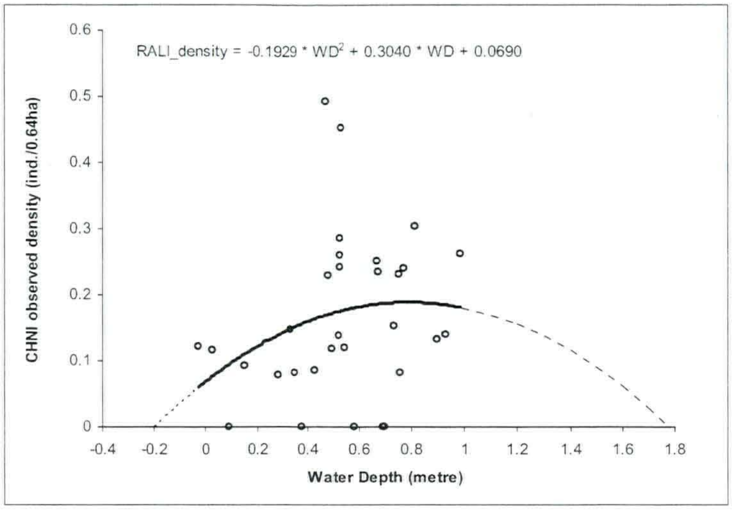


Figure 3.4.2a Relationship between water depth (WD) in metres and Virginia Rail breeding pair density (RALI_density / 0.64ha). Circle represents observed data from 31 field sites, and solid line, the predicted relationship. The formula gives the sub-PI algorithm without water level fluctuations (IN=0; DE=0). Negative water depth values indicate water table depth below the ground surface.

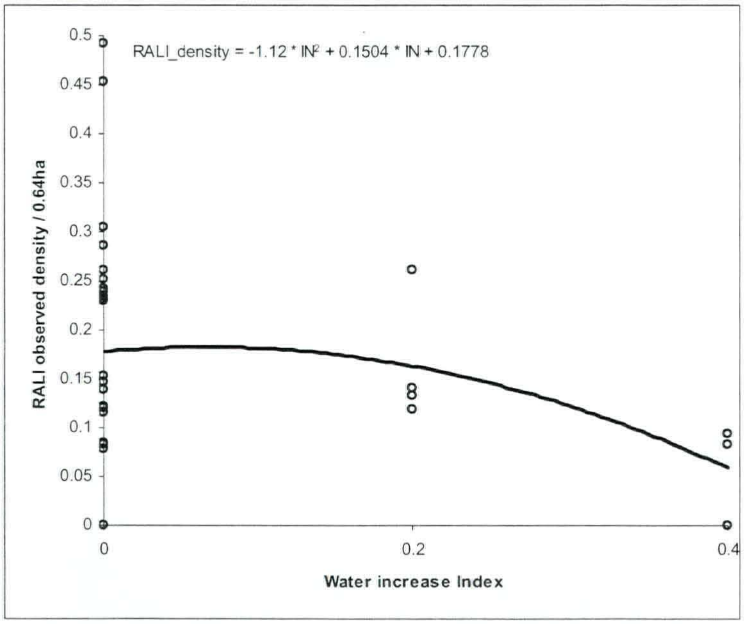


Figure 3.4.2b Relationship between water increase index (IN) and Virginia Rail breeding pair density (RALI_density / 0.64ha). Circle represents observed data from 31 field sites, and solid line, the predicted relationship. The weighting factors included in density algorithm were derived from the formula equation.

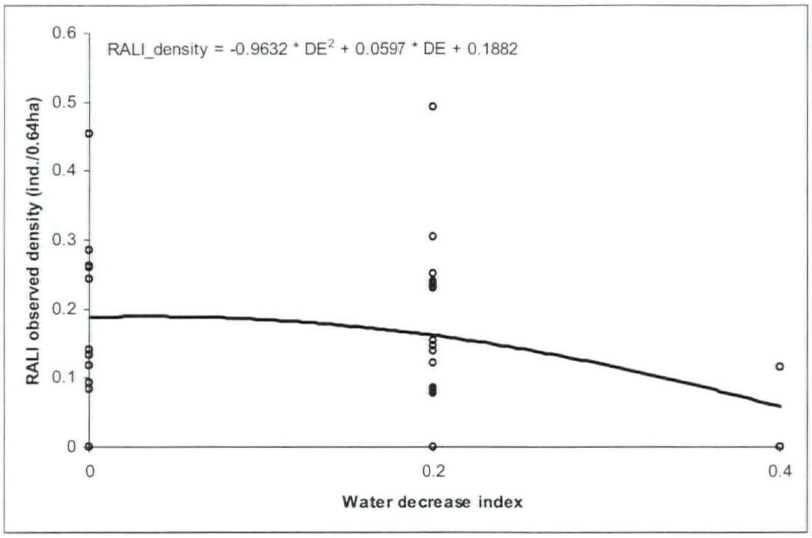


Figure 3.4.2c Relationship between water decrease index (DE) and Virginia Rail breeding pair density (RALI_density / 0.64ha). Circle represents observed data from 31 field sites, and solid line, the predicted relationship. The weighting factors included in density algorithm were derived from the formula equation

For wetland habitats that are typically only inundated during spring floods, and at the onset of the breeding season, we chose two species whose nests are usually located in shrub or tree branches, and more rarely built directly on the ground. These species are:

- Song Sparrow (*Melospiza melodia)* in shrub swamp habitats (Arcese 2002); and
- Veery (*Catharus fuscescens)* in treed swamp habitats (Moskoff 1995).

Song Sparrow (which prefers shrub swamp habitats) and Veery (which prefers treed swamp habitats) nest mainly in areas where the water table is relatively close to the surface. These two species showed a water depth preference toward selecting damp soil (Figures K.2) Based on the predicted data, Veery tends to be less tolerant to the occurrence of flooded habitats (or standing water) than Song Sparrow. Song Sparrow and Veery breeding pair density declined significantly with water level increase (Appendix K).

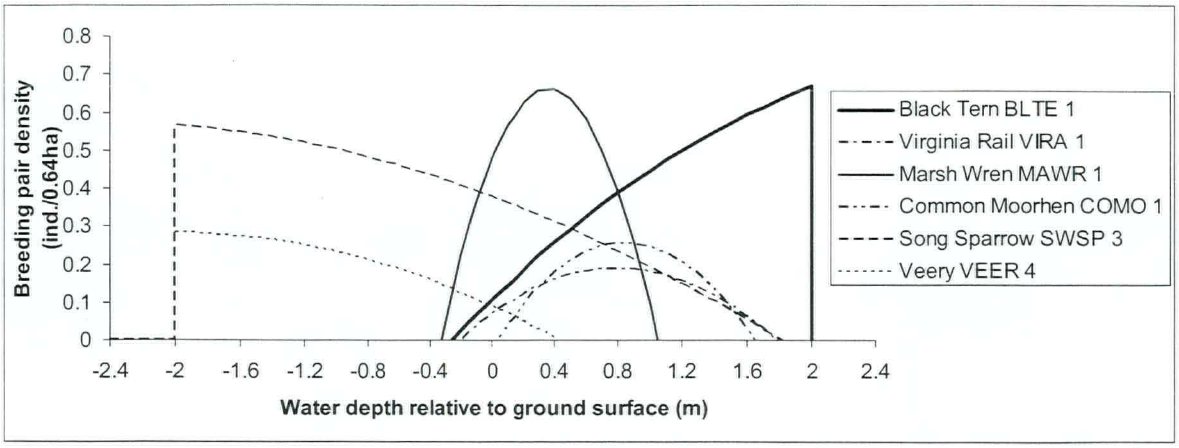


Figure 3.4.3 Relationships of indicator species to water depth in their preferred nesting habitat. Number of species per habitat are: 1 emergent marsh habitat, 2 wet meadow habitat (no indicator), 3 shrub swamp habitat, and 4 treed swamp habitat.

Since none of the wetland bird species associated with wet meadow habitat showed meaningful correlations with hydrological conditions, readers may refer to the work of Lehoux *et al.* (2005) on ducks that nest early in spring in this type of wetland habitat, which has been largely transformed by agriculture in the St. Lawrence flood plains. That study has revealed that the foreseen St. Lawrence water levels are unlikely to significantly limit duck nesting habitat availability. However, water level increase does represent a threat to nesting females through nest flooding, especially when water levels rise in June, when nesting females are abundant and when chances of renesting are substantially reduced. On the other hand, low water levels can reduce the amount of suitable escape cover for broods and may be responsible for greater egg and chick predation and/or infectious epidemics such as botulism (Lehoux et al. 2005). Water-level fluctuations, though they do not influence the optimum water depths sought out by the indicator species, do contribute to appreciable reductions in 7 of the 8 indicator species (Table 3.4.1 and Appendix K). The distribution and abundance of wet meadow, or meadow marsh habitat is strongly influenced by long term water level cycles on Lake Ontario, as such, meadow marsh habitat estimates are being used as an environmental PI in this study region (Wilcox et al. 2005).

Table 3.4.1 Breeding pair reductions (in %) of 9 indicator species from rapid water level fluctuations in their preferred nesting habitat.

	Water level fluctuation index		Marsh habitat 1						Wet meadow habitat	Shrub swamp habitat	Treed swamp habitat
			BLTE	VIRA	MAWR	COMO	AMBI	LEBI	SWSP	SOSP	VEER
Water increase	0	Low	-26	-8	-41	-46	-44	-	-	0	-18
	0.2	Moderate	-91	-67	-84	-99	-88			-3	-37
	0.4	High				-				-25	-56
	0.6	Very High								-64	-74
Water decrease	0	Low	-	-14	-	-	-	-	-	-	-
	0.2	Moderate		-69							
	0.4	High									
	0.6	Very High									

1 Percent lost of nesting pairs with water level fluctuations

When there were rapid or moderate increases in water levels, observed breeding populations of the Black Tern, Marsh Wren, Common Moorhen, and American Bittern were reduced by 84% or more. In the case of Virginia Rail, dramatic decreases in breeding pair occurrence were also observed due to moderate increases and decreases in water levels. In shrub or treed swamp habitats, a large rise in water levels lead to a 25% loss in occurrence of nesting pairs of Song Sparrows and 56% of nesting pairs of Veery (Table 3.4.1). When there was significant water level fluctuations on the Lower St. Lawrence River during the 2002 breeding season, there was a dramatic decrease in breeding pair occurrences of about two-thirds among Song Sparrows and three-quarters among Veery. These analyses clearly show that marsh habitat species react the most strongly to hydrological conditions in their nesting habitats. The fact that marsh species usually build nests on floating vegetation or fairly low in emergent vegetation explains sensitivity. If water levels rise too high, their nests can be drowned; if levels fall too low, the nests may be stranded and hence become abandoned or more accessible to land-based predators (Weller 1961 ; Post 1998). Key PIs within the IERM were selected among marsh species for of these reasons. The density index algorithms for the two key species are presented in Tables 3.4.2 and 3.4.3.

Table 3.4.2 Black Tern density algorithms with different water increase index values

Water increase index (IN)	Algorithms
0	CHNI_CC = (0.1074 + 0.3979 * WD – 0.0590 * WD ^{2}) * 1
0.2	CHNI_CC = (0.1074 + 0.3979 * WD – 0.0590 * WD ^{2}) * 0.74
0.4	CHNI_CC = (0.1074 + 0.3979 * WD – 0.0590 * WD ^{2})* 0.09
>0.4	CHNI_CC = 0

Wetlands type applicable = Emergent, shallow and deep marshes;
Water depth algorithm lower and upper limits = [-0.26metre to 1.8metre];
Null carrying capacity upper limits = 0.033 ind./0.64ha.

Table 3.4.3 Virginia Rail density algorithms with different water increase and decrease index values

Water increase index (IN)	Water decrease index (DE)	Algorithms
0	0	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 1
0.2	0	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.92
0.4	0	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.33
0	0.2	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.86
0	0.4	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.31
0.2	0.2	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.79
0.4	0.2	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.28
0.2	0.4	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.28
0.4	0.4	RALI_CC = (0.0690 + 0.3040 * WD – 0.1929 * WD ^{2}) * 0.10
>0.4	>0.4	RALI_CC = 0

Wetlands type applicable = Emergent and swallow marshes
Water depth algorithm lower and upper limits = [-0.1metre to 1metre];
Null carrying capacity upper limits = 0.0032 ind./0.64ha.

Wetland breeding bird nest success rate: A comparison of nest record data from Lake Ontario-Upper St. Lawrence River and the Lower St. Lawrence River regions, and results of field based bird surveys indicate only small differences between species specific nest initiation (i.e. egg laying) dates in the two study areas. Nest record data was combined for the two study regions and estimated percent nest initiation summaries created for use in the entire study area (Table 3.4.4).

Table 3.4.4 Number of nest records and estimated percent nest initiation by quarter month for emergent marsh indicator species, Ontario and Quebec nest records combined.

	# of nest	Quarter Month (mid-April to end of July)													
Species	records	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Black Tern	224	0.0	0.0	0.0	0.4	7.1	24.1	26.8	18.3	12.1	5.8	2.7	1.3	0.4	0.9
Common Moorhen	114	0.0	0.0	2.6	4.4	14.0	21.1	15.8	16.7	13.2	3.5	4.4	1.8	1.8	0.9
Virginia Rail	50	0.0	0.0	4.0	6.0	26.0	26.0	14.0	8.0	6.0	4.0	0.0	4.0	2.0	0.0
Least Bittern	52	0.0	0.0	0.0	0.0	3.8	21.2	17.3	15.4	23.1	17.3	0.0	0.0	0.0	1.9
Marsh Wren	67	0.0	0.0	0.0	1.5	3.0	19.4	32.8	10.4	9.0	9.0	0.0	11.9	3.0	0.0
American Bittern	11	0.0	9.1	0.0	9.1	18.2	45.5	9.1	9.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	518	0.0	1.5	1.1	3.6	12.0	26.2	19.3	13.0	10.5	6.6	1.2	3.2	1.2	0.6

Although it is not uncommon for these species to start nesting in early May, peak nest initiation for most of the emergent marsh indicator species is estimated to occur during the last quarter month of May and the first quarter month of June. For the purposes of water regulation plan evaluation, the first and third quarter month of June were set as standard start dates for the first and second peak nesting attempts within the study area for all indicator species. Least Bittern and Black Tern nesting studies in Ontario, Quebec and New York provide additional documentation that peak nesting and renesting activities occur during this time period (Mazzocchi et al. 1997; Bognor 2001; Picard and Shaffer 2003). Nest attempts beyond two have been documented, but this is not considered common, and was not accounted for in the nest success rate calculation.

Once egg laying has begun, the nest attempt remains exposed to potential failure due to flooding or stranding until the eggs hatch and the chicks are able to leave the nest. This period was estimated to range from 26 to 33 days, with the period exceeding 30 days for most of the emergent marsh indicator species. Since water level data for this study is calculated at quarter month intervals, a 5 quarter month period (approximately 35 days) was used as the exposure period for each nesting attempt.

Hydrologic conditions at nest locations based upon nest record data are summarized in Table 3.4.5, and indicate the range of preferences represented by the indicator species. Based upon nest record data, Black Tern, Common Moorhen and Least Bittern nests are typically found in moderate to deeply flooded wetland habitats. Virginia Rail nests typically occur in shallowly flooded habitat, and American Bittern, Song Sparrow and Veery nests in unflooded wetland habitats. Nest record summary results are also supported by published literature on nest height above water (Conway 1995; Dunn and Agro 1995; Gibbs et al. 1992; Mazzocchi et al. 1997), with Black Tern and Common Moorhen nesting on or near the water surface. The nesting record data and bird survey data presented previously indicate very similar nesting habitat preferences for all the marsh nesting species.

Table 3.4.5 Mean and standard deviation of nest height above the water or ground, and water depth below the nest.

Species	Nest height above water or ground (cm) Mean	SD	Water depth below nest (cm) Mean	SD
Black Tern	6	12	62	15
Common Moorhen	11	15	66	21
Virginia Rail	12	17	30	16
Least Bittern	53	32	67	27
Marsh Wren	81	30	51	25
American Bittern	6	7	NA	
Song Sparrow	29	45	NA	
Veery	41	49	NA	

The indicator species are thought to vary in their nest resiliency to flooding (i.e. floating nests and ability to build up the nest), and probability of nest failure due to stranding (i.e. nest abandonment or predation). Table 3.4.6 summarizes nest height adjustment and probability of nest failure due to stranding parameters used in nest loss probability calculations. Baseline nest success (in the absence of hydrologic impacts) and renest rates used in the nest success rate calculation are also provided in Table 3.3.6. Published literature was used to establish species specific baseline parameters (Arcese et al. 2002; Bannor and Kiviat 2002; Bogner 2001; Bogner and Baldassarre 2002; Conway 1995; Gibbs et al. 1992; Kroodsma and Verner 1997; Mazzocchi et al. 1997; Moskoff 1995; Servello 2000). The availability of specific estimates varied among the indicator species. Estimation of some parameters using surrogate species was justified by the fact that these parameters are constant values within an index that is used for relative comparison among plans, uncertainties, or adjustments to the parameters should affect plan specific index values equally.

Table 3.4.6 Nest height adjustment, probability of nest loss due to stranding and nesting parameters used in calculating annual nest success rates.

Species	Species code	Nest height adjustment (cm)	Prob. of nest failure due to stranding	Baseline nest success	Renest rate
Black Tern	CHNI	30	1	0.5	0.5
Common Moorhen	GACH	30	1	0.7	0.6
Virginia Rail	RALI	20	0.5	0.5	0.4
Least Bittern	IXEX	10	0.5	0.6	0.6
Marsh Wren	CIPA	0	0.5	0.6	0.8
American Bittern	BOLE	10	0	0.6	0.6
Song Sparrow	MEME	0	0	0.5	1
Veery	CAFU	0	0	0.5	0.7

Probabilities of nest flooding or stranding were estimated during each nest attempt based upon a statistical relationship between the magnitude of water level change over the 5-quarter month exposure period and percent cumulative distributions of nest height above water and water depth below the nest respectively. Table 3.4.7 lists the regression equations and upper and lower equation limits. Estimated probabilities based on nest record data and predicted probabilities based upon regression models are graphically represented in Appendices L & N.

Table 3.4.7 Probability of nest flooding and stranding regression equations and equation limits.

Species	Nest flooding probability	If water level increase is <, probability equals 0 (cm)	If water level increase is >, probability equals 1 (cm)
Black Tern	Prob. of flooding (CHNI) = 0.3277Ln(x) - 0.3838	30	69
Common Moorhen	Prob. of flooding (GACH) = 0.5931Ln(x) - 1.6069	30	82
Virginia Rail	Prob. of flooding (RALI) = 0.4222Ln(x) - 0.8359	20	78
Least Bittern	Prob. of flooding (IXEX) = -5E-05x^2 + 0.0159x - 0.2544	20	138
Marsh Wren	Prob. of flooding (CIPA) = -3E-05x^2 + 0.0137x - 0.3896	31	153
American Bittern	Prob. of flooding (BOLE) = 0.4717Ln(x) - 0.6521	10	33
Song Sparrow	Prob. of flooding (MEME) = = 0.2075Ln(x) - 0.001	2	125
Veery	Prob. of flooding (CAFU) = 0.2093Ln(x) - 0.0803	0	180

Species	Nest stranding probability	If water level decrease is <, probability equals 0 (cm)	If water level decrease is >, probability equals 1 (cm)
Black Tern	Prob. of stranding (CHNI) = -0.0002x^2 + 0.0453x - 1.3473	36	81
Common Moorhen	Prob. of stranding (GACH)= 0.0112x - 0.1645	16	104
Virginia Rail	Prob. of stranding (RALI)= 0.5853Ln(x) - 1.4525	12	67
Least Bittern	Prob. of stranding (IXEX) = 0.7461Ln(x) - 2.4948	29	109
Marsh Wren	Prob. of stranding (CIPA) = 0.0107x + 0.0085	1	94

Annual nest success rate estimates were calculated using the following formula:

Annual nest success algorithm=$n_1 + [(1-n_1) \times rr \times n_2]$

where n_i = nest success, attempt i

rr = renest rate

n_i = bn x (1- pf)

or

n_i = bn x (1- (ps x psf)

where bn = baseline nest success

pf = prob. of nest flooding

ps = prob. of nest stranding

psf = prob. of nest failure due to stranding

Maximum water level change was calculated annually over the first and second nest attempt period, and either the probability of flooding or stranding used depending on which had the higher probability value.

Wetland breeding bird reproductive index: A reproductive index algorithm was created by multiplying the carrying capacity (estimated number of breeding pairs based upon habitat conditions) and the nest success rate (estimated percentage of breeding pairs that have a successful nesting attempt over the breeding season).

To reduce the redundancy in ETWG performance indicators included in the IERM and to suggest an optimal number of avian PIs, we calculated the correlation among the avian

PIs (Proc Reg, SAS 2001). In marshes, the responses of five PIs were similar (R^2 > 0.90), as were responses for the two swamp species (R^2 = 0.91). Only the Least Bittern response differs from that of the other marsh species. We selected three key PIs out of the five marsh bird PIs: Black Tern, Least Bittern and Virginia Rail. Another important performance indicator, but not retained as key PIs, is the species richness of birds that nest preferentially in shallow marshes.

Wetland bird metric and index model overview:

1) Assumptions: Metrics were developed under certain assumptions that are:

- Breeding habitat supply and reproductive success are significant factors influencing the size and integrity of regional breeding populations.
- Sampling design and survey locations were representative of wetland habitats within the larger study area.
- Wetland habitat models are providing an accurate, relative estimate of emergent marsh habitat.
- Breeding bird density models developed from LSL data are representative of the larger study area.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted bird response to hydrologic conditions based on statistical modelling is valid.
- Transformation from a 2D to 1D hydrologic model in the LSL is correct.

2) Confidence: We are confident in the associations between water levels and the three key wetland bird PIs. Black Tern, Least Bittern and Virginia Rail nest almost exclusively in wetland habitats, and are thus sensitive to hydrologic alterations that affect the area of wetland vegetation communities (Keddy 2002, Wilcox et al. 2005). Lake Ontario and St. Lawrence River specific research results and a moderate body of scientific literature also document the close association between species occurrence, wetland habitat area and water depth. Thus, we are confident that the PI allows for an accurate relative comparison of breeding habitat availability and suitability among alternate water level and flow regimes within the study area. The second hydrologic association is related to water depth and fluctuation within the various wetland vegetation habitats. Again, our research and the scientific literature support the influence of water depth and fluctuation on the probability of wetland bird species presence and abundance for the key bird species (PIs). Both the wetland habitat and breeding bird estimates are based upon hydrologic associations derived from a subset of study wetlands that are extrapolated to generate study area estimates.

Although hydrologic variables are strongly associated with habitat and bird density and occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess theoretical 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and survival) and environmental variables (e.g. predation, food availability, pollution, exotic species) that can also impact reproductive success (habitat carrying capacity and nest success), and have an influence on regional breeding bird populations. For these reasons, the PI values should only be considered as relative measures between plans (index).

3) Significance: Black Tern is experiencing regional population declines (Ontario and New York State) and the North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to its regional population integrity (Milko *et al.*, 2003). The Black Tern PI is also a surrogate species for Pied-billed Grebe (*Podilymbus podiceps*) and Common Moorhen (*Gallinula chloropus*) and several wildfowl species that use deep emergent marshes as feeding and rearing habitats. The Black Tern and Pied-billed Grebe are listed by the NYSDEC as endangered and threatened respectively. The Black Tern is also listed as vulnerable by OMNR.

The Least Bittern is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the Species at Risk Act; the species and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. The North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes / St. Lawrence plain (BCR 13) as critical to Least Bittern regional population integrity (Milko *et al.*, 2003).

Although Virginia Rail is a regionally common species, the North American Bird Conservation Initiative (NABCI) consider the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to the natural cycle of this species. The Virginia Rail is also representative of a group of wetland breeding birds that require shallowly flooded emergent marsh habitats for breeding. The Virginia Rail is a surrogate species for American Bittern and Sora, and utilizes similar habitat to that of the King Rail.

4) Sensitivity: Black Tern, Least Bittern and Virginia Rail PIs were retained as key PIs because they clearly demonstrate an important vulnerability and sensitivity to alternations in water levels and flows, and, as such, are valuable in evaluation of potential environmental responses to alternative water regulation plans.

4. The IERM/SVM Process

4.1. The Integrated Ecosystem Response Model [IERM]

The IERM was designed to analyse the ecological impacts of proposed water level control plans for the Lake Ontario/ St. Lawrence River system (http://www.limno.com/ierm/). The IERM software is comprised of two main components, a simulation of proposed water regulation plans, and a visualization of simulated ecological impacts. The IERM framework provides a comprehensive suite of graphical tools for visualizing model output for individual performance indicators (PIs). These tools provide the user with a variety of approaches for viewing, interpreting, and comparing PI output for multiple regulation plans, including a target plot that constitutes a straightforward way to compare results for a large number of individual PIs by displaying single points representing performance indicator ratios.

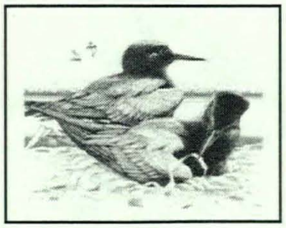
4.2. Wetland bird key PI fact sheets

Concise fact sheets were prepared for each key performance indicator included within the IERM. These fact sheets are meant to provide study board members with a brief description of the performance indicator, and provide information that would help in the plan review process. They are included as an inset in the body of our report for rapid consultation since they constitute the four key wetland bird PIs we believe are the most useful for water regulation plan review by the study board.

ENCLOSURE 1 Black Tern

Integrated Ecosystem Response Model:
Performance indicator fact sheet on wetland bird: CHNI PI

Black Tern (*Chlidonias niger*) reproductive index in emergent marshes.



Research by: Drolet, B., J. Ingram, J.-L. DesGranges
Modeled by: Drolet, B., J. Ingram, J. Morin, S. Martin, O. Champoux, T. Redder

Activity represented by this indicator: It represents an index of reproductive potential in emergent marsh during the breeding season, based on the carrying capacity, an annual estimate of the number of potential breeding pairs in emergent marsh weighted by water depth and water level increase, multiplied by an annual estimate of nest success, based on the probability that a breeding female will successfully hatch a nest, according to the magnitude of water level change.

Link to water levels: Black Tern construct nests on floating vegetation in emergent marsh vegetation, and require marsh habitat that is flooded for nesting and feeding. Emergent marsh habitat availability is directly linked to long term water supplies. The percentage of marsh habitat flooded or stranded, and the rate of water level change (rapid rise > 20cm) are also important annual hydrologic factors. During the nesting period, water level increases can drown eggs and chicks, and water level decreases, increase ground predator access to nests.

Performance Indicator Metrics: The PI response includes an aggregation of annual index values into a 2 year moving mean value. This smoothing technique was used to reduce extreme annual PI values and incorporate a lag in the response of the PI to changing habitat conditions. The aggregated 100 year plan scenarios are expressed by the percent of time that the PI index exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2 S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

Temporal validity: Valid for Black Tern breeding season from second week of May to the end of July (QM 18 to QM28). The PI does not consider cumulative effect from previous years.

Spatial validity: Valid for the Lake Ontario, Upper St. Lawrence River Unit 1, and the Lower St. Lawrence River to Lake Saint-Pierre (except Lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values based on a 2D water level and topographic model, for the carrying capacity values, and upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest, for the nest success rate. Three hydraulic attributes were considered:

mean water depth, the maximum *water level increase* and the maximum *water level decrease*.

The Algorithm: Algorithm for Black Tern reproductive success PI (index) is made from the multiplication of the carrying capacity values (estimated number of breeding pairs) and nest success rate.

Carrying capacity value: The algorithm is based on water depth relationship with the density of breeding pairs, weighted by a persistency rate of breeding activities due to water increase using a water increase index (Tab. 1). The water increase index was determined using: 1) the highest increase of water level (in metres) between two quarter-month during the breeding periods; and 2) the wetland transition before and after fluctuation (Tab. 1).

Black Tern carrying capacity value = $(0.1074 + 0.3979 * WD - 0.0590 * WD^2) * P_{rate}$

Where: WD = water depth; P_{rate} = Persistency rate calculated from the non linear relationship between breeding pair density and water increase index (IN): if IN = 0 then P_{rate} = 1; if IN = 0.2 then P_{rate} = 0.74; if IN = 0.4 then P_{rate} = 0.09 and if IN = >0.4 then P_{rate} = 0; water depth algorithm lower and upper limits = -0.26 meter to 1.8 meter; null carrying capacity upper limits = 0.033 ind./0.64ha.

Table 1: Determination of water increase index (IN)

Wetland transition	Increase of water level (meter)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Nest success rate: This rate is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Black Tern specific nest resilience to flooding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the preceding five quarter month period (Tab. 2). Either the probability of flooding or stranding was used depending on which had the higher probability value. The other reproductive variables included in the annual nest success rate equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (renesting rate) were held constant.

Black Tern nest success rate = $n_1 + [(1 - n_1) * rr * n_2]$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) **or** BN * (1 - (PS * PSF)
BN = Baseline nest success = 0.5; PF = Prob. of nest flooding (see Tab.2); PS = Prob. of nest stranding (see Tab. 2); PSF = Prob. of nest failure due to stranding = 1; rr = renest rate = 0.5

Table 2: Black Tern nest flooding/stranding probability (PF/PS)

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Black Tern flooding/stranding probability
If RW <= 30	and RW > DW	PF = 0
If RW > 30 and RW < 69	and RW > DW	PF = 0.3277 * Ln (RW) – 0.3838
If RW > 69	and RW > DW	PF = 1
If RW < DW	and DW <= 36	PS = 0
If RW < DW	and DW > 36 and DW < 94	PS = -0.0002 * DW^2 + 0.0453 DW – 1.3473
If RW < DW	and DW > =94	PS = 1

Validation: No external or internal validation as been performed. The relationship between Black Tern and water level are biologically significant and were verified with scientific literature and expert opinion.

Documentation and References: Jean-Luc DesGranges, Joel Ingram, Bruno Drolet, Caroline Savage, Jean Morin and Daniel Borcard (2005) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

PI Assumptions:

- Breeding habitat supply and reproductive success are significant factors influencing the size and integrity of regional breeding populations.
- Sampling design and survey locations were representative of wetland habitats within the larger study area.
- Wetland habitat models are providing an accurate, relative estimate of emergent marsh habitat.
- Breeding bird density models developed from LSL data are representative of the larger study area.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted bird response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model in the LSL is correct.

Confidence, Significance and Sensitivity:

1) Confidence rating: We are confident in the associations between water levels and wetland bird PIs. Black Terns nest almost exclusively in wetland habitats and are thus sensitive to hydrologic alterations that affect wetland vegetation communities. Lake Ontario and St. Lawrence River specific research results and a moderate body of scientific literature document the close association between Black Tern occurrence, emergent marsh area and water depth (i.e. if flooded emergent marsh habitat does not exist, the birds do not occur in the wetland). Thus, we are confident that the PI allows for an accurate relative comparison of Black Tern breeding habitat availability and suitability among alternate water level and flow regimes within the study area. This is the first level of hydrologic association. The second is related to water depth and fluctuation within the various wetland vegetation habitats. Again, our research and published literature support the influence of water depth and fluctuation on the probability of wetland bird species presence and abundance for several species (PIs). Both the wetland habitat and breeding bird estimates are based upon hydrologic associations derived from a subset of study wetlands that are extrapolated to generate study area estimates.

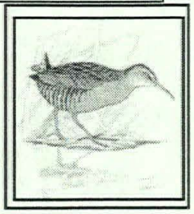
Although hydrologic variables are strongly associated with habitat and bird density and occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, pollution, exotic species) that can also impact reproductive success (habitat carrying capacity and nest success), and have an influence on regional Black Tern breeding populations. For these reasons, the PI values should only be considered as relative measures between plans (index).

2) Significance of PI: Black Tern is experiencing regional population declines (Ontario and New York State) and the North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to its natural cycle. The Black Tern PI is also a surrogate species for Pied-billed Grebe (*Podilymbus podiceps*) and Common Moorhen (*Gallinula chloropus*) and several wildfowl species that use deep emergent marshes as feeding and rearing habitats. The Black Tern and Pied-billed Grebe are listed by the NYSDEC as endangered and threatened respectively. The Black Tern is also listed as vulnerable by OMNR.

3) Sensitivity of PI: Black Tern PI is retained as a Key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and as such, it should be used to evaluate potential environmental responses to alternative water regulation plans.

ENCLOSURE 2 Virginia Rail

Integrated Ecosystem Response Model:
Performance indicator fact sheet on wetland bird: RALI PI



Virginia Rail (*Rallus limnicola*) reproductive index in emergent marsh

Research by: Drolet, B., J. Ingram, J.-L. DesGranges
Modeled by: Drolet, B., J. Ingram, J. Morin, S. Martin, O. Champoux, T. Redder

Activity represented by this indicator: It represents an index of reproductive potential in emergent marsh during the breeding season, based on the carrying capacity, an annual estimate of the number of potential breeding pairs in emergent marsh weighted by water depth and water level increase and decrease, multiplied by an annual estimate of nest success, based on the probability that a breeding female will successfully hatch a nest, according to the magnitude of water level changes.

Link to water levels: Virginia Rail construct nests close to the ground in emergent marsh vegetation, and prefer marsh habitat that is flooded, but will also breed in unflooded marsh vegetation near water. Emergent marsh habitat availability is directly linked to long term water supplies. The percentage of marsh habitat flooded or stranded, and the rate of water level change (rapid rise > 20cm) are also important annual hydrologic factors. During the nesting period, water level increases can drown eggs and chicks, and water level decreases, increase ground predator access to nests.

Performance Indicator Metrics: The PI response includes an aggregation of annual index values into a 2 year moving mean value. This smoothing technique was used to reduce extreme annual PI values and incorporate a lag in the response of the PI to changing habitat conditions. The aggregated 100 year plan scenarios are expressed by the percent of time that the PI index exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2 S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

Temporal validity: Valid for Virginia Rail breeding season from the second week of May to the end of July (QM 18 to QM 28). The PI does not consider cumulative effects from previous years.

Spatial validity: Valid for the Lake Ontario, Upper St. Lawrence River Unit 1 and 3, and the Lower St. Lawrence River to Lake Saint-Pierre (except Lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values based on a 2D water level and topographic model, for the carrying capacity values, and upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest, for the nest success rate. Three hydraulic attributes were considered: *mean water depth*, the maximum *water level increase* and the maximum *water level decrease*.

The Algorithm: Algorithm for Virginia Rail reproduction success PI (index) is made from the multiplication of the carrying capacity values (estimated number of breeding pairs) and nest success rate.

Carrying capacity: The algorithm is based on water depth relationship with the density of breeding pairs, weighted by a persistency rate of breeding activities due to water increase and/or decrease using a water increase and a water decrease index (Tab.1 and 2). The water increase and water decrease index were determined using: 1) the highest increase index and the highest decrease index of water level (in meters) between two quarter-months during the breeding period; 2) the wetland transition before and after fluctuation; and 3) for water decrease index, the water depth after drop (Tab. 1 and 2).

Virginia Rail carrying capacity value = $(0.0690 + 0.3040 * WD - 0.1929 * WD^2) * P_{rate}$

Where: WD = water depth; P_{rate} = Persistency rate calculated from the non linear relationship between breeding pair density and water increase index and (IN)/or water decrease index (DE): If IN = 0 and DE = 0 then P_{rate} = 1; If IN = 0.2 and DE = 0 then P_{rate} = 0.92; if IN = 0.4 and DE = 0 then P_{rate} = 0.33; if IN = 0 and DE = 0.2 then P_{rate} = 0.86; if IN =0 and DE = 0.4 then P_{rate} = 0.31, if IN = 0.2 and DE = 0.2 then P_{rate} = 0.79; if IN = 0.4 and DE = 0.2 then P_{rate} = 0.28; if IN = 0.2 and DE = 0.4 then P_{rate} = 0.28; if IN = 0.4 and DE = 0.4 then P_{rate} = 0.10, and, if IN > 0.4 and/or DE > 0.4 then P_{rate} = 0.; water depth algorithm lower and upper limits = -0.1metre to 1metre; null carrying capacity upper limits = 0.0032 ind./0.64ha.

Table 1: Determination of water increase index (IN)

Wetland transition	Increase of water level (metre)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Table 2: Determination of water decrease index (DE)

Water depth after drop	Wetland transition	Decrease of water level (metre)			
		0-0.2	0.21-0.50	0.51-0.70	>0.70
> 0.45 metre	Wet-wet	0	0.2	0.2	0.4
< 0.45 metre	Wet-wet	0	0.4	0.4	0.6
N/A	Wet-dry	0.2	0.6	0.8	0.8
N/A	Dry-dry	0.6	0.8	0.8	0.8

Nest success: This rate is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Virginia Rail specific nest resilience to flooding and stranding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the preceding five quarter month period (Tab. 3). Either the probability of flooding or stranding was used depending on which had the higher probability value. The other reproductive variables included in the annual nest success rate equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (renesting rate) were held constant.

$$\text{Virginia Rail nest success rate} = n_1 + [(1- n_1) * rr * n_2]$$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) **or** BN * (1 - (PS * PSF)
BN = Baseline nest success = 0.5; PF = Prob. of nest flooding (see Tab. 3); PS = Prob. of nest stranding (see Tab. 3); PSF = Prob. of nest failure due to stranding = 0.5; rr = renest rate = 0.4

Table 3: Virginia Rail nest flooding/stranding probability (PF/PS)

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Virginia Rail flooding/stranding probability
If RW <= 20	and RW > DW	PF = 0
If RW > 20 and RW < 78	and RW > DW	PF = 0.4222 * Ln (RW) – 0.8359
If RW >= 78	and RW > DW	PF = 1
If RW < DW	and DW <= 12	PS = 0
If RW < DW	and DW > 12 and DW < 67	PS = 0.5853 * Ln (DW) – 1.4525
If RW < DW	and DW >= 67	PS = 1

Validation: No external or internal validation was performed. Relationship between Virginia Rail and water level are biologically significant and were verified with scientific literature and expert opinion.

Documentation and References: Jean-Luc DesGranges, Joel Ingram, Bruno Drolet, Caroline Savage, Jean Morin and Daniel Borcard (2005) Lake Ontario - St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2004).

PI Assumptions:

- Breeding habitat supply and reproductive success are significant factors influencing the size and integrity of regional breeding populations.
- Sampling design and survey locations were representative of wetland habitats within the larger study area.
- Wetland habitat models are providing an accurate, relative estimate of emergent marsh habitat.
- Breeding bird density models developed from LSL data are representative of the larger study area.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted bird response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model in the LSL is correct.

Confidence Significance and Sensitivity:

1) Confidence rating: We are confident in the associations between water levels and wetland bird PIs. Virginia Rails nest almost exclusively in wetland habitats and are thus sensitive to hydrologic alterations that affect wetland vegetation communities. Lake Ontario and St. Lawrence River specific research results and a moderate body of scientific literature document the close association between Virginia Rail occurrence, emergent marsh area and water depth. Thus, we are confident that the PI allows for an accurate relative comparison of Virginia Rail breeding habitat availability and suitability among alternate water level and flow regimes within the study area. This is the first level of hydrologic association. The second is related to water depth and fluctuation within the various wetland vegetation habitats. Again, our research and published literature support the influence of water depth and fluctuation on the probability of wetland bird species presence and abundance for several species (PIs). Both the wetland habitat and breeding bird estimates are based upon hydrologic associations derived from a subset of study wetlands that are extrapolated to generate study area estimates.

Although hydrologic variables are strongly associated with habitat and bird density and occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, pollution, exotic species) that can also impact reproductive success (habitat carrying capacity and nest success), and have an influence on regional Virginia Rail breeding populations. For these reasons, the PI values should only be considered as relative measures between plans (index).

2) Significance of PI: Although a regionally common species, the North American Bird Conservation Initiative (NABCI) consider the Lower Great Lakes/St. Lawrence plain (BCR 13) critical to the natural cycle of Virginia Rail. The Virginia Rail is also representative of a group of wetland breeding birds that require shallowly flooded emergent marsh habitats for breeding. The Virginia Rail is a surrogate species for American Bittern (*Botaurus lentiginosus*) and Sora (*Porzana carolina*), and also utilizes similar habitat to that of the Viginia Rail

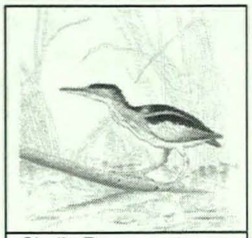
3) Sensitivity of PI: Virginia Rail is retained as a Key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and as such, it should be used to evaluate potential environmental responses to alternative water regulation plans.

ENCLOSURE 3 Least Bittern

Integrated Ecosystem Response Model: Performance indicator fact sheet on wetland bird: IXEX PI

Least Bittern (*Ixobrychus exilis*) reproductive index in emergent marshes.

Research by: Giguère, S., J. Ingram, B. Drolet, J.-L. DesGranges & P. Laporte
Modeled by: Morin, J., S. Martin, O. Champoux, for Lower St. Lawrence River, T. Redder, for Lake Ontario and Upper St. Lawrence River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Activity represented by this indicator: It represents an index of reproductive potential in emergent marsh during the breeding season, based on the habitat supply, annual estimate of the number of potential breeding pairs using the study area, and annual estimate of nest success rate that is influenced by water levels fluctuations.

Link to water levels: Least Bittern usually construct nests in emergent vegetation 20 cm to 80 cm above to water surface, and require marsh habitat that is flooded for nesting and feeding. Nests are typically located in emergent marsh with water depths ranging from 10 cm to 100 cm. Emergent marsh habitat availability is directly linked to long term water supplies. The percentage of marsh habitat flooded or stranded, flood amplitude, recurrence and duration, as well as the rate of water level change (rapid rise or drop > 20 cm) are also important hydrologic factors. During the nesting period, water levels increases can drown eggs and chicks, and water level decreases, increase ground predator access to nests.

Performance Indicator Metrics: The PI response includes an aggregation of annual index values into a 2 year moving mean value. This smoothing technique was used to reduce extreme annual PI values and incorporate a lag in the response of the PI to changing habitat conditions. The aggregated 100 year plan scenarios are expressed by the percent of time that the PI index exceeds the first quartile value for plan 1958DD for the comparable water supply series (e.g. Historic, S1, S2 S3, etc). This metric will be used for plan evaluation by calculating a ratio of metrics between two plans.

Temporal validity: Valid for the Least Bittern breeding season from last quarter month of May to end of July (QM 19 –QM 28).

Spatial validity: Valid for the Lake Ontario, Upper St. Lawrence River (Unit 1), and the Lower St. Lawrence River to Lake Saint-Pierre (except Lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes responsible for nesting habitat availability and nest success rate. More specifically, the potential nesting habitat was developed for the Lower St. Lawrence River section, using 2D probabilistic modeling based on the combination of hydrodynamic (water depth) and emerging plants models. In Lake Ontario and Upper St.

Lawrence River, the potential nesting habitat was developed using presence/absence modeling based on the same parameters as in the Lower St. Lower. For both regions, the nest success rate was based upon Ontario and Québec nest record data of nesting chronology, nest heights and water depths below the nest. Three hydraulic attributes were considered: *mean water depth*, the maximum *water level increase* and the maximum *water level decrease*.

The Algorithm: Algorithm for Least Bittern reproductive success PI (index) is made from the multiplication of the carrying capacity values (estimated number of breeding pairs) and nest success rate.

Carrying capacity value in Lower St. Lawrence River section: The algorithm gives the carrying capacity value of Least Bittern (estimated number of breeding pairs) based on the probability occurrence of Least Bittern nesting habitat within the study area [Eq. 1] multiplied by a fix density value [Eq. 2]. The estimated nesting habitat [Eq. 1] is based on water depth suitability (*pIXEX*) ; probability occurrence of Cattail (*pTYPHA_A* and *pTYPHA_L*) and of deep marshes vegetation (ex: *Scirpus fluviatilis*) (*pMp*). The parameters [Eq. 1] and the fix density [Eq. 2] were determined upon expert opinion and literature review.

[Equation 1] Least Bittern nesting habitat probability in Lower St. Lawrence River section = presIXEX = (power(pIXEX,0.5) * power(pTYPHA_A,0.2) * power(pTYPHA_L,0.2 * power(pMp,0.1))

where: pIXEX = ((1/0.248*sqrt(2*π)))*exp(-0.5*(power(((depth-0.598)/0.248),2))))/1.6086

nesting habitat is considered as suitable if presIXEX > 0.5

[Equation 2] Least Bittern carrying capacity value (pair #/0.64ha) = presIXEX * 0.0384

Carrying capacity value in Lake Ontario and Upper St. Lawrence River (Unit 1): Suitable nesting habitat area was based on an annual estimate of emergent marsh habitat that contained an average of 10 to 100 cm of standing water during the breeding season. The area estimate was multiplied by a fix pair density (0.06 pairs/ha) to generate an annual carrying capacity estimate. The habitat parameters and density were determined upon expert opinion and literature review.

Nest success rate: This rate is based on nest initiation estimates, nest height and water depth below nest data. Nest height data was adjusted to account for Least Bittern specific nest resilience to flooding. Probability of nest loss estimates due to water level increases or decreases were determined based upon a statistical relationship between magnitude of water level change and probability of nest flooding or stranding. Water level change over a nest exposure period was calculated as the maximum water level increase and decrease from the quarter month of nest initiation over the preceding five quarter month period (Tab. 2). Either the probability of flooding or stranding was used depending of which had the higher probability value. The other reproductive variables included in the annual nest success rate equation, baseline nest success (in the absence of hydrologic impact) and the probability that a female will renest if the first nest attempt is unsuccessful (renesting rate) were held constant.

[Equation 3] Least Bittern nest success rate = $n_1 + [(1- n_1) * rr * n_2]$

Where: n_1 or n_2 = nest success attempt 1 or 2 where n_i = BN * (1-PF) **or** BN * (1 - (PS * PSF)

BN = Baseline nest success = 0.6; PF = Prob. of nest flooding (see Tab. 1); PS = Prob. of nest stranding (see Tab. 1); PSF = Prob. of nest failure due to stranding = 0.5; rr = renest rate = 0.6

Table 1: Least Bittern nest flooding/stranding probability (PF/PS)

Rise of water level (RW; cm)	Decrease of water level (DW; cm)	Black Tern flooding/stranding probability
If RW <= 20	and RW > DW	PF = 0
If RW > 20 and RW < 82	and RW > DW	$PF = -5E-05 * RW^2 + 0.0159 * RW$
If RW > 82	and RW > DW	PF = 1
If RW < DW	and DW <= 29	PS = 0
If RW < DW	and DW > 29 and DW < 1.09	PS = 0.7461 * Ln(DW) – 2.4948
If RW < DW	and DW > =1.09	PS = 1

Validation: For Lower St. Lawrence River section, existing data were used for external validation of the potential nesting habitat (50 recorded observations). The rate of correct predictions was 80%. No internal or external validation was performed for the carrying capacity value for Lake Ontario and Upper St. Lawrence River section and for the nest success rate.

Documentation and References:
Giguère, S, J. Morin, P. Laporte and Mingelbier, M. (2005) Évaluation des impacts des fluctuations hydrologiques sur les espèces en péril. Tronçon fluvial du Saint-Laurent (Cornwall – Pointe-du-Lac). Rapport final déposé à CMI (2002 - 2005). Environnement Canada, Région du Québec, Service canadien de la faune

DesGranges, J.-L., J. Ingram, B. Drolet, C. Savage, J. Morin, and D. Borcard. (2005) Lake Ontario- St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2005).

PI Assumptions:

- Breeding habitat supply and reproductive success are significant factors influencing the size and integrity of regional breeding populations.
- Predicted bird response to hydrologic conditions based upon literature review and experts opinion are valid.
- Wetland habitat models are providing an accurate, relative estimate of emergent marsh habitat.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted bird response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model in the LSL is correct.

Confidence, Significance and Sensitivity:

1) Confidence rating:

This PI has a good confidence rating. It has been built from a moderate amount of literature information that was available from region of interest. The models have also been evaluated with the assistance of SAR experts, and the Lower St. Lawrence carrying capacity for Least Bittern has been validated with independent field data. A "precaution" principle has also been used in order to obtain a "conservative" type PI. Thus, we are confident that the PI allows for an accurate relative comparison among alternate water level and flow regimes within the study area for: (1) Least Bittern breeding habitat availability and suitability and (2) impacts of water levels fluctuation on the nest success rate.

Although hydrologic variables are strongly associated with habitat and Least Bittern density and occurrence, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore, or hold constant other important population variables (e.g. productivity, age and sexes distribution) and environmental variables (e.g. predation, food availability, pollution, exotic species) that can also impact reproductive success (habitat carrying capacity and nest success), and have an influence on regional Least Bittern breeding populations. For these reasons, the PI values should only be considered as relative measures between plans (index).

2) Significance of the species: Least Bittern is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is listed in the Schedule 1 of the Species at Risk Act; the species and its critical habitat are legally protected under this Act. Critical habitat protection will be applied when it is identified within the Recovery Strategy or Action Plan. The North American Bird Conservation Initiative (NABCI) considers the Lower Great Lakes / St. Lawrence plain (BCR 13) as critical to the natural cycle of Least Bittern.

3) Sensitivity to water levels management: Least Bittern nest exclusively in wetland habitats. Lake Ontario and St. Lawrence River specific research results and scientific literature document the close association between Least Bittern occurrence and specific hydrological conditions. Least Bittern PI is retained as a key PI because it clearly shows an important vulnerability and sensitivity to alternations in water levels and flows, and is listed as a Species at Risk. As such, it should be used to evaluate potential environmental responses to alternative water regulation plans.

ENCLOSURE 4 Wetland bird species richness
Integrated Ecosystem Response Model: Performance indicator fact sheet on wetland bird: WBSR PI

Wetland obligate breeding bird species richness in emergent marshes

Research by: Drolet, B., J.-L. DesGranges and J. Ingram
Modeled by: Drolet, B., J. Morin, S. Martin, O. Champoux, T. Redder

Activity represented by this indicator: It represents the number of wetland obligate breeding bird species that could be expected to occur in emergent marshes during nesting period weighted by the magnitude of water level change.

Link to water levels: Wetland obligate bird species build their nest either on a floating platform over water, on the ground near the water edge or in robust vegetation slightly above water (Tab. 1). The nests of the 18 most regular wetland obligate breeding bird species are susceptible to flooding due to storm events and rapid water level rises (>20 cm) during the breeding season. Water level rises will affect different subsets of marsh species depending on the number of nesting strata that happen to be flooded during the nesting season. It thus has a direct effect on the potential number of wetland breeding bird species (i.e. species richness) that can successfully breed in a particular marsh. On the other hand, water stranding does not seem to affect species richness. This PI represents the estimated number of wetland obligate breeding bird species computed from all nodes found in emergent marshes. It does not represent cumulative species richness and should be equal for all emergent marshes in absence of significant fluctuation of water level.

Table 1: Wetland obligate breeding bird species.

	Names			Nesting strata		
IERM	Latin	English	French	Floating	Ground	Above water
	Fulica americana	American Coot	Foulque d'Amérique	x		
KEY PI	*Chlidonias niger*	Black Tern	Guifette noire	x		
ASS. PI	*Gallinula chloropus*	Common Moorhen	Gallinule poule-d'eau	x		
	Podilymbus podiceps	Pied-billed Grebe	Grèbe à bec bigarré	x		
	Porzana carolina	Sora	Marouette de Caroline	x	x	
KEY PI	*Rallus limicola*	Virginia Rail	Râle de Virginie	x	x	
	Aythya americana	Redhead	Fuligule à tête rouge	x	x	
ASS. PI	*Botaurus lentiginosus*	American Bittern	Butor d'Amérique		x	
	Anas americana	American Wigeon	Canard d'Amérique		x	
	Anas discors	Blue-winged Teal	Sarcelle à ailes bleues		x	
	Gallinago gallinago	Common Snipe	Bécassine des marais		x	
	Anas strepera	Gadwall	Canard chipeau		x	
	Anas platyrhynchos	Mallard	Canard colvert		x	
	Anas clypeata	Northern Shoveler	Canard souchet		x	
	Actitis macularia	Spotted Sandpiper	Chevalier grivelé		x	
ASS. PI	*Cistothorus palustris*	Marsh Wren	Troglodyte des marais			x
KEY PI	*Ixobrychus exilis*	Least Bittern	Petit Blongios			x
	Melospiza georgiana	Swamp Sparrow	Bruant des marais			x

Performance Indicator Metrics: The ratio between 1958DD mean richness and alternative plans.

Temporal validity: Valid for the obligate wetland bird breeding season from second week of May to the end of July (QM 18 to QM28). This PI does not consider cumulative effects from previous years.

Spatial validity: Valid for the Lake Ontario, Upper St. Lawrence River Unit 1, and the lower St. Lawrence River to Lake Saint-Pierre (except Lake Saint-François and Laprairie Basin) where emergent marsh exists.

Links with hydrology used to create the PI algorithm: This PI is influenced by hydraulic attributes that are responsible for emergent marsh surface area. More specifically, its algorithm was developed using Lower St. Lawrence hydrologic values, based on a 2D water level and topographic model. Only one hydraulic attribute showed direct linkages on wetland obligate breeding bird species richness: the maximum *water level increase* (negative effect) between two consecutive quarter months during the breeding season.

The Algorithm: The algorithm is based on the water level increase index (IN) linear relationship with wetland obligate breeding bird species richness. The water level increase index was determined using: 1) the highest increase of water level (in metres) between two quarter-month during the breeding period; and 2) the wetland transition before and after fluctuation (Tab. 2).

Wetland obligate breeding bird species richness = 8.1262 – 6.9571 * IN

Emergent marsh water depth lower and upper limits = -0.33 metre to 1.8 metres;

Table 2: Determination of water level increase index (IN)

	Increase of water level (metre)			
	0-0.2	0.21-0.50	0.51-0.70	>0.70
Wet-wet	0	0.4	0.4	0.6
Dry-wet	0.2	0.6	0.8	0.8
Dry-dry	0.6	0.8	0.8	0.8

Validation: No external or internal validation has been performed for the wetland obligate breeding bird species richness PI. The relationship between richness and water level increase index is statistically and biologically significant ($p < 0.001$), explained 33% of richness variation and was verified with scientific and expert opinion.

Documentation and References: Jean-Luc DesGranges, Joel Ingram, Bruno Drolet, Caroline Savage, Jean Morin, and, Daniel Borcard (2005) Lake Ontario - St. Lawrence river water level regulation review: Use of wetland breeding bird evaluation criteria within an integrated environmental response model. IJC final wetland bird technical report (2000-2005).

PI Assumptions:

- Breeding habitat supply and reproductive success are significant factors influencing the size and integrity of regional breeding populations.

- Sampling design and survey locations were representative of wetland habitats within the larger study area.
- Wetland habitat models are providing an accurate, relative estimate of emergent marsh habitat.
- Breeding bird density models developed from LSL data are representative of the larger study area.
- Quarter month hydrologic data is representative of real hydrologic conditions.
- Predicted bird response to hydrologic conditions based on statistical modeling is valid.
- Transformation from a 2D to 1D hydrologic model in the LSL is correct.

Confidence, Significance and Sensitivity:

1) Confidence rating: We are confident in the associations between water levels and wetland obligate breeding bird species richness PIs. The species considered are obligate nesters in wetland habitat, mainly marshes, and are thus very sensitive to hydrologic alterations that affect wetland vegetation communities. Lake Ontario and St. Lawrence River specific research results document the close association between wetland obligate breeding bird species and emergent marsh (i.e. if flooded emergent marsh habitat does not exist, the species richness will be significantly reduced in the wetland). Thus, we are confident that the PI allows for an accurate relative comparison of species richness among alternate water level and flow regimes within the study area. This is the first level of hydrologic association. The second is related to the water level fluctuation within emergent marshes. Again, our research and publishes literature support the influence of water level fluctuation on the probability of wetland obligate bird species presence for several species. Both the wetland habitat and species richness estimates are based upon hydrologic associations derived from a subset of study wetlands that are extrapolated to generate study area estimates. Although hydrologic variables are strongly associated with habitat and bird richness, there is also a significant amount of variation not explained by hydrology. In order to assess 100 year water level scenarios, the predictive models necessarily ignore or hold constant other important environmental variables (e.g. predation, food availability, pollution, habitat quality) that can also impact the number of wetland obligate breeding bird species, and have an influence on regional species richness. For these reasons, the PI values should only be considered as relative measures between plans (index).

2) Significance of PI: Species richness is often used as a proxy for biodiversity, and as such, can be seen as an indicator of ecosystem integrity. Species richness tended to be greater in marshes with stable breeding season water levels. Being easily understandable, this PI can be used to insure the public opinion is sensitive to the environmental consequences of water regulation.

3) Sensitivity of PI: Wetland obligate breeding bird species richness PI is retained as a key PI because it clearly shows an important sensitivity to alternations in water levels and flows, and as such, it should be used to evaluate potential environmental responses to alternative water regulation plans.

4.3. Wetland breeding bird hydrologic criteria sensitivity

The overall ETWG objective is to identify a regulation plan that can improve on the current plan 1958DD by causing less impact to wildlife and their habitats With respect to wetland breeding birds, Table 4.3.1 summarizes the hydrological conditions identified to be important to indicator palustrine bird species, waterfowl (Lehoux *et al.* 2005), and one species of bird at risk, the Least Bittern (Giguère *et al.* 2005) during the breeding season.

Ducks begin to nest very early, in mid-April, and as such are the first group of birds during the breeding season that have specific hydrologic criteria. The most critical period for island and floodplain nesting waterfowl on the Lower St. Lawrence River is from peak nesting through to brood rearing which runs from the second week of April to the second week of August (Lehoux *et al.* 2005). During the start of this period, any major rise in water levels within the Lower St. Lawrence River should be avoided, so as not to flood these birds' nests. The higher the water levels are, the smaller any rises should be. As a general rule, any increase in the frequency and magnitude of water level increases of more than 20 cm when the average water levels at the Sorel station are above the 4.9 m will be detrimental to nest success. During the period when the nestlings are being reared, the water level should be managed between 4.9 m and 4.5 m, so as to ensure the presence of high quality marsh for rearing the young. Once the ducklings are well grown, the water level can be further reduced gradually at the end of the summer, so that it reaches 4.1 m at Sorel by the beginning of the fall (Lehoux *et al.* 2005).

In early May, a great diversity of wetland bird species return to the Lake Ontario and St. Lawrence wetland habitats and initiate nesting activities. From that time on, several species of birds require very specific wetland habitats and hydrologic conditions. Obligate wetland nesting bird species prefer to build their nests in flooded emergents or on floating vegetation. This guild includes the three key indicator species proposed for the IERM: Virginia Rail, Least Bittern, and Black Tern. Water regulation criteria that increase the amount of flooded marsh habitats with standing water between 0.2 m and 2.0 m deep will be beneficial to these species. In additional, since most of these species usually build their nests very close to the water's surface, during the nesting period, care should also be taken to reduce, as much as possible, the frequency and magnitude of water level changes (increase or decrease) that exceeds 0.2 m to minimize nest loss due to flooding or stranding.

Within this same time window, it is important to maintain wet meadow habitats, especially in the relatively limited locations that may provide suitable breeding grounds for Yellow Rail, a species at risk (Robert and Laporte, 1996; Bookhout and Stenzel, 1987). The nests of this species are typically located directly on the ground, so flooding of this habitat later in the nesting season may flood Yellow Rail nests (Giguère *et al.*, 2005).

Table 4.3.1 Hydrological conditions needed by wetland dependant fauna.

DETAILED LOWER RIVER ENVIRONMENTAL CRITERIA FROM ETWG PERFORMANCE INDICATOR

		January				February				March				April				May				June				July				August				September				October				November				December			
	QM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1	Muskrat (hibernation)	meanH(QM41to 44) + 0.3m ≥H ≥ meanH(QM41 to 44) - 0.2m																																												meanH(QM41-44)+0.3m ≥H≥ meanH(QM41-44)-0.2m			
1	Fish (repro natural marshes)													H ≥ 0.35m over MPP; Mobile calendar (see next sheet) last 6						D ≤ 0.3m / QM																															
2	Fish (repro managed marshes)													Mobile calendar (next sheet); h>5.6m											H ≤ 5.0m																								
1	Fish (living / feeding habitat)																													H<4.60m or <9500 m^3/s Sorel																			
1	Waterfowl (migration)														H ≥ 5.4m/QM																																		
1	Waterfowl (repro)													6.45m >H> 5.60m	6.30m >H> 5.55m	6.50m >H> 5.80m	6.65m >H> 6.00m	6.60m >H> 5.80m	6.50m >H> 5.60m	6.30m >H> 5.25m	6.05m >H> 5.10m	5.75m >H> 5.00m	5.45m >H> 4.90m	5.30m >H> 4.85m	5.25m >H> 4.85m	5.25m >H> 4.75m	5.20m >H> 4.70m	5.20m >H> 4.65m	5.20m >H> 4.60m	5.15m >H> 4.2m	5.10m >H> 4.2m	5.10m >H> 4.2m	5.00m >H> 4.2m	4.90m >H> 4.2m	4.90m >H> 4.2m	4.90m >H> 4.2m	5.00m >H> 4.2m	5.05m >H> 4.2m	5.10m >H> 4.5m	5.10m >H> 4.6m	5.10m >H> 4.6m								
2	Waterfowl (repro)																R ≤ 0.4m/QM if H≥4.9m		R ≤ 0.2m/QM if H≥4.9m							R ≤ 0.3m if H≥4.9m																							
1	Wetlands birds																		0.5 m over MPP; D & R ≤ 0.2 m																														
1	Least Bittern (SAR)																				R ≤ 0.30m / QM																												
1	Spiny Softshell & Map Turtle (SAR)																						R ≤ H(QM22) + 0.5m																										
1	Bridle Shiner (SAR)																					D ≤ 0.2m / QM																											

H = water level at Sorel gauge station R = raise D = drop

Premisses

1) Spring flood is a fundamental characteristic of the St-Lawrence River hydrology, we recognize however that the spring flood is mostly linked with downstream tributaries rather than the St. Lawrence River at Cornwall
2) Discharge regulation of the system is annual: the influence of discharge control does not influence next year discharge nor it is influenced by last year discharge management
3) The modulation of the hydrology presented herein is mimicking a typical preproject's hydrogram, it is structured to "improve" developed PI scores not necessarily to reproduce the natural hydrological conditions.

Definition of criteria priority level

Level 1 = Priority criteria, it is the criteria that should be respected in priority relative to an associated Level 2 criteria
Level 2 = Fallback criteria, it is always associated with a Level 1 criteria, if the level 1 criteria can not be respected the Level 2 brings some improvement in the PI scores

Calculation of MPP elevation (Marais peu profond = shallow marshes)

Elevation of the shallow marshes (MPP) is done using the mean water level (m) at Sorel of the last 3 years growth season, from quarter-month 13 to 42. So in order to predict the elevation of MPP for the year 1976, the quarter-month 13 to 42 are averaged for the years 1975, 1974 and 1973.
The following equation; ***Y = 1.8993*X^2 - 16.46*X + 39.899***, where ***Y*** is the mean elevation (m) of the MPP (relative to Sorel) and ***X*** is the mean water level elevation (m) at Sorel for the growth season (QM 13 to 42) of the previous 3 years.

Example	mean measured level Sorel (QM 13-42)	measured MPP elevation	equation prediction of MPP
1976 (1975-1973)	5.31	6.03	6.03
1984 (1983-1980)	4.96	4.99	4.99
1964 (1963-1960)	4.32	4.24	4.24

Nesting activities of species that prefer shrub swamp habitats and treed swamp habitats for breeding appear to be less sensitive to breeding season specific hydrology. However, maintenance of plant communities within the swamp habitats is reliant on longer term inter-annual water level fluctuations.

4.4. Alternate regulation plan comparisons

The IERM will be used to compare the predicted impacts of various regulation plans, under several 100 year water supply scenarios. The IERM provides a special framework that reports the PI index score ratio (alternative/baseline regulation plans), the aggregate index scores, and a description of the aggregate method/function used to compute the scores and ratios. In addition to displaying the PI time series results, the quarter monthly hydraulic simulation results are shown in the lower pane for the relevant study location (Fig. 4.4.1).

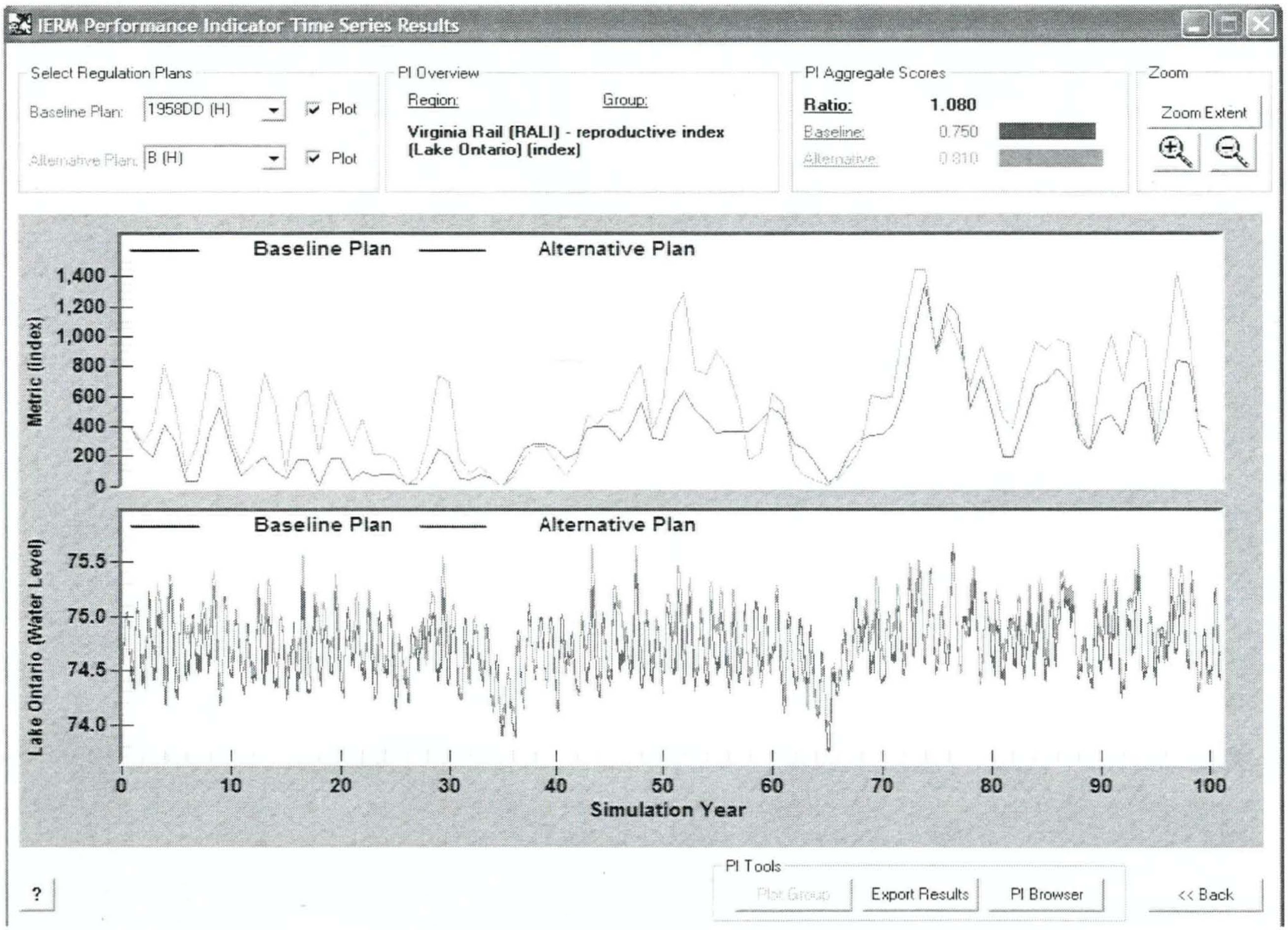

Figure 4.4.1 Virginia Rail reproductive index PI time series scores and Lake Ontario water levels for Plan 1958DD and Plan B, based upon a 100 year historic water supply scenario. (Wetland Bird PI example extracted from the IERM).

The PI and hydraulic time series graphics can be used to develop an understanding of how the PI responds to changes in water level or flow regime. It is also possible to generate a bar chart that compares the response of a selected performance indicator to all regulation plans that have been evaluated within the IERM framework (Fig. 4.4.2).

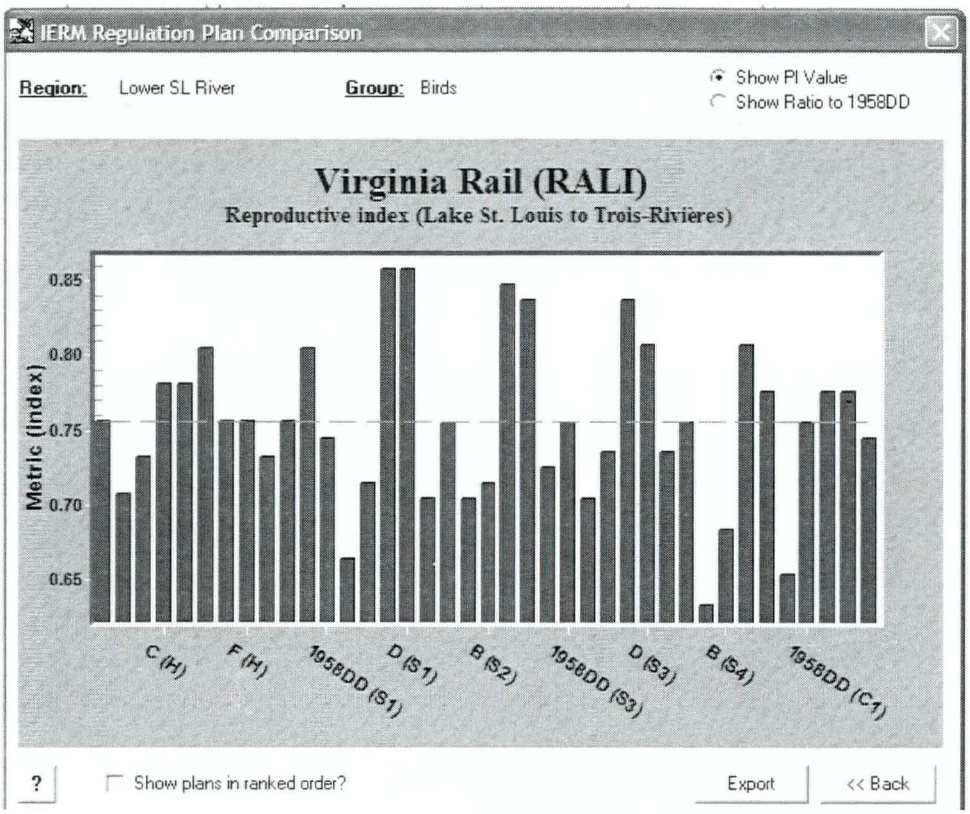

Figure 4.4.2 Bar chart used to compare the response of Virginia Rail reproductive index aggregations among alternate regulation plans and scenarios in the Lower St. Lawrence River. (Wetland Bird PI Example extracted from the IERM).

The most important ecological process in maintaining a diversity of wetland habitats and the biodiversity they support is daily, seasonal and annual variations in the water level and flow regime. Changes in this regime, due to management or climate change, can result in changes in the relative areas of different wetland habitat types (Morin *et al.* 2005; Wilcox *et al.* 2005). This can also have significant repercussions on the important regional role freshwater wetland habitats along the Lake Ontario and the St. Lawrence River provide to hundreds of bird species that frequent this area, particularly those during the breeding season. All wetlands within the system have one or more habitat gradients influenced by water levels and the duration of flooding during fluctuations in the water regime. The main predictors involved are duration of flooding that affects the total area of wetlands and water depth that influences the physiognomic composition of habitats (Morin *et al.* 2005; Wilcox *et al.* 2005). Depending on the plant species present and their spatial organization, a series of habitat associations are created, that in turn affect wildlife species presence and abundance. In the case of birds, this study has identified several types of avian assemblages in the St. Lawrence and Lake Ontario freshwater system containing several species at risk.

Best water regulation plans for obligate wetland bird reproduction: Our objective in this section is:

- to rank from the best to the worst for wetland birds, the six available (as of 31 March 2005) water regulation plans (plans A, B, C, D, E and baseline (1958DD) developed by the Plan Formulation and Evaluation Group (PFEG),
- identify the main problems in these plans in term of wetland bird reproduction or hydrological impacts, and
- recommend possible modifications in the regulation strategies to reduce potential impacts on wetland bird reproduction.

For conducting this exercise, we fixed two premises:

- Plan 1958DD, the actual plan and baseline, is the worst acceptable regulation plan, any new plan should perform better than 1958DD,
- the Pre-Project conditions (i.e. the historic records; 1900 to 2000 for Lake Ontario and 1960 to 2000 for the Lower St-Lawrence) are the best way of regulating the system for the environment as a whole.

It should be remembered that not all plans and scenarios were available at the time of this analysis. Furthermore, some of the available plans may still undergo modifications to address current stakeholder issues. Therefore, the analysis and recommendations presented here should be considered as a first "iteration" intended to inform the study board and serve direct further plan refinement. ETWG evaluations and recommendations will continue as alternate plans are developed or refined by the PFEG.

The present ranking was based on the IERM (version 4) and the following outputs: (i) target diagram; (ii) plan comparison diagram; and (iii) time series diagrams for of each of the PIs. In the summary table (Table 4.4.1) and supporting Appendix N, what appeared as possible improvements relative to Plan 1958DD (alternative/baseline regulation plans >= 1.10) were shaded in green (+), while likely impacts (alternative/baseline regulation plans <= 0.90) were shaded in red (-). We simply summed the number of detrimental (-) and favourable conditions (+) under all possible plan-scenario combinations (for Lake Ontario and Lower St. Lawrence separately) to indicate what appears to be the best and the worst overall LOSL plan-scenario for wetland bird reproduction. Afterwards, 1) we identified avian problems still remaining with the plans that score bests for birds, 2) determined the hydrological conditions that are responsible for those suspected impacts on birds arising from the best plans, and 3) suggested modifications to further improve the best plans for the birds.

Table 4.4.1 gives the number of likely positive (in green) PI comparative ratios (alternative/baseline (1958DD) regulation plans (≥ 1.10)), and likely negative (in red) (PI comparative ratios (≤ 0.90)). The best alternate plan-scenarios are found in the upper left corner of the table, while the worst combinations are found in the lower right corner of the table.

Table 4.4.1 Evaluation of wetland bird acceptability of plan scenarios combinations (available as of 31 March 2005)

Plans		Scénarios (Times series)									
		Stochastic 3		Stochastic 2		Historic		Stochastic 1		Stochastic 4	
		LSP[1] (n = 14)	LO n = 6)	LSP	LO	LSP	LO	LSP	LO	LSP	LO
Plan D "Fay B"	+[2]	5[3]	6	7	1	3	3	2	0	1	0
	-	0	0	0	3	0	0	0	6	0	5
Plan E "Pre-project"	+	2	6	4	6	1	6	1	6	2	3
	-	2	0	0	0	4	0	4	0	7	0
Plan C "Fay A"	+	7	6	7	0	5	1	2	0	1	0
	-	0	0	0	3	0	3	0	6	8	6
Plan B "Natural Y"	+	1	6	2	2	1	3	1	0	1	0
	-	2	0	1	0	5	0	5	1	8	3
Plan A "Cornell IV"	+	1	6	1	0	1	3	1	0	2	0
	-	3	0	1	3	7	1	9	6	8	6

[1] LSL: Lower St. Lawrence; LO: Lake Ontario

[2] + : PI comparative ratios (alternate plans / baseline (1958DD)) ≥1.10
- : PI comparative ratios ≤ 0.90
non significant differences are not shown

[3] Major differences (≥ 20%) between plans are presented in bold

All regulation plans could be detrimental to obligate wetland birds if they were to be used under the "Stochastic 4" or the "Stochastic 1" water supply series (Table 4.4.1). Under these hydrological conditions, wetland birds would be impacted in most cases (7 out of 10 combinations for LO compared to 7 out of 10 for LSL). Furthermore, Plan A ("Cornell IV") appears to be the worst plan relative to 1958DD for LSL wetland birds (4 out of 5 scenarios), while Plan C ("Fay A") is the poorest scoring plan for LO wetland birds (4 out of 5 scenarios). These unfavourable results indicate that the current regulation plan ("1958DD") constitutes the best option for obligate wetland birds, especially when compared to Plan A ("Cornell IV") and Plan C ("Fay A").

In other respects, Plan E (""Pre-project") performs better than 1958DD for wetland bird reproduction under all scenarios in LO and under Stochastic 2 and 3 (usually) in LSL. Plan B ("Natural Y") performs well relative to "1958DD" for LO under all but Stochastic 4, but performs poorly in the LSL for Stochastic 4 and 1, as well as for Historic water supplies. Plan D ("Fay B") performs well under all scenarios for the LSL, but poorly under two scenarios in LO (S4 & S1). It appears that obligate wetland birds do better under regulated conditions (Plan D) within the LSL. The opposite is true for LO, where Plan E and B, are resulting in improvements relative to 1958DD.

Climate change projections indicate future reductions in water supplies within the Great Lakes basin, so the poor performance of alternate plans under reduced supply scenarios (stochastic 1 and 4) is a concern. Otherwise, Plan D, E, and B represent the best potential alternatives to

1958DD provided that current criteria can be modified to address poor performance under specific scenarios within the LSL and LO respectively.

It must also be recognized that this assessment is for obligate wetland birds only, and these results need to be considered within a larger environmental context that includes all of the ETWG performance indicators. Recently, the Lower St. Lawrence ETWG (March 2005, *in litt)* recommended that plan A ("Cornell IV") be considered the best "environmental" compromise because, for most of the IERM Key PIs, this plan ranked best or second best of all the available regulation plans under the historic series (stochastic series not being available at that time). Despite the fact that Plan A ("Cornell IV") appears to be the best of the available plans with respect to all ETWG key PIs, some of the obligate wetland birds, frogs and fish PIs still exhibit fairly low scores under the historic and most stochastic supplies . These affected PIs belong for the most part to species that are reproducing late in the spring (mid-April to late-June) and that have eggs and juveniles that are very sensitive to short term water level fluctuations during that critical period. Upon evaluation of all supply scenarios, Plan D ("Fay B") results in fewer negative and positive impacts compared to Plan A ("Cornell IV") in the LSL . Finally, it should be emphasized that in the LSL at least, none of the alternate plans-scenarios combinations show substantial benefit or any major problem to waterfowl that would rule them out completely (Lehoux *et al.* 2005). On the other hand, the Yellow Rail (the only other endangered wetland bird species look at by Giguère *et al.* (2005)) would not gain or loose significantly if an alternate plan was to be selected in replacement of plan 1958DD.

A primary objective of the ETWG is, "a reduction in adverse environmental impacts in the natural environment resulting from existing and planned water management plans and from those that are expected to impact on the environment as a result of climate change." Given this philosophy, Plan E ("Pre-project"), and B ("Natural Y") should be the primary focus for continued development from a strictly environmental standpoint. Within the larger context of the study, Plans B ("Natural Y") and D ("Fay B") with additional modifications likely represent the most viable alternatives to meet all stakeholder concerns. According to the most recent version of the SVM ("Toronto Board Room", April 2005), Plan D ("Fay B" ; for the historic time series and Stochastic 2 (the wettest century, on average, of all the stochastic supply sequences)), and plan B ("Natural Y") (for S2), would produce net average annual benefits for all economic performance indicators.

***Recommendations*:** The integrity of freshwater ecosystems depends upon adequate quantity, quality, timing, and temporal variability of water flow (Baron et al. 2002). Sustainability normally requires these systems to fluctuate within a natural range of variation. Although studies conducted by the Environment Technical Working Group (ETWG) have identified various biotic performance indicators to evaluate alternate water regulation plans, the limited understanding of the complex ecological processes that affect those indicators suggest the need to undertake a management regime that minimizes the alteration of natural hydrologic dynamics of the LOSL system. An approach that has been recommended in many other water regulation studies (Nilsson and Dynesius 1994; Ward and Tockner 2001; Baron et al. 2002; and Kozlowski 2002). In situations where conflict occurs between naturally fluctuating water levels, and LOSL stakeholder interests, regulation criteria to minimize these impacts can be evaluated using performance indicators as presented here.

The construction of hydro dams and other water regulation structures such as those on the LOSL system are typically for the specific purpose of altering the natural water level cycle. Under circumstances where water regulation criteria cannot be altered to remove known environmental impacts, mitigation measures should be introduced that support the protection of habitat diversity and integrity from additional and cumulative human related impacts (e.g. shoreline development and watershed degradation). Where necessary site-specific restoration efforts using well-grounded ecological principles can also be applied to maintain specific environmental values (e.g. species at risk habitats). In the case of LOSL wetland bird habitats, several suggestions based upon the most current science can be found in the North American Waterbird Conservation Plan (Kushlan et al. 2002) and in the Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (Environment Canada 2004).

Consequently, the recommendation of criteria should include "mitigation" actions for the LOSL study according to the following categories:

1) Mitigation (lessen the harm) should be considered if any existing purpose (hydropower, navigation, M&I water supply) is determined to be "disproportionately harmed" (made significantly worse than Plan 58DD) by the resulting plan in terms of the net economic, social or environmental consequences. (Fundamentally, the mitigation action is to formulate a more suitable plan).

2) Specific mitigative (alleviate the damage) actions should be considered for any plan which is deemed to be acceptable in its overall achievement of Study goals and objectives, but performs unacceptably for any critical individual indicator (e.g. endangered or threatened species, minimum navigation depths at Montreal).

3) Opportunities for amelioration (improving the condition) should be considered for any particular critical indicator (e.g. improve wetland functions by manipulating wetland water levels independent of lake levels; or structural adjustments for improving navigation safety during high flow periods).

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APPENDICES

Appendix A Field sampling effort 2000-2004.

A.1 According to hydrozones.

Hydrozone	# site		Total time effort (min)	Total surface area effort (ha)	Species Richness	Estimated number of individuals
Lake Ontario	107	Total	3466	240	64	1430
		Mean	44	2.2	7	13
		SD	30	1	4	10
Upper St. Lawrence River	31	Total	1267	79	68	814
		Mean	41	2.5	13	26
		SD	23	1.6	7	16
Lake Saint Francis	86	Total	3640	179	74	1769
		Mean	42	2.1	11	21
		SD	27	1.3	4	11
Lake Saint-Louis	78	Total	3466	190	83	1812
		Mean	44	2.4	11	23
		SD	30	1.7	6	18
Fluvial corridor	33	Total	2046	116	55	806
		Mean	60	3.4	10	24
		SD	30	1.6	3	13
Lake Saint-Pierre	134	Total	3808	349	77	3461
		Mean	50	2.6	11	26
		SD	31	1.8	4	17
Total	469		17693	1153	421	10092

A.2 According to hydrosere habitats.

Major Habitat Types	# site		Total time effort (min)	Total surface area effort (ha)	Species Richness	Estimated number of individuals
Marsh	53	Total	4661	251	31	1765
		Mean	88	4.7	10	33
		SD	23	1.3	3	14
Wet Meadows	31	Total	2487	148	27	704
		Mean	80	4.8	8	23
		SD	16	0.8	3	9
Shrub Swamp	17	Total	1528	71	37	794
		Mean	90	4.2	15	47
		SD	37	1.1	4	17
Treed Swamp	25	Total	2307	117	41	1131
		Mean	92	4.7	16	45
		SD	18	1.4	4	21
Total	126		10983	587	136	4394

Appendix B Methods for study sites description (size, position, remote sensing habitat class, actual habitat, dominant vegetation).

B1.1 Steps leading to the development of a wetland bird habitat typology.

The following schema (Figure B1.1) presents the steps that were completed to obtain a wetland bird habitat typology. The first year of sampling allowed us to capture a large amount of data on the floristic, habitat heterogeneity, disturbances and other environmental variables across a wide range of wetland types within the LOSL study region. Furthermore, spatial analyses of classified vegetation maps allowed for identification of different classes of landscape context that could influence wetland bird habitats. The second step was to compute complete linkage clustering analyses (see appendix G) on the different groups of data to identify habitat structures. The information was still complex, so the habitat groups were analysed in relation to the bird data using a multivariate analysis (canonical correspondence). The more significant classes helped to define the preliminary typologies that directed the bird survey sampling design in 2003. The sampling design in 2002 consisted in circular plots with 75 meter radius and in 2003, 3 to 5 hectares validation polygons were used (B1.2). These preliminary typologies of floristic, structure, disturbances and landscape context greatly simplified the data collection during the field work. The last step was to cross link the preliminary typologies of floristic and structure to the hydrological variables. The preliminary typologies of disturbances and landscape context were found in all of the habitat types. As such, they did not help define the final typology, but were used in subsequent analyses. The outcome of this exercise was a final wetland bird habitat typology with 10 classes of wetland defined by their floristic, structural and hydrological traits that birds are associated with.

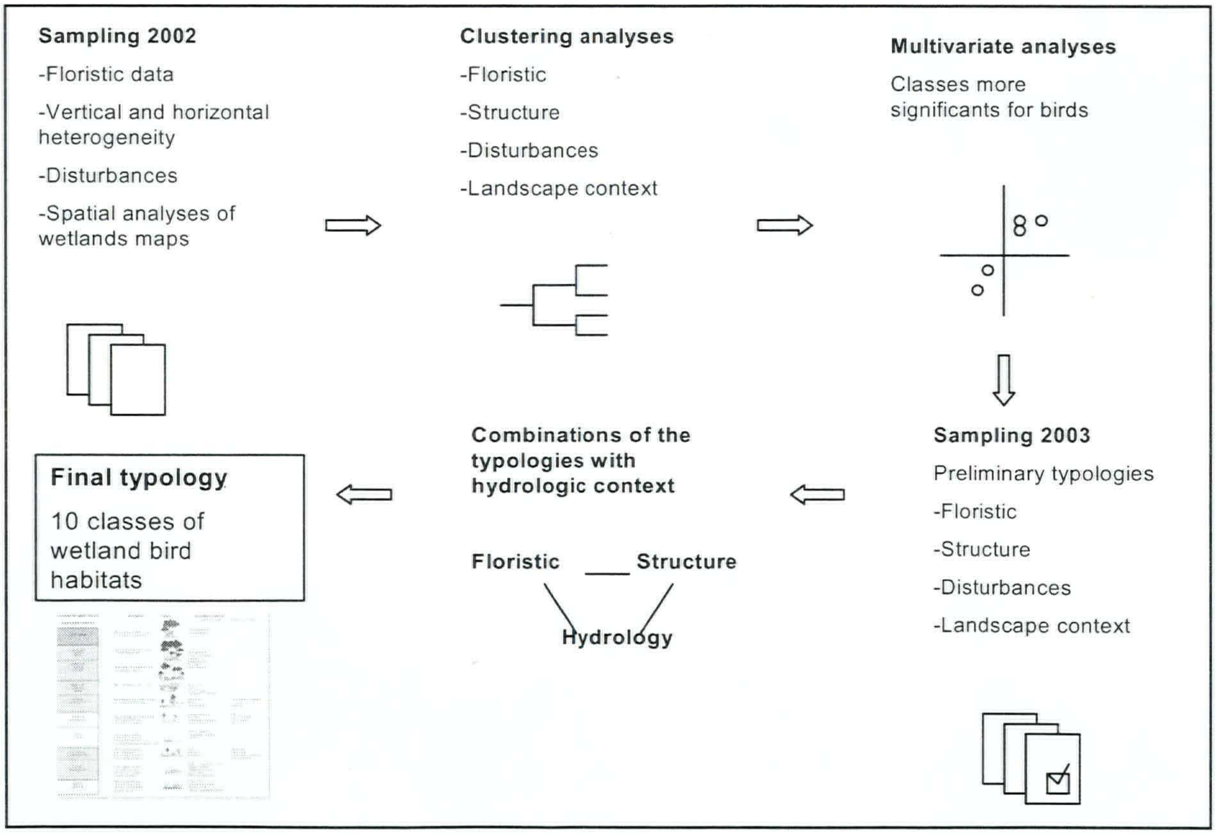


Figure B1.1 Schema of analyses steps for the development of the wetland bird habitat typology.

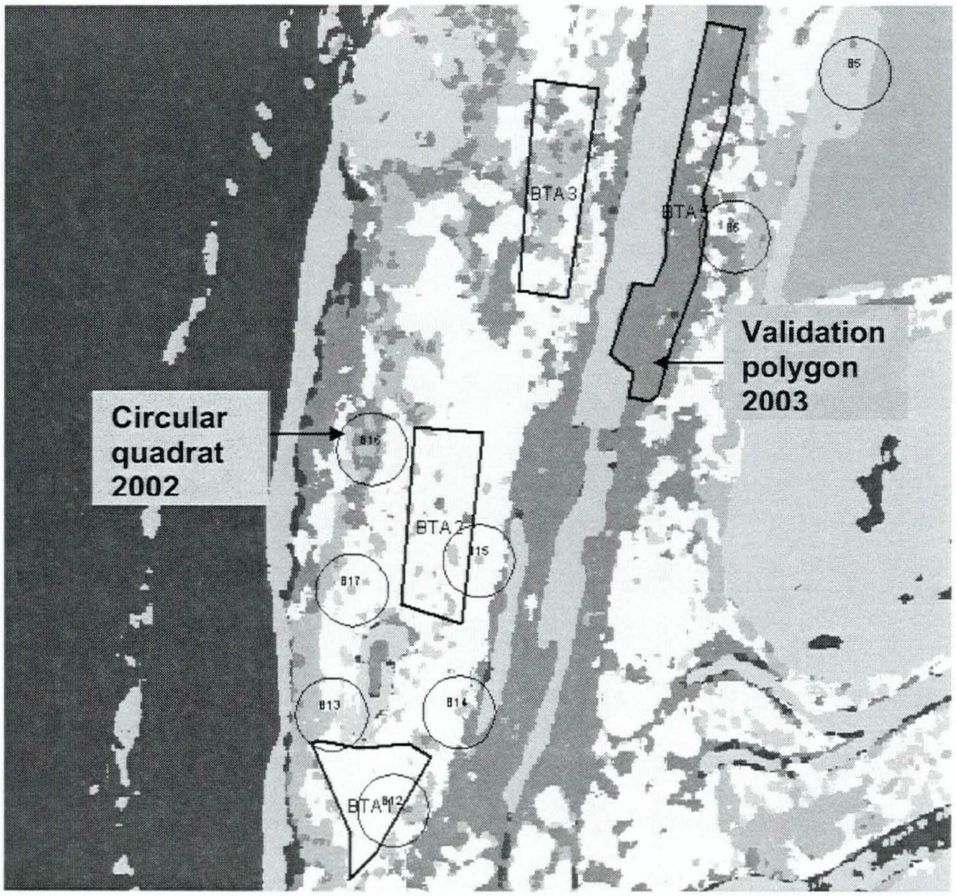


Figure B1.2 Representation of the circular quadrats of 75 m radius in 2002 and the validation polygons in 2003 at Boucherville Islands.

Analyses of data on vegetation composition and structure as well as hydrological variables were used to define a typology of wetland bird habitats, including ecocomplexes which are heterogeneous habitats consisting of semi-open wetlands with varying proportions of herbaceous species (grasses and emergent plants), shrubs and trees. The ecocomplexes (B1.3) are often found where dikes are present (example of National Wildlife Area of Lake St. Francois), where the surface is heterogeneous with microtopographic features such as ridges and mounds and water levels are more variable.

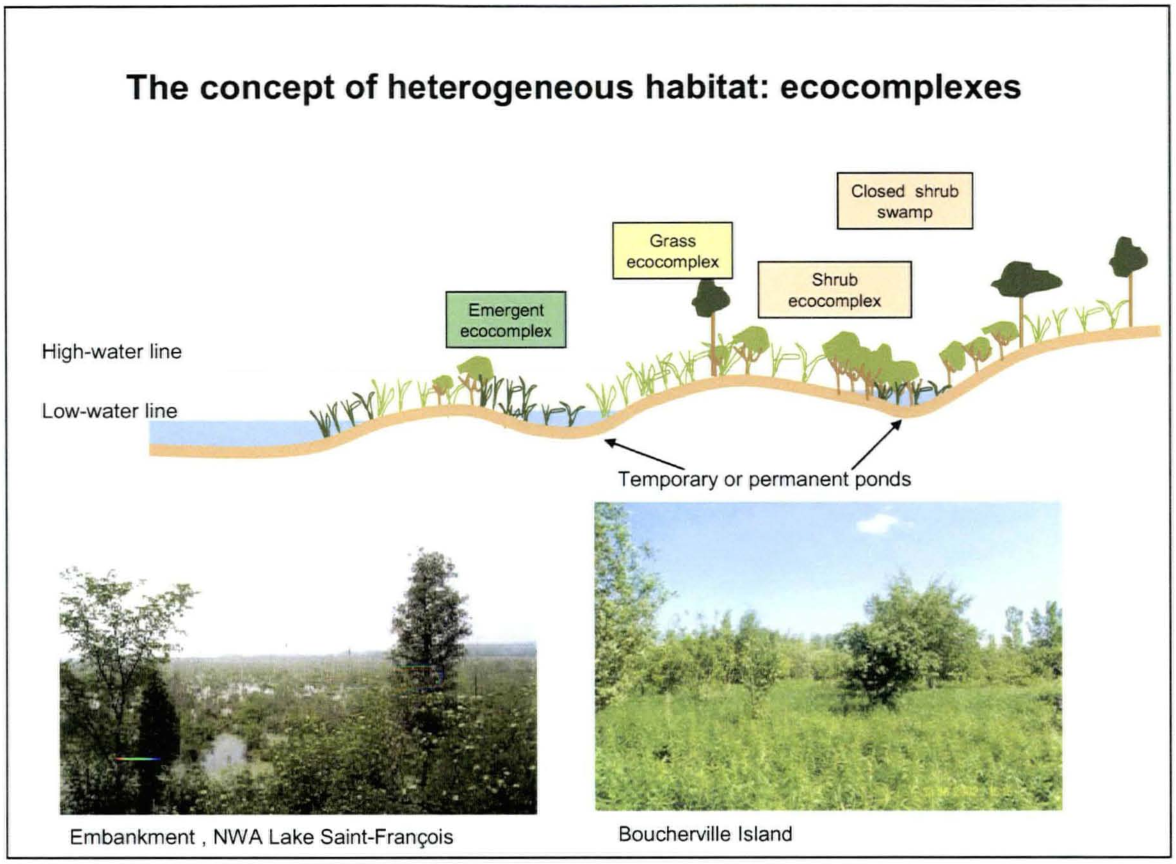


Figure B1.3. The concept of heterogeneous habitat:: ecocomplexes.

To improve the understanding of the data, two types of profiles were sketched in the field (Figures B1.4a & B1.4b). They were used extensively to validate data during the data entry stage and served as a useful visual point of reference for the plot itself. In addition, the vertical diagrams were used to validate the vegetation cover data used for the training sites when reclassifying IKONOS 2002 remote sensing images covering all the wetlands along the St. Lawrence.

We usually found many permanent or temporary ponds in these habitats. In some places (example of Boucherville Islands), ecocomplexes could be the result of vegetation succession where the area was previously used for agriculture purposes.

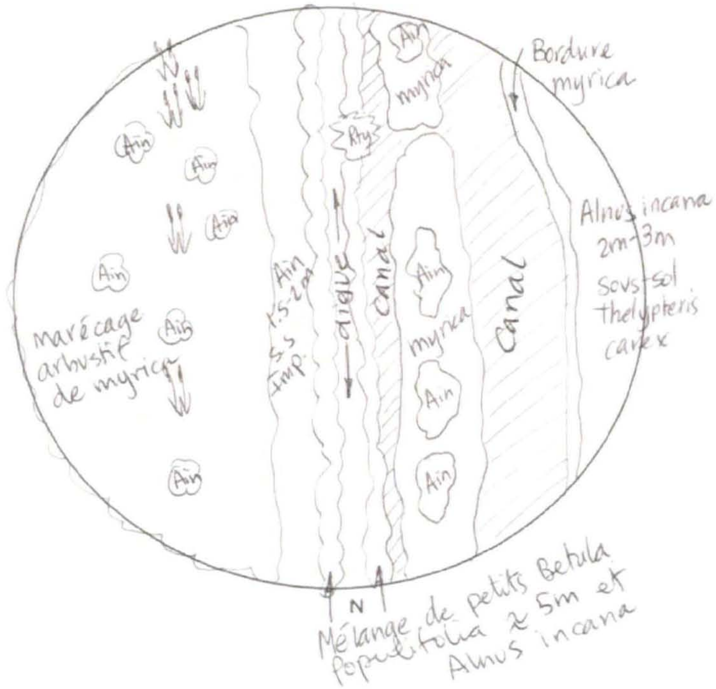


Figure B1.4a : Vertical profile.

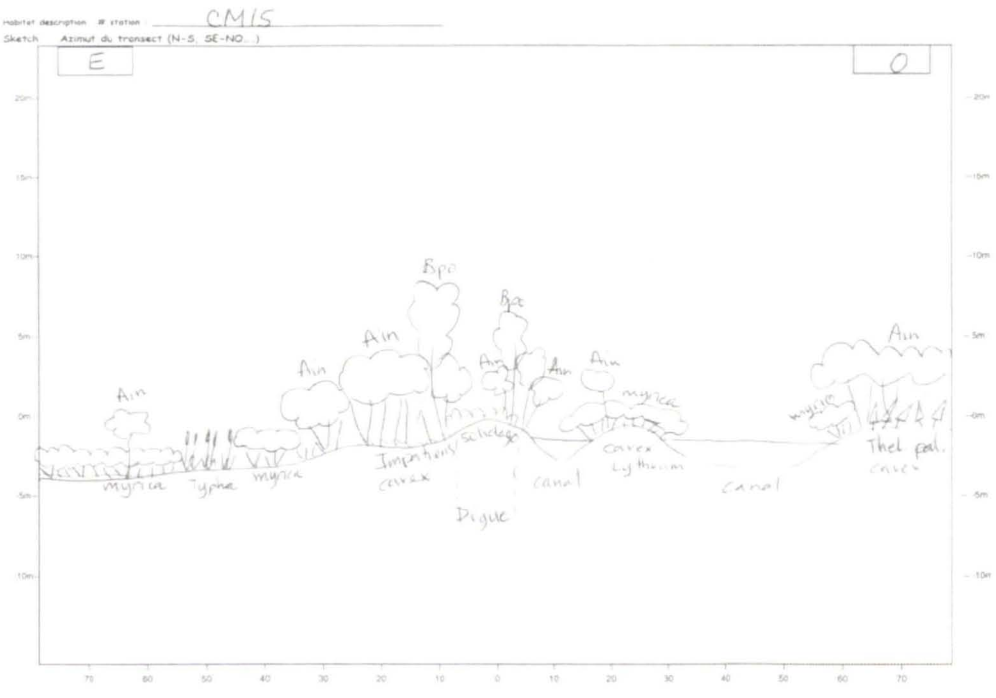


Figure B1.4b : Horizontal profile.

In comparing « clips » and the field generated profiles, it has been determined that 31 % of the 2003 sites needed moderate (10 to 50 % of the polygon) to high corrections (> 50 %). The 2000 to 2002 data (parcels of 50 m or 75 m radius) and 2003 (variable forms and dimensions) were verified and corrected when the differences exceeded 25 % of the site. Figure B1.5 provides an example of validation polygons clipped on IKONOS 2002 wetland maps for the Contrecoeur region. It can be observed that two polygons on the left part of the figure have been modified in correlation with what was found on the field (on the right). The mistakes were attributed to an overestimation of the shrub and tree cover due to the presence of dead vegetation mats (dead bulrush) when the remote sensing images were taken, which caused a spectral signature similar to that of woody material (trees and shrubs). The classfied MEIS 2000 and IKONOS 2002 maps have been corrected using specific field work for map validation. The present project data (profiles and vegetation data from 2002 and 2003) have been used as well for validation of these maps.

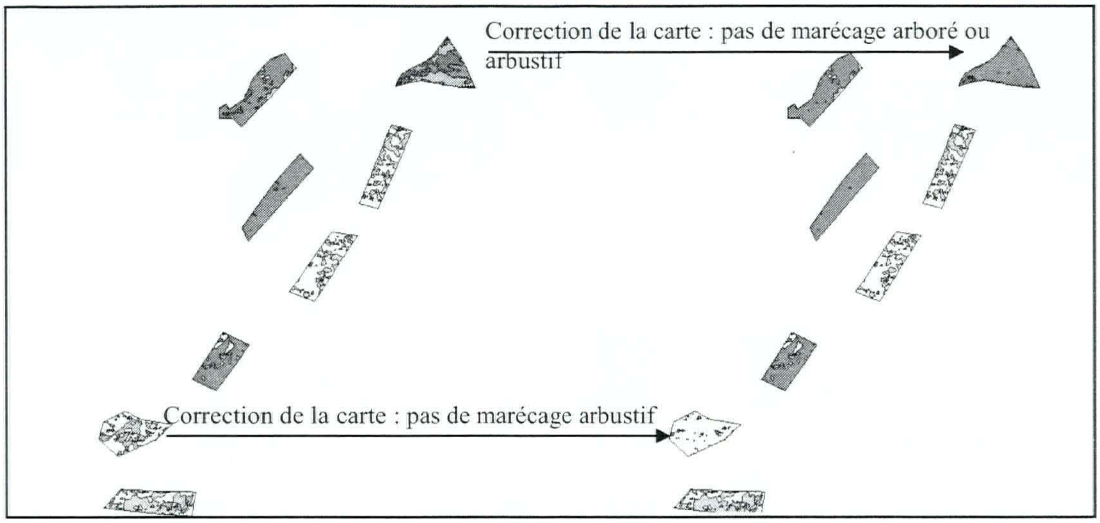


Figure B1.5 Corrections of the maps IKONOS 2002.

B2.1 Landscape structure of wetland habitats

We characterized the landscape structure of the sampling sites. The spatial analysis of sites was done using Arcview software and the Patch Analyst extension, a modified version of Fragstats. The procedure used is illustrated in Figures B2.1a to B2.1d.

First, for a given region (Kanawake, Lake St. Louis, for example), the wetland map provided by the St. Lawrence Centre (corresponding to MEIS 2000 remote sensing imagery) was reclassified based on the main type of wetland found (open water, aquatic vegetation, marsh, wet meadow, shrub swamp, treed swamp) as well as on the terrestrial and anthropogenic environments near the sites sampled (agriculture, wildlands, forest, built-up area).

For the Lake Ontario sites, interpretations of the aerial photographs were incorporated in the software, reclassified, and analysed using the same method. The map was transformed into vector format to create a polygon map. Lastly, a file containing the centroids of the sites was created.

Second, buffer zones were defined around the centroids: one with a radius of 75 m for the sample plot (shown in green) and another with a radius of 350 m (shown in yellow), corresponding to the surrounding landscape's area of influence.

Next, the 75-m and 350-m landscape limits were used to "clip" the corresponding areas on the underlying map of wetlands. This produced plots with a radius of 75 m and 350 m containing a mosaic of varied habitat fragments. Some of the plots are homogeneous since they were established in uniform wetland habitat, while others are very heterogeneous, given the habitat diversity found on these sites.

The bird survey plots then underwent spatial analyses (using the Patch Analyst extension). Ten independent variables describing the extent of horizontal heterogeneity were measured (class area [CA], total landscape area [TLA], edge density [ED], mean patch size [MPS], number of patches [NUMP], mean shape index [MSI], mean perimeter-area ratio [MPAR], mean patch fractal dimension [MPFD], Shannon's diversity index [SDI] and Shannon's evenness index [SEI]). The choice of variables describing the landscape was based on a review of the literature on landscape variables known to influence breeding birds.

These variables were calculated for the different classes (water, marsh, wet meadow, etc.) individually as well as taken as a whole (all classes in a given site [landscape]). By definition, diversity and evenness can only be calculated at the landscape level. Therefore, for each site, two results were obtained for each variable: one for the 75-m-radius plot and another for the 350-m-radius plot.

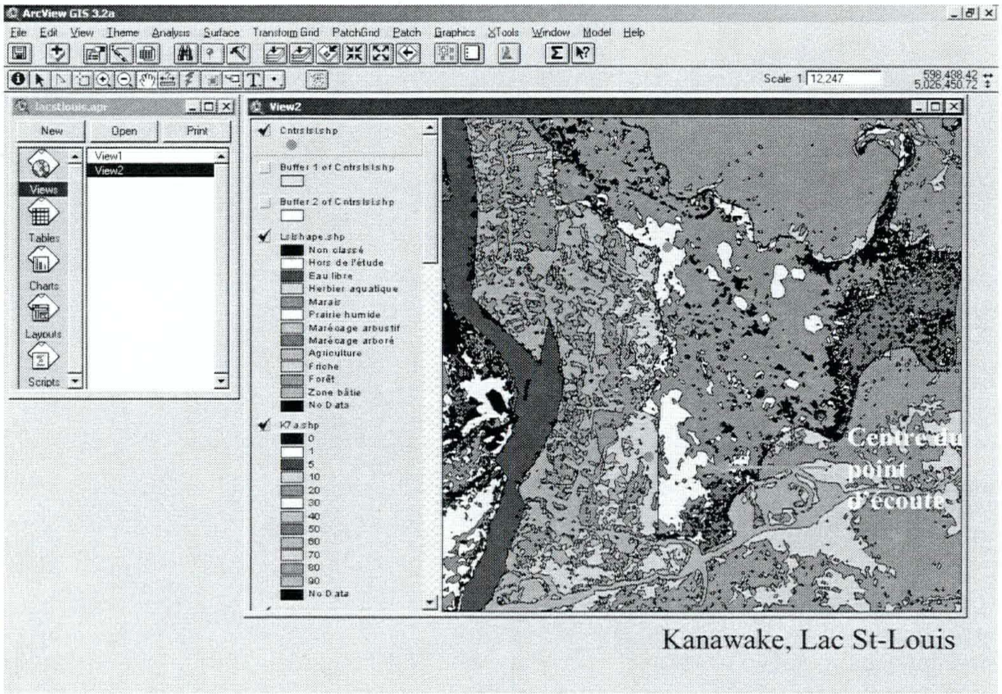


Figure B2.1a: Step 1: Location of centroids of survey plots.

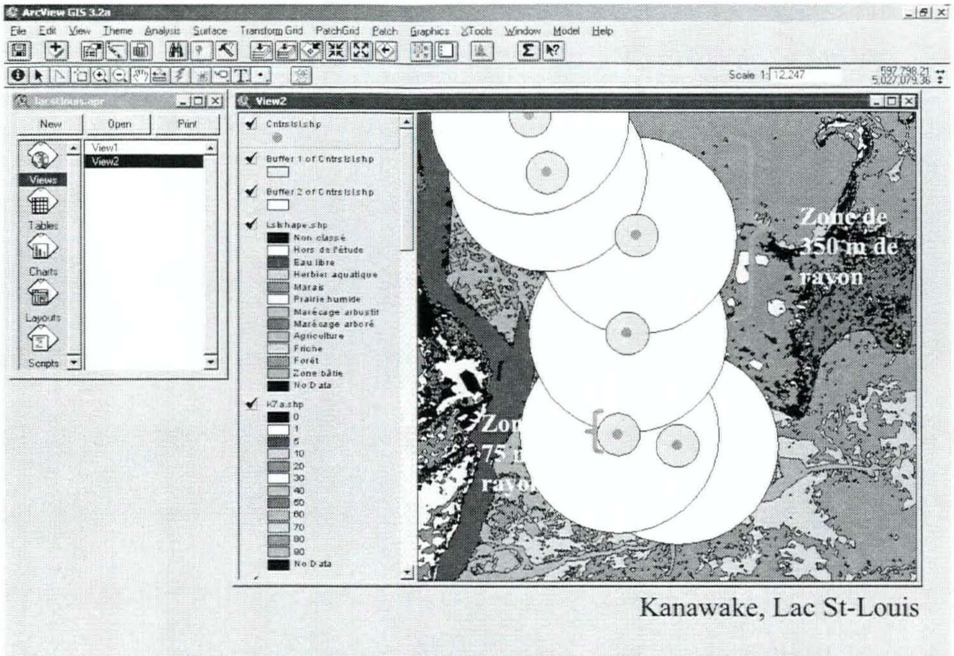


Figure B2.2b: Step 2: Creation of landscape limits with a 75-m and 350-m radius.

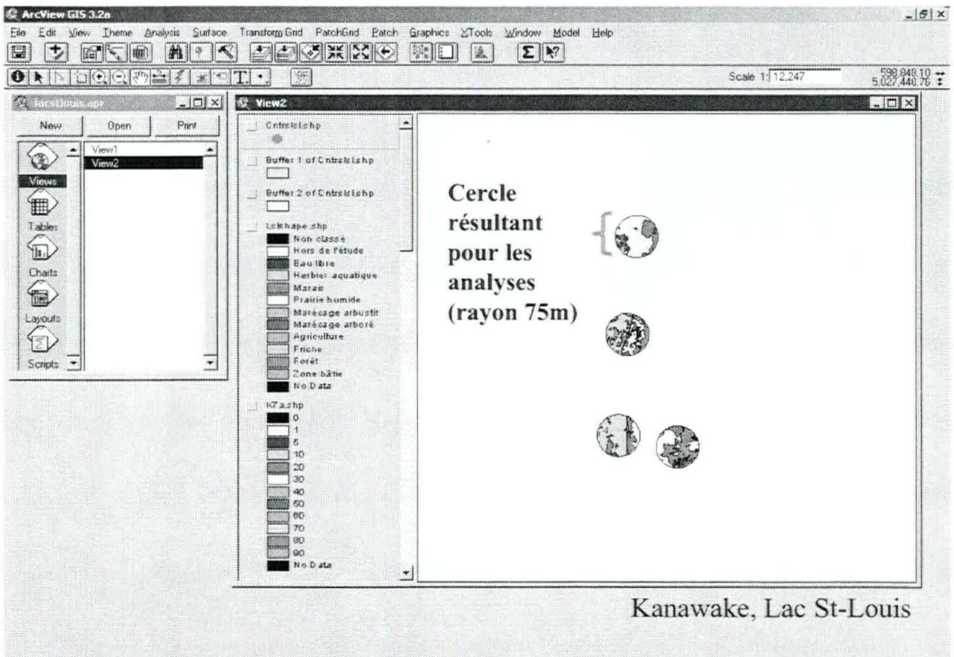


Figure B2.3c : Step 3: Resulting 75-m-radius plots for spatial analyses.

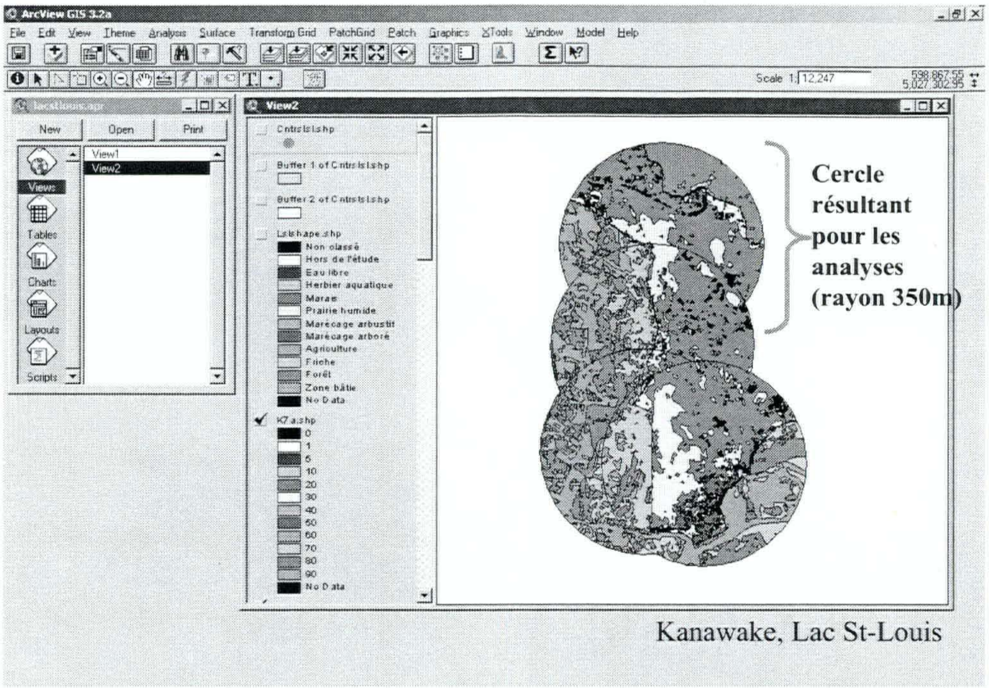


Figure B2.4d : Step 3: Resulting 350-m-radius plots for spatial analyses.

Appendix C Scientific, English and French name of bird species surveyed and justification for excluding some species from analyses.

Latin Names	English Name	French Name	Inventory code	IERM code	Analysis statut	Reason of exclusion
Podilymbus podiceps	Pied-billed Grebe	Grèbe à bec bigarré	PBGR	POPO	INCLUDED	
Botaurus lentiginosus	American Bittern	Butor d'Amérique	AMBI	BOLE	INCLUDED	
Ixobrychus exilis	Least Bittern	Petit Blongios	LEBI	IXEX	INCLUDED	
Butorides virescens	Green Heron	Héron vert	GNBH		INCLUDED	
Aix sponsa	Wood Duck	Canard branchu	WODU		INCLUDED	
Anas platyrhynchos	Mallard	Canard colvert	MALL		INCLUDED	
Anas discors	Blue-winged Teal	Sarcelle à ailes bleues	BWTE		INCLUDED	
Anas clypeata	Northern Shoveler	Canard souchet	NSHO		INCLUDED	
Anas strepera	Gadwall	Canard chipeau	GADW		INCLUDED	
Anas americana	American Wigeon	Canard d'Amérique	AMWI		INCLUDED	
Aythya americana	Redhead	Fuligule à tête rouge	REDH		INCLUDED	
Aythya collaris	Ring-necked Duck	Fuligule à collier	RNDU		INCLUDED	
Bonasa umbellus	Ruffed Grouse	Gélinotte huppée	RUGR		INCLUDED	
Rallus limicola	Virginia Rail	Râle de Virginie	VIRA	RALI	INCLUDED	
Porzana carolina	Sora	Marouette de Caroline	SORA	SORA	INCLUDED	
Gallinula chloropus	Common Moorhen	Gallinule poule-d'eau	COMO	GAGH	INCLUDED	
Fulica americana	American Coot	Foulque d'Amérique	AMCO		INCLUDED	
Charadrius vociferus	Killdeer	Pluvier kildir	KILL		INCLUDED	
Actitis macularia	Spotted Sandpiper	Chevalier grivelé	SPSA		INCLUDED	
Bartramia longicauda	Upland Sandpiper	Maubèche des champs	UPSA		INCLUDED	
Gallinago gallinago	Common Snipe	Bécassine des marais	COSN		INCLUDED	
Scolopax minor	American Woodcock	Bécasse d'Amérique	AMWO		INCLUDED	
Phalaropus tricolor	Wilson's Phalarope	Phalarope de Wilson	WIPH		INCLUDED	
Chlidonias niger	Black Tern	Guifette noire	BLTE	CHNI	INCLUDED	
Zenaida macroura	Mourning Dove	Tourterelle triste	MODO		INCLUDED	
Coccyzus erythropthalmus	Black-billed Cuckoo	Coulicou à bec noir	BBCU		INCLUDED	
Asio flammeus	Short-eared Owl	Hibou des marais	SEOW		INCLUDED	
Archilochus colubris	Ruby-throated Hummingbird	Colibri à gorge rubis	RTHU		INCLUDED	
Melanerpes carolinus	Red-bellied Woodpecker	Pic à ventre roux	RBWO		INCLUDED	
Sphyrapicus varius	Yellow-bellied Sapsucker	Pic maculé	YBSA		INCLUDED	
Picoides pubescens	Downy Woodpecker	Pic mineur	DOWO		INCLUDED	
Picoides villosus	Hairy Woodpecker	Pic chevelu	HAWO		INCLUDED	
Colaptes auratus	Northern Flicker	Pic flamboyant	NOFL		INCLUDED	
Dryocopus pileatus	Pileated Woodpecker	Grand Pic	PIWO		INCLUDED	
Contopus virens	Eastern Wood-Pewee	Pioui de l'Est	EWPE		INCLUDED	
Empidonax alnorum	Alder Flycatcher	Moucherolle des aulnes	ALFL		INCLUDED	
Empidonax traillii	Willow Flycatcher	Moucherolle des saules	WIFL		INCLUDED	
Empidonax minimus	Least Flycatcher	Moucherolle tchébec	LEFL		INCLUDED	
Sayornis phoebe	Eastern Phoebe	Moucherolle phébi	EAPH		INCLUDED	
Myiarchus crinitus	Great Crested Flycatcher	Tyran huppé	GCFL		INCLUDED	
Tyrannus tyrannus	Eastern Kingbird	Tyran tritri	EAKI		INCLUDED	
Tachycineta bicolor	Tree Swallow	Hirondelle bicolore	TRES		INCLUDED	
Hirundo pyrrhonota	Cliff Swallow	Hirondelle à front blanc	CLSW		INCLUDED	
Parus atricapillus	Black-capped Chickadee	Mésange à tête noire	BCCH		INCLUDED	
Sitta canadensis	Red-breasted Nuthatch	Sittelle à poitrine rousse	RBNU		INCLUDED	
Sitta carolinensis	White-breasted Nuthatch	Sittelle à poitrine blanche	WBNU		INCLUDED	
Certhia americana	Brown Creeper	Grimpereau brun	BRCR		INCLUDED	
Thryothorus ludovicianus	Carolina Wren	Troglodyte de Caroline	CARW		INCLUDED	
Troglodytes aedon	House Wren	Troglodyte familier	HOWR		INCLUDED	
Troglodytes troglodytes	Winter Wren	Troglodyte mignon	WIWR		INCLUDED	
Cistothorus platensis	Sedge Wren	Troglodyte à bec court	SEWR		INCLUDED	
Cistothorus palustris	Marsh Wren	Troglodyte des marais	MAWR	CIPA	INCLUDED	
Sialia sialis	Eastern Bluebird	Merlebleu de l'Est	EABL		INCLUDED	
Catharus fuscescens	Veery	Grive fauve	VEER	CAFU	INCLUDED	
Catharus ustulatus	Swainson's Thrush	Grive à dos olive	SWTH		INCLUDED	
Catharus guttatus	Hermit Thrush	Grive solitaire	HETH		INCLUDED	
Hylocichla mustelina	Wood Thrush	Grive des bois	WOTH		INCLUDED	
Turdus migratorius	American Robin	Merle d'Amérique	AMRO		INCLUDED	
Dumetella carolinensis	Gray Catbird	Moqueur chat	GRCA		INCLUDED	
Toxostoma rufum	Brown Thrasher	Moqueur roux	BRTH		INCLUDED	
Sturnus vulgaris	European Starling	Étourneau sansonnet	EUST		INCLUDED	
Vireo solitarius	Solitary Vireo	Viréo à tête bleue	SOVI		INCLUDED	
Vireo flavifrons	Yellow-throated Vireo	Viréo à gorge jaune	YTVI		INCLUDED	
Vireo gilvus	Warbling Vireo	Viréo mélodieux	WAVI		INCLUDED	
Vireo philadelphicus	Philadelphia Vireo	Viréo de Philadelphie	PHVI		INCLUDED	
Vireo olivaceus	Red-eyed Vireo	Viréo aux yeux rouges	REVI		INCLUDED	
Vermivora ruficapilla	Nashville Warbler	Paruline à joues grises	NAWA		INCLUDED	
Parula americana	Northern Parula	Paruline à collier	NOPA		INCLUDED	

Appendix C (following)

Latin Names	English Name	French Name	Inventory code	IERM code	Analysis statut	Reason of exclusion
Dendroica petechia	Yellow Warbler	Paruline jaune	YWAR		INCLUDED	
Dendroica pensylvanica	Chestnut-sided Warbler	Paruline à flancs marron	CSWA		INCLUDED	
Dendroica magnolia	Magnolia Warbler	Paruline à tête cendrée	MAGW		INCLUDED	
Dendroica caerulescens	Black-throated Blue Warbler	Paruline bleue	BTBW		INCLUDED	
Dendroica virens	Black-throated Green Warbler	Paruline à gorge noire	BTNW		INCLUDED	
Dendroica fusca	Blackburnian Warbler	Paruline à gorge orangée	BLBW		INCLUDED	
Dendroica pinus	Pine Warbler	Paruline des pins	PIWA		INCLUDED	
Mniotilta varia	Black-and-white Warbler	Paruline noir et blanc	BAWW		INCLUDED	
Setophaga ruticilla	American Redstart	Paruline flamboyante	AMRE		INCLUDED	
Seiurus aurocapillus	Ovenbird	Paruline couronnée	OVEN		INCLUDED	
Oporornis philadelphia	Mourning Warbler	Paruline triste	MOWA		INCLUDED	
Geothlypis trichas	Common Yellowthroat	Paruline masquée	COYE		INCLUDED	
Wilsonia canadensis	Canada Warbler	Paruline du Canada	CAWA		INCLUDED	
Piranga olivacea	Scarlet Tanager	Tangara écarlate	SCTA		INCLUDED	
Cardinalis cardinalis	Northern Cardinal	Cardinal rouge	NOCA		INCLUDED	
Pheucticus ludovicianus	Rose-breasted Grosbeak	Cardinal à poitrine rose	RBGR		INCLUDED	
Passerina cyanea	Indigo Bunting	Passerin indigo	INBU		INCLUDED	
Spizella passerina	Chipping Sparrow	Bruant familier	CHSP		INCLUDED	
Spizella pusilla	Field Sparrow	Bruant des champs	FISP		INCLUDED	
Passerculus sandwichensis	Savannah Sparrow	Bruant des prés	SAVS		INCLUDED	
Ammodramus leconteii	Le Conte's Sparrow	Bruant de Le Conte	LESP		INCLUDED	
Ammodramus nelsoni	Nelson's Sharp-tailed Sparrow	Bruant de Nelson	STSP		INCLUDED	
Melospiza melodia	Song Sparrow	Bruant chanteur	SOSP	MEME	INCLUDED	
Melospiza georgiana	Swamp Sparrow	Bruant des marais	SWSP	MEGE	INCLUDED	
Zonotrichia albicollis	White-throated Sparrow	Bruant à gorge blanche	WTSP		INCLUDED	
Dolichonyx oryzivorus	Bobolink	Goglu des prés	BOBO		INCLUDED	
Agelaius phoeniceus	Red-winged Blackbird	Carouge à épaulettes	RWBL		INCLUDED	
Sturnella magna	Eastern Meadowlark	Sturnelle des prés	EAME		INCLUDED	
Quiscalus quiscula	Common Grackle	Quiscale bronzé	COGR		INCLUDED	
Icterus galbula	Baltimore Oriole	Oriole de Baltimore	BAOR		INCLUDED	
Carpodacus purpureus	Purple Finch	Roselin pourpré	PUFI		INCLUDED	
Passer domesticus	House Sparrow	Moineau domestique	HOSP		INCLUDED	
Gavia immer	Common Loon	Plongeon huard	COLO		EXCLUDED	1, 2
Ardea herodias	Grand Heron	Grand Héron	GTBH		EXCLUDED	1, 2, 3
Branta canadensis	Canada Goose	Bernache du Canada	CAGO		EXCLUDED	2, 3
Anas rubripes	American Black Duck	Canard noir	ABDU		EXCLUDED	2, 3
Anas acuta	Northern Pintail	Canard pilet	NOPI		EXCLUDED	2, 3
Pandion haliaetus	Osprey	Balbuzard pêcheur	OSPR		EXCLUDED	1, 2
Accipiter striatus	Sharp-shinned Hawk	Épervier brun	SSHA		EXCLUDED	1, 2
Buteo jamaicensis	Red-tailed Hawk	Buse à queue rousse	RTHA		EXCLUDED	1, 2
Falco sparverius	American Kestrel	Crécerelle d'Amérique	AMKE		EXCLUDED	1, 2
Larus delawarensis	Ring-billed Gull	Goéland à bec cerclé	RBGU		EXCLUDED	2, 3
Larus marinus	Great Black-backed Gull	Goéland marin	GBBG		EXCLUDED	2, 3
Bubo virginianus	Great Horned Owl	Grand-duc d'Amérique	GHOW		EXCLUDED	1, 2
Chordeiles minor	Common Nighthawk	Engoulevent d'Amérique	CONI		EXCLUDED	3
Chaetura pelagica	Chimney Swift	Martinet ramoneur	CHSW		EXCLUDED	3
Ceryle alcyon	Belted Kingfisher	Martin-pêcheur d'Amérique	BEKI		EXCLUDED	1, 2
Progne subis	Purple Martin	Hirondelle noire	PUMA		EXCLUDED	3
Riparia riparia	Bank Swallow	Hirondelle de rivage	BNKS		EXCLUDED	3
Hirundo rustica	Barn Swallow	Hirondelle rustique	BARS		EXCLUDED	3
Cyanocitta cristata	Blue Jay	Geai bleu	BLJA		EXCLUDED	3
Corvus brachyrhynchos	American Crow	Corneille d'Amérique	AMCR		EXCLUDED	3
Bombycilla cedrorum	Cedar Waxwing	Jaseur d'Amérique	CWAX		EXCLUDED	3
Dendroica palmarum	Palm Warbler	Paruline à couronne rousse	PAWA		EXCLUDED	4
Dendroica striata	Blackpoll Warbler	Paruline rayée	BPLW		EXCLUDED	4
Seiurus noveboracensis	Northern Waterthrush	Paruline des ruisseaux	NOWA		EXCLUDED	4
Wilsonia pusilla	Wilson's Warbler	Paruline à calotte noire	WIWA		EXCLUDED	4
Euphagus carolinus	Rusty Blackbird	Quiscale rouilleux	RUBL		EXCLUDED	4
Molothrus ater	Brown-headed Cowbird	Vacher à tête brune	BHCO		EXCLUDED	3
Carduelis pinus	Pine Siskin	Tarin des pins	PISI		EXCLUDED	3
Carduelis tristis	American Goldfinch	Chardonneret jaune	AMGO		EXCLUDED	3

1 Too large home range or breeding territory
2 Not a song bird
3 Not territorial or vagrant
4 Migrant or not its habitat

Appendix D Correction factor for target species used to calibrate bird density data from different census surface area for statistical analyses.

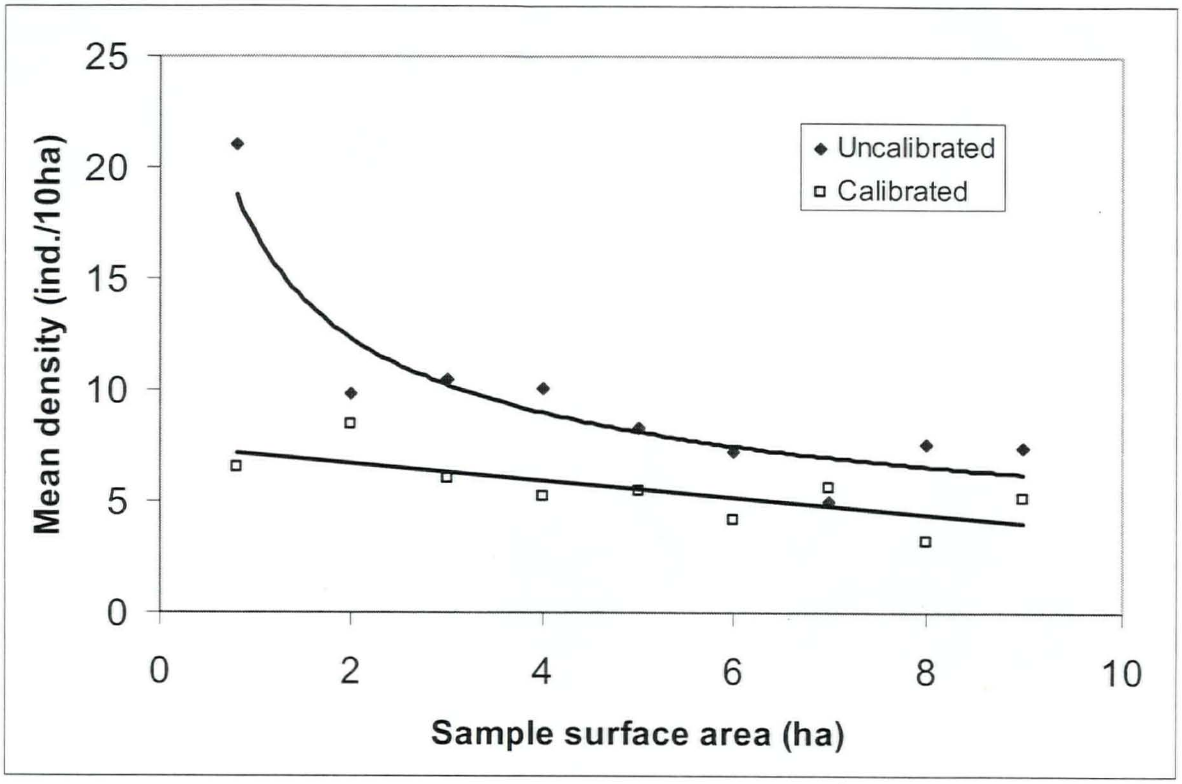


Figure D1: Effect of surface area calibration on census breeding pair density.

Table D.1 Calculated wetland bird species calibration ratios

	Mean observed density (#/10ha) per classes of surface area census (ha)						Calibration ratio per classes of surface area census (ha)					
CodeSP	1	2	3	4	5	6	1	2	3	4	5	6
ALFL	18.04	7.47	5.90	3.90	1.94	4.78	0.27	0.64	0.81	1.23	2.46	1
AMBI	12.73	6.22	4.08	3.50	3.75	2.41	0.19	0.39	0.59	0.69	0.64	1
AMRE	29.49	8.10	7.17	4.80	6.57	4.52	0.15	0.56	0.63	0.94	0.69	1
AMRO	18.63	8.47	5.30	8.51	7.59	7.28	0.39	0.86	1.37	0.86	0.96	1
AMWI	12.73	6.94		4.49	2.98	2.33	0.18	0.34		0.52	0.78	1
BAOR	14.43	6.04	5.99	4.61	3.88	1.97	0.14	0.33	0.33	0.43	0.51	1
BAWW	17.83	6.35				2.66	0.15	0.42				1
BCCH	20.69	8.03		3.85	3.54	1.88	0.09	0.23		0.49	0.53	1
BLTE	38.20	12.55	10.46	13.51	10.42	9.80	0.26	0.78	0.94	0.73	0.94	1
BOBO	25.46	11.90			1.89	1.76	0.07	0.15			0.93	1
BRCR	12.73	8.08		2.38	5.50	1.47	0.12	0.18		0.62	0.27	1
BWTE		10.64		2.49	3.89	1.72		0.16		0.69	0.44	1
CLSW		5.56	2.98			1.63		0.29	0.55			1
COGR	16.08	9.30	9.15	13.09	10.83	10.37	0.64	1.12	1.13	0.79	0.96	1
COMO	12.73	10.02	3.00	5.72	4.42	5.28	0.42	0.53	1.76	0.92	1.20	1
COSN	14.38	6.68	5.72	4.04	4.26	3.17	0.22	0.47	0.55	0.78	0.74	1
COYE	21.42	9.07	10.09	7.66	6.33	6.32	0.29	0.70	0.63	0.83	1.00	1
CSWA	14.85	6.48	6.60	2.35	7.68	2.11	0.14	0.33	0.32	0.90	0.28	1
DOWO	14.32	5.97	3.28	3.90	4.49	4.40	0.31	0.74	1.34	1.13	0.98	1
EAKI	14.15	6.39	3.38	3.29	3.12	2.79	0.20	0.44	0.82	0.85	0.89	1
EUST	14.74	6.20	14.25	30.08	6.72	5.36	0.36	0.86	0.38	0.18	0.80	1
EWPE	16.86	6.36	13.12	4.44	3.76	2.52	0.15	0.40	0.19	0.57	0.67	1
GADW	12.73	6.85		5.25	6.58	5.30	0.42	0.77		1.01	0.80	1
GCFL	14.85	7.26	11.66	3.84	2.66	3.32	0.22	0.46	0.28	0.86	1.25	1
GRCA	14.69	6.43	5.22	5.14	2.23	2.23	0.15	0.35	0.43	0.43	1.00	1
HAWO	15.92	5.88	3.08	5.42	2.82	3.06	0.19	0.52	0.99	0.56	1.08	1
HOWR	12.73	6.30	2.87	10.11	7.18	1.75	0.14	0.28	0.61	0.17	0.24	1
KILL	12.73	5.56		2.55		1.53	0.12	0.27		0.60		1
LEBI	12.73	5.98		2.42	1.97	1.39	0.11	0.23		0.57	0.70	1
LEFL	20.26	8.77	16.40	8.48	4.75	2.41	0.12	0.27	0.15	0.28	0.51	1
MALL	12.73	11.83	8.93	14.96	9.29	11.09	0.87	0.94	1.24	0.74	1.19	1
MAWR	23.08	12.67	14.83	17.81	13.86	9.62	0.42	0.76	0.65	0.54	0.69	1
MODO	14.43	6.22	3.89	4.77	2.74	2.72	0.19	0.44	0.70	0.57	0.99	1
NOFL	12.73	5.99	7.77	2.86	2.01	2.56	0.20	0.43	0.33	0.90	1.28	1
PBGR	17.51	7.36	3.00	5.70	4.07	2.52	0.14	0.34	0.84	0.44	0.62	1
PHVI		5.56				1.17		0.21				1
PIWO	12.73	6.25				1.65	0.13	0.26				1
RBGR	12.73	6.29	5.22	2.38	2.04	1.35	0.11	0.21	0.26	0.57	0.66	1
RBWO		5.56				1.53		0.27				1
REVI	21.99	7.31	3.28	3.81	3.08	2.97	0.13	0.41	0.90	0.78	0.96	1
RUGR	12.73	5.56			2.17	1.17	0.09	0.21			0.54	1
RWBL	31.92	18.40	25.11	21.10	20.19	15.99	0.50	0.87	0.64	0.76	0.79	1
SEWR	12.73	6.35			1.89	1.42	0.11	0.22			0.75	1
SORA	12.73	5.54		3.54	4.62	1.69	0.13	0.30		0.48	0.37	1
SOSP	23.65	8.82	6.24	9.30	5.99	6.71	0.28	0.76	1.07	0.72	1.12	1
SPSA	12.73	5.38	2.87	3.88	3.18	1.80	0.14	0.33	0.62	0.46	0.56	1
SWSP	27.18	11.60	17.74	12.93	10.97	12.99	0.48	1.12	0.73	1.00	1.18	1
TRES	14.85	10.52	13.31	13.54	10.84	9.47	0.64	0.90	0.71	0.70	0.87	1
VEER	26.43	9.59	8.28	5.99	8.91	4.69	0.18	0.49	0.57	0.78	0.53	1
VIRA	16.37	8.86	5.95	3.51	4.68	2.95	0.18	0.33	0.50	0.84	0.63	1
WAVI	17.08	6.89	3.28	7.89	4.11	2.62	0.15	0.38	0.80	0.33	0.64	1
WBNU	14.47	6.22		2.44	3.38	5.03	0.35	0.81		2.07	1.49	1
WIFL	15.92	8.34	3.32	4.67	3.47	2.02	0.13	0.24	0.61	0.43	0.58	1
WODU	12.73	7.58	4.06	7.62	5.12	4.46	0.35	0.59	1.10	0.58	0.87	1
WTSP	17.19	10.83	6.97		3.31	2.34	0.14	0.22	0.34		0.71	1
YWAR	31.83	11.40	15.91	16.29	8.94	9.86	0.31	0.87	0.62	0.61	1.10	1
Mean calibration ratio							**0.24**	**0.48**	**0.70**	**0.70**	**0.83**	**1**

Appendix E Overview of wetland habitat modeling for the St. Lawrence River and Lake Ontario

This represents an overview of the wetland habitat modelling systems that have been implemented within the St. Lawrence River and Lake Ontario, as described in detail in Morin *et al.* (2005) and Wilcox *et al.* (2005) .

E.1.1 General approach for the study design

Spatial domain: As part of the study design, the domain was divided into three regions: Lake Ontario (LO), the Upper St. Lawrence (USL) and the Lower St. Lawrence (LSL). The LO region covers the entire area of LO and its banks, on both the American and Canadian sides of the lake, and ends where the USL region begins, i.e. at Ogdensburg; the USL region ends upstream from the Moses–Saunders Dam in Cornwall. The LSL region covers the entire area extending downstream from the Cornwall dam to Trois Rivières. The Lac St. François region, which covers the area between the Moses–Saunders Dam and Beauharnois, was not included in the study design, as water levels there are already regulated and vary by no more than 15 cm annually. The section further downstream, from Trois Rivières to Quebec City, was also excluded from the study design, because the impact of regulation there is minimal and lunar tides have a greater influence on water level fluctuations in that stretch of the river.

Temporal step: The International St. Lawrence River Board of Control regulates water levels using a temporal step consisting of quarter-month (QM) periods. A quarter-month period basically corresponds to one week, although some QM periods have seven or eight days. The advantage of using QM periods is that each year is made up of 48 quarter-months, making it easier to compare data over long time series. However, the disadvantage consists in the smoothing of intra-QM fluctuations as this can affect environmental components that are very sensitive to water level and flow variations.

Hydrologic series and regulation plans: To carry out the mandate issued by the IJC, it was decided that the plans would be evaluated based on 100-year hydrologic series beginning in 1900 and ending in 2000. A number of hydrologic series were used for the study. A hydrologic series is defined as a series of water levels or flows (in a number of locations) ordered chronologically according to the QM periods of each year. All of the hydrologic series used for the study and for each location begin with QM 1 of the year 1900 and end with QM 48 of the year 2000, for a total of 4,800 QMs.

The first hydrologic series is a historical time series derived from available records of water supply conditions for the 20th century. The second hydrologic series, which is "stochastic," is likewise based on historical data, but these data are extrapolated using statistical methods to cover the wetter or drier periods that occurred over the last 100 years. The stochastic series are derived for 10,000-year periods, from which a 100-year subseries is chosen based on its statistical similarity to the time series. The third series that is used is a "climate change" series, in which water supply conditions are modified. For the latter two types of series, a number of modifications or changes to parameters can produce many climate change series (e.g. reducing or increasing the water supply parameter for Lake Ontario can give rise to several "climate change" series).

The regulation plans are independent of the hydrologic series. These plans correspond to a set of rules for determining how (timing and quantity released) the water available in the system will be distributed over time (annually). The set of rules or criteria underpinning the plans take various uses and interests into account. For instance, Rule "P" in Plan 1958-D stipulates that the maximum outflows from Lake Ontario need to be limited to prevent water level increases that will cause flooding along the St. Lawrence River, relative to pre-plan conditions (before regulation). The hydrologic series can be managed in relation to a number of plans. The effects of different series/plan combinations were analysed using the results of the various models developed by the technical working groups, in order to determine which regulation plan should be used in the near future. Plan 1958-DD is currently being used to manage water in the system.

E.2.1 Integrated Ecosystem Response Model (IERM)

Owing to the hydrological complexity of the Lake Ontario–St. Lawrence River system, the relationships between the hydrology and the habitat of a number of species are also very complex and vary in space and time. An innovative modelling approach has been developed to document this spatial and temporal complexity.

The IERM grid: The preferred 2D modelling uses a nodal approach. The IERM grid was integrated into the geodatabase (GDB) constructed to support all calculated and simulated environmental data and physical variables. This approach allows for the spatial harmonization of various data sets and facilitates the development of habitat models and other applications. The grid's spatial resolution was adjusted in relation to various biological phenomena. Grid resolution within the Lower St. Lawrence River ranges from 20 m to 40 m for floodplains through 80 m for shallow water and 160 m for deep water. For the area as a whole, from Lake St. Louis to Trois Rivières (excluding the Laprairie Basin), the IERM grid has 124,121 nodes for which all of the physical and environmental variables are known.

Habitat models: Habitat models can be developed very effectively in a GDB environment when all of the basic independent variables have been properly integrated. Models are produced as follows: the observation points (georeferenced) for fish, plants or birds that are used to calibrate habitat models are incorporated into the GDB; the independent variables identified beforehand by specialists are assigned (measured variables) or simulated (modelled variables) for the period corresponding to the observation period at each observation point. Statistical analyses are conducted outside the GDB environment using specialized software to derive predictive mathematical relationships, which can be reincorporated into the GDB. Habitat calculations are then done using GDB functions and procedures and the results are projected onto the IERM grid. The coded functions and procedures (algorithms) in the GDB are what drive the habitat models integrated with the GDB. The models are used to produce and gather the information needed to calculate the coded mathematical relationships describing habitat.

E.2.2 Operation of the IERM

Hydrologic scenarios: The temporal variability of water level and flow conditions in the St. Lawrence River is significant. Relative flows between the Great Lakes, the Ottawa River and other tributaries, the presence of ice and aquatic plants and the effect of wind and tides create many different conditions that can be simulated. However, because these conditions represent a great deal of information that is often redundant, reference scenarios were selected to represent the area's physical diversity and to characterize the variability of water levels and flows using a limited number of conditions.

The number of scenarios is limited in order to provide calibrated and validated events and to permit valid comparisons between different flow scenarios for a given season or between similar flows in different seasons. The adoption and use of reference scenarios by research teams will aid in quantifying the effects of rising and falling water levels on the ecosystem and thus serve as a guide for environmentally responsible management of the river.

Selecting scenarios is a lengthy process that involves using reconstituted data for the flows at Sorel and Trois Rivières. The distribution of daily flows was assessed as a whole and seasonally to determine normal events and extreme events. Because water level regulation and major dredging operations began in 1960, only the 1960–1998 portion of the series was used. Recurrence analysis was used to determine the return periods for summer low-water conditions and spring flooding. Lastly, the main inflows (Lasalle, Milles Îles/Prairies) and the flows of tributaries, along with the corresponding water level data were characterized to define the hydrological parameters (boundary conditions) for each scenario.

The choice of scenarios has to take hydrological seasons and return periods into account and has to cover the full spectrum of potential conditions. The eight scenarios selected were characterized by the discharge at Sorel and cover the entire spectrum of observed discharges, with a recurrence interval of close to 1/10,000 years for floods and low-water periods. Not all discharges occur in each hydrological season, as some discharges have an extremely low probability of occurrence during some seasons. The scenarios were defined using summer and winter means, which are nearly 9,500 m^3/s (Scenario 4), and the springtime mean, which is close to 12,000 m^3/s (Scenario 5). The 2,500 m^3/s difference between the scenarios was maintained until Scenario 7, which represents a recurrence interval of 1/16 years. The extreme scenario of 20,500 m^3/s is 1,500 m^3/s higher than the weekly calculated maximum. For low-water scenarios, a lower step of 1,500 m^3/s was adopted to obtain a relative resolution that is similar to the stronger discharges. The recurrence intervals for low-water scenarios are similar to those for the selected flood discharge scenarios. The extreme scenario of 5,000 m^3/s corresponds to a very long recurrence interval of close to 1/10,000 years. Although no discharge like this was observed in the reconstituted series, the scenario was selected to represent possible conditions involving a drop of at least 20% in water supplies.

The discharge scenarios described above were completed using the water inflow conditions for tributaries in the system. For extremely rare flows for which no tributary data exist, extrapolations were performed using curves established for each tributary on the basis of the "normal" scenarios (Scenarios 2 to 7). Water level conditions can change considerably during a given hydrological season and from one season to another. The boundary water level conditions used for the different scenarios have to vary seasonally. Aquatic plants, ice and the inputs from downstream tributaries affect the flow, causing water levels to fluctuate at the outlet of the section, at Trois Rivières, and within the section itself.

E.3.1 St. Lawrence River measured environmental variables

Bathymetry and topography: Bathymetric data were taken mainly from Canadian Hydrographic Service (CHS) field sheets, which cover the entire area at a scale of 1:12,000, with soundings every 50–100 m. Additional bathymetric information was obtained in the spring of 2001 from a shallow-water survey carried out by the Meteorological Service of Canada (MSC). Bathymetric information about this area was inadequate, as the CHS and CCG are responsible for mapping deep water areas used for navigation. The data were georeferenced using the MTM (Modified Transverse Mercator) reference system based on the NAD83 (North American Datum of 1983). The vertical datum is based on local chart datum (CD). The CHS defines CD as the lowest water level and/or tide that can occur locally.

Depth data referenced with respect to CD need to be adjusted so that their reference is mean sea level (MSL), allowing them to be properly integrated together and into the digital terrain model. This transformation turns depth data into topographic data. Like the IGLD85 (International Great Lakes Datum of 1985) reference system, the MSL reference system is used to directly compare water levels in the area extending from Lake Superior to the St. Lawrence Estuary. The MSL and IGLD85 differ by a few centimetres. The difference between the CD and MSL can be determined for each sampling point through spatial interpolation and mathematical operations.

The topographic data were acquired using airborne laser technology (LIDAR: LIght Detection And Ranging) in the St. Lawrence River floodplain. The boundaries of the area to be measured were delineated by the low water line and the 100-year flood boundary for all sections of the river between the Montreal archipelago and Trois Rivières. The data were stored as georeferenced points (x, y and z values) and in the same datum (horizontal and vertical) as the bathymetric data. The large amount of data obtained from the topographic survey (more than 200 million points) was reduced to obtain topographic data sets containing the most representative points. The LIDAR data were calibrated using 30,292 geodetic control points throughout the area and they were integrated into the digital terrain model (Fig. E.3.1) to update and complete it.

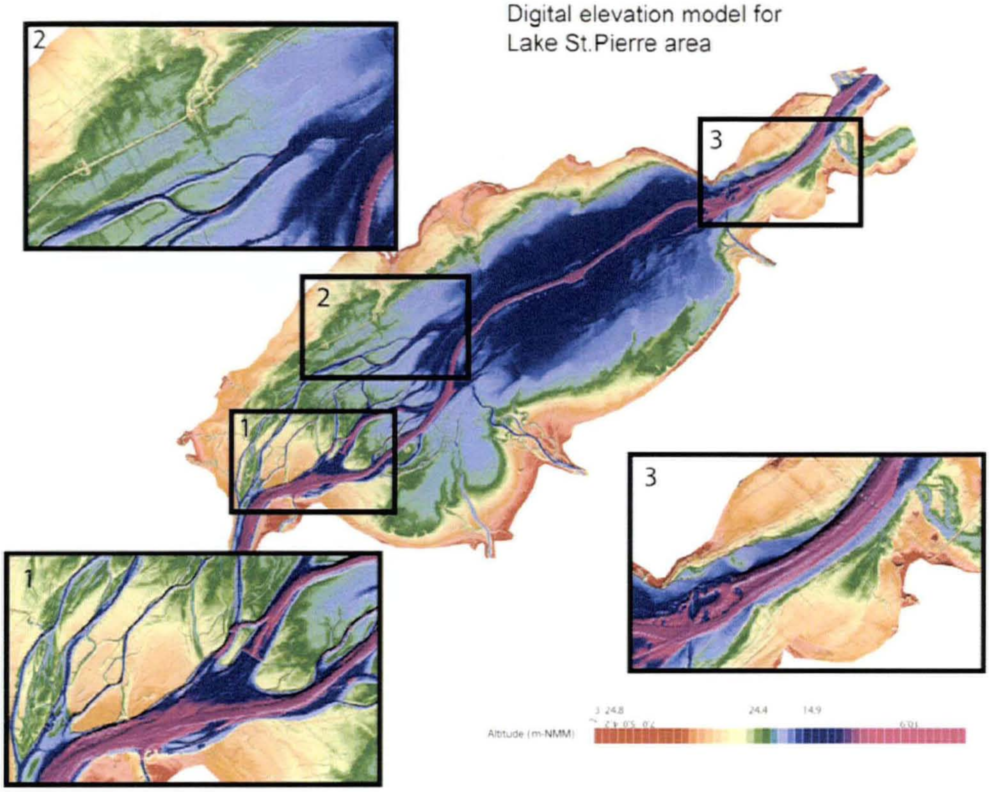


Figure E.3.1 Digital elevation model of the Lac St. Pierre area

Although the data were subjected to extensive post-processing and quality control cycles, manual correction was necessary in order to reduce the error associated with densely vegetated marshes and managed wildlife habitats. For heterogeneous environments such as these and areas covered with water for much of the year, LIDAR measurements contain significant errors and need to be corrected.

Aquatic plants: Submerged vegetation has a major influence on the spatial distribution of currents and water masses. Throughout the growing season, the size and composition characteristics of aquatic plants affect water levels and flow patterns. In some stretches of the St. Lawrence River, water levels can be 50 cm higher than in other areas in response to the same spring discharge levels. In the hydrodynamic model, the effect of aquatic plants, which in summer exceeds that of the substrate, is introduced by converting morphological plant data (e.g. the type of plants and leaves, height, density and percent cover of each species) to a local Manning coefficient, as is done for the substrate. In order to properly integrate data on resistance caused by aquatic plants, more than 7,000 field observations were made through georeferenced echo sounding and underwater videography. These measurements were used to map the assemblages of aquatic plants that were used in the parameterization of friction.

Emergent vegetation: In floodplain areas, flow resistance is mainly associated with wetland vegetation. The St. Lawrence River floodplain is covered by extensive areas of wetlands (treed swamps, shrub swamps, shallow and deep marshes). The maps produced from the extensive mapping done by Jacques (1986) of wetland vegetation around Lac St. Pierre, specifically twenty-three 1:10,000-scale paper maps covering 550 km² of wetlands, were digitized to produce more than 6,000 polygons of marshy vegetation. Parameterization of the Manning coefficient associated with the emergent wetland vegetation was done using the method described by Chow (1959); slight modifications were made during calibration of the hydrodynamic model.

E.3.2 Environmental variables in the St. Lawrence River hydrodynamic model

Hydrodynamic modelling was performed using the HYDROSIM model, developed at the INRS-Eau. This approach involves two-dimensional numerical modelling of long-wave equations, also known as shallow-water equations, which are solved using the finite element method. The size of the finite elements can be adjusted in order to reflect specific topographic characteristics. The HYDROSIM model uses the conservative form of mass conservation and momentum conservation equations which, for the shallow-water equations, takes into account the friction parameters related to substrates, aquatic plants and ice at the local scale. The conservation of energy is a fundamental concept of physics along with the conservation of mass and the conservation of momentum. Within some problem domain, the amount of energy remains constant and energy is neither created nor destroyed. Energy can be converted from one form to another (potential energy can be converted to kinetic energy) but the total energy within the domain remains fixed. The output consists of the x,y components of the mean speed (integrated in the vertical plane) at all computational nodes. The entire simulation domain is therefore described either directly at the computational nodes or between the nodes by interpolation. The model takes into account shoreline areas that are covered with water or exposed by examining discharge and water levels. The elements used are six-node triangles (P1-isoP2 interpolation), all of which are included in the calculation of the mean speeds. The nodes provide information on friction and topography. The topography and water levels are included in the three midside nodes; linear interpolation is used to determine these variables for the entire element.

The hydrodynamic model was calibrated based on two hydrologic events: a low flow event (spring 1999) and a high flow event (spring 1996). Many simulations need to be performed to adjust the various parameters (physical and numerical) so that the simulated levels would be consistent with the levels measured at gauging stations along the St. Lawrence River. Following calibration of the model, water level predictions were accurate to within 5 cm for the entire study area.

Water level modelling: Water level fluctuations in the study area are substantial. The historical data recorded at the Sorel station show that, between 1967 and 2001, water levels varied by as much as 5 m. Although water level variations can be determined at gauging stations where levels are recorded, the topographical and hydrodynamic complexity of the St. Lawrence River preclude the extrapolation of water level fluctuation data from such stations to the entire area or their use in determining water level at a point between two stations. Two-dimensional hydrodynamic modelling is used to accurately calculate this variation. Hydrodynamic simulations aid in identifying the effects that local topography, substrate and flow velocity have on water levels. Therefore, by simulating all potential water level conditions (water level fluctuations) in the St. Lawrence River, it is possible to determine all the fluctuations at any point in the study area. Although the reference events are intended to reflect all water level conditions, they only represent average conditions. For instance, for a given discharge at Sorel, which defines the reference event, tributary flow variations may occur that will affect water levels locally. In order to properly integrate water level fluctuations caused by tributary discharge variations in a given reference event, one-dimensional relationships for predicting water levels at gauging stations were used in conjunction with hydrodynamic scenario simulations.

Water level projection: The projection method used for each IERM grid point involves combining the one-dimensional relationships specific to the stations (pier No. 1, Varennes, Sorel, Lac St. Pierre and Trois Rivières) that were computed by Fan and Fay (2002) with the relationships for local and spatially extrapolated water levels calculated by performing hydrodynamic simulations of the different reference events (scenarios). By using the flows from the scenarios developed by Morin and Bouchard (2001) in the relationships derived by Fan and Fay (2002), it is possible to determine the water levels of the scenarios calculated using those relationships. This approach is used to correct the water-surface slope, which varies non-linearly between two gauging stations. The last step in the water level calculation is a correction that takes into account the discrepancies between water levels at real stations and those at points chosen in our analysis to represent the stations.

Water levels in residual and managed marshes: In some areas, the hydrology, the hydrodynamics and the topography of the St. Lawrence River floodplain create conditions that favour the development of residual marshes. These marshes have hydrologic characteristics similar to those of the St. Lawrence when local water levels are equal to or higher than their topographic sill, but their hydrologic behaviour differs when the river water levels are lower, locally, than the topographic sill. Figure E.3.2.1 shows the spatial distribution of residual and managed marshes in Lac St. Pierre.

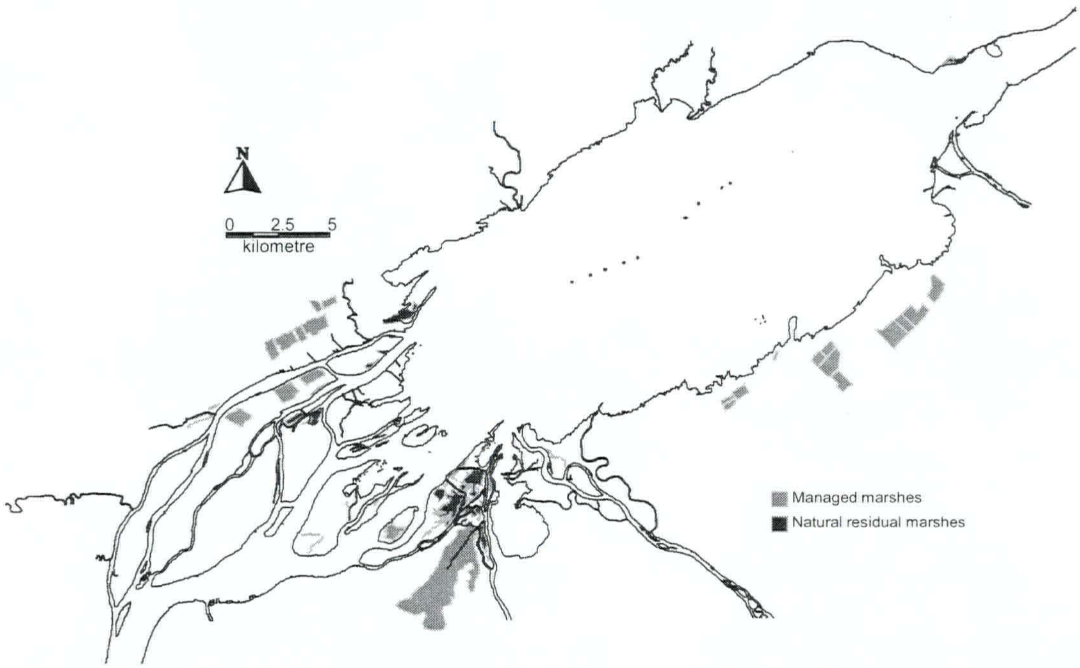


Figure E.3.2.1 Location of residual (red polygons) and managed (blue polygons) marshes in the Lac St. Pierre floodplain in Quebec.

The hydrologic behaviour of residual marshes is controlled by the water balance, i.e. precipitation and evaporation (Fig. E.3.2.2). The decline in the area of wetlands that has been observed for a number of years now has prompted the construction of managed marshes in order to compensate for wetland losses. Managed marshes have two main purposes: to increase quality habitat for the fish spawning period in spring and to increase habitat available to migratory waterfowl. Water levels in managed marshes are controlled to optimize conditions for the fish and waterfowl communities that use those areas. Water level management in such marshes is discussed in Mingelbier and Douguet (1999).

The presence of residual and managed marshes necessitated the development of an additional computational step for the determination of water levels. In the case of managed marshes, for which some water levels are not controlled, a water evaporation function is applied as of the last quarter-month in which water levels were managed For residual marshes, a threshold level was determined separately for each marsh using 1997 LIDAR topography. All the water levels are calculated based on the assumption that the marshes are full of water from fall to the following spring. Consequently, the water level attributed to points that are part of these marshes corresponds to the level calculated using the method described above in the “water level modelling” section, when this level is higher than the marsh’s threshold level. In other cases, water levels are calculated using an evaporation function, taking into account the last date on which the level was above the threshold or the time that has elapsed since spring (refilling period).

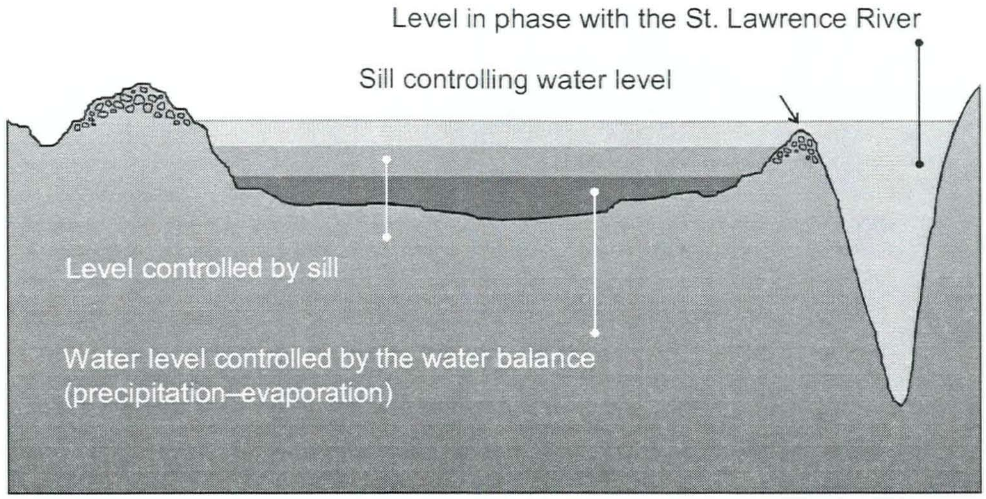


Figure E.3.2.2 Cross-sectional diagram of a residual marsh illustrating hydrologic behaviour when water level is controlled by a sill

Habitat modelling: Habitat preferences that can be partly described through physical variables are useful for explaining a large proportion of the occurrence data for a species. Once habitat preferences have been delineated in terms of physical variables, a number of modelling techniques can be employed to construct habitat models with the capacity to predict potential habitats from a number of hydrologic conditions. Validation involves superimposing the modelling results on the observations obtained, for a given hydrologic condition, and comparing the number of accurate predictions to assess the performance of each model. In cases where field data or observations are lacking, validation is done by a group of independent experts, who evaluate the quality of model output based on their knowledge about the species. Once validated, the model is deemed to be operational and capable of simulating habitats in various hydrologic conditions.

Three types of variables are used in habitat models. The first group of variables used consists of measurements and observations. These variables are obtained from literature data that has been digitized, field measurements and observations and the digital terrain model. Substrate, aquatic plants, emergent vegetation, soil use and all of the topography-derived variables (local slope) are included in this group. The second group, which is the most important in terms of data quality and complexity, consists of modelled variables obtained using the hydrodynamic model. These modelled variables include current speed, water depth, specific discharge, nodal period, hydrozones, orbital wave speed, the amount of available light on the river bottom, the deposited matter index and water temperature. The third group includes variables that are derived from habitat models and that are used as independent variables in other habitat models. The presence of submerged vegetation and wetland vegetation classes fall into this group of variables.

Wetland modelling was done by using dominant and co-dominant plant species and statistical classification methods to delineate broad wetland classes. As well, logistic regression models were employed to model the spatial and temporal relationships that exist between the broad wetland classes of the St. Lawrence River floodplain and a number of environmental variables (derived from 2D hydrodynamic simulations) that influence their distribution (Turgeon et al. 2004). Furthermore, to represent the evolution of wetlands over time, a complementary temporal model was developed to represent potential plant succession patterns in wetlands. Lastly, the temporal plant community transition model was refined using data from the three years preceding the sampling and it was then validated using remotely sensed images (MEIS 2000 and IKONOS 2002).

The spatial position of wetlands can evolve as hydrologic conditions change over time. Changes in wetland distribution can be characterized with reference to the zonation of the vegetation (Fig. E.3.2.3). For example, after a number of consecutive years of low water levels, a wave-swept deep-water marsh eventually becomes deep marsh. As a result of this spatial "migration" of wetlands, species' habitats are also displaced. The use of land for farming or grazing purposes in the past has interfered significantly with the natural toposequence of wetlands. Areas that were once treed swamps have been converted to farmland, and abandoned fields have been colonized by invasive plants, such as *Phalaris arundinacea* and *Calamagrostis canadensis*, which have displaced the silver maples (*Acer sacharrinum*) that typify the vegetation of treed swamps (Turgeon et al. 2004).

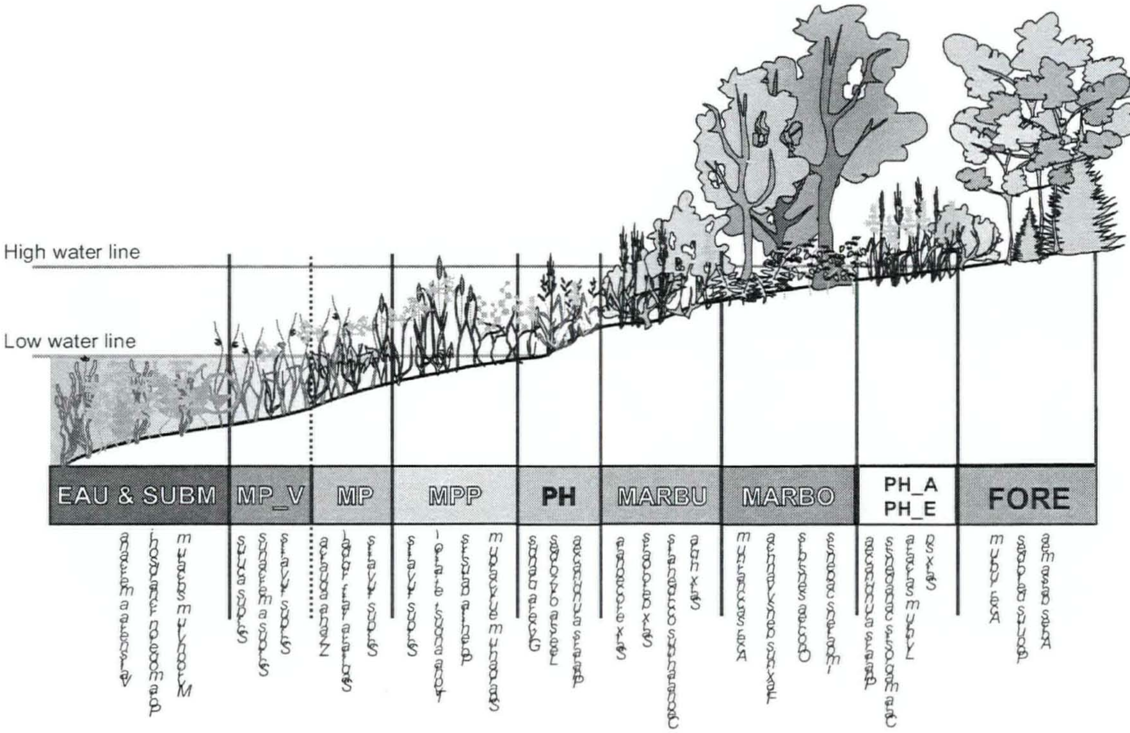


Figure E.3.2.3 Illustration of the position of wetland classes (along with their dominant and co-dominant species) in the toposequence of the Lac St. Pierre floodplain, in Quebec.

E.4.1 Lake Ontario – Upper St. Lawrence River Wetland Habitat Model

Outputs from Lake Ontario – Upper St. Lawrence River wetland habitat models were used as input variables for the wetland bird models. The following provides a brief description of the wetland habitat model, which is described in detail by Wilcox *et al.* (2005).

Wetland plant species and community distribution is strongly dependent on the hydroperiod at a particular elevation. In particular, the current flood condition and the flood and dewatering history will strongly influence the probability of wetland plant species occurrence at a specific elevation. In turn, specific groups of plant species will result in communities with unique species diversity and structural characteristics along a hydroperiod gradient.

Environmental variables such as the degree of wetland exposure to wave attack and ice scour, and hydrologic influences from sources other than Lake Ontario (i.e. drainage basin rivers) will influence how wetland plant communities response to Lake Ontario and Upper St. Lawrence River water level fluctuations. For this reason, unique wetland models have been developed for four distinct coastal wetland types (Fig. E.4.1.1). Wetlands protected from wave attack by **barrier beaches**, thus retaining organic sediments and developing a flatter topographic profile; protected wetlands in **drowned river mouths** that also have organic sediments, a flatter topographic profile and riverine hydrologic input; wetlands exposed to wave attack in **open embayments**, thus having predominantly inorganic sediments and a steeper topographic profile; and wetlands of intermediate wave exposure in **protected embayments**.

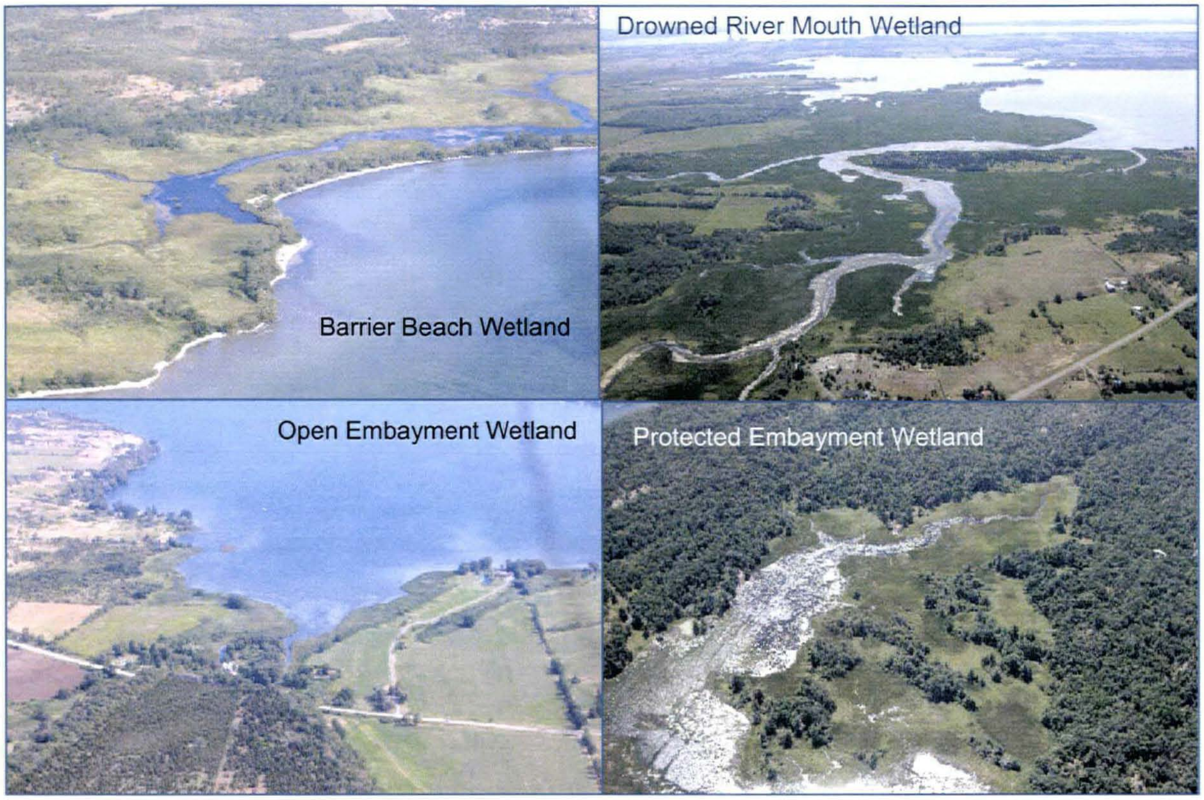


Fig. E.4.1.1 Aerial oblique photographs of the four distinct coastal wetland types in Lake Ontario.

Approach used to develop generalized wetland models: Eight wetlands of each type were selected in the Lake Ontario basin for the completion of detailed site-level wetland plant community research. The 32 wetlands, are considered to be representative of the other Lake Ontario - Upper St. Lawrence River wetlands. Hydrologic associations and predictive models developed using data from the study sites were extrapolated to a basin-level wetland database to allow estimation of basin-level trends.

Wetland vegetation models: Specific elevations with ecological significance based on past water level history were located within each wetland study site. Since the existing wetland vegetation in the lake has developed in response to the history of high and low lake levels, the selected elevations reflect unique water level histories. The elevations (IGLD85) are as follows: A) 75.60 m, last flooded 30 years ago; B) 75.45 m, last flooded 10 years ago; C) 75.35 m, last flooded 5 years ago; D) 75.0 m, last flooded 1 year ago and last dewatered during growing season 2 years ago (variable flooding and dewatering over past 3 years); E) 74.85 m, last dewatered during growing season 4 years ago; F) 74.7 m last dewatered during growing season 38 years ago; G) 74.25 m, last dewatered during growing season 68 years ago .

Vegetation data was collected along each elevation via quadrat sampling and analyzed for species prominence using non-metric multidimensional scaling (NMDS). Plant species were also assigned vegetation structural categories and summarized by mean cover for each unique transect in order to provide habitat information for faunal models (Table E.4.1).

Table E.4.1 Mean percent cover of vegetation structural categories by unique transect sampling elevations for each of the wetland types (BB=barrier beach, DRM=drowned river mouth, OE=open embayment, PE=protected embayment)

	BB	DRM	OE	PE	BB	DRM	OE	PE	BB	DRM	OE	PE	PE	BB	DRM	OE	PE
Structural Category	A,B,C MEAN COVER (420 quads)	A,B,C MEAN COVER (420 quads)	A,B,C MEAN COVER (480 quads)	A,B,C MEAN COVER (420 quads)	D MEAN COVER (140 quads)	D MEAN COVER (140 quads)	D MEAN COVER (160 quads)	D MEAN COVER (140 quads)	E,F MEAN COVER (280 quads)	E,F MEAN COVER (280 quads)	E,F MEAN COVER (320 quads)	E MEAN COVER (140 quads)	F MEAN COVER (140 quads)	G MEAN COVER (140 quads)	G MEAN COVER (140 quads)	G MEAN COVER (160 quads)	G MEAN COVER (140 quads)
Broad-Leaf Emergent	0.1	0.2	0.5	0.2	3.7	0.4	0.6	1.6	3.7	0.4	1.7	2.4	3.2	3.4	0.2	0.1	6.0
Thin-Stem Emergent	0.6	3.0	0.8	0.4	7.3	0.3	0.4	1.2	6.3	0.4	2.3	1.3	1.7	0.2	0.0	0.8	0.2
Thin-Stem Persistent Emergent	0.6	1.4	2.2	0.8	46.8	50.9	41.0	30.1	43.7	39.4	42.1	45.2	46.4	0.5	0.6	2.5	7.0
Submerged Broad-Leaf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6	1.5	2.2
Submerged Narrow-Leaf	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1	6.2	0.6	3.5	0.1	4.0	16.9	36.7	44.2	51.2
Floating Leaf	0.0	0.0	0.0	0.0	11.0	8.7	3.8	4.3	17.5	25.7	13.7	14.4	41.9	16.9	21.0	2.2	16.2
Algae	0.0	0.0	0.0	0.0	0.5	0.0	1.4	0.0	4.5	0.0	2.0	0.0	0.0	16.1	21.2	3.5	10.0
Grasses	10.4	13.7	22.4	9.0	11.6	8.2	6.5	18.2	2.8	8.2	6.0	16.1	5.6	2.6	0.1	0.0	1.2
Sedges	1.3	8.0	9.2	9.3	1.3	2.0	2.0	6.1	1.3	0.3	0.2	3.1	1.6	0.0	0.0	0.0	0.0
Forbs	20.9	28.7	24.2	22.7	2.9	4.8	10.5	4.2	0.5	0.6	0.9	1.6	2.2	0.1	0.0	0.0	0.0
Moss	0.0	0.1	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ferns	12.9	1.2	1.8	5.3	0.2	0.0	0.5	3.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
Trees/Shrubs	27.7	19.0	17.9	14.3	3.7	3.8	0.7	7.4	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vines	1.5	5.3	5.7	3.2	1.3	0.8	1.8	2.0	0.3	0.8	1.5	1.1	0.7	0.0	0.0	0.0	0.0
Miscellaneous	0.6	1.4	3.5	4.9	0.0	0.8	0.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Mean Cover	76.6	81.9	88.2	70.5	90.8	80.5	69.2	79.3	87.5	76.5	74.1	85.9	107.1	57.0	80.3	54.9	94.1

Transects A, B, and C contained similar plant species across all wetland types consisting predominantly of sedges, grasses, and some upland species, with varying degree of shrub occurrence. Transect D vegetation was identified as a second community consisting of sedge, grass and emergent plant species and was similar across all wetland types. Transects E and F comprised a third community dominated by emergent plant species and were similar in all wetland types except protected embayments, where transect F contained a higher component of floating-leaf vegetation. Vegetation at transect G was identified as the fourth unique community and was also found to be similar across all wetland types. This transect was dominated by submerged narrow-leaf, floating leaf, and algae species.

Wetland elevation models: Topographic and bathymetric data formats and sources varied for the 32 study sites. An Inverse Distance Weighting (IDW) interpolation method with a power value of 2.4 and weighting value of 8 meters was used to create individual elevation surface maps for each of the study wetlands. To meet the needs of the IJC study, four models representing the four wetland geomorphic types were developed to provide the required predictive capability. The generalized models were developed by determining the relative areal proportion of each individual wetland that lies above, below, or between selected contour intervals. ArcGIS 3D Analyst was used to generate generalized geometric models for each of the four wetland types studied based on the elevation surface maps from the groups of wetlands for each wetland geomorphic type. The resultant models for open embayment, protected embayment, barrier beach, and drowned river mouth wetlands are meant to represent all wetlands of each specific type but not any individual site (Fig. E.4.1.2). As such, the model outputs are extrapolated to a complete coastal wetland database for Lake Ontario and the Upper St. Lawrence River to obtain a basin level vegetation area estimates.

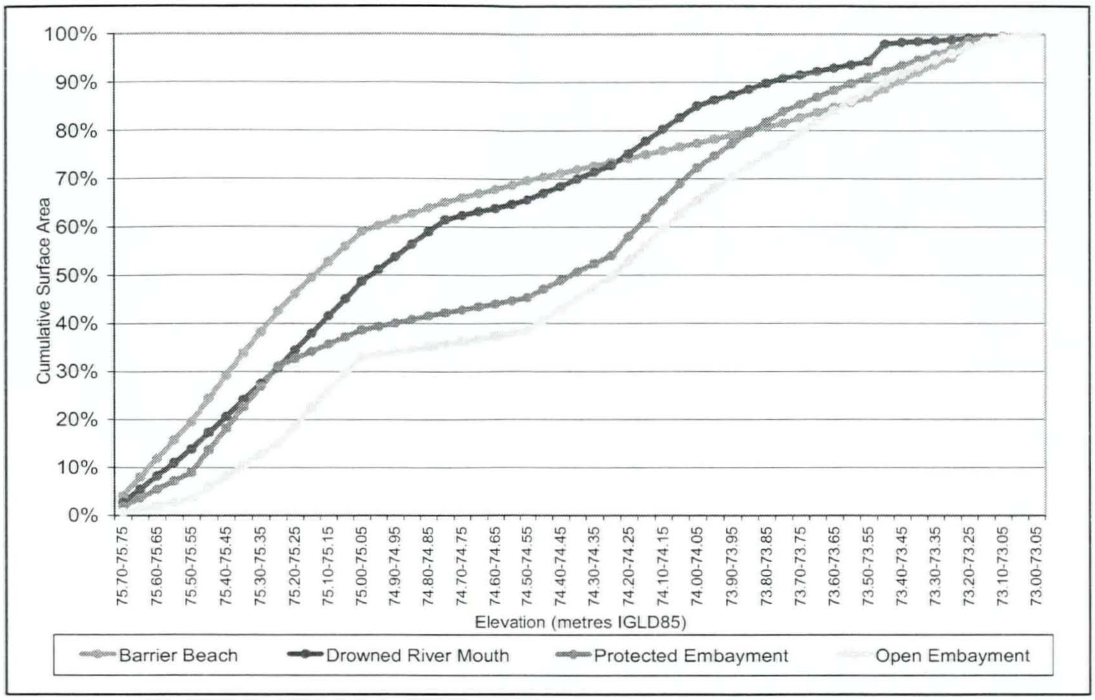


Figure E.4.1.2 Cumulative percent area of generalized wetland elevation models by wetland type.

E.4.2 Modelling links with hydrology

Assignment of vegetation types (ABC, D, EF (E and F are separate for protected embayments only), or G) to various elevation ranges is based on the number of years since last flooded or the number of years last dewatered among the transect elevations used for sampling and grouped together as individual vegetation types. Professional judgment based on discussions among prominent Great Lakes wetland scientists was used to determine break points between classes.

Estimations of the number of years since last flooded and/or dewatered for each elevation increment are calculated based on the following process.

For "last flooded" determinations of A, B, C, D :

- All portions of elevation model above the highest peak identified across the entire regulation plan are never flooded by the lake and are automatically assigned to U (transition to Upland) up to 75.75m
- For other peaks, locate peak Quarter Month (QM).
- Identify 3 adjacent (4 total) highest QMs (doesn't matter which side of peak).
- Select elevation of the QM that is lowest of the 4.
- In most cases, this selects an elevation that has been flooded for 3 QMs.

IF: the most recent "last-flooded" peak year selected is <5 years ago and its elevation selected from the 4 highest QMs as described above is less than the most recent dewatered year elevation, then use the single peak QM for the "last flooded" elevation determination, rather than the elevation selected from the 4 highest QMs.

For "last dewatered in summer" determinations of D, E, EF, F, G :

- Use annual peak QM elevation.
- All portions of the elevation model below the lowest summertime peak identified across the entire regulation plan are continuously flooded and automatically assigned to G down to 73.0m.
- This procedure selects an elevation that largely remained dewatered during the entire growing season, although it could be flooded short term if the peak QM elevation reported did not represent the actual peak day. In addition, this elevation could periodically be flooded by seiches.

Annual vegetation assignments to various elevations ranges are based upon the following vegetation rules-based models:

Open Embayment Wetlands

Not flooded >30 years: assign to U (transition to Upland) and go up to elevation of 75.75m
Not flooded 5-30 years: assign to (A+B+C)
Not flooded <5 years or Not dewatered <4 years: assign to (D)
Not dewatered 4-39 years: assign to (E+F)
Not dewatered 40 years or more: assign to (G) and go down to elevation of 73.0m

Protected Embayment Wetlands

Not flooded >30 years: assign to U (transition to Upland) and go up to elevation of 75.75m
Not flooded 5-30 years: assign to (A+B+C)
Not flooded <5 years or Not dewatered <4 years: assign to (D)
Not dewatered 4-20 years: assign to (E)
Not dewatered 21-39 years: assign to (F)
Not dewatered 40 years or more: assign to (G) and go down to elevation of 73.0m

Barrier Beach Wetlands

Not flooded >30 years: assign to U (transition to Upland) and go up to elevation of 75.75m
Not flooded 5-30 years: assign to (A+B+C)
Not flooded <5 years or Not dewatered <4 years: assign to (D)
Not dewatered 4-39 years: assign to (E+F)
Not dewatered 40 years or more: assign to (G) and go down to lowest elevation in model

Drowned River Mouth Wetlands

Not flooded >30 years: assign to U (transition to Upland) and go up to elevation of 75.75m
Not flooded 5-30 years: assign to (A+B+C)
Not flooded <5 years or Not dewatered <4 years: assign to (D)
Not dewatered 4-39 years: assign to (E+F)
Not dewatered 40 years or more: assign to (G) and go down to lowest elevation in model

Linking wetland vegetation model outputs to bird model inputs: Annual estimates of specific wetland habitat types were required in order to run the wetland bird models. Table E.4.2 indicates the bird habitat categories that were assigned based upon transect structural summary results.

Table E.4.2 Habitat categories assigned to wetland vegetation model outputs for use in wetland bird models.

Wetland Type	A	B	C	D	E	F	G
OE	Treed Swamp	Meadow Marsh	Meadow Marsh	Emergent Marsh	Emergent Marsh	Emergent Marsh	NA
PE	Treed Swamp	Meadow Marsh	Meadow Marsh	Emergent Marsh	Emergent Marsh	Emergent Marsh	NA
BB	Treed Swamp	Shrub Swamp	Meadow Marsh	Emergent Marsh	Emergent Marsh	Emergent Marsh	NA
DRM	Treed Swamp	Shrub Swamp	Meadow Marsh	Emergent Marsh	Emergent Marsh	Emergent Marsh	NA

Appendix F Wetland bird species natural traits.

#	Code	Bird Name	Number of breeding habitat	Number of feeding ways	Number of feeding habitat	Reproduction strategy index1	weight (g)	Species Types 2	Study occ. (%)
1	RWBL	Red-winged Blackbird	2	2	3	3	42	1	91
2	SWSP	Swamp Sparrow	2	2	4	4	17	2	72
3	YWAR	Yellow Warbler	1	1	1	4	9	1	71
4	SOSP	Song Sparrow	1	2	2	5	21	1	69
5	COYE	Common Yellowthroat	2	1	2	4	10	1	56
6	COSN	Common Snipe	1	1	3	4	116	2	45
7	TRES	Tree Swallow	2	1	3	3	22	1	45
8	AMRO	American Robin	1	2	3	5	77	1	42
9	MAWR	Marsh Wren	1	1	1	5	11	2	29
10	COGR	Common Grackle	3	3	3	3	100	1	29
11	WAVI	Warbling Vireo	1	1	1	4	12	1	29
12	BLTE	Black Tern	3	2	2	3	65	2	23
13	AMBI	American Bittern	2	2	3	4	706	2	21
14	BAOR	Baltimore Oriole	1	3	2	3	33	1	21
15	VIRA	Virginia Rail	1	2	2	5	75	2	20
16	EWPE	Eastern Wood-Pewee	2	1	1	3	14	1	19
17	VEER	Veery	1	2	1	4	31	1	19
18	GCFL	Great Crested Flycatcher	2	2	2	3	33	1	18
19	PBGR	Pied-billed Grebe	2	2	1	5	442	2	17
20	GRCA	Gray Catbird	1	2	1	3	37	1	17
21	DOWO	Downy Woodpecker	1	2	2	3	27	1	16
22	GADW	Gadwall	1	2	1	5	835	2	15
23	MODO	Mourning Dove	1	1	2	5	115	0	15
24	WIFL	Willow Flycatcher	1	1	2	4	14	1	15
25	EUST	European Starling	2	2	1	4	80	1	14
26	SORA	Sora	1	1	3	5	75	2	14
27	LEFL	Least Flycatcher	2	1	1	4	10	0	13
28	COMO	Common Moorhen	2	2	2	5	334	2	13
29	EAKI	Eastern Kingbird	2	2	2	4	39	1	13
30	AMRE	American Redstart	2	1	2	4	8	1	12
31	MALL	Mallard	2	3	1	4	1107	2	12
32	NOFL	Northern Flicker	1	2	2	5	129	0	10
33	WBNU	White-breasted Nuthatch	1	2	2	5	21	0	9
34	REVI	Red-eyed Vireo	2	1	1	4	17	1	9
35	HOWR	House Wren	1	1	1	6	10	0	8
36	HAWO	Hairy Woodpecker	1	2	1	3	63	0	7
37	WODU	Wood Duck	2	3	3	4	635	2	7
38	ALFL	Alder Flycatcher	1	1	2	4	13	1	6
39	NSHO	Northern Shoveler	1	2	1	5	590	2	6
40	RBGR	Rose-breasted Grosbeak	1	2	1	3	46	0	6
41	BOBO	Bobolink	1	2	1	5	37	0	5
42	SPSA	Spotted Sandpiper	3	2	2	6	40	2	5
43	SAVS	Savannah Sparrow	1	2	1	4	20	1	5
44	BCCH	Black-capped Chickadee	1	2	1	5	11	1	5
45	BBCU	Black-billed Cuckoo	1	2	2	4	51	0	4
46	WOTH	Wood Thrush	1	2	1	4	47	0	4
47	AMWO	American Woodcock	1	1	1	4	219	1	4
48	AMWI	American Wigeon	1	1	2	4	719	2	3
49	WTSP	White-throated Sparrow	1	2	1	5	26	0	3
50	LEBI	Least Bittern	2	2	1	4	77	2	3
51	BRCR	Brown Creeper	1	1	1	5	8	0	2
52	AMCO	American Coot	2	2	2	4	560	2	2
53	REDH	Redhead	1	1	1	4	971	2	2
54	BWTE	Blue-winged Teal	1	3	1	4	376	2	1
55	CSWA	Chestnut-sided Warbler	2	1	1	4	9	0	1
56	EAME	Eastern Meadowlark	1	2	1	5	76	0	1
57	NAWA	Nashville Warbler	2	1	1	4	9	1	1
58	OVEN	Ovenbird	1	1	1	4	19	0	1
59	SEWR	Sedge Wren	2	1	3	6	9	2	1
60	BAWW	Black-and-white Warbler	2	1	1	3	11	0	0
61	BTBW	Black-throated Blue Warbler	2	1	1	4	10	0	0
62	CHSP	Chipping Sparrow	1	2	1	4	15	0	0
63	EAPH	Eastern Phoebe	4	3	3	5	20	1	0
64	GNBH	Green Heron	2	2	3	4	212	2	0
65	KILL	Killdeer	2	1	1	4	101	1	0
66	MOWA	Mourning Warbler	1	1	1	4	12	0	0
67	NOCA	Northern Cardinal	1	2	1	5	44	0	0
68	RTHU	Ruby-throated Hummingbird	2	2	1	4	3	0	0
69	RUGR	Ruffed Grouse	1	3	1	5	532	0	0
70	STSP	Nelson's Sharp-tailed Sparrow	1	2	2	5	18	2	0
71	UPSA	Upland Sandpiper	1	1	1	4	190	1	0
72	WIWR	Winter Wren	1	1	1	6	9	0	0

(1) 1 = R-; 2 = R; 3 = R+; 4 = K-; 5 = K; 6 = K-

(2) 0 = not a wetland specie ; 1= optional wetland specie; 2 = obligate wetland specie

Appendix G Analytical methods used to define a typology describing the wetland bird habitats and to select variables (from vegetation composition and structure as well as hydrological variables) that are influencing habitat selection by wetland birds

G.1.1 Classifications of wetland bird assemblages and their environment

Over the course of the research, several steps were required to understand the structure of wetland bird communities and their association to environmental variables. The classifications below were created based on the 2002 data, consisting of 214 sites and 71 species. These analyses, along with other vegetation-based analyses, directed and focused surveys in 2003-04, and to the final classification in 10 habitats presented in Chapter 3 of this report.

Statistical analysis: for the determination of wetland bird assemblages, the "bird" data matrix underwent two types of analysis:

(i) A simple analysis consisting of a complete-linkage clustering based on a Steinhaus similarity matrix (S17, see below the numbering system). This type of cluster analysis produces a typology based exclusively on avian data, which are interpreted *a posteriori* using the environmental characteristics of the sites of the groups retained and the indicator species identified by the *IndVal* method;

(ii) A more complex analysis to determine how birds perceive and "classify" their environment. It involved:

- pre-transforming or pre-processing if necessary avian and descriptive data;
- carrying out a canonical ordination (in this case, a redundancy analysis RDA) with the forward selection of in dependent variables, retaining only those that contribute significantly to explain the variance in the avian matrix;
- based on the independent variables retained, constructing a site similarity matrix (S16), weighting each independent variable with its importance in the RDA (in this case, the four main axes in the RDA);
- carrying out a cluster analysis on the similarity matrix (S16) obtained. The result is a first typology of 12 habitats as described by the variables most important for the avian community (Figure G.1.3); the final one, comprising 10 habitats, is presented in Section 2.4.
- interpreting the results of the cluster analysis, particularly by identifying indicator species and examining the avian and environmental characteristics of the clusters retained.

This double analytical flow is represented on figure G.1.1.

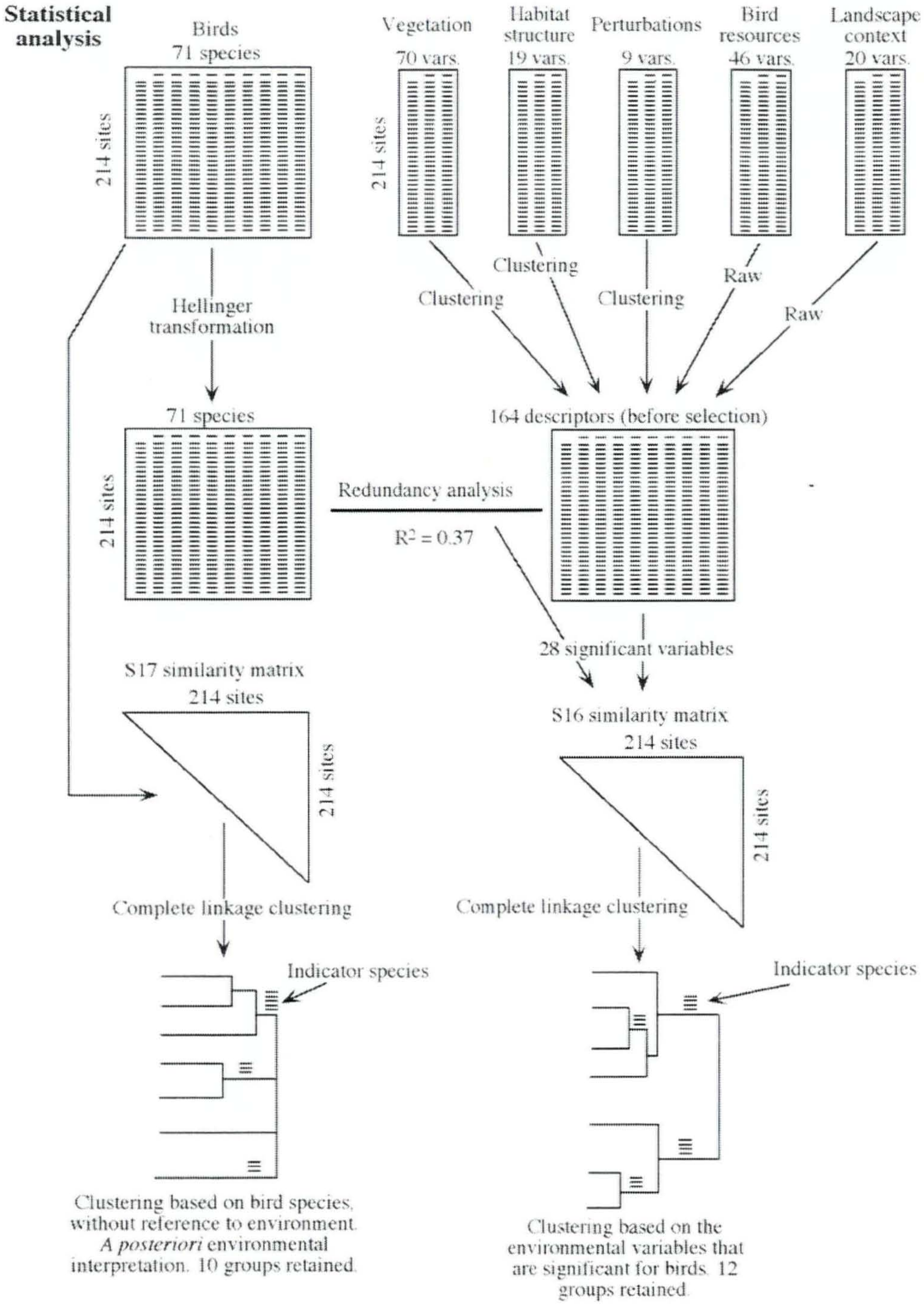


Figure G.1.1 **Flowchart of the analyses applied in the classification study**. Rectangles represent raw data matrices, while triangles show association (similarity) matrices. The left-hand classification results appear on Figure G.1.2, the right-hand one on Figure G.1.3. List (with codes) of the environmental (hydrological and vegetation) variables considered in the statistical analysis are presented in appendix H.

G.1.2 Technical issues about the statistical methods

The double zero problem: the methods used here work on an association matrix among sites, containing a resemblance measure between all pairs of sites. The choice of the resemblance measure is critical for the analysis to be successful. Indeed, all resemblance measures are not devised for all types of data (Legendre & Legendre, 1998). Some measures consider a double zero (i.e. a value of 0 given to two sites for the descriptor considered) as a resemblance between the two objects. This is generally valid for physico-chemical variables, where 0 is a value like any other. For instance, finding 0 µg/L of dissolved oxygen in two lakes is indeed a resemblance between the two lakes and bears the same consequences on the organisms living in these waters. Euclidean distance is a classical example of a distance measure considering the double zero as a resemblance. This distance can be used as a basis for site classification on quantitative environmental variables, and it is the one preserved among sites in PCA or RDA on untransformed variables, for example.

On the contrary, the double zero cannot be treated this way when one deals with species abundances or presences/absences. In most situations, one cannot be sure that a species absent from two different sites are absent for the same reason: a bird can be absent from one site because it is too cold, from another because it is too wooded, and from a third one because the ornithologist missed it when making their census. These 3 sites "resemble" each other because the bird species is absent from the three, but this is not the indication of an ecological resemblance between the sites. This is why one usually uses resemblance measures that do not include double zeros when dealing with species data. Bray-Curtis distance D14, one of the most commonly used indices in vegetation studies (and its reciprocal the Steinhaus similarity S17) as well as the Jaccard community index are examples of indices of this type, which are called asymmetrical indices because they do not handle double zeros the same way as double presences. Correspondence analysis and canonical correspondence analyses are ordination methods that also respect this principle, as well as PCA and RDA on appropriately pre-transformed species data.

Hierarchical linkage cluster analysis: In general, cluster analyses are well suited for identifying typologies of avian communities and for grouping data on vegetation or other sources of influence. In this study, clustering was based on an association matrix between objects. This triangular matrix contains a measurement of the similarity between each pair of objects, calculated by an index (of similarity or distance); as explained above, the selection of the appropriate index is crucial to the success of the cluster analysis. We used the Steinhaus index of similarity (Motyka 1947 *in* Legendre and Legendre 1998). When the clustering of quantitative data was planned, we used the Euclidian distance (D1 in Legendre and Legendre 1998). When different mathematical types of variables were to be combined in one analysis, we used Estabrook and Rogers' S16 index, which was designed to take advantage of the information provided by qualitative, semi-quantitative and quantitative descriptors.

Hierarchical clustering methods start with separate objects (sites) and group them together progressively, beginning with the nearest pair. The result is a dendrogram showing the hierarchy of groups formed from isolated objects. But here, too, several variants are possible. At one end of the spectrum is single-linkage clustering, where objects are associated progressively, beginning with the nearest neighbour using very liberal criteria. This method easily uncovers a large gradient when present, but tends to produce a dendrogram of successive chaining that is difficult to interpret in depth. At the other extreme, complete-linkage clustering uses very restrictive criteria to join two groups, tending to produce a highly contrasting typology. Intermediate-linkage clustering can also be used (connectedness between 0 and 1, to be chosen by the user). In the current study, we sometimes used complete-linkage clustering and sometimes intermediate-linkage clustering with a connectedness of 0.5, which is exactly the middle ground between the two extremes discussed above.

Clustering is a heuristic, descriptive method rather than a statistical test. Interpretation begins with the visual examination of the dendrogram, a fairly complex diagram when several hundred objects are involved. Methods exist that allow to objectively select a single fusion level to interpret the dendrogram. We believe, however, that in most cases there is no justification for postulating that the optimal level of interpretation is the same for all the main branches of the dendrogram. Consequently, we prefer a more subjective interpretation.

Calculations were carried out with the R Package (Legendre, Casgrain and Vaudor 2002).

Ordination and canonical ordination : The method mostly used here to relate avian communities and their environment is a form of canonical ordination. Canonical ordination is a type of analysis that emphasizes gradients by revealing major trends in data variation on a reduced number of main axes. Classical examples of these methods are Principal Component Analysis (PCA), used for quantitative data, Correspondence Analysis (CA) used for the analysis of species abundance data, and Principal Coordinate Analysis (PCoA), which allows the choice of the resemblance measure and can hence be applied to any type of data. In canonical ordination, axes are constrained to be linear combinations of independent variables. It therefore combines ordination and multiple regression. The two most well-known variants are redundancy analysis (RDA), the constrained version of PCA, and canonical correspondence analysis (CCA) (ter Braak 1986), the constrained version of CA that applies to species data tables. CA and CCA have traditionally been the preferred methods for handling species data. They have some drawbacks, however, and studies have shown that they do not optimally represent principal data structures, due to technical characteristics that we will not go into here. Recently, there has been an attempt to substitute more powerful methods. An additional explanation is needed here.

The double zero problem also occurs in ordination. Nevertheless, the problems and limitations inherent in CA and CCA have led Legendre and Gallagher (2001) to propose the use of PCA and RDA, but only after species data have been transformed, so that, after the analysis, the Euclidean distance is not preserved between sites but rather a distance appropriate to species data (and which does not, therefore, take account of double zeros). As a result of our experience at Pierre Legendre's lab, we often opt for a transformation method that preserves the Hellinger distance between sites. Often, the resulting ordination is clearer and easier to interpret than one obtained with CA or CCA. We will use this transformation here.

In addition, in canonical ordination and multiple regression, it may be useful to select the independent variables that contribute most significantly to explaining variance. This can be done by using the forward selection method. The process involves first calculating the portion of the variation explained by each independent variable individually, choosing the best one and testing the contribution. If the latter is significant, the variable is selected for the analysis. Then the partial contributions of all the other variables are calculated (taking into account the variable already admitted in the model), and the best one tested in turn. The process is continued until none of the candidate variables are found to have a significant additional contribution, according to the threshold selected. In this study, to avoid being too conservative, we used forward selection with a probability threshold of 0.10. Finally, canonical ordinations also have a partial form (as does regression) : one can evaluate the contribution of a group of variables while controlling for the effect of another group.

Ordination diagrams and transformations were prepared with the R Package (Legendre, Casgrain & Vaudor. 2002) and the ordinations themselves were computed using CANOCO, Version 3.12 (ter Braak 1988).

Variation partitioning: In order to quantify the proportion of variation of the bird data explained uniquely or in combination by the four sources of variation exposed above, we used a technique of variation partitioning described by Borcard et al. (1992). This method is based on canonical and partial canonical ordinations. It consists of running a series of analyses allowing to estimate the proportion of variance explained separately or commonly by the various classes of explanatory variables available, producing a summary in the form of a Venn diagram showing how the bird variation is partitioned among diverse sources of variation. Note, however, that here the sources of variation are not linearly independent, as would be the case in most ANOVA designs.

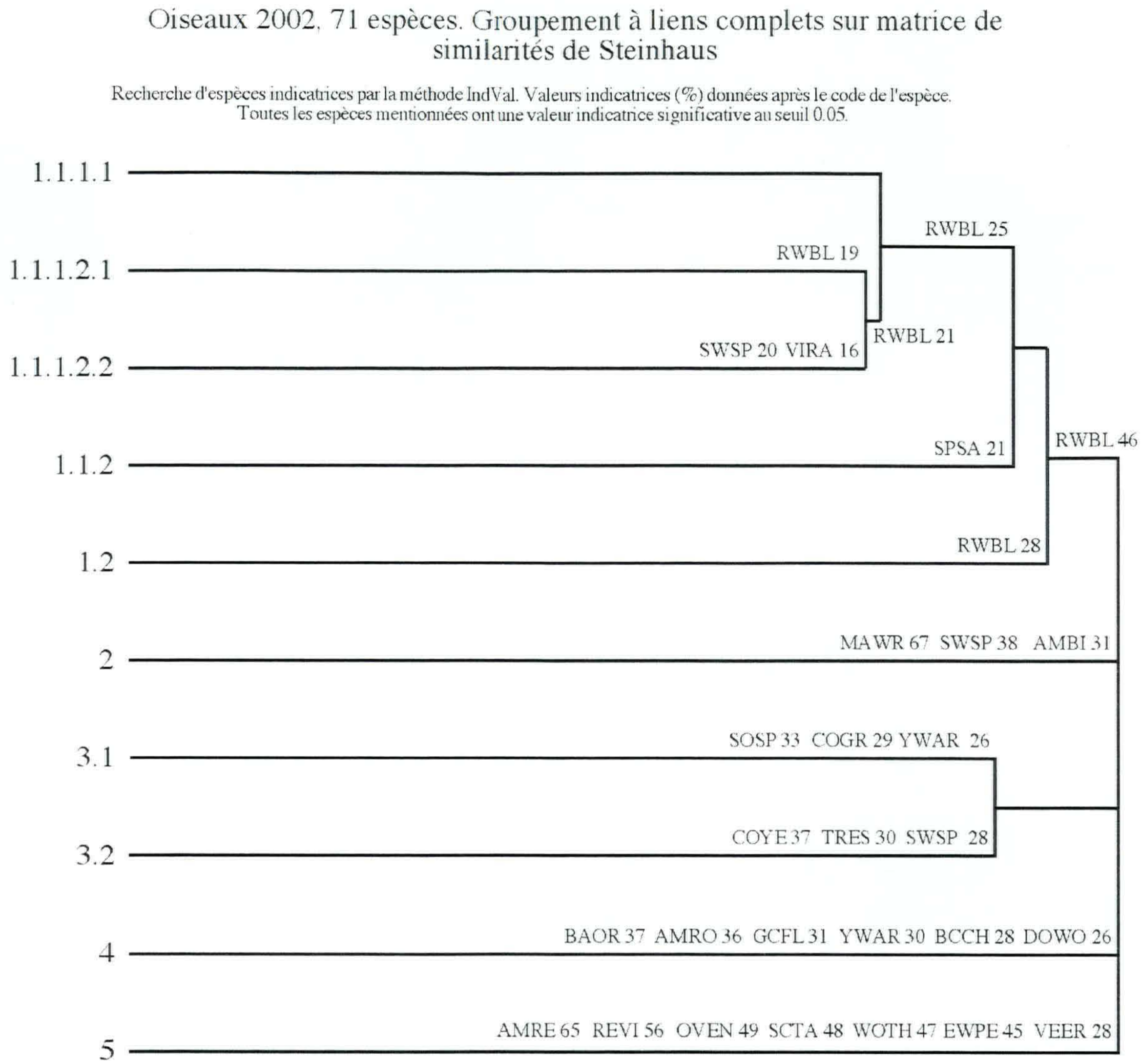
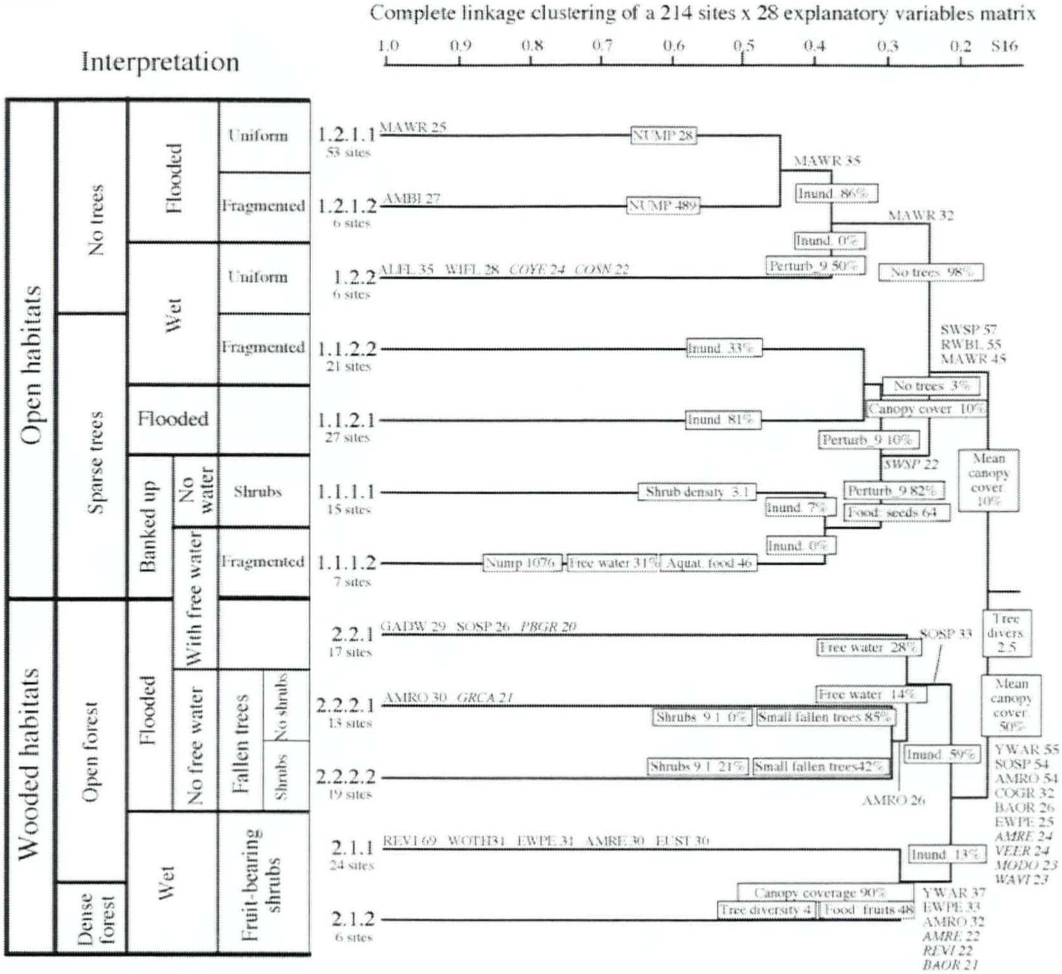


Figure G.1.2. Simplified dendrogram, complete linkage clustering of 214 sites and 71 bird species sampled in 2002 (see Figure G.1.1, left-hand flow). The codes indicate species whose Indicator Value *IndVal* is significant and equals at least 20%.

Determination of indicator species: To better determine the ecological identity of the groups retained (in the hierarchy created by agglomerative clustering), indicator species—as defined by Dufrêne and Legendre (1997)—were identified. The indicator value *IndVal* is defined as the product of two quantities:

- specificity of a species to a given group (species' mean abundance at sites associated with the group in question, divided by the sum of mean abundances for the species in all groups); the maximum value (=1) occurs when the species is only present in the group in question;
- fidelity of a species, or the number of sites associated with the group where the species is present divided by the total number of sites for the group. Fidelity equals 1 when the species occurs at all of the group's sites.

In hierarchical clustering, all the fusion levels can be coded separately, which provides indicator values (*IndVal*) for all species each time there is a fusion. The significance of each *IndVal* is tested using permutation. In addition, an arbitrary threshold can be established, above which the *IndVal* value will be retained in the analysis. The threshold was set at 20% to avoid retaining too low indicator values. Indicator values were calculated with Dufrêne's *IndVal* program.



Simplified dendrogram of the complete linkage clustering computed on the 28 explanatory variables that are significant in a "bird x environment" RDA. Estabrook-Rogers (S16) similarity matrix. The codes of the significant indicator species whose indicator value is ≥ 20% are indicated at the appropriate branchings.

Figure G.1.3 Simplified dendrogram, complete linkage clustering of 214 sites and 28 environmental variables explaining the bird assemblages significantly in an RDA (see text). 2002 sampling year (se Figure G.1.1, right-hand flow). The variables best characterizing each branch are indicated. The codes indicate species whose Indicator Value *IndVal* is significant and equals at least 20%.

G.2.1 Selection of vegetation, structure and hydrology variables best explaining the variance of wetland bird assemblages and canonical ordination of bird communities

The analyses presented below have two objectives: (1) a better understanding of the ecological constraints acting on the wetland bird communities, and (2) the selection of a parsimonious set of explanatory variables to be used in further steps of IJC ecological modeling.
These analyses were based on canonical ordination. We defined four categories of explanatory variables: (i) vegetation, (ii) geography and heterogeneity, (iii) remote sensing and (iv) hydrology.

In the case of ordination analyses,

- the first step consisted of assembling the "clean" data, i.e., those devoid of missing values. Since subgroups were different for the various categories of environmental variables, the analyses were not always done on the same data. The general aim was always to optimize the analyses for the number of available sites.
- in the second step, for the definition of a minimum set of variables for the IJC modeling we assembled the complete data set with all the variables that could potentially prove useful. These data consisted of 141 sites, 63 bird species and 76 environmental variables. These data were submitted to an RDA with Hellinger-transformed species abundances and forward selection of explanatory variables. After this selection, an *a posteriori* elimination of variables that were too collinear to others finally allowed to retain a model with 25 environmental variables explaining 45.8% variance of the bird data.
- the third step aimed at a broader selection of explanatory variables, mainly devoted to a better understanding of the ecology of the avian communities. The principle is the same as in the previous step, except that the number of explanatory variables available was higher (138). Various models have been retained and examined, the one being finally retained explaining 53.9% of bird variation by means of 37 explanatory variables.
- the fourth step consisted in a variation partitioning. The aim of such a partitioning is to evaluate the unique and common contributions of various sources of variation to the variation of the species data. In this case we had 4 groups of explanatory variables: (1) dominant plant species, (2) geographic variables and descriptors of horizontal and vertical heterogeneity, (3) remote sensing variables and (4) hydrological variables. globally, these variables explain about 70% of the bird data variance. The partitioning details are given below.

G.2.2 The search for a parsimonious subset of explanatory variables

Independent variables for bird–habitat relationships: Canonical redundancy analyses (CRA) were performed as the first step in identifying a parsimonious set of explanatory variables for bird–habitat–hydrology relationships that could be used in neural network modelling. A number of attempts were made using different selection strategies for explanatory variables. The following general principles were applied:

- The variables needed to be easy to obtain or calculate.
- The variables needed to explain the variance in bird communities as clearly and as parsimoniously as possible. A restricted subset of variables was to be selected from the variables in Appendix H.

The data used are limited to 141 sites at locations ranging from the Montreal archipelago to Lac St. Pierre, because these are the only sites for which all of the necessary environmental descriptors are available (e.g. hydrologic data). The following strategy was used to produce the most satisfactory model: the forcing of four broad habitat variables, followed by the selection of other classes of variables in an attempt to exhaust the important hydrologic variables and then move on to plant species and geographic variables.

FragStat (remote sensing) variables were not used in this modelling, owing to the additional computational step required to characterize them (assuming that classified satellite images are readily available).

A model consisting of 25 explanatory variables (23 variables, in fact, as two are collinear with the others) was obtained, with an R^2 of 45.8%. It has three significant axes which explain 33.9% of the variance of bird communities. It is comprised of six hydrologic variables (forced into the model), four broad habitat variables, ten plant species (secondary priority), the three hydrozones and two wetland type variables.

The 1 x 2 and 2 x 3 planes of the analysis are shown in Figures G.2.2.1 and G.2.2.2, respectively. The codes are explained in appendices C and H.

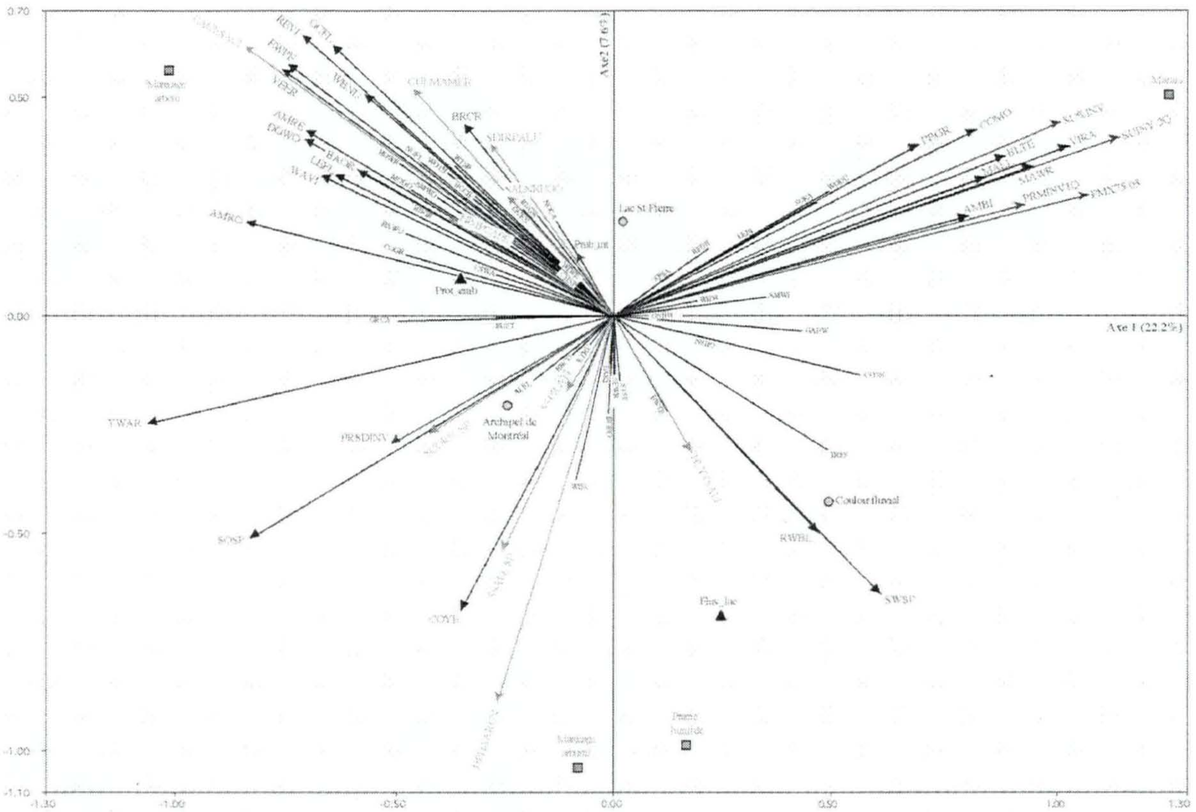


Figure G.2.2.1 Redundancy analysis; 141 sites, 63 bird species (Hellinger transformation), 25 significant explanatory variables. Selection: the forcing of wetland classes, with priority being given to hydrologic variables (brown arrows), followed by plant species (green arrows), then other explanatory variables. See Appendix H for code definitions. Plane 1x2 (29.8% of variance explained). Red: wetland classes. Orange: hydrozones. Black: Wilcox/Ingram classification. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

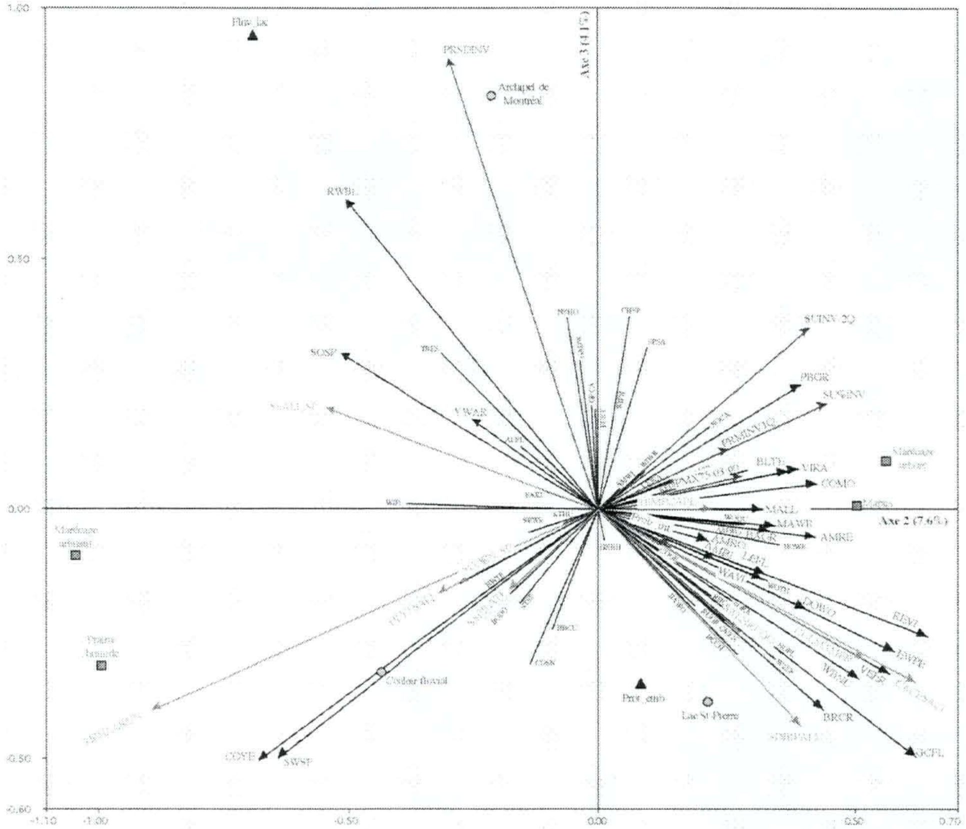


Figure G.2.2.2 Redundancy analysis; 141 sites, 63 bird species (Hellinger transformation), 25 significant explanatory variables. Selection: the forcing of wetland classes, with priority being given to hydrologic variables (brown arrows), followed by plant species (green arrows), then other explanatory variables. See Appendix H for code definitions. Plane 2x3 (11.7% of variance explained). Red: wetland classes. Orange: hydrozones. Black: DWilcox/JIngram classification. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

G.2.3 The search for an ecologically more complete explanatory model

This series of analyses, involving the same 141 sites as the ones discussed above, is reported in more detail in the February 25, 2004 report by Daniel Borcard. It involved the forcing of 10 pre-established classes of habitats into the model, followed by oriented selection of explanatory variables. The word "oriented" means that on the basis of previous knowledge and the examination of intermediate results, the significant explanatory variables were allowed into the model in a stepwise sequence, the first one being the plant species, followed by landscape and heterogeneity variables and finally the hydrological variables. The remote sensing variables (or, more precisely, the variables derived from remote sensing data by the FragStat program) were left out of the model due to the difficulty of obtaining them as well as their redundancy with the variables already allowed.

The result was a synthetic, ecological model that included 37 explanatory variables: 10 habitat classes, 15 plant species, 3 hydrozones, 2 heterogeneity variables, 4 landscape variables and 32 hydrological variables that explain 53.9% of the bird data variance. The 1 x 2 analysis plane is presented in Figure 3.2.1 and it forms part of the basis for the interpretation of the bird-habitat relationships (Section 3.2 of this Report).

Analysis by habitat class, controlled selection: The model shown below and in Figure 3.2.1, deemed very promising, required three complementary analyses in order to more accurately define the ecological needs of some species: one restricted to wooded areas (wetland categories MAF and FH), one to marshes (MP and MPP) and one to intermediate habitats (MAO, MUF, PH, TA, TE and TG). Of course, in all three cases, the reduction in the number of sites resulted in fewer bird species and the elimination of some of the possible explanatory variable classes. In all three cases, the selection was made in the following order: the forcing of habitat classes, followed by plants, hydrology and the remaining environmental variables.

The analysis involving marsh birds covered 30 sites and 31 bird species. Of the 48 possible explanatory variables, 8 were selected in addition to the two forced habitat classes. The set explains 53.8% of the bird data variance. A single canonical axis, explaining 20.6% of variance, is significant; the second is only marginally significant (p=0.08, 99 permutations). The model consists of the two habitat classes, two plant species, two hydrologic variables and four landscape variables.

The 1 x 2 plane of the analysis is shown in Figure G.2.3.1. The codes are defined in appendices C and H.

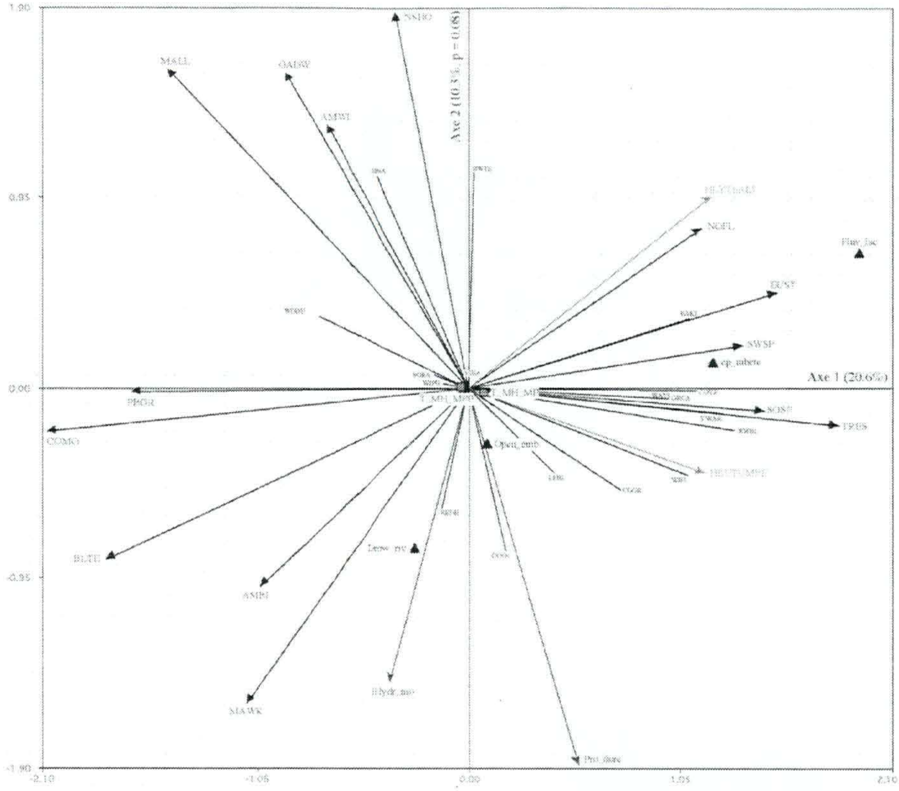


Figure G.2.3.1 Redundancy analysis; 30 marsh sites, 31 bird species (Hellinger transformation), 10 significant explanatory variables. Selection: the forcing of the 2 wetland classes, with priority being given to (1) plant species (green arrows, (2) hydrologic variables (brown arrows), (3) geographical and heterogeneity explanatory variables. See Appendix H for code definitions. Plane 1x2 (30.9% of variance explained). The first axis is significant while the second axis is marginally significant (p=0.08). Red: wetland classes. Orange: hydrozones. Black: DWilcox/JIngram classification. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

The analysis involving birds in semi-open complexes covered 84 sites and 57 bird species. Of the 75 possible explanatory variables, 17 were selected in addition to 6 classes of forced habitat. The set explains 43.3% of the bird data variance. Three canonical axes, explaining 25.8% of the variance, are significant. The model consists of the six habitat classes, 11 plant species, three hydrologic variables and three landscape and heterogeneity variables.

The 1 x 2 and 2 x 3 planes of the analysis are shown in Figures G.2.3.2 and G.2.3.3, respectively. The codes are defined in appendices C and H.

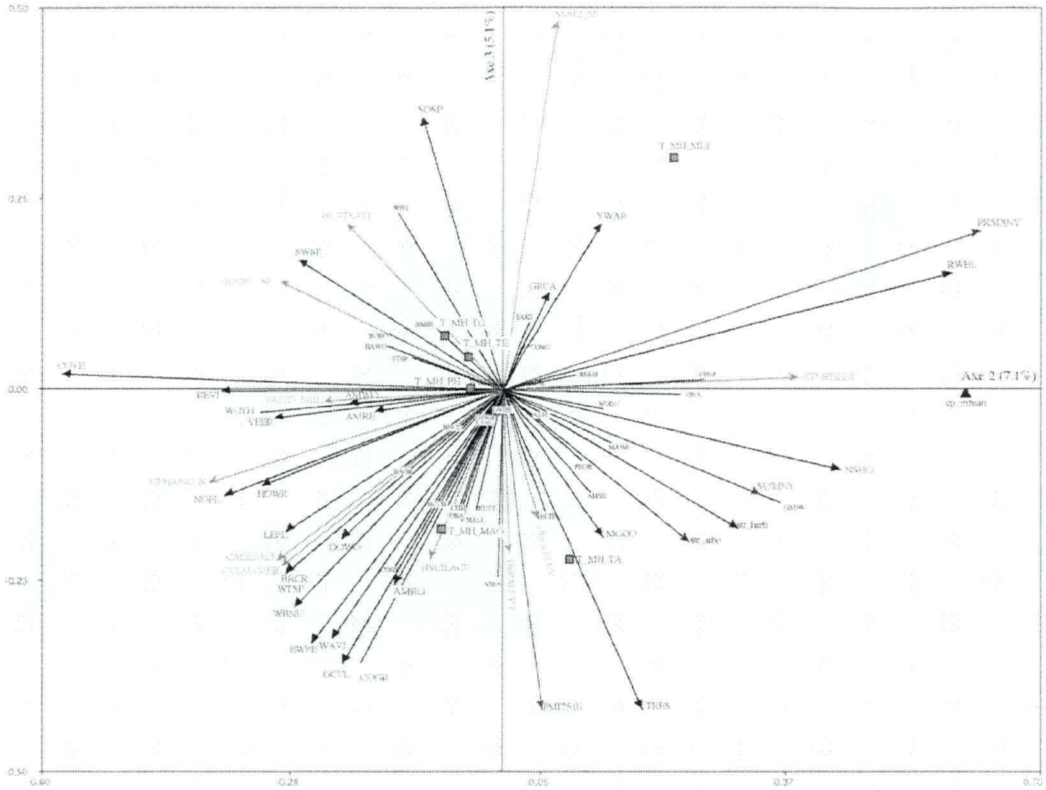


Figure G.2.3.2 Redundancy analysis; 84 treed swamp sites, 57 bird species (Hellinger transformation), 23 significant explanatory variables. Selection: the forcing of the 2 wetland classes, with priority being given to (1) plant species (green arrows, (2) hydrologic variables (brown arrows), (3) geographical and horizontal heterogeneity explanatory variables. See Appendix H for code definitions. Plane 1x2 (20.7% of variance explained). Red: wetland classes. Orange: hydrozones. Black: DWilcox/JIngram classification. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

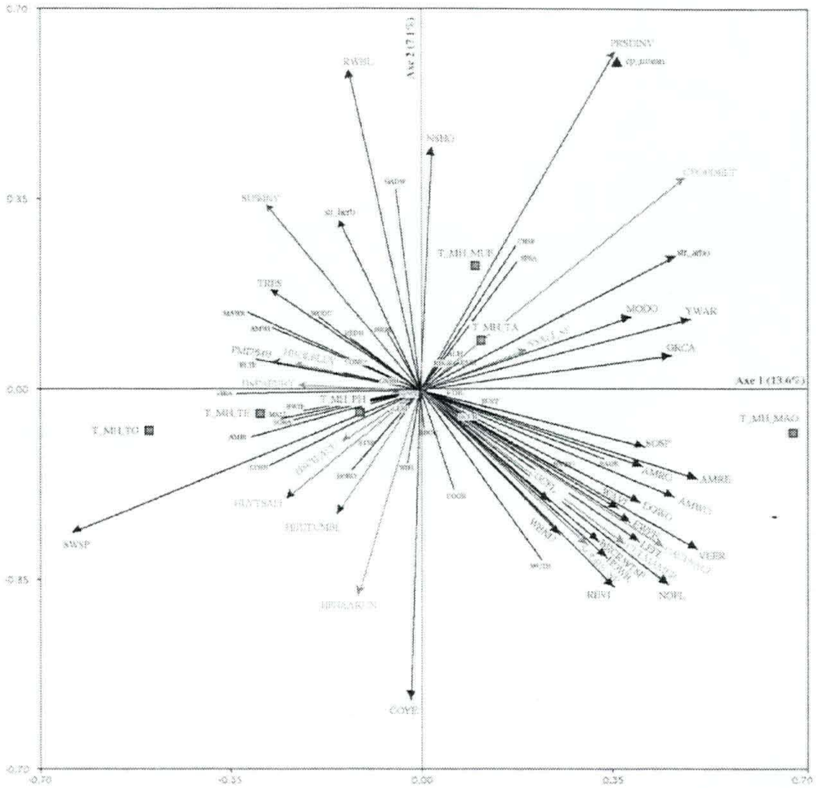


Figure G.2.3.3 Redundancy analysis; 84 treed swamp sites, 57 bird species (Hellinger transformation), 23 significant explanatory variables. Selection: the forcing of the 2 wetland classes, with priority being given to (1) plant species (green arrows), (2) hydrologic variables (brown arrows), (3) geographical and heterogeneity explanatory variables. See Appendix H for code definitions. Plane 2x3 (12.2% of variance explained). Red: wetland classes. Orange: hydrozones. Black: geographical and landscape variables. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

The analysis regarding birds in treed swamp covered 27 sites and 46 bird species. Of the 61 possible explanatory variables, 5 were selected in addition to 2 forced habitat classes. The set explains 33.4% of the bird data variance. A single canonical axis, explaining 13.7% of variance, is significant. The model consists of two habitat classes, two plant species and three hydrologic variables.

The 1 x 2 plane of the analysis is shown in Figure G.2.3.4. The codes are defined in appendices C and H.

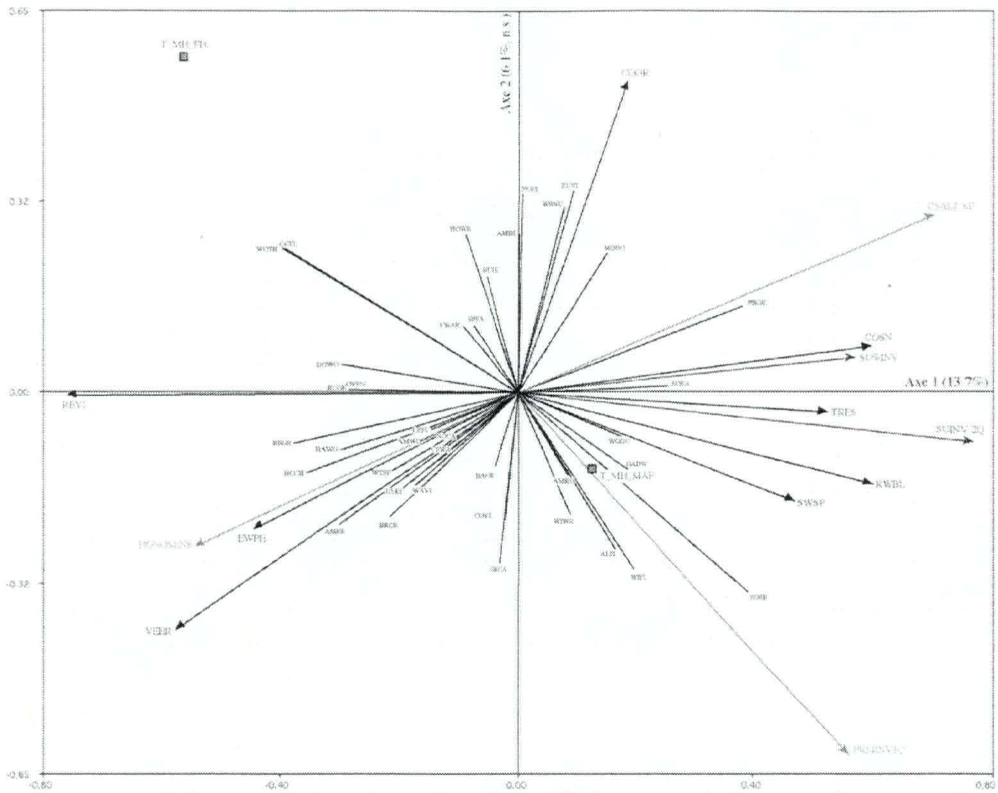


Figure G.2.3.4 Redundancy analysis; 27 treed swamp sites, 47 bird species (Hellinger transformation), 7 significant explanatory variables. Selection: the forcing of the 2 wetland classes, with priority being given to (1) plant species (green arrows, (2) hydrologic variables (brown arrows), (3) geographical and heterogeneity explanatory variables. See Appendix H for code definitions. Plane 1x2 (33.7% of variance explained). The first axis is significant while the second axis is added for graphical reasons. Red: wetland classes. Orange: hydrozones. Black: geographic and landscape variables. Angles between arrows reflect their correlations. The orthogonal projections of the centroids of binary variables onto the bird vectors reflect their relationship with the species in question. Solid-arrow bird vectors, large print: species for which at least 20% of variance is explained by the three significant axes of the analysis. The other species are represented by a headless vector and small print.

G.3.1 Variance partitioning

The purpose of this analytical component differs slightly from those above, although the overall logic is the same. Here, the significant variables are identified and the impact that the different sources of variation have on birds is quantified independently for each class of explanatory variables. The results are then reviewed to determine which fraction of the bird variance is explained independently and jointly by all of the possible combinations of the four classes of explanatory variables. In the present case involving four sets of explanatory variables, 15 canonical analyses and 27 subtractions are needed to estimate the value of the 16 variance fractions of the whole model.

During the preliminary stages, the selection of the explanatory variables from each of the four classes was done by using as many sites as possible in order to optimize the use of the information contained in the database:

- Geographic, plant and remote sensing (FragStat) variables: selection based on 341 sites (from 2002 and 2003) and 80 bird species; 95 candidate explanatory variables.
- Hydrologic variables: selection based on 215 sites (from 2002 and 2003) and 74 bird species; 21 candidate hydrologic variables.

Variance partitioning was required for a set of sites for which complete information on all of the variables was available. The set consisted of the 141 sites used in the preceding analyses. It follows that some variables that were selected are no longer represented. For instance, the binary "Lake Ontario" variable is no longer included in the reduced database, as it is limited to sites in the Montreal archipelago, the river corridor and Lac St. Pierre.

Pierre Legendre's Partitioning_X1X3 program was used to carry out the partitioning. The program allows for automatic partitioning and testing of three testable fractions for three explanatory matrices. In order to conduct the partitioning of four explanatory matrices, the results of the three partitionings had to be combined with three matrices in which the explanatory matrices were alternately combined two-by-two. Table G.3.1 below sets out the variables used for the final partitioning.

Table G.3.1 Variables for the general partitioning of bird data variance (141 sites x 63 bird species) among four explanatory variable blocks. Codes are defined in Appendix H.

Geography + heterogeneity	Vegetation	FragStat	Hydrology
Arch_MTL	CACERUBR	CP_Eauli	PMI75-03
Cou_fluv	CACESACI	CP_Marai	PSI75-03
L_StPier	CFRAPENN	CP_Marbo	PRMOINV
T_MH_FH	CPOPDELT	CP_Marbu	PRSDINV
T_MH_MAF	CULMAMER	ED_Agric	SUINV-2Q
T_MH_MAO	HBOLFLUV	ED_Eauli	SU%INV
T_MH_MP	HBUTUMBE	ED_Foret	Prob_int
T_MH_MPP	HCALCANA	ED_Frich	
T_MH_MUF	HCARE_SP	ED_Hbaqu	
T_MH_TA	HIMPCAPE	ED_Marai	
T_MH_TE	HONOSENS	ED_Marbo	
Hethoriz	HPHAARUN	ED_Marbu	
str_arbo	HSCILACU	ED_Prhum	
str_arbu	HSOLI_SP	MPARagri	
str_herb	HSPAEURY	MPARphum	
cp_mhete	HTYPH_SP	MPSeauli	
cp_mhumi	SALNRUGO	MPSmarai	
Fluv_lac	SCORN_SP	MPSmarbo	
	SILEVERT	MPSphumi	
	SMYRGALE	PN_eauli	
	SSALI_SP	PN_hbaqu	
		PN_marbo	
		PN_phumi	
		PN_zbati	

Figure G.3.1 shows a diagram of the fractions resulting from the partitioning of four explanatory matrices; Table G.3.2 sets out their values.

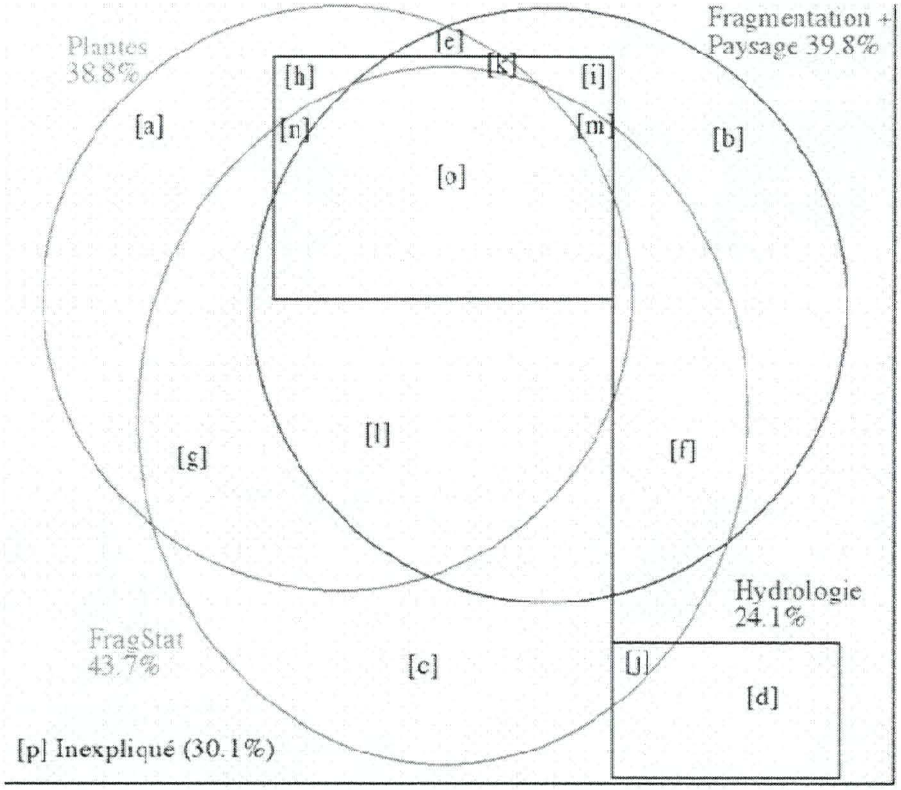


Figure G.3.1 Diagram showing the various fractions stemming from the partitioning of 4 explanatory matrices. Percents refer to total variance explained by the group of environmental variables considered.

The partitioning shows the following elements:

- Blocks of "plant species", "landscape+fragmentation" and "FragStat" variables together explain around 40% of the variance in the bird community, with an overlap of approximately 30%. Individually they account for approximately 10% (fractions [a], [b] and [c]).
- Hydrologic variables explain less variance than the other blocks, both collectively (24.1%) and individually (fraction [d], 4.0%).
- The proportion of variance explained by the four blocks of variables is high (fraction [o], 14.7%), as are the fractions of variance explained by two or three blocks of variables. This is what provides the flexibility noted earlier with respect to canonical ordination, when the decision was made to eliminate a block of explanatory variables with the expectation that elements from another block could replace it in the model.

Table G.3.2 Variance explained by various fractions during the general partitioning.

Fraction	R^2	p*	Remarks
Plants (total)	0.38822	0.005	[a]+[e]+[g]+[h]+[k]+[l]+[n]+[o]
Landscape (total)	0.39843	0.005	[b]+[e]+[f]+[i]+[k]+[l]+[m]+[o]
FragStat (total)	0.43674	0.005	[c]+[f]+[g]+[j]+[l]+[m]+[n]+[o]
Hydrology (total)	0.24111	0.005	[d]+[h]+[i]+[j]+[k]+[m]+[n]+[o]
[a]	0.10411	0.040	Unique contribution of plant species
[b]	0.10455	0.005	Unique contribution of landscape variables
[c]	0.12066	0.020	Unique contribution of FragStat variables
[d]	0.03995	0.015	Unique contribution of hydrological variables
[e]	0.00057		
[f]	0.01008		
[g]	0.01817		
[h]	0.00271		
[i]	0.00449		
[j]	0.00486		
[k]	0.00592		
[l]	0.09980		
[m]	0.02623		
[n]	0.01015		
[e]+[k]+[l]+[o]	0.25308		Variance explained by Plants + Landscape
[g]+[l]+[n]+[o]	0.27491		Variance explained by Plants + FragStat
[h]+[k]+[n]+[o]	0.16557		Variance explained by Plants + Hydrology
[f]+[l]+[m]+[o]	0.28290		Variance explained by Landscape + FragStat
[i]+[k]+[m]+[o]	0.18343		Variance explained by Landscape + Hydrology
[j]+[m]+[n]+[o]	0.18803		Variance explained by FragStat + Hydrology
[l]+[o]	0.24659		Variance expl. by Plants + Landscape + FragStat
[k]+[o]	0.15271		Variance expl. by Plants + Landscape + Hydrology
[m]+[o]	0.17302		Variance expl. By Landscape + FragStat + Hydrology
[o]	0.14679		Variance explained by the 4 sources of variation
[p]	0.30095		Unexplained variance

*probabilities are given for fractions which can be (and as been) calculated. 199 permutations.

It should be noted that the variance fractions that are common to various blocks of explanatory variables are *in no way related* to interactions in the usual sense (ANOVA). The common fractions result solely from the fact that the blocks of explanatory variables are not linearly independent (orthogonal); on the contrary, the variables comprising them are correlated from one block to another. For instance, some hydrologic variables are correlated with plant species abundance. These correlations explain why the blocks of variables partly explain the same variance in the avian data. It is also for this reason that a block of variables can be replaced relatively easily by another block in the data dealt with here: the variance fractions explained by two or more blocks of environmental variables are large.

Appendix H List (with codes) of the environmental (hydrologic and vegetation) variables considered in the statistical analysis of habitat selection by wetland.

Année	Year of the inventory
Hydrozone	Geographical section of the LOSL
SupInv	Survey plot surface area
CodeSP	Bird species code
Spp palustre	3 classes of bird species based on specialisation to wetlands
Nbr10ha_COR	Breeding pair density corrected to 10 ha
Types_MH	Major wetland types
CP_Agriculture	Percentage (%) of the quadrat consisting of agricultural lands
CP_Sol_nu	Percentage (%) of the quadrat consisting of bare soil
CP_Zone_batie	Percentage (%) of the quadrat consisting of construction
CP_Eau_libre	Percentage (%) of the quadrat consisting of open water
CP_Foret	Percentage (%) of the quadrat consisting of forests
CP_Friche	Percentage (%) of the quadrat consisting of fallows
CP_Herbier_aquatique	Percentage (%) of the quadrat consisting of emergent plants
CP_Marais	Percentage (%) of the quadrat consisting of marshes
CP_Marecage_arbore	Percentage (%) of the quadrat consisting of treed swamps
CP_Marecage_arbustif	Percentage (%) of the quadrat consisting of shrub swamps
CP_Plage_sable	Percentage (%) of the quadrat consisting of sandy beaches
CP_Prairie_humide	Percentage (%) of the quadrat consisting of wet meadows
ED_Agriculture	Length of habitat edge in the quadrat for the named habitat class
ED_Eau_libre	Length of habitat edge in the quadrat for the named habitat class
ED_Foret	Length of habitat edge in the quadrat for the named habitat class
ED_Friche	Length of habitat edge in the quadrat for the named habitat class
ED_Herbier_aquatique	Length of habitat edge in the quadrat for the named habitat class
ED_Marais	Length of habitat edge in the quadrat for the named habitat class
ED_Marecage_arbore	Length of habitat edge in the quadrat for the named habitat class
ED_Marecage_arbustif	Length of habitat edge in the quadrat for the named habitat class
ED_Prairie_humide	Length of habitat edge in the quadrat for the named habitat class
ED_Sol_nu	Length of habitat edge in the quadrat for the named habitat class
ED_Zone_batie	Length of habitat edge in the quadrat for the named habitat class
ED_Paysage_total	Length of habitat edge in the quadrat for the named habitat class
MPAR_Agriculture	Average perimeter/area ratio for the named habitat class
MPAR_Eau_libre	Average perimeter/area ratio for the named habitat class
MPAR_Foret	Average perimeter/area ratio for the named habitat class
MPAR_Friche	Average perimeter/area ratio for the named habitat class
MPAR_Herbier_aquatique	Average perimeter/area ratio for the named habitat class
MPAR_Marais	Average perimeter/area ratio for the named habitat class
MPAR_Marecage_arbore	Average perimeter/area ratio for the named habitat class
MPAR_Marecage_arbustif	Average perimeter/area ratio for the named habitat class
MPAR_Prairie_humide	Average perimeter/area ratio for the named habitat class
MPAR_Sol_nu	Average perimeter/area ratio for the named habitat class
MPAR_Zone_batie	Average perimeter/area ratio for the named habitat class
MPAR_Paysage_total	Average perimeter/area ratio for the named habitat class

Appendix H (following)

MPS_Agriculture	Average patch size in the quadrat, by habitat type
MPS_Foret	Average patch size in the quadrat, by habitat type
MPS_Friche	Average patch size in the quadrat, by habitat type
MPS_Herbier_aquatique	Average patch size in the quadrat, by habitat type
MPS_Marais	Average patch size in the quadrat, by habitat type
MPS_Marecage_arbore	Average patch size in the quadrat, by habitat type
MPS_Marecage_arbustif	Average patch size in the quadrat, by habitat type
MPS_Prairie_humide	Average patch size in the quadrat, by habitat type
MPS_Sol_nu	Average patch size in the quadrat, by habitat type
MPS_Zone_batie	Average patch size in the quadrat, by habitat type
MPS_Paysage_total	Average patch size in the quadrat, by habitat type
PN_Agriculture	Number of patches in the quadrat, by habitat type
PN_Eau_libre	Number of patches in the quadrat, by habitat type
PN_Foret	Number of patches in the quadrat, by habitat type
PN_Friche	Number of patches in the quadrat, by habitat type
PN_Herbier_aquatique	Number of patches in the quadrat, by habitat type
PN_Marais	Number of patches in the quadrat, by habitat type
PN_Marecage_arbore	Number of patches in the quadrat, by habitat type
PN_Marecage_arbustif	Number of patches in the quadrat, by habitat type
PN_Prairie_humide	Number of patches in the quadrat, by habitat type
PN_Sol_nu	Number of patches in the quadrat, by habitat type
PN_Zone_batie	Number of patches in the quadrat, by habitat type
PN_Paysage_total	Total number of patches in the landscape (all classes)
canopy1	Principal tree species
dens_c1	Density of the principal tree species
canopy2	Secondary tree species
dens_c2	Density of the secondary tree species
canopy3	Tertiary tree species
dens_c3	Density of the tertiary tree species
shrub1	Principal shrub species
dens_s1	Density of the principal shrub species
shrub2	Secondary shrub species
dens_s2	Density of the secondary shrub species
shrub3	Tertiary shrub species
dens_s3	Density of the tertiary shrub species
herbacee1	Principal herbaceous species
dens_h1	Density of the principal herbaceous species
herbacee2	Secondary herbaceous species
dens_h2	Density of the secondary herbaceous species
herbacee3	Tertiary herbaceous species
dens_h3	Density of the tertiary herbaceous species
Clas_pertu	Intensity of disturbance class
Hétér. horizontale 1	Number of habitat classes in the remote sensing map
. formes de milieux >25%	Number of habitat classes > 25% in the remote sensing map
. strates arborées	Number of tree strata (1 to 3)
. strates arbustives	Number of shrub strata (1 to 3)
. strates herbacées	Number of herbaceous strata (1 to 3)

Appendix H (following)

Hétéro. verticale	Sum of the tree, shrub and herbaceous strata
Hauteur arbre (m)	Tree strata height (m)
Hauteur arbuste (m)	Shrub strata height (m)
Hauteur herbacée (m)	Herbaceous strata height (m)
Eau dans la végétation	Water in vegetation (damp to flooded)
Niveau de l'eau libre	Open water depth
Niveau de l'eau végétation	Water depth in the vegetation (5 classes of depth)
Contextes paysagers	Landscape context (qualitative variables)
Paysage	Landscape (Heterogeneous vs homogeneous)
Longitude	Longitude
Latitude	Latitude
Sites_insulaires	Located on an island or not (1 or 0)
Sites_aménagés	Impoundment or not (1 or 0)
Morphologie de la rive	Bank morphology (Classification from DesGranges et Ducruc 2000)
Nat_geomorpho_rive	DFO shoreline classification

Appendix I Bird species found in the four major habitat types along the wetland hydrosphere, together with data on their abundance (density and occurrence).

#	Code	Engligh Name	Marsh Habitat					Wet meadow habitat					Total
			X	SD	MIN	MAX	Oc %	X	SD	MIN	MAX	Oc %	Oc %
1	RWBL	Red-winged Blackbird	0,696	0,472	0,167	2,355	100	0,896	0,612	0	2,472	95	91
2	SWSP	Swamp Sparrow	0,599	0,560	0	1,876	84	0,742	0,486	0	2,151	89	72
3	YWAR	Yellow Warbler	0,017	0,081	0	0,447	6	0,370	0,369	0	1,847	73	71
4	SOSP	Song Sparrow	0,111	0,313	0	1,513	19	0,276	0,267	0	1,352	71	69
5	COYE	Common Yellowthroat	0,024	0,059	0	0,240	16	0,283	0,246	0	0,961	68	56
6	COSN	Common Snipe	0,136	0,146	0	0,463	58	0,116	0,161	0	0,844	49	45
7	TRES	Tree Swallow	0,318	0,403	0	2,006	81	0,137	0,229	0	1,028	40	45
8	AMRO	American Robin	0	0	0	0	0	0,118	0,254	0	1,528	29	42
9	MAWR	Marsh Wren	0,533	0,514	0	1,867	81	0,218	0,396	0	1,599	31	29
10	COGR	Common Grackle	0,033	0,117	0	0,525	10	0,068	0,150	0	0,525	22	29
11	WAVI	Warbling Vireo	0,003	0,015	0	0,086	3	0,018	0,049	0	0,271	14	29
12	BLTE	Black Tern	0,300	0,281	0	1,134	74	0,055	0,134	0	0,694	19	23
13	AMBI	American Bittern	0,114	0,109	0	0,391	71	0,039	0,086	0	0,414	22	21
14	BAOR	Baltimore Oriole	0	0	0	0	0	0,017	0,048	0	0,232	13	21
15	VIRA	Virginia Rail	0,164	0,123	0	0,492	84	0,021	0,064	0	0,420	13	20
16	EWPE	Eastern Wood-Pewee	0	0	0	0	0	0,004	0,023	0	0,141	3	19
17	VEER	Veery	0	0	0	0	0	0,007	0,031	0	0,174	4	19
18	GCFL	Great Crested Flycatcher	0	0	0	0	0	0,013	0,044	0	0,182	8	18
19	PBGR	Pied-billed Grebe	0,098	0,108	0	0,332	55	0,019	0,077	0	0,487	9	17
20	GRCA	Gray Catbird	0,004	0,024	0	0,135	3	0,008	0,034	0	0,247	5	17
21	DOWO	Downy Woodpecker	0	0	0	0	0	0,007	0,041	0	0,262	3	16
22	GADW	Gadwall	0,128	0,207	0	0,725	39	0,042	0,117	0	0,550	14	15
23	MODO	Mourning Dove	0	0	0	0	0	0,011	0,038	0	0,156	8	15
24	WIFL	Willow Flycatcher	0,011	0,047	0	0,236	6	0,022	0,048	0	0,213	21	15
25	EUST	European Starling	0,010	0,042	0	0,216	6	0,041	0,179	0	1,537	10	14
26	SORA	Sora	0,037	0,073	0	0,333	29	0,016	0,042	0	0,217	15	14
27	LEFL	Least Flycatcher	0	0	0	0	0	0,004	0,018	0	0,098	4	13
28	COMO	Common Moorhen	0,194	0,240	0	0,935	52	0,022	0,091	0	0,562	8	13
29	EAKI	Eastern Kingbird	0,012	0,049	0	0,234	6	0,027	0,062	0	0,310	19	13
30	AMRE	American Redstart	0	0	0	0	0	0	0	0	0	0	12
31	MALL	Mallard	0,295	0,428	0	1,703	55	0,020	0,076	0	0,435	8	12
32	NOFL	Northern Flicker	0,005	0,030	0	0,167	3	0,005	0,029	0	0,165	3	10
33	WBNU	White-breasted Nuthatch	0	0	0	0	0	0,002	0,018	0	0,176	1	9
34	REVI	Red-eyed Vireo	0	0	0	0	0	0	0	0	0	0	9
35	HOWR	House Wren	0	0	0	0	0	0,002	0,016	0	0,112	2	8
36	HAWO	Hairy Woodpecker	0	0	0	0	0	0,004	0,024	0	0,183	2	7
37	WODU	Wood Duck	0,047	0,080	0	0,231	29	0,023	0,157	0	1,463	4	7
38	ALFL	Alder Flycatcher	0	0	0	0	0	0,011	0,050	0	0,301	4	6
39	NSHO	Northern Shoveler	0,054	0,163	0	0,804	16	0	0	0	0	3	6
40	RBGR	Rose-breasted Grosbeak	0	0	0	0	0	0,003	0,014	0	0,076	3	6
41	BOBO	Bobolink	0	0	0	0	0	0,013	0,044	0	0,315	12	5
42	SPSA	Spotted Sandpiper	0,014	0,038	0	0,152	13	0,005	0,026	0	0,202	4	5
43	SAVS	Savannah Sparrow	0	0	0	0	0	0,040	0,132	0	0,685	11	5
44	BCCH	Black-capped Chickadee	0	0	0	0	0	0,001	0,009	0	0,083	1	5
45	BBCU	Black-billed Cuckoo	0	0	0	0	0	0,007	0,036	0	0,197	3	4
46	WOTH	Wood Thrush	0	0	0	0	0	0	0	0	0	0	4
47	AMWO	American Woodcock	0	0	0	0	0	0	0	0	0	0	4
48	AMWI	American Wigeon	0,021	0,057	0	0,230	13	0,003	0,023	0	0,190	2	3
49	WTSP	White-throated Sparrow	0	0	0	0	0	0	0	0	0	0	3
50	LEBI	Least Bittern	0,006	0,023	0	0,094	6	0,004	0,018	0	0,089	4	3
51	BRCR	Brown Creeper	0	0	0	0	0	0	0	0	0	0	2
52	AMCO	American Coot	0,006	0,035	0	0,197	3	0,004	0,029	0	0,197	0	2
53	REDH	Redhead	0,015	0,083	0	0,461	3	0,005	0,038	0	0,343	0	2
54	BWTE	Blue-winged Teal	0,003	0,018	0	0,099	3	0,002	0,016	0	0,108	0	1
55	CSWA	Chestnut-sided Warbler	0	0	0	0	0	0	0	0	0	7	1
56	EAME	Eastern Meadowlark	0	0	0	0	0	0,003	0,020	0	0,171	0	1
57	NAWA	Nashville Warbler	0	0	0	0	0	0,002	0,018	0	0,171	0	1
58	OVEN	Ovenbird	0	0	0	0	0	0	0	0	0	3	1
59	SEWR	Sedge Wren	0	0	0	0	0	0,002	0,013	0	0,091	0	1
60	BAWW	Black-and-white Warbler	0	0	0	0	0	0	0	0	0	0	0
61	BTBW	Black-throated Blue Warbler	0	0	0	0	0	0	0	0	0	0	0
62	CHSP	Chipping Sparrow	0	0	0	0	0	0	0	0	0	0	0
63	EAPH	Eastern Phoebe	0	0	0	0	0	0,002	0,018	0	0,171	0	0
64	GNBH	Green Heron	0	0	0	0	0	0,002	0,023	0	0,221	0	0
65	KILL	Killdeer	0	0	0	0	0	0	0	0	0	0	0
66	MOWA	Mourning Warbler	0	0	0	0	0	0	0	0	0	0	0
67	NOCA	Northern Cardinal	0	0	0	0	0	0	0	0	0	3	0
68	RTHU	Ruby-throated Hummingbird	0	0	0	0	0	0	0	0	0	0	0
69	RUGR	Ruffed Grouse	0	0	0	0	0	0	0	0	0	3	0
70	STSP	Nelson's Sharp-tailed Sparrow	0	0	0	0	0	0,001	0,010	0	0,100	0	0
71	UPSA	Upland Sandpiper	0	0	0	0	0	0,002	0,018	0	0,171	0	0
72	WIWR	Winter Wren	0	0	0	0	0	0	0	0	0	3	0

Appendix I (following)

			Shrub Swamp Habitat					Treed Swamp Habitat					Total
#	Code	English Name	X	SD	MIN	MAX	Oc %	X	SD	MIN	MAX	Oc %	Oc %
1	RWBL	Red-winged Blackbird	0,842	0,444	0	2,449	98	0,470	0,463	0	1,236	60	91
2	SWSP	Swamp Sparrow	0,405	0,455	0	1,592	62	0,094	0,161	0	0,398	30	72
3	YWAR	Yellow Warbler	0,723	0,464	0	2,510	93	0,801	0,597	0	3,251	97	71
4	SOSP	Song Sparrow	0,450	0,333	0	1,508	85	0,341	0,292	0	1,238	80	69
5	COYE	Common Yellowthroat	0,299	0,257	0	1,010	71	0,112	0,179	0	0,526	33	56
6	COSN	Common Snipe	0,082	0,104	0	0,360	44	0,044	0,086	0	0,338	23	45
7	TRES	Tree Swallow	0,206	0,298	0	1,280	44	0,140	0,288	0	1,280	27	45
8	AMRO	American Robin	0,321	0,315	0	1,109	65	0,396	0,276	0	1,178	83	42
9	MAWR	Marsh Wren	0,054	0,159	0	0,810	13	0	0	0	0	0	29
10	COGR	Common Grackle	0,249	0,434	0	1,982	36	0,281	0,351	0	1,576	57	29
11	WAVI	Warbling Vireo	0,094	0,110	0	0,406	51	0,092	0,086	0	0,315	60	29
12	BLTE	Black Tern	0,041	0,150	0	0,833	9	0,017	0,065	0	0,278	7	23
13	AMBI	American Bittern	0,002	0,016	0	0,117	2	0,005	0,025	0	0,138	3	21
14	BAOR	Baltimore Oriole	0,049	0,076	0	0,232	35	0,067	0,088	0	0,286	43	21
15	VIRA	Virginia Rail	0,013	0,055	0	0,355	7	0	0	0	0	0	20
16	EWPE	Eastern Wood-Pewee	0,058	0,089	0	0,282	35	0,105	0,102	0	0,366	60	19
17	VEER	Veery	0,075	0,128	0	0,622	35	0,152	0,181	0	0,646	53	19
18	GCFL	Great Crested Flycatcher	0,051	0,099	0	0,364	24	0,118	0,118	0	0,375	57	18
19	PBGR	Pied-billed Grebe	0,022	0,058	0	0,244	15	0,008	0,031	0	0,122	7	17
20	GRCA	Gray Catbird	0,056	0,077	0	0,329	40	0,031	0,058	0	0,179	23	17
21	DOWO	Downy Woodpecker	0,081	0,144	0	0,670	29	0,149	0,174	0	0,602	50	16
22	GADW	Gadwall	0,035	0,107	0	0,550	11	0,009	0,050	0	0,275	3	15
23	MODO	Mourning Dove	0,059	0,124	0	0,623	27	0,050	0,074	0	0,223	33	15
24	WIFL	Willow Flycatcher	0,026	0,059	0	0,258	18	0,003	0,016	0	0,086	3	15
25	EUST	European Starling	0,035	0,109	0	0,615	15	0,093	0,157	0	0,615	33	14
26	SORA	Sora	0,002	0,015	0	0,108	2	0,014	0,037	0	0,108	13	14
27	LEFL	Least Flycatcher	0,032	0,071	0	0,293	22	0,054	0,084	0	0,311	37	13
28	COMO	Common Moorhen	0,014	0,059	0	0,338	5	0	0	0	0	0	13
29	EAKI	Eastern Kingbird	0,019	0,060	0	0,337	11	0,005	0,028	0	0,155	3	13
30	AMRE	American Redstart	0,048	0,122	0	0,599	16	0,131	0,148	0	0,477	53	12
31	MALL	Mallard	0	0	0	0	0	0	0	0	0	0	12
32	NOFL	Northern Flicker	0,029	0,068	0	0,304	18	0,035	0,065	0	0,164	23	10
33	WBNU	White-breasted Nuthatch	0,033	0,108	0	0,575	11	0,134	0,184	0	0,621	40	9
34	REVI	Red-eyed Vireo	0,011	0,043	0	0,236	7	0,085	0,119	0	0,534	47	9
35	HOWR	House Wren	0,013	0,043	0	0,259	13	0,035	0,067	0	0,210	27	8
36	HAWO	Hairy Woodpecker	0,021	0,058	0	0,257	13	0,041	0,091	0	0,283	20	7
37	WODU	Wood Duck	0	0	0	0	0	0,007	0,038	0	0,209	3	7
38	ALFL	Alder Flycatcher	0,029	0,089	0	0,432	11	0,023	0,069	0	0,228	10	6
39	NSHO	Northern Shoveler	0,013	0,045	0	0,171	7	0,006	0,032	0	0,195	0	6
40	RBGR	Rose-breasted Grosbeak	0,004	0,017	0	0,076	5	0,017	0,035	0	0,109	20	6
41	BOBO	Bobolink	0	0	0	0	0	0	0	0	0	0	5
42	SPSA	Spotted Sandpiper	0,004	0,022	0	0,119	4	0,004	0,022	0	0,119	3	5
43	SAVS	Savannah Sparrow	0	0	0	0	0	0	0	0	0	0	5
44	BCCH	Black-capped Chickadee	0,010	0,034	0	0,167	9	0,017	0,046	0	0,167	13	5
45	BBCU	Black-billed Cuckoo	0,011	0,042	0	0,197	7	0,004	0,026	0	0,197	3	4
46	WOTH	Wood Thrush	0,002	0,015	0	0,111	2	0,074	0,184	0	0,919	23	4
47	AMWO	American Woodcock	0,018	0,053	0	0,219	11	0,010	0,037	0	0,171	7	4
48	AMWI	American Wigeon	0	0	0	0	0	0	0	0	0	0	3
49	WTSP	White-throated Sparrow	0,004	0,019	0	0,111	4	0,017	0,048	0	0,182	13	3
50	LEBI	Least Bittern	0	0	0	0	0	0	0	0	0	0	3
51	BRCR	Brown Creeper	0,002	0,013	0	0,071	4	0,009	0,030	0	0,138	10	2
52	AMCO	American Coot	0,004	0,027	0	0,197	2	0	0	0	0	2	2
53	REDH	Redhead	0,003	0,023	0	0,171	2	0	0	0	0	2	2
54	BWTE	Blue-winged Teal	0	0	0	0	0	0	0	0	0	2	1
55	CSWA	Chestnut-sided Warbler	0	0	0	0	0	0,009	0,034	0	0,135	0	1
56	EAME	Eastern Meadowlark	0	0	0	0	0	0	0	0	0	2	1
57	NAWA	Nashville Warbler	0,003	0,023	0	0,171	2	0	0	0	0	1	1
58	OVEN	Ovenbird	0,003	0,023	0	0,171	2	0,015	0,084	0	0,459	0	1
59	SEWR	Sedge Wren	0	0	0	0	0	0	0	0	0	2	1
60	BAWW	Black-and-white Warbler	0,003	0,020	0	0,149	2	0	0	0	0	0	0
61	BTBW	Black-throated Blue Warbler	0,003	0,023	0	0,171	1	0	0	0	0	0	0
62	CHSP	Chipping Sparrow	0,003	0,023	0	0,171	1	0	0	0	0	0	0
63	EAPH	Eastern Phoebe	0	0	0	0	0	0	0	0	0	1	0
64	GNBH	Green Heron	0	0	0	0	0	0	0	0	0	1	0
65	KILL	Killdeer	0,002	0,013	0	0,098	2	0	0	0	0	0	0
66	MOWA	Mourning Warbler	0,003	0,023	0	0,171	2	0	0	0	0	0	0
67	NOCA	Northern Cardinal	0	0	0	0	0	0,006	0,031	0	0,171	0	0
68	RTHU	Ruby-throated Hummingbird	0,003	0,023	0	0,171	2	0	0	0	0	0	0
69	RUGR	Ruffed Grouse	0	0	0	0	0	0,002	0,014	0	0,075	0	0
70	STSP	Nelson's Sharp-tailed Sparrow	0	0	0	0	0	0	0	0	0	1	0
71	UPSA	Upland Sandpiper	0	0	0	0	0	0	0	0	0	1	0
72	WIWR	Winter Wren	0	0	0	0	0	0,006	0,031	0	0,171	0	0

Appendix J Species composition and estimated density of nesting pairs in the 10 types of bird assemblages found along the wetland hydrosphere over four years of field work

#	Code	English Name	Damp Forest (n=12)					Closed Treed Swamp (n = 39)					Open Treed Swamp (n = 49)				
			X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%
1	RWBL	Red-winged Blackbird	1.61	3.76	0.00	9.66	17	6.51	6.89	0.00	19.32	62	12.78	8.96	0.00	38.63	90
2	SWSP	Swamp Sparrow	0.51	1.76	0.00	6.08	8	2.51	3.51	0.00	12.44	41	5.59	6.55	0.00	24.87	57
3	YWAR	Yellow Warbler	11.66	7.84	0.00	19.73	75	10.23	9.51	0.00	50.80	87	9.24	5.94	0.00	30.99	86
4	COYE	Common Yellowthroat	2.55	3.40	0.00	7.74	42	1.89	3.20	0.00	15.49	36	5.48	4.13	0.00	18.53	78
5	SOSP	Song Sparrow	4.12	4.32	0.00	12.67	58	4.74	4.16	0.00	19.35	82	7.37	5.44	0.00	23.56	86
6	TRES	Tree Swallow	0.42	1.44	0.00	5.00	8	1.77	4.02	0.00	20.01	26	4.54	8.00	0.00	43.10	41
7	COSN	Common Snipe	0.00	0.00	0.00	0.00	0	0.53	1.21	0.00	5.27	18	0.75	1.35	0.00	5.27	27
8	MAWR	Marsh Wren	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.58	2.07	0.00	12.65	10
9	AMRO	American Robin	4.82	5.42	0.00	14.32	58	7.28	5.29	0.00	24.89	90	5.04	5.15	0.00	17.33	61
10	COGR	Common Grackle	1.55	2.80	0.00	6.19	25	3.68	4.96	0.00	24.62	54	4.68	7.51	0.00	30.97	45
11	AMBI	American Bittern	0.00	0.00	0.00	0.00	0	0.11	0.48	0.00	2.16	5	0.19	0.65	0.00	3.13	8
12	WIFL	Willow Flycatcher	0.11	0.39	0.00	1.35	8	0.10	0.48	0.00	2.69	5	0.26	0.68	0.00	2.69	14
13	WAVI	Warbling Vireo	0.35	0.82	0.00	2.12	17	1.52	1.55	0.00	5.87	59	1.72	1.77	0.00	6.35	57
14	GRCA	Gray Catbird	0.80	0.99	0.00	1.93	42	0.78	1.09	0.00	3.44	36	0.69	1.05	0.00	3.86	33
15	BAOR	Baltimore Oriole	0.60	1.18	0.00	3.63	25	1.11	1.60	0.00	7.60	44	1.02	1.20	0.00	3.63	49
16	VEER	Veery	3.39	2.53	0.00	8.14	75	3.16	4.66	0.00	20.94	49	1.28	2.10	0.00	9.71	37
17	EAKI	Eastern Kingbird	0.00	0.00	0.00	0.00	0	0.17	0.59	0.00	2.42	8	0.49	1.36	0.00	6.96	16
18	GCFL	Great Crested Flycatcher	1.51	1.72	0.00	5.08	50	1.86	1.72	0.00	5.86	59	1.09	1.71	0.00	5.69	33
19	EWPE	Eastern Wood-Pewee	1.44	1.71	0.00	4.41	50	1.63	1.56	0.00	5.71	64	1.16	1.43	0.00	4.41	45
20	VIRA	Virginia Rail	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.05	0.32	0.00	2.23	2
21	PBGR	Pied-billed Grebe	0.00	0.00	0.00	0.00	0	0.10	0.43	0.00	1.90	5	0.19	0.58	0.00	2.34	10
22	ALFL	Alder Flycatcher	0.87	1.58	0.00	3.56	25	0.26	0.91	0.00	3.56	8	0.22	1.13	0.00	7.11	4
23	BLTE	Black Tern	0.00	0.00	0.00	0.00	0	0.20	0.89	0.00	4.34	5	0.72	2.50	0.00	13.02	10
24	MODO	Mourning Dove	0.60	1.09	0.00	2.43	25	0.78	1.16	0.00	3.48	33	0.99	2.03	0.00	9.73	29
25	AMRE	American Redstart	1.81	2.46	0.00	6.19	42	2.41	2.63	0.00	9.75	59	1.03	2.06	0.00	9.35	24
26	DOWO	Downy Woodpecker	1.02	1.85	0.00	4.09	25	2.01	2.62	0.00	9.41	44	1.38	2.50	0.00	10.46	29
27	MALL	Mallard	0.00	0.00	0.00	0.00	0	0.09	0.56	0.00	3.53	3	0.51	2.39	0.00	14.95	6
28	WODU	Wood Duck	0.00	0.00	0.00	0.00	0	0.36	1.08	0.00	4.17	10	0.37	1.68	0.00	9.38	6
29	GADW	Gadwall	0.00	0.00	0.00	0.00	0	0.11	0.69	0.00	4.29	3	0.58	1.67	0.00	8.22	12
30	EUST	European Starling	1.20	2.99	0.00	9.61	17	1.25	2.70	0.00	13.88	31	0.91	2.24	0.00	9.61	20
31	LEFL	Least Flycatcher	0.13	0.44	0.00	1.52	8	1.00	1.36	0.00	4.86	44	0.70	1.29	0.00	4.57	29
32	NOFL	Northern Flicker	0.20	0.69	0.00	2.38	8	0.54	1.01	0.00	2.56	23	0.65	1.19	0.00	4.76	27
33	COMO	Common Moorhen	0.00	0.00	0.00	0.00	0	0.06	0.35	0.00	2.20	3	0.33	1.41	0.00	8.41	6
34	SORA	Sora	0.00	0.00	0.00	0.00	0	0.17	0.52	0.00	1.69	10	0.03	0.23	0.00	1.62	2
35	REVI	Red-eyed Vireo	1.98	2.16	0.00	6.76	58	1.43	1.95	0.00	8.34	46	0.26	0.83	0.00	4.51	10
36	BCCH	Black-capped Chickadee	0.69	1.44	0.00	4.63	25	0.61	0.99	0.00	3.44	31	0.11	0.46	0.00	2.27	6
37	WBNU	White-breasted Nuthatch	0.37	1.30	0.00	4.50	8	1.69	2.67	0.00	9.70	33	0.63	1.81	0.00	8.98	14

Appendix J (following)

#	Code	English Name	Damp Forest (n=12) X	SD	MIN	MAX	Oc%	Closed Treed Swamp (n = 39) X	SD	MIN	MAX	Oc%	Open Treed Swamp (n = 49) X	SD	MIN	MAX	Oc%
38	RBGR	Rose-breasted Grosbeak	0.20	0.46	0.00	1.19	17	0.31	0.58	0.00	1.69	23	0.07	0.29	0.00	1.19	6
39	BOBO	Bobolink	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
40	AMGO	American Goldfinch	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.21	0.73	0.00	3.07	8
41	GNBH	Green Heron	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.28	1.15	0.00	5.84	6
42	SPSA	Spotted Sandpiper	0.00	0.00	0.00	0.00	0	0.05	0.30	0.00	1.85	3	0.08	0.37	0.00	1.85	4
43	HOWR	House Wren	0.52	1.01	0.00	3.09	25	0.28	0.80	0.00	3.28	15	0.22	0.71	0.00	4.04	12
44	HAWO	Hairy Woodpecker	0.00	0.00	0.00	0.00	0	0.68	1.45	0.00	4.42	21	0.17	0.57	0.00	2.44	8
45	NSHO	Northern Shoveler	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.11	0.54	0.00	2.68	4
46	LEBI	Least Bittern	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.02	0.13	0.00	0.94	2
47	SAVS	Savannah Sparrow	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
48	BBCU	Black-billed Cuckoo	0.00	0.00	0.00	0.00	0	0.08	0.49	0.00	3.07	3	0.14	0.56	0.00	3.07	6
49	NOWA	Northern Waterthrush	0.48	1.12	0.00	3.07	17	0.36	0.96	0.00	3.07	13	0.11	0.54	0.00	2.68	4
50	WOTH	Wood Thrush	1.63	2.53	0.00	6.15	33	0.93	2.85	0.00	14.35	13	0.04	0.25	0.00	1.74	2
51	SEWR	Sedge Wren	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.03	0.18	0.00	1.24	2
52	WTSP	White-throated Sparrow	0.24	0.58	0.00	1.73	17	0.23	0.73	0.00	2.84	10	0.11	0.46	0.00	2.34	6
53	AMWO	American Woodcock	0.22	0.77	0.00	2.68	8	0.05	0.29	0.00	1.79	3	0.36	0.93	0.00	3.43	14
54	BHCO	Brown-headed Cowbird	0.26	0.89	0.00	3.07	8	0.08	0.49	0.00	3.07	3	0.13	0.88	0.00	6.15	2
55	BRCR	Brown Creeper	0.00	0.00	0.00	0.00	0	0.22	0.56	0.00	2.15	15	0.06	0.25	0.00	1.11	6
56	AMCO	American Coot	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
57	AMWI	American Wigeon	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
58	BWTE	Blue-winged Teal	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.04	0.25	0.00	1.72	2
59	CSWA	Chestnut-sided Warbler	0.00	0.00	0.00	0.00	0	0.22	0.68	0.00	3.06	10	0.00	0.00	0.00	0.00	0
60	RTHU	Ruby-throated Hummingbird	0.00	0.00	0.00	0.00	0	0.07	0.43	0.00	2.68	3	0.11	0.54	0.00	2.68	4
61	AMCR	American Crow	0.00	0.00	0.00	0.00	0	0.08	0.49	0.00	3.07	3	0.18	0.95	0.00	6.15	4
62	BLJA	Blue Jay	0.77	1.91	0.00	6.15	17	0.00	0.00	0.00	0.00	0	0.13	0.61	0.00	3.07	4
63	KILL	Killdeer	0.00	0.00	0.00	0.00	0	0.04	0.24	0.00	1.53	3	0.00	0.00	0.00	0.00	0
64	OVEN	Ovenbird	1.44	2.81	0.00	8.03	25	0.33	1.30	0.00	7.18	5	0.05	0.38	0.00	2.68	2
65	REDH	Redhead	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.05	0.38	0.00	2.68	2
66	BAWW	Black-and-white Warbler	0.32	0.74	0.00	1.90	17	0.09	0.56	0.00	3.51	3	0.05	0.33	0.00	2.33	2
67	CWAX	Cedar Waxwing	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.29	1.03	0.00	5.35	8
68	NOCA	Northern Cardinal	0.48	1.12	0.00	3.07	17	0.16	0.69	0.00	3.44	5	0.00	0.00	0.00	0.00	0
69	SCTA	Scarlet Tanager	0.22	0.77	0.00	2.68	8	0.07	0.43	0.00	2.68	3	0.05	0.38	0.00	2.68	2
70	YBSA	Yellow-bellied Sapsucker	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.25	1.08	0.00	5.35	6
71	EAPH	Eastern Phoebe	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
72	GTBH	Great Blue Heron	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.03	0.19	0.00	1.34	2
73	CAGO	Canada Goose	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.06	0.44	0.00	3.07	2
74	CLSW	Cliff Swallow	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
75	GBBG	Great Black-backed Gull	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
76	RUGR	Ruffed Grouse	0.00	0.00	0.00	0.00	0	0.06	0.26	0.00	1.17	5	0.00	0.00	0.00	0.00	0

Appendix J (following)

			Closed Shrub Swamp (n = 41)					Shrub Ecocomplex (n = 39)					Grass Ecocomplex (n = 89)				
#	Code	English Name	X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%
1	RWBL	Red-winged Blackbird	9.27	5.49	0.00	19.56	90	11.42	7.65	0.00	38.26	92	11.87	9.13	0.00	36.22	94
2	SWSP	Swamp Sparrow	11.35	7.97	0.00	31.09	90	11.71	7.85	0.00	31.09	82	11.26	7.59	0.00	33.61	89
3	YWAR	Yellow Warbler	10.94	5.70	0.00	28.69	98	9.72	7.61	0.00	39.22	90	5.71	5.12	0.00	28.85	78
4	COYE	Common Yellowthroat	6.38	5.05	0.00	18.00	76	5.35	4.34	0.00	15.78	79	4.69	3.50	0.00	15.02	75
5	SOSP	Song Sparrow	3.91	3.76	0.00	12.67	66	3.69	3.79	0.00	12.67	64	4.01	4.19	0.00	21.12	64
6	TRES	Tree Swallow	3.04	3.44	0.00	10.00	49	3.75	4.35	0.00	20.01	59	3.15	5.38	0.00	37.51	46
7	COSN	Common Snipe	2.07	2.10	0.00	7.84	59	1.58	1.64	0.00	5.81	54	1.48	2.23	0.00	13.19	43
8	MAWR	Marsh Wren	0.87	2.93	0.00	14.67	7	2.16	3.40	0.00	12.65	33	2.66	4.99	0.00	25.31	29
9	AMRO	American Robin	3.56	4.19	0.00	14.32	49	3.13	3.55	0.00	14.32	54	1.92	4.02	0.00	23.87	30
10	COGR	Common Grackle	2.36	3.85	0.00	18.58	37	3.28	5.16	0.00	18.58	36	1.12	2.40	0.00	8.21	20
11	AMBI	American Bittern	0.44	1.11	0.00	4.46	15	0.47	0.98	0.00	3.41	21	0.75	1.47	0.00	6.47	25
12	WIFL	Willow Flycatcher	1.73	2.24	0.00	13.43	66	0.97	1.28	0.00	4.04	41	0.48	0.89	0.00	3.36	27
13	WAVI	Warbling Vireo	0.17	0.54	0.00	2.12	10	0.59	1.14	0.00	3.91	23	0.26	0.75	0.00	4.23	12
14	GRCA	Gray Catbird	1.06	1.61	0.00	7.47	41	0.74	1.03	0.00	3.96	38	0.12	0.54	0.00	3.87	6
15	BAOR	Baltimore Oriole	0.34	1.26	0.00	7.60	12	0.62	1.49	0.00	7.60	21	0.30	0.78	0.00	3.63	15
16	VEER	Veery	1.80	3.38	0.00	14.72	34	0.84	2.07	0.00	8.14	18	0.11	0.50	0.00	2.71	4
17	EAKI	Eastern Kingbird	0.82	1.65	0.00	6.88	24	0.74	1.39	0.00	5.92	26	0.42	0.96	0.00	4.84	18
18	GCFL	Great Crested Flycatcher	0.17	0.61	0.00	2.54	7	0.50	1.26	0.00	5.52	15	0.17	0.65	0.00	2.84	7
19	EWPE	Eastern Wood-Pewee	0.00	0.00	0.00	0.00	0	0.08	0.37	0.00	1.90	5	0.05	0.31	0.00	2.20	2
20	VIRA	Virginia Rail	0.24	0.98	0.00	5.55	7	0.21	0.65	0.00	2.73	10	0.16	0.55	0.00	3.70	8
21	PBGR	Pied-billed Grebe	0.22	0.72	0.00	3.67	10	0.29	0.81	0.00	3.81	13	0.23	1.16	0.00	7.61	6
22	ALFL	Alder Flycatcher	2.76	3.45	0.00	13.78	49	1.21	2.31	0.00	9.45	26	0.43	1.27	0.00	6.75	11
23	BLTE	Black Tern	0.19	0.77	0.00	4.34	5	0.11	0.69	0.00	4.34	3	0.57	1.80	0.00	10.85	11
24	MODO	Mourning Dove	0.24	0.77	0.00	3.44	10	0.62	1.40	0.00	5.88	21	0.12	0.49	0.00	2.43	6
25	AMRE	American Redstart	0.41	1.12	0.00	3.90	12	0.45	1.25	0.00	4.90	13	0.03	0.33	0.00	3.10	1
26	DOWO	Downy Woodpecker	0.43	1.19	0.00	4.09	12	0.74	1.51	0.00	4.09	21	0.05	0.43	0.00	4.09	1
27	MALL	Mallard	0.04	0.28	0.00	1.80	2	0.47	1.44	0.00	5.49	10	0.15	0.92	0.00	7.12	3
28	WODU	Wood Duck	0.87	3.41	0.00	20.64	12	0.23	1.05	0.00	5.77	5	0.49	2.61	0.00	22.86	7
29	GADW	Gadwall	0.13	0.83	0.00	5.30	2	0.44	1.64	0.00	8.59	8	0.75	2.08	0.00	11.21	15
30	EUST	European Starling	0.47	2.70	0.00	17.20	5	0.38	1.63	0.00	9.61	10	0.27	1.09	0.00	6.10	7
31	LEFL	Least Flycatcher	0.00	0.00	0.00	0.00	0	0.12	0.43	0.00	1.72	8	0.06	0.29	0.00	1.52	4
32	NOFL	Northern Flicker	0.25	0.85	0.00	4.35	10	0.29	0.87	0.00	3.44	10	0.12	0.52	0.00	2.56	6
33	COMO	Common Moorhen	0.20	0.93	0.00	5.28	5	0.00	0.00	0.00	0.00	0	0.16	1.02	0.00	8.79	3
34	SORA	Sora	0.04	0.26	0.00	1.69	2	0.07	0.33	0.00	1.69	5	0.15	0.55	0.00	3.39	8
35	REVI	Red-eyed Vireo	0.09	0.58	0.00	3.69	2	0.09	0.55	0.00	3.44	3	0.00	0.00	0.00	0.00	0
36	BCCH	Black-capped Chickadee	0.24	0.63	0.00	2.60	15	0.29	0.74	0.00	2.60	15	0.03	0.19	0.00	1.30	2
37	WBNU	White-breasted Nuthatch	0.08	0.54	0.00	3.44	2	0.11	0.71	0.00	4.43	3	0.03	0.29	0.00	2.74	1

Appendix J (following)

			Closed Shrub Swamp (n = 41)					Shrub Ecocomplex (n = 39)					Grass Ecocomplex (n = 89)				
#	Code	English Name	X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%	X	SD	MIN	MAX	Oc%
38	RBGR	Rose-breasted Grosbeak	0.11	0.56	0.00	3.44	5	0.06	0.27	0.00	1.35	5	0.04	0.22	0.00	1.19	3
39	BOBO	Bobolink	0.02	0.14	0.00	0.88	2	0.00	0.00	0.00	0.00	0	0.15	0.60	0.00	4.39	7
40	AMGO	American Goldfinch	0.07	0.48	0.00	3.07	2	0.24	0.83	0.00	3.07	8	0.34	1.21	0.00	6.69	9
41	GNBH	Green Heron	0.31	0.91	0.00	4.15	12	0.25	0.76	0.00	2.68	10	0.04	0.35	0.00	3.30	1
42	SPSA	Spotted Sandpiper	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.12	0.52	0.00	3.15	6
43	HOWR	House Wren	0.03	0.19	0.00	1.23	2	0.01	0.08	0.00	0.48	3	0.02	0.16	0.00	1.55	1
44	HAWO	Hairy Woodpecker	0.17	0.76	0.00	4.01	5	0.14	0.59	0.00	2.89	5	0.00	0.00	0.00	0.00	0
45	NSHO	Northern Shoveler	0.15	0.67	0.00	3.40	5	0.07	0.43	0.00	2.68	3	0.12	0.58	0.00	3.04	4
46	LEBI	Least Bittern	0.04	0.25	0.00	1.63	2	0.00	0.00	0.00	0.00	0	0.01	0.14	0.00	1.29	1
47	SAVS	Savannah Sparrow	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.24	1.19	0.00	8.03	4
48	BBCU	Black-billed Cuckoo	0.00	0.00	0.00	0.00	0	0.19	0.69	0.00	3.07	8	0.04	0.24	0.00	1.87	2
49	NOWA	Northern Waterthrush	0.07	0.42	0.00	2.68	2	0.16	0.98	0.00	6.15	3	0.03	0.33	0.00	3.07	1
50	WOTH	Wood Thrush	0.15	0.96	0.00	6.15	2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
51	SEWR	Sedge Wren	0.06	0.27	0.00	1.24	5	0.04	0.23	0.00	1.42	3	0.06	0.29	0.00	1.42	4
52	WTSP	White-throated Sparrow	0.08	0.54	0.00	3.47	2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
53	AMWO	American Woodcock	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
54	BHCO	Brown-headed Cowbird	0.07	0.48	0.00	3.07	2	0.00	0.00	0.00	0.00	0	0.19	0.83	0.00	5.35	6
55	BRCR	Brown Creeper	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
56	AMCO	American Coot	0.07	0.48	0.00	3.07	2	0.00	0.00	0.00	0.00	0	0.09	0.65	0.00	5.35	2
57	AMWI	American Wigeon	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.02	0.20	0.00	1.86	1
58	BWTE	Blue-winged Teal	0.00	0.00	0.00	0.00	0	0.04	0.28	0.00	1.72	3	0.06	0.31	0.00	1.76	3
59	CSWA	Chestnut-sided Warbler	0.05	0.33	0.00	2.13	2	0.15	0.66	0.00	3.62	5	0.00	0.00	0.00	0.00	0
60	RTHU	Ruby-throated Hummingbird	0.04	0.26	0.00	1.66	2	0.07	0.43	0.00	2.68	3	0.00	0.00	0.00	0.00	0
61	AMCR	American Crow	0.07	0.48	0.00	3.07	2	0.16	0.98	0.00	6.15	3	0.00	0.00	0.00	0.00	0
62	BLJA	Blue Jay	0.07	0.48	0.00	3.07	2	0.08	0.49	0.00	3.07	3	0.00	0.00	0.00	0.00	0
63	KILL	Killdeer	0.04	0.23	0.00	1.46	2	0.08	0.34	0.00	1.53	5	0.00	0.00	0.00	0.00	0
64	OVEN	Ovenbird	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
65	REDH	Redhead	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
66	BAWW	Black-and-white Warbler	0.04	0.28	0.00	1.81	2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
67	CWAX	Cedar Waxwing	0.00	0.00	0.00	0.00	0	0.08	0.49	0.00	3.07	3	0.00	0.00	0.00	0.00	0
68	NOCA	Northern Cardinal	0.07	0.48	0.00	3.07	2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
69	SCTA	Scarlet Tanager	0.00	0.00	0.00	0.00	0	0.08	0.49	0.00	3.07	3	0.00	0.00	0.00	0.00	0
70	YBSA	Yellow-bellied Sapsucker	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
71	EAPH	Eastern Phoebe	0.00	0.00	0.00	0.00	0	0.07	0.43	0.00	2.68	3	0.03	0.28	0.00	2.68	1
72	GTBH	Great Blue Heron	0.08	0.54	0.00	3.44	2	0.08	0.49	0.00	3.07	3	0.00	0.00	0.00	0.00	0
73	CAGO	Canada Goose	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
74	CLSW	Cliff Swallow	0.04	0.25	0.00	1.63	2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
75	GBBG	Great Black-backed Gull	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.06	0.40	0.00	2.68	2
76	RUGR	Ruffed Grouse	0.00	0.00	0.00	0.00	0	0.03	0.19	0.00	1.17	3	0.00	0.00	0.00	0.00	0

Appendix J (following)

#	Code	English Name	Wet Meadow (n = 30) X	SD	MIN	MAX	Oc%	Emergent Ecocomplex (n = 66) X	SD	MIN	MAX	Oc%	Shallow Marsh (n = 45) X	SD	MIN	MAX	Oc%
1	RWBL	Red-winged Blackbird	12.18	12.34	0.00	48.29	87	15.26	10.19	0.00	51.02	98	25.51	5.84	1.35	25.51	100
2	SWSP	Swamp Sparrow	11.43	7.34	0.00	24.33	80	12.33	7.76	0.00	48.67	97	29.31	7.67	0.00	29.31	93
3	YWAR	Yellow Warbler	1.42	2.43	0.00	10.69	33	5.26	5.33	0.00	26.63	71	9.62	2.63	0.00	9.62	40
4	COYE	Common Yellowthroat	3.24	3.80	0.00	13.29	57	3.29	3.39	0.00	15.49	62	13.79	3.22	0.00	13.79	40
5	SOSP	Song Sparrow	2.61	3.50	0.00	15.44	53	2.35	3.10	0.00	18.22	48	11.47	3.05	0.00	11.47	29
6	TRES	Tree Swallow	2.31	4.41	0.00	22.23	37	5.03	7.13	0.00	40.01	55	22.23	5.28	0.00	22.23	62
7	COSN	Common Snipe	1.98	2.59	0.00	10.55	50	1.57	2.45	0.00	10.85	39	7.23	2.05	0.00	7.23	38
8	MAWR	Marsh Wren	3.11	6.33	0.00	21.09	30	7.45	10.33	0.00	61.99	62	24.26	6.81	0.00	24.26	78
9	AMRO	American Robin	0.00	0.00	0.00	0.00	0	1.38	2.83	0.00	9.95	23	0.00	0.00	0.00	0.00	0
10	COGR	Common Grackle	0.71	1.91	0.00	8.21	13	3.00	8.83	0.00	61.95	26	8.21	1.61	0.00	8.21	13
11	AMBI	American Bittern	0.92	1.41	0.00	4.46	33	0.69	1.23	0.00	4.46	27	6.11	1.84	0.00	6.11	44
12	WIFL	Willow Flycatcher	0.09	0.35	0.00	1.62	7	0.43	1.01	0.00	5.38	20	2.69	0.66	0.00	2.69	11
13	WAVI	Warbling Vireo	0.07	0.36	0.00	1.96	3	0.21	0.72	0.00	4.23	9	0.00	0.00	0.00	0.00	0
14	GRCA	Gray Catbird	0.06	0.35	0.00	1.93	3	0.18	0.66	0.00	3.86	8	0.00	0.00	0.00	0.00	0
15	BAOR	Baltimore Oriole	0.03	0.17	0.00	0.95	3	0.11	0.44	0.00	2.00	6	0.00	0.00	0.00	0.00	0
16	VEER	Veery	0.08	0.41	0.00	2.26	3	0.03	0.28	0.00	2.26	2	0.00	0.00	0.00	0.00	0
17	EAKI	Eastern Kingbird	0.32	0.75	0.00	2.51	17	0.62	1.32	0.00	5.02	20	3.66	0.72	0.00	3.66	7
18	GCFL	Great Crested Flycatcher	0.00	0.00	0.00	0.00	0	0.08	0.46	0.00	2.84	3	0.00	0.00	0.00	0.00	0
19	EWPE	Eastern Wood-Pewee	0.00	0.00	0.00	0.00	0	0.06	0.33	0.00	1.90	3	0.00	0.00	0.00	0.00	0
20	VIRA	Virginia Rail	0.29	1.12	0.00	4.59	7	0.71	1.52	0.00	7.40	23	7.69	1.88	0.00	7.69	47
21	PBGR	Pied-billed Grebe	0.06	0.33	0.00	1.83	3	0.41	0.88	0.00	3.67	20	5.19	1.42	0.00	5.19	27
22	ALFL	Alder Flycatcher	0.44	1.14	0.00	3.37	13	0.16	0.73	0.00	3.56	5	8.01	1.34	0.00	8.01	7
23	BLTE	Black Tern	0.07	0.40	0.00	2.17	3	0.68	1.70	0.00	8.68	17	17.72	3.77	0.00	17.72	38
24	MODO	Mourning Dove	0.00	0.00	0.00	0.00	0	0.24	0.80	0.00	4.02	9	0.00	0.00	0.00	0.00	0
25	AMRE	American Redstart	0.00	0.00	0.00	0.00	0	0.03	0.24	0.00	1.95	2	0.00	0.00	0.00	0.00	0
26	DOWO	Downy Woodpecker	0.00	0.00	0.00	0.00	0	0.31	1.21	0.00	7.82	6	0.00	0.00	0.00	0.00	0
27	MALL	Mallard	1.69	3.29	0.00	13.01	27	0.85	2.62	0.00	13.50	12	26.61	5.67	0.00	26.61	36
28	WODU	Wood Duck	0.15	0.81	0.00	4.46	3	0.92	2.30	0.00	11.29	18	3.62	1.17	0.00	3.62	22
29	GADW	Gadwall	0.83	2.77	0.00	12.88	10	0.29	1.10	0.00	5.54	8	11.33	2.58	0.00	11.33	22
30	EUST	European Starling	0.98	4.46	0.00	24.02	7	0.25	1.02	0.00	4.80	8	1.63	0.24	0.00	1.63	2
31	LEFL	Least Flycatcher	0.00	0.00	0.00	0.00	0	0.02	0.19	0.00	1.52	2	1.52	0.23	0.00	1.52	2
32	NOFL	Northern Flicker	0.00	0.00	0.00	0.00	0	0.11	0.51	0.00	2.57	5	2.62	0.39	0.00	2.62	2
33	COMO	Common Moorhen	0.00	0.00	0.00	0.00	0	0.53	1.99	0.00	12.66	11	17.92	4.17	0.00	17.92	27
34	SORA	Sora	0.06	0.31	0.00	1.69	3	0.25	0.60	0.00	2.57	17	5.20	1.13	0.00	5.20	16
35	REVI	Red-eyed Vireo	0.00	0.00	0.00	0.00	0	0.07	0.39	0.00	2.25	3	0.00	0.00	0.00	0.00	0
36	BCCH	Black-capped Chickadee	0.00	0.00	0.00	0.00	0	0.02	0.16	0.00	1.30	2	0.00	0.00	0.00	0.00	0
37	WBNU	White-breasted Nuthatch	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0

Appendix J (following)

#	Code	English Name	Wet Meadow (n = 30) X	SD	MIN	MAX	Oc%	Emergent Ecocomplex (n = 66) X	SD	MIN	MAX	Oc%	Shallow Marsh (n = 45) X	SD	MIN	MAX	Oc%
38	RBGR	Rose-breasted Grosbeak	0.00	0.00	0.00	0.00	0	0.02	0.15	0.00	1.19	2	0.00	0.00	0.00	0.00	0
39	BOBO	Bobolink	0.78	1.19	0.00	4.92	43	0.01	0.10	0.00	0.82	2	0.00	0.00	0.00	0.00	0
40	AMGO	American Goldfinch	0.43	1.42	0.00	6.69	10	0.05	0.38	0.00	3.07	2	0.00	0.00	0.00	0.00	0
41	GNBH	Green Heron	0.00	0.00	0.00	0.00	0	0.30	0.93	0.00	4.63	11	0.00	0.00	0.00	0.00	0
42	SPSA	Spotted Sandpiper	0.06	0.33	0.00	1.80	3	0.15	0.50	0.00	1.85	9	2.37	0.39	0.00	2.37	4
43	HOWR	House Wren	0.06	0.32	0.00	1.75	3	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
44	HAWO	Hairy Woodpecker	0.10	0.52	0.00	2.85	3	0.03	0.27	0.00	2.18	2	0.00	0.00	0.00	0.00	0
45	NSHO	Northern Shoveler	0.09	0.49	0.00	2.68	3	0.00	0.00	0.00	0.00	0	6.29	1.09	0.00	6.29	7
46	LEBI	Least Bittern	0.05	0.25	0.00	1.39	3	0.17	0.58	0.00	3.44	9	1.46	0.30	0.00	1.46	4
47	SAVS	Savannah Sparrow	1.74	3.28	0.00	10.70	27	0.04	0.33	0.00	2.68	2	0.00	0.00	0.00	0.00	0
48	BBCU	Black-billed Cuckoo	0.10	0.56	0.00	3.07	3	0.09	0.53	0.00	3.07	3	0.00	0.00	0.00	0.00	0
49	NOWA	Northern Waterthrush	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
50	WOTH	Wood Thrush	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
51	SEWR	Sedge Wren	0.09	0.36	0.00	1.42	7	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
52	WTSP	White-throated Sparrow	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
53	AMWO	American Woodcock	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
54	BHCO	Brown-headed Cowbird	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
55	BRCR	Brown Creeper	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
56	AMCO	American Coot	0.00	0.00	0.00	0.00	0	0.05	0.38	0.00	3.07	2	3.07	0.46	0.00	3.07	2
57	AMWI	American Wigeon	0.19	0.73	0.00	2.97	7	0.00	0.00	0.00	0.00	0	2.33	0.49	0.00	2.33	4
58	BWTE	Blue-winged Teal	0.06	0.31	0.00	1.68	3	0.03	0.23	0.00	1.89	2	1.55	0.23	0.00	1.55	2
59	CSWA	Chestnut-sided Warbler	0.00	0.00	0.00	0.00	0	0.03	0.22	0.00	1.81	2	0.00	0.00	0.00	0.00	0
60	RTHU	Ruby-throated Hummingbird	0.05	0.29	0.00	1.57	3	0.04	0.28	0.00	2.31	2	0.00	0.00	0.00	0.00	0
61	AMCR	American Crow	0.20	0.78	0.00	3.07	7	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
62	BLJA	Blue Jay	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
63	KILL	Killdeer	0.00	0.00	0.00	0.00	0	0.05	0.27	0.00	1.64	3	0.00	0.00	0.00	0.00	0
64	OVEN	Ovenbird	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
65	REDH	Redhead	0.00	0.00	0.00	0.00	0	0.15	0.76	0.00	5.35	5	7.20	1.47	0.00	7.20	4
66	BAWW	Black-and-white Warbler	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
67	CWAX	Cedar Waxwing	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
68	NOCA	Northern Cardinal	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
69	SCTA	Scarlet Tanager	0.00	0.00	0.00	0.00	0	0.05	0.38	0.00	3.07	2	0.00	0.00	0.00	0.00	0
70	YBSA	Yellow-bellied Sapsucker	0.00	0.00	0.00	0.00	0	0.09	0.53	0.00	3.07	3	0.00	0.00	0.00	0.00	0
71	EAPH	Eastern Phoebe	0.00	0.00	0.00	0.00	0	0.12	0.73	0.00	5.35	3	0.00	0.00	0.00	0.00	0
72	GTBH	Great Blue Heron	0.00	0.00	0.00	0.00	0	0.05	0.38	0.00	3.07	2	0.00	0.00	0.00	0.00	0
73	CAGO	Canada Goose	0.22	1.22	0.00	6.69	3	0.05	0.38	0.00	3.07	2	0.00	0.00	0.00	0.00	0
74	CLSW	Cliff Swallow	0.00	0.00	0.00	0.00	0	0.05	0.28	0.00	1.63	3	0.00	0.00	0.00	0.00	0
75	GBBG	Great Black-backed Gull	0.04	0.24	0.00	1.34	3	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0
76	RUGR	Ruffed Grouse	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0

Appendix J (following)

#	Code	English Name	Deep Marsh (n = 35) X	SD	MIN	MAX	Oc%	Total Oc%
1	RWBL	Red-winged Blackbird	11.63	7.37	0.00	36.80	94	89
2	SWSP	Swamp Sparrow	8.26	8.00	0.00	33.49	69	78
3	YWAR	Yellow Warbler	1.44	2.61	0.00	9.62	26	70
4	COYE	Common Yellowthroat	2.02	2.64	0.00	7.74	46	62
5	SOSP	Song Sparrow	1.51	4.36	0.00	23.65	20	58
6	TRES	Tree Swallow	5.44	6.64	0.00	31.34	69	48
7	COSN	Common Snipe	0.72	1.84	0.00	7.47	17	38
8	MAWR	Marsh Wren	8.84	8.31	0.00	33.74	77	36
9	AMRO	American Robin	0.00	0.00	0.00	0.00	0	35
10	COGR	Common Grackle	0.44	1.48	0.00	6.19	11	28
11	AMBI	American Bittern	0.86	1.13	0.00	3.55	40	23
12	WIFL	Willow Flycatcher	0.14	0.66	0.00	3.68	6	22
13	WAVI	Warbling Vireo	0.04	0.23	0.00	1.35	3	19
14	GRCA	Gray Catbird	0.06	0.36	0.00	2.11	3	18
15	BAOR	Baltimore Oriole	0.00	0.00	0.00	0.00	0	17
16	VEER	Veery	0.00	0.00	0.00	0.00	0	16
17	EAKI	Eastern Kingbird	0.07	0.41	0.00	2.42	3	16
18	GCFL	Great Crested Flycatcher	0.00	0.00	0.00	0.00	0	14
19	EWPE	Eastern Wood-Pewee	0.05	0.32	0.00	1.90	3	13
20	VIRA	Virginia Rail	0.76	1.83	0.00	8.53	20	13
21	PBGR	Pied-billed Grebe	1.07	1.65	0.00	5.71	34	13
22	ALFL	Alder Flycatcher	0.00	0.00	0.00	0.00	0	13
23	BLTE	Black Tern	2.19	4.60	0.00	21.70	26	13
24	MODO	Mourning Dove	0.00	0.00	0.00	0.00	0	12
25	AMRE	American Redstart	0.00	0.00	0.00	0.00	0	12
26	DOWO	Downy Woodpecker	0.00	0.00	0.00	0.00	0	12
27	MALL	Mallard	0.87	2.55	0.00	12.87	17	11
28	WODU	Wood Duck	0.56	1.17	0.00	3.27	20	11
29	GADW	Gadwall	0.73	2.02	0.00	8.98	14	11
30	EUST	European Starling	0.10	0.57	0.00	3.37	3	10
31	LEFL	Least Flycatcher	0.04	0.26	0.00	1.51	3	9
32	NOFL	Northern Flicker	0.00	0.00	0.00	0.00	0	9
33	COMO	Common Moorhen	2.09	3.79	0.00	17.92	31	9
34	SORA	Sora	0.13	0.45	0.00	1.80	9	8
35	REVI	Red-eyed Vireo	0.00	0.00	0.00	0.00	0	8
36	BCCH	Black-capped Chickadee	0.00	0.00	0.00	0.00	0	7
37	WBNU	White-breasted Nuthatch	0.00	0.00	0.00	0.00	0	5

Appendix J (following)

			Deep Marsh (n = 35)					Total
#	Code	English Name	X	SD	MIN	MAX	Oc%	Oc%
38	RBGR	Rose-breasted Grosbeak	0.00	0.00	0.00	0.00	0	5
39	BOBO	Bobolink	0.00	0.00	0.00	0.00	0	5
40	AMGO	American Goldfinch	0.00	0.00	0.00	0.00	0	4
41	GNBH	Green Heron	0.00	0.00	0.00	0.00	0	4
42	SPSA	Spotted Sandpiper	0.12	0.39	0.00	1.80	9	4
43	HOWR	House Wren	0.00	0.00	0.00	0.00	0	4
44	HAWO	Hairy Woodpecker	0.00	0.00	0.00	0.00	0	4
45	NSHO	Northern Shoveler	0.41	2.14	0.00	12.57	6	3
46	LEBI	Least Bittern	0.03	0.18	0.00	1.07	3	3
47	SAVS	Savannah Sparrow	0.00	0.00	0.00	0.00	0	3
48	BBCU	Black-billed Cuckoo	0.00	0.00	0.00	0.00	0	3
49	NOWA	Northern Waterthrush	0.00	0.00	0.00	0.00	0	3
50	WOTH	Wood Thrush	0.00	0.00	0.00	0.00	0	2
51	SEWR	Sedge Wren	0.00	0.00	0.00	0.00	0	2
52	WTSP	White-throated Sparrow	0.00	0.00	0.00	0.00	0	2
53	AMWO	American Woodcock	0.00	0.00	0.00	0.00	0	2
54	BHCO	Brown-headed Cowbird	0.00	0.00	0.00	0.00	0	2
55	BRCR	Brown Creeper	0.00	0.00	0.00	0.00	0	2
56	AMCO	American Coot	0.23	0.76	0.00	2.68	9	2
57	AMWI	American Wigeon	0.18	0.68	0.00	3.59	9	2
58	BWTE	Blue-winged Teal	0.00	0.00	0.00	0.00	0	2
59	CSWA	Chestnut-sided Warbler	0.00	0.00	0.00	0.00	0	2
60	RTHU	Ruby-throated Hummingbird	0.09	0.52	0.00	3.07	3	2
61	AMCR	American Crow	0.00	0.00	0.00	0.00	0	2
62	BLJA	Blue Jay	0.00	0.00	0.00	0.00	0	1
63	KILL	Killdeer	0.00	0.00	0.00	0.00	0	1
64	OVEN	Ovenbird	0.00	0.00	0.00	0.00	0	1
65	REDH	Redhead	0.00	0.00	0.00	0.00	0	1
66	BAWW	Black-and-white Warbler	0.00	0.00	0.00	0.00	0	1
67	CWAX	Cedar Waxwing	0.00	0.00	0.00	0.00	0	1
68	NOCA	Northern Cardinal	0.00	0.00	0.00	0.00	0	1
69	SCTA	Scarlet Tanager	0.00	0.00	0.00	0.00	0	1
70	YBSA	Yellow-bellied Sapsucker	0.00	0.00	0.00	0.00	0	1
71	EAPH	Eastern Phoebe	0.00	0.00	0.00	0.00	0	1
72	GTBH	Great Blue Heron	0.00	0.00	0.00	0.00	0	1
73	CAGO	Canada Goose	0.00	0.00	0.00	0.00	0	1
74	CLSW	Cliff Swallow	0.00	0.00	0.00	0.00	0	1
75	GBBG	Great Black-backed Gull	0.00	0.00	0.00	0.00	0	1
76	RUGR	Ruffed Grouse	0.00	0.00	0.00	0.00	0	1

Appendix K Relationships of seven indicator species to water depth and water level fluctuation in their preferred habitat.

Predicted densities of seven species (five marsh, one shrub swamp and one treed swamp habitats) in association with water depth and degree of water level change during the breeding period in their preferred habitat (Figs K.1 and K.2) (see Table 3.4.1 for water level fluctuation index).

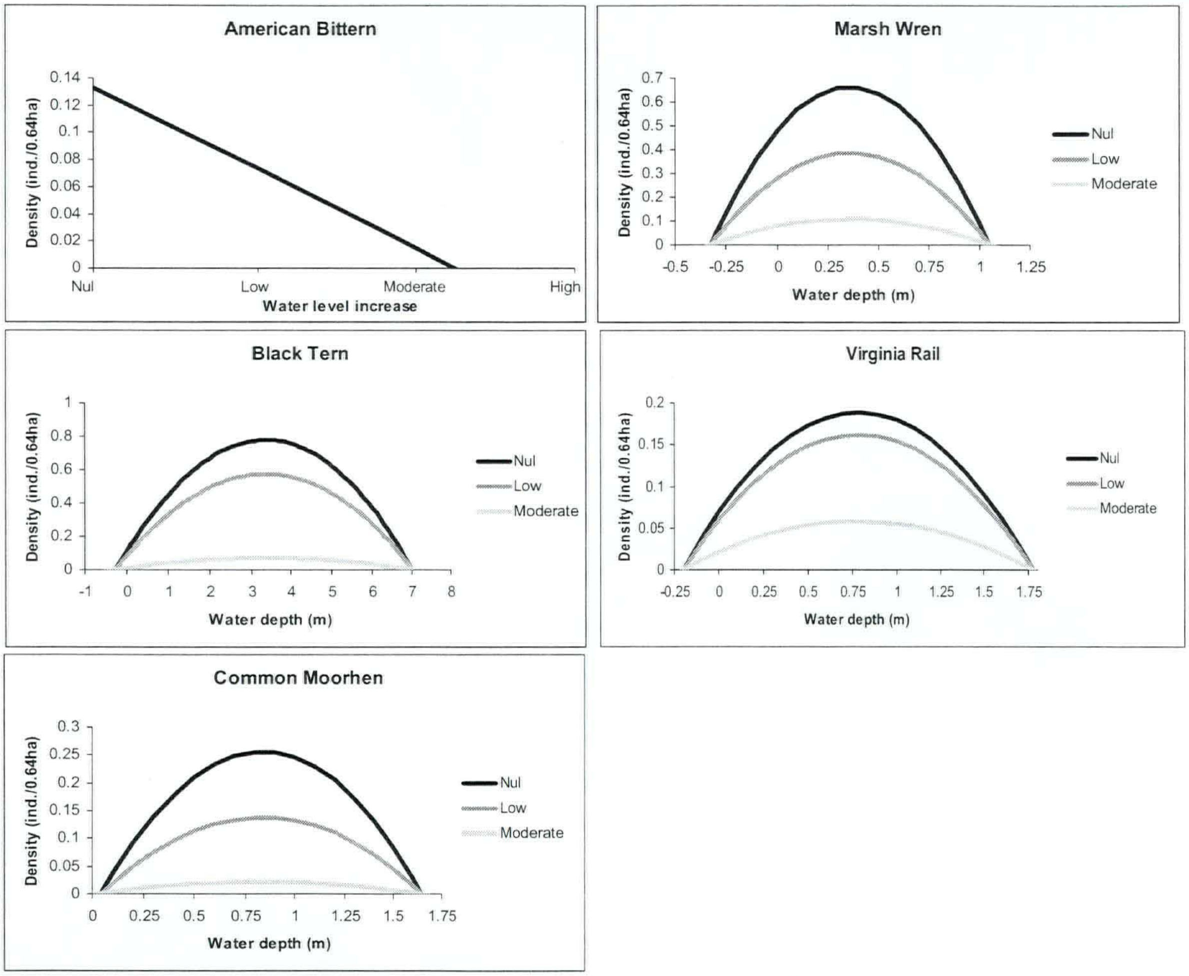


Figure K.1 **Five marsh bird species response to water depth and water fluctuations.**

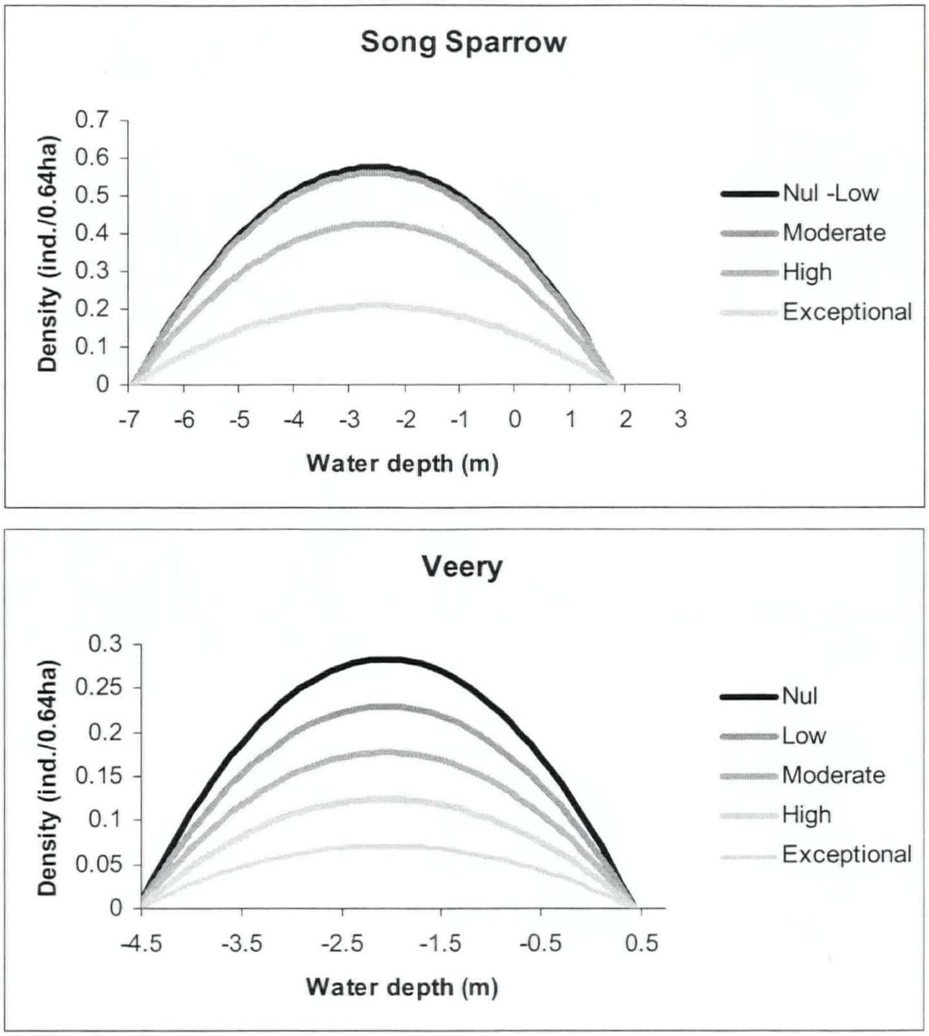


Figure K.2 **Two swamp bird species response to water depth and water fluctuations.**

Appendix L Relationships of ten indicator species to water depth and water level fluctuation in their preferred habitat.

Although the water level fluctuation does not affect the optimum water depth of these indicator species, it does correlate with a marked reduction in the breeding density of eigh species (Figs L.1 and L.2).

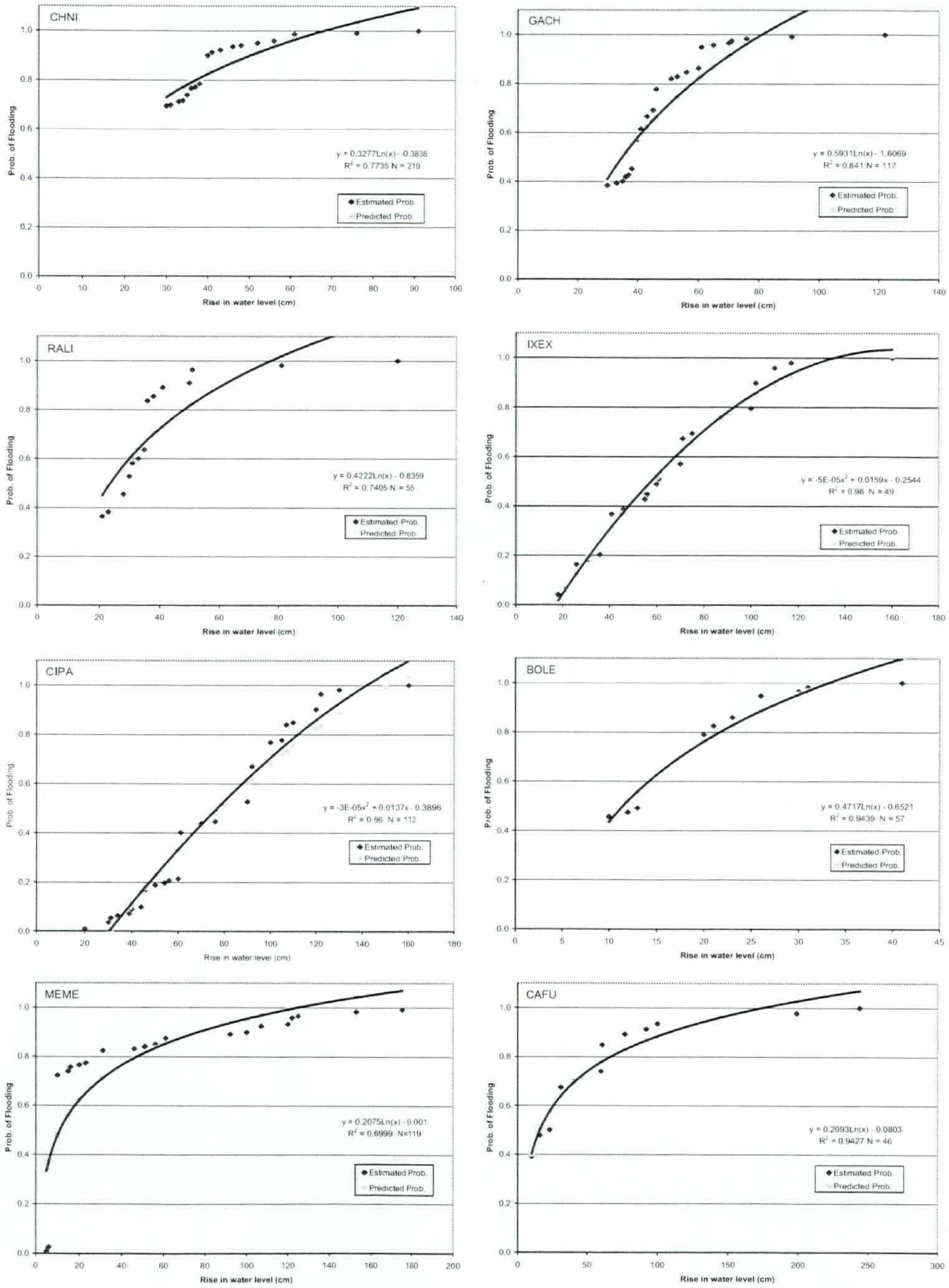


Figure L.1 Probability of nest flooding, estimated and predicted for wetland bird indicator species.

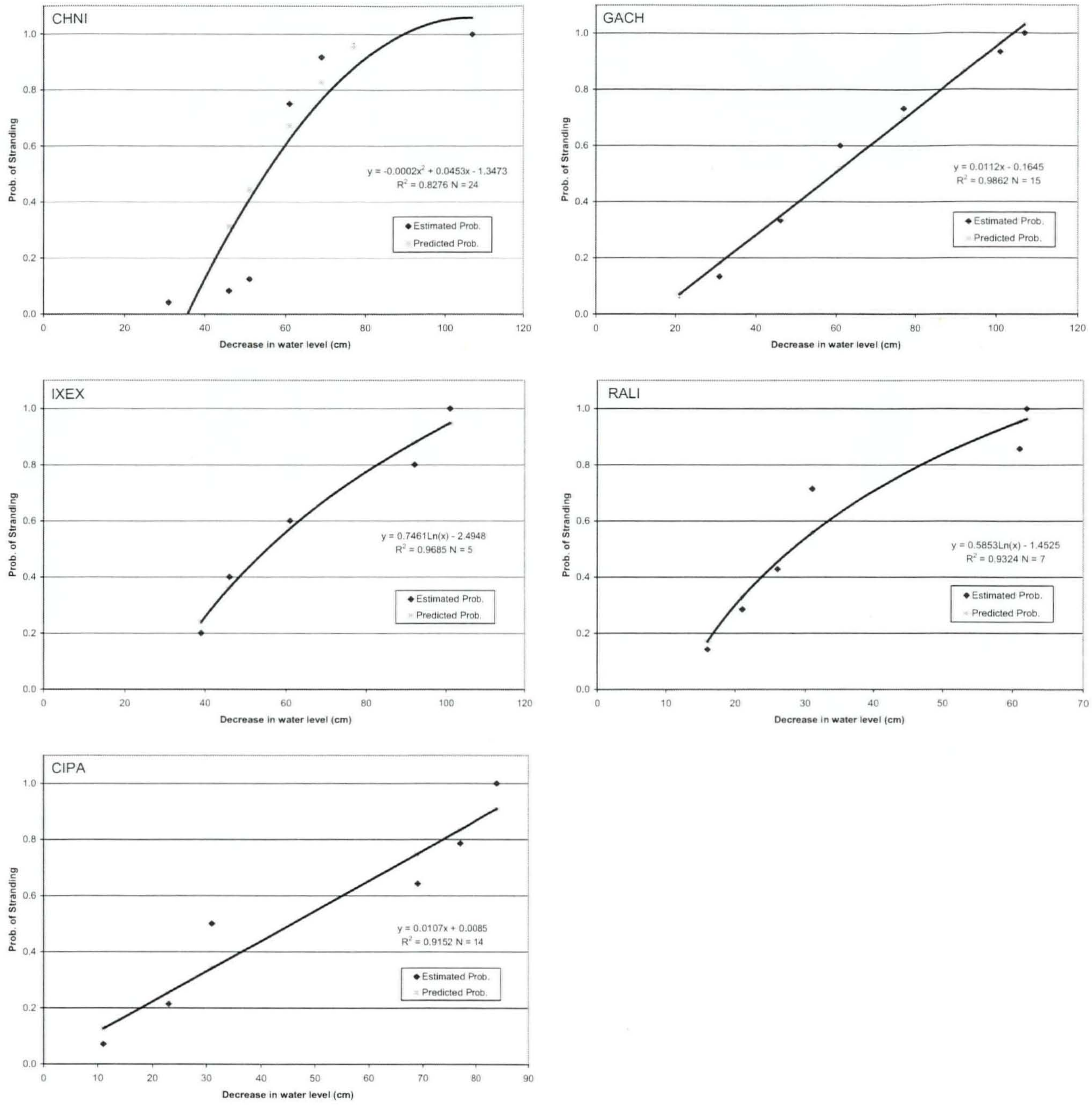


Figure L.2 Probability of nest stranding, estimated and predicted for wetland bird indicator species.

Appendix M Statistical regression parameters for the development of Performance Indicator models for the effect of water depth (m), increase and decrease of water level (index) on target wetland bird species.

Species/ occurrence		Coef.	Standard error	95% confidence limites Lower limite	Upper limite	R2	Pr > F
Black Tern							
23/31	Intercept	0.11	0.16	-0.22	0.43	0.10	0.24
	Water depth	0.40	0.65	-0.93	1.72		
	Water depth2	-0.06	0.64	-1.37	1.25		
	Intercept	0.34	0.06	0.23	0.46	0.11	0.19
	Increase water index	-0.12	1.49	-3.17	2.93		
	Increase water index2	-1.64	4.02	-9.88	6.59		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
Common Moorhen							
16/31	Intercept	-0.03	0.13	-0.30	0.25	0.11	0.19
	Water depth	0.67	0.55	-0.45	1.79		
	Water depth2	-0.40	0.54	-1.51	0.71		
	Intercept	0.23	0.05	0.13	0.33	0.09	0.25
	Increase water index	-0.48	1.28	-3.11	2.14		
	Increase water index2	-0.22	3.46	-7.32	6.87		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
Virginia Rail							
26/31	Intercept	0.07	0.07	-0.07	0.21	0.08	0.33
	Water depth	0.30	0.29	-0.28	0.89		
	Water depth2	-0.19	0.28	-0.77	0.39		
	Intercept	0.18	0.02	0.13	0.23	0.08	0.30
	Increase water index	0.15	0.66	-1.21	1.51		
	Increase water index2	-1.12	1.79	-4.78	2.54		
	Intercept	0.19	0.04	0.11	0.26	0.06	0.40
	Decrease water index	0.06	0.46	-0.88	1.00		
	Decrease water index2	-0.96	0.14	-3.81	1.88		
Marsh Wren							
25/31	Intercept	0.48	0.29	-0.12	1.08	0.07	0.34
	Water depth	1.01	1.19	-1.43	3.46		
	Water depth2	-1.40	1.18	-3.83	1.02		
	Intercept	0.62	0.10	0.42	0.84	0.11	0.15
	Increase water index	-1.29	2.69	-8.97	2.07		

Appendix M (following)

Species/ occurrence		Coef.	Standard error	95% confidence limites Lower limite	Upper limite	R2	Pr > F
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
American Bittern							
22/31	Intercept	.	.	.	.	.	.
	Water depth	.	.	.	.		
	Water depth2	.	.	.	.		
	Intercept	0.13	0.02	0.89	0.18	0.13	0.05
	Increase water index	-0.30	0.57	-1.76	0.57		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
Song Sparrow							
47/55	Intercept	0.38	0.06	0.27	0.49	0.10	0.06
	Water depth	-0.15	0.07	-0.30	-0.01		
	Water depth2	-0.03	0.03	-0.10	0.04		
	Intercept	0.53	0.05	0.43	0.63	0.17	0.01
	Increase water index	0.35	0.92	-1.50	2.21		
	Increase water index2	-0.97	1.21	-3.40	1.45		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
Veery							
16/30	Intercept	0.09	0.03	0.02	0.16	0.36	0.002
	Water depth	-0.19	0.05	-0.29	-0.09		
	Water depth2	-0.05	0.01	-0.07	-0.02		
	Intercept	0.21	0.04	0.12	0.30	0.14	0.13
	Increase water index	-0.47	0.52	-1.54	0.60		
	Increase water index2	0.39	0.73	-1.11	1.90		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		
	Decrease water index2	.	.	.	.		
Species richness							
	Intercept	.	.	.	.	.	.
	Water depth	.	.	.	.		
	Intercept	8.13	0.03	1.71	1.84	0.33	< 0.001
	Increase water index	-6.96	0.22	-1.30	-0.38		
	Intercept	.	.	.	.	.	.
	Decrease water index	.	.	.	.		

Appendix N PI comparative ratios (alternate/baseline (1958DD)) regulation plans for the breeding wetland bird key performance indicators compiled for six regulation plans under the historic time series (H) and four stochastic time series (S1, S2, S3 and S4). Assessment PI are shown for the Lower St. Lawrence River region (LSL ; 14 PIs) and Lake Ontario (6 PIs).

N.1 PI metric = Arithmetic mean

Mean		Lower Saint Lawrence River							Lake Ontario		
		Key Performance Indicators			Assessment Performance Indicators				Key Performance Indicators		
Scenario	Regulation Plans	CHNI	RALI	IXEX	GACH	MEME	CAFU	Spp_Ric	CHNI	RALI	IXEX
Historic	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	**0,70**	0,81	1,01	**0,70**	**0,73**	1,02	0,95	**1,27**	**1,29**	**1,29**
	B	0,87	0,91	1,03	0,83	**0,76**	0,99	0,97	**1,51**	**1,49**	**1,47**
	C	1,18	1,12	0,99	**1,22**	1,09	1,03	1,03	1,06	1,08	1,10
	D	1,09	1,08	0,98	1,11	1,10	1,04	1,02	**1,28**	**1,29**	**1,31**
	E	0,91	0,94	1,05	0,88	**0,73**	0,98	0,98	**3,59**	**3,05**	**2,71**
S1	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	**0,63**	**0,77**	1,07	**0,55**	**0,68**	0,96	0,95	**0,40**	**0,50**	**0,60**
	B	0,81	0,88	1,05	**0,76**	**0,78**	0,96	0,97	0,88	0,93	0,99
	C	1,09	1,09	0,98	1,09	**1,30**	1,03	1,03	**0,35**	**0,44**	**0,54**
	D	1,02	1,03	0,97	1,01	**1,30**	1,03	1,01	**0,42**	**0,52**	**0,64**
	E	0,85	0,92	1,07	**0,79**	**0,79**	0,95	0,98	**1,72**	**1,52**	**1,41**
S2	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	0,91	0,96	1,03	0,92	1,00	1,00	0,97	**0,55**	**0,65**	**0,74**
	B	1,10	1,08	1,05	1,07	0,99	0,99	1,01	1,17	1,11	1,08
	C	**1,47**	**1,38**	1,00	**1,60**	1,02	1,02	1,09	**0,61**	**0,70**	**0,78**
	D	**1,32**	**1,28**	1,00	**1,42**	1,03	1,03	1,07	**0,66**	**0,75**	0,83
	E	1,15	1,11	1,06	1,14	0,98	0,98	1,01	**2,13**	**1,81**	**1,56**
S3	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	0,84	0,91	1,03	0,81	0,89	1,00	0,95	**1,43**	**1,42**	**1,44**
	B	0,96	0,96	1,06	0,90	**0,75**	1,00	0,99	**1,55**	**1,48**	**1,45**
	C	**1,50**	**1,35**	1,01	**1,57**	**1,24**	1,00	1,07	**1,31**	**1,32**	**1,36**
	D	**1,30**	**1,22**	1,01	**1,34**	**1,22**	1,00	1,04	**2,04**	**1,94**	**1,97**
	E	1,01	0,99	1,07	0,93	**0,70**	0,99	0,99	**3,60**	**3,16**	**2,99**
S4	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	**0,66**	**0,74**	1,11	**0,58**	**0,60**	1,02	0,94	**0,29**	**0,34**	**0,34**
	B	**0,78**	0,81	1,07	**0,72**	**0,70**	1,03	0,95	**0,68**	**0,70**	**0,71**
	C	1,00	1,02	0,97	1,00	1,07	1,00	1,02	**0,22**	**0,25**	**0,28**
	D	0,93	0,96	0,96	0,92	1,09	1,00	1,00	**0,36**	**0,41**	**0,46**
	E	0,83	0,85	1,09	**0,77**	**0,67**	1,02	0,96	**1,29**	**1,22**	1,13

N.2 PI metric = First quartile

Q1		Lower Saint Lawrence River							Lake Ontario		
		Key Performance Indicators			Assessment Performance Indicators				Key Performance Indicators		
Scenario	Regulation Plans	CHNI	RALI	IXEX	GACH	MEME	CAFU	Spp_Ric	CHNI	RALI	IXEX
Historic	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	**0,70**	0,90	1,07	0,84	1,03	1,13	0,83	0,91	0,91	0,88
	B	**0,77**	1,00	1,10	0,87	1,03	0,97	0,90	1,09	1,08	1,03
	C	1,07	1,10	1,03	1,03	1,03	**1,20**	1,03	0,87	0,85	0,85
	D	1,00	1,06	1,03	1,03	1,07	**1,20**	1,03	0,93	0,93	0,95
	E	0,80	1,00	1,10	0,87	1,00	0,93	1,07	1,13	1,13	1,13
S1	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	0,88	0,84	1,12	**0,74**	0,89	1,00	0,88	**0,79**	**0,77**	**0,80**
	B	1,03	0,95	1,10	0,88	0,97	0,96	0,95	1,07	1,07	1,05
	C	1,08	1,12	0,99	0,99	1,05	1,01	1,07	**0,72**	**0,69**	**0,75**
	D	1,08	1,11	0,97	0,95	1,04	1,03	1,00	0,80	0,80	0,83
	E	1,04	0,93	1,14	0,86	0,95	0,96	0,96	1,11	1,11	1,12
S2	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	0,97	0,93	1,14	0,82	1,00	1,10	0,97	1,03	1,04	1,03
	B	1,04	0,97	1,11	0,89	1,01	1,04	1,01	1,08	1,08	1,08
	C	1,16	1,14	1,03	1,12	1,05	1,05	1,18	1,05	1,05	1,08
	D	1,11	1,12	1,03	1,11	1,07	1,07	1,15	1,09	1,09	1,11
	E	1,01	0,99	1,11	0,91	0,99	1,04	1,03	1,19	1,19	**1,20**
S3	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	1,05	0,95	1,12	0,89	1,03	0,99	1,00	**1,20**	**1,20**	**1,20**
	B	1,10	1,00	1,08	0,91	0,84	1,05	1,05	1,15	1,15	1,13
	C	1,16	1,08	1,05	1,15	1,04	1,04	1,10	1,15	1,13	1,17
	D	1,11	1,07	1,03	1,08	1,07	1,05	1,07	**1,25**	**1,25**	**1,24**
	E	1,14	1,00	1,16	0,95	0,81	1,01	1,03	**1,20**	1,19	**1,20**
S4	1958DD	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	A	0,82	0,84	1,16	**1,32**	**0,64**	1,00	0,81	**0,57**	**0,61**	**0,59**
	B	0,88	0,88	1,08	**1,32**	**0,75**	1,01	0,88	0,93	0,93	0,99
	C	0,97	1,07	0,96	**1,32**	1,01	1,03	1,04	**0,39**	**0,37**	**0,47**
	D	0,95	1,00	0,96	**1,32**	1,07	1,01	1,00	0,87	0,88	0,92
	E	0,90	0,88	1,11	**1,32**	**0,74**	1,00	0,88	1,05	1,05	1,08

CHNI = Blacktern ; RALI = Virginia Rail ; IXEX = Least Bittern ; GACH = Common Moorhen ; MRMR = Song Sparrow ; CAFU = Veery ; Spp_Ric = Obligate wetland bird species richness

≤ 0,90 ≥ 1,10