Environment Canada Environnement Canada

www.ec.gc.ca

Evaluation of a Landscape Analysis Approach for Migratory Birds and Species at Risk Habitat Conservation Planning in the Mixedwood Plains Ecozone: Case Study in Lake Saint-Pierre

Benoît Jobin, Renée Langevin, Matthieu Allard, Sandra Labrecque, Diane Dauphin, Martine Benoit, Pierre Aquin

Quebec Region

Canadian Wildlife Service
March 2013

CANADIAN WILDLIFE SERVICE TECHNICAL REPORT SERIES

This series of reports, introduced in 1986, contains technical and scientific information on Canadian Wildlife Service projects. The reports are intended to make available material that is either of interest to a limited audience or is too extensive to be accommodated in scientific journals or in existing CWS series.

Demand for the Technical Reports is usually limited to specialists in the fields concerned. Consequently, they are produced regionally and in small quantities. They are numbered according to a national system but can be obtained only from the address given on the back of the title page. The recommended citation appears on the title page.

Technical Reports are available in CWS libraries and are listed in the catalogue of Library and Archives Canada, which is available in science libraries across the country. They are printed in the official language chosen by the author to meet the language preference of the likely audience, with an abstract in the second official language. **To determine whether there is sufficient demand to make the Reports available in the second official language, CWS invites users to specify their official language preference. Requests for Technical Reports in the second official language should be sent to the address on the back of the title page.**

SÉRIE DE RAPPORTS TECHNIQUES DU SERVICE CANADIEN DE LA FAUNE

Cette série de rapports, créée en 1986, donne des informations scientifiques et techniques sur les projets du Service canadien de la faune (SCF). Elle vise à diffuser des études qui s'adressent à un public restreint ou sont trop volumineuses pour paraître dans une revue scientifique ou une autre série du SCF.

Ces rapports techniques ne sont habituellement demandés que par les spécialistes des sujets traités. C’est pourquoi ils sont produits à l'échelle régionale et en quantités limitées. Ils sont toutefois numérotés à l'échelle nationale. On ne peut les obtenir qu'à l'adresse indiquée au dos de la page titre. La référence recommandée figure à la page titre.

Les rapports techniques sont conservés dans les bibliothèques du SCF et figurent dans le catalogue de Bibliothèque et Archives Canada, que l’on retrouve dans les principales bibliothèques scientifiques du Canada. Ils sont publiés dans la langue officielle choisie par l'auteur, en fonction du public visé, accompagnés d’un résumé dans la deuxième langue officielle. **En vue de déterminer si la demande est suffisante pour publier ces rapports dans la deuxième langue officielle, le SCF invite les usagers à lui indiquer leur langue officielle préférée. Les demandes de rapports techniques dans la deuxième langue officielle doivent être envoyées à l'adresse indiquée au dos de la page titre.**

EVALUATION OF A LANDSCAPE ANALYSIS APPROACH FOR MIGRATORY BIRDS AND SPECIES AT RISK HABITAT CONSERVATION PLANNING IN THE MIXEDWOOD PLAINS ECOZONE: CASE STUDY IN LAKE SAINT-PIERRE

Benoît Jobin
Renée Langevin
Matthieu Allard
Sandra Labrecque
Diane Dauphin
Martine Benoit
Pierre Aquin

March 2013
Canadian Wildlife Service
Quebec Region

This report may be cited as follows:
Jobin B., R. Langevin, M. Allard, S. Labrecque, D. Dauphin, M. Benoit and P. Aquin. 2013. Evaluation of a Landscape Analysis Approach for Migratory Birds and Species at Risk Habitat Conservation Planning in the Mixedwood Plains Ecozone: Case Study in Lake Saint-Pierre. Technical report series No. 527. Environment Canada, Canadian Wildlife Service, Quebec Region, Quebec. 69 p. and appendices.

A copy of this report can be obtained by contacting:
Environment Canada
Canadian Wildlife Service
Quebec Region
801-1550 D'Estimauville Avenue
Québec (Québec)   G1J 0C3

ISBN 978-1-100-22361-2
Cat. No.: CW69-5/527E-PDF

Aussi disponible en français

ACKNOWLEDGEMENTS

We would like to thank Daniel Robitaille and Luc Bélanger of the Canadian Wildlife Service, Quebec Region (CWS-QC) for their support throughout the project. We thank Daniel Bordage, Vincent Carignan, Bruno Drolet, Gilles Falardeau, Christine Lepage, Jean-François Rail, François Shaffer and Josée Tardif, also from the CWS-QC, for data sharing and for their comments on the habitat criteria for priority species. André Desrochers and Monique Poulin from Université Laval were also consulted for their expertise on peat bogs, and we thank them for their input. We would also like to thank the following people for the information they shared: Martin Jean of Environment Canada (Water Quality Monitoring and Surveillance Division); Pascale Dombrowski, Marc Mingelbier, Réjean Dumas and Charles Racine of the Ministère des Ressources naturelles du Québec (MRN); Jacques Perron of the Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs (MDDEFP), Jason Beaulieu of Ducks Unlimited Canada (DUC); Pascal Hébert of Nature Conservancy of Canada (NCC); Christine Bélanger of the Fondation de la faune du Québec (FFQ); Ludyvine Millien of the Réseau de milieux naturels protégés (RMN); and Roxanne Dugas of the Lake Saint-Pierre Biosphere Reserve (LSPBR).

Project Team

This project was conducted by the Landscape Assessment and Planning Unit of the Canadian Wildlife Service, Quebec Region, as part of a pilot project designed to develop a methodology for habitat conservation planning.

Benoît Jobin
Renée Langevin
Matthieu Allard
Sandra Labrecque
Diane Dauphin
Martine Benoit
Pierre Aquin

ABSTRACT

Environment Canada's Canadian Wildlife Service (CWS), Quebec Region, has conducted a pilot project to develop and test a method to identify priority sites for migratory bird conservation within Bird Conservation Region (BCR) 13, located in the Mixedwood Plains ecozone. The approach is based on the landscape ecology theory, making it possible to associate habitat needs of priority bird species with a finer description of habitat composition and spatial distribution. This landscape-based approach is more integrative and allows for work on a broader scale instead of the more conservative approach based on known priority sites (hot spots) traditionally used in conservation planning. A logic model illustrating the steps for preparing a conservation plan was developed and tested. The Lake Saint-Pierre region (included within BCR 13) was selected as the study area.

The goal of the project was to determine the current and potential structure of the landscape in order to maintain and restore functional and viable habitats for the priority species for this project. A total of 48 species identified in the BCR 13 conservation plan as species of conservation concern were selected, including species at risk for which critical habitat was proposed or designated. The issue regarding those priority species is for the most part associated with breeding habitat availability. A land cover map of the study region has been produced and validated. A total of 7 general (anthropogenic, shrubland, annual crops, perennial crops, water, forest, wetland) and 21 detailed land cover classes were delineated. Data on the protected areas and species at risk present in the study area were also compiled.

The analysis performed with ArcGIS and FRAGSTATS software was divided into two major components: 1, descriptive analysis; and 2, landscape functionality. The analysis was performed at the study area level, at the regional county municipality (RCM) scale and at the watershed scale. The last two spatial units were selected because they foster effective implementation of the conservation recommendations whereby priority sites can be considered in regional land-use planning activities. The study area is largely dominated by agriculture: annual and perennial crops cover 31% and 20% of the study area respectively, followed by forest (24%), open water (10%), wetlands (10%), anthropogenic areas (4%) and shrubland (which accounts for only 1% of the area). A detailed analysis also identified portions of the study area most suitable for forest birds, where forest fragmentation is reduced and where forest interior habitats still prevail.

Landscape functionality was analyzed by comparing the composition of the landscape with known habitat thresholds, by identifying movement corridors for forest birds, and by assessing the availability of certain classes of priority habitat. The thresholds used to compare the landscape of the study area, RCM and watersheds were taken from the document *How Much Habitat is Enough?* and focused on forest habitat, wetlands and riparian buffer strips. Forest habitats are under-represented in the study area, though forest interior habitats could probably support forest bird populations. Wetlands are abundant around Lake Saint-Pierre, but their presence is limited in the rest of the area. Furthermore, the integrity of these habitats is at risk because the adjacent habitats are strongly influenced by human activity. The same is true for riparian buffer strips.

The identification of movement corridors for forest birds focused on connecting forest patches > 1000 ha. Using Corridor Designer software, 14 movement corridors were selected based on pre-established criteria (width > 300 m; distance between woodlots < 200 m). Priority breeding habitats were then identified using the coarse- and fine-filter approaches. Hundreds of habitat patches occupying the minimum surface area necessary to meet the needs of multiple priority species (coarse-filter approach) were identified throughout the study area and in various types of environments (forest > 100 ha, perennial crops > 40 ha, shrubland > 5 ha, marsh > 5 ha, shrub swamp > 5 ha, peatland > 20 ha). All patches of forest swamp and wet meadow were considered priority sites because no minimum area threshold is known for those habitat classes. The best patches in each habitat class were then prioritized according to a series of criteria related to their significance for the establishment and maintenance of nesting bird populations (e.g. patch shape, % of interior habitat) or their ecological role in the landscape (e.g. creation of a buffer zone around protected areas, presence of species at risk). Finally, other habitat components specific to certain species (fine-filter approach) such as sand pits and rocky outcrops in forest environments were also identified.

A diagnosis of the ability of the landscape to provide functional habitat for priority bird species was performed. The deficiencies noted in the study area included the limited surface area occupied by shrubland (1%), the lack of forest cover (< 30%), the inadequate distribution of wetlands (few are located outside the immediate vicinity of Lake Saint-Pierre), severe disturbance of riparian buffer strips, and forest corridors that do not meet the established criteria. A conservation plan for migratory bird and species at risk habitat was developed taking into account the description and analysis of landscape functionality, as well as regional development issues. The conservation plan proposes detailed conservation actions at the RCM and watershed scales: prioritization of spatially explicit habitat patches (habitat of avian species at risk, coarse- and fine-filter patches, forest corridors), protection of non-spatially explicit habitat components (e.g. large-diameter snags, Purple Martin nest boxes), and landscape attributes to be considered for the maintenance of ecological processes (e.g. vegetated riparian buffer strips). The conservation plan must be validated at the site level because the data on certain habitats may be outdated. Possible actions and proposals for the implementation of the conservation plan are also presented. Lastly, a general summary of the project points out the benefits and some shortcomings of the landscape-based approach that was used and highlights some problems encountered. A suite of recommendations are proposed to help with the application of the approach and to support a joint involvement of partners and stakeholders in land use planning.

RÉSUMÉ

Le Service canadien de la faune (SCF) d'Environnement Canada, région du Québec, a réalisé un projet pilote afin de développer et de tester une méthodologie permettant de déterminer les sites prioritaires pour la conservation des oiseaux migrateurs à l'échelle de la région de conservation des oiseaux (RCO) 13 située dans l'écozone des Plaines à forêts mixtes. L'approche utilisée est basée sur l'écologie du paysage et permet de coupler les besoins réels en matière d'habitat des espèces prioritaires à une analyse fine de la composition et de la répartition spatiale des habitats. Ceci permet donc d'avoir une vision plus intégratrice et à plus grande échelle du territoire au lieu de cibler la protection de sites déjà connus comme importants pour les oiseaux (approche par « hot spot » traditionnellement utilisée en conservation). Un modèle logique, qui illustre les étapes nécessaires à la réalisation d'un plan de conservation selon cette approche paysage, a été développé et testé. La région du lac Saint-Pierre (incluse dans la RCO 13) a été choisie comme aire d'étude.

Le but du projet était de déterminer la structure actuelle et potentielle du paysage dans le but de maintenir et de rétablir des habitats fonctionnels et viables pour les espèces considérées comme prioritaires pour ce projet. Au total, 48 espèces présentant des enjeux de conservation identifiées dans le plan de conservation de la RCO 13 ont été retenues, incluant les espèces en péril pour lesquelles des habitats essentiels sont proposés ou désignés. Ces enjeux sont presque tous associés à la disponibilité des habitats de nidification. Une carte d'occupation du sol a été réalisée et validée. Au total, sept classes générales (anthropique, arbustif, culture annuelle, culture pérenne, eau, forestier, milieu humide) et 21 classes détaillées d'occupation du sol ont été retenues. Les données sur les aires protégées et sur les espèces en péril présentes dans l'aire d'étude ont aussi été compilées et utilisées.

L'analyse réalisée à l'aide des logiciels ArcGIS et FRAGSTATS se divise en deux grands volets : 1- l'analyse descriptive et 2- la fonctionnalité du paysage. Cette analyse a été réalisée à l'échelle de l'aire d'étude, ainsi qu'à celle des MRC et des bassins versants. Ces deux derniers découpages spatiaux ont été retenus car ils facilitent la mise en œuvre des recommandations de conservation en les intégrant au processus usuel de planification du territoire au Québec. L'aire d'étude est largement dominée par l'agriculture : les cultures annuelles et pérennes couvrent respectivement 31 % et 20 % du territoire. Suivent les milieux forestiers (24 %), les zones d'eau libre (10 %), les milieux humides (10 %), les milieux anthropiques (4 %) et les milieux arbustifs, qui ne couvrent que 1 % du territoire. Une analyse détaillée a aussi permis de localiser les secteurs de l'aire d'étude où la fragmentation forestière est réduite et où se situent les habitats forestiers d'intérieur.

La fonctionnalité du paysage a été analysée en comparant la composition du paysage à des seuils de référence connus, en déterminant des corridors de déplacement potentiels pour les oiseaux forestiers et en évaluant la disponibilité de certaines classes d'habitats prioritaires. Les seuils de référence utilisés ont été extraits du document « Quand l'habitat est-il suffisant » et ciblaient les habitats forestiers, les milieux humides et les bandes riveraines. Les habitats forestiers sont sous-représentés dans l'aire d'étude, bien que les habitats forestiers d'intérieur qui s'y trouvent permettent de soutenir des populations d'oiseaux forestiers. Les milieux humides sont abondants

autour du lac Saint-Pierre, mais leur présence est limitée ailleurs sur le territoire. De plus, l'intégrité de ces habitats est menacée puisque les milieux adjacents sont fortement anthropisés. On observe la même situation pour les bandes riveraines.

Des corridors de déplacement pour les oiseaux forestiers visant à relier les massifs forestiers > 1000 ha ont été déterminés à l'aide du logiciel *Corridor Designer*. Quatorze corridors ont été retenus en fonction de critères préétablis (largeur > 300 m, distance entre les boisés < 200 m). Enfin, les habitats prioritaires de nidification ont été déterminés en appliquant les principes de filtre grossier et de filtre fin. Des centaines de parcelles d'habitat occupant des superficies minimales requises pour combler les besoins des espèces prioritaires (filtre grossier) ont ainsi été sélectionnées dans toute l'aire d'étude et pour différentes classes de milieux (forêt > 100 ha, culture pérenne > 40 ha, milieu arbustif > 5 ha, marais > 5 ha, marécage arbustif > 5 ha, tourbière > 20 ha). Toutes les parcelles de marécage arboré et de prairie humide ont été considérées comme prioritaires puisqu'aucun seuil de superficie minimale n'est connu pour ces classes d'habitat. Une priorisation des meilleures parcelles de chacune des classes d'habitat a ensuite été faite à l'aide d'une série de critères portant sur leur importance pour l'établissement et le maintien de populations d'oiseaux nicheurs (ex., forme des parcelles; % d'habitat d'intérieur) ou sur leur rôle écologique dans le paysage (ex., mise en place de zone tampon autour des aires protégées; présence d'espèces en péril). Finalement, d'autres composantes d'habitats recherchées par certaines espèces (filtre fin) ont été localisées sur le territoire d'étude comme des sablières et des sols dénudés en milieu forestier.

Un diagnostic sur la capacité du paysage à procurer des habitats fonctionnels aux espèces d'oiseaux prioritaires a ensuite été réalisé. Parmi les lacunes relevées, on note la faible superficie occupée par les friches arbustives (1 %), le manque de couverture forestière (inférieur au seuil de 30 % établi), la répartition inadéquate des milieux humides (peu présents en dehors de la région immédiate du lac Saint-Pierre), une forte perturbation des bandes riveraines adjacentes aux cours d'eau, ainsi que des corridors forestiers qui répondent peu aux critères de sélection. Un plan de conservation des habitats de nidification des oiseaux migrateurs et des espèces en péril a été développé qui tient compte de la description et de l'analyse de la fonctionnalité du paysage, de même que des enjeux de développement régional. Ce plan de conservation propose des actions de conservation qui sont détaillées à l'échelle des MRC et des bassins versants : la priorisation de parcelles d'habitats avec référence spatiale (habitats d'espèces d'oiseaux en péril, parcelles du filtre grossier et du filtre fin, corridors forestiers), la protection de composantes d'habitat sans référence spatiale (ex., chicots de grand diamètre, nichoirs à Hirondelle noire) et les éléments du paysage à considérer pour le maintien de processus écologiques (ex., bandes riveraines végétées). Une validation est toutefois nécessaire car les données relatives à certains habitats peuvent dater de plusieurs années. Des pistes et des propositions pour la mise en œuvre du plan de conservation sont aussi présentées. Enfin, un bilan général du projet soulève les différents avantages et certains inconvénients de l'approche paysage retenue et met en lumière certaines problématiques rencontrées. Diverses recommandations sont proposées permettant d'appliquer la méthode d'analyse utilisée afin de favoriser l'arrimage des outils existants et la concertation des intervenants impliqués dans l'aménagement du territoire.

TABLE OF CONTENTS

Acknowledgements i

Abstract iii

Résumé v

List of Acronyms and Abbreviations ix

1.0 Introduction 1

2.0 Concepts of Landscape Ecology 1

2.1 Definition 1
2.2 Structure of the Landscape 2
2.3 Landscape Fragmentation 2
2.4 Buffer Zone 2
2.5 Landscape Study 2

3.0 Development of a Logic Model 3

4.0 Delineation of the Study Area for the Pilot Project 4

5.0 Step 1 − Goal and Objectives of the Pilot Project 6

6.0 Step 1a − Identifying Targets: Priority Species and Habitats 6

6.1 Selection of Priority Species for the Pilot Project 6
6.2 Selection of Priority Habitats for the Pilot Project 8

7.0 Step 2 – Data collection and management 10

7.1 Data Sources 10
7.2 Production of the Final Land Use Map 11
7.3 Data on Protected Areas 11
7.4 Data on Species at Risk and Critical Habitats 12

8.0 Step 2a – Planning and Mapping Tools 14

8.1 Reviewing Existing Softwares 14
8.2 Decisions Made Prior to Analysis 15

8.2.1 Spatial analysis scale 15
8.2.2 Overlapping of habitat patches 15
8.2.3 Selection of landscape metrics 15
8.2.4 Forest fragmentation 16

9.0 Step 3 – Landscape Analysis 17
9.1 Descriptive Analysis 17
9.1.1 Land use: Study area 17
9.1.2 Land use: RCM 20
9.2 Functionality of the Landscape 24
9.2.1 Comparison of the landscape with known reference thresholds.................... 24
9.2.2 Identification of forest corridors 30
9.2.3 Application of coarse filter criteria 36
9.2.4 Prioritization of coarse filter patches 39
9.2.5 Application of fine filter criteria 43
10.0 Step 4 − Final Analysis and Specific Issues 43
10.1 Analysis of Current Situation 43
10.2 Regional Issues and Threats 45
11.0 Step 8 – Conservation Plan for the Study Area 46
11.1 Priority Habitat Patches with Spatial Reference 46
11.2 Priority Habitats Without Spatial Reference 47
11.3 Landscape Elements to Consider for Maintaining Ecological Processes 49
11.4 Special Considerations of the Conservation Plan 50
11.5 Conservation Plan Specific to Each RCM and Watershed 51
11.5.1 Example of a detailed conservation plan: Bécancour RCM 52
11.6 Limits of the Conservation Plan 54
12.0 Step 9 − Implementation of the Conservation Plan: Approaches and Proposals....................55
13.0 Additional Information 55
13.1 Overall Assessment of the Project 55
13.1.1 Advantages of the landscape approach 55
13.1.2 Disadvantages of the landscape approach 56
13.1.3 Involvement of other CWS units, partners, etc. 57
13.1.4 Steps to complete 57
13.2 Problems Encountered and Recommendations 57
13.2.1 Data 57
13.2.2 Softwares.................... 58
13.2.3 Teamwork 59
14.0 Conclusion 59
15.0 Literature Cited 60

LIST OF ACRONYMS AND ABBREVIATIONS

AAFC: Agriculture and Agri-Food Canada
AARQ: Atlas of Amphibians and Reptiles of Quebec
BCR: Bird Conservation Region
CDPNQ: Centre de données sur le patrimoine naturel du Québec
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
CWI: Canadian Wetland Inventory
CWS: Canadian Wildlife Service
CWS-QC: Canadian Wildlife Service, Quebec Region
DUC: Ducks Unlimited Canada
EC: Environment Canada
EHJV: Eastern Habitat Joint Venture
FFQ: Fondation de la faune du Québec
GIS: Geographic information system
HSP: Habitat Stewardship Program
HPP : Habitat Priority Planner
LSPBR: Lake Saint-Pierre Biosphere Reserve
MBS: Migratory bird sanctuary
MDDEFP: Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs
MRN: Ministère des Ressources naturelles
NABCI: North American Bird Conservation Initiative
NAESI: National Agri-Environmental Standards Initiative
NCC: Nature Conservancy of Canada
NGO: Non-governmental organization
NTDB: National Topographic Data Base
RCM: Regional county municipality
RMN: Réseau de milieux naturels protégés
ROW: Right-of-Way
SARA: *Species at Risk Act*
SIEF: Ecoforestry information system of Quebec
SLAP: St. Lawrence Action Plan
SOS-POP: Suivi de l'occupation des stations de nidification des populations d'oiseaux en péril du Québec

1.0 INTRODUCTION

In 2005, Canada, the United States and Mexico signed the NABCI (North American Bird Conservation Initiative) Declaration of Intent in an effort to strengthen international cooperation in the field of bird conservation in North America (NABCI International 2012). Bird conservation strategies are developed for Bird Conservation Regions (BCRs) and contain population goals, habitat needs and conservation issues for a number of priority species within a BCR. In this context, the Canadian Wildlife Service (CWS) – Quebec Region has developed and evaluated a methodology to identify priority sites for the conservation of migratory birds. The approach used under this pilot project is based on the landscape ecology theory, which allows for associating actual habitat needs of priority species with a detailed analysis of the composition and spatial distribution of habitats. This conservation planning process is based on an integrated assessment of the landscape instead of the more traditional approach used in conservation planning where the identification of priority sites for bird conservation is based on past surveys ("hot spot" approach). The landscape approach not only offers the advantage of working on a larger scale, it also allows to integrate in the analysis various components of the landscape (biological, geographical, physical, socio-economic and heritage-related) that characterize the study area (habitats, species at risk, protected areas, hydrology, climate, human activities, etc.).

This report presents the method used, its advantages and disadvantages, and the resulting recommendations that constitute the conservation plan. It aims to provide information to anyone interested in learning more about the application of a landscape-based approach to determine priority sites for conservation and will be useful to land managers acting at various levels (government, municipalities, non-governmental organizations). The project was carried out in the Lake Saint-Pierre region, a portion of the BCR 13 located in the Mixedwood Plains ecozone, and recognized for its high level of biodiversity and its significance for migratory birds, but also for the intensive anthropogenic pressure affecting natural habitats. This report summarizes the main points and results of the pilot project. The reader is invited to consult a related report (Jobin et al. 2013) for a detailed description of the methodological development, analyses, and results. A few concepts underlying the landscape-based approach are described in the following section.

2.0 CONCEPTS OF LANDSCAPE ECOLOGY

2.1 DEFINITION

Landscape ecology focuses on the spatial and temporal dynamics of biological, physical and social landscapes (humanized and/or natural) where humans are also a component of the landscape (Turner et al. 2001). Through their activities, humans can affect the structure and integrity of the landscape and interfere with ecological processes. In the context of this project, landscape ecology is defined as *the study of the interaction between landscape structure (its composition and configuration) and the processes that determine the abundance and distribution of species*.

2.2 STRUCTURE OF THE LANDSCAPE

A landscape is a heterogeneous and dynamic mosaic composed of three main components: the matrix, the patch (habitats) and the corridors (Forman 1995). A landscape is thus a mosaic of important habitats (patches) for a species or species group that are spread across a dominant component of the landscape (the matrix). Corridors are the elements that connect patches. Habitat composition of the various elements and their configuration in the landscape, in other words, their juxtaposition relative to each other, is what characterizes the structure of the landscape. A landscape approach therefore requires consideration of the ecological requirements of the species (habitats), but also their method and limits for travel between habitat patches.

2.3 LANDSCAPE FRAGMENTATION

The natural environments of southern Quebec have been fragmented by human activities (roads, agriculture, etc.) (Bélanger and Grenier 1998, 2002; Latendresse et al. 2008). This fragmentation of the landscape, i.e. the replacement of landscape elements by others and the decrease in patch size, has significant consequences for the biodiversity of an area (Saunders et al. 1991; Andrén 1994; Fahrig 2003; Stephens et al. 2003), due to patch isolation and edge effects. With habitat patches becoming smaller and more isolated from each other, the resulting "insularization" has implications for the dispersal of individuals and genetics exchange. For several species, corridors help compensate for landscape fragmentation.

2.4 BUFFER ZONE

A buffer zone is a strip of more or less natural vegetation that reduces the contrast between a given habitat and adjacent habitats, thereby maintaining or improving ecological integrity (Bentrup 2008). Depending on the context and objectives set, the buffer zone can be contiguous to specific sites such as protected areas. It may also extend along watercourses and reduce runoff, siltation and nonpoint source pollution. These are called riparian buffer strips. The establishment of buffer zones adjacent to protected areas helps reduce anthropogenic pressures and edge effects that can affect many species.

2.5 LANDSCAPE STUDY

The development of new technologies such as remote sensing, as well as specialized GIS (geographic information systems) softwares facilitates the study of landscapes and their evolution. In addition, a variety of landscape metrics have been developed to describe the composition, structure and spatial configuration of habitat patches and landscapes (McGarigal et al. 2002). The use of landscape ecology concepts, along with the use of these analytical tools in studies aimed at understanding the distribution and abundance of living organisms and their habitats, is now common practice (Huber et al. 2011; Thompson 2011; Watling et al. 2011), and their use in the study of bird communities is widespread (Naugle et al. 2000; Renfrew and Ribic 2008; Holzmueller et al. 2011; Schwenk and Donovan 2011; Shanahan et al. 2011; Uezu and Metzger 2011).

Moreover, the spatial scale under analysis varies depending on the issue or study species and should consider the needs of individuals (e.g. the landscape extent of a salamander is very different from that of a black bear), such as nesting or feeding needs, and needs for genetic exchange and dispersal within a population (metapopulation concept). In the case of bird populations, the spatial scale under analysis can cover an area that extends over hundreds of square kilometres, such as an administrative region or an ecoregion.

3.0 DEVELOPMENT OF A LOGIC MODEL

We developed a logic model designed to organize and visually present the steps necessary to achieve a conservation plan, regardless of the spatial scale (ecozone, particular ecosystem, BCR, etc.) (Figure 1). Used as part of this project, the model is divided into several steps and presents the logical links to the available resources to ensure the successful completion of the project (such as partners, inventories), as well as factors that may influence its outcome (such as laws and regulations).

The goal and general objectives of the project initially depend on the issues and priorities that are specific to the landscape under study, ideally in collaboration with the project partners. This is followed by a series of steps ranging from data collection and the selection of appropriate tools (e.g. software), to a detailed analysis of the landscape leading to a diagnosis of the state of ecosystems and current issues. It may be useful to model changes or disruptions to the landscape in order to define the best strategies for landscape planning, taking into account future anthropogenic developments. The conservation plan integrates the results of the previous steps and identifies priority areas for conservation. Naturally, implementation of the actions identified in the conservation plan entails a variety of conservation and habitat restoration options and rests on the involvement of local partners and stakeholders (municipalities, RCMs, etc.) in the context of policies, laws and regulations that may have an impact on the land. Finally, actions taken should be monitored in order to determine if the results meet the objectives. Finally, this model is adaptative as new information that becomes available can improve its outcome.

Since this was a pilot project with a set deadline, some of the steps in the logic model were intentionally omitted (steps 4a, 5, 6, 7, 9 and 10, Figure 1). Similarly, the collection of data was limited to biological, physical and geographical data. Some crucial links in the logic model were also not established during this project. For example, stakeholders and partners working in the study area were not invited to participate in the project since the exercise was to develop and test a methodology. However, the implementation of this pilot project helped test the logic and usefulness of the model.

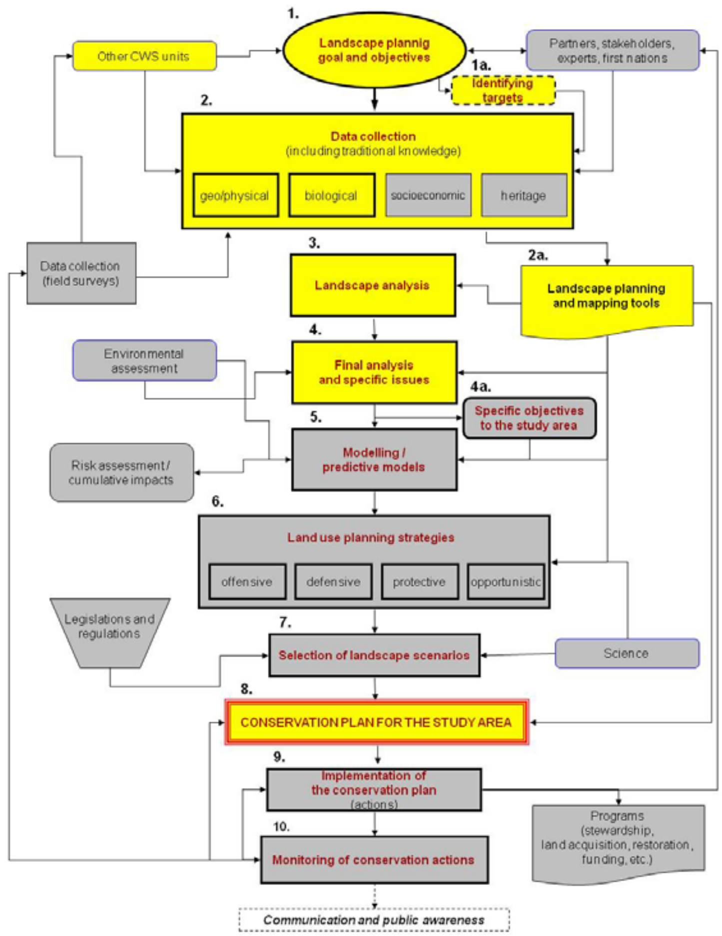


Figure 1 – Diagram of the logic model[1] (the steps completed are in yellow)

4.0 DELINEATION OF THE STUDY AREA FOR THE PILOT PROJECT

The Mixedwood Plains ecozone is one of the priority ecosystems for habitat conservation in Canada. This ecozone ranges from the Great Lakes in Ontario to Québec (Quebec City) and includes the St. Lawrence River fluvial system where habitat conservation and restoration are major objectives of the St. Lawrence Action Plan for over 20 years (www.planstlaurent.qc.ca/en/home.html). The Lake Saint-Pierre, which is a widening of the St. Lawrence River upstream of Trois-Rivières, and its floodplain, form an area that sustain a very rich biodiversity, which led to its designation as a RAMSAR site (www.ramsar.org) and as a Biosphere Reserve (www.biospherelac-st-pierre.qc.ca). Human activities (agriculture, navigation, urban and industrial developments) create significant pressures on the natural environment, and conservation actions are needed to protect and restore

[1] Adapted from Leitão and Ahern 2002, and Ahern 2006.

key habitats. Other reasons support our choice of this region as the study area for the pilot project:

- This sector is included in BCR 13;
- This sector is home to a wide diversity of species and habitats and is important for the migration, feeding and breeding of numerous migratory birds and species at risk;
- Environment Canada holds several territories in the region; there is a migratory bird sanctuary (Nicolet MBS), numerous public and private protected areas, and two Aboriginal reserves;
- Several projects of the Habitat Stewardship Program (HSPs) are underway;
- The study area is located within the range of the Eastern Habitat Joint Venture (EHJV) and the St. Lawrence Action Plan (SLAP);
- A large amount of biological, physical, geographical and hydrological data are available for this region.

The study area for the project was established using the boundaries of the Lake Saint-Pierre Biosphere Reserve, while retaining municipalities with more than half of their area contained in BCR 13 (Figure 2). Some municipalities were excluded in the western part in order to limit the study area at the head of Lake Saint-Pierre, but the industrial centre of Sorel-Tracy and all the islands of the Berthier-Sorel archipelago have been preserved. The study area covers an area of 4194 km^2.

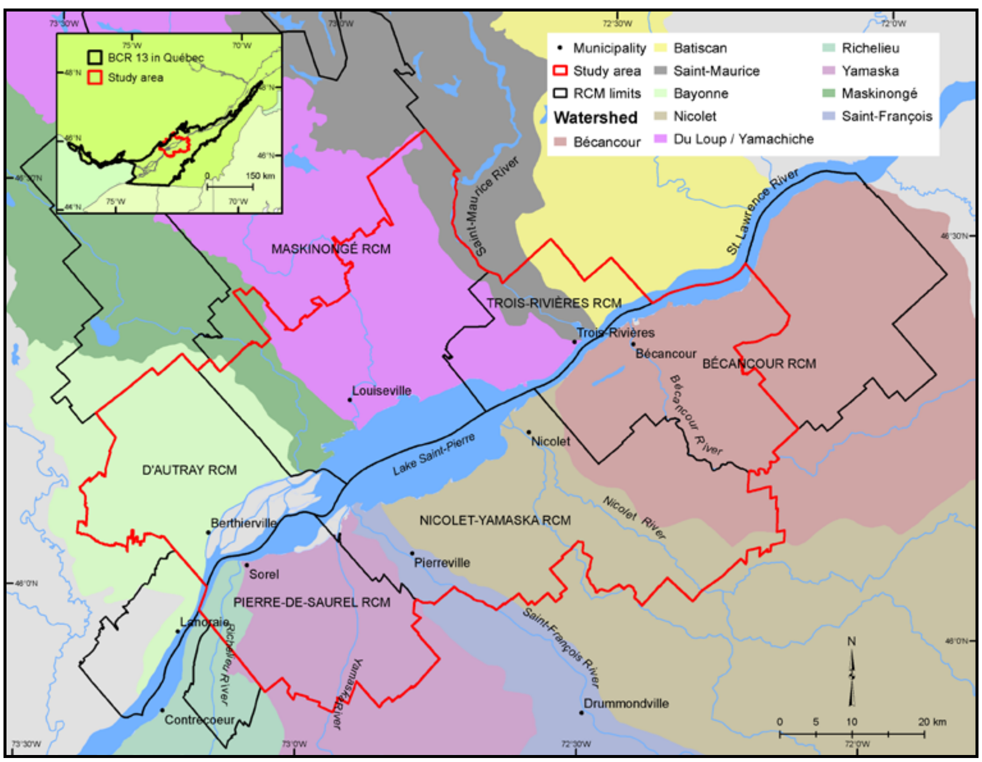


Figure 2 – Delineation of the study area for the pilot project

5.0 STEP 1 − GOAL AND OBJECTIVES OF THE PILOT PROJECT

The goal of the pilot project is to "determine the current and potential structure[2] of the landscape in order to maintain and restore functional and viable habitats of species considered priority for this project." More specifically, the objectives are to:

- determine priority species in the study area;
- determine the types of habitat that are essential to the life cycle of these priority species;
- evaluate the functionality of the landscape (compare with reference values, determine travel corridors for forest birds, locate potential habitats for priority species);
- identify regional issues and threats to habitats;
- produce a landscape conservation plan.

6.0 STEP 1A − IDENTIFYING TARGETS: PRIORITY SPECIES AND HABITATS

The first two objectives of the project are to determine priority species in the study area and to determine the habitats necessary for their life cycle. The following sections describe the steps needed to meet these objectives.

6.1 SELECTION OF PRIORITY SPECIES FOR THE PILOT PROJECT

The priority species in the context of the pilot project are:

- Priority species for conservation purpose identified in the BCR 13 bird conservation plan;
- Species at risk listed under Schedule 1 of the *Species at Risk Act* (SARA) for which critical habitats are identified.

In Quebec's integrated BCR 13 plan (November 2010 version, Fournier et al. 2010), 67 species of birds are considered a priority. However, many of these species are not a priority in the current project because some are very rare or do not inhabit the study area, or other species do not require immediate conservation action (priority species for reasons of stewardship or overabundant species). In collaboration with experts from the CWS, 48 priority species were retained (33 species of landbirds, 4 species of waterfowl, 6 species of marshbirds/waterbirds, 5 species of shorebirds), 9 of which were selected according to precautionary principle (Table 1). Conservation issues for priority species largely deal with breeding habitats. Appendix 1 lists the 19 species that were not selected. The study area includes identified critical habitats for only 1 species at risk designated under SARA, the Least Bittern, which is also a priority species in the BCR 13.

[2] The structure is defined as follows: configuration and composition of spatio-temporal components of the landscape.

Table 1 – List of 48 priority bird species found in the BCR 13 and selected for the pilot project

English name[1]	Latin name	Group[2]
American Kestrel	*Falco sparverius*	Land.
Baltimore Oriole	*Icterus galbula*	Land.
Bank Swallow	*Riparia riparia*	Land.
Barn Swallow	*Hirundo rustica*	Land.
Barred Owl	*Strix varia*	Land.
Belted Kingfisher	*Megaceryle alcyon*	Land.
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Land.
Bobolink*	*Dolichonyx oryzivorus*	Land.
Brown Creeper	*Certhia americana*	Land.
Brown Thrasher	*Toxostoma rufum*	Land.
Canada Warbler*	*Wilsonia canadensis*	Land.
Chimney Swift*	*Chaetura pelagica*	Land.
Common Nighthawk*	*Chordeiles minor*	Land.
Eastern Kingbird	*Tyrannus tyrannus*	Land.
Eastern Meadowlark	*Sturnella magna*	Land.
Eastern Screech-Owl	*Megascops asio*	Land.
Eastern Wood-Pewee	*Contopus virens*	Land.
Horned Lark	*Eremophila alpestris*	Land.
Long-eared Owl	*Asio otus*	Land.
Nelson's Sparrow	*Ammodramus nelsoni*	Land.
Northern Flicker	*Colaptes auratus*	Land.
Northern Harrier	*Circus cyaneus*	Land.
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Land.
Northern Saw-whet Owl	*Aegolius acadicus*	Land.
Palm Warbler	*Dendroica palmarum*	Land.
Peregrine Falcon (*anatum*)*	*Falco peregrinus anatum*	Land.
Purple Martin	*Progne subis*	Land.
Savannah Sparrow	*Passerculus sandwichensis*	Land.
Sedge Wren	*Cistothorus platensis*	Land.
Short-eared Owl*	*Asio flammeus*	Land.
Vesper Sparrow	*Pooecetes gramineus*	Land.
Whip-poor-will*	*Caprimulgus vociferus*	Land.
Wood Thrush	*Hylocichla mustelina*	Land.
American Woodcock	*Scolopax minor*	Shor.
Killdeer	*Charadrius vociferus*	Shor.
Upland Sandpiper	*Bartramia longicauda*	Shor.
Wilson's Phalarope	*Steganopus tricolor*	Shor.
Wilson's Snipe	*Gallinago delicata*	Shor.
American Bittern	*Botaurus lentiginosus*	Mar.

English name[1]	Latin name	Group[2]
Black Tern	*Chlidonias niger*	Mar.
Common Tern	*Sterna hirundo*	Mar.
Least Bittern*	*Ixobrychus exilis*	Mar.
Sora	*Porzana carolina*	Mar.
Virginia Rail	*Rallus limicola*	Mar.
Blue-winged Teal	*Anas discors*	Wat.
Greater Scaup	*Aythya marila*	Wat.
Lesser Scaup	*Aythya affinis*	Wat.
Wood Duck	*Aix sponsa*	Wat.

1 The species followed by an asterisk are listed as species at risk in SARA or by COSEWIC. Species in italics are selected according to precautionary principle (no data on population trends, but actual or perceived issues and threats are identified).

2 Land. = Landbirds; Shor. = Shorebirds; Mar. = Marshbirds/Waterbirds; Wat. = Waterfowl

6.2 SELECTION OF PRIORITY HABITATS FOR THE PILOT PROJECT

Priority habitats are selected based on the coarse filter/fine filter approach since no specific, quantitative criteria (e.g. the minimum area for species "X") are presented for priority species in the BCR 13 conservation plan and the preferred habitat classes are not determined for each species. The coarse filter approach consists of identifying the most common habitats that meet the needs of many species and determining the minimum area thresholds required for breeding, while the fine filter approach identifies habitat components specific to certain species that are not identified by the coarse filter. The priority habitat classes used in the coarse filter approach fall under three (3) major types of habitat:

1. Farmland: perennial crops, old fields
2. Forests: deciduous, mixed, coniferous
3. Wetlands: marshes, swamps, bogs, wet meadows

These habitats were determined by analyzing the integrated BCR 13 conservation plan (Fournier et al. 2010), descriptive data on nesting habitats used to produce the plan (according to CWS-QC experts), conservation plans produced for each species group (Chapdelaine and Rail 2004; Aubry and Cotter 2007; Environment Canada 2010a, 2010b; Lepage et al. 2010) and the Quebec Breeding Bird Atlas (Gauthier and Aubry 1996). All of these are breeding habitats, except for the migration habitats of two species of scaups. These habitat classes must be discernible on the digital land-use layers. The minimum area thresholds were determined for each habitat class based on information taken from conservation plans specific to four groups of birds, as well as from scientific literature and expert opinions. Appendix 2 presents the species targeted for each habitat class. The criteria and thresholds selected, as well as a justification for their selection, are described below:

Farmland

- Maintain perennial crops (forage, pastures) > 40 ha (Environment Canada 2010a, 2010b)
- Maintain old fields > 5 ha (Dettmers 2003; Schlossberg and King 2008; G. Falardeau, CWS-QC, pers. comm.)

- Favour square or rectangular fields that are non-elongated to minimize edge effects (Renfrew et al. 2005)

Forests

- Maintain forest patches > 1000 ha and increase connectivity (B. Drolet, CWS-QC, pers. comm.)
- Maintain woodlots > 100 ha in farming and urban areas (Environment Canada 2010a, 2010b)
- Favour square or rectangular patches to minimize edge effects (Langevin and Bélanger 1994; Langevin 1997; Environment Canada 2004)

Wetlands

- Preserve the critical habitats of the Least Bittern
- Maintain large marshes (> 5 ha) (Brown and Dinsmore 1986; Gratton 2010)
- Maintain large shrub swamps (> 5 ha) (Brown and Dinsmore 1986; Gratton 2010)
- Maintain large bogs (> 20 ha) (Poulin et al. 2006)
- Maintain wooded swamps (no area specified)
- Maintain wet meadows (no area specified)
- Maintain areas that are abundant in wetlands (wetland complex) (Calmé 1998; Naugle et al. 2000; Fairbairn and Dinsmore 2001; Riffell et al. 2003; Tozer et al. 2010)

Finally, breeding habitats for 7 of the 48 priority species are not targeted by the coarse filter criteria, while two species were selected because they use significant areas for feeding during migration periods. The habitats identified by the fine filter criteria are described in Table 2.

Table 2 – Habitats identified by the fine filter criteria for priority species, whose needs are not targeted by the coarse filter criteria

Species	Specific need
Common Nighthawk*	Nesting: Gravel roofs; bare soils in forested areas; rocky outcrops; forest disturbance (fire and logging)
Peregrine Falcon (*anatum*)*	Nesting: Human structures; cliffs
Northern Rough-winged Swallow	Nesting: Sandy shores; sand pits
Bank Swallow	Nesting: Sandy shores; sand pits
Purple Martin	Nesting: Cavities (natural or human-made)
Belted Kingfisher	Nesting: Sandy shores; sand pits
Common Tern	Nesting: Low-lying islands along the St. Lawrence waterway
Greater Scaup	Nesting: Aquatic beds along the shore (within 150 m) of Lake Saint-Pierre
Lesser Scaup	Nesting: Aquatic beds along the shore (within 150 m) of Lake Saint-Pierre

* Species listed at risk according to SARA or COSEWIC

7.0 STEP 2 – DATA COLLECTION AND MANAGEMENT

The data collected and used in the analyses were mainly geographical, physical (land use, administrative boundaries) and biological (flora, fauna, species at risk, protected areas, critical habitats for species at risk) in nature.

7.1 DATA SOURCES

The following spatial and mapping data sources were used to produce the land use map for the study area:

Farmland: Classification of land use generated by Agriculture and Agri-Food Canada (AAFC) using Landsat-7 images (2001–2002; 25 m resolution). Annual crops, perennial crops, old fields and shrublands (land expanses occupied by relatively low woody vegetation, typically ± –2 m) can be seen.

Forests: Ecoforestry information system of Quebec (SIEF) maps 3rd decadal on a scale of 1:20 000 generated by Quebec's Ministère des Ressources naturelles. Three main classes of forests (deciduous, mixed, coniferous), as well as signs of burning, logging and other disturbances can be seen. The sheets were produced between 1991 and 2006, but the majority of them were produced before 1996. The resolution used to convert the data into matrix format was set at 5 m.

Urban areas: The land use map produced by the CWS (1999–2003) using Landsat-7 imagery (25 m resolution). This was considered alongside the AAFC classification, which provides a better delineation of urban areas. Green spaces in urban areas were classified as "other anthropogenic". The resulting layer was filtered (3x3) to eliminate isolated pixels.

Wetlands: Four sources of information were combined by importance (quality of data, accuracy, precision, date) in the following order:

1. Detailed mapping of wetlands by Ducks Unlimited Canada in the Montérégie area (orthophotos from 2006) (GéoMont 2008);
2. Centre St-Laurent mapping (Ikonos imagery from 2000) on the banks of the St. Lawrence river;
3. Modelling by Ducks Unlimited Canada using a formula applied to ecoforestry maps (SIEF) (Ménard et al. 2006);
4. The CWS Conservation Atlas of Wetlands in the St. Lawrence Valley (combination of Landsat-5 imagery from 1993–1994 and Radarsat imagery from 1999) (Bélanger and Grenier 2003).

Eight classes of wetlands were identified: 1) shallow water (including submerged vegetation), 2) marsh, 3) swamp, 4) shrub swamp, 5) forest swamp, 6) wet meadow, 7) bog and 8) unidentified wetland.

In addition to these habitat classes, a few other landscape elements are required for certain priority species:

- The SIEF class "bare soil" corresponds to rocky outcrops in forested areas.

- Sand and gravel pits were extracted using a combination of SIEF data and topographic maps 1:50,000 (NTDB). Polygons were visually validated using high resolution images and additional data (photos taken by helicopter, list of mining establishments [Institut de la statistique du Québec 2010]).
- Sandy shores were extracted from information on the CWS database (1994) about the banks of the St. Lawrence River (Cornwall – Montmagny). A combination of attributes (vegetation, slope) was performed to determine the location of sandy shores with steep slopes.
- Linear elements (electrical ROWs, watercourses/hydrography, railroads, etc.) were extracted from topographic maps 1:20 000. The SIEF road cover was chosen because roads in wooded and agriculture areas are identified.

7.2 PRODUCTION OF THE FINAL LAND USE MAP

The final land use map integrated data from the different sources into a single information layer. This integration in raster mode involved using the AAFC classification as the "background" layer and overlaying the other layers of information in order of priority based on the reliability and quality of data, with the highest priority layer being added last:

- Priority 1 – Polygons of wetlands
- Priority 2 – AAFC classification for farmland and old fields
- Priority 3 – SIEF for forested areas
- Priority 4 – Map of urban areas

This land use map is the foundation for all geospatial landscape analyses. Given that several sources of information date back more than 10 years, and significant changes could have occurred in the landscape since then, a validation exercise was carried out based on the method developed as part of the Canadian Wetland Inventory (CWI) (Grenier et al. 2007). This method consists of randomly selecting polygons from each land use class that 2 photo-interpretation teams then identify using recent high-resolution images (SPOT, Quickbird). The validation of general habitat classes resulted in an overall accuracy of 76.0% and 71.8% for both teams. Steps and methods used in the production of the land use map, detailed results and problems encountered during the validation exercise are presented in Jobin et al. (2013).

7.3 DATA ON PROTECTED AREAS

In order to have a better understanding of the study area and to guide the prioritization of habitat patches, a list of existing protected areas[3] was compiled. Several departments (MRN, MDDEFP, EC-CWS) and conservation organizations that manage properties for the conservation of natural habitats (DUC, NCC, FFQ, RMN, LSPBR) were consulted along with the Municonsult report (2002). Some information on land tenure was also validated, in part with the help of the Registre foncier du Québec (Quebec Land Register) (MRNF 2012a), because several designation and names could be attributed to the same sites.

[3] The MDDEFP (2002) defines a protected area as follows: a geographically defined expanse of land or water established under a legal and administrative framework designed specifically to ensure the protection and maintenance of biological diversity and of related natural and cultural resources.

Only protected areas with a protection status high enough to justify the actions covered by the pilot project, such as the creation of buffer zones around them, were included in our analyses. These include ecological reserves, nature reserves, wildlife refuges, migratory bird sanctuaries, rare forests, habitats of threatened or vulnerable plant species, federal and provincial lands without reserve status and land protected by an NGO charter or private organization. The following areas were not included: wildlife habitats (muskrat habitat, waterfowl gathering area), regional parks, city parks, managed marshes but not legally protected, exceptional forest ecosystem proposed but not protected, conservation landmarks identified in a development plan. Overall, there are 47 protected areas in the study area, covering a total of approximately 10 500 ha, more than half of which are sites protected by an NGO charter (Figure 3).

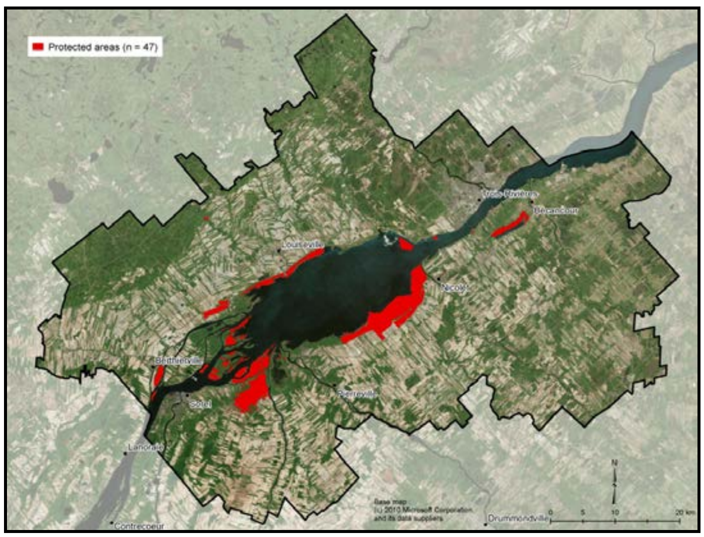


Figure 3 – Protected areas located in the study area and selected for analysis

7.4 DATA ON SPECIES AT RISK AND CRITICAL HABITATS

Four sources of information were used to obtain data on species at risk in the study area :

Critical habitats for species listed under SARA

As of July 2011, critical habitats were identified for only one species, the Least Bittern. Eight sites were identified as critical habitats[4] in the study area, seven of which are human-made impoundments (only Baie Saint-François is a natural wetland) (Figure 4).

Habitat polygons of avian species from CDPNQ and SOS-POP data

As of February 2011, breeding habitat polygons of certain avian species at risk, all associated with wetlands, have been delineated from known observations. These polygons were extracted from the Centre de données sur le patrimoine naturel du Québec (CDPNQ) and were traced for

[4] Critical habitat refers to suitable breeding habitat (marshes and shrubby swamps containing tall and robust emergent herbaceous and/or woody vegetation interspersed with areas of open water) located within these polygons (Environment Canada 2011).

the Least Bittern (n=14 polygons), the Short-eared Owl (n=3), the Nelson's Sharp-tailed Sparrow (n=2) and the Sedge Wren (n=4) (Figure 5). In addition to these polygons, well-located and recently used nesting sites for the Chimney Swift (n=29) and the Peregrine Falcon (n=4) and one probable nesting site for the Bald Eagle were extracted from the SOS-POP database.

Figure 4 – Location of identified critical habitats of the Least Bittern

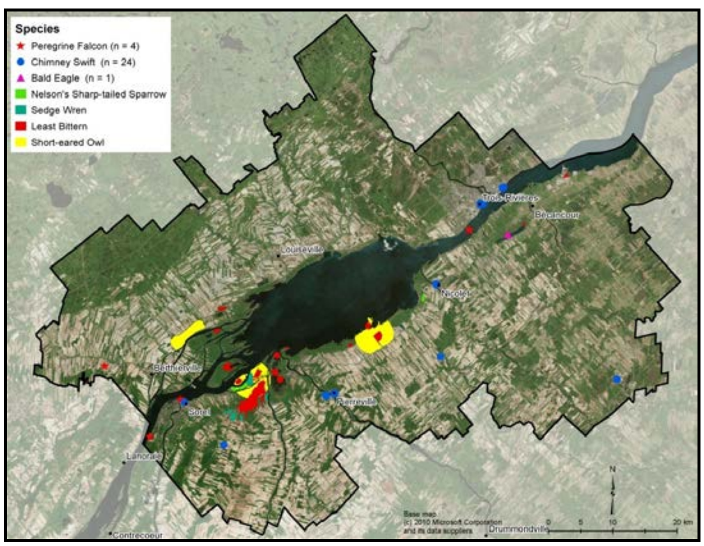


Figure 5 – Location of habitat polygons and breeding sites for avian species at risk

CDPNQ data for species other than birds

Records of species at risk collected in Quebec for decades, both for animals and flora, are collated in the CDPNQ database. As of December 14, 2010, there were 131 well-located and recent records of 57 species at risk on the pilot project territory, the majority of which were vascular plants (Figure 6). Records of avian species were not considered because they are already included in the SOS-POP database.

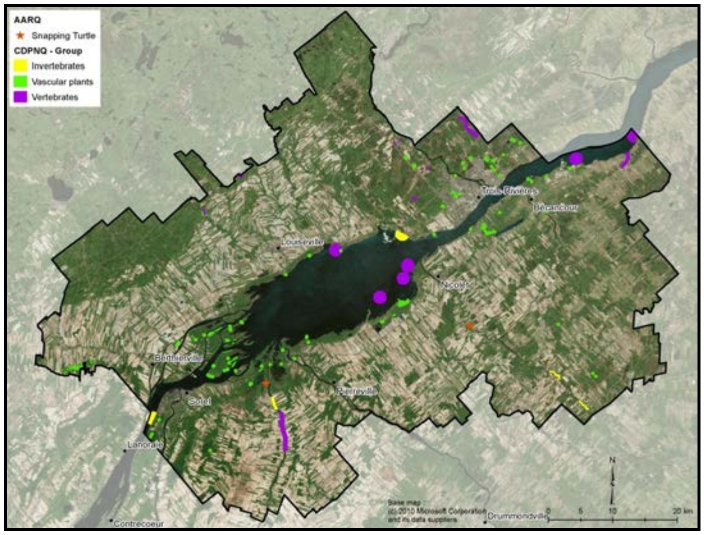


Figure 6 – Location of records of species at risk (other than avifauna)

Data from the Atlas of Amphibians and Reptiles of Québec

Records of the Snapping Turtle (*Chelydra serpentina*), a species of special concern in Canada, were extracted from the database of the Atlas of Amphibians and Reptiles of Quebec (AARQ). Among the 13 sightings in the study area (as of July 2011), 2 recent and accurate records were retained (Figure 6).

8.0 STEP 2A – PLANNING AND MAPPING TOOLS

8.1 REVIEWING EXISTING SOFTWARES

In order to locate priority conservation areas, statistics must be calculated for each habitat patch (e.g. number, geometry) and the connectivity between them, or any other spatial element that may have an impact on the distribution and movement of wildlife in the area, must be assessed. Existing softwares were assessed to determine which is most appropriate for achieving the project objectives. Compatibility with ArcGIS and the frequency of updates to the software were key criteria in the selection process.

Nine software packages frequently used in habitat conservation and landscape planning were assessed, including CLUZ, ConsNet, C-Plan, Habitat Priority Planner, LINK, Marxan, P.A.N.D.A., Vista and ZONATION. The Habitat Priority Planner (HPP) software was selected for its ease of use, features for calculating landscape metrics based on FRAGSTATS (McGarigal et al. 2002), compatibility with ArcGIS (ArcGIS 9.3 or 10 + *Spatial Analyst*) as well as its capability to produce different scenarios based on changes in land use. However, a technical problem made HPP incompatible for several months, and the landscape metrics calculated with HPP could not meet all needs of this project. Therefore, FRAGSTATS had to be used to obtain more comprehensive statistics on the landscape components.

The Corridor Designer software was selected amongst eight packages frequently used to design wildlife corridors (Circuitscape, Connectivity Analysis Toolkit, Connefor Sensinode, Corridor Designer, FunnConn, Guidos, Marine Geospatial Ecology tools [MGET] and Pathmatrix) because of its ease of use, compatibility with ArcGIS and ability to create habitat suitability models. The quality of the proposed corridors can be assessed with an additional optional module by calculating several statistics, such as corridor width, distance between viable habitat patches and the location of bottlenecks.

8.2 DECISIONS MADE PRIOR TO ANALYSIS

8.2.1 Spatial analysis scale

In addition to a descriptive analysis across the entire study area, the landscape was described in smaller spatial units in order to facilitate the implementation of the conservation plan. The landscape has been described through an administrative division of Quebec, i.e. the regional county municipalities (RCMs), and an ecological division (watershed).

8.2.2 Overlapping of habitat patches

Landscape metrics calculated to describe the spatial configuration of habitat patches may be biased if patches overlapping more than one RCM or a watershed are artificially cut at their boundaries (e.g. a large wooded area located on the edge of two RCMs would be considered two separate patches). Habitat patches overlapping more than one RCM or watershed were assigned to each RCM or watershed, and landscape metrics were calculated on the actual boundaries of the patch. Thus, the selection of priority habitat patches in the conservation plan is based on the intrinsic character of the patches (total area) and not on an artificial division. However, habitat patches located along the boundaries of the study area whose scope extends beyond those boundaries were cut at the boundaries of the pilot project territory. This may have biased the calculation of landscape metrics for these patches; however, large woodlots located at the fringe of the study area were considered to select forest corridors.

8.2.3 Selection of landscape metrics

Landscape metrics were calculated using FRAGSTATS for the three landscape divisions (entire study area, RCM, watershed) and at three spatial scales (patch, habitat class, entire landscape) to describe the composition and configuration of habitats in the study area. The metrics calculated for the habitat patches provide insight into the intrinsic nature of the patches (e.g. their shape). The metrics calculated for the habitat classes provide insight into the relative importance of each habitat class (e.g. the total area covered by each class) or the spatial configuration of habitat patches (e.g. the proximity of patches of the same class). Finally, the metrics calculated for the entire landscape inform us on the distribution patterns of habitat classes and thus the heterogeneity and diversity of the landscape as a whole (e.g. Simpson's diversity index).

Several metrics calculated by FRAGSTATS are redundant and/or difficult to interpret. We selected a few metrics based on knowledge gained in past studies (Jobin et al. 2001; Maheu-Giroux et al. 2006; Latendresse et al. 2008), the metrics' ease of interpretation and the literature (Gustafson 1998; Hargis et al. 1998; Trani and Giles 1999; Jaeger 2000; Shao et al. 2001;

McGarigal et al. 2002; Corry 2004). Correlations were also used to select otherwise redundant metrics. Landscape metrics were calculated on general and detailed land use habitat classes (Table 3). Interior forest habitats were calculated using three edge widths (100 m, 200 m, 300 m). To calculate the proximity index (PROX) of patches in the same habitat class, the analysis range was determined at 200 m for forests, 1 km for perennial crops and 5 km for wetlands. Appendix 3 presents the matrices formed to calculate the edge contrast index (ECON).

Table 3 – Landscape metrics selected for the pilot project and calculated with FRAGSTATS

				Utility			
Spatial scale	Landscape metric	FRAGSTATS acronym	Unit	Land use	Fragmentation	Forest corridors	Patch prioritization
Patch	Area	AREA	ha	X		X	X
	Core area	CORE	ha	X			
	Core area index	CAI	%	X			X
	Edge contrast	ECON	%			X	X
	Fractal dimension (shape)	FRAC	none			X	X
	Proximity index	PROX	none			X	X
Habitat class	Number of patches	NP	none	X			
	Class area	CA	ha	X			
	% cover of the landscape	PLAND	%	X			
	Mean patch area	AREA_MN	ha	X			
	Coef. var. in patch area	AREA_CV	%	X			
	Area-weighted mean patch area	AREA_AM	none		X		
	Total core area	TCA	ha	X	X		
	Mean core area	CORE_MN	ha	X	X		
	Core area percentage of landscape	CPLAND	%	X	X		
	Patch density	PD	n/100 ha		X		
	Clumpiness index	CLUMPY	%		X		
	Splitting index	SPLIT	none		X		
Landscape (study area)	Shannon's diversity index	SHDI	none	X			
	Shannon's evenness index	SHEI	none	X			
	Simpson's diversity index	SIDI	none	X			
	Simpson's evenness index	SIEI	none	X			
	Contagion index	CONTAG	%		X		
	Aggregation index	AI	%		X		
	Interspersion & juxtaposition index	IJI	%		X		
	Edge density	ED	m/ha		X		
	Patch density	PD	n/100 ha		X		
	Landscape shape index	LSI	none		X		
	Patch richness density	PRD	n/100 ha		X		

* See McGarigal et al. 2002 for a description of the selected metrics.

8.2.4 Forest fragmentation

Certain species of forest birds avoid crossing open areas that lie between two forest patches for various reasons (increased risk of predation, unsuitable habitat, etc.). Several studies conducted in Quebec (Desrochers and Hannon 1997; Rail et al. 1997; Duchesne et al. 1998; Bélisle and Desrochers 2002) show that, in general, forest birds easily cross gaps < 30–50 m wide. Therefore, anthropogenic structures in the landscape whose width is less than 50 m do not contribute to the fragmentation of forest cover. Only highway right-of-ways (ROWs) contribute to the fragmenting of forest cover, as their width is > 65 m (Bélanger et al. 2006). A habitat class called "highway ROW" has been created so that highways and their ramps are shown on the land use map by creating a buffer zone of 40 m extending from the centre of the highway to both sides, for a total ROW of 80 m. Power line ROWs were visually inspected individually and only those with a width greater than 50 m were considered to influence forest fragmentation. No change in forest patches has been made to reflect the fragmentation caused by watercourses.

9.0 STEP 3 – LANDSCAPE ANALYSIS

Analysis of the landscape of the study area allows us to describe and understand the distribution and the interaction of the various landscape elements. The approach used quantifies the availability (composition) and spatial distribution (configuration) of habitats in order to assess whether the landscape of the study area is able to maintain viable populations of priority bird species and ensure the integrity of habitats. The landscape analysis is divided into two main parts, each broken down into distinct sections:

1. Descriptive analysis
    - Description of the land use (study area, RCM, watersheds)
2. Functionality of the landscape
    - Comparison of the landscape with known reference thresholds
    - Identification of forest corridors
    - Application of coarse filter criteria
    - Prioritization of coarse filter patches
    - Application of fine filter criteria

All analyses presented in this report for RCMs were also done for watersheds. Results for each watershed are presented in the detailed methodological report (Jobin et al. 2013).

9.1 DESCRIPTIVE ANALYSIS

9.1.1 Land use: Study area

Figures 7 and 8 illustrate land use in the study area according to 7 general classes and 21 detailed classes. Farmlands cover more than half of the territory, 31% of which is annual crops (corn, soybean) and 20% is perennial crops (forage, hayfield, pasture) (Table 4). Patches of perennial crops are, on average, much smaller (18 ha) than those of annual crops (40 ha). There are 143 patches of perennial crops covering > 100 ha. Forests cover 24% of the study area, dominated by deciduous forests (12%) or mixed forests (9%). All types combined, the average forest covers 45 ha, but 118 of these forests cover > 100 ha. More than 1500 forest patches provide interior habitats when a 100 m edge is eliminated, covering more than 12% of the territory (Table 5). These numbers are cut in half and by a quarter when wide edges (200 m and 300 m respectively) are eliminated.

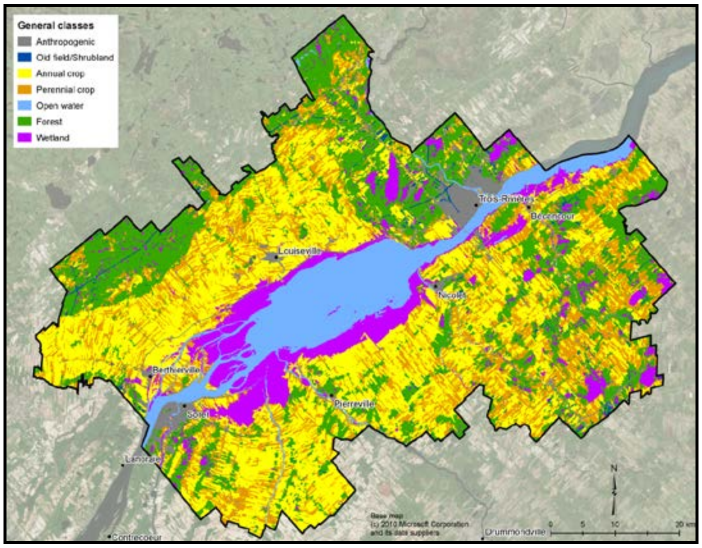


Figure 7 – Land use in the study area, general classes

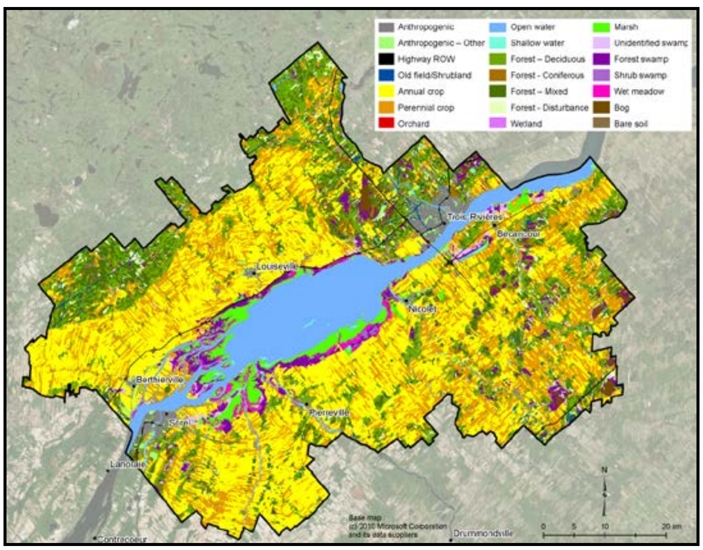


Figure 8 – Land use in the study area, detailed classes

Table 4 – Area and description of the general and detailed habitats classes in the study area

General class	Detailed class	Area km^2	Area %	Patch Number	Patch Mean (ha)	Patch Coef. Var.
Anthropogenic		172	4.1	1649	10.4	1741.5
	Anthropogenic	128	3.1	1835	7.0	791.9
	Anthropogenic – Other	20	0.5	337	5.9	247.9
	Highway ROW	24	0.6	4	595.5	130.2
Annual crop		1316	31.4	3340	39.4	1311.1
Perennial crop		837	20.0	4644	18.0	525.6
	Perennial crop	837	20.0	4644	18.0	525.7
	Orchard	0	0.0	4	2.8	43.0
Old field/Shrubland		42	1.0	1184	3.5	257.1
Forest		998	23.8	2221	45.0	774.7
	Forest – Coniferous	65	1.5	720	9.0	157.8
	Forest – Deciduous	506	12.1	2902	17.4	416.3
	Forest – Mixed	354	8.5	2292	15.5	307.6
	Forest – Disturbance	72	1.7	976	7.3	154.5
	Bare soil	1	0.0	38	3.4	83.6
Wetland		398	9.5	1082	36.8	840.7
	Marsh	120	2.9	733	16.4	699.6
	Unidentified swamp	48	1.1	689	7.0	281.1
	Shrub swamp	15	0.4	357	4.2	281.7
	Forest swamp	125	3.0	545	23.0	267.7
	Wet meadow	36	0.9	391	9.2	290.8
	Bog	40	1.0	301	13.3	371.3
	Shallow water	12	0.3	279	4.3	233.9
	Unidentified wetland	2	0.0	217	0.9	75.1
Open water		431	10.3	356	121.2	1543.5

Table 5 – Description of interior forest habitats in the study area based on three forest edge widths

		Edge width	
Interior forest habitat	**100 m**	**200 m**	**300 m**
Number of patches	1534	839	419
Total area (ha)	51 014	24 585	12 012
Percent cover of the study area	12.2	5.9	2.9
Mean patch area (ha)	23.0	11.1	5.4

Wetlands cover nearly 10% of the landscape, mostly located in the Lake Saint-Pierre flood plain. The wooded swamps and marshes bordering the lake cover large areas, particularly on the south shore of Lake Saint-Pierre, in the Berthier-Sorel archipelago and in the Lavallière, Saint-François and Maskinongé bay areas. We also note the presence of large bogs in the Trois-Rivières and Daveluyville areas. Apart from a few large rivers flowing into the study area (Saint-Maurice, Yamaska, Saint-François, Richelieu, Bécancour), open water areas (10% of the territory) are represented by Lake Saint-Pierre and the St. Lawrence River. Anthropogenic areas (4%) are concentrated around the cities of Trois-Rivières (130 000 inhabitants) and Sorel-Tracy (35 000 inhabitants) and in municipalities with a lower population, including Bécancour

(11 000 inhabitants), Nicolet (8 000 inhabitants), Louiseville (8 000 inhabitants) and Berthierville (4 000 inhabitants). Finally, old fields and shrublands cover only 1% of the territory, and are generally small in size (avg. = 3.5 ha). The largest ones fall under the electric ROWs.

9.1.2 Land use: RCM

The study area was divided up based on the boundaries of the RCMs in order to describe the landscape in terms of territorial divisions favourable to the implementation of the habitat conservation plan. Some of the RCMs are partially located in the study area, and the areas analyzed vary greatly between the RCMs (Table 6). Thus, only 36% of the Maskinongé RCM is included in the study area while the Nicolet-Yamaska and Trois-Rivières RCMs are fully included. Similarly, the Nicolet-Yamaska and Maskinongé RCMs together cover more than half of the study area, while the other four RCMs each cover less than 15% of the territory.

Table 6 – Area covered by the RCMs in the study area

RCM	Total area (km^2)	Area within the study area (km^2)	% of the RCM located within the study area	% cover of the study area
D'Autray	1353	587	43.4	14.0
Maskinongé	2643	957	36.2	22.8
Trois-Rivières	335	335	100.0	8.0
Bécancour	1234	584	47.3	13.9
Nicolet-Yamaska	1189	1190	100.0	28.4
Pierre-De Saurel	639	542	84.9	12.9
Total	**7393**	**4195**	**56.7**	**100.0**

Table 7 presents the absolute (ha) and relative (%) area of the general and detailed habitat classes in each RCM, and figures 9 and 10 are used to compare the RCMs to determine the habitats present and the distribution of habitat classes in each RCM. We observe that:

- The relative importance of forest cover is higher in the northern (Maskinongé and D'Autray RCMs) and eastern RCMs (Bécancour and Trois-Rivières RCMs).
- Forests cover less than 20% of the Pierre-De Saurel and Nicolet-Yamaska RCMs.
- About two thirds of anthropogenic areas are found in the Pierre-De Saurel and Trois-Rivières RCMs.
- There are few old fields in the study area and virtually none in the Pierre-De Saurel RCM.
- Farmland covers more than half of the RCMs, except for the Trois-Rivières RCM, where it covers less than 20% of the territory.
- Annual crops dominate in the Pierre-De Saurel and D'Autray RCMs.
- Wetlands (all types combined) cover between 6% and 12% of each RCM.
- There are very few marshes, shrub swamps, wet meadows and shallow water areas in the Trois-Rivières RCM.
- There are no wet meadows in the Bécancour RCM.
- There are very few bogs in the D'Autray and Pierre-De Saurel RCMs.

Table 7 – Area (km^2 and %) of general and detailed classes of habitats in the RCMs

		D'Autray		Maskinongé		Trois-Rivières		Bécancour		Nicolet-Yamaska		Pierre-De Saurel	
General class	**Detailed class**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Anthropogenic		14	2.4	24	2.5	68	20.3	12	2.1	19	1.6	35	6.4
	Anthropogenic	10	1.7	15	1.6	54	16.0	8	1.4	13	1.1	28	5.1
	Anthropogenic – Other	2	0.3	2	0.2	8	2.3	1	0.1	2	0.2	6	1.0
	Highway ROW	3	0.4	7	0.7	7	2.1	3	0.6	3	0.2	1	0.2
Annual crop		225	38.3	299	31.2	36	10.6	128	22.0	396	33.2	233	43.0
Perennial crop		103	17.5	177	18.5	27	7.9	158	27.1	272	22.9	101	18.6
	Perennial crop	103	17.5	177	18.5	27	7.9	158	27.1	272	22.8	101	18.6
	Orchard	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Old field/Shrubland		7	1.2	9	0.9	10	3.1	5	0.9	9	0.8	2	0.3
Forest		147	25.1	259	27.1	118	35.4	170	29.2	227	19.0	77	14.1
	Forest – Coniferous	6	1.0	18	1.9	17	5.1	10	1.7	8	0.7	6	1.1
	Forest – Deciduous	63	10.8	125	13.1	47	14.1	101	17.3	125	10.5	44	8.2
	Forest – Mixed	68	11.6	97	10.1	47	13.9	44	7.6	76	6.4	23	4.2
	Forest – Disturbance	9	1.5	19	1.9	7	2.2	15	2.6	18	1.5	4	0.7
	Bare soil	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Wetland		49	8.3	63	6.5	33	9.9	60	10.4	132	11.1	62	11.4
	Marsh	18	3.1	21	2.2	3	0.9	11	1.9	45	3.8	21	4.0
	Unidentified swamp	4	0.7	3	0.3	4	1.3	15	2.6	11	0.9	11	2.0
	Shrub swamp	5	0.8	2	0.2	0	0.0	1	0.2	7	0.6	0	0.1
	Forest swamp	13	2.3	24	2.5	14	4.2	19	3.2	41	3.4	14	2.6
	Wet meadow	6	1.1	5	0.5	0	0.1	0	0.0	14	1.2	10	1.9
	Bog	0	0.1	7	0.8	11	3.2	10	1.8	9	0.8	2	0.4
	Shallow water	1	0.2	0	0.0	0	0.1	3	0.6	5	0.4	2	0.4
	Unidentified wetland	0	0.1	0	0.0	0	0.1	1	0.1	0	0.0	0	0.0
Open water		43	7.3	126	13.2	43	12.8	49	8.5	136	11.4	34	6.3

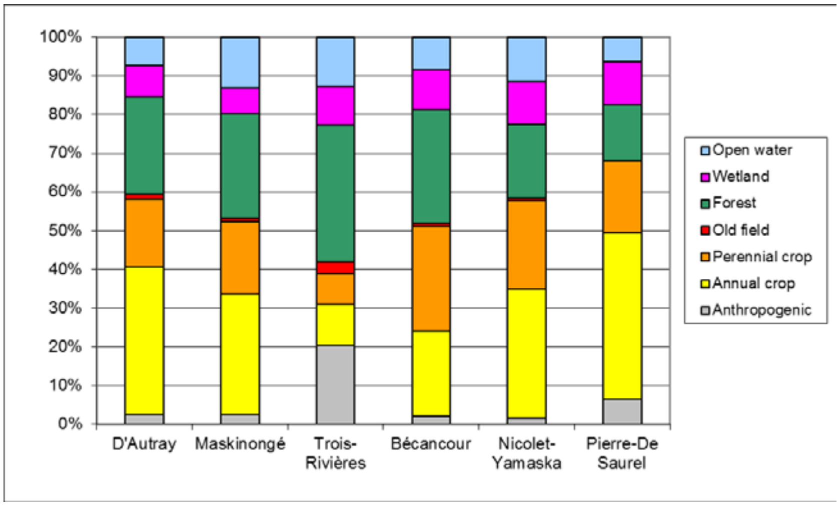


Figure 9 – Cover (%) of the seven general habitat classes by RCM

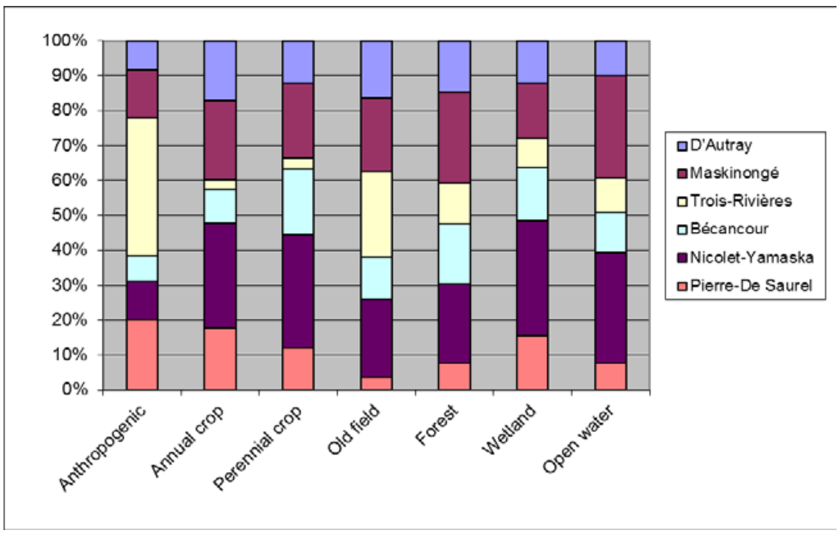


Figure 10 – Breakdown of general habitat classes in the RCMs

A more detailed analysis of the quality of forests and woodlots in the RCMs indicates that woodlots offering the largest and most numerous areas of interior habitats are found in the D'Autray and Maskinongé RCMs, regardless of the width of the forest edge (100 m, 200 m, 300 m) (Figure 11). On the other hand, the Pierre-De Saurel and Nicolet-Yamaska RCMs offer the least amount of interior forest habitats. In addition, the four metrics used to describe the degree of forest fragmentation (Figure 12) indicate that woodlands are the rarest and most fragmented in the Pierre-De Saurel and Nicolet-Yamaska RCMs. The combination of this information on the quality of forest habitats (interior forest habitats, fragmentation) makes it possible to determine the RCMs that offer the most suitable woodlots to forest birds (Figure 13).

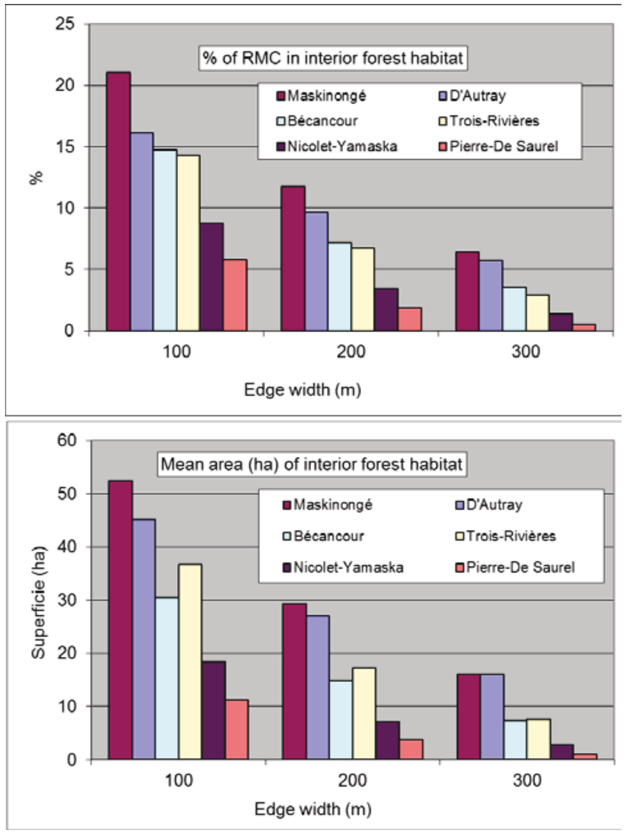


Figure 11 − Relative importance (%) of the cover and mean area (ha) of interior forest habitats in the RCMs for forest edges that are 100 m, 200 m and 300 m wide

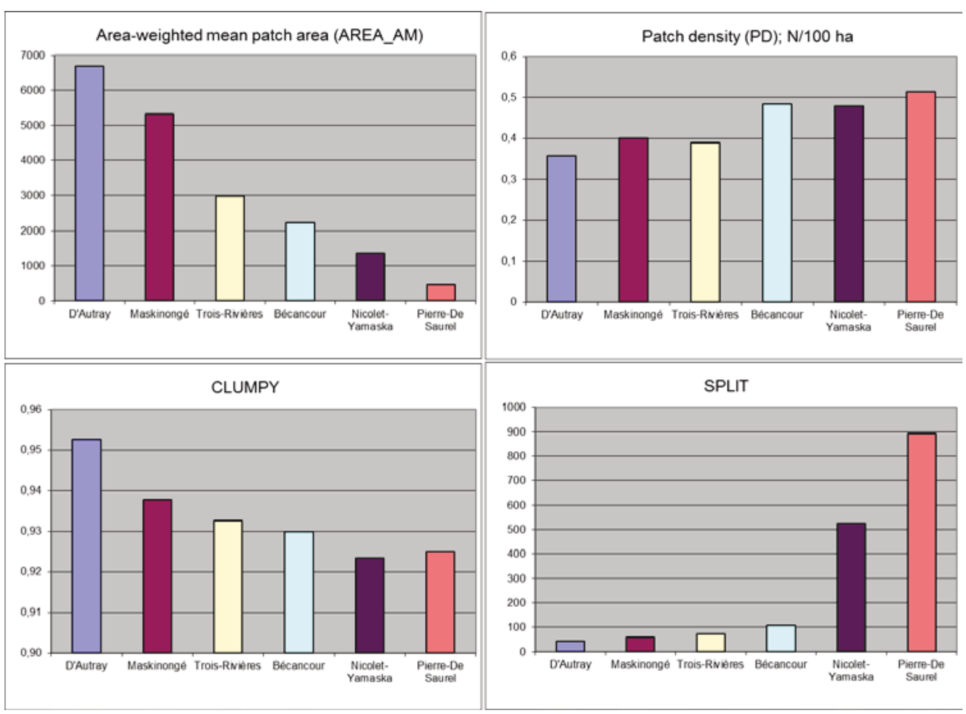


Figure 12 − Landscape metrics (4) illustrating woodlot fragmentation in the RCMs

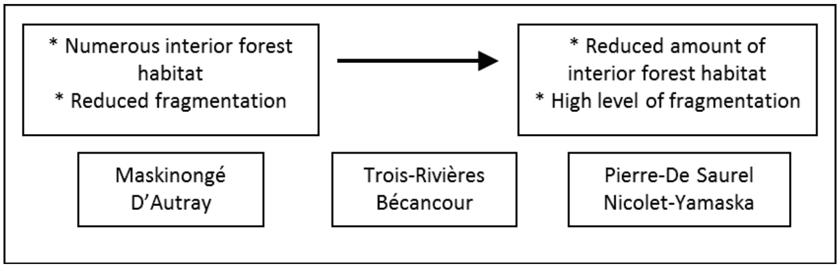


Figure 13 – RCMs ordered by the importance of interior forest habitats and woodlot fragmentation

9.2 FUNCTIONALITY OF THE LANDSCAPE

Different approaches have been used to assess whether the landscape in our study area provides functional habitats for priority species. The availability and integrity of nesting habitats, as well as landscape permeability allowing for the movement of forest birds, were evaluated in several ways: comparison with known reference thresholds, identification of forest corridors, application of coarse filter and fine filter criteria.

9.2.1 Comparison of the landscape with known reference thresholds

Habitat availability in the study area was compared to reference thresholds values known to sustain minimum viable wildlife populations and help maintain selected ecosystem functions. The thresholds used are those created by Environment Canada in Ontario in the development of guidelines for the conservation and restoration of wetland, riparian and forest habitats (Environment Canada 2004). Comparing current wildlife habitat cover in the various spatial units with these thresholds makes it possible to determine the parts of the study area where habitat cover is adequate and regions where conservation and restoration needs would be justified. This approach was also adopted as part of the National Agri-Environmental Standards Initiative (NAESI) in Canada (Maheu-Giroux and Belvisi 2007; McPherson et al. 2009; Neave et al. 2009).

Forests

Studies have shown that when forest cover of a landscape is above a certain threshold, ranging from 20 to 35%, the persistence of bird species was virtually ensured or that habitat configuration had little or no effect on species richness or abundance (Andrén 1994; Fahrig 1997; Tate 1998; Villard et al.1999; Rompré et al. 2010). Also, certain bird species avoid forest edges, and their abundance increases based on the area of interior forest habitat (Austen et al. 2001). It is even more imperative to determine the availability of interior forest habitat knowing that forest cover is highly reduced and fragmented in several RCM in southern Quebec (Bélanger and Grenier 2002).

- At least 30% of the territory (study area, RCM, watershed) should be forested.
- At least 10% of the territory (study area, RCM, watershed) should be forested, representing interior forest conditions at 100 m or more from the forest edge.
- At least 5% of the territory (study area, RCM, watershed) should be forested, representing interior forest conditions at 200 m or more from the forest edge.

Forests cover less than 24% of the study area (Table 8), which means that the current landscape is not adequate to sustain viable bird communities. On a smaller scale, the threshold of 30% forest cover is reached only in the Trois-Rivières RCM (Figure 14). In the Nicolet-Yamaska and Pierre-De Saurel RCMs, forests are very scarce, covering less than 20% of the territory.

Table 8 – Comparison of the study area and the RCMs landscape with reference thresholds values known to support forest bird communities and maintain wetlands and watercourses functions

	Threshold value							
	Forest			Wetland		Riparian habitat		
	% total cover	% interior habitat 100 m	% interior habitat 200 m	% total cover	% of sites with 100% natur. veget. Buffer zone=100m (max. number of sites)	% natur. veget.	% natur. veget. (buffer zone) Width=30m	% natur. veget. (buffer zone) Width=100m
Region	> 30%	> 10%	> 5%	> 6% ou 10%		> 75%	> 75%	> 75%
Study area	23.8	12.2	5.9	9.5	43.5 (n=3512)	36.2	34.3	32.2
RCM D'Autray	25.1	16.1	9.6	8.3	48.2 (n=745)	33.2	31.6	28.6
Maskinongé	27.1	21.1	11.8	6.5	44.5 (n=661)	41.2	39.2	35.9
Trois-Rivières	35.4	14.3	6.7	9.9	37.6 (n=340)	59.0	57.8	54.7
Bécancour	29.2	14.7	7.2	10.4	29.7 (n=445)	38.4	36.0	35.1
Nicolet-Yamaska	19.0	8.8	3.5	11.1	45.8 (n=918)	30.8	29.2	27.7
Pierre-De Saurel	14.1	5.8	1.9	11.4	46.6 (n=474)	30.5	27.6	25.9

Note: The numbers highlighted in green indicate that the threshold is reached or exceeded.

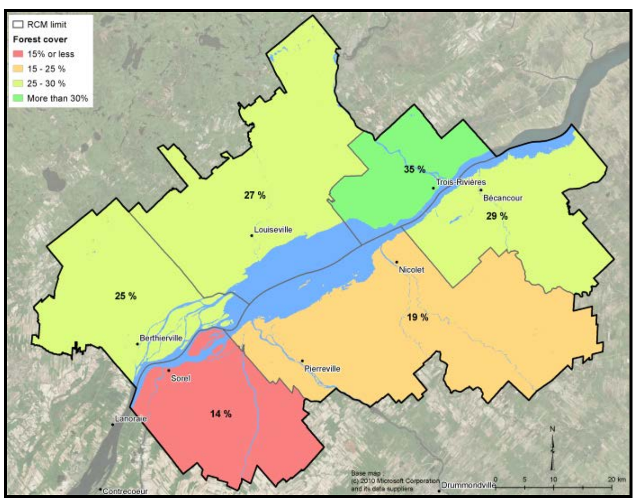


Figure 14 - Cover (%) of forest cover by RCM

Despite the fact that forests cover less than 30% of the territory, they still offer numerous interior forest habitats, regardless of whether the forest edge is 100 m or 200 m wide. In fact, the respective thresholds of 10% and 5% of interior forest coverage for both forest edge widths are reached across the entire study area, as well as in the majority of RCMs and watersheds (Table 8). However, these thresholds are not met in the Nicolet-Yamaska and Pierre-De Saurel RCMs (Figures 15 and 16).

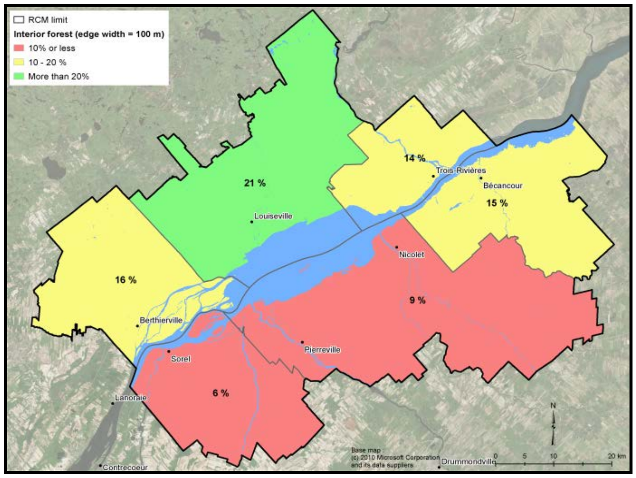


Figure 15 – Cover (%) of interior forest habitat by RCM (edge = 100 m)

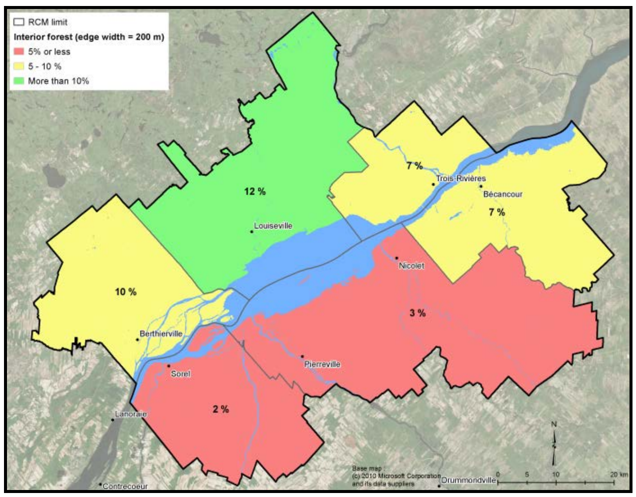


Figure 16 – Cover (%) of interior forest habitat by RCM (edge = 200 m)

Wetlands

Wetlands should cover at least 10% of a watershed, or at least 6% of a subwatershed, in order to ensure adequate spatial distribution of wetlands across the landscape (Detenbeck et al. 1999; Environment Canada 2004). Also, to maintain key wetland functions and attributes, it is recommended to preserve an area 100 m wide of natural vegetation around wetlands (Environment Canada 2004).

- At least 10% of a watershed and at least 6% of a subwatershed should be covered by wetlands.
- A buffer zone of 100 m or more in width, composed of natural vegetation[5] should be preserved around wetlands.

5 Natural vegetation includes the following habitat classes: coniferous forests, mixed forests, deciduous forests, other wetlands, old fields and shrublands, water, rocky outcrops, sand dunes, plantations.

With 9.5% wetland coverage (Table 8), the study area almost reaches the minimum threshold required to ensure suitable habitats for wetland species. The 6% threshold targeted for subwatersheds here refers to the parts of the RCM that are located in the study area. This threshold is reached for almost all spatial units, with wetlands even covering > 10% in several RCMs (Figure 17). Note, however, that the wetlands are largely concentrated in the immediate vicinity of Lake Saint-Pierre and are scarce elsewhere in the study area.

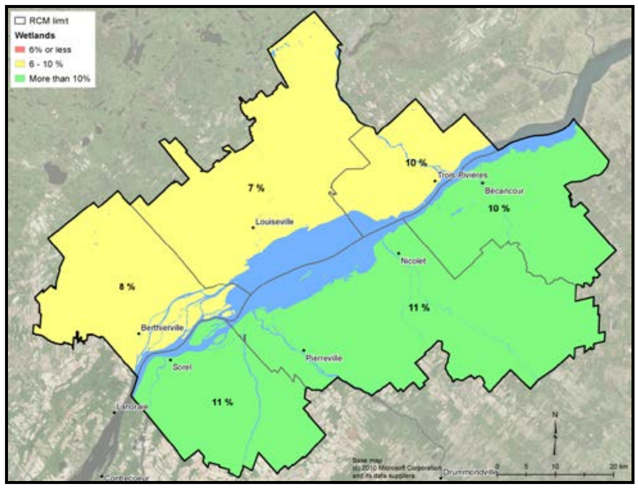


Figure 17 – Percentage of wetland coverage by RCM

There are 3512 patches of wetlands in the study area and less than half of them (43.5%) have a 100-m-wide buffer zone that is completely covered with natural vegetation (including aquatic areas) (Figure 18, Table 9). Less than 60% of wetlands in the RCMs have such a vegetated buffer zone. Interestingly, of the 1986 wetlands whose buffer zone do not have full natural vegetation coverage, 407 have a buffer zone with 90% coverage, and 818 are 75% covered with natural vegetation. On the other hand, 100 wetlands have less than 10% of their buffer zone covered with natural vegetation. The shrub swamps and wet meadows are those wetland types mostly bordered by a buffer zone of 100% natural vegetation, with 70% and 62% of patches, respectively, while less than 35% of undefined wetlands, undefined swamps, wooded swamps and peat bogs have a buffer zone completely covered with natural vegetation.

There are significant differences between the RCMs (Table 9). A high proportion (74%) of wet meadows in the Nicolet-Yamaska RCM has a buffer zone completely covered with natural vegetation; this figure is only 14% in the Trois-Rivières RCM.

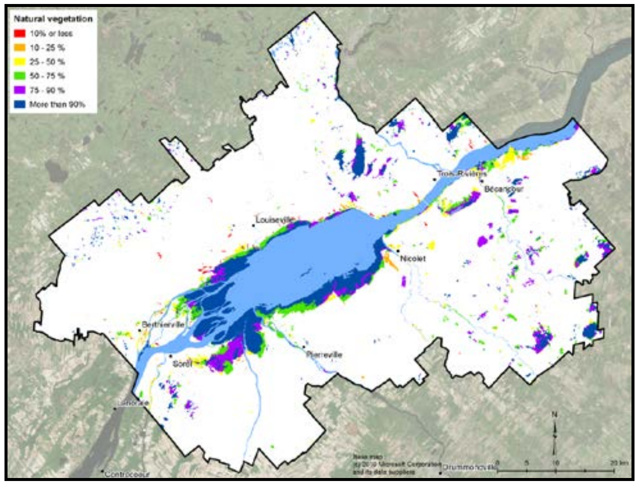


Figure 18 – Percentage of natural vegetation cover (including aquatic areas) in a 100-m-wide buffer zone around each wetland patch

Table 9 – Number (n) and proportion (%) of wetland patches with 100-m-wide buffer zones that are completely covered with natural vegetation (including aquatic areas)

Study area			
Wetland type	Total	n	%
Shallow water	279	135	48.4
Marsh	733	363	49.5
Forest swamp	545	166	30.5
Shrub swamp	357	249	69.7
Unidentified swamp	689	211	30.6
Unidentified wetland	217	57	26.3
Wet meadow	391	242	61.9
Bog	301	103	34.2
Total	3512	1526	43.5

RCM	D'Autray			Maskinongé			Trois-Rivières			Bécancour			Nicolet-Yamaska			Pierre-De Saurel		
Wetland type	Total	n	%	Total	n	%	Total	n	%	Total	n	%	Total	n	%	Total	n	%
Shallow water	34	16	47.1	8	4	50.0	3	0	0.0	55	20	36.4	113	47	41.6	76	52	68.4
Marsh	251	126	50.2	148	80	54.1	72	38	52.8	58	20	34.5	119	60	50.4	103	47	45.6
Forest swamp	90	43	47.8	136	32	23.5	60	13	21.7	70	16	22.9	148	48	32.4	61	19	31.1
Shrub swamp	122	78	63.9	80	54	67.5	1	0	0.0	8	6	75.0	137	107	78.1	11	4	36.4
Unidentified swamp	80	17	21.3	98	40	40.8	80	34	42.5	133	30	22.6	183	44	24.0	124	51	41.1
Unidentified wetland	50	7	14.0	27	13	48.1	26	6	23.1	62	12	19.4	27	9	33.3	27	12	44.4
Wet meadow	102	67	65.7	99	53	53.5	14	2	14.3	0	–	–	119	88	73.9	64	36	56.3
Bog	16	5	31.3	65	18	27.7	84	35	41.7	59	28	47.5	72	17	23.6	8	0	0.0
Total	745	359	48.2	661	294	44.5	340	128	37.6	445	132	29.7	918	420	45.8	474	221	46.6

Riparian habitats

Maintaining natural habitats along watercourses helps improve water quality. An Ontario study revealed a degradation of watercourses where vegetation cover was less than 75% along the banks (Steedman 1987; McPherson et al. 2009).

- At least 75% of of stream length should be naturally vegetated.
- At least 75% of a 100-m-wide riparian habitat along a watercourse should be naturally vegetated.

There are more than 31 616 km of riparian habitats in the study area, and only 36% of those are naturally vegetated, which is far from the goal of 75%. The riverbanks are mostly covered with natural vegetation (67%), while the banks of small streams have less coverage of natural habitats (25%). If the vegetation is not natural, the banks are often covered by annual or perennial crops (52% and 41% respectively). Few banks in the study area are in urban settings (5%). By including perennial crops in the natural vegetation class, the percentage of natural vegetation along the watercourses greatly increases but does not reach the 75% threshold for small streams and creeks.

Table 10 shows the proportion of riparian habitats composed of natural vegetation by RCM. Apart from riparian habitats in the Bécancour area, the percentage of riparian habitats covered with natural vegetation is still below the threshold of 75% for the three main types of watercourses (gullys, streams and rivers) in each RCM. It is particularly worrying that these percentages are often less than 30% in several RCMs. Areas with the most highly modified riparian habitats are the Pierre-De Saurel and Nicolet-Yamaska RCMs, while the area where riparian habitats are mostly natural is the Trois-Rivières RCM.

Table 10 – Total length of the riparian habitats (watercourses, small bodies of water) and total length of riparian habitats of natural vegetation based on the type of watercourses in each RCM

		Total length		Length natur. veget.				Total length		Length natur. veget.	
RCM	Type	Metres	%	Metres	%	RCM	Type	Metres	%	Metres	%
D'Autray						Bécancour					
	Gully	2300992	50.2	442427	19.2		Gully	2597903	53.6	755511	29.1
	Stream	1338149	29.2	493643	36.9		Stream	1546169	31.9	562237	36.4
	River	774058	16.9	482359	62.3		River	537009	11.1	442097	82.3
	Pond	152921	3.3	95432	62.4		Pond	98631	2.0	44852	45.5
	Lake	14032	0.3	7890	56.2		Lake	55961	1.2	50019	89.4
	Culvert	4761	0.1	837	17.6		Culvert	4618	0.1	1620	35.1
	Pool	536	0.0	536	100.0		Pool	4503	0.1	3730	82.8
	Total	4585448	100.0	1523125	33.2		Total	4844794	100.0	1860065	38.4
Maskinongé						Nicolet-Yamaska					
	Gully	3680931	54.1	1065736	29.0		Gully	6049761	65.9	1305956	21.6
	Stream	2294198	33.7	1188677	51.8		Stream	1743505	19.0	536839	30.8
	River	459837	6.8	255177	55.5		River	1184313	12.9	869310	73.4
	Pond	258663	3.8	192559	74.4		Pond	161670	1.8	85490	52.9
	Lake	44689	0.7	44039	98.5		Pool	16939	0.2	16939	100.0
	Reservoir	44664	0.7	40778	91.3		Basin	9233	0.1	7505	81.3
	Pool	16597	0.2	14080	84.8		Lake	6588	0.1	6588	100.0
	Culvert	9303	0.1	2559	27.5		Culvert	1741	0.0	116	6.7
	Total	6808881	100.0	2803606	41.2		Total	9173750	100.0	2828744	30.8
Trois-Rivières						Pierre-De Saurel					
	Stream	875601	45.3	478362	54.6		Gully	2384250	55.6	463581	19.4
	Gully	755917	39.1	483719	64.0		Stream	926458	21.6	255206	27.5
	River	183095	9.5	108364	59.2		River	768028	17.9	478969	62.4
	Pond	101998	5.3	67172	65.9		Pond	138551	3.2	57792	41.7
	Culvert	14044	0.7	2030	14.5		Lake	32312	0.8	32312	100.0
	Lake	2984	0.2	553	18.5		Pool	17267	0.4	17267	100.0
	Total	1933640	100.0	1140199	59.0		Culvert	11688	0.3	734	6.3
							Basin	9783	0.2	0	0.0
							Total	4288338	100.0	1305860	30.5

At least 75% of a 30-m-wide buffer adjacent to streams should be naturally vegetated on both sides of the streams to maintain satisfactory water quality (Environment Canada 2004). A buffer zone of > 100 m wide along watercourses is often required to provide suitable habitats for several species of birds (Fischer 2000). The percentage of natural vegetation in riparian corridors 30 m and 100 m in width was calculated.[6] Similar to the analysis of riparian habitats along watercourses (previous reference threshold), we have observed that natural vegetation covers less than 35% of the riparian corridors for both widths analyzed (Table 11). The 75% threshold was also not reached for any RCM. In fact, the trends observed with the previous reference threshold (% of stream length naturally vegetated) are the same as those observed when riparian habitats are 30 m or 100 m wide. The threshold of 75% cover of natural vegetation in these riparian habitats is not met for the study area as a whole or for the RCMs even when perennial crops are considered as natural vegetation.

Table 11 – Area (ha and %) of natural vegetation in 30 m and 100 m wide riparian habitats in the study area and the RCMs. The figures in parentheses include perennial crops in the calculation of natural vegetation cover.

Buffer zone = 30 m				**Buffer zone = 100 m**			
		Natural vegetation				**Natural vegetation**	
Region		**ha**	**%**	**Region**		**ha**	**%**
Study area		14956.7	34.3 (60.0)	Study area		43240.6	32.2 (58.0)
RCM	D'Autray	2023.8	31.6 (53.7)	RCM	D'Autray	5627.5	28.6 (51.2)
	Maskinongé	3757.5	39.2 (62.4)		Maskinongé	10627.2	35.9 (59.6)
	Trois-Rivières	1589.2	57.8 (69.3)		Trois-Rivières	4684.1	54.7 (67.5)
	Bécancour	2308.7	36.0 (69.9)		Bécancour	6912.4	35.1 (69.0)
	Nicolet-Yamaska	3666.6	29.2 (58.7)		Nicolet-Yamaska	10713.0	27.7 (57.2)
	Pierre-De Saurel	1610.9	27.6 (50.3)		Pierre-De Saurel	4676.3	25.9 (48.1)

9.2.2 Identification of forest corridors

While identifying the nesting habitats of priority bird species (coarse filter and fine filter), one must also consider the travel corridors between forest patches because several species of birds require a continuous forest cover to move through the landscape on a daily basis and for the dispersal of populations (Beier and Noss 1998). The conservation plan for BCR 13 does not specify the criteria required for forest bird species to move across the landscape. However, one of the criteria used is *to increase connectivity between forest patches > 1000 ha*. The Corridor Designer software used pre-set parameters to identify potential corridors to connect those forest

[6] The criterion suggested by Environment Canada (2004) reads as follow: "Streams should have a minimum 30 m wide naturally vegetated adjacent-lands areas on both sides, greater depending on site-specific conditions." This criterion is measured by analyzing the type of habitat adjacent to a buffer zone 30 m or 100 m in width along the watercourse (G. Bryan, CWS-Ontario, pers. comm.). We adapted this criterion to measure only the percentage of natural vegetation found in riparian corridors 30 m and 100 m in width.

patches > 1000 ha. The proposed corridors were then evaluated based on criteria related to their spatial configuration and discontinuities.

Recent studies have focused on methods for identifying corridors and on associated decisions required to develop adequate predictive models (Beier et al. 2008; García-Feced et al. 2011). However, there is no consensus in the literature on a "minimum corridor width" or a "minimum distance between woodlots" because of the large variability of bird communities studied, the landscape context, the geographical location of the studies, etc. Some criteria have been proposed for the minimum corridor width (Stauffer and Best 1980; Keller et al. 1993; Spackman and Hugues 1995; Hodges and Krementz 1996; Duchesne and Bélanger 1997; Environment Canada 2004; Mason et al. 2007) and for the distance between woodlots (Duchesne et al. 1998, 1999). Kampf and Stavast (2005) defined distance thresholds between habitat patches within a given corridor based on the size of the birds: 1000 m for large birds, 500 m for medium-sized birds and 200 m for small birds. These habitat patches located inside corridors are called *stepping stones* and their presence is vital for discontinuous corridors or if they include less suitable habitats such as areas with intensive farming activities (Bennett 1999; Van der Sluis et al. 2004). The following criteria were selected in this study to evaluate corridor functionality for forest birds:

- The corridors should have a minimum width of 100 m, or ideally 200–300 m.
- The distance between woodlots should be < 200 m.

Creating a map of potential habitats

The first step in creating corridors consisted of selecting criteria that can be represented spatially and used to create the map of potential habitat use by forest birds (*Habitat Suitability Model*). Each criterion is weighted according to its relative importance to the movement of birds, and a score is then assigned to each habitat patch in order to rank the quality of each patch for each of the criteria. In the context of this study, six criteria were used (Table 12). A quality index was first assigned to each land use habitat class according to their probability of use by forest birds; some habitat classes are more conducive than others to the movement of forest species (e.g. old fields compared to corn fields). The permeability of the matrix of non-forested habitats that would prove hostile to the movement of forest birds has been considered, whereby the habitats were not categorized into a simple dichotomy of suitable and unsuitable habitats (Baum et al. 2004; Debinski 2006; Watling et al. 2011). To do this, the relative importance of each habitat class for the movement of forest birds was assessed by five CWS experts and the average assessment was used. This approach of calling on experts is a common practice for Corridor Designer users (Majka et al. 2007). We considered that birds prefer woodlots located more than a kilometre from urban centres (> 50 ha) and avoid woodlots located close (within 250 m) to them. Landscape metrics calculated in FRAGSTATS for each of the habitat patches were used to assign weights to the four other criteria: *TOTAL AREA* for size, *PROXIMITY* for isolation, *FRACTAL DIMENSION INDEX* for shape and *EDGE CONTRAST INDEX* for contrast. Three or four classes were created for each of the criteria, and the Jenks optimization method was used to determine the best distribution of values or each criterion (de Smith et al. 2011). For each habitat patch in the study area, the weight of each criterion was multiplied by the score associated with each patch, and a map of potential habitats was created as a basis for creating corridor scenarios (Figure 19).

Table 12 – Weighting of the criteria to determine corridors in Corridor Designer

Land use habitat class	
Annual crop	10
Anthropogenic	20
Bog	30
Forest	100
Forest swamp	75
Marsh	10
Old field/Shrubland	60
Open water	5
Perennial crop	20
Shallow water	5
Shrub swamp	50
Unidentified swamp	50
Unidentified wetland	10
Wet meadow	20
Weight	50

Total area	
0 – 30 m	25
30 – 100 m	50
100 – 200 m	75
200 m and over	100
Weight	20

Distance from a urban centre	
0 – 250 m	0
250 – 1000 m	50
1000 m and over	100
Weight	5

Proximity index	
0 – 5 m	0
5 – 250 m	50
250 m and over	100
Weight	12

Fractal Dimension Index (shape)	
1.00 - 1.06	100
1.06 – 1.12	50
1.12 and over	0
Weight	5

Edge Contrast Index	
0 – 40	100
40 – 65	50
65 and over	0
Weight	8

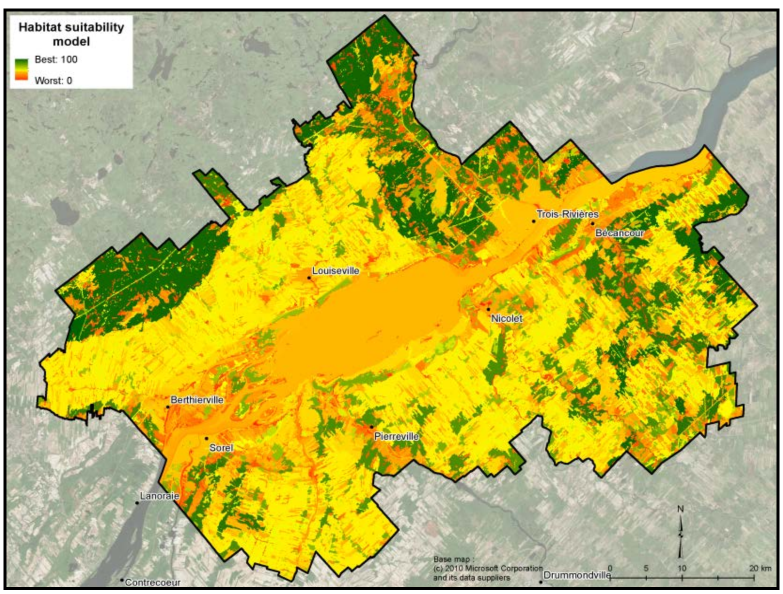


Figure 19 – Habitat suitability model for priority birds, generated by Corridor Designer

Creating corridor scenarios

Corridor scenarios are designed to connect the 13 forest patches > 1000 ha found in the study area, all of which are located in the northern part of study region. Four woodlots > 500 ha (patches #14, 15, 16 and 17, Figure 20) located south of the St. Lawrence River were added in order to study the connectivity of forest patches throughout the study area. In total, 21 corridors were proposed (Figures 20 and 21). Only those habitat patches with a suitability value > 60 were selected to establish the corridors; they were selected based on the cost of travelling, in other words, the habitat characteristics that influence the species' ability to move between two areas. The selected corridor is the best biological choice for the species and may contain one or more branches. Several scenarios are proposed according to the desired size of the corridor; this size is calculated based on its relative cover to the rest of the territory. Thus, the smallest possible corridor is the one that covers 0.1% of the landscape, representing the best route based on geographical and biological habitat characteristics between two patches. However, it is often unnecessary to select a scenario that covers a large proportion of the landscape, because the software will be forced to identify habitats that are unsuitable for forest birds.

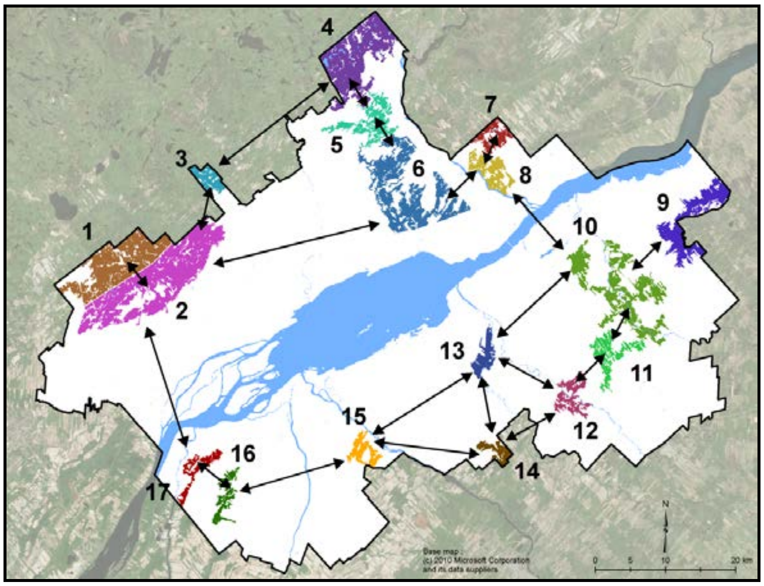


Figure 20 – Selected forest patches and location of established corridors

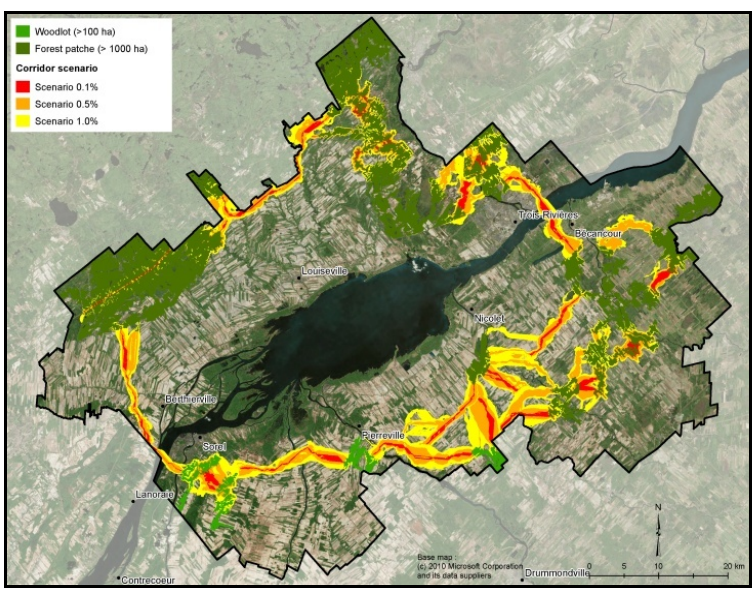


Figure 21 – Examples of proposed corridor scenarios

Selecting corridors

We used a minimum corridor width of 300 m, as a corridor width between 100 and 300 m facilitates the movement of forest birds. However, several of the proposed corridors cross through habitats that are not conducive to forest birds (potential < 60 as for annual crops). Therefore, it was determined that the selected corridors should have a width of at least **300 m** across at least **75%** of their area. For this, the statistics for the smallest scenario proposed (0.1%) were calculated, and the size was increased until the thresholds were met. This was done using the *Evaluation Tools* extension tool. This extension tool also allows one to identify bottlenecks based on the minimum width identified, and to represent them spatially. Some corridors were eliminated because they provided too close of a connection between forests (e.g. scenario 1_2) or because the best travel options for species between the forests were outside of the study area (e.g. scenario 2_3). On the other hand, other scenarios were selected, such as scenario 2_17, because they provide a connection between two forest patches even if only a section of the route is found within the study area. In total, 14 proposed corridors were selected (Figure 22).

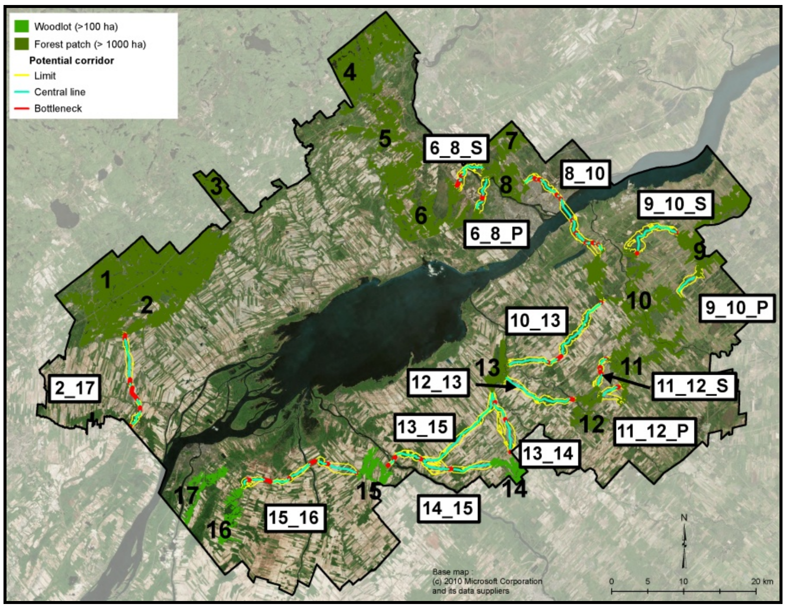


Figure 22 – Final selection of potential corridor scenarios (P = main area branch, S = secondary area branch) and location of bottlenecks (width < 300 m)

Assessment of the quality of potential corridors

A detailed analysis of the proposed corridors helped identify the functional corridors (those where the criteria are met) as well as corridors where problem areas are noted (bottlenecks, distance between woodlots). Duchesne et al. (1999) presented a detailed methodology for assessing the quality of forest corridors, including various criteria such as the length of the forest corridor, the average minimum width, the number and size of forest cover interruptions, the number of bottlenecks, and habitat heterogeneity. Many of these criteria were calculated automatically by Corridor Designer, including the frequency and location of bottlenecks (Figure 22), as well as the length and proportion of the corridor with a width greater than the threshold of 300 m. In terms of the habitat heterogeneity criterion, the cover (%) of each general habitat class was evaluated for each corridor (Figure 23). Overall, forests cover half of the area where the proposed corridors are found, while annual and perennial crops cover 24% and 18% respectively. This helps identify corridors where habitats are less suitable for forest birds, such as corridors 2_17 and 15_16, which cross large areas covered with annual crops. On the other hand, some corridors, such as 6_8_S and 9_10_S, are almost entirely composed of wooded areas, and priority conservation actions could concentrate on the bottlenecks (width < 300 m) and on areas where the distance between woodlots is > 200 m so that corridor functionality and quality could be increased. For example, plantation programs could increase forest cover, habitats that are less conducive to forest bird dispersal in the matrix could be converted into more suitable habitats (e.g. crop abandonment, conversion of annual crops to perennial crops), and windbreaks and riparian corridors could be planted to increase connectivity.

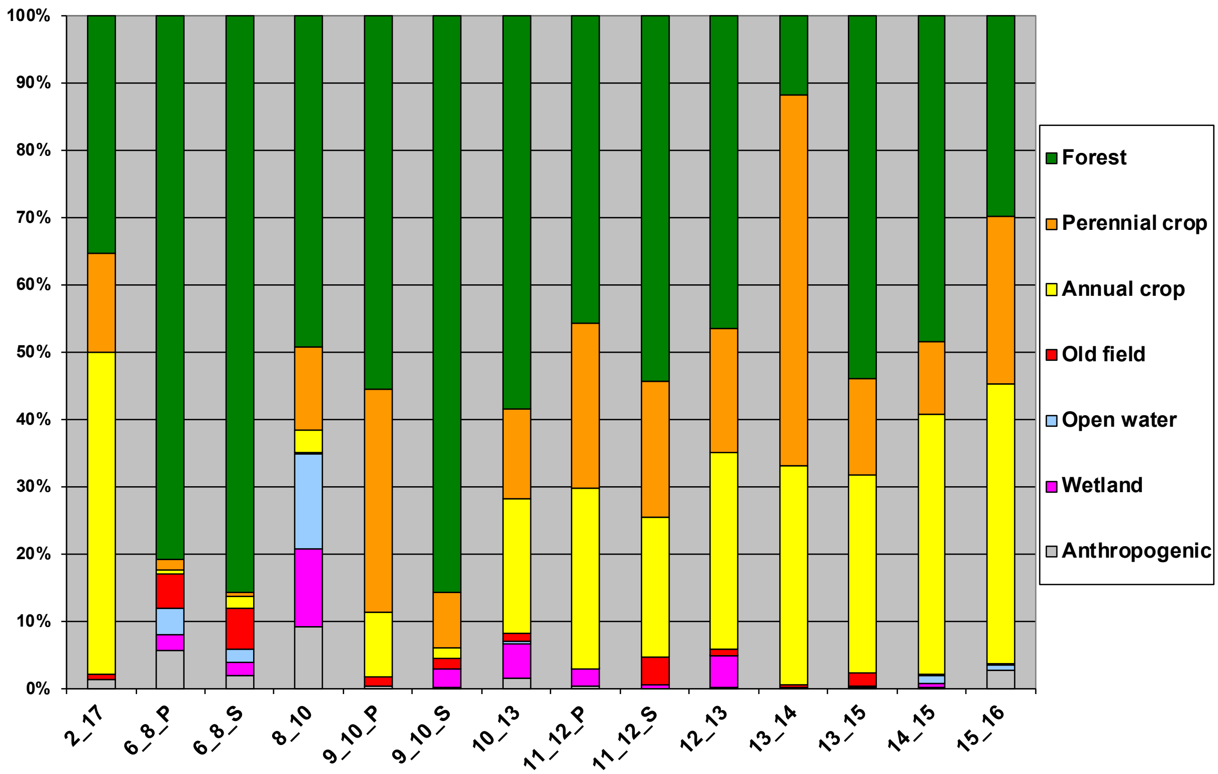


Figure 23 – Cover (%) of the general habitat classes in the potential corridors

Figure 24 shows an enlarged section of corridor 10_13. We can see the proposed route, located in a suitable environment, where the length and width of the corridor are adequate (in blue). We also see the sections of the corridor that cross unsuitable environments (red) and the bottlenecks (in purple), most of which are between 500 m and 1 km long. Portion of the proposed corridor go through unsuitable habitats, such as areas covered with annual crops, but these are short distances (< 200 m), which will have little impact on the movement of species. However, in cases where this distance is > 200 m, small forest patches could be created to serve as stepping stones, or more realistically, a conversion of annual crops to perennial crops could significantly improve the quality of the corridor.

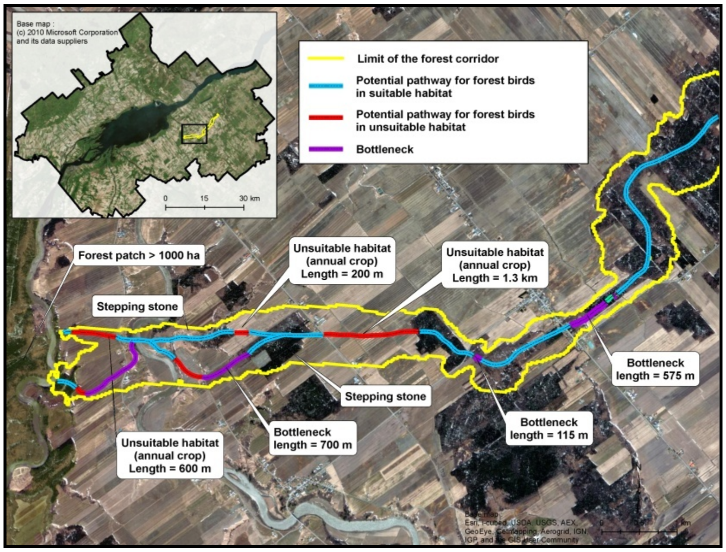


Figure 24 – Detailed analysis of corridor 10_13

9.2.3 Application of coarse filter criteria

Coarse filter criteria were used to determine minimum area thresholds for several habitat types needed to sustain viable populations of several priority bird species (see section 6.2). These thresholds were determined for agricultural habitats (perennial crops, old fields), forest habitats and wetlands (marshes, shrub swamps, bogs), and the habitat polygons that fulfill these thresholds were extracted from our land use maps. Tables 13 and 14 present the results of applying coarse filter criteria in the study area and in each of the RCMs, while Figure 25 shows the spatial location of patches that meet the coarse filter criteria for each habitat class.

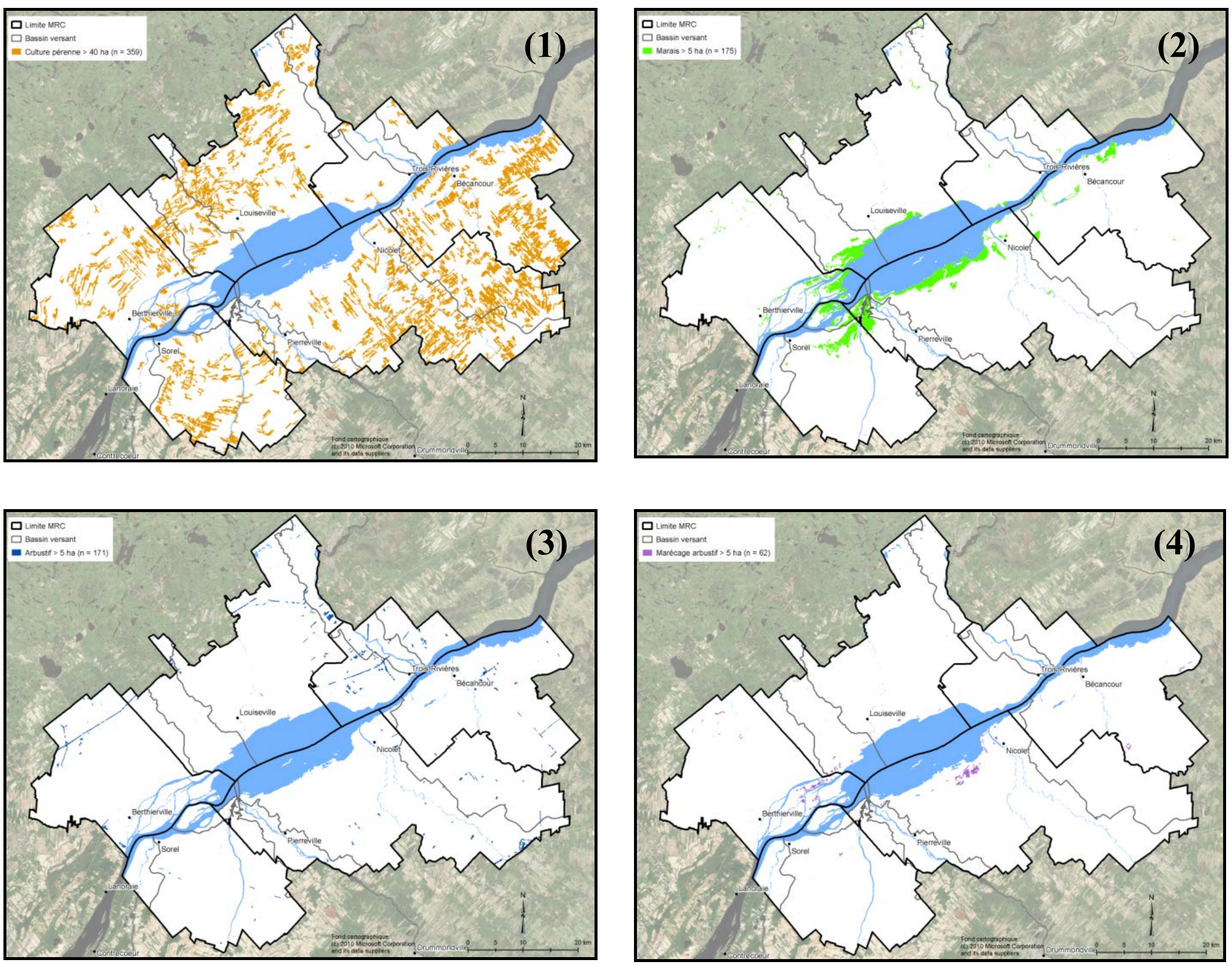
Table 13 – Description of the habitat patches that meet the coarse filter criteria in the study area

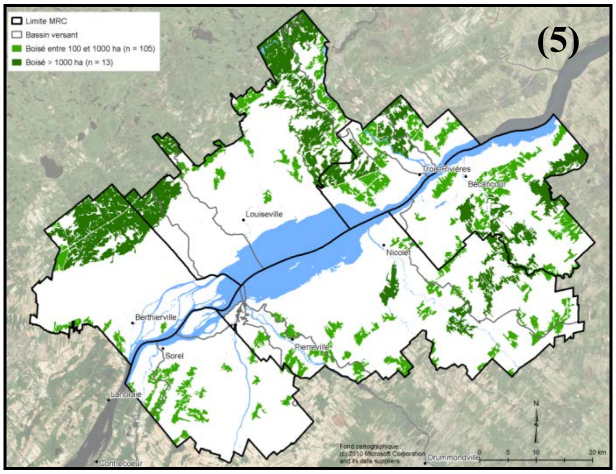
		Area (ha)				
Habitat	**Number**	**Mean**	**Stand. error**	**Min**	**Max**	**Total**
Perennial crop > 40 ha	359	171.6	15.8	40.1	2728.3	61 590
Old field > 5 ha	171	15.8	1.5	5.1	141.5	2704
Forest > 100 ha	118	697.8	125	101.1	9570.9	82 344
Marsh > 5 ha	169	65.7	17.9	5.1	2279.9	11 104
Shrub swamp > 5 ha	62	17.4	3.1	5.2	143.6	1080
Bog > 20 ha	34	93.2	20.9	21.4	666.9	3168

Table 14 – The number of habitat patches that meet the coarse filter criteria in the study area and by RCM

Region		Area (km^2)	Number of patches/habitat class: Farmland – Perennial crop > 40 ha	Farmland – Old field > 5 ha	Forest – Patch > 1000 ha	Forest – Woodlot > 100 ha	Wetland – Marsh > 5 ha	Wetland – Shrub swamp > 5 ha	Wetland – Bog > 20 ha
Study area		4194.8	359	171	13	118	169	62	34
RCM	D'Autray	586.8	54	20	2	11	54	24	0
	Maskinongé	957.1	76	39	6	22	34	13	3
	Trois-Rivières	334.9	15	42	3	15	15	0	12
	Bécancour	583.7	58	23	2	23	22	6	9
	Nicolet-Yamaska	1189.9	116	42	4	42	28	19	9
	Pierre-De Saurel	542.4	54	8	0	15	27	1	3

Note: The sum of all patches for all RCMs may be higher than the total in the study area because some patches overlap > 1 RCM.





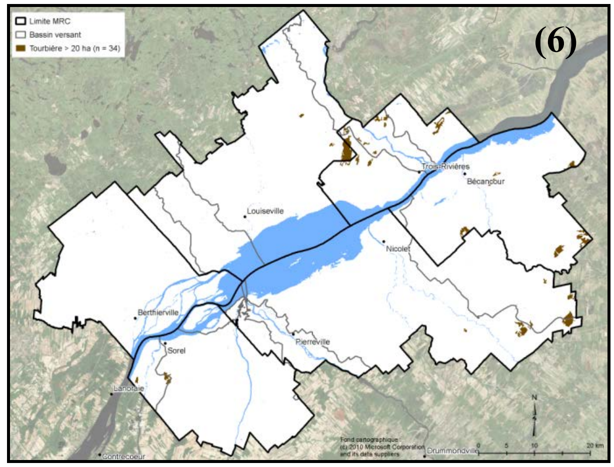


Figure 25 – Location of all habitat patches that meet the coarse filter criteria for (1) perennial crops, (2) marshes, (3) old fields, (4) shrub swamps, (5) woodlots, and (6) bogs

- A total of 359 perennial crop patches, or 7.7% of 4 644 patches found in the study area, are larger than 40 ha. These patches cover an average of 172 ha and their total area is 61 590 ha. The greatest number of these large perennial crop patches, many of them covering more than 1 000 ha, are found in the Nicolet-Yamaska and Maskinongé RCMs.
- A total of 171 old fields, or 14.4% of the 1 184 polygons of old fields found in the study area, are larger than 5 ha. These old fields cover an average of 16 ha and their total area is 2 700 ha. The greatest numbers of these old fields, many of them covering more than 100 ha, are found in the Trois-Rivières, Nicolet-Yamaska and Maskinongé RCMs.
- There are 13 forests > 1 000 ha in the study area, 6 of which are entirely or partly located in the Maskinongé RCM. None of these forests are found in the Pierre-De Saurel RCM. A total of 118 forest patches, representing just 5.3% of 2 221 patches found in the study area, are larger than 100 ha. These patches cover an average of nearly 700 ha and their total area is 82 350 ha. The greatest numbers of these large forest patches are found in the Nicolet-Yamaska, Bécancour and Maskinongé RCMs.
- A total of 169 marshes, or 23.1% of the 733 marshes found in the study area, are larger than 5 ha. These marshes cover an average of 66 ha and their total area is 11 100 ha. Many marshes > 5 ha can be found in each RCM, but most of them are found in the D'Autray and Maskinongé RCMs. Several marshes cover more than 100 ha.
- Only 62 shrub swamps (17.4% of 357 shrub swamps identified in the study area) > 5 ha are found in the study area. These marshes cover an average of 17 ha and their total area is 1 080 ha. The majority of shrub swamps > 5 ha are found in the D'Autray, Nicolet-Yamaska and Maskinongé RCMs, while 1 can be found in the Pierre-De Saurel RCM and none are found in the Trois-Rivières RCM. Only 9 shrub swamps are > 25 ha. Note that other shrub swamps are certainly present in the study area, but the images used to generate the land use mapping cannot distinguish between shrub swamps and wooded swamps in many areas.
- Only 34 bogs (11.3% of the 301 bogs found in the study area) > 20 ha are found in the study area. These bogs cover an average of 93 ha and their total area is 3 170 ha.

The majority of bogs > 20 ha are found in the Trois-Rivières, Nicolet-Yamaska and Bécancour RCMs, while none are found in the D'Autray RCM. Only 8 bogs cover > 100 ha.

Finally, the 545 wooded swamps and 391 wet meadows found in the study area have been considered priority sites because no minimum area threshold is known for these types of habitat (Table 15). Figure 26 shows their spatial distribution. The wooded swamps are mainly found on the shores of Lake Saint-Pierre, in the Berthier-Sorel archipelago and in the eastern part of the study area, while wet meadows are found mainly on the shores of Saint-Pierre, in the Berthier-Sorel archipelago and on the southern end of the Saint-François and Lavallière bays.

Table 15 – Number of wooded swamps and wet meadows in the study area and by RCM

Region		Forest swamp	Wet meadow
Study area		545	391
RCM	D'Autray	90	102
	Maskinongé	136	99
	Trois-Rivières	60	14
	Bécancour	70	0
	Nicolet-Yamaska	148	119
	Pierre-De Saurel	61	64

Note: The sum of all patches for all RCMs may be higher than the total in the study area because some patches overlap > 1 RCM.

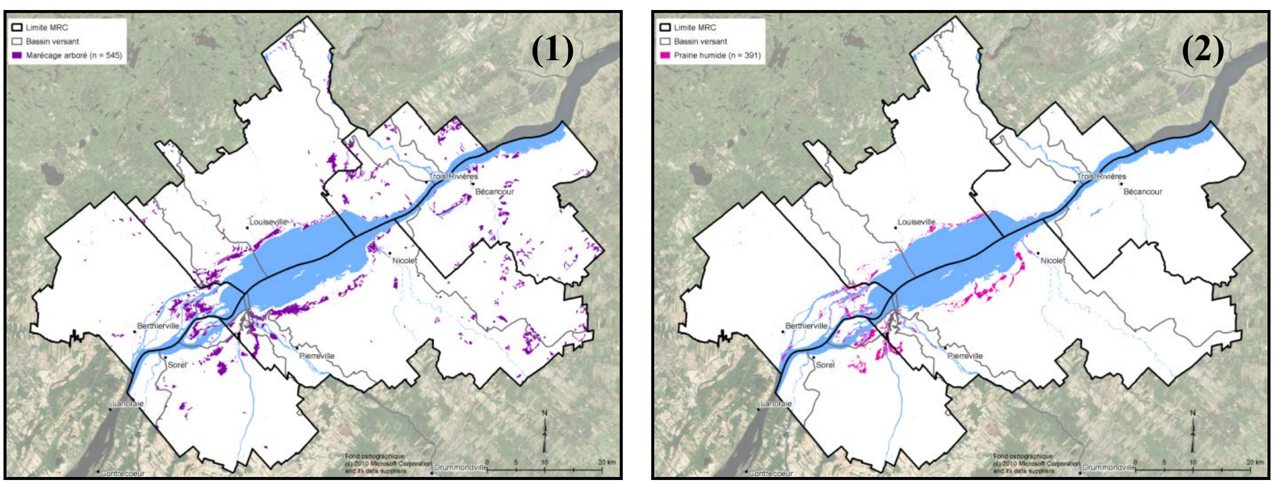


Figure 26 – Location of (1) wooded swamps, and (2) wet meadows in the study area

9.2.4 Prioritization of coarse filter patches

Figure 27 shows the spatial location of habitat patches that meet the coarse filter criteria. All these plots are, a priori, important for nesting birds and deserve to be protected, or at the very least, anthropogenic pressures that may affect them should be reduced. However, due to their large number, these plots must be prioritized in order to identify those that can contribute more to the needs of priority species in the study landscape.

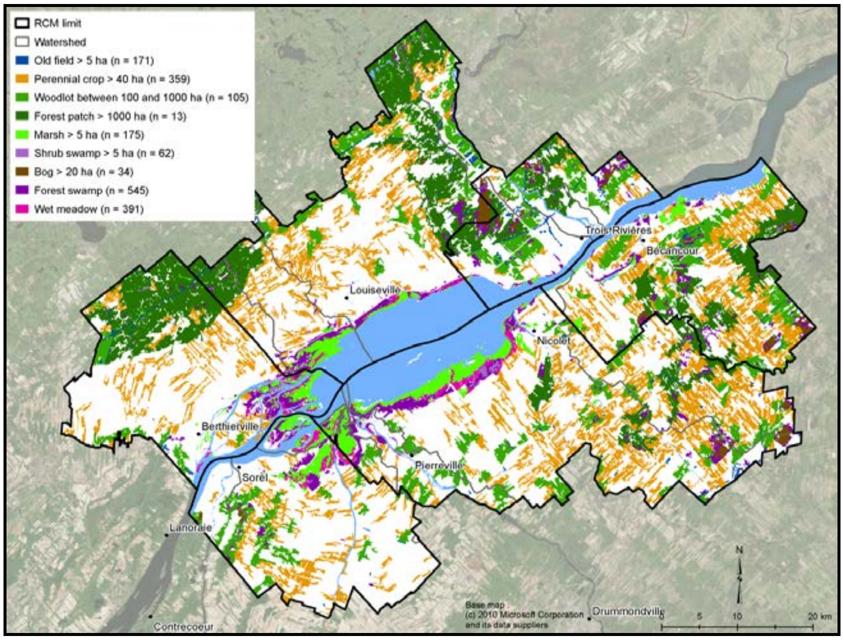


Figure 27 – Location of all habitat patches that meet the coarse filter criteria

There are numerous ways to prioritize habitats (see Langevin and Bélanger 1995; McGarigal et al. 2005; Qiu 2010; Holzmueller et al. 2011), and these methods are often dictated by common factors such as the presence of species at risk or rare ecosystems, the proximity to a protected area, the size and shape of habitat patches, and the identification of criteria specific to target species (e.g. threat reduction around habitats of species at risk). A weighting factor is then added to the criteria in order to calculate an index for each habitat patch. This type of multi-criteria analysis was used to prioritize farm woodlots and wetlands in southern Quebec (Langevin 1997; Nature-Action 2009; Gratton 2010; CRECQ 2012).

This type of multi-criteria analysis method was used to prioritize coarse filter habitats for each habitat class. Habitat criteria were identified based on the specific needs of bird guilds and the landscape context where the habitat patches are located, and a weighting factor was given to each criterion according to its relative importance. For each criterion, a score was then assigned to each patch according to its value in relation to other patches within the established classes (percentiles, ranges with determined limits, etc.). Finally, the weighting used for each criterion was multiplied with the score given to each patch for each criterion, and the sum of these multiplications produced a final prioritization index for each patch, where *C* is the weight of the criterion *i*, P is the score given to each patch for criterion *i*, and *n* is the number of criteria:

$$Index = \sum_{i=1}^{n} C_i P_i$$

The criteria were divided into two groups. The first group refers to the attributes of the patches given their importance for the establishment and maintenance of breeding bird populations. The shape index and % of interior habitat reduce edge effects, the edge contrast index focuses on patches found in a landscape matrix that is less hostile for birds, the proximity index favours the selection of patches located in areas dominated by the same habitat class, and the % of natural vegetation in a buffer zone of 100 m around wetlands is used to select patches that are less prone to anthropogenic pressures. The second group of criteria is used to prioritize patches based on their ecological role in the landscape of the study area, such as the creation of buffer zones around critical habitats of species at risk, wetlands or existing protected areas in order to reduce pressures and threats that can affect those sites. Habitat patches already located in a protected area (see section 7.3) received a score of "0" for the criterion that is designed to prioritize patches according to their proximity to a protected area, because they do not require conservation action. On the other hand, those patches that are partially included in a protected area received the maximum score, because the portions bordering protected areas should be prioritized so that buffer zones can be created around them. The distance to a significant urban centre (> 50 ha) is also considered. Similarly, forests, shrublands and swamps located in a proposed forest corridor are prioritized. Finally, the presence and number of species at risk designated under SARA (species that are endangered, threatened or of special concern) or *An Act Respecting Threatened or Vulnerable Species* in Quebec (species that are threatened, vulnerable, or likely to be designated threatened or vulnerable) are also considered when prioritizing patches. Prioritization of patches was done across the study area and all criteria were considered in one analysis. The criteria chosen and the relative weight given to each criterion are presented in Table 16. A justification of the criteria chosen for each habitat class and of the score given to the habitat patches for each criterion are presented in Jobin et al. (2013).

Table 16 – Criteria chosen and weighting used to prioritize patches for each coarse filter habitat class

Prioritization criteria	**Perennial crop**	**Old field**	**Forest**	**Forest swamp**	**Shrub swamp**	**Bog**	**Marsh**	**Wet meadow**
Patch attribute								
Shape index	10	10	10	10	10	10	10	10
Edge contrast index	10	10	10	10	10	10	10	10
% interior habitat (edge = 200 m)	20		20					
Proximity index	10		10	20	20	20	20	20
% natural vegetation (buffer = 100 m)				15	15	15	15	15
Ecological role in the landscape								
Proximity of a critical habitat	15	15	15	15	15	15	15	15
Proximity of a wetland	15	15						
Proximity of a protected area		15	15	15	15	15	15	15
Distance to a urban centre > 50 ha			10	10	10	10	10	10
Located in a potential corridor		5	20	20	10			
Presence/abundance of species at risk	10	10	10	10	10	10	10	10

Note: The proximity index is calculated for a distance of 200 m for forests, 1 km for perennial crops and 5 km for wetlands.

The habitat patches that meet the coarse filter criteria are then classified according to the final prioritization index, which allows one to select the higher quality patches for each habitat class, with a high index being representative of a high-priority patch. This selection can be made randomly or based on statistics. Various scenarios were tested (see Jobin et al. 2013), and two selected scenarios are shown in Figure 28 (top 25 patches for each habitat class) and in Figure 29 (patches included in the top 10th percentile of each habitat class). Notably, Pearson's correlations indicate that the final patch prioritization index is independent of their size, which shows that the criteria chosen are appropriate for prioritizing conservation sites compared to traditional methods, which are often based on habitat size. Other prioritization criteria have also been considered but were not retained in the final process due to data availability or duplication with selected criteria (patch uniqueness, largest patch index in a RCM, etc.).

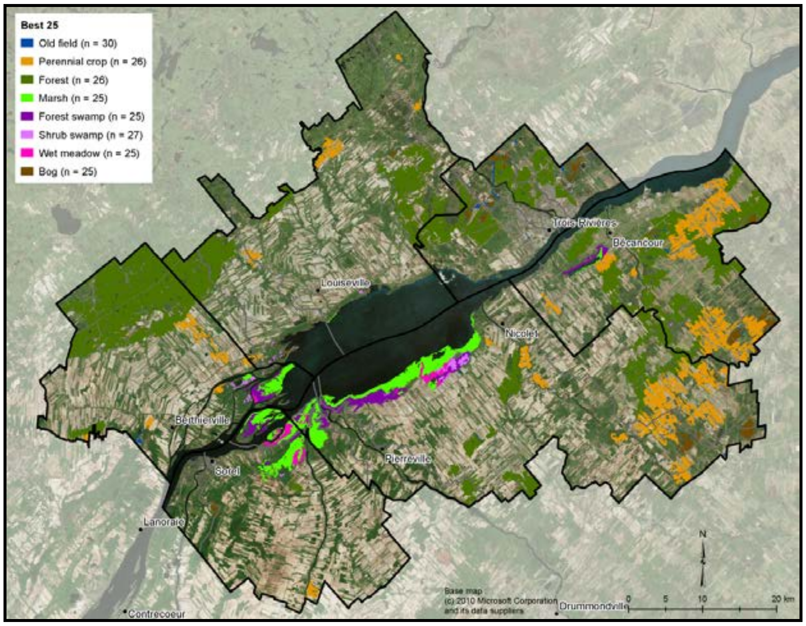


Figure 28 – Location of the 25 patches with the highest priority index for each coarse filter habitat class

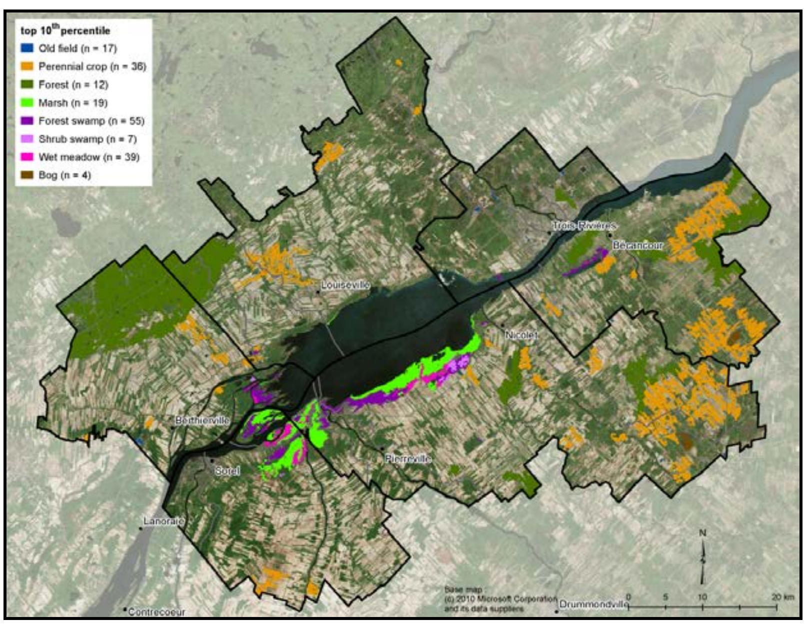


Figure 29 – Location of the patches whose prioritization index is in the top 10th percentile for each coarse filter habitat class

9.2.5 Application of fine filter criteria

The spatial distribution of the habitats identified by the fine filter criteria (forest disturbances, bare soil in forests, sand/gravel pits, sandy shores with steep slopes) is shown in Figure 30. This information is incomplete for certain habitat types such as sand pits, because there is not enough information about their spatial distribution in the study area. There are forest disturbances in almost all of the forest patches in the study area (except the wooded swamps bordering Lake Saint-Pierre). Sandy shores with steep slopes are located along the banks of some islands and watercourses in the Sorel region, and the bare soil (rocky outcrops) are mostly found at the top of forests in the northwestern portion of the study area (D'Autray RCM).

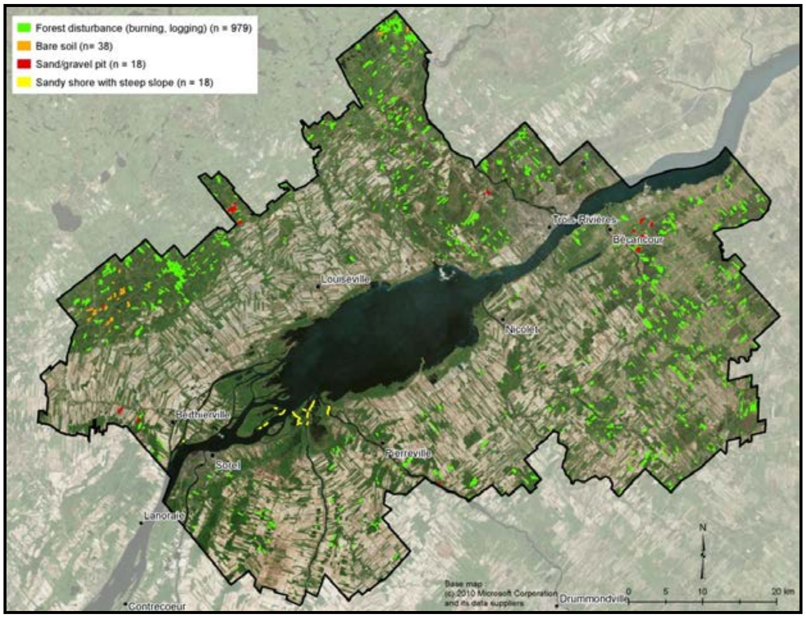


Figure 30 – Location of habitat patches that meet the fine filter criteria

Habitats identified by the fine filter approach are also used by species already included in the coarse filter criteria, such as the Eastern Whip-poor-will, which may nest in sand pits, or the American Kestrel and the Northern Flicker, which also nest in burnt-out areas and logging areas.

Finally, following the identification of priority habitats using coarse filter and fine filter criteria, the nesting needs of the two species, the Peregrine Falcon (*anatum*) and the Purple Martin, still have not been considered. Similarly, it is well known that the Common Nighthawk nests on gravel roofs in urban areas. These species prefer to nest on anthropogenic structures, and these needs are considered in section 11.

10.0 STEP 4 – FINAL ANALYSIS AND SPECIFIC ISSUES

10.1 ANALYSIS OF THE CURRENT SITUATION

Analyzing the functionality of the landscape can help produce a diagnosis of the landscape's ability to provide functional habitats for priority bird species. Although many patches in each priority habitat class are adequate to meet breeding needs of priority species, comparison of the landscape with habitat thresholds known to support sustainable bird populations identifies gaps in habitat availability in the landscape. Also, some of the proposed corridors present problems that make them less suitable for the movement of forest birds.

It should be pointed out that the existing protected areas are almost exclusively located around Lake Saint-Pierre, reflecting past efforts in wetland protection in this region. Hence, the majority of terrestrial habitats in the study area do not hold any protection status.

Farmland

The study area includes farmland habitats suitable for bird species that require large areas of perennial crops (e.g. Bobolink), particularly in the Maskinongé, Bécancour and Nicolet-Yamaska RCMs. However, the marked dominance of annual crops indicates that farmlands are generally not suitable to grassland birds. Similarly, old fields and shrublands are scarce in the study area (they are practically absent from the Richelieu region) and are mostly located under power line ROWs, therefore subject to periodic perturbations for maintenance purposes.

Forests

Although the forests found in the study area provide quality interior habitats for area-sensitive forest bird species in almost all of the RCMs, the forest cover in the study area (24%) is below the minimum 30% required to sustain forest bird communities. Therefore, it is imperative to preserve existing forested areas and to try to increase forest cover, particularly in the southern part of the study area (Pierre-De Saurel and Nicolet-Yamaska RCMs) where highly fragmented forests cover less than 20% of the territory. This is also particularly urgent as very few forests are located in existing protected areas. Note also that the northern (Maskinongé and D'Autray RCMs) and eastern (Bécancour and Trois-Rivières RCMs) parts of the study area are well forested. Various reasons, both historical and current, may explain how these habitat patches were preserved in the landscape (e.g. low-quality soils for agriculture, difficult access, woodlots used for logging or sugar maple production), which reduces their conservation needs. Note that the bare soils found in forests are almost entirely located at the top of the mountains in the northwest region of the study area (D'Autray RCM) and deserve special attention.

Wetlands and riparian corridors

Although wetlands cover 9.5% of the study region, nearing the 10% threshold required to maintain quality habitats, and the 6% threshold targeted for subwatersheds are met in all the RCMs, the spatial distribution of wetlands shows that they are highly concentrated in the immediate vicinity of Lake Saint-Pierre and are scarce elsewhere in the study area. Many of the wetlands are currently protected by existing protected areas (e.g. Nicolet MBS, Lavallière Bay, île du Moine, Leon-Provencher ecological reserve), and it is important to pay particular attention to the extensive wetlands located elsewhere in the St. Lawrence Lowlands (bogs in the Trois-Rivières, Nicolet-Yamaska and Bécancour RCMs; wooded swamps in the eastern part of the study area).

In addition, the integrity of the wetlands is at risk because the 100 m buffer zone surrounding them is totally naturally vegetated on 44% of sites. Special efforts should be made to reduce the presence of human activity (agriculture, urban infrastructure) along wetlands, particularly in areas identified as critical habitat for the Least Bittern. Similarly, riparian habitats adjacent to watercourses are heavily disturbed by human activity, and conservation measures should be implemented to improve the water quality and to offer quality riparian habitats for wildlife. These efforts are particularly needed in the Nicolet-Yamaska and Pierre-De Saurel RCMs, where watercourses are bordered by natural vegetation along only 30% of their banks.

Forest corridors

Of the 14 proposed corridor scenarios, only three have over 75% of forest cover across their total area (6_8_P, 6_8_S and 9_10_S). Some proposed corridors seem to be functional, as is the case for those located in the Trois-Rivières and Bécancour RCMs, and crop abandonment, especially near the bottlenecks, could substantially increase the quality of the corridors. On the other hand, several of the proposed corridors hardly seem suitable for birds, such as corridors 2_17 and 15_16, which are covered by annual crops on nearly half of the proposed routes. Few stepping stones exist in less conducive environments, and the numerous bottlenecks may affect the movement of birds. That being said, habitat connectivity might be deficient in several places. For some of the more problematic corridors, such as those located in the D'Autray and Pierre-De Saurel RCMs, isolated initiatives would probably not be enough to provide viable and functional corridors for forest birds in areas of intense farming activity. Since considerable efforts would be needed to improve the situation, an in-depth analysis would be needed to assess whether the functionality of these corridors can be restored.

Even though the cover of several habitats meets the minimum area thresholds at various scales (study area, RCMs, watersheds), it is impossible to determine whether the current landscape can maintain sufficient numbers of breeding pairs in priority habitats because there are no quantitative population targets for priority species in the BCR 13 conservation plan. In addition, our study area covers only a portion of BCR 13, making it more difficult to interpret the quantitative targets that could have been developed for a region larger than our study area.

10.2 REGIONAL ISSUES AND THREATS

The Lake Saint-Pierre region is located in the St. Lawrence Lowlands, the most populous ecoregion of Quebec, where anthropogenic pressures are the highest. Therefore, several development issues may cause conflict when it comes to protecting natural environments. Jobin et al. (2007) studied the recent habitat dynamics in the St. Lawrence Lowlands for the period 1993–2001, and observed a significant conversion of perennial crops into annual crops. This trend was particularly significant in the D'Autray, Pierre-De Saurel, Bécancour and Nicolet-Yamaska RCMs. Agriculture intensification in the Lake Saint-Pierre flood plain was also noted by Richard et al. (2011) for the period 1950–2000. Jobin et al. (2007) also noted that forested areas declined during the 1993–2001 period in all RCMs of the study area, mainly due to the increase in cultivated areas and, to a lesser degree, to urbanization. Savoie (2002) also noted a loss of forest area in the Centre-du-Québec region for the same period.

Monitoring of wetland coverage in the Lake Saint-Pierre region shows that the area covered by these habitats remained relatively stable between the 1990–1991 and 2000–2002 periods, but that the spatio-temporal dynamic of the habitat classes was highly variable (Jean and Létourneau 2011). As such, several wetlands were converted into open water or were drained for farming purposes on the south shore of the lake, while low marshes became high marshes dominated by Reed Canarygrass (*Phalaris arundinacea*) and by wooded swamps in the Lavallière and Saint-François bay areas. These changes would be related to large-scale changes in water levels of the St. Lawrence River. On the other hand, the wetlands in the Montérégie region showed a significant decrease (22% of the sectors considered) in size due to farming (GéoMont and Environment Canada 2008) between 1964 and 2006, and several wetlands located in the Lake Saint-Pierre agricultural plain might have suffered the same fate during this period. In fact, wetlands continue to disappear in southern Quebec despite existing regulations (Queste 2011). For example, the area used for cranberry production increased from 1000 ha in 1999 to 2500 ha in 2009 in the Centre-du-Quebec region, where 80% of Quebec's cranberry growers are found (Poirier 2010), and the remaining natural bogs in the landscape may be altered if this trend holds. A visual analysis of satellite images available on Google Earth© shows recent conversions of bogs into cranberry fields in areas located on the edge of the study area (municipalities of Saint-Louis-de-Blandford, Manseau and Notre-Dame-de-Lourdes).

Industrial and urban development continues to modify the landscape in the Lake Saint-Pierre region. Jobin et al. (2007) as well as Jean and Létourneau (2011) noted a sharp increase in anthropogenic developments around the city of Trois-Rivières, at the expense of natural habitats. A visual analysis of satellite images available on Google Earth© shows recent residential developments in areas once covered by farmland or forests (e.g. Trois-Rivieres, Nicolet and Sorel-Tracy). Finally, the possible extraction of shale gas in the St. Lawrence Valley, a region targeted for this type of operation (MRNF 2012b), could change the landscape and affect the availability and integrity of habitats available to nesting birds.

11.0 STEP 8 – CONSERVATION PLAN FOR THE STUDY AREA

The conservation actions included in the BCR 13 conservation plan (Fournier et al. 2010) along with the analysis of the spatial distribution of priority habitats in the study area enable us to target habitats and areas where protective measures would be required. The proposed conservation plan for the pilot project is divided into three sections:

- Priority habitat patches with spatial reference
- Priority habitats without spatial reference
- Landscape elements to consider for maintaining ecological processes

11.1 PRIORITY HABITAT PATCHES WITH SPATIAL REFERENCE

The priority habitats that should be maintained to provide functional and viable habitats for priority species in this project were determined in the previous sections. These habitats all have a spatial reference, which allows us to locate them in the study area.

Habitat polygons for avian species at risk

Some sites are high priority because of the known presence of nesting bird species at risk. Notably the identified critical habitats for the Least Bittern and the known nesting sites for avian species at risk: the Least Bittern (occurrences other than the critical habitats), the Short-eared Owl, the Sedge Wren and Nelson's Sharp-tailed Sparrow. Admittedly, these priority sites are based on our current knowledge of these species' distribution, which parallels the more traditional “hot spot” approach for site prioritization. However, protection of these sites is of utmost importance because of the status of these species.

Point data on nesting avian species at risk

Point records on nesting sites frequented by avian species at risk are also available; notably, the Chimney Swift, which nests in chimneys, and the Peregrine Falcon, whose known nesting sites are located on anthropogenic structures.

Coarse filter polygons (prioritization of patches)

The scenario where the top 25 patches of each habitat class are prioritized is included in the conservation plan. It should be noted again that all patches that meet the coarse filter criteria are, a priori, important for nesting birds and should be considered (see sections 9.2.3 and 9.2.4).

Fine filter polygons

The habitat classes identified by the fine filter are bare soil in forested areas, forest disturbances (burning, logging), sand/gravel pits and sandy shores with steep slopes.

Corridors

Forest corridors identified in section 9.2.2. Bottlenecks found in these corridors are also illustrated.

Figure 31 shows the spatial distribution of these priority sites in the territory of the pilot project as well as the location of existing protected areas. Priority terrestrial habitats include forests in the northwest part of the study area and in the Trois-Rivières region, as well as in the eastern part of the study area located south of the St. Lawrence River. Few priority sites are located in the agricultural areas. Most priority sites located in aquatic areas are clustered on the south shore of Lake Saint-Pierre and in the Berthier-Sorel archipelago.

11.2 PRIORITY HABITATS WITHOUT SPATIAL REFERENCE

Other habitat components described in the BCR 13 conservation plan and specific to the project's priority species are not discernible on the land-use digital layers and therefore are not considered in the coarse and fine filter criteria. These habitats are generally uncommon but essential for some species. Appropriate conservation measures should be implemented to ensure that these specific needs are met.

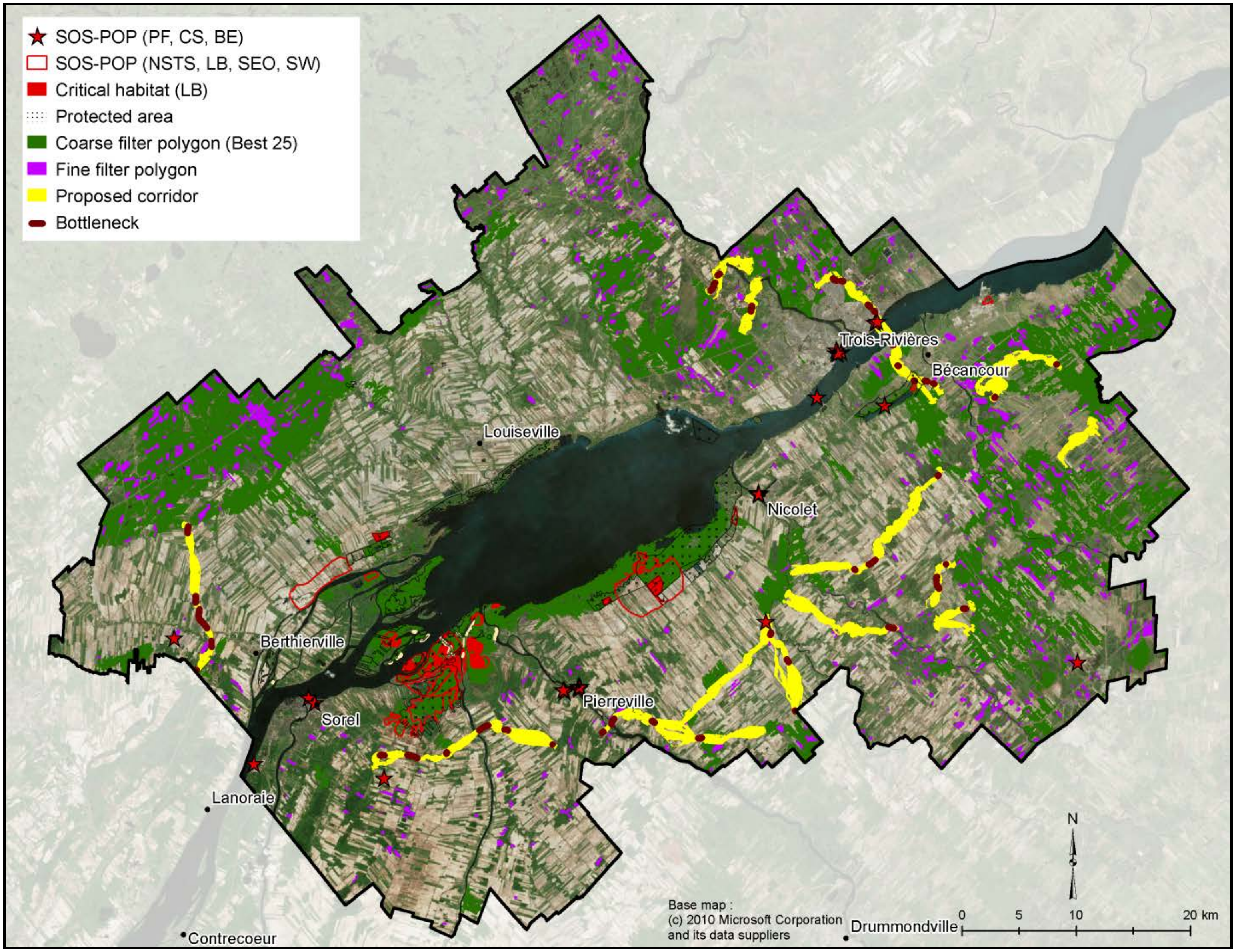


Figure 31 − Priority habitat patches with spatial reference
(see Figure 27 for the spatial distribution of all patches that meet the coarse filter criteria)

These measures should be supplemented by specific actions that promote safe nesting conditions for these priority species. Table 17 lists some of these conservation measures and the species that are targeted.

Table 17 – Conservation measures and species targeted for priority habitats without spatial reference

Conservation measures	Species targeted
Preserve trees and snags with large diameters (> 30 cm)	American Kestrel; Barred Owl; Brown Creeper; Chimney Swift; Eastern Screech-Owl; Northern Flicker; Northern Saw-whet Owl; Wood Duck
Install and maintain nesting boxes	American Kestrel; Eastern Screech-Owl; Northern Saw-whet Owl; Purple Martin*; Wood Duck
Encourage the implementation of protective perimeters proposed by the MRNF around nesting sites, both on private and public lands	Peregrine Falcon
Promote the upkeep of gravel roofs in urban areas	Common Nighthawk
Promote the upkeep of old farm buildings	Barn Swallow
Promote the conservation and upkeep of suitable chimneys in urban areas	Chimney Swift
Avoid disturbances in sand pits near nesting sites	Bank Swallow; Belted Kingfisher; Northern Rough-winged Swallow; Whip-poor-will
Avoid disturbing areas of shallow water and aquatic vegetation in Lake Saint-Pierre	Greater Scaup; Lesser Scaup (foraging areas during migration)
Avoid the use of herbicides and promote the mechanical maintenance of vegetation in power line ROWs	American Woodcock; Brown Thrasher; Eastern Kingbird

* This species nests almost exclusively in human-made nesting boxes (only a few breeding records in natural cavities exist for the 20th century in eastern North America) (Brown 1997).

11.3 LANDSCAPE ELEMENTS TO CONSIDER FOR MAINTAINING ECOLOGICAL PROCESSES

Landscape elements must be considered in the conservation plan in order to maintain ecological processes and the integrity of habitats in the study area. General conservation measures that reduce anthropogenic pressures on watercourses, waterbodies and wetlands should be established.

Vegetated riparian habitats

The need to maintain vegetated riparian habitats along watercourses is raised in the BCR 13 conservation plan (Fournier et al. 2010) in order to maintain water quality for birds nesting or feeding in these habitats. The effectiveness of riparian corridors in reducing diffuse agricultural pollution is well documented in Quebec (Duchemin and Majdoub 2004; Gagnon and Gangbazo 2007; Duchemin and Hogue 2009), and various guidelines have been issued in this regard (OMAFRA 2004; Bentrup 2008; Fondation de la faune du Québec and Union des producteurs agricoles 2011). The information presented in section 9.2.1 clearly shows that watercourses found in the study area are highly vulnerable to anthropogenic pressures (pollution, erosion, etc.), and the proportion of watercourses with naturally vegetated riparian habitats and adjacent buffer zone is far from the 75% threshold. Corrective measures are strongly needed to remedy this situation.

Buffer zones around wetlands

The recommendations for riparian habitats also apply to wetlands, as the 100-m-wide buffer zone around them is totally naturally vegetated on less than half of the sites. Wetlands are therefore vulnerable to diffuse agricultural pollution, and additional efforts to protect shorelines are required, especially in areas dominated by intensive farming activity where the drift and runoff of pesticides and fertilizers into aquatic ecosystems can be harmful (Roy 2002; Lee et al. 2003; Lovell and Sullivan 2006).

Toposequence of wetlands in Lake Saint-Pierre

The abundance and diversity of wetlands found in the Lake Saint-Pierre region led to this area being designated as a Ramsar site and as a Biosphere Reserve. There is still an assemblage of wetlands in certain areas that form a natural toposequence ranging from areas of shallow water and aquatic beds to marshes, wet meadows, shrub swamps and wooded swamps. These are remnants of coastal wetlands that were subject to the natural variations in water levels of the St. Lawrence River and should be given special attention.

11.4 SPECIAL CONSIDERATIONS OF THE CONSERVATION PLAN

Certain general facts should be considered in order to guide conservation activities toward habitats that can provide maximum benefits for the project's priority species. First, the area covered by some habitat classes does not reach the minimum area threshold required to provide a functional landscape for nesting birds in several of the RCMs. Maintaining forests and large woodlands located in the agricultural matrix or in urban areas should be prioritized, as they contribute to the diversity of the regional avifauna (Environment Canada 2007; Minor and Urban 2010; Oliver et al. 2011), while prioritizing the patches identified in section 9.2.4. Similarly, in areas where forest cover exceeds the 30% threshold, it would be appropriate to maintain woodlots located in areas prone to human development, such as those located on the outskirts of urban areas, in order to ensure that the forest cover remains above this threshold (Environment Canada 2007).

Again, various factors can explain how these habitat patches were preserved in the landscape, despite the existing anthropogenic pressures that may impact them at various levels (see section 10.1). Some priority sites may be located in areas less prone to human development and are protected “de facto” because they are not under immediate threats. It is therefore important to quantify the anthropogenic pressures that may impact priority sites and concentrate conservation efforts where they are most urgent. Second, the restoration or creation of habitats should be considered in order to increase the size of these habitat classes where required. The landscape analysis to identify areas to be restored in the study area remains to be done. The creation of buffer zones around existing protected areas or critical habitats for species at risk should also be considered, whereby priority sites that meet the coarse filter criteria are first on the list.

Furthermore, breeding site selection for several bird species acts at several spatial scales, and landscape composition plays an important role in this selection. Several species will nest in landscapes where their preferred nesting habitats are locally abundant. This is why conservation efforts should be focused on preserving priority habitat patches in areas where these habitats are already present, in order to provide an optimal landscape for nesting birds. For example, several wetland-dependant species select their breeding sites in areas where wetlands abound (Brown and Dinsmore 1986; Calmé 1998; Naugle et al. 2000; Fairbairn and Dinsmore 2001; Riffell et al. 2003; Forcey et al. 2011). The protection of natural bogs located near exploited bogs should therefore be prioritized (Environment Canada 2010b) because of their vulnerability to future exploitation, as is currently the case with cranberry fields in the Centre-du-Québec region. Similarly, it is well documented that grassland bird species prefer to nest in areas where perennial crops dominate the matrix and avoid areas dominated by annual crops, forested and anthropogenic areas (Hamer et al. 2006; Veech 2006; Renfrew and Ribic 2008; Jobin and Falardeau 2010). As such, grassland birds are amongst the species groups where population declines are the steepest in southern Quebec (North American Bird Conservation Initiative Canada 2012). Therefore, it would be justified to preserve and increase the availability of perennial crops in areas that are already well covered by these habitats in order to increase their importance at the regional level, as in the Maskinongé and Bécancour RCMs. On the other hand, preserving perennial crops in areas where these habitats are rare would most likely be less suited because these habitat patches may become "sink habitats." A socioeconomic analysis and modelling of future landscape scenarios would help determine the most suitable areas for these species. An in-depth analysis is thus required before considering a large-scale conversion of annual crops to perennial crops in areas that are now under intensive farming activity, such as the Pierre-De Saurel RCM.

11.5 CONSERVATION PLAN SPECIFIC TO EACH RCM AND WATERSHED

The landscape analysis and the prioritization of coarse filter patches were done globally for the entire study area so as not to divide habitat patches according to administrative boundaries that are irrelevant from a biological point of view. However, the implementation of the conservation plan's recommendations will require appropriate tools useful to local stakeholders. The recommendations in the conservation plan are thus detailed for each RCM, i.e., the scale where the territorial planning takes place, and for each watershed, i.e., the ecological division where watershed-based organizations work towards the conservation of habitats at the regional scale. Table 18 presents a summary of priority habitats and conservation measures required in each RCM and watershed. However, in order to keep the report short, a detailed conservation plan (including maps showing the spatial distribution of priority habitats) is presented only for the Bécancour RCM as an example. The comprehensive conservation plan for each RCM and each watershed is presented in the associated methodological report (Jobin et al. 2013).

Table 18 – Summary of the presence of protected areas, priority habitat types and conservation measures required in each RCM and watershed

		Species at risk			Coarse filter polygon (25 best/habitat class)								Fine filter polygon				Maintain and create			
	Existing protected area	Critical habitat for the LEBI	CDPNQ polygon	SOS-POP nesting site	Perennial crop	Old field	Forest	Marsh	Shrub swamp	Forest swamp	Wet meadow	Bog	Sand/gravel pit	Sandy shore with steep slope	Bare soil	Forest disturbance	Vegetated riparian habitat	Vegetated buffer zone (wetland)	Woodlot and forests	Proposed forest corridor
RCM																				
D'Autray	√		√		√	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Maskinongé	√	√			√	√	√	√	√			√	√		√	√	√	√	√	
Trois-Rivières	√			√	√	√	√					√	√			√	√	√	√	√
Bécancour	√		√	√	√	√	√	√		√		√	√			√	√	√	√	√
Nicolet-Yamaska	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√
Pierre-de Saurel	√	√	√	√	√		√	√	√	√	√	√		√		√	√	√	√	√
Watershed																				
Bayonne	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Maskinongé	√	√			√		√		√							√	√	√	√	
Du Loup/Yamachiche	√			√	√	√	√	√	√			√				√	√	√	√	√
Saint-Maurice					√	√	√					√	√		√	√	√	√	√	√
Batiscan				√		√	√					√				√	√	√	√	√
Bécancour	√		√	√	√	√	√			√		√	√			√	√	√	√	√
Nicolet	√	√	√	√	√	√	√	√	√	√	√	√				√	√	√	√	√
Saint-François		√		√			√			√			√	√		√	√	√	√	√
Yamaska	√	√	√	√	√		√	√	√	√	√	√				√	√	√	√	√
Richelieu				√								√				√	√	√	√	

11.5.1 Example of a detailed conservation plan: Bécancour RCM

Figures 32 and 33 show the spatial distribution of priority sites for the Bécancour RCM. Less than 50% of this RCM, namely its western region, is included in the study area. Descriptive results and conservation actions proposed below thus refer only to this area of the RCM. A large watercourse, the Bécancour River, flows in this area. More than half of the study area of this RCM is occupied by farmland, especially perennial crops, with several priority patches exceeding the threshold value of 40 ha. This is the only RCM where perennial crops dominate annual crops. Several old fields and shrublands cover > 5 ha, with some covering > 50 ha. Forests occupy nearly 30% of the territory (desired threshold), and several forest patches cover > 100 ha, with some covering > 1000 ha. Many of these patches have also been identified as priority sites, and three forest corridors have been proposed. In addition, several forest disturbances, potentially conducive to certain species of birds, are present.

None of the priority wetland patches selected is located along the St. Lawrence River. They are almost exclusively located within and around the Léon-Provancher ecological reserve, except from a few large bogs (> 20 ha) located in the centre and east of the RCM. Overall, the area covered by wetlands in the RCM reached the threshold value of 10%. The presence of the ecological reserve allows for the preservation of habitats used by species at risk, including the Least Bittern and the Bald Eagle.

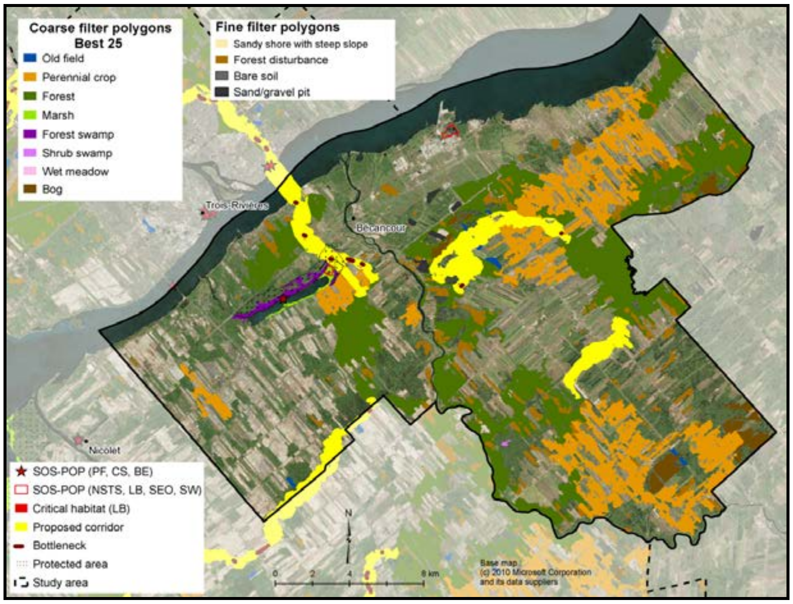


Figure 32 – Spatial distribution of priority habitats in the Bécancour RCM (including those amongst the 25 best patches of each habitat class determined for the whole study area)

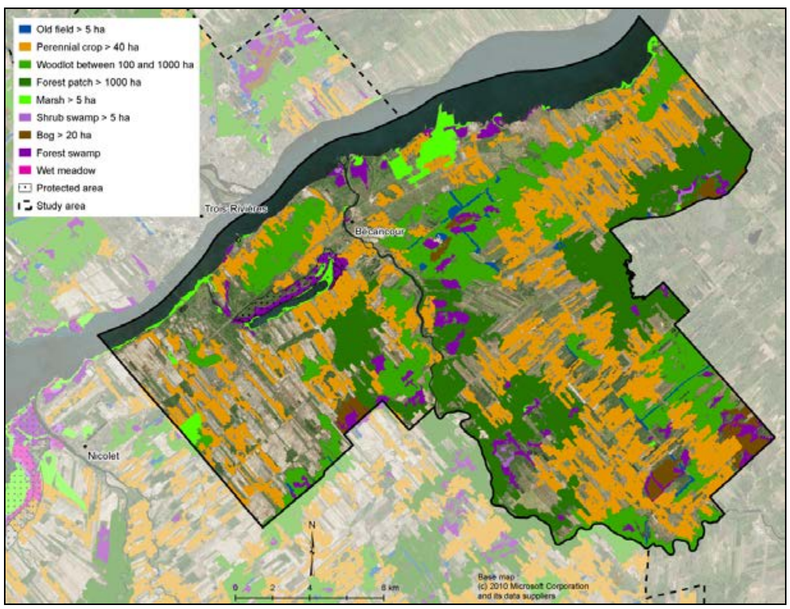


Figure 33 – Spatial distribution of all habitat patches that meet the coarse filter criteria in the Bécancour RCM

The proposed conservation actions are to:

- ensure the protection of wetlands used by the Least Bittern and other marsh birds in the Bécancour industrial park;
- conserve large existing forests (to reach and maintain 30% of forest cover in the RCM), with special attention paid to those identified as priority sites;
- maintain existing forests in order to promote the movement of forest birds (preservation of existing forest corridors and promotion of proposed corridors);

- evaluate the possibility of improving the functionality of the proposed corridors through targeted actions (e.g. planting, conversion of annual crops to perennial crops, crop abandonment in less productive sectors);
- conserve bogs located in the Saint-Sylvère region and north of Sainte-Marie-de-Blandford;
- maintain perennial crops in order to promote a regional concentration of forages and pastures conducive to grassland birds, mainly around the Léon-Provancher ecological reserve and in the eastern part of the RCM;
- verify if birds (e.g. swallows, Belted Kingfisher) nest in the sand/gravel pits east of Bécancour and, where appropriate, limit disturbances that these operations may cause during the nesting season;
- ensure that existing wetlands remain intact;
- promote the creation and preservation of naturally vegetated riparian habitats along watercourses;
- promote the establishment and preservation of natural habitats in a 100 m buffer zone surrounding wetlands.

11.6 LIMITS OF THE CONSERVATION PLAN

The proposals submitted are based on the best information currently available on land use of the study region and on the knowledge of the breeding ecology of birds in Quebec. Some habitats are highly dynamic, such as perennial crops and shrublands, and the layers of information that can spatially represent them may have been produced several years ago. The regional issues mentioned in section 10.2 may also have caused changes to the landscape since the creation of the land use map. The proposed conservation plan is therefore intended to guide conservation actions toward those sites deemed most important for birds and species at risk, but a validation of the current status of the proposed sites, both in terms of their nature and their spatial limits, is essential.

It should also be noted that the sites of interest identified in the project aim to preserve the habitats of priority migratory birds and critical habitats of species at risk. Sites known to harbour species at risk for which critical habitats are not identified are not specifically documented in this conservation plan (e.g. the American Water-willow, Green Dragon and Wood Turtle), and documents that present specific conservation actions for these species exist for most of them (federal: recovery strategies, action plans, management plans; provincial: conservation plans). Records of these species, however, were considered in the prioritization of coarse filter habitat patches. In addition, other sites of interest for the conservation of flora and wildlife exist in the region, such as exceptional forest ecosystems and wildlife habitats (e.g. muskrat habitat, heron colony) identified by the MRN and the MDDEFP, and efforts to conserve these sites should be carried out in conjunction with those identified in this conservation plan.

12.0 STEP 9 – IMPLEMENTATION OF THE CONSERVATION PLAN: APPROACHES AND PROPOSALS

The priority sites and conservation actions proposed in the conservation plan focus on various types of habitats in the Lake Saint-Pierre region, including many wetlands. Protected areas were established in the region essentially to protect significant wetlands located around Lake Saint-Pierre. Priority sites were also identified in terrestrial environments (forests, shrublands, perennial crops) that are essential for the nesting and dispersal of nesting birds, but their protection is currently inadequate.

Several laws, regulations and policies allow for the protection of natural elements (e.g. *Canada Wildlife Act*, *An Act Respecting Threatened or Vulnerable Species*, *An Act Respecting the Conservation and Development of Wildlife*), and others whose primary objective is not directly protecting habitats have their place in this protection (e.g. the *Cultural Property Act*). Moreover, land development and habitat protection issues are defined during land use planning. The RCMs have the power to integrate the protection of the natural environment into their land use and development planning as do municipalities in their urban planning. There are also many voluntary conservation options available to owners of private property who wish to protect their land (Longtin 1996; Queste 2011). Finally, funding programs exist to support stewardship and habitat protection activities, made possible by non-governmental organizations and other local stakeholders (Environment Canada 2012; ROBVQ 2012).

The conservation priorities identified in the conservation plan can thus serve as a foundation to guide local actions through various funding programs such as the Habitat Stewardship Program for Species at Risk (HSP) or the EcoAction Community Funding Program. They can also complement existing action plans such as the Eastern Habitat Joint Venture (EHJV) and the St. Lawrence Action Plan (SLAP). As such, layers of digital information (shapefiles) showing the spatial location of priority sites identified in this pilot project are made available to the public who wish to incorporate them in their own land-use planning process. It is by securing existing tools and consulting stakeholders in the field that important natural habitats for migratory birds and species at risk can be protected.

13.0 ADDITIONAL INFORMATION

13.1 OVERALL ASSESSMENT OF THE PROJECT

13.1.1 Advantages of the landscape approach

Habitat conservation has traditionally taken a species-by-species approach or been based on sites known to be important for biodiversity (hot spots). However, these approaches have limitations because they generally ignore the potential of sites that have not been inventoried and often include small areas only. In addition, the connectivity between these sites is usually not considered. The need to account for species dispersal is an important challenge that requires a different analysis of the landscape. The advent of the landscape ecology theory, linked to the evolution of associated theoretical ecology concepts (island biogeography, metapopulations, etc.) provides a more holistic and dynamic perception of the landscapes. Moreover, new technologies (e.g. GIS and landscape analysis software such as FRAGSTATS) and access to geospatial data (e.g. satellite images) now facilitate the implementation of the landscape approach. Knowledge of the importance of the spatial context for wildlife conservation and access to better tools to address environmental or land use issues on a large scale provides opportunities to perceive and analyze habitat conservation in a new way.

Determining minimum area thresholds to select priority habitat polygons has the advantage of locating high-potential sites for certain bird species even though no targeted on-site survey has been performed. As such, there is a strong agreement between priority woodlots and wetlands identified by Gratton (2010), CRECQ (2012), and ours because these prioritization exercises were all based on a multicriteria analysis that included patch area as a selection criterion. Patches located far from the immediate Lake Saint-Pierre area were thus selected, whereas the vast majority of priority sites identified in previous bird conservation plans in the BCR 13 were along Lake Saint-Pierre (Chapdelaine and Rail 2004; Aubry and Cotter 2007; Environnement Canada 2010a, 2010b; Lepage et al. 2010). Adding the connectivity analysis between woodlots, habitat classes not previously considered (perennial crops, old fields), and criteria aiming to prioritize habitat patches based on their intrinsic value (e.g. shape, interior habitat) and their ecological role in the landscape (e.g. buffer zones around critical habitat and protected areas, forest corridor) clearly demonstrate the added value of the landscape approach used in this pilot project.

The landscape approach therefore goes well beyond the simple consideration of important habitats for species or guilds of species and helps determine the functionality of the landscape (habitat availability, connectivity) while considering the importance of the surrounding environment (matrix). The logic model developed during this study is based on the landscape ecology theory and can therefore be applied to various spatial scales (ecozone, BCR, RCM, etc.). These scales determine the level of accuracy of the information and data necessary to study the landscape of a given territory. As such, several ongoing research initiatives in Quebec are based on the concepts of landscape ecology (Connexion Montérégie 2012; Nature-Action 2012; Université de Montréal 2012). The approach initiated as part of the pilot project and the lessons learned should encourage the implementation of similar projects in other regions where anthropogenic pressures may affect the landscape.

13.1.2 Disadvantages of the landscape approach

The landscape approach requires a more comprehensive and thus more complex process than traditional approaches used in conservation. It is therefore important to portray the landscape as realistically as possible. Geomatic tools greatly facilitate the implementation of this approach but require advanced equipment (high performance computers, appropriate and functional softwares) and specialized expertise (GIS specialists, cartographers). We estimate that the pilot project required the contribution of a full-time biologist/analyst for about 1.75 year and a GIS specialist for about 10 months. Note that the production of the land-use map of the study area by combining data from different sources needed a large involvement by the geomatic people (see section 13.2). The availability of resources to accomplish such a project can therefore become an issue.

Landscape ecology also requires the adoption of a multidisciplinary perspective and involves the use of data (e.g. socio-economic data) or specialized tools (planning or modeling software) that are less familiar than traditional ecology approaches. Available data and limited knowledge of an area can therefore restrict the application of the landscape approach in a given territory.

13.1.3 Involvement of other CWS units, partners, etc.

The expertise of several knowledgeable people from the government, non-governmental organizations, universities and co-workers from the CWS was required at various stages of the project (acquisition and sharing of data, validation of various decisions). Other experts in land use planning or in modelling could also be involved in such an integrative approach (data, predictive models, planning strategies, scenarios, etc.). An update of data and monitoring of actions taken are essential, and regional and local stakeholders, experts, and partners in conservation must take part in such a project because they have good knowledge of the terrain and regional development issues (and possibly more adequate or recent data). As outlined in the logic model, they should be involved in the early stage of the project in order to ensure the project is understood by those in the field, its adequate execution and that it is properly implemented (Leitão and Ahern 2002; Thompson 2011). In addition, an upstream involvement from such a vast array of partners allows a common understanding of what landscape ecology is and the benefits of such an approach.

13.1.4 Steps to complete

Some of the steps in the logic model were omitted intentionally or have not been fully completed because this was a pilot project with a limited timeframe. For example, the data collected was limited to biological, geographical and physical data. The contribution of socio-economic data such as the demographic characteristics of the territory, forthcoming urban expansion and land development (agriculture, industry, etc.), as well as "heritage" data, such as Aboriginal land claims, would have clarified the human portrait of the study area and major regional issues. Coupled with a predictive model, the development of different conservation scenarios would help assess the impacts (positive and negative) of anthropogenic developments, such as projects subject to environmental assessments on the structure, composition and integrity of the landscape.

The identification of key areas where restoration efforts would be justified to favour biodiversity (breeding habitats, functional corridors) was not completed, but this analysis would bring an added value to the conservation plan. It would also be necessary to validate the recommendations of the conservation plan. In fact, the land use map does not provide an updated portrait of the current habitat distribution across the landscape, and it will be essential to check its validity with local partners before implementing the conservation plan. A few guidelines accompany the conservation plan, and this aspect could be further explored to better describe the conservation options available to regional stakeholders and help with its implementation.

13.2 PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

13.2.1 Data

The production of this conservation plan is dependent on information found in the BCR plans regarding the selection of priority bird species and habitats. Some recommendations had to be validated by CWS experts before they were integrated into the landscape analysis. In addition, a landscape ecology study requires data coming from a variety of sources. Associated with this wealth of data are data management issues. It is essential to document each completed step, both in terms of the people contacted and data processing and conversions. Metadata files must be completed systematically in order to ensure that the information is documented and retained, while metadata from external files should be consulted carefully before integrating them in the analyses. In fact, some data were not used because metadata were missing or incomplete. Also, consider the delay that may occur between a request for data acquisition from partners and reception of these data, as well as subsequent processing required to convert them into the appropriate format for the project.

The quality of geospatial data is another obstacle, as their inclusion may be difficult considering their variability (resolution, date, projection, etc.). The production of the land use map by integrating data representing different thematics and coming from varied sources was laborious. The use of a single land-use map (e.g. classified images from AAFC) would have greatly reduced the resources needed to have this base map. On the other hand, the quality of the data associated with each habitat class coming from a single source would have been reduced. In addition, some data on the same topic had conflicting information (e.g. protected areas limits), which required additional research to clarify the information. Finally, the data were kept in a common data server accessible to all members of the work team, which created certain problems in terms of accessibility and management of the file versions. Hence the importance of properly documenting all steps performed. The presence of a data manager would have facilitated this process while allowing other team members to focus on other steps of the project.

The lack of quality data to represent certain topics such as old fields and gravel and sand pits was problematic. Other habitat features associated with priority species could not be represented spatially and were not included in the spatial analysis, such as the location of adequate chimneys to breeding Chimney Swifts.

13.2.2 Softwares

The choice of the appropriate softwares requires a good understanding of how data will be handled and processed in order to ensure that the softwares are compatible with the project objectives. This helps determine the required formats (raster or vector) in order to limit the number of conversions and reduce the risk of errors. Our choice of using Corridor Designer and FRAGSTATS was dictated by their compatibility with ArcGIS and the wide selection of spatial analyses they offer. However, these softwares require an adequate knowledge of geomatics tools and a good understanding of landscape metrics. Certain situations, such as changes in software versions, can lead to incompatibilities when programming scripts, as was the case with the HPP and FRAGSTATS software. The frequency of software updates and technical support offered should therefore be considered when choosing processing tools. Finally, the availability of high performance computers able to handle the software and the large size of geospatial files must be considered in project planning. At a minimum, we recommend using ArcGIS 9.1 (or an earlier version) with the *Spatial Analyst* extension, a computer with a 2.2 GHz processor, 2 GB RAM, 2.4 GB of free space, and a 256 MB RAM graphic card.

13.2.3 Teamwork

The magnitude of this project required rigorous teamwork and a great amount of cooperation among team members. The roles of all members on such a multidisciplinary team (biology, geomatics, geography, planning, etc.) should be defined based on the strengths and expertise of each member. Day-to-day discussions between team members allowed everyone to gain knowledge that goes beyond the scope of the project. Indeed, the synergy associated with the multiple expertise involved in the project certainly contributed to a more rigorous product than if the project had been accomplished by a reduced team. Meetings were held regularly to share information, and meeting notes were produced to document decisions. These notes became essential for monitoring the project. In addition, it often proved very useful to refer to the purpose and objectives of the project in order not to wander into unnecessary analyses.

14.0 CONCLUSION

The Lake Saint-Pierre pilot project gave us the opportunity to develop and test a methodology to determine priority habitats for nesting birds in a portion of the BCR 13. Based on the landscape ecology theory, the approach developed is more dynamic and inclusive than traditional approaches in conservation (i.e. by "hot spot" or species) because it allows to work on a larger scale and to analyze the landscape as a whole, taking into account the various components (biological, geographical/physical, socio-economic, etc.) that characterize it. Priority sites identified are no longer considered as separate entities, but rather as different components that are more or less interconnected and part of a whole.

Compared to traditional approaches, the landscape approach, more complex in terms of data collection and analysis, requires the establishment of a team with varied skills and highlights the essential contribution of geomatics and various planning and mapping tools. Although the investment of time and money may be larger, the results of such a landscape approach allow for more informed decisions regarding conservation on vast territories by identifying priority sites that would be overlooked by the traditional “hot spot” approach. The benefits of this more holistic landscape approach make the challenge of its practical implementation worthwhile.

The pilot project was an opportunity to define a phased approach in order to achieve a comprehensive conservation plan in the Lake Saint-Pierre region, to determine a suite of action to achieve conservation priorities in the field, and most importantly, to develop the know-how required to achieve the habitat protection objectives of the conservation plans for migratory birds (BCR plans) and the recovery programs for species at risk. Results from our analyses, namely maps of priority sites and the associated digital layers (shapefiles), are made available to the public and local stakeholders who wish to incorporate them in their own land-use planning process (e.g. when RCM development plans are revised). We hope that this project will draw attention to this type of integrated approach and will stimulate discussion on its applicability to bird conservation plans developed for the BCRs or any other conservation initiative such as the St. Lawrence Action Plan or the Eastern Habitat Joint Venture.

15.0 LITERATURE CITED

Ahern, J. 2006. Theories, methods and strategies for sustainable landscape planning. Pages 119-131, In: From Landscape Research to landscape Planning: Aspects of Integration, Education and Application. Tress, B., G. Tress, G. Fry, et P. Opdam, Editeurs. Springer. The Netherlands.

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355-366.

Aubry, Y. and R. Cotter. 2007. Quebec Shorebird Conservation Plan. Environment Canada, Canadian Wildlife Service, Quebec Region, Sainte-Foy. xvi + 196 pp.

Austen, M.J.W., C.M. Francis, D.M. Burke and M.S. Bradstreet. 2001. Landscape context and fragmentation effects on forest birds in southern Ontario. Condor 103: 704-714.

Baum, K.A., K.J. Haynes, F.P. Dillemuth and J.T. Cronin. 2004. The matrix enhances the effectiveness of corridors and stepping stones. Ecology 85: 2671-2676.

Beier, P. and R.F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12: 1241-1252.

Beier, P., D.R. Majka and W.D. Spencer. 2008. Forks in the road : Choices in procedures for designing wildland linkages. Conservation Biology 22: 836-851.

Bélanger, L. and M. Grenier. 1998. Importance et causes de la fragmentation forestière dans les agroécosystèmes du sud du Québec. Série de rapports techniques n° 327, Service canadien de la faune, Environnement Canada, région du Québec, 39 p.

Bélanger, L. and M. Grenier. 2002. Agriculture intensification and forest fragmentation in the St. Lawrence valley, Québec, Canada. Landscape Ecology 17: 495–507.

Bélanger, L. and M. Grenier. 2003. Atlas de conservation des terres humides. Environnement Canada, Sevice canadien de la faune, région du Québec.

Bélanger, L., B. Jobin, G. Lacroix and Y. Bédard. 2006. Utilisation par l'avifaune des emprises autoroutières du sud du Québec faisant l'objet d'une gestion écologique de la végétation. Série de rapports techniques n° 388, Service canadien de la faune, région du Québec, Environnement Canada, Sainte-Foy, xii + 89 p. et annexes.

Bélisle, M. and A. Desrochers. 2002. Gap-crossing decisions by forest birds : an empirical basis for parameterizing spatially-explicit, individual-based models. Landscape Ecology 17: 219-231.

Bennett, A.F. 1999. Linkages in the landscape : the role of corridors and connectivity in wildlife conservation. IUCN, Gland, Switzerland and Cambridge, U.K.

Bentrup, G. 2008. Conservation buffers: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station. 110 p. Site: http://nac.unl.edu/bufferguidelines/index.html

Brown, C. R. 1997. Purple Martin (Progne subis), The Birds of North America Online (A. Poole, Ed.). Cornell Lab of Ornithology; Ithaca, USA. Site: http://bna.birds.cornell.edu/bna/species/287

Brown, M. and J.J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management 50: 392-397.

Calmé, S. 1998. Les patrons de distribution des oiseaux des tourbières du Québec méridional. Thèse de Doctorat. Département des Sciences du bois et de la forêt. Faculté de Foresterie et de Géomatique, Université Laval, Québec. 93 p.

Chapdelaine, G. and J.-F. Rail. 2004. Quebec's Waterbird Conservation Plan. Migratory Bird Division, Canadian Wildlife Service, Quebec Region, Environment Canada, Sainte-Foy, Quebec. 99 pp.

Connexion Montérégie. 2012. Biodiversity, Ecosystem Services, and Connectivity in Montérégie. Site: www.connexionmonteregie.com/index.html

Corry, R.C. 2004. Characterizing fine-scale patterns of alternative agricultural landscapes with landscape pattern indices. Landscape Ecology 20: 591-608.

CRECQ. 2012. Portrait des milieux humides du Centre-du-Québec. Conseil régional de l'environnement du Centre-du-Québec, 135 p.

Debinski, D.M. 2006. Forest fragmentation and matrix effects : the matrix *does* matter. Journal of Biogeography 33: 1791-1792.

De Smith, M., M. Goodchild and P. Longley. 2011. Geospatial Analysis – A Comprehensive Guide, 3rd edition. Site: www.spatialanalysisonline.com/output/

Desrochers, A. and S.J. Hannon. 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology 11: 1204-1210.

Detenbeck, N., S.M. Galatowitsch, J. Atkinson and H. Ball. 1999. Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. Wetlands 19: 789-829.

Dettmers, R. 2003. Status and conservation of shrubland birds in the northeast US. Forest Ecology and Management 185: 81-93.

Duchemin, M. and R. Majdoub. 2004. Les bandes végétales filtrantes : de la parcelle au bassin versant. Vecteur Environnement 37: 36-50.

Duchemin, M. and R. Hogue. 2009. Reduction in agricultural non-point source pollution in the first year following establishment of an integrated grass/tree filter strip system in southern Quebec (Canada). Agriculture, Ecosystems and Environment 131: 85-97.

Duchesne, S. and L. Bélanger. 1997. Fragmentation forestière et corridors verts en paysage agricole : 1. Revue des principales normes de conservation. Série de rapports techniques n° 288, Service canadien de la faune, région du Québec, Environnement Canada, Sainte-Foy, 68 p.

Duchesne, S., L. Bélanger and J.-P.L. Savard. 1998. Fragmentation forestière et corridors verts en paysage agricole : 2. Effets de bordure et de discontinuité des boisés. Série de rapports techniques n^{o} 318, Service canadien de la faune, région du Québec, Environnement Canada, Sainte-Foy, 70 p.

Duchesne, S., L. Bélanger, M. Grenier and F. Hone. 1999. Guide de conservation des corridors forestiers en milieu agricole. Environnement Canada, Service canadien de la faune, région du Québec et Fondation Les oiseleurs du Québec inc., 60 p.

Environment Canada. 2004. How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern (Second Edition). Environment Canada, Canadian Wildlife Service, Ontario Region. Downsview, Ontario. 80 p.

Environment Canada. 2007. Area-Sensitive Forest Birds in Urban Areas. Environment Canada, Canadian Wildlife Service, Ontario Region, Toronto. 58 p.

Environnement Canada. 2010a. Plan de conservation des oiseaux terrestres du Québec : volume 1, oiseaux des milieux forestiers. Environnement Canada, Service canadien de la faune, région du Québec. Rapport préliminaire inédit.

Environnement Canada. 2010b. Plan de conservation des oiseaux terrestres du Québec : volume 2, oiseaux des milieux agricoles, humides, urbains, arctiques, alpins et des falaises. Environnement Canada, Service canadien de la faune, région du Québec. Rapport préliminaire inédit.

Environment Canada. 2011. Recovery Strategy for the Least Bittern (Ixobrychus exilis) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada. Ottawa. v + 34 pp.
Site: www.registrelep.gc.ca/document/default_e.cfm?documentID=1291

Environment Canada 2012. Funding.
Site: www.ec.gc.ca/financement-funding/Default.asp?lang=En&n=3A49CF19-1

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management 61: 603-610.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics 34: 487-515.

Fairbairn, S.E. and J.J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the Prairie Pothole Region of Iowa, USA. Wetlands 21: 41-47.

Fischer, R.A. 2000. Width of riparian zones for birds. EMRRP Technical Notes Collection (TN EMRRP-SI-09), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Fondation de la faune du Québec and Union des producteurs agricoles. 2011. Manuel d’accompagnement pour la mise en valeur de la biodiversité des cours d’eau en milieu agricole. 122 p.

Forcey, G.M., W.E. Thogmartin, G.M. Linz, W.J. Bleier and P.C. McKann. 2011. Land use and climate influences on waterbirds in the Prairie Potholes. Journal of Biogeography 38: 1694-1707.

Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, England.

Fournier, F., B. Audet and S. Paradis. 2010. Bird conservation plan for the Lower Great Lakes/St. Lawrence Plain Bird Conservation region (BCR 13) in Quebec. Draft Report – Unpublished. Canadian Wildlife Service, Environment Canada. Québec, Quebec.

Gagnon, E., and G. Gangbazo. 2007. Efficacité des bandes riveraines : analyse de la documentation scientifique et perspectives. Ministère du Développement durable, de l'Environnement et des Parcs, Direction des politiques de l'eau, Québec. 17 p.

García-Feced, C., S. Saura and R. Elena-Rosselló. 2011. Improving landscape connectivity in forest districts: A two-stage process for prioritizing agricultural patches for reforestation. Forest Ecology and Management 261: 154-161.

Gauthier, J. and Y. Aubry. 1996. The breeding birds of Quebec: atlas of the breeding birds of southern Québec. Association québécoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, Canadian Wildlife Service. Quebec Region, Montréal, Quebec.

GéoMont. 2008. Cartographie de base des milieux humides de la Montérégie. GéoMont et Canards Illimités.
Site: http://foliogis.ducks.ca/qc/fr/monteregie/reg16_rapport_avril08.pdf

GéoMont and Environnement Canada. 2008. Évaluation des changements des terres humides entre 1964 et 2006 – Secteur de la Montérégie. Agence géomatique Montérégienne (GéoMont) et Environnement Canada, Service canadien de la faune. Rapport de projet. 45 p.

Gratton, L. 2010. Plan de conservation de la vallée du Saint-Laurent et du lac Champlain, région du Québec. Conservation de la Nature Canada, Montréal, Quebec. 150 p.

Grenier, M., Demers, A.-M., Labrecque, S., Benoit, M., Fournier, R.A., and Drolet, B. 2007. An object-based method to map wetland using RADARSAT-1 and Landsat ETM images : test case on two sites in Québec, Canada. Canadian Journal of Remote Sensing, vol. 33, suppl. 1, pp. S28-S45.

Gustafson, E.J. 1998. Quantifying landscape spatial pattern: what is the state of the art? Ecosystems 1: 143-156.

Hamer, T.L., C.H. Flather and B.R. Noon. 2006. Factors associated with grassland bird species richness : the relative roles of grassland area, landscape structure, and prey. Landscape Ecology 21: 569-583.

Hargis, C.D., J.A. Bissonette and J.L. David. 1998. The behavior of landscape metrics commonly used in the study of habitat fragmentation. Landscape Ecology 13: 167-186.

Hodges Jr., M.F. and D.G. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. Wilson Bulletin 108: 496-506.

Holzmueller, E.J., M.D. Gaskins and J.C. Mangun. 2011. A GIS approach to prioritizing habitat for restoration using neotropical migrant songbird criteria. Environmental Management 48: 150-157.

Huber, P.R., J.H. Thorne, N.E. Roth and M.M. McCoy. 2011. Assessing, ecological condition, vulnerability, and restorability of a conservation network under alternative urban growth policies. Natural Areas Journal 31: 234-245.

Institut de la statistique du Québec. 2010. Répertoire des établissements miniers du Québec – Liste des établissements producteurs pour certaines régions et substances. 39 p. Also available at: http://diff1.stat.gouv.qc.ca/rem/classes/accueil

Jaeger, J.A.G. 2000. Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecology 15: 115-130.

Jean, M. and G. Létourneau. 2011. Changes to the wetlands of the St. Lawrence River from 1970 to 2002. Environment Canada, Science and Technology Branch, Quebec Water Quality Monitoring and Surveillance Section, Technical Report No. 511, 293 p.

Jobin, B. and G. Falardeau. 2010. Habitat Associations of Grasshopper Sparrows in Southern Québec. Northeastern Naturalist 17: 135–146.

Jobin, B., M. Grenier and P. Laporte. 2001. Disponibilité de l'habitat de nidification préférentiel de la Pie-grièche migratrice au Québec. Série de rapports techniques n° 377, Environnement Canada, Service canadien de la faune, région du Québec, Sainte-Foy. xii + 65 p. + 2 annexes.

Jobin, B., C. Latendresse, C. Maisonneuve, A. Sebbane and M. Grenier. 2007. Changements de l'occupation du sol dans le sud du Québec pour la période 1993-2001. Série de rapports techniques n° 483, Environnement Canada, Service canadien de la faune, région du Québec, Sainte-Foy, Québec. 112 p. + annexes.

Jobin B., R. Langevin, M. Allard, S. Labrecque, D. Dauphin, M. Benoit and P. Aquin. 2013. Évaluation d'une approche d'analyse du paysage pour planifier la conservation des habitats des oiseaux migrateurs et des espèces en péril dans l'écozone des Plaines à forêts mixtes : étude de cas au lac Saint-Pierre – Rapport méthodologique. Environnement Canada, Service canadien de la faune, région du Québec, Québec. Rapport non publié. 196 p. et annexes.

Kampf, H. and F. Stavast. 2005. Committee of experts for the development of the Pan-European ecological network: report on the implementation of the Pan-European ecological network. The Netherlands. Ministry of Agriculture, Nature and Food Quality: Ede, NL. Site: www.minlnv.nl/txmpub/files/?p_file_id=14151

Keller, C.M.E., C.S. Robbins and J.S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13: 137-144.

Langevin, R. 1997. Guide de conservation des boisés en milieu agricole. Service canadien de la faune, Environnement Canada, Sainte-Foy. 77 p.

Langevin, R. and L. Bélanger. 1994. Conservation des îlots boisés en paysage agricole. I.- Revue de littérature et synthèse des connaissances sur leur utilisation par l'avifaune. Série de rapports techniques n° 221. Environnement Canada, Service canadien de la faune, région du Québec. 87 p.

Langevin, R. and L. Bélanger. 1995. Conservation des îlots boisés en paysage agricole. II.- Choix des critères et grille d'évaluation à des fins de conservation : Série de rapports techniques n° 224. Environnement Canada, Service canadien de la faune, région du Québec. 44 p.

Latendresse, C., B. Jobin, A. Baril, C. Maisonneuve, C. Boutin and D. Côté. 2008. Dynamique spatio-temporelle des habitats fauniques dans l'écorégion des Basses terres du fleuve Saint-Laurent, 1950-1997. Série de rapports techniques n° 494, Environnement Canada, Service canadien de la faune, région du Québec, Québec, 83 p. + annexes.

Lee, K.H., T.M. Isenhart and R.C. Schultz. 2003. Sediment and nutrient removal in an established multi-species riparian buffer. Journal of Soil and Water Conservation 58: 1-8.

Leitão, A.B. and J. Ahern. 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning 59: 65-93.

Lepage, C., D. Bordage, D. Dauphin, F. Bolduc and B. Audet. 2010. Plan de conservation de la sauvagine du Québec – 2010. Environnement Canada, Service canadien de la faune, région du Québec. Rapport préliminaire inédit.

Longtin, B. 1996. Options de conservation : Guide du propriétaire. Centre québécois du droit de l'environnement. Montréal, Quebec. 100 p.

Lovell, S.T. and W.C. Sullivan. 2006. Environmental benefits of conservation buffers in the United States: evidence, promise, and open questions. Agriculture, Ecosystems and Environment 112: 249-260.

Maheu-Giroux M., S. de Blois and B. Jobin. 2006. Dynamique des paysages de quatre Réserves nationales de faune du Québec : Suivi des habitats et des pressions périphériques. Université McGill, Département de sciences végétales et Environnement Canada, Service canadien de la faune, région du Québec. 67 p. + annexes.

Maheu-Giroux, M. and J. Belvisi. 2007. Volet biodiversité de l'Initiative nationale d'élaboration de normes agroenvironnementales – Projet pilote de la portion québécoise de l'écorégion des basses-terres du Saint-Laurent – Phase 1. Série technique de l'Initiative nationale d'élaboration de normes agroenvironnementales rapport n° 3-16. 243 p.

Majka, D., P. Beier and J. Jenness. 2007. CorridorDesigner ArcGIS Toolbox Tutorial, Environmental Research, Development and Education for the New Economy (ERDENE) initiative from Northern Arizona University, 25 p.

Mason, J., C. Moorman, G. Hess and K. Sinclair. 2007. Designing suburban greenways to provide habitat for forest-breeding birds. Landscape and Urban Planning 80: 153-164.

McGarigal, K., S.A. Cushman, M.C. Neel and E. Ene. 2002. FRAGSTATS v3: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Site: www.umass.edu/landeco/research/fragstats/fragstats.html

McGarigal, K., B.W. Compton, S.D. Jackson, K. Rolih and E. Ene. 2005. Conservation Assessment and Prioritization System (CAPS) Highlands Communities Initiative, PHASE 1. Final Report. 22 p. Site: www.umass.edu/landeco/research/caps/caps.html

McPherson, M., C. Nielsen, and K. Proudlock. 2009. The Development of Tier 1 Generalized Habitat-based Standards for Ecozones in Agricultural Regions of Canada. National Agri-Environmental Standards Initiative Synthesis Report No. 3. Environment Canada. Gatineau, Quebec. 137 p.

Ménard, S., M. Darveau, L. Imbeau and L. V. Lemelin. 2006. Méthode de classification des milieux humides du Québec boréal à partir de la carte écoforestière du 3e inventaire décennal. Québec, Canards Illimités Canada.

Ministère des Ressources naturelles et de la Faune du Québec (MRNF). 2012a. Registre foncier du Québec. Site: www.registrefoncier.gouv.qc.ca/Sirf

Ministère des Ressources naturelles et de la Faune du Québec (MRNF). 2012b. Système d'information géoscientifique pétrolier et gazier. Cartes des permis. Site: http://sigpeg.mrnf.gouv.qc.ca/gpg/classes/igpg

Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs (MDDEFP). 2002. Aires protégées. Site: www.mddefp.gouv.qc.ca/biodiversite/aires_protegees/index.htm

Minor, E. and D. Urban. 2010. Forest bird communities across a gradient of urban development. Urban Ecosystems 13: 51–71.

Municonsult. 2002. Réserve de la biosphère du lac Saint-Pierre, Habitats, ressources fauniques et exploitation, 33 p.

NABCI International. 2012. Background, Vision, and Strategy: NABCI Declaration of Intent. North American Bird Conservation Initiative. Site: www.nabci.net/International/English/background.html

Nature-Action. 2009. Plan de conservation et de mise en valeur des boisés de la municipalité régionale de comté de Pierre-De Saurel. Pour la MRC de Pierre-De Saurel. Rapport final. 39 p.

Nature-Action. 2012. Nature-Action Québec. Les milieux naturels. Site: www.nature-action.qc.ca/site/realisations/milieux-naturels

Naugle, D.E., R.R. Johnson, M.E. Estey and K.F. Higgins. 2000. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands 20 : 588-604.

Neave, E., D. Baldwin, and C. Nielsen. 2009. Tier 2 and 3 Standards – Developing Landscape-specific, Habitat-based Standards Using Multiple Lines of Evidence. National Agri-Environmental Standards Initiative Synthesis Report No. 4. Environment Canada. Gatineau, Quebec. 138 p.

North American Bird Conservation Initiative Canada. 2012. The State of Canada's Birds, 2012. Environment Canada, Ottawa, Canada. 36 p.

Oliver, A.J., C. Hong-Wa, J. Devonshire, K.R. Olea, G.F. Rivas and M.K. Gahl. 2011. Avifauna richness enhanced in large, isolated urban parks. Landscape and Urban Planning 102: 215-225.

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2004. Best Management Practices: Buffer Strips. Ontario Cattlemen's Association, Canada, Agriculture and Agri-Food Canada, Ontario. Ministry of Agriculture, Food and Rural Affairs. 141 p.

Poirier, I. 2010. La canneberge au Québec et dans le Centre-du-Québec : Un modèle de développement durable, à la conquête de nouveaux marchés. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Direction régionale du Centre-du-Québec, Victoriaville, Quebec. 35 p.

Poulin, M., M. Bélisle and M. Cabeza. 2006. Within-site habitat configuration in reserve design: A case study with a peatland bird. Biological Conservation 128: 55-66.

Qiu, Z. 2010. Prioritizing agricultural lands for conservation buffer placement using multiple criteria. Journal of the American Water Resources Association 46: 944-956.

Queste, C., 2011. Les milieux humides dans le sud du Québec : entre destruction et protection. Analyse critique et élaboration d'une stratégie de conservation. Rapport de stage présenté à Nature Québec, à l'Université du Littoral Côte d'Opale, et à l'Université des Sciences et Technologies de Lille 1, Nature Québec, Quebec, 44 p.

Rail, J.-F., M. Darveau, A. Desrochers and J. Huot. 1997. Territorial responses of boreal forest birds to habitat gaps. Condor 99: 976-980.

Renfrew, R.B. and C.C. Ribic. 2008. Multi-scale models of grassland passerine abundance in a fragmented system in Wisconsin. Landscape Ecology 23: 181-193.

Renfrew, R.B., C.A. Ribic and J.L. Nack. 2005. Edge avoidance by nesting grassland birds: a futile strategy in a fragmented landscape. Auk 122: 618-636.

Richard, G., D. Côté, M. Mingelbier, B. Jobin, J. Morin and P. Brodeur. 2011. Utilisation du sol dans la plaine inondable du lac Saint-Pierre (fleuve Saint-Laurent) durant les périodes 1950, 1964 et 1997 : interprétation de photos aériennes, numérisation et préparation d'une base de données géoréférencées. Rapport technique préparé pour le ministère des Ressources naturelles et de la Faune et Environnement Canada. 42 p.

Riffell, S. K., B. E. Keas and T. M. Burton. 2003. Birds in North American Great Lakes coastal wet meadows: is landscape context important? Landscape Ecology 18: 95-111.

ROBVQ. 2012. Recherche de financement : Document d'orientation à l'intention des OBV. Regroupement des organismes de bassins versants du Québec. 28 p.

Rompré, G., Y. Boucher, L. Bélanger, S. Côté and D. Robinson. 2010. Conservation de la biodiversité dans les paysages forestiers aménagés : utilisation des seuils critiques d'habitat. The Forestry Chronicle 86: 572-579.

Roy, L. 2002. Les impacts environnementaux de l'agriculture sur le Saint-Laurent. Le Naturaliste canadien 126: 67-77.

Saunders, D.A., R.J. Hobbs and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32.

Savoie, C. 2002. Le phénomène de déboisement : Évaluation par télédétection entre le début des années 1990 et 1999-2000. Région Le Centre-du-Québec. Direction de l'environnement et du développement durable, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec. 24 p.

Schlossberg, S. and D.I. King. 2008. Are shrubland birds edge specialists? Ecological Applications 18: 1325-1330.

Schwenk, W.S. and T.M. Donovan. 2011. A multispecies framework for landscape conservation planning. Conservation Biology 25: 1010-1021.

Shanahan, D.F., C. Miller, H.P. Possingham and R.A. Fuller. 2011. The influence of patch area and connectivity on avian communities in urban revegetation. Biological Conservation 144: 722-729.

Shao, G., D. Liu and G. Zhao. 2001. Relationships of image classification accuracy and variation of landscape statistics. Canadian Journal of Remote Sensing 27: 33-43.

Spackman, S.C. and J.W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. Biological Conservation 71: 325-332.

Stauffer, D.F. and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management 44: 1-15.

Steedman, R.J. 1987. Comparative analysis of stream degradation and rehabilitation in the Toronto area. Ph.D. Thesis, University of Toronto. 172 p.

Stephens, S.E., D.N. Koons, J.J. Rotella and D.W. Willey. 2003. Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. Biological Conservation 115: 101–110.

Tate, D.P. 1998. Assessment of the biological integrity of forest bird communities – a Draft Methodology and Field Test in the Severn Sound Area of Concern. Severn Sound RAP Technical Report. Canadian Wildlife Service, Ontario Region.

Thompson, B.A. 2011. Planning for implementation: Landscape-level restoration planning in an agricultural setting. Restoration Ecology 19: 5-13.

Tozer, D.C., E. Nol and K.F. Abraham. 2010. Effects of local and landscape-scale habitat variables on abundance and reproductive success of wetland birds. Wetlands Ecology and Management 18: 679-693.

Trani, M.K. and R.H. Giles Jr. 1999. An analysis of deforestation: metrics used to describe pattern change. Forest Ecology and Management 114: 459-470.

Turner, M.G., R.H. Gardner and R.V. O'Neill. 2001. Landscape ecology in theory and practice: pattern and process. Springer, New York. 404 p.

Uezu, A. and J.P. Metzger. 2011. Vanishing bird species in the Atlantic Forest: relative importance of landscape configuration, forest structure and species characteristics. Biodiversity and Conservation 20: 3627-3643.

Université de Montréal. 2012. Chaire en paysage et environnement. Site: www.paysage.umontreal.ca/

Van der Sluis, T., M. Bloemmen and I.M. Bouwma. 2004. European corridors: Strategies for corridor development for target species. ECNC, Tilburg, the Netherlands and Alterra. The Netherlands. 32 p.

Veech, J.A. 2006. A comparison of landscapes occupied by increasing and decreasing populations of grassland birds. Conservation Biology 20: 1422-1432.

Villard, M.A., M.K. Trzcinski and G. Merriam. 1999. Fragmentation effects on forest birds: Relative influence of woodland cover configuration on landscape occupancy. Conservation Biology 13: 774-783.

Watling, J.I., A.J. Nowakowski, M.A. Donnelly and J.L. Orrock. 2011. Meta-analysis reveals the importance of matrix composition for animals in fragmented habitat. Global Ecology and Biogeography 20: 209-217.

APPENDIX 1 − LIST OF 19 BIRD SPECIES NOT SELECTED FOR THE PILOT PROJECT

English name	Latin name	Group[1]	Reason
Bald Eagle	*Haliaeetus leucocephalus*	Land.	No known nesting site in the study area
Cerulean Warbler*	*Dendroica cerulea*	Land.	No known nesting site in the study area
Eastern Towhee	*Pipilo erythrophthalmus*	Land.	Rare species in the region
Field Sparrow	*Spizella pusilla*	Land.	Rare species in the region
Golden-winged Warbler*	*Vermivora chrysoptera*	Land.	No known nesting site in the study area
Grasshopper Sparrow	*Ammodramus savannarum*	Land.	No known nesting site in the study area
Loggerhead Shrike*	*Lanius ludovicianus*	Land.	No known nesting site in the study area
Olive-sided Flycatcher*	*Contopus cooperi*	Land.	Rare species in the region
Willow Flycatcher	*Empidonax traillii*	Land.	No conservation issue in BCR 13 in Québec
Red-headed Woodpecker*	*Melanerpes erythrocephalus*	Land.	Rare species in the region
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Land.	Stewardship species
Yellow-throated Vireo	*Vireo flavifrons*	Land.	Rare species in the region
Common Loon	*Gavia immer*	Mar.	Stewardship species
Yellow Rail*	*Coturnicops noveboracensis*	Mar.	Rare species in the region
American Black Duck	*Anas rubripes*	Wat.	Stewardship species
Brant	*Branta bernicla*	Wat.	Rare species in the region
Canada Goose (Atlantic Flyway Resident)	*Branta canadensis maxima*	Wat.	Overabundant species
Canada Goose (Atlantic))	*Branta canadensis canadensis*	Wat.	Stewardship species
Snow Goose	*Chen caerulescens atlantica*	Wat.	Overabundant species

1 Land. = Landbirds; Mar. = Marshbirds/Waterbirds; Wat. = Waterfowl

* Species with an asterisk are listed at risk according to SARA or COSEWIC.

APPENDIX 2 − SPECIES ASSOCIATED WITH COARSE FILTER HABITAT CLASSES

		Priority habitat classes							
		Farmland		Forest	Wetlands				
Group	English name	Perennial crop	Old field/Shrubland	Decid, Mixt, Conif	Marsh	Shrub swamp	Forest swamp	Wet meadow	Bog
Landbirds	American Kestrel	X							
	Baltimore Oriole			X					
	Bank Swallow								
	Barn Swallow	X							
	Barred Owl			X					
	Belted Kingfisher								
	Black-billed Cuckoo		X	X					
	Bobolink	X							
	Brown Creeper			X			X		
	Brown Thrasher		X						
	Canada Warbler					X			X
	Chimney Swift			X			X		
	Common Nighthawk								
	Eastern Kingbird		X		X	X			
	Eastern Meadowlark	X							
	Eastern Screech-Owl			X					
	Eastern Wood-Pewee			X					
	Horned Lark	X							
	Long-eared Owl			X					
	Nelson's Sparrow	X			X			X	
	Northern Flicker			X					
	Northern Harrier	X			X			X	X
	Northern Rough-winged Swallow								
	Northern Saw-whet Owl			X					
	Palm Warbler								X
	Peregrine Falcon (anatum)								
	Purple Martin								
	Savannah Sparrow	X						X	X
	Sedge Wren				X			X	X
	Short-eared Owl	X			X			X	X
	Vesper Sparrow	X							
	Whip-poor-will			X					
	Wood Thrush			X					
Shorebirds	American Woodcock		X						
	Killdeer	X							
	Upland Sandpiper	X							X
	Wilson's Phalarope				X			X	
	Wilson's Snipe				X			X	X
Marshbirds/ Waterbirds	American Bittern				X	X		X	
	Black Tern				X	X			
	Common Tern								
	Least Bittern				X	X			
	Sora				X				
	Virginia Rail				X				
Waterfowl	Blue-winged Teal	X	X		X	X			
	Greater Scaup								
	Lesser Scaup								
	Wood Duck						X		

Species not associated with a habitat class are considered in the fine filter criteria.

APPENDIX 3 − MATRICES USED TO CALCULATE THE EDGE CONTRAST INDEX OF HABITAT PATCHES FOR GENERAL AND DETAILED LAND USE CLASSES

General classes

	Open water	Wetland	Anthropogenic	Annual crop	Perennial crop	Old field	Forest
Open water	0.00						
Wetland	0.50	0.00					
Anthropogenic	1.00	1.00	0.00				
Annual crop	1.00	0.75	0.75	0.00			
Perennial crop	1.00	0.75	0.75	0.25	0.00		
Old field	1.00	0.50	1.00	0.75	0.50	0.00	
Forest	1.00	0.50	1.00	0.75	0.75	0.25	0.00

Detailed classes

	Open water	Shallow water	Marsh	Unidentified wetland	Unidentified swamp	Shrub swamp	Forest swamp	Bog	Anthropogenic	Anthropogenic – Other	Highway ROW	Bare soil	Annual crop	Perennial crop	Wet meadow	Old field/Shrubland	Orchard	Forest disturbance	Forest – Deciduous	Forest – Mixed	Forest – Coniferous
Open water	0.00																				
Shallow water	0.00	0.00																			
Marsh	0.50	0.50	0.00																		
Unidentified wetland	0.50	0.50	0.50	0.00																	
Unidentified swamp	0.50	0.50	0.50	0.50	0.00																
Shrub swamp	0.50	0.50	0.25	0.50	0.00	0.00															
Forest swamp	0.75	0.75	0.50	0.50	0.25	0.25	0.00														
Bog	0.50	0.50	0.25	0.50	0.50	0.25	0.50	0.00													
Anthropo-genic	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00												
Anthropo-genic – Other	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00											
Highway ROW	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.00										
Bare soil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	0.25	0.25	0.00									
Annual crop	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.50	0.00								
Perennial crop	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.50	0.75	0.75	0.75	0.75	0.25	0.00							
Wet meadow	1.00	1.00	0.50	0.50	0.50	0.50	0.75	0.25	1.00	1.00	0.75	0.75	0.50	0.25	0.00						
Old field/Shrubland	1.00	1.00	0.50	0.50	0.50	0.25	0.50	0.25	1.00	1.00	0.75	0.75	0.75	0.50	0.50	0.00					
Orchard	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.75	1.00	1.00	1.00	1.00	0.75	0.50	0.50	0.50	0.00				
Forest disturbance	1.00	1.00	1.00	0.75	0.75	0.50	0.75	0.75	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.25	0.50	0.00			
Forest – Deciduous	1.00	1.00	1.00	0.75	0.50	0.75	0.25	0.50	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.25	0.50	0.75	0.00		
Forest – Mixed	1.00	1.00	1.00	0.75	0.50	0.75	0.25	0.50	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.25	0.50	0.75	0.00	0.00	
Forest – Coniferous	1.00	1.00	1.00	0.75	0.50	0.75	0.25	0.50	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.25	0.50	0.75	0.00	0.00	0.00

www.**ec**.**gc**.**ca**

Additional information can be obtained at:

Environment Canada
Inquiry Centre
10 Wellington Street, 23rd Floor
Gatineau QC K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800
Fax: 819-994-1412
TTY: 819-994-0736
Email: enviroinfo@ec.gc.ca