St. Lawrence
Plan
For a Sustainable Development

Changes to the wetlands of the St. Lawrence River from 1970 to 2002

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Management Perspective

This document is published as part of the federal–provincial St. Lawrence Action Plan and the Monitoring the State of the St. Lawrence River Program.

Approved in 1991, the Federal Policy on Wetland Conservation is one of the tools used by Canada to meet its commitment to ensure the wise use of wetlands on federal Crown land. The federal policy subscribes to a number of principles, including no net loss of wetland functions on all federal lands and waters, which it applies by mitigating the effects of development related to these wetlands and by enhancing and rehabilitating wetlands in areas where the continued loss and degradation of wetlands or their functions have reached critical levels. The approaches used to implement the policy include the conduct of wetland inventories and evaluations of wetland status, of which the present report on the St. Lawrence is an example.

Wetlands are an ongoing concern for researchers, decision makers and users of the St. Lawrence River. The surface area occupied by wetlands is an indicator of primary importance for tracking wetland status. This report presents a portrait of the changes in wetland area and vegetation composition observed in certain key areas along the St. Lawrence between the 1970s and 2002 and provides an essential means for monitoring wetland dynamics.

Perspective de gestion

Ce rapport est publié dans le cadre du Plan d'action Saint-Laurent et du Programme Suivi de l'état du Saint-Laurent.

La Politique fédérale sur la conservation des terres humides approuvée en 1991 est un des outils dont se sert le Canada pour respecter son engagement face aux directives d'utilisation rationnelle des terres humides sur les terres publiques fédérales. Elle souscrit aux principes qui comprennent, entre autres, de ne permettre aucune perte nette des fonctions des terres humides dans toutes les terres et les eaux fédérales, et ce, par l'atténuation de tous les effets de l'aménagement lié à ces terres humides et par l'amélioration et le rétablissement des terres humides dans les zones où les pertes ou la dégradation continues des terres humides ou de leurs fonctions ont atteint des niveaux critiques. Les approches permettant la mise en œuvre de la politique incluent la réalisation d'inventaires et l'évaluation de l'état des milieux humides, dont le présent document fait état pour le Saint-Laurent.

Les milieux humides sont l'objet de préoccupations constantes de la part des chercheurs, des décideurs et des usagers du Saint-Laurent. L'un des premiers indices permettant de suivre l'état des milieux humides est leur superficie. L'analyse présentée dans les pages qui suivent dresse le portrait des changements de superficie et de végétation des milieux humides de certains secteurs clés, observés entre les années 1970 et 2002, et procure un élément essentiel pour faire le suivi de sa dynamique.

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Lastly, we wish to thank Sylvie de Blois and Christiane Hudon for reviewing this document.

Abstract

The main aim of the present work is to support the Monitoring the State of the St. Lawrence River Program by laying the groundwork for recurring monitoring of the wetlands along the St. Lawrence River. More specifically, this involves monitoring changes in wetland area, examining wetland dynamics, and identifying the outcome of recent pressures on these significant ecosystems.

The analysis draws on large-scale published studies aimed at taking stock of the wetland losses along the St. Lawrence River (Groupe Dryade 1981; Environment Canada 1985; Robitaille et al. 1988; Marquis et al. 1991; Gosselin 2003).

We were able to compare the results obtained earlier to the most recent data. We harmonized the legends of the maps published by Groupe Dryade (1980) and by Létourneau and Jean (2005, 2006a, 2006b, 2006c), and we documented marsh and swamp dynamics between the 1970s and 2000–2002. Our results show that wetland dynamics of the period from the 1970s to 2000–2002 are very different from the situation observed between 1945 and the 1970s. More specifically, the area of marshes and swamps (excluding shallow water areas) increased slightly between 1990–1991 and 2000–2002. These environments occupied an area of 28 228 hectares (ha) in 1990–1991 compared with 28 992 ha in 2000–2002, which represents an increase of 764 ha or 2.7%. The sector-by-sector results provide a different picture of wetland dynamics, however. Net losses were observed in the Montréal–Longueuil area as well as around Lake Saint-Pierre. In contrast, significant gains were recorded in the fluvial estuary, the upper estuary and part of the lower estuary.

This report provides an overview of the dynamics of the different components of the St. Lawrence wetlands and shows that several factors, including water levels and tides, can have a major effect on estimates of wetland area. Many changes occurring within the river's wetlands underscore the dynamic character of these ecosystems. In several sectors along the St. Lawrence, there is a drying trend within wetlands. Although this may be a natural trend, we can postulate that the drop in water levels recorded over the past 10 years, as well as eutrophication, may have accelerated this phenomenon.

The findings of the past decade appear encouraging. Conservation and restoration efforts carried out along the St. Lawrence by many different organizations have borne fruit. For example, the creation of national wildlife areas and migratory bird sanctuaries along the river has played a key role in the preservation of wetlands. However, this does not detract from the finding that the wetlands still face strong pressures. Continued vigilance is in order, and only through long-term commitment to continuing this monitoring effort can we secure the information needed to guide decision making and actions.

Résumé

Le présent exercice vise principalement à contribuer au Programme Suivi de l'état du Saint-Laurent par la mise en place d'un suivi récurrent des milieux humides du fleuve Saint-Laurent. Son objectif est de surveiller l'évolution de la superficie des milieux humides, de rendre compte de la dynamique de ces milieux et de mettre en lumière le résultat des pressions récentes qui s'exercent sur ces écosystèmes d'importance.

Ce projet s'inspire d'importants travaux publiés qui visaient à comptabiliser les pertes en milieux humides survenues le long du fleuve Saint-Laurent (Groupe Dryade, 1981; Environnement Canada, 1985; Robitaille *et al.*, 1988; Marquis *et al.*, 1991; Gosselin, 2003).

Nous avons réussi à comparer les résultats antérieurs aux données les plus récentes. Nous avons harmonisé les légendes des cartographies publiées par le Groupe Dryade (1980) et Létourneau et Jean (2005, 2006a, 2006b, 2006c), et nous avons documenté la dynamique des marais et des marécages entre les années 1970 et 2000-2002. Nos résultats montrent que la dynamique des milieux humides durant la période entre les années 1970 et 2000-2002 est très différente de celle enregistrée entre 1945 et les années 1970. Plus précisément, la superficie des marais et marécages (excluant les eaux peu profondes) a légèrement augmenté entre 1990-1991 et 2000-2002. Ainsi, ces milieux occupaient 28 228 hectares (ha) en 1990-1991 et 28 992 ha en 2000-2002, une augmentation de 764 ha ou 2,7 p. 100. Les résultats sectoriels montrent cependant des dynamiques différentes. Des pertes nettes de milieux humides sont observées dans le secteur Montréal-Longueuil de même qu'au lac Saint-Pierre. À l'opposé, d'importants gains sont enregistrés dans l'estuaire fluvial, le moyen estuaire et une partie de l'estuaire maritime.

Ce travail met en lumière la grande dynamique des faciès des milieux humides du Saint-Laurent où plusieurs facteurs, dont les niveaux de l'eau et les marées, peuvent avoir un effet important sur l'estimation des superficies. Par ailleurs, de nombreux changements survenus au sein même des milieux humides renforcent l'image dynamique de ces écosystèmes. On remarque dans plusieurs secteurs du fleuve une tendance vers l'assèchement relatif des milieux humides. Bien que cette tendance puisse être naturelle, il nous est permis d'émettre l'hypothèse que la

baisse des niveaux d’eau enregistrée durant les dix dernières années, ainsi que l’eutrophisation, aient pu avoir un effet accélérateur sur ce phénomène.

Le constat des dix dernières années nous semble encourageant. Les efforts de conservation et de restauration, réalisés le long du Saint-Laurent par de multiples organisations, ont porté des fruits. Parmi ceux–ci, la création, le long du Saint-Laurent, des réserves nationales de faune et des refuges d’oiseaux migrateurs a marqué une étape déterminante dans la préservation des milieux humides. Cela ne diminue en rien, toutefois, le constat que les milieux humides subissent encore d’importantes pressions. La vigilance est de rigueur et seul un engagement à long terme de poursuivre un tel suivi pourra fournir de l’information permettant de statuer en la matière et d’orienter les actions.

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Definitions

Marsh – A wetland in which the water level is shallow and typically fluctuates on a daily, seasonal or annual basis. The vegetation is dominated by herbaceous species. Low marshes, which are flooded during most of the growing season or during low tide, are distinguished from high marshes (including wet meadows), which are submerged during high water periods or only during high tide. Marshes are dominated by emergent vegetation.

Progressive change – A change that occurs in the direction of a later stage of succession (e.g., from open water to high marsh)

Regressive change – A change that occurs in the direction of an earlier stage of succession (e.g., from forested swamp to low marsh)

Shallow water – A wetland that is transitional between saturated or seasonally wet (bog, marsh or swamp) wetlands and deep perennial water bodies that typically have a well-developed deep water area (generally more than 3 m deep). This type of environment, also called an aquatic bed, may contain areas of submerged aquatic vegetation.

Swamp – A wetland that is dominated by shrubs (shrub swamp) or trees (forested swamp).

Wetland – Land that is saturated with water long enough to promote wetland or aquatic processes: poorly drained soils, hydrophytic vegetation and various kinds of biological activities that are adapted to this environment.

1 Introduction

Wetland vegetation is considered a very important component of the St. Lawrence River fluvial ecosystem. The different ecological services and functions of wetlands, as well as the values associated with this environment, are essential elements for evaluating the health of the St. Lawrence.

It is for this reason that an indicator of wetland area is used in the State of the St. Lawrence Monitoring Program. It involves periodically monitoring the area occupied by the river's freshwater wetlands (St. Lawrence Centre 1996). However, it has been difficult to obtain information on changes in wetland area because of the absence of a comparative analysis of the available inventories (St. Lawrence Centre 1996; Quilliam and Millet 1998). The only available studies were a comparative analysis of the areal extent of the wetland losses that occurred prior to the 1970s (Groupe Dryade 1981; Environment Canada 1985), a cumulative inventory of fish habitat modifications (Robitaille et al. 1988; Marquis et al. 1991), and wetland cartography dating from 1990–1991 (Létourneau and Jean 1996, 2005).

This report complements the Groupe Dryade studies (1980, 1981) in that it incorporates recent data up to 2002 (Létourneau and Jean 2005, 2006a, 2006b). The work involves recoding the inventories and then comparing them in order to identify all possible changes. The report also sketches out the dynamics of the St. Lawrence wetlands in order to update the portrait of the ecosystems.

Most of the scientific names used in this document to identify vascular plants are taken from Marie-Victorin (1997).

2 Study region

The map analysis presented in this document covers the area along the St. Lawrence from Cornwall to Cap Tourmente on the north shore and from the Lac Saint-François National Wildlife Area (Dundee) to Trois-Pistoles on the south shore. Figure 1 shows the study region. It should be noted that, in the Montréal area, only the south shore of Montréal Island was covered. Lac des Deux Montagnes, the Rivière des Prairies and the Rivière des Mille Îles were excluded, because these areas are not covered in recent datasets (from 1990 onwards). The region was divided into study areas based on the priority intervention zones (ZIP Program), in order to process information according to territorial units. The zones concerned have fairly homogeneous biophysical and socio-economic characteristics. Figure 2 shows the river's 13 study sectors. As Burton (1991) explains:

> [Translation] "The main goal of dividing the region into subgroups is to facilitate understanding of local phenomena that can be associated with local human activities. This division makes it easier to identify uses and resources located near riverside communities.
>
> While focusing on local causes of deterioration and contamination of the natural environment, the ZIP Program seeks to highlight valued components (uses and resources) of the area in order to encourage riverside community partners to participate in concerted efforts to reclaim uses of the river and conserve resources, as well as implement preventive measures."

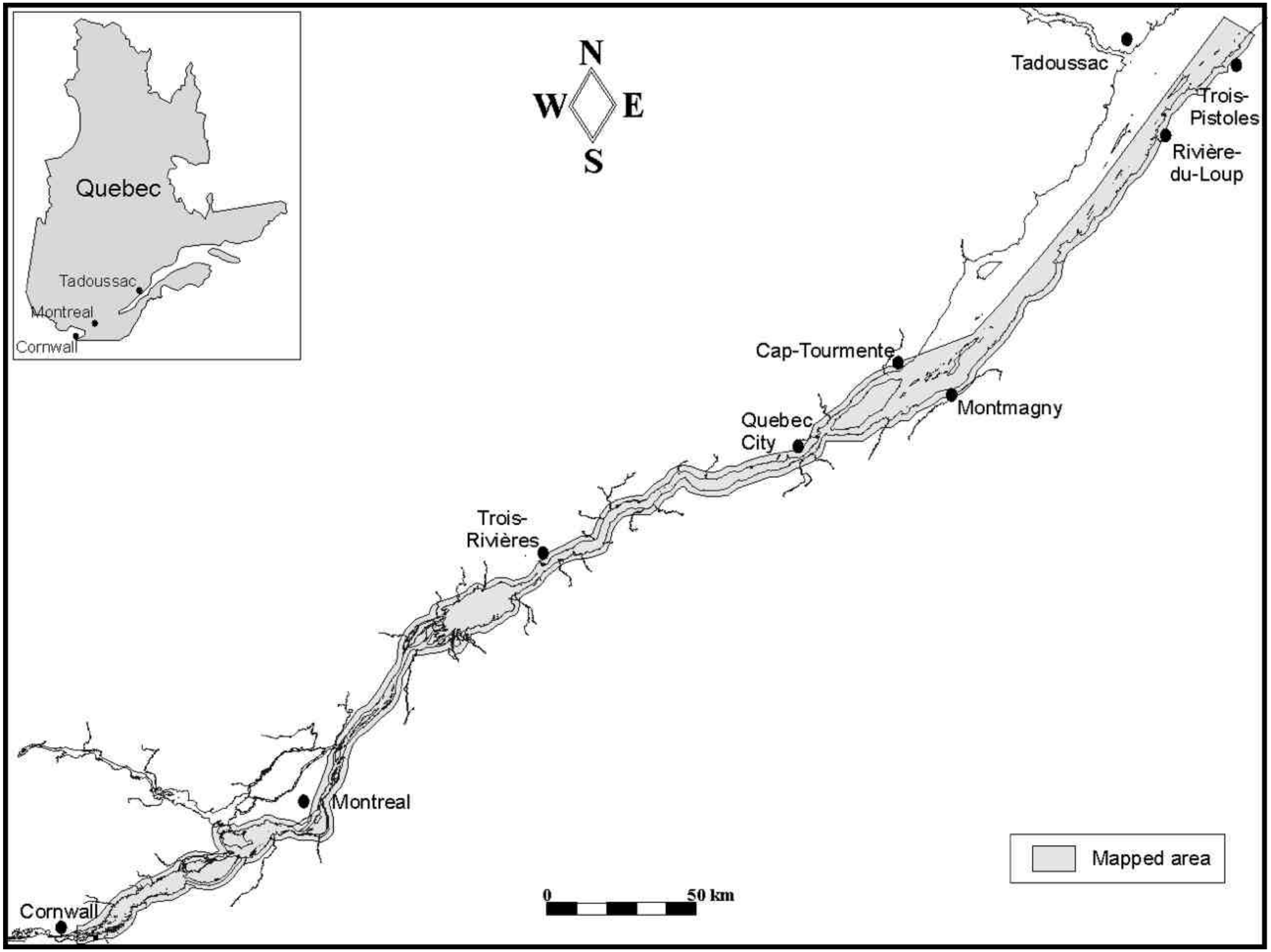


Figure 1 Study region

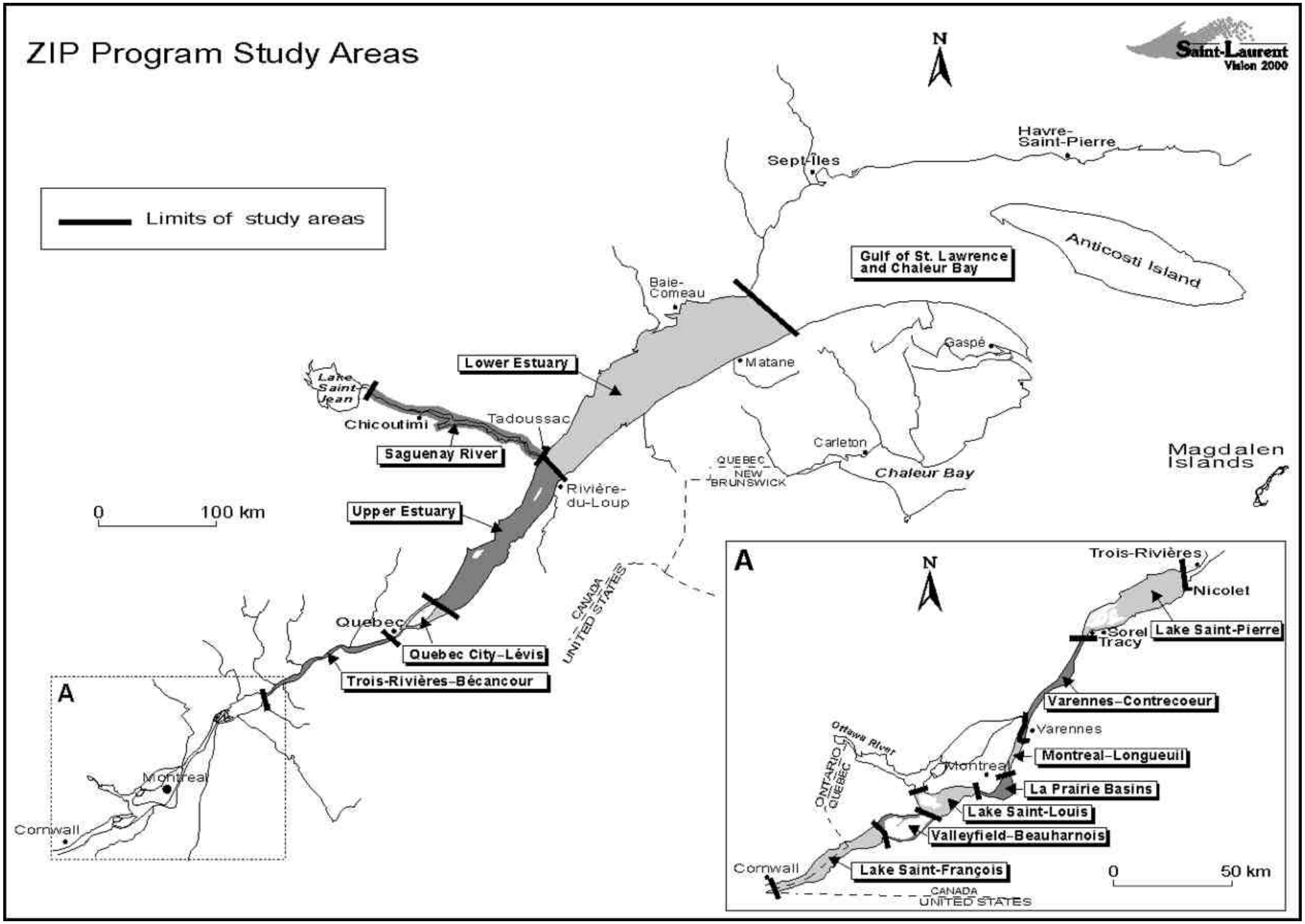


Figure 2 **Study sectors under the ZIP (priority intervention zones) Program**

3 Materials and methods

The methodology used for documenting wetland dynamics involves two main steps: the preparation of cartographic documents (acquisition of map coverages and harmonization of geometries, scales and legends); and map comparison and creation of transition matrices. These steps are described in detail below for each coverage used.

3.1 COVERAGES USED

We used a total of four map coverages to take stock of wetland dynamics along the St. Lawrence River. Table 1 provides a brief description of the map coverages used in this study.

Table 1 Map coverages used in change analysis

Period	Initial Resolution (m)	Total Number of Classes	Reference
1970–1978	10	52	Groupe Dryade (1980)
1990–1991	7	65	Létourneau and Jean (2005)
1996–1997	3	124	Létourneau and Jean (2006a)
2002–2002	3.5 and 4	124	Létourneau and Jean (2006b, 2006c)

3.1.1 Migratory bird habitats

Many specialists and users rightfully consider the mapping of migratory bird habitats carried out by Groupe Dryade (1980) as the primary reference for the location of wetlands in the St. Lawrence. Before this massive study was published, no overall map of the wetlands in the river and its main tributaries was available. The objectives of the Groupe Dryade study were to locate and measure [Translation] “the area of swamps [*sic*] bordering the St. Lawrence from Cornwall to Blanc-Sablon on the north shore and from Cornwall [*sic*] to Matapédia on the south shore, the Ottawa and Richelieu rivers and the Magdalen Islands” (Groupe Dryade 1980). The study also included a temporal analysis of disturbances at three sites, which were selected based on their diversity and their proximity to urban centres (La Prairie, Gentilly and Kamouraska).

In parallel to this mapping study, Groupe Dryade also carried out another indispensable study, an analysis of changes occurring along the St. Lawrence, from Cornwall to Matane, between 1945 and 1976 (Groupe Dryade 1981). This study, along with the previous one, became the baseline for the development of an indicator of wetland area (in hectares) as part of the *State of the Environment Report on the St. Lawrence River* (St. Lawrence Centre 1996) and the State of the St. Lawrence Monitoring Program (Quilliam and Millet 1998; Painchaud and Villeneuve 2003; St. Lawrence Plan 2010).

As mentioned earlier, the spatial coverage in these studies is remarkable; it includes the Richelieu and Ottawa rivers, the St. Lawrence River (to Cap Tourmente), the estuary, the north shore of the Gulf of St. Lawrence, the Gaspé Peninsula and the Magdalen Islands. The objective of the Groupe Dryade study was to map suitable migratory bird habitat, which limits its usefulness in wetland research. Although the authors identified 52 land cover classes, several areas dominated by forested swamps were not included in the study area.

In the Dryade study, migratory bird habitats were mapped using aerial photographs taken between 1970 and 1978. Photographs were taken mainly in spring before plant communities were fully developed, possibly resulting in the underestimation of wetland area and misidentification of the dominant vegetation present. Emulsions used included colour, black and white and infrared, and maps ranged in scale from 1:10 000 to 1:20 000.

The Groupe Dryade maps were produced from mosaics of aerial photographs obtained over eight years, which makes it difficult to obtain a portrait of the entire river at a given point in time; in addition, this makes comparisons between map coverages difficult. According to the historical data, water levels along the St. Lawrence were highly variable between 1970 and 1978, with very high water levels recorded particularly in the upstream part of the river, which had a major impact on certain wetlands (Astrade and Bégin 2003; Jean et al. 1992). In addition, the mapping of some sectors (between Gentilly and Trois-Pistoles) did not take significant tidal effects into account, which complicates interpretation.

In the present study, only maps covering the major wetland complexes in the St. Lawrence were used (Table 2), since time and budgetary constraints made it impossible to digitize all the maps involved.

Table 2 Maps by Groupe Dryade (1980) digitized for this study

Map Number	Sector	Location
1	St. Lawrence River	Saint-Régis
2	St. Lawrence River	Lake Saint-François
6	St. Lawrence River	Lake Saint-Louis
10	St. Lawrence River	Boucherville Islands
11	St. Lawrence River	Verchères Islands
12	St. Lawrence River	Contrecœur Islands
13	St. Lawrence River	Sorel Islands
14	St. Lawrence River	Maskinongé Bay
15	St. Lawrence River	Baieville
16	St. Lawrence River	Pointe du Lac
18	St. Lawrence River	Gentilly
24	St. Lawrence River	Île d'Orléans
25A and 25B	St. Lawrence River	Cap Tourmente
28	St. Lawrence River	Montmagny
29	St. Lawrence River	Île aux Grues
1SA and 1SB	St. Lawrence estuary	Kamouraska Bay
2S	St. Lawrence estuary	Kamouraska Islands

Biorex (1998) was commissioned to digitize the maps selected. Table 3 shows the classes in the Groupe Dryade (1980) maps that were included in the digitization. Digitization was carried out manually and is accurate to within about 20 metres (m) (Biorex Inc. 1998).

Table 3 Digital classes in the Groupe Dryade mapping (1980)

Number	Class	Symbol
1	Woodland	A
2	Shrubland	a
3	Herbaceous meadow	h
5	Cropland and pastureland	c
6	Fallow land	fr
7	Periodically flooded woodland	Ai
10	Herbaceous meadow with shrubs	ha
11	Herbaceous meadow with trees	hA
14	Aquatic vegetation dominated by emergent plants	H
15	Aquatic vegetation dominated by submerged plants	Hs
16	Islands of shrubs dispersed in H	Ha
26	Sand or gravel deposits	S
51	Cropland and pastureland on bedrock	CR

Source: Biorex Inc. (1998)

During digitization, several cartographic anomalies, topological in nature, were discovered on the maps, including open and unidentified polygons and polygons containing more than one identifier. In the latter case, the dominant identifier was retained as the class of the polygon.

In addition, spatial positioning errors were also present on the computerized versions of the maps. The St. Lawrence shoreline is sometimes masked by polygons on these maps, which can make it very difficult to accurately pinpoint control points.

Lastly—and this is a problem common to geographic maps of the St. Lawrence shoreline in general—very few fixed control points are present, a situation that prevents a high degree of accuracy in georeferencing.

3.1.2 Mapping the wetlands of the St. Lawrence using remote sensing (1990–1991)

The objective of the first comprehensive wetland mapping project carried out by the St. Lawrence Centre (Environment Canada) was to catalogue land cover classes within the first kilometre inland from the shoreline and in the waters of the river itself (Létourneau and Jean

2005). The *State of the Environment Report on the St. Lawrence River* (St. Lawrence Centre 1996) recommended that these wetland maps be used as a reference point for measuring changes in wetland area along the St. Lawrence.

As Table 4 shows, the data used in this study were acquired during two different periods, July 26 and August 21, 1990 (between Cornwall and Trois-Rivières), and September 3, 1991 (between Trois-Rivières and Trois-Pistoles).

Table 4 Sectors covered in remote sensing of wetlands in the St. Lawrence (1990–1991)

Sector	Image Acquisition Date
Lake Saint-François	July 26, 1990
Valleyfield–Beauharnois	July 26 and August 21, 1990
Lake Saint-Louis	August 21, 1990
La Prairie Basins	August 21, 1990
Montréal–Longueuil	August 21, 1990
Varennes–Contrecœur	July 26 and August 21, 1990
Lake Saint-Pierre	July 26 and August 21, 1990
Trois-Rivières–Bécancour	September 3, 1991
Quebec City–Lévis	September 3, 1991
Upper estuary (south shore only)	September 3, 1991
Lower estuary (south shore to Trois-Pistoles only)	September 3, 1991

Source: Létourneau and Jean (2005)

Particular emphasis was put on distinguishing between the various marsh and swamp classes and on adequately estimating areas of submerged vegetation.

Wetlands were mapped using a MEIS–II airborne sensor with a spatial resolution of 7 m, allowing 65 land cover classes to be distinguished, including 46 wetland classes. Wetland classes consisted of two open water classes, two shallow water classes (covering over 28 100 ha), 20 classes of low marsh (over 17 450 ha), 16 classes of high marsh (over 9500 ha) and five swamp classes (totalling over 6470 ha). For logistical reasons, only the area between Cornwall and Cap Tourmente on the north shore and between the Lac Saint-François National Wildlife Area (Dundee) and Trois-Pistoles on the south shore were covered in the images.

Wetland and upland areas had to be classified separately, particularly in agricultural areas since, with remote sensing images, there is a high risk of confusing some types of agricultural land with some types of wetlands.

The Létourneau and Jean study, the most ambitious since the Groupe Dryade study (1980), resulted in a number of findings regarding methodological issues. It demonstrated that, although remote sensing images alone cannot be used to identify dominant and codominant plant species in wetlands, they do allow spectral signatures often associated with physiognomic vegetation classes to be identified. Classes can then be pinpointed by consulting reference documents and field data that allow them to be associated with plant communities. Consequently, the thematic accuracy of mapping depends to a large degree on the information available for associating spectral signatures with what actually exists on the ground. In the present case, some sectors like the Lac Saint-François National Wildlife Area, Îles de la Paix, Contrecœur Islands, Lake Saint-Pierre and the L'Isle-Verte sector were sampled shortly after image acquisition, allowing vegetation to be accurately identified. Classification was not as accurate in other sectors owing to a paucity of field data.

The primary problem with this study is the lack of field data for validation during the processing of the raw images. The aerial images were classified based solely on published data and the opinions of experts on wetland vegetation. The lack of accurate data on field conditions at the time of image acquisition prevented the identification of stands to the dominant species level.

3.1.3 Mapping the wetlands of the St. Lawrence using remote sensing (1996–1997)

Environment Canada obtained partial map coverage of wetlands in the St. Lawrence in 1996 and 1997. This dataset was acquired for an initial comparison under a project carried out to monitor changes in St. Lawrence wetlands and to test airborne multispectral video technology (Létourneau and Jean 2006a).

The project resulted in the mapping of various land cover classes within the first kilometre inland from the shoreline, along with the waters of the river itself, in several sectors. Particular emphasis was placed on differentiation of the various marsh and swamp classes. Shallow water areas were not mapped, however, because of the difficulty of identifying and measuring them accurately.

Raw data from 1996–1997 with a spatial resolution of 3 m were acquired in September and October of 1996 and August 1997 (Létourneau and Jean 2006a). In all, ten sectors were analyzed (Table 5).

Table 5 Aerial multispectral video coverage of wetlands in the St. Lawrence

Sector	Image Acquisition Date
Lac Saint-François National Wildlife Area	August 9, 1997
Îles de la Paix National Wildlife Area	October 17, 1996
Saint-Bernard Island and Ruisseau Saint-Jean	October 17, 1996
Boucherville Islands and Sainte-Thérèse Island	October 17, 1996
Contrecœur	October 17, 1996
Lake Saint-Pierre islands, Saint-François Bay and Lavallière Bay	August 10, 1997
Gentilly Flats	August 10, 1997
Côte-de-Beaupré and Cap Tourmente	September 6, 1996
Kamouraska Flats	August 10, 1997
Saint-Fulgence (Saguenay)	August 10, 1997

Source: Létourneau and Jean (2006a)

Unlike the 1990–1991 coverage, airborne multispectral videographic image acquisition was accompanied by field work, with a total of 183 sampling stations visited (Létourneau and Jean 2006a). The information obtained involved mainly vegetation and was structured according to Jacques and Hamel's classification system (1982), including land use, wetland class and subclass, growth form, and dominant and subdominant plant species as required. Cover classes were used to characterize the main vegetation strata present at the sites. In addition, 250 photographs of the wetlands visited were taken.

The results obtained with the airborne multispectral videographic sensor allowed 43 land cover classes to be distinguished, 35 of which are specific to wetlands. The latter include three open water classes, two shallow water classes (over 2410 ha), 15 low marsh classes (over 7880 ha), nine high marsh classes (over 5210 ha) and five swamp classes (over 7600 ha).

Despite the use of field data, the mapping fell short of the maps produced in 1990–1991 in terms of accuracy of the identification of dominant plant species, owing to the poorer spectral resolution of aerial videography. However, it did provide good results at the scale of major wetland classes.

From a technical point of view, the process of creating image mosaics from aerial multispectral videographic images resulted in significant radiometric variations, particularly for the 1997 data. Therefore, image processing and identification of wetlands proved to be more difficult than expected (Létourneau and Jean 2006a).

3.1.4 Mapping the wetlands of the St. Lawrence using remote sensing (2000 and 2002)

Environment Canada recently produced two maps of wetlands along the St. Lawrence River (Létourneau and Jean 2006b, 2006c). The objective of the 2000 mapping project was to produce coverage similar to that obtained in 1990–1991.

Like the 1990–1991 dataset, the 2000 dataset was obtained with an airborne MEIS–II scanner. The results obtained from the images allowed 70 land cover classes to be obtained, including 50 wetland classes. The latter were broken down into three open water classes, three shallow water classes (covering close to 2290 ha), 17 low marsh classes (over 14 470 ha), 13 high marsh classes (over 7244 ha), 12 swamp classes (over 10 980 ha) and one class for harvested peatlands (215 ha).

The multispectral images captured by the airborne MEIS–II scanner in 2000 had major geometric problems in some sectors. Despite excellent correction work, some sectors still had significant geometric distortion (Létourneau and Jean 2006b).

To deal with this problem, an additional set of IKONOS satellite images was acquired in 2002 (Létourneau and Jean 2006c). Field work in 2003 allowed 40 sampling stations and 247 validation polygons to be added to the field data collected in 2000 and 2001. The new images allowed 71 land cover classes to be distinguished, including 50 wetland classes.

The raw 2000 data (spatial resolution of 3.5 m) were acquired between September 19 and September 26, 2000, between Cornwall and Trois-Pistoles (Table 6).

The raw data for 2002 (with a spatial resolution of 4 m) were acquired between July 25 and August 21, 2002, except for an archived image acquired on July 17, 2001, of the Lake Saint-François sector (Létourneau and Jean 2006b). Since the purpose of these images was to provide coverage of the sectors of the St. Lawrence where the images collected in 2000 had been problematic, only 10 sectors were covered between Lake Saint-François and L'Isle-Verte (Table 7).

Table 6 MEIS–2000 coverage

Sector	Image Acquisition Date
Lake Saint-François	September 18 and 19, 2000
Valleyfield–Beauharnois	September 18 and 19, 2000
Lake Saint-Louis	September 18 and 19, 2000
La Prairie Basins	September 10, 18 and 19, 2000
Montréal–Longueuil	September 18 and 19, 2000
Varennes–Contrecœur	September 18 and 19, 2000
Lake Saint-Pierre	September 18, 19 and 20, 2000
Trois-Rivières–Bécancour	September 19 and 20, 2000
Quebec City–Lévis	September 19, 24 and 26, 2000
Upper estuary (south shore only)	September 19, 22, 24 and 26, 2000
Lower estuary (south shore to Trois-Pistoles only)	September 19, 22 and 26, 2000

Source: Létourneau and Jean (2006b)

Table 7 IKONOS coverage

Sector	Image Acquisition Date
Lake Saint-François: Lac Saint-François National Wildlife Area	July 17, 2001, and August 8, 2002
Lake Saint-Louis: Îles de la Paix National Wildlife Area	August 10 and 21, 2002
Montréal–Longueuil: Boucherville Islands	August 10, 2002
Varennes–Contrecœur: Îles de Contrecoeur National Wildlife Area	August 11, 2002
Lake Saint-Pierre	July 25 and August 13, 2002
Trois-Rivières–Bécancour: Portneuf	July 25, 2002
Quebec City–Lévis: eastern portions of Côte-de-Beaupré and Île d'Orléans	July 25 and 28, 2002
Upper estuary: Cap Tourmente National Wildlife Area, Montmagny and Kamouraska	July 21, 25 and 28 and August 21, 2002
Lower estuary: Cacouna and Baie de l'Isle-Verte National Wildlife Area	August 16 and 21, 2002

Source: Létourneau and Jean (2006c)

Major fieldwork was carried out to support the mapping. A total of 538 stations were sampled from late June to late August 2000, covering the region between Cornwall and Trois-Rivières. In 2001, additional sampling of wetland vegetation was performed to cover the stretch between Lake Saint-Pierre and Trois-Pistoles: 346 stations were added to those sampled in 2000. An additional 40 sites were visited in the summer of 2003 to complete the sampling of areas not covered during the 2000 and 2001 fieldwork. In all, 924 stations were sampled to characterize wetland vegetation for this overview (Létourneau and Jean 2006b).

Data gathered in the field were similar to those obtained in the 1997 fieldwork, with the addition of a detailed inventory of vegetation at the stations along with estimated cover for each species using a semi-quantitative scale.

The 2002 coverage allowed 71 land cover classes to be identified, including 50 wetland classes. The latter were broken down into three open water classes, two shallow water classes (over 1165 ha), 20 low marsh classes (over 13 670 ha), 11 high marsh classes (over 7215 ha), 12 swamp classes (over 10 215 ha) and a harvested peatland class (88 ha).

Merging of these two map coverages was carried out especially for the purposes of the present comparison.

Despite the high number of field sampling stations, some particularly diverse sectors (especially Lake Saint-Pierre) would have benefited from more field data.

The merging of maps resulting from the 2000 images and the 2002 images introduced undesirable variability (particularly of water levels) in mapping and this affected the comparisons.

3.2 ANALYSIS OF DATA

3.2.1 Recoding of mapping data

Table 8 summarizes the mapping data used in the analysis.

Table 8 Map coverages used in data analysis

Year	Type of Coverage	Total Number of Classes	Territory Covered	Number of Sampling Stations
1970–1978	Aerial photographs	52	Sectors between Cornwall and Trois-Pistoles (see Table 2)	0
1990–1991	Airborne MEIS-II sensor	65	Cornwall to Trois-Pistoles	0
1996–1997	Airborne multispectral videographic sensor	43	Sectors between Cornwall and Trois-Pistoles (see Table 5)	183
2000–2002	Airborne MEIS-II sensor and IKONOS satellite sensor	71	Cornwall to Trois-Pistoles	924

The post-classification comparison change detection method (Jensen 2005) was used in this study. In this very popular method, two thematic maps in a matrix format are compared cell by cell, generating a map of changes and a transition matrix. The method was chosen because of its simplicity and effectiveness when heterogeneous data sources are used (in our case, different sensors) or when the use of historical data interpreted by different authors makes it impossible to carry out a more in-depth comparative spectral-change analysis (Anonymous 1995). The technique is not completely foolproof, however, and the quality of the results obtained depends primarily on the accuracy of the maps used (Anonymous 1995).

The post-classification comparison technique requires that the same spatial resolution and a common legend be established for all the maps. To harmonize spatial resolution, the resolution in the least accurate map is generally used as the minimum mapping unit. Since, as mentioned above, the Groupe Dryade (1980) maps were digitized to be accurate within approximately 20 m, it was decided that a 25-m spatial resolution should be used for all the maps.

To standardize the legends, we again had to use the Groupe Dryade (1980) mapping as a basis and simplify the standardized legend. Standardized legends generally include major wetland classes (National Wetlands Working Group 1988), supplemented by certain upland classes and more specific classes to illustrate regionally characteristic wetlands or specific issues such as dominance by invasive species. Table 9 illustrates the coding of the Groupe Dryade maps and the correspondence between the Dryade classes and the standardized legend.

Table 9 Correspondence between the Groupe Dryade (1980) legend and the standardized legend

Groupe Dryade Class	Standardized Classification	Number
Water	Open water	1
Aquatic vegetation dominated by submerged plants	Submerged or floating vegetation	2
Silt deposit Sand or gravel deposit Bedrock Thin layer of silt over bedrock Thin layer of sand over bedrock Boulders over silt Boulders over sand or gravel Sand and silt over bedrock Sand and silt Silt and sand with boulders Sand and silt with boulders Bedrock and boulders Silt and boulders over bedrock	Denuded substrate	3
Aquatic vegetation dominated by emergent plants	Low marsh	10
Saltmarsh dominated by Smooth Cordgrass Smooth Cordgrass and boulders Smooth Cordgrass with pools and boulders Smooth Cordgrass with pools (0–20 %) Smooth Cordgrass with pools (20–40%)	Low marsh dominated by *Spartina alterniflora*	11
Community dominated by *Scirpus* Common Threesquare over bedrock Common Threesquare over silt	Low marsh dominated by *Schoenoplectus pungens*	12
Herbaceous community Herbaceous community with some shrubs Herbaceous community with some trees	High marsh	20
Saltmeadow Saltmeadow with salt pans (3–20%) Saltmeadow with salt pans (21–40%) Saltmeadow with salt pans (41% or more)	Saltmeadow	21
Meadow dominated by Saltmeadow Cordgrass Saltmeadow Cordgrass with salt pans (21–40%) Saltmeadow Cordgrass with salt pans (41% or more) Saltmeadow Cordgrass with salt pans (3–20%)	High marsh dominated by *Spartina patens*	23
Shrub community Shrub community with shrubs Shrub community with herbaceous vegetation Islands of shrubs dispersed within herbaceous community Periodically flooded shrub community	Shrub swamp	30

Groupe Dryade Class	Standardized Classification	Number
Periodically flooded woodland Shrubby woodland Woodland with herbaceous vegetation	Forested swamp	40
Cropland and pastureland	Agriculture	50
Fallow land	Fallow land	51
Land	Upland	53
Woodland	Forest	54

The other mapping datasets were converted into GRID format using ArcMap 9 software (Environmental Systems Research Institute Inc., Redlands, California). Once transformed, the data were resampled at 25 m and recoded to correspond to the standardized legend used throughout this report (Table 10).

Table 10 Correspondence between legends used in recent mapping projects and the standardized legend

Classification Used by Létourneau and Jean (2005, 2006a, 2006b, 2006c)	Standardized Classification	Number
Suspended matter Open water Muddy shoal Sedimentation basin Logs	Open water	1
Shallow water dominated by floating vegetation Shallow water dominated by algae Shallow water dominated by *Myriophyllum* sp.	Submerged or floating vegetation	2
Denuded substrate Substratum	Denuded substrate	3
Low marsh dominated by *Zizania* sp. Low marsh dominated by *Impatiens capensis* Low marsh dominated by *Juncus arcticus* var. *balticus* Low marsh dominated by *Bolboschoenus fluviatilis* or *Butomus umbellatus* Low marsh dominated by *Sagittaria* sp. Low marsh dominated by *Scirpus lacustris* Low marsh dominated by *Bolboschoenus fluviatilis* Low marsh dominated by *Salicornia europaea* L. (S.L.) Low marsh dominated by *Eleocharis* sp. Low marsh dominated by *Butomus umbellatus* Low marsh dominated by *Potentilla palustris* Low marsh dominated by *Pontederia cordata* Low marsh dominated by *Acorus calamus* Low marsh dominated by *Lythrum salicaria* Low marsh dominated by floating vegetation Low marsh dominated by *Typha* sp. Low marsh dominated by *Bolboschoenus fluviatilis* and/or *Typha* sp. and/or *Scirpus lacustris*	Low marsh	10

Classification Used by Létourneau and Jean (2005, 2006a, 2006b, 2006c)	Standardized Classification	Number
Low marsh dominated by *Sparganium eurycarpum*		
Low marsh dominated by *Eupatorium maculatum*		
Low marsh dominated by narrow-leaved vegetation		
Low marsh dominated by dense narrow-leaved vegetation (*Typha* sp. and *Scirpus* sp.)		
Low marsh dominated by sparse narrow-leaved vegetation (*Typha* sp. and *Scirpus* sp.)		
Low marsh dominated by emergent and floating vegetation		
Low marsh dominated by robust vegetation		
Low marsh dominated by robust vegetation and other herbaceous plants		
Low marsh dominated by *Typha* sp. and *Zizania* sp.		
Low marsh dominated by narrow-leaved vegetation (*Typha* sp. and *Sparganium* sp.)		
Low marsh dominated by dead vegetation		
Low marsh		
Low marsh dominated by *Bolboschoenus fluviatilis* and *Lythrum salicaria*		
Low marsh dominated by *Typha* sp. and *Bolboschoenus fluviatilis*		
Low marsh dominated by *Spartina alterniflora*	Low marsh dominated by *Spartina alterniflora*	11
Low marsh dominated by *Spartina alterniflora* and *Salicornia europaea* L. (S.L.)		
Low marsh dominated by *Schoenoplectus pungens*	Low marsh dominated by *Schoenoplectus pungens*	12
Low marsh dominated by *Schoenoplectus pungens* and other emergent plants		
Low marsh dominated by *Schoenoplectus pungens* and *Scirpus lacustris*		
Submerged low marsh dominated by *Schoenoplectus pungens*		
Low marsh dominated by sparse *Schoenoplectus pungens* and/or other emergent plants		
High marsh	High marsh	20
High marsh dominated by tall grasses		
High marsh dominated by short grasses		
High marsh dominated by *Carex* sp.		
High marsh dominated by *Spartina pectinata*		
High marsh dominated by *Calamagrostis canadensis*		
High marsh dominated by *Glyceria grandis*		
High marsh dominated by *Leersia oryzoides*		
High marsh dominated by *Leymus mollis*		

Classification Used by Létourneau and Jean (2005, 2006a, 2006b, 2006c)	Standardized Classification	Number
High marsh dominated by *Taraxacum officinale*		
High marsh dominated by broad-leaved vegetation		
High marsh used for agriculture		
High marsh dominated by *Salicornia europaea* L. (S.L.) and *Spergularia canadensis*		
High marsh dominated by *Spartina patens* and *Bolboschoenus maritimus* var. *paludosus*		
High salt marsh	Saltmeadow	21
High marsh dominated by *Phragmites australis*	High marsh dominated by *Phragmites australis*	22
High marsh dominated by *Spartina patens*	High marsh dominated by *Spartina patens*	23
High marsh dominated by *Spartina patens* and *Hierochloe odorata*		
High marsh dominated by *Spartina patens* and *Plantago maritime*		
High marsh dominated by *Phalaris arundinacea*	High marsh dominated by *Phalaris arundinacea*	24
High marsh dominated by *Lythrum salicaria* or other broad–leaved vegetation	High marsh dominated by *Lythrum salicaria*	25
High marsh dominated by *Lythrum salicaria* and *Carex* sp.		
Shrub swamp	Shrub swamp	30
Shrub swamp dominated by *Cornus rugosa*		
Shrub swamp dominated by *Alnus incana* ssp. *rugosa*		
Shrub swamp dominated by *Myrica gale*		
Forested swamp	Forested swamp	40
Forested swamp dominated by *Fraxinus pennsylvanica*		
Forested swamp dominated by *Acer rubrum*	Swamp dominated by *Acer rubrum*	41
Forested swamp dominated by *Larix laricina*	Swamp dominated by *Larix laricina*	42
Forested swamp dominated by *Acer saccharinum*	Swamp dominated by *Acer saccharinum*	43
Forested swamp dominated by *Populus deltoides*	Swamp dominated by *Populus deltoides*	45
Shrub swamp dominated by *Salix* sp. and *Spiraea latifolia*	Swamp dominated by *Salix* sp.	46
Shrub swamp dominated by *Salix* sp.		
Forested swamp dominated by *Salix nigra*		
Forested swamp dominated by *Salix fragilis*		
Forested swamp dominated by *Salix* sp.		

Classification Used by Létourneau and Jean (2005, 2006a, 2006b, 2006c)	Standardized Classification	Number
Agriculture Meadow dominated by *Calamagrostis canadensis* Meadow dominated by *Eupatorium maculatum* Meadow dominated by *Poa pratensis* Meadow dominated by *Solidago* sp. Dry meadow Ploughed land	Agriculture	50
Fallow land Fallow land dominated by *Rhus typhina* Fallow land dominated by *Crataegus* sp. Fallow land dominated by *Populus tremuloides* Fallow land dominated by *Populus balsamifera* Fallow land dominated by *Betula populifolia*	Fallow land	51
Built-up area	Built-up area	52
Forest Deciduous forest Coniferous forest Mixed forest or coniferous plantation Forest with no dominant species Plantation Forest dominated by *Populus deltoides* Forest dominated by *Ulmus* sp. Forest dominated by *Betula populifolia* Semi-denuded soil with regenerating deciduous trees Shrub Forest dominated by *Acer rubrum* on poorly drained soil	Forest	54
Meadow dominated by *Phalaris arundinacea*	Fallow land dominated by *Phalaris arundinacea*	55
Harvested peatlands	Harvested peatlands	89

3.3 MAP ANALYSIS

Figures 3 to 6 provide an overview of the change analysis procedure used. Two series of data analyses were carried out. In the first series, four map coverages were used to maximize temporal coverage (Figure 3).

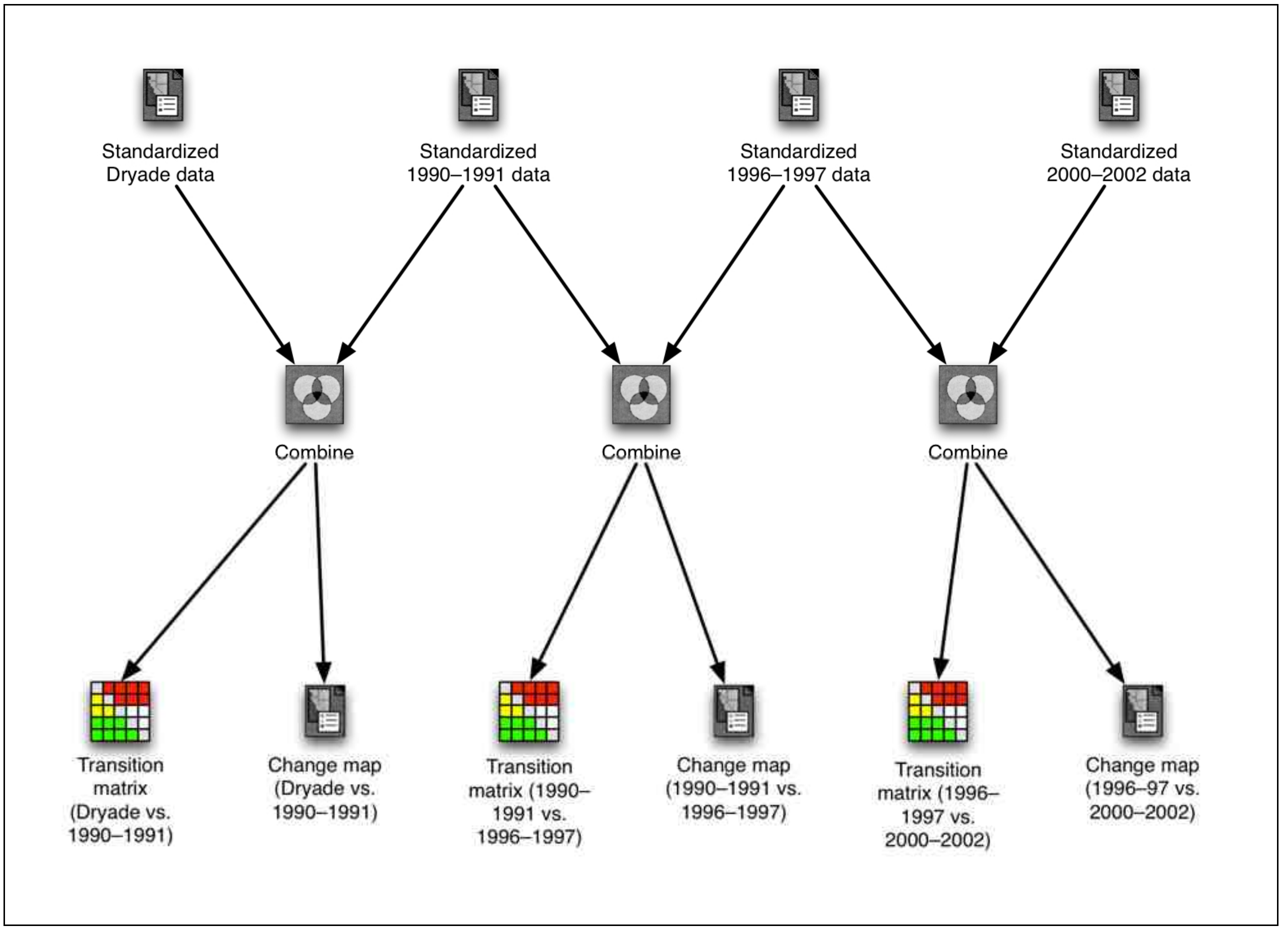


Figure 3 Overview of data analysis procedure for periods 1970–1978 to 2000–2002

Once the procedure described above was carried out, only the sectors of the St. Lawrence covered in all the mapping projects were used. Figure 4 shows the territory covered in this analysis.

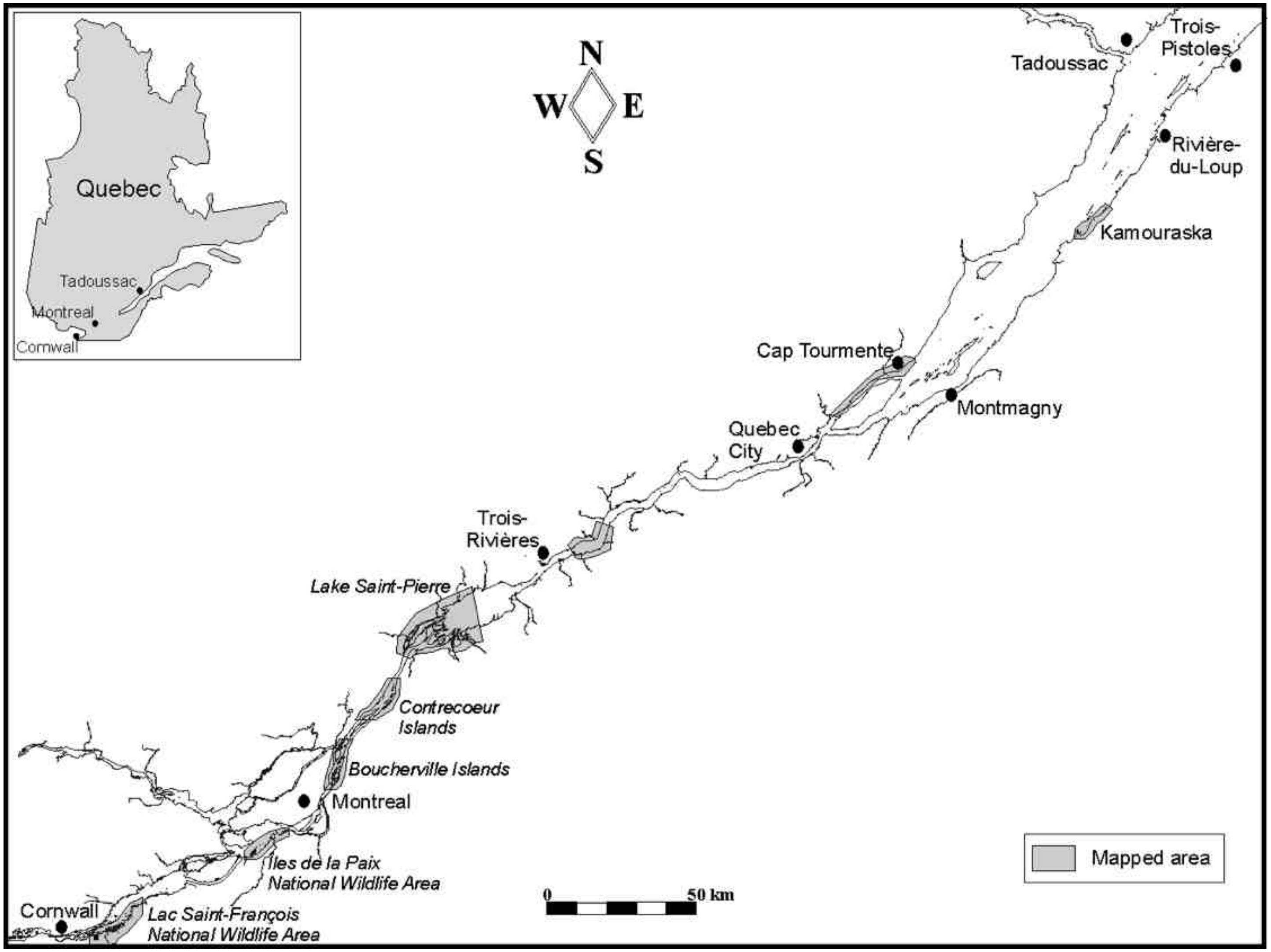


Figure 4 Territory covered by map analysis for periods 1970–1978 to 2000–2002

The second analysis was limited to the two mapping projects that covered the entire study area from Cornwall to Trois-Pistoles, that is, the 1990–1991 and 2000–2002 mapping projects (Figures 5 and 6).

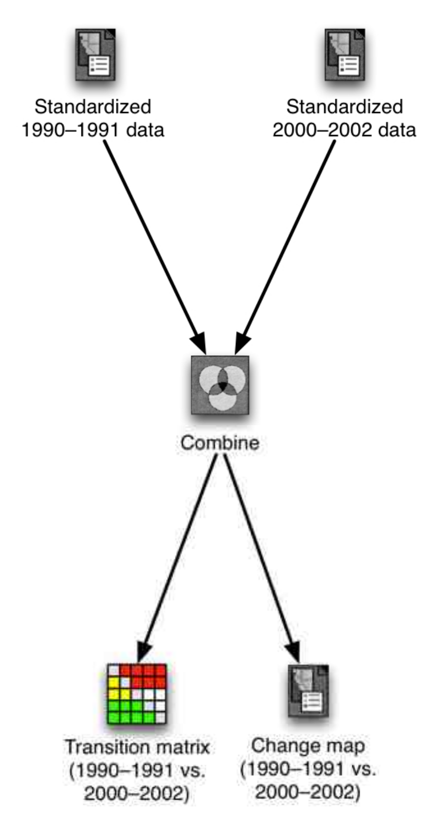


Figure 5 Overview of data analysis procedure for periods 1990–1991 to 2000–2002

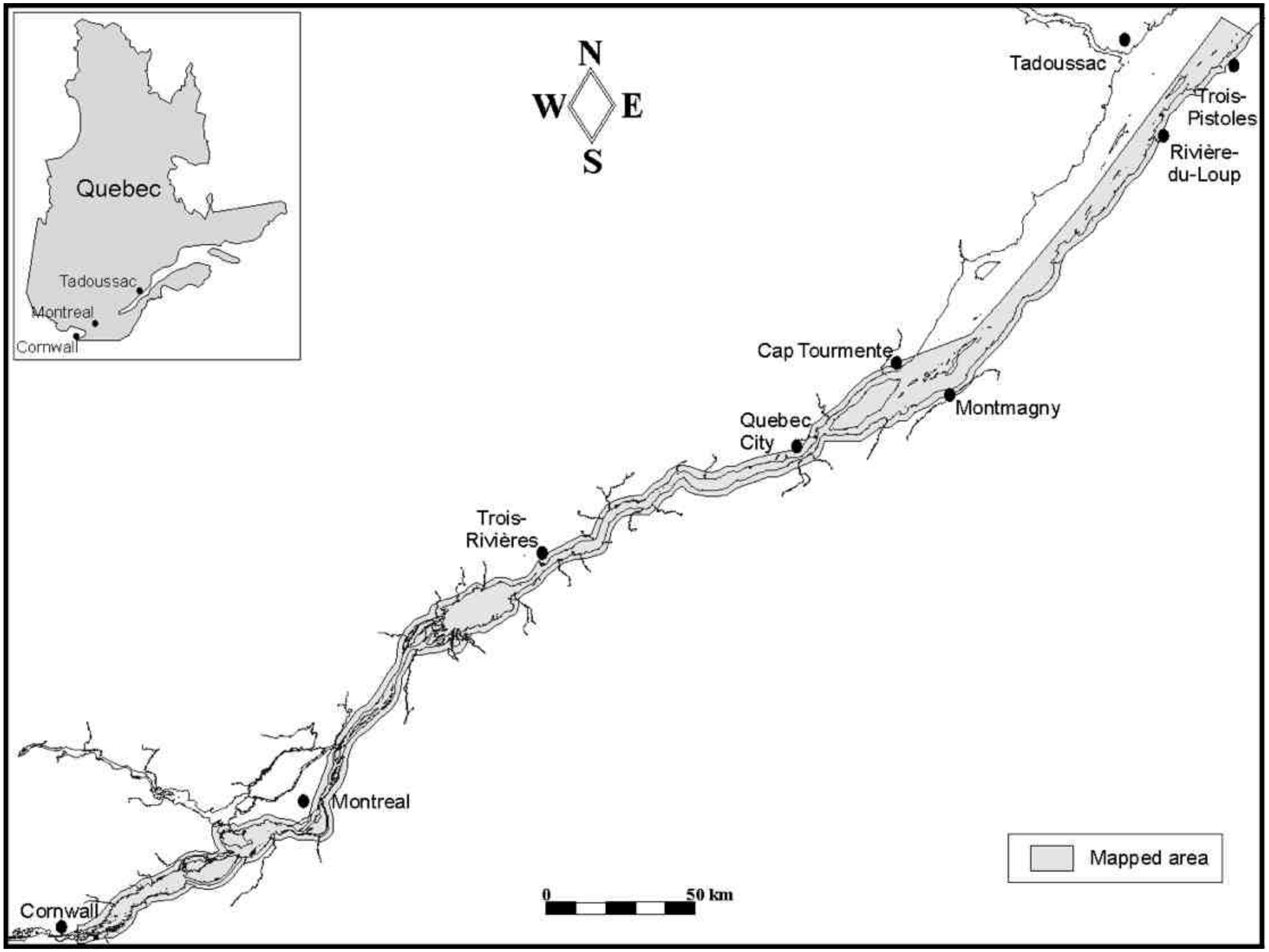
The data analysis was carried out in the same way in both series. Standardized maps (with a common legend and spatial resolution) were compared in groups of two. Each pair of maps with contiguous temporal coverage was compared cell by cell to produce a transition matrix with dimensions of $n \times n$, where n equals the number of classes in the standardized legend. All the classes in the standardized legend were used except for “submerged or floating vegetation” ("shallow water" according to the terminology used by the National Wetland Working Group 1988), which could not be reliably mapped throughout the study area. The aforementioned class was merged with the "open water" class before map comparison, except in the Trois-Rivières–Bécancour sector (fluvial estuary) where large expanses of low marshes dominated by *Schoenoplectus pungens* submerged by the tide were detected; in this case, the "submerged or floating vegetation class" was merged with the "low marsh" class.

As Jensen (1993, 2005) has suggested, using a colour code in transition matrices helps to identify types of changes that merit special attention.

A series of statistics were calculated for each transition matrix. First, the relative drying index (RDI) was calculated to determine the direction of change observed in wetlands—i.e., whether these communities are drying up or becoming wetter. The index is calculated using the following equation:

$$RDI = \log \sum \left(\frac{changes\ to\ drier\ environment}{changes\ to\ wetter\ environment} \right)$$

An RDI greater than 0 indicates a relative trend towards drier wetlands (for example, if low marshes are transformed into high marshes or swamps, or if high marshes become swamps). Conversely, an RDI value less than 0 indicates wetter conditions (for example, if swamps are transformed into marshes or high marshes become low marshes).



Source: Létourneau and Jean (2005)

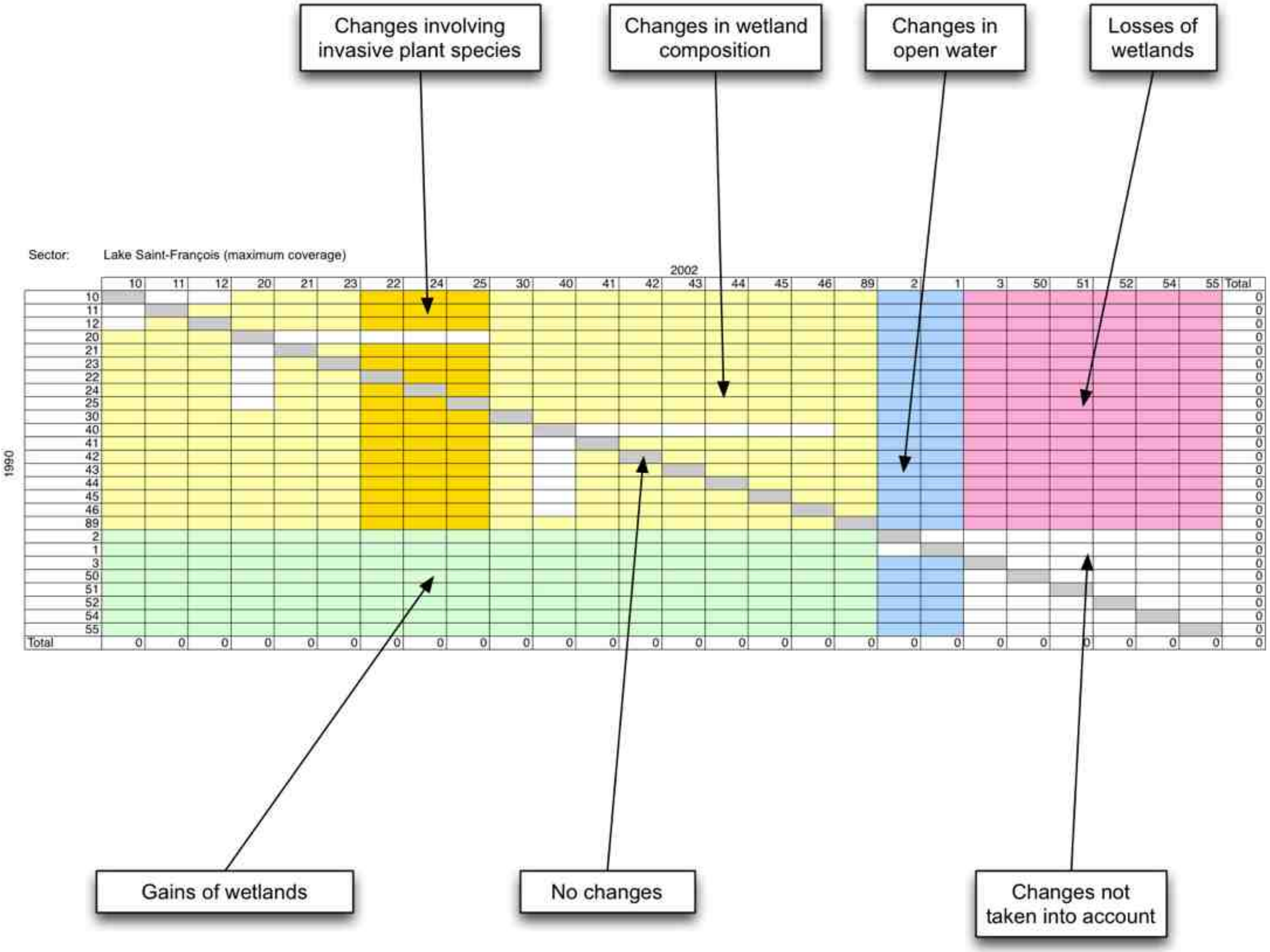
Figure 6 Territory covered by map analysis for the period 1990–1991 to 2000–2002

As illustrated in Figure 7, coloured areas can be used to identify and thus highlight the following types of changes in transition matrices:

- Losses of wetlands
- Gains in wetlands
- Changes to open water
- Changes in wetland composition
- Changes involving invasive plant species

Lastly, we calculated the Kappa coefficient of agreement (Cohen 1960) to measure the resemblance between two maps. This index ranges from –1 (total divergence) to 1 (perfect agreement) and can be used to gauge whether the resemblance between two maps is random. The Kappa coefficient of agreement can be used to compare two maps of the same region and is commonly used to validate models (Rosenfield and Fitzpatrick-Lins 1986; Manel et al. 2001), estimate the accuracy of thematic maps (Rosenfield and Fitzpatrick-Lins 1986; Carstensen 1987) or carry out a mapping time series analysis (Eastman et al. 1995).

More recently published work indicates that cell-by-cell comparison methods have some shortcomings, including the fact that these methods interpret simple geometric shifts as actual changes. Although human interpreters can easily take such differences into account, this has not been the case with map comparison algorithms until recently. Consequently, a variation on the Kappa coefficient, the fuzzy Kappa, has been developed to deal with this problem (Hagen 2003; Hagen-Zanker et al. 2005). This solution has arisen from map comparison methods developed using the mathematical theory of fuzzy sets (Zadeh 1965). This new index is still based on cell-by-cell comparisons but also takes into account the nearness of matching categories in the neighbourhood, resulting in a fuzzy similarity map. This comparison method therefore takes the two types of possible uncertainty—in assigning classes and in geographic position—into account. As in the case of the traditional Kappa, two overall coefficients are calculated: mean similarity (the fuzzy equivalent of the fraction correct in the traditional Kappa) and fuzzy Kappa (the equivalent of the Kappa coefficient in the traditional method).



Sector: Lake Saint-François (maximum coverage)

2002

1990

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12																											0
20																											0
21																											0
23																											0
22																											0
24																											0
25																											0
30																											0
40																											0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1																											0
3																											0
50																											0
51																											0
52																											0
54																											0
55																											0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 7 **Zones of interest identified in transition matrices**

Kappa and fuzzy Kappa coefficients were calculated using Map Comparison Kit software (Visser and De Nijs 2006). Along with the traditional Kappa coefficient, we used two other components, quantitative similarity (*KHisto*) and spatial similarity (*KLoc*). To calculate Kappa indices, terrestrial (upland) classes were merged to simplify these parts of the maps and therefore emphasize the wetland classes. Default parameters were used to calculate the fuzzy Kappa (neighbourhood radius set at four cells, exponential distance decay function with a halving distance of two cells). The similarity matrix used to define the proximity of classes was constructed so that classes belonging to the same wetland category are considered identical. For example, in all comparisons between high marsh classes, these classes were treated as identical (value of 1 in similarity matrix).

Lastly, thanks to all these datasets, change maps as well as transition matrices were used to examine changes observed and assess their plausibility based on the information available and knowledge of field conditions. The raw remote sensing images used in classification were sometimes employed to validate the plausibility of changes or identify inconsistencies in one or more of the maps.

In some cases, water levels taken from historical data and tidal data estimated using the Mr. Tides software (August Hahn 2006) were used to interpret changes involving open water.

To streamline the description of the changes observed, only those totalling more than 10 ha will be addressed, with a few exceptions.

4 Results

4.1 OVERVIEW

Groupe Dryade (1980) estimated the area of marshes and swamps (excluding shallow water) between Cornwall and Trois-Pistoles during the 1970–1978 period to be roughly 18 945 ha.

More recently, the surface area of marshes and swamps in the same area was estimated at 22 228 ha for 1990–1991 and 28 992 ha for 2000–2002 (Figure 8). These figures are conservative, since they exclude areas with noticeable inconsistencies at any given point during the period covered.

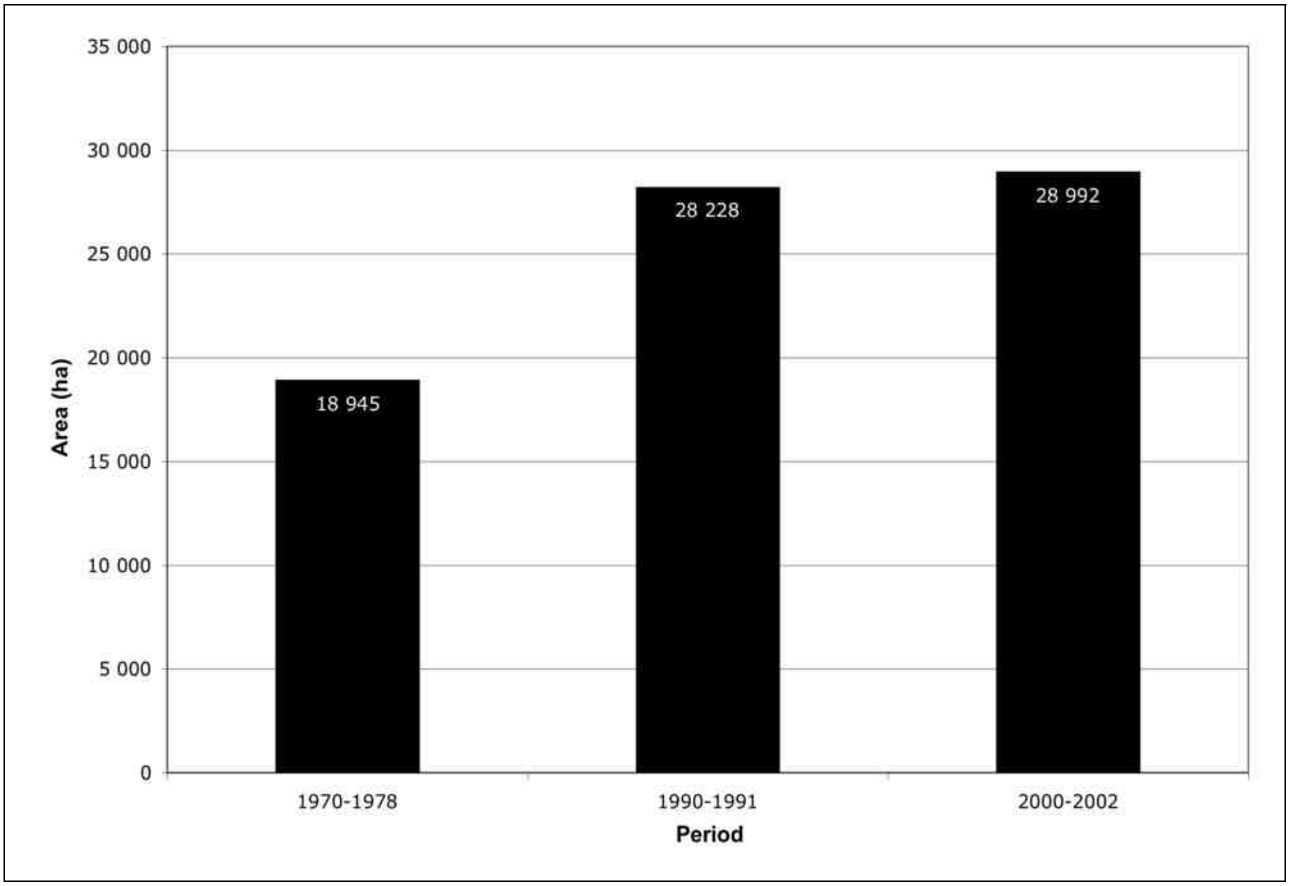


Figure 8 Changes in total wetland area between 1970 and 2002

This shows an increase of 10 047 ha of wetlands during the period, or an increase of 53% relative to the 1970s. This significant change cannot be considered entirely an actual gain of wetlands, since Groupe Dryade's analysis greatly underestimated shrub and forested swamps along the St. Lawrence. These were estimated to total 8604 ha in 2000–2002 in the study area as a whole. In the Groupe Dryade mapping, wetlands were most severely underestimated on lakes Saint-Pierre and Saint-François and, to a lesser extent, Lake Saint-Louis, all of which support significant areas of forested swamps. The more recent map-based estimates of wetland area in the fluvial estuary (including the Quebec City–Lévis section) are lower than the Groupe Dryade estimates.

The comparison of the two most recent map coverages shows an increase of 764 ha of wetlands (or 2.7%). This contrasts with the analysis of the 1945–1976 period published by Groupe Dryade (1981), showing that modifications to the shoreline of the St. Lawrence between Cornwall and Matane resulted in a loss of 3642 ha of wetlands, 75% of which occurred between 1945 and 1960. Significant wetland conservation efforts carried out since the 1970s (particularly the establishment of national wildlife areas and migratory bird sanctuaries, as well as numerous private initiatives) have certainly played a vital role in preserving large areas of wetlands along the St. Lawrence.

The net gain in wetland area between 1990–1991 and 2000–2002 obscures some major differences among sectors (Table 11). Net gains were observed in the Beauharnois–Valleyfield, Lake Saint-Louis and Varennes–Contrecœur sectors, as well as in the fluvial, upper and lower estuaries. In contrast, net losses of wetland area occurred in the Montréal–Longueuil and Lake Saint-Pierre sectors, while no net changes were found in Lake Saint-François, the La Prairie Basins and the Quebec City–Lévis sector.

Table 11 Changes in wetland area between 1990–1991 and 2000–2002

	Area (ha)			
Study Sector	1990–1991	2000–2002	Difference	Percentage
Lake Saint-François	2043	2043	0	0
Beauharnois–Valleyfield	96	102	6	6.2
Lake Saint-Louis	643	685	42	6.5
La Prairie Basins	0	2	2	–
Montréal–Longueuil	332	267	–55	–17.1
Varennes–Contrecœur	860	934	74	8.6
Lake Saint-Pierre	16 180	16 098	–82	–0.5
Fluvial estuary	2552	2999	447	17.4
Quebec City–Lévis	951	951	0	0
Upper estuary*	3123	3279	156	4.7
Lower estuary*	1458	1632	174	11.9
Total	28 228	28 992	764	2.7

*partial coverage

The following sections provide a detailed assessment of the changes in the various sectors of the St. Lawrence River.

4.2 LAKE SAINT-FRANÇOIS

In the Lake Saint-François sector, a total of 28 170 ha were analyzed in both 1990–1991 and 2000–2002, including open water and adjacent terrestrial habitats (Appendices 1 and 2). Because of cloud cover, a large portion of the southwestern part of the lake was not mapped in 1990–1991, resulting in the underestimation of wetlands in this portion.

Only the western part of Lake Saint-François, representing a total of 6391 ha, was mapped in all four time periods (Appendices 3 to 6).

Relative drying indices for Lake Saint-François are shown in Table 12. These statistics show a relatively wetter trend in wetlands between 1978 and 1990, and stable values after 1990.

Table 12 Relative drying indices for the Lake Saint-François sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	–0.40
Between 1990–1991 and 1996–1997	0.06
Between 1996–1997 and 2000–2002	0.06
Between 1990–1991 and 2000–2002	0.08

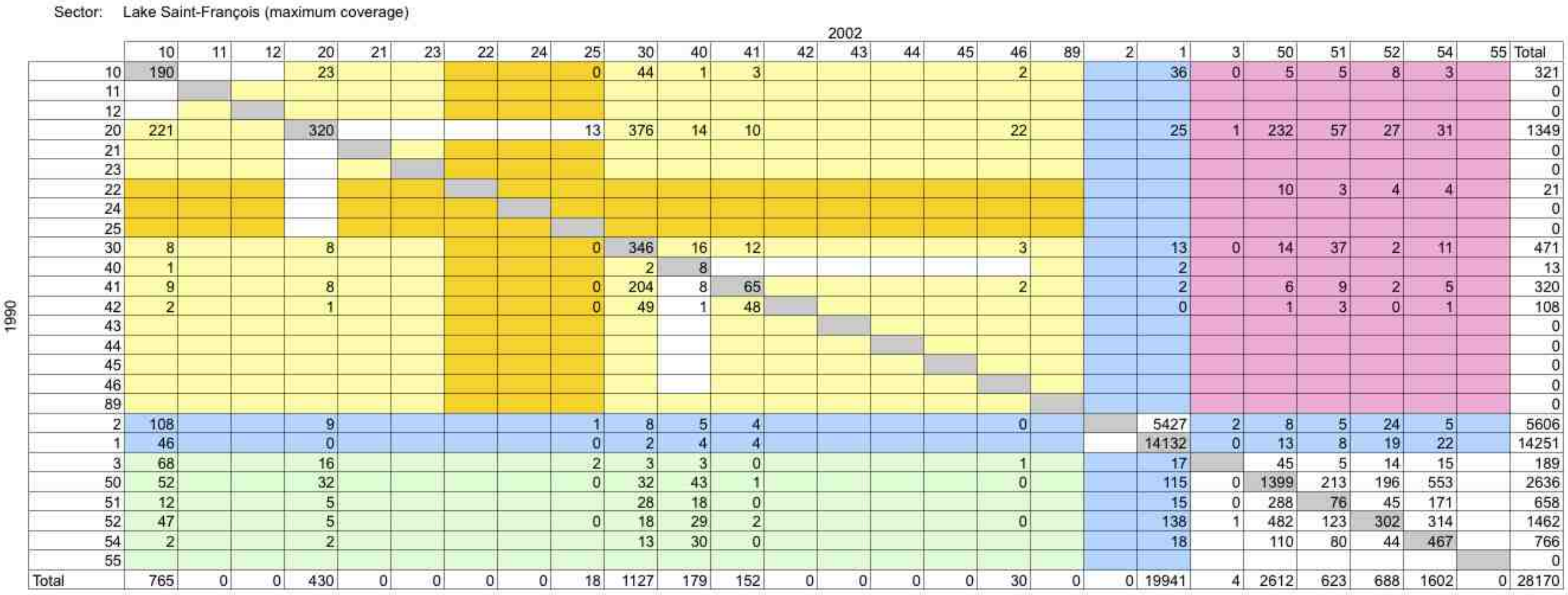
4.2.1 Overall changes between 1990–1991 and 2000–2002

An examination of the period from 1990–1991 to 2000–2002 for the entire sector shows that wetland area increased by 98 ha (from 2602 ha to 2700 ha), an increase of 3.7% (Figure 9). Estimated losses were 559 ha, while estimated gains were 657 ha. When inconsistencies are considered, however, the net balance is zero, with no appreciable gains or losses. The corrected areal extent of wetlands was 2043 ha.

The relative drying index for this period is 0.08, illustrating a slight drying trend in Lake Saint-François wetlands (Table 12). Excluding changes involving open water, a trend towards drier conditions in these wetlands can still be observed, albeit a less significant one.

No losses or gains were retained in this analysis (Appendix 7).

While no changes in wetland area were retained for analysis purposes, several transformations within wetlands were apparent. The most significant progressive change was the conversion of 376 ha of high marshes into shrub swamps. The area east of Rivière aux Saumons has seen a spectacular increase in shrub swamps since the 1940s due to the fact that *Carex* marshes are no longer burned (Jean and Bouchard 1991). In 1983, there were an estimated 385 ha of shrub swamps. For the portion of the Lake Saint-François sector examined, the area of shrub swamps grew from 471 ha in 1990–1991 to 1127 ha in 2000–2002, representing an increase of 656 ha or 139%. Although shrub swamps mapped in 2000–2002 were overestimated, the transformation of high marshes dominated by *Carex* into swamps seems to be continuing.



Sector: Lake Saint-François (maximum coverage)

2002

1990

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	190			23					0	44	1	3					2			36	0	5	5	8	3		321
11																											0
12																											0
20	221			320					13	376	14	10					22			25	1	232	57	27	31		1349
21																											0
23																											0
22																						10	3	4	4		21
24																											0
25																											0
30	8			8					0	346	16	12					3			13	0	14	37	2	11		471
40	1									2	8									2							13
41	9			8					0	204	8	65					2			2		6	9	2	5		320
42	2			1					0	49	1	48								0		1	3	0	1		108
43																											0
44																											0
45																											0
46																											0
89																											0
2	108			9					1	8	5	4					0			5427	2	8	5	24	5		5606
1	46			0					0	2	4	4								14132	0	13	8	19	22		14251
3	68			16					2	3	3	0					1			17		45	5	14	15		189
50	52			32					0	32	43	1					0			115	0	1399	213	196	553		2636
51	12			5						28	18	0								15	0	288	76	45	171		658
52	47			5					0	18	29	2					0			138	1	482	123	302	314		1462
54	2			2						13	30	0								18		110	80	44	467		766
55																											0
Total	765	0	0	430	0	0	0	0	18	1127	179	152	0	0	0	0	30	0	0	19941	4	2612	623	688	1602	0	28170

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 9 Transition matrix for the Lake Saint-François sector between 1990–1991 and 2000–2002

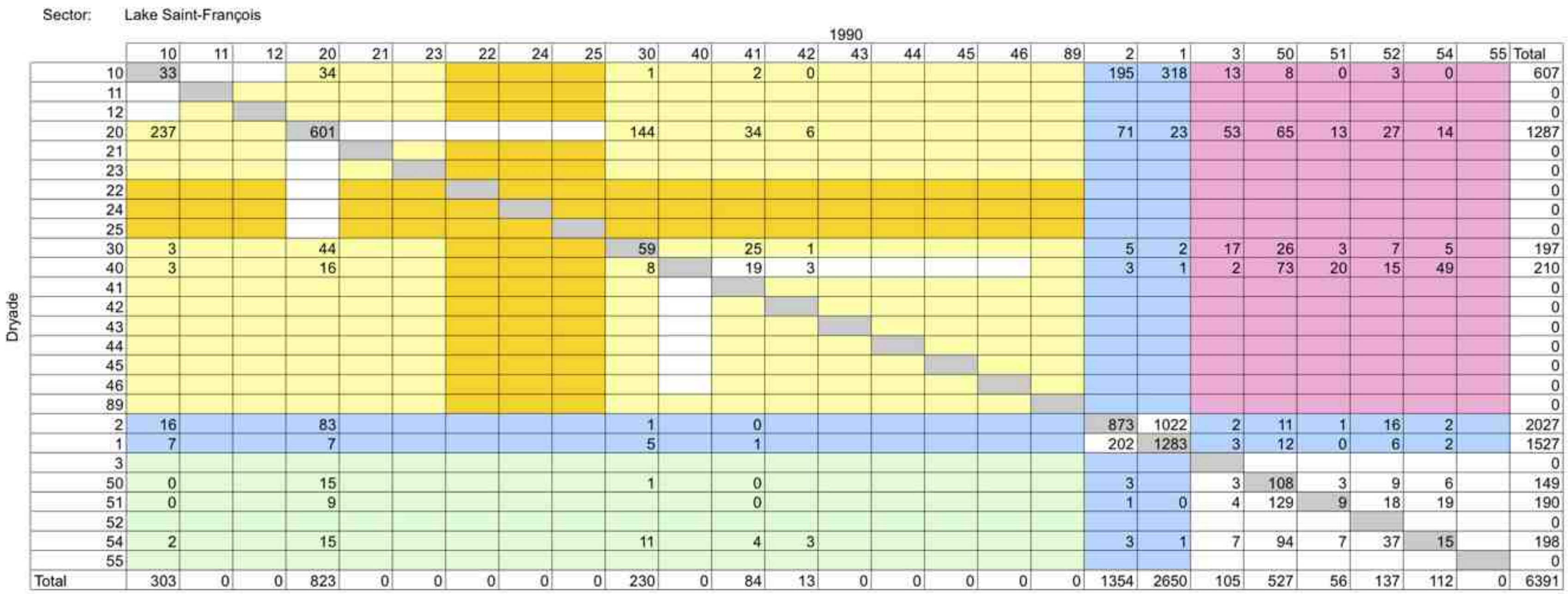
In addition, 44 ha of low marshes were transformed into shrub swamps near the mouth of the Rivière aux Saumons, while 23 ha of low marshes were transformed into high marshes (drying trend), 0.25 ha of which is dominated by *Lythrum salicaria*. These 23 ha of newly formed high marshes occurred most often in wetland enclaves northeast of the Lac Saint-François National Wildlife Area. In addition, 46 ha of high marshes were transformed into swamps. Of these 46 ha, 14 ha did not have a dominant species identified, while the rest was dominated by *Salix* sp. (22 ha) or *Acer rubrum* (10 ha). Lastly, 31 ha of shrub swamps scattered over the study area became forested swamps (i.e., 3 ha of *Salix* swamps, 12 ha of *Acer rubrum* swamps and 16 ha without a dominant species identified).

Two significant regressive changes (indicating a trend toward more aquatic environments) occurred within wetlands. First, 221 ha of high marshes were transformed into low marshes, particularly at Leblanc Point. In addition, 256 ha of forested swamps dominated by *Acer rubrum* reverted to shrub swamps; this was seen in forested swamps throughout the sector but particularly in the Lac Saint-François National Wildlife Area. In addition, 12 ha of forested swamps (2 ha dominated by *Larix laricina*, 9 ha by *Acer rubrum* and 1 ha with no dominant species identified) became low marshes.

Regarding invasive plant species, over 13 ha of high marshes dominated by *Lythrum salicaria* were identified in 2000–2002 in the Lake Saint-François area; this species was not recorded in the previous mapping project.

4.2.2 Partial changes between 1970–1978 and 1990–1991

Marshes and swamps in the western part of Lake Saint-François decreased from 2300 ha to 1452 ha during this period, representing a drop of 848 ha or 36.9% (Figure 10). Losses were estimated at 1027 ha and gains at 179 ha. When inconsistencies are excluded, the corrected area of wetlands stands at 1902 ha in the 1970s compared with 1392 ha in 1990–1991, a decrease of 510 ha or nearly 27%. Corrected losses were estimated at 628 ha and gains at 119 ha (Figure 11).



Sector: Lake Saint-François

1990

Dryade

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	33			34						1		2	0						195	318	13	8	0	3	0		607
11																											0
12																											0
20	237			601						144		34	6						71	23	53	65	13	27	14		1287
21																											0
23																											0
22																											0
24																											0
25																											0
30	3			44						59		25	1						5	2	17	26	3	7	5		197
40	3			16						8		19	3						3	1	2	73	20	15	49		210
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	16			83						1		0							873	1022	2	11	1	16	2		2027
1	7			7						5		1							202	1283	3	12	0	6	2		1527
3																											0
50	0			15						1		0							3		3	108	3	9	6		149
51	0			9								0							1	0	4	129	9	18	19		190
52																											0
54	2			15						11		4	3						3	1	7	94	7	37	15		198
55																											0
Total	303	0	0	823	0	0	0	0	0	230	0	84	13	0	0	0	0	0	1354	2650	105	527	56	137	112	0	6391

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 10 Transition matrix for the portion of the Lake Saint-François sector covered between 1970–1978 and 1990–1991

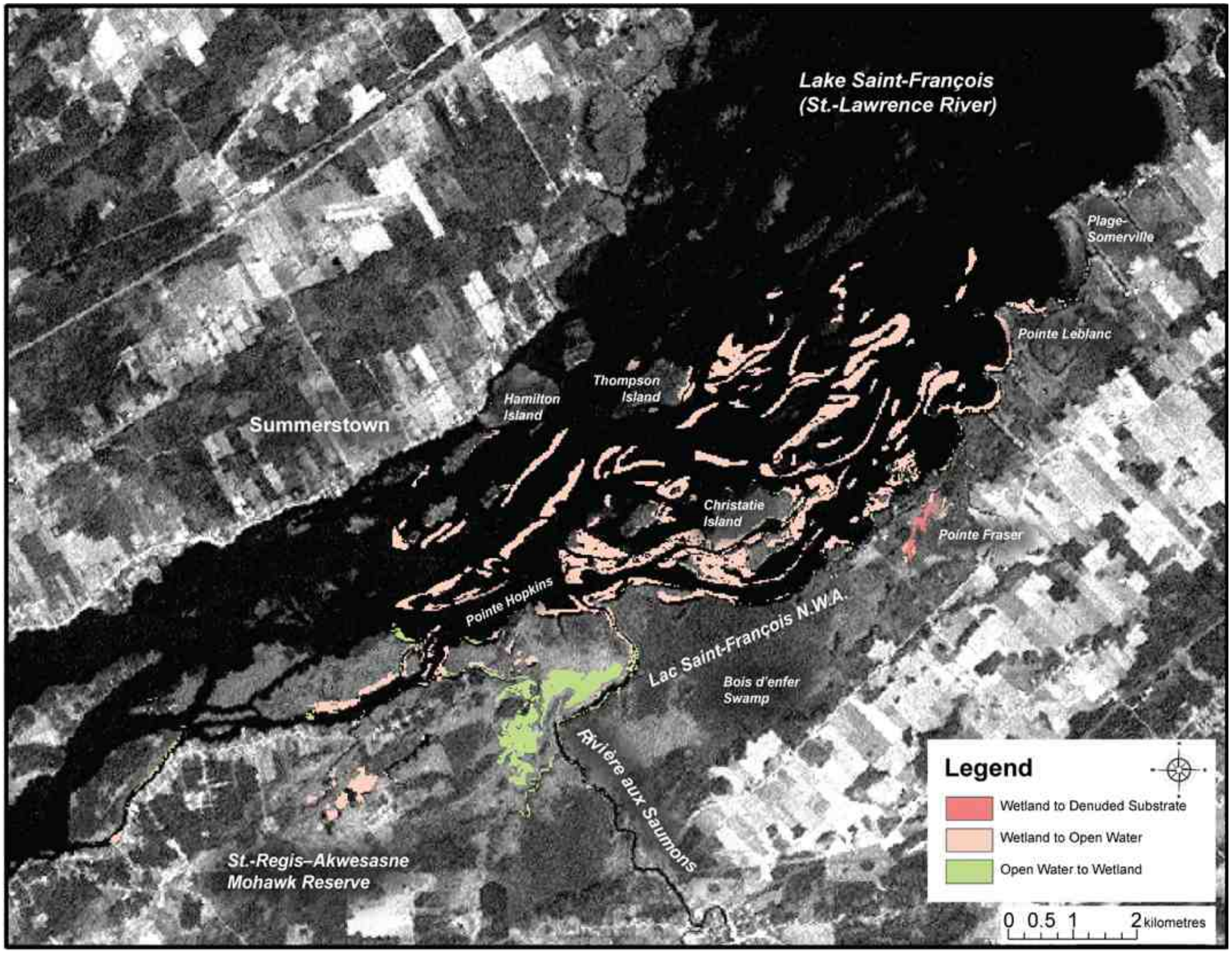


Figure 11 Losses and gains of marshes and swamps in the portion the Lake Saint-François sector covered between 1970–1978 and 1990–1991

The relative drying index (Table 12) was –0.40, showing that, overall, wetlands were wetter in 1990–1991 than in the late 1970s. Excluding changes involving open water, a trend towards more aquatic environments (i.e. wetter conditions) was observed in wetlands, although it was less significant.

The main losses retained in this analysis involve the transformation of wetlands into open water (616 ha). These changes could result from natural fluctuations (minimal in Lake Saint-François since the 1960s) or artificial fluctuations in water levels. Changes of the latter type include a small area in the Saint-Régis–Akwesasne Mohawk Reserve (totalling 22 ha), which clearly shows a transition from low marsh to open water. This change may be due to wildlife habitat development. In the Fraser Point area, the appearance of 12 ha of denuded substrate could also be attributable to the same kind of development.

In terms of wetland gains, the only ones retained involve the transformation of 119 ha of open water to wetlands in 1990–1991. This phenomenon was seen near Hopkins Point Road in the Saint-Régis–Akwesasne Mohawk Reserve. This major difference between the two coverages could be due to the use of aerial photos acquired in spring, a time when the vegetation in low marshes is often not visible. These changes are plausible and were therefore taken into account in this study.

Gains and losses not retained in the study are described in Appendix 7.

Among the progressive changes observed within wetlands during this period (i.e. changes that occurred in the normal direction of ecological succession towards more terrestrial environments), 34 ha of low marshes were transformed into high marshes, mainly in the Saint-Régis–Akwesasne Mohawk Reserve. In addition, 39 ha of high marshes scattered throughout the sector were transformed into forested swamps (34 ha consisted of *Acer rubrum* swamp). As has been documented in the scientific literature (Jean and Bouchard 1991), large areas of high marsh were colonized by shrubs. According to the data analyzed, 144 ha of high marshes, mainly in the Lac Saint-François National Wildlife Area, were lost in 1990–1991 to shrub swamps dominated by *Alnus incana* ssp. *rugosa*.

Regressive changes within wetlands (indicating a trend toward more aquatic environments) observed during the same period include the transformation of 237 ha of high marshes to low marshes. This occurred almost everywhere in the study area, with significant concentrations in the Saint-Régis–Akwesasne Mohawk Reserve, at the mouth of the Rivière aux Saumons and around Christatie Island. In addition, small scattered areas of shrub swamps, totalling 44 ha, reverted to high marshes. Moreover, 16 ha of forested swamps reverted to high marshes in 1990–1991. Lastly, 26 ha of forested swamps became shrub swamps in the southwest part of the large swamp in the Lac Saint-François National Wildlife Area.

No expansion of invasive exotic plants occurred during this period.

4.2.3 Partial changes between 1990–1991 and 1996–1997

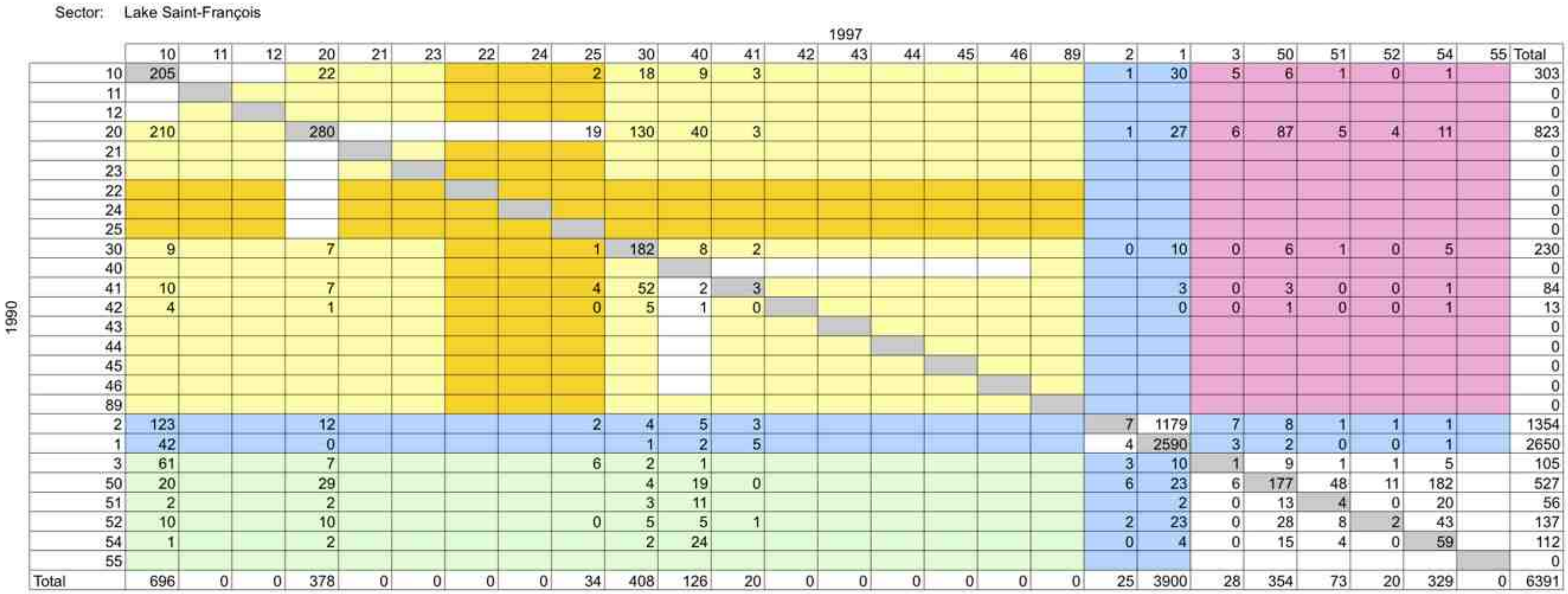
During this period, the area of wetlands increased from 1452 ha to 1662 ha, or by 210 ha or roughly 14.5% (Figure 12). Estimated losses were 215 ha and gains, 425 ha. When inconsistencies were excluded, the net balance was zero, with an estimated 1237 ha representing the minimum stable area of wetlands.

The relative drying index for the period was 0.06, denoting very little relative drying (Table 12). Excluding changes related to open water, a slight trend toward more aquatic environments could be observed.

No losses or gains were retained in the analysis (Appendix 7).

Several progressive changes within wetlands occurred during this period. A total of 12 ha of low marshes scattered over the sector were transformed into forested swamps (including 3 ha dominated by *Acer rubrum*). In addition, 18 ha of low marshes were replaced by shrub swamps and 24 ha of low marshes dried out enough to be classified as high marshes (2 ha of which, located mainly near Fraser Point, are dominated by *Lythrum salicaria*).

In addition, 43 ha of high marshes were converted to forested swamps, particularly around Hopkins Point. Of these, 3 ha are dominated by *Acer rubrum*. A sizeable area of high marshes (130 ha) was transformed into shrub swamps (dominated by *Alnus incana* ssp. *rugosa*), around Hopkins Point, in the Lac Saint-François National Wildlife Area (bordering Rivière aux Saumons, Bois d'enfer Swamp and Fraser Point), McMillan Brook, Leblanc Point and Somerville Beach. In addition, 10 ha of shrub swamps were transformed into forested swamp (2 ha of which are dominated by *Acer rubrum*), mainly in the Saint-Régis–Akwesasne Mohawk Reserve.



Sector: Lake Saint-François

		1997																									
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10	205			22					2	18	9	3							1	30	5	6	1	0	1		303
	11																											0
	12																											0
	20	210			280					19	130	40	3							1	27	6	87	5	4	11		823
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	9			7					1	182	8	2							0	10	0	6	1	0	5		230
	40																											0
	41	10			7					4	52	2	3								3	0	3	0	0	1		84
	42	4			1					0	5	1	0								0	0	1	0	0	1		13
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2	123			12					2	4	5	3							7	1179	7	8	1	1	1		1354
	1	42			0						1	2	5							4	2590	3	2	0	0	1		2650
	3	61			7					6	2	1								3	10	1	9	1	1	5		105
	50	20			29						4	19	0							6	23	6	177	48	11	182		527
	51	2			2						3	11									2	0	13	4	0	20		56
	52	10			10					0	5	5	1							2	23	0	28	8	2	43		137
	54	1			2						2	24								0	4	0	15	4	0	59		112
	55																											0
	Total	696	0	0	378	0	0	0	0	34	408	126	20	0	0	0	0	0	0	25	3900	28	354	73	20	329	0	6391

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 12 Transition matrix for the portion of the Lake Saint-François sector covered between 1990–1991 and 1996–1997

In terms of regressive changes within wetlands, 14 ha of forested swamps (10 ha dominated by *Acer rubrum* and 4 ha by *Larix laricina*) reverted to low marshes and 9 ha of shrub swamps were converted to low marshes. In addition, 210 ha of high marshes (the most significant internal change) reverted to low marshes, in the vicinity of Hopkins Point, Christatie Island, Fraser Point, Leblanc Point and Somerville Beach. Additionally, 12 ha of forested swamps (including 1 ha dominated by *Acer rubrum*) became high marshes (including 4 ha dominated by *Lythrum salicaria*), located mainly near McMillan Brook, east of Fraser Point and around Somerville Beach. Only 8 ha of shrub swamps were converted to high marshes (including less than 1 ha dominated by *Lythrum salicaria*), located in very specific parts of the Lac Saint-François National Wildlife Area. Lastly, 57 ha of forested swamps (including 5 ha dominated by *Larix laricina* and the remainder by *Acer rubrum*) reverted to shrub swamps, in the Lac Saint-François National Wildlife Area and around McMillan Brook, Leblanc Point and Somerville Beach.

As mentioned earlier, high marshes dominated by *Lythrum salicaria* were identified on the 1997 maps; a total of 34 ha of such marshes were observed, divided between Fraser Point, McMillan Brook and Leblanc Point. It is very unlikely that this species was first observed after the 1970s; it was probably just not mapped at the time (Groupe Dryade 1980).

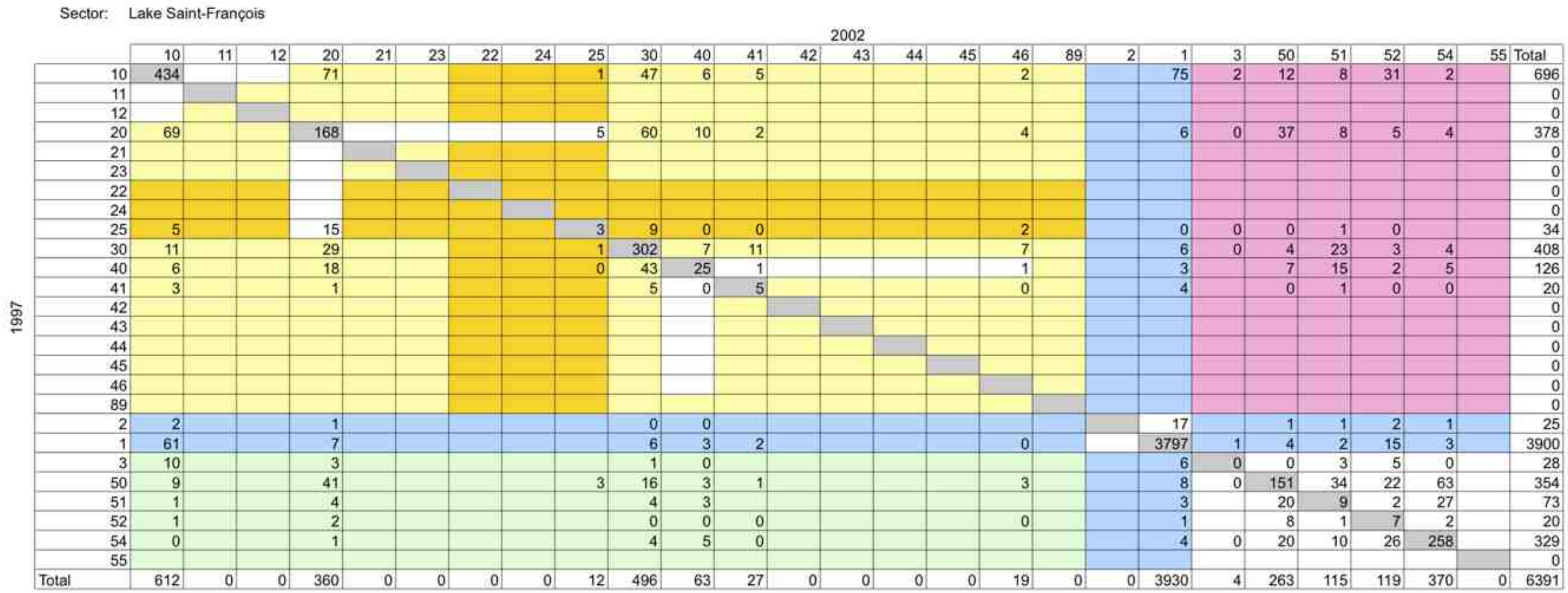
4.2.4 Partial changes between 1996–1997 and 2000–2002

During this period, the areal extent of wetlands decreased from 1662 ha to 1590 ha, a decline of 72 ha or 4.3% (Figure 13). Losses totalled 270 ha, compared with 199 ha of gains. When inconsistencies are excluded, there are no gains or losses. The corrected wetland area is 1392 ha for both periods.

The estimated relative drying index was 0.06, as in the previous period, showing that there were no pronounced trends during the period. Excluding changes involving open water, a similar slight trend towards more terrestrial environments (i.e. drier conditions) was observed.

All losses and gains were rejected after an examination of their plausibility (Appendix 7).

Compared with the previous periods, changes within wetlands were less significant. Progressive changes included the conversion of 13 ha of low marshes to forested swamps (including 5 ha dominated by *Acer rubrum* and 2 ha by *Salix* sp.), which occurred mainly on islands. The expansion of shrub swamps, dominated mainly by *Alnus incana* ssp. *rugosa*, continued during this period; 47 ha of low marshes were transformed into shrub swamps around the Rivière aux Saumons (Saint-Régis–Akwesasne Mohawk Reserve and the Lac Saint-François National Wildlife Area), Fraser Point, Leblanc Point and Somerville Beach. In addition, 71 ha of high marshes replaced the low marshes present in 1996–1997; this occurred in scattered locations throughout the main areas of wetlands in the sector. Of these new high marshes, 1 ha in the Fraser Point area is dominated by *Lythrum salicaria*. Moreover, 18 ha of high marshes were converted to forested swamps (6 ha dominated by *Salix* sp. and 2 ha by *Acer rubrum*), mainly on Hamilton Island, which consists of upland habitats. Confusion between classes is likely the reason. In addition, 25 ha of shrub swamps concentrated in the Leblanc Point sector became forested swamps in 2000–2002; of these 25 ha, 7 ha are dominated by *Salix* sp. and 11 ha by *Acer rubrum*.



Sector: Lake Saint-François

	2002																										
1997	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	434			71					1	47	6	5					2			75	2	12	8	31	2		696
11																											0
12																											0
20	69			168					5	60	10	2					4			6	0	37	8	5	4		378
21																											0
23																											0
22																											0
24																											0
25	5			15					3	9	0	0					2			0	0	0	1	0			34
30	11			29					1	302	7	11					7			6	0	4	23	3	4		408
40	6			18					0	43	25	1					1			3		7	15	2	5		126
41	3			1						5	0	5					0			4		0	1	0	0		20
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	2			1						0	0									17		1	1	2	1		25
1	61			7						6	3	2					0			3797	1	4	2	15	3		3900
3	10			3						1	0									6	0	0	3	5	0		28
50	9			41					3	16	3	1					3			8	0	151	34	22	63		354
51	1			4						4	3									3		20	9	2	27		73
52	1			2						0	0	0					0			1		8	1	7	2		20
54	0			1						4	5	0								4	0	20	10	26	258		329
55																											0
Total	612	0	0	360	0	0	0	0	12	496	63	27	0	0	0	0	19	0	0	3930	4	263	115	119	370	0	6391

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 13 Transition matrix for the portion of the Lake Saint-François sector covered between 1996–1997 and 2000–2002

Lastly, 69 ha of high marshes (including 9 ha dominated by *Lythrum salicaria*) were transformed into shrub swamps, mainly around Somerville Beach, McMillan Brook, Fraser Point (probably underestimated in 1996–1997) and the Saint-Régis–Akwesasne Mohawk Reserve.

Regressive changes included 9 ha of forested swamps (including 3 ha dominated by *Acer rubrum*) which were replaced by low marshes, specifically at the mouth of the Rivière aux Saumons, Fraser Point and Leblanc Point. In addition, 11 ha of shrub swamps reverted to low marshes; these marshes were observed along several small natural or artificial streams. Extensive areas (74 ha) of high marshes were converted to low marshes, including 5 ha dominated in 1996–1997 by *Lythrum salicaria*. Also, 19 ha of forested swamps apparently reverted to high marsh (including 2 ha dominated by *Lythrum salicaria*)—much of this reversion appears to have been due to a classification problem related to the more upland portions of Christatie and Plum islands. Furthermore, 48 ha of forested swamps (including 5 ha dominated by *Acer rubrum*) were converted to shrub swamps in the Saint-Régis–Akwesasne Mohawk Reserve. A total of 30 ha of shrub swamps reverted to high marshes, including 1 ha dominated by *Lythrum salicaria*; these swamps are concentrated around McMillan Brook, Leblanc Point and, to a lesser extent, Fraser Point.

During the same period, the area of wetlands dominated by *Lythrum salicaria* increased from under 2 ha to 6 ha. However, this should not be interpreted as an increase in abundance of this invasive alien species; it is more likely the result of increased effort in fieldwork in 2000–2002 that allowed dominant species to be more accurately identified.

4.3 VALLEYFIELD–BEAUHARNOIS

A total of 15 560 ha in the Valleyfield–Beauharnois sector were analyzed in 1990-1991 and 2000–2002, and maps for the two periods were compared, including open water and the adjacent terrestrial habitats (Appendices 9 and 10). Almost all of the shoreline in the sector was covered, except for a few portions masked by cloud cover.

As mapping for this sector was carried out only in 1990-1991 and in 2000-2002, comparison with other time periods was not possible.

Examination of the only relative drying index calculated for the Beauharnois–Valleyfield sector (Table 13) shows a trend towards wetter habitats between 1990–1991 and 2000–2002, characterized by the conversion of marshes to open water.

Table 13 Relative drying indices for the Valleyfield–Beauharnois sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	–
Between 1990–1991 and 1996–1997	–
Between 1996–1997 and 2000–2002	–
Between 1990–1991 and 2000–2002	–0.56

4.3.1 Overall changes between 1990–1991 and 2000–2002

An examination of wetland dynamics for this 10-year period for the entire sector shows a drop in wetland area. Wetland area decreased from 753 ha to 146 ha, a drop of 81% (Figure 14). Losses were estimated at 737 ha and gains at 129 ha, for a net loss of 608 ha. However, when inconsistencies are taken into account, the net balance is reversed. The corrected wetland area was 96 ha for 1990–1991 and 102 ha for 2000–2002, an increase of 6 ha or 6%. Corrected losses were 80 ha and gains were 85 ha (Figure 15).

The relative drying index for this period was –0.56, illustrating a trend towards more aquatic environments in the sector (Table 13). When changes involving open water are excluded, the same trend is observed.

The only losses retained consist of 80 ha of wetlands that were flooded. Half of these were low marshes concentrated around Pointe du Buisson and Pointe-des-Cascades. The remainder, areas dominated by *Phragmites australis*, were converted to open water in the settling basins (impoundments) located along the Beauharnois Canal. The reduction of the presence of *Phragmites australis* in those basins are the results of efforts undertaken by Ducks Unlimited Canada to control this invasive species in the sector.

Sector: Beauharnois–Valleyfield

2002

1990

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																				40		10	5	0	1		55
11																											0
12																											0
20																						0	0				0
21																											0
23																											0
22	8			6						0	2								21	19	8	455	108	9	59		694
24																											0
25																											0
30																											0
40																											0
41																											0
42																											0
43																				1		2	0	0	1		3
44																											0
45																											0
46																											0
89																											0
2																				218		1	2	1	1		223
1	19			2							1								40	5349	2	125	26	28	27		5620
3				0							1									38		21	5	13	7		85
50	8			12						4	3								9	70	4	3370	369	116	232		4198
51	4			4						4	4								2	22	0	419	230	14	69		770
52	32			13							8								37	239	3	1596	273	523	195		2920
54	4			2						0	3								1	33		194	241	10	501		991
55																											0
Total	76	0	0	39	0	0	0	0	0	8	22	0	0	0	0	0	0	0	111	6028	17	6193	1259	715	1091	0	15560

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 14 Transition matrix for the Valleyfield–Beauharnois sector between 1990–1991 and 2000–2002

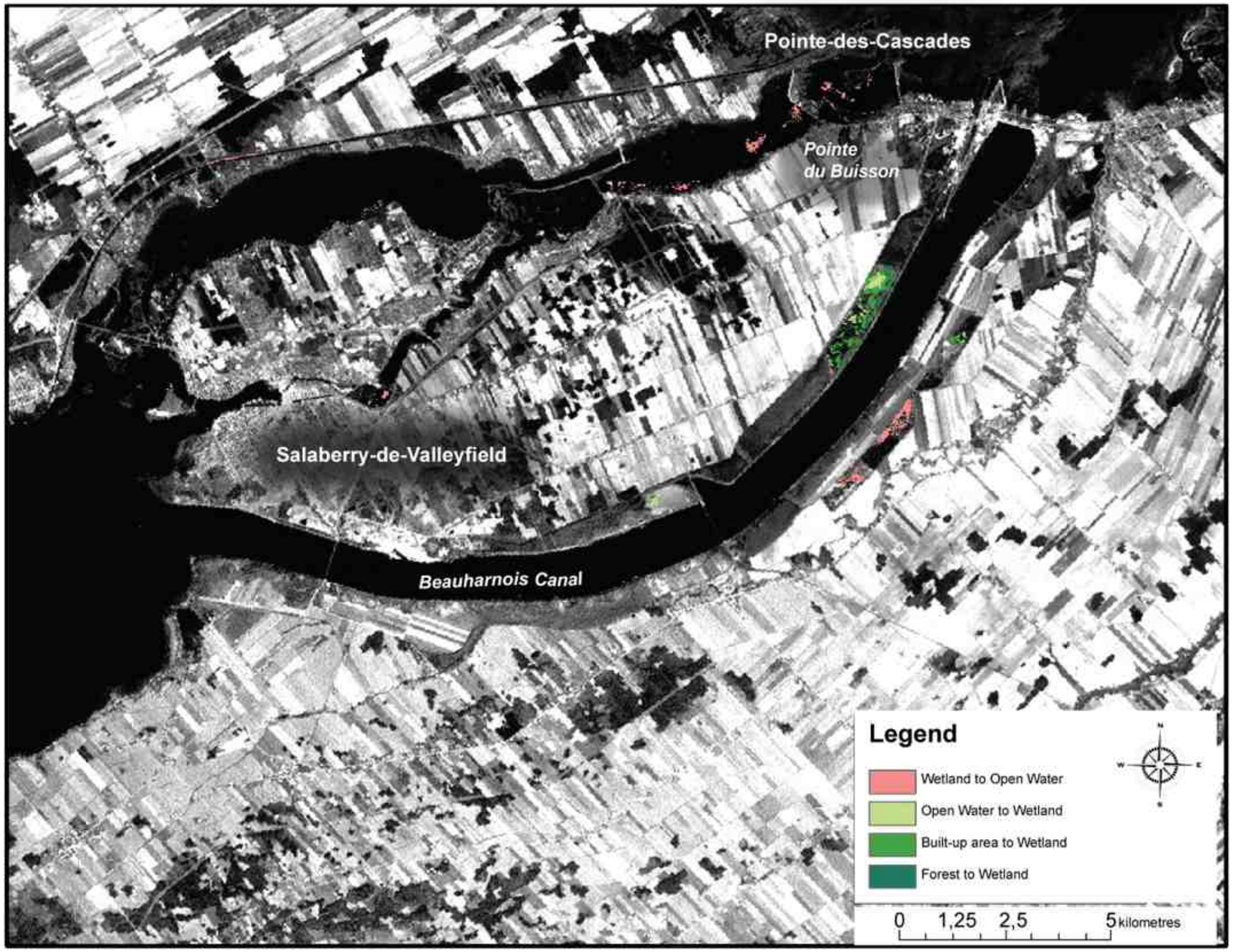


Figure 15 **Losses and gains of marshes and swamps in the Valleyfield–Beauharnois sector between 1990–1991 and 2000–2002**

Gains retained in this analysis fall into several change categories. First, 22 ha of open water were identified as low marshes in 2000–2002 in the impoundments located on the north side of the Beauharnois Canal. These changes are plausible and were retained. In addition, 53 ha of wetlands (mostly low marshes) replaced open water, which was incorrectly identified in the 1990–1991 images as built-up areas due to sun glitter on the water. Lastly, 10 ha of forest reverted to wetlands, most likely the result of trees dying along the edges of the impoundments near the canal.

Losses and gains not retained in the analysis are described in Appendix 11.

No significant changes (i.e., those affecting over 10 ha) to wetlands were detected in this sector and no invasive species were identified on the images, although large colonies of *Phragmites australis* are known to be invading the impoundments bordering the Beauharnois Canal.

4.4 LAKE SAINT-LOUIS

A total of 22 317 ha in the Lake Saint-Louis sector were analyzed in both 1990–1991 and 2000–2002, including open water and the adjacent terrestrial habitats. These two maps provided almost complete coverage of the sector (Appendices 13 and 14).

However, the area examined between in the other time periods (1970–1978 and 1996-1997) only covers the southern portion of the lake, estimated at 15 443 ha (Appendices 15 to 18).

Relative drying indices for Lake Saint-Louis are shown in Table 14. These statistics show a relative trend towards more aquatic environments in wetlands during the study period, except for the interval between 1996–1997 and 2000–2002.

Table 14 Relative drying indices for the Lake Saint-Louis sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	–0.51
Between 1990–1991 and 1996–1997	–0.13
Between 1996–1997 and 2000–2002	0.24
Between 1990–1991 and 2000–2002	–0.04

4.4.1 Overall changes between 1990–1991 and 2000–2002

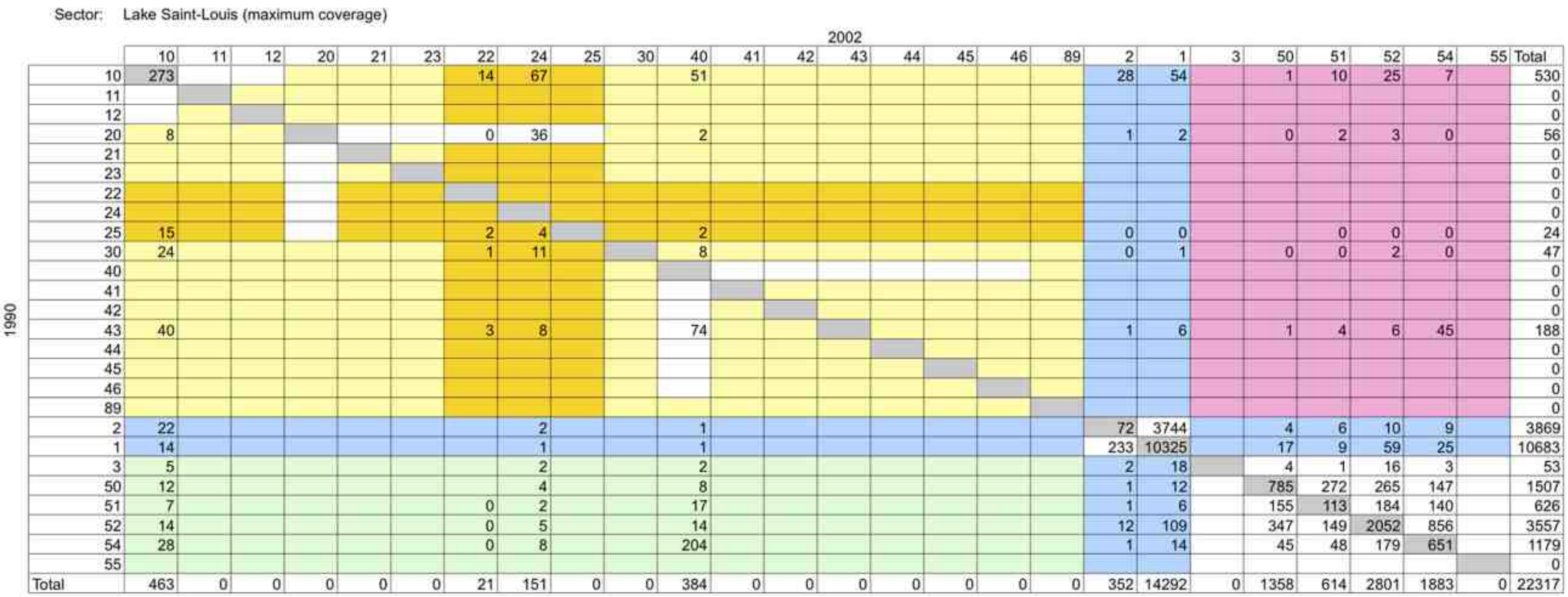
Between 1990–1991 and 2000–2002, the Lake Saint-Louis sector gained 174 ha of wetlands, which went from 844 ha in 1990–1991 to 1018 ha in 2000–2002 (Figure 16), an increase of roughly 21%. Losses totalled 201 ha and gains totalled 374 ha. When inconsistencies are excluded, the corrected area of wetlands was 643 ha in 1990–1991 and 685 ha in 2000–2002, resulting in a gain of 41 ha, or 7%. Corrected losses were zero, and gains, 41 ha (Figure 17).

The relative drying index (Table 14) was –0.04, showing that, overall, there were no pronounced trends involving changes within wetlands. When changes involving open water were excluded, a relative trend toward more terrestrial environments was observed.

The only gains retained during this period involved the conversion of 41 ha of open water in 1990–1991 to low marshes in 2000–2002, concentrated mainly in the protected portion of the Îles de la Paix National Wildlife Area, which suggests that this sector is in transition.

Losses and gains not retained in the analysis are described in Appendix 19.

As was the case in Lake Saint-François, historical data on Lake Saint-Louis were used to examine changes to wetlands during this period (Jean et al. 1992). In terms of progressive changes within wetlands, 51 ha of low marshes were transformed into forested swamps, concentrated mainly on the northern point of Saint-Bernard Island. In addition, invasive plant species continue to gain ground, as shown by the transformation of 82 ha of low marshes into high marshes, 67 ha of which are dominated by *Phalaris arundinacea* and 14 ha by *Phragmites australis*. The first species is found in the Îles de la Paix National Wildlife Area and on Saint-Bernard Island, while the second one is observed on the western end of the Kahnawake Mohawk Reserve. The presence of *Phragmites australis* was particularly noticeable in 2002. Although the species could be detected on the raw 1990–1991 images, owing to the absence of specific field data on this plant community, we were not able to identify it on the maps for the same year.



Sector: Lake Saint-Louis (maximum coverage)

		2002																										
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10	273						14	67			51								28	54		1	10	25	7		530
	11																											0
	12																											0
	20	8						0	36			2								1	2		0	2	3	0		56
	21																											0
	23																											0
	22																											0
	24																											0
	25	15						2	4			2								0	0			0	0	0		24
	30	24						1	11			8								0	1		0	0	2	0		47
	40																											0
	41																											0
	42																											0
	43	40						3	8			74								1	6		1	4	6	45		188
	44																											0
	45																											0
	46																											0
	89																											0
	2	22							2			1								72	3744		4	6	10	9		3869
	1	14							1			1								233	10325		17	9	59	25		10683
	3	5							2			2								2	18		4	1	16	3		53
	50	12							4			8								1	12		785	272	265	147		1507
	51	7						0	2			17								1	6		155	113	184	140		626
	52	14						0	5			14								12	109		347	149	2052	856		3557
	54	28						0	8			204								1	14		45	48	179	651		1179
	55																											0
Total		463	0	0	0	0	0	21	151	0	0	384	0	0	0	0	0	0	0	352	14292	0	1358	614	2801	1883	0	22317

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 16 Transition matrix for the Lake Saint-Louis sector between 1990–1991 and 2000–2002

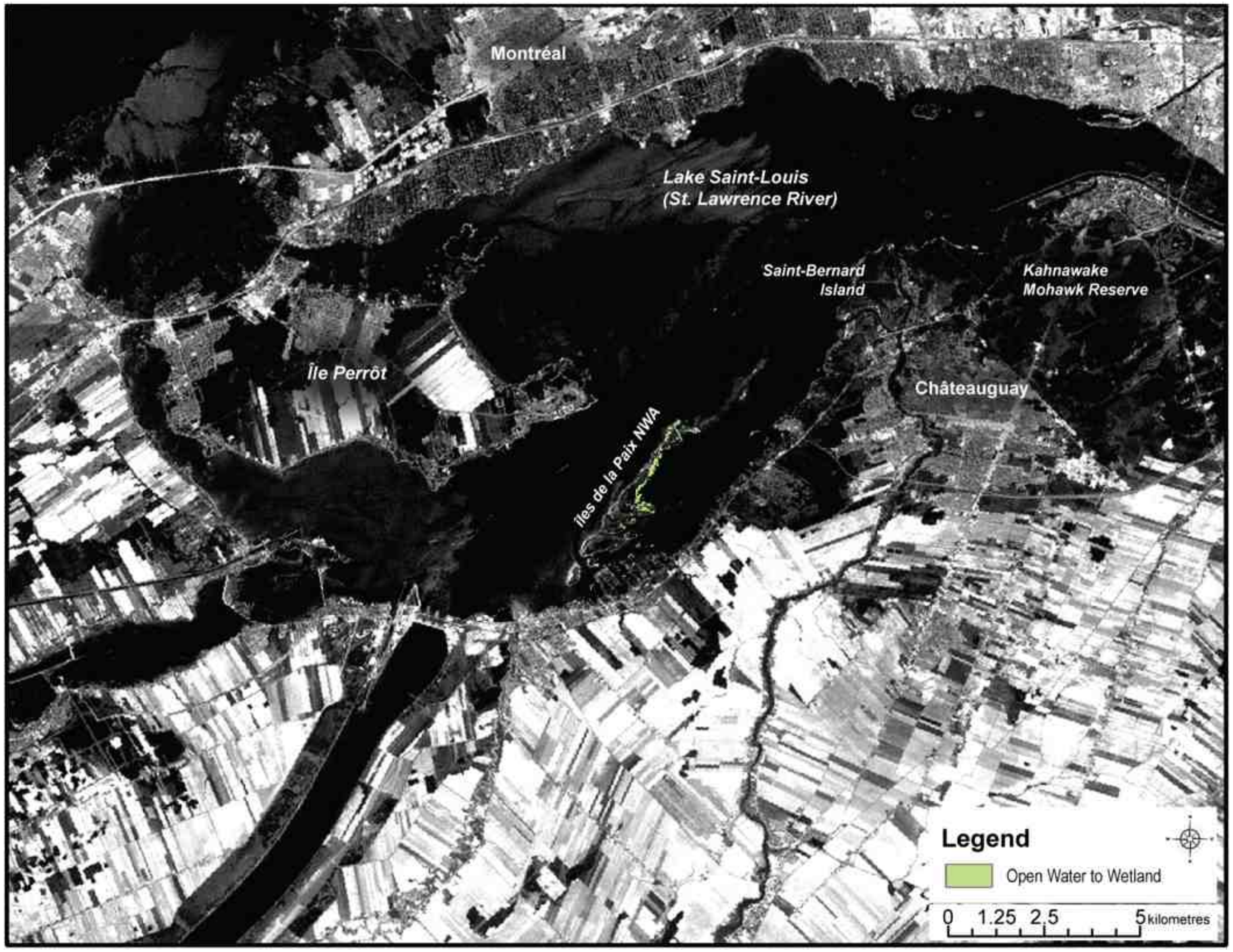


Figure 17 **Losses and gains of marshes and swamps in the the Lake Saint-Louis sector between 1990–1991 and 2000–2002**

Conversely, 23 ha of high marshes, 15 ha of which were dominated by *Lythrum salicaria*, were transformed into low marshes, visible in the western part of Châteauguay, suggesting an apparent decrease in the dominance of this invasive species in the sector. In addition, 24 ha of shrub swamps, mainly in the centre of Saint-Bernard Island, reverted to low marshes as a result of a period of high water levels in the 1970s and the development of wildlife habitat in the area beginning in the early 2000s. Furthermore, 40 ha of swamps dominated by *Acer saccharinum* reverted to low marshes, concentrated in the western part of the Kahnawake Mohawk Reserve; however, this can be partially attributed to an overestimation of the area of swamps in 1990. Shrub swamps decreased by 12 ha as a result of conversions to high marshes, with 11 ha dominated by *Phalaris arundinacea* and 1 ha by *Phragmites australis*. Two concentrations of new high marshes are present, in the western part of the Îles de la Paix National Wildlife Area and on Saint-Bernard Island. Lastly, 11 ha of forested swamps dominated by *Acer saccharinum* reverted to high marshes (8 ha dominated by *Phalaris arundinacea* and 3 ha by *Phragmites australis*).

In the Îles de la Paix National Wildlife Area, there was a significant increase in the area of high marshes dominated by *Phalaris arundinacea*. The 1990–1991 map shows a complete absence of this type of wetland in the sector. According to Jean et al. (1992), this plant community was present on the islands in 1991. Consequently, it is plausible that the species was underestimated in the 1990–1991 mapping. In addition, according to data from Jean et al. (1992), the area of high marsh dominated by *Phalaris arundinacea* is slightly less than that shown on the 2000–2002 map.

4.4.2 Partial changes between 1970–1978 and 1990–1991

During this period, the area of wetlands in the sector rose from 387 ha to 440 ha, an increase of 53 ha or 13.7% (Figure 18). Losses were estimated at 103 ha and gains at 155 ha. When inconsistencies are excluded, the corrected area was 366 ha in the 1970s and 344 ha in 1990–1991, a decrease of 22 ha or 6%. Corrected losses totalled 84 ha and gains totalled 58 ha (Figure 19).

The relative drying index (Table 14) was –0.51, showing that, overall, wetlands were wetter in 1990–1991 than in the late 1970s. When changes involving open water are excluded, an even stronger trend towards more aquatic environments was observed.

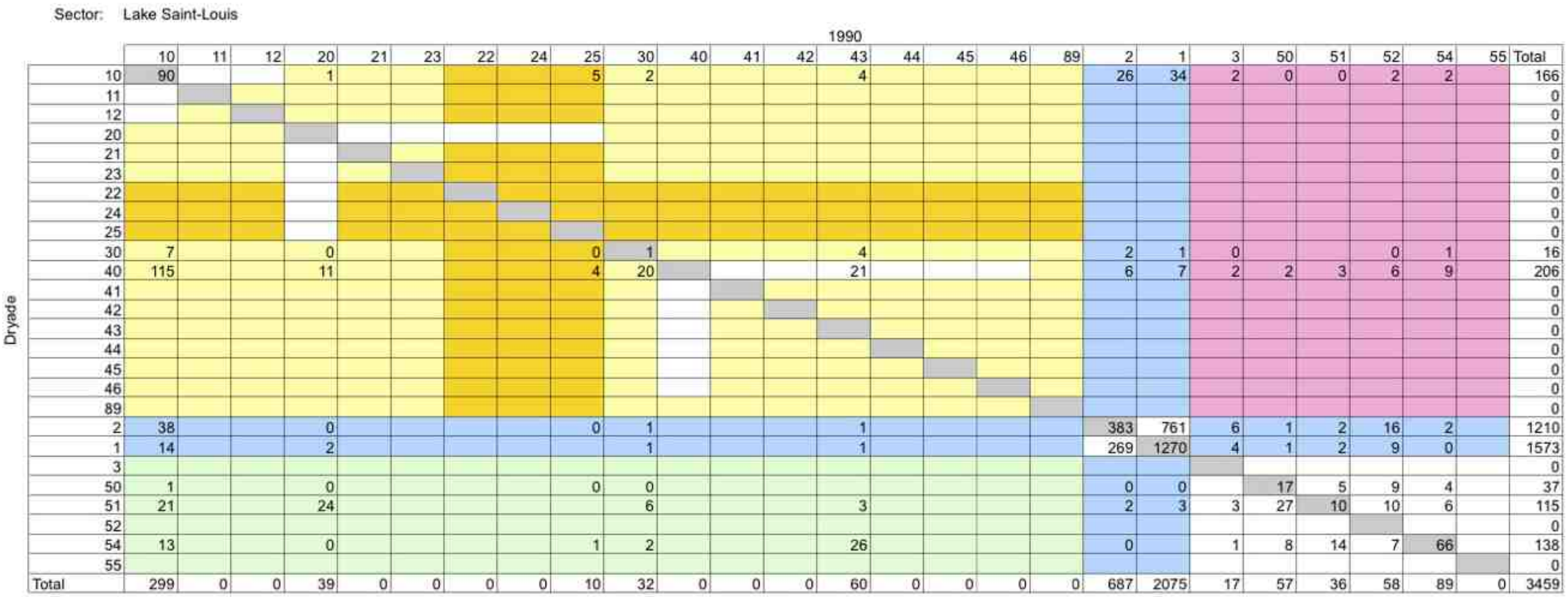
The main losses retained involved wetlands lost to open water (76 ha), mainly around the Îles de la Paix. Most of these changes were probably caused by water level fluctuations or by the fact that Groupe Dryade used data from the spring, when low marsh vegetation was not yet visible. Since we do not have access to the exact dates of the aerial photographs used by the authors, it is impossible to determine which explanation is more plausible. In addition, roughly 8 ha of wetlands around Ross Point and the Kahnawake Mohawk Reserve were converted to built-up area in 1990–1991. These appear to be real losses.

The gains retained (58 ha) occurred at the expense of open water and were found mainly around the Îles de la Paix and near Saint-Bernard Island. As in the case of the losses, we do not have any information leading us to believe that these changes are not plausible.

Gains and losses not retained in the analysis are described in Appendix 19.

During the same period, few progressive changes occurred within wetlands. A total of 6 ha of low marshes were transformed into high marshes, 5 ha of which are dominated by *Lythrum salicaria*, while other low marshes became shrub swamps (2 ha) or forested swamps (4 ha). Lastly, 4 ha of shrub swamps became forested swamps.

Among the regressive changes observed within wetlands, 15 ha of forested swamps reverted to high marshes, 4 ha of which were specifically linked to the presence of *Lythrum salicaria*. In addition, 115 ha of forested swamps reverted to low marshes, mainly in the centre of Saint-Bernard Island and on the Îles de la Paix. Lastly, 20 ha of forested swamps were converted to shrub swamps. All these changes within wetlands could be the result of the period of high water levels observed in the mid 1970s (Jean et al. 1992).



Sector: Lake Saint-Louis

1990

Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	90			1					5	2				4					26	34	2	0	0	2	2		166
11																											0
12																											0
20																											0
21																											0
23																											0
22																											0
24																											0
25																											0
30	7			0					0	1				4					2	1	0			0	1		16
40	115			11					4	20				21					6	7	2	2	3	6	9		206
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	38			0					0	1				1					383	761	6	1	2	16	2		1210
1	14			2						1				1					269	1270	4	1	2	9	0		1573
3																											0
50	1			0					0	0									0	0		17	5	9	4		37
51	21			24						6				3					2	3	3	27	10	10	6		115
52																											0
54	13			0					1	2				26					0		1	8	14	7	66		138
55																											0
Total	299	0	0	39	0	0	0	0	10	32	0	0	0	60	0	0	0	0	687	2075	17	57	36	58	89	0	3459

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 18 Transition matrix for the portion of the Lake Saint-Louis sector covered between 1970–1978 and 1990–1991

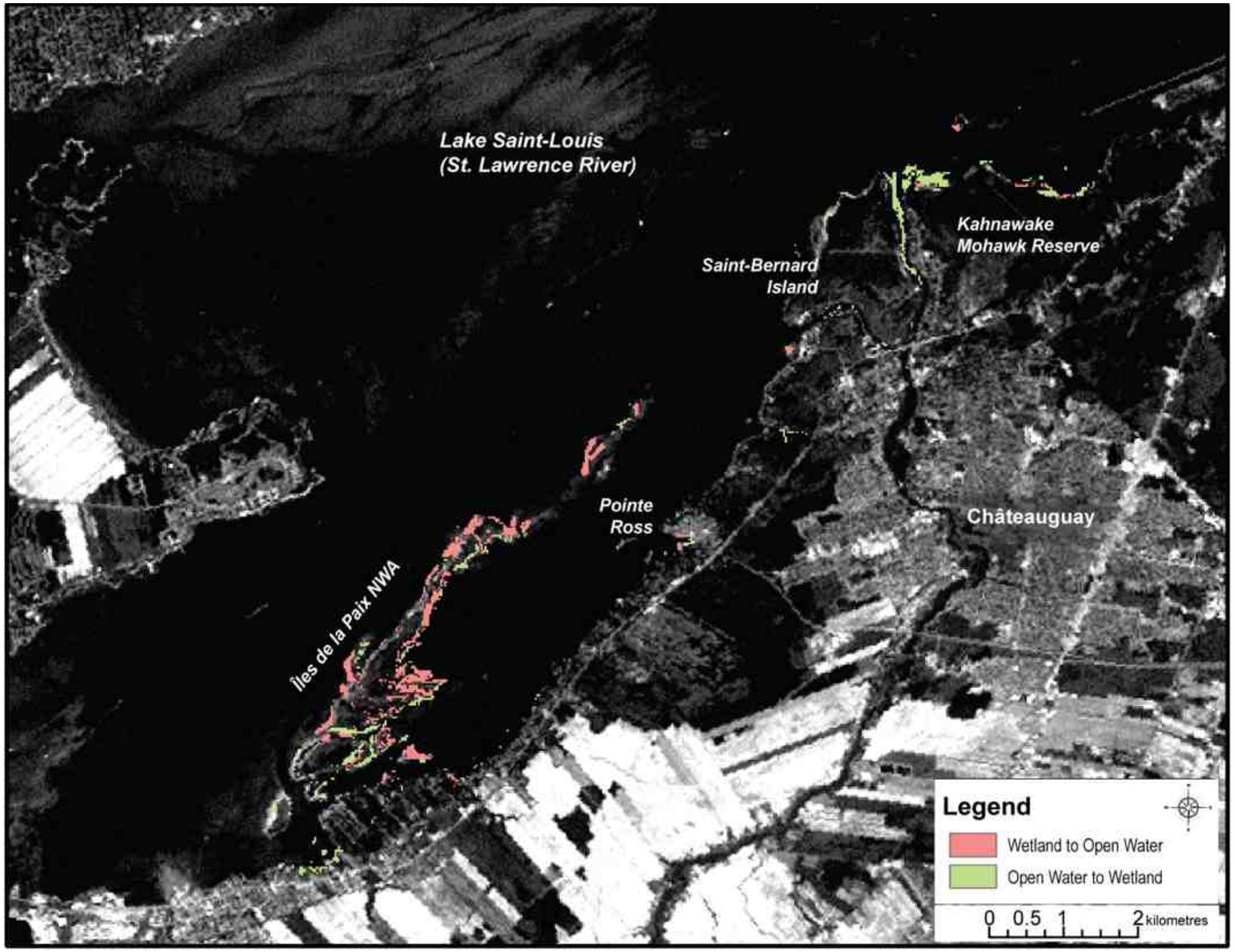


Figure 19 **Losses and gains of marshes and swamps in the portion of the Lake Saint-Louis sector covered between 1970–1978 and 1990–1991**

4.4.3 Partial changes between 1990–1991 and 1996–1997

During this period, the area of wetlands decreased from 440 ha in 1990–1991 to 374 ha in 1996–1997, a drop of 66 ha or 15% (Figure 20). Estimated losses were 107 ha, while gains were estimated at 42 ha. When inconsistencies are excluded, the corrected wetland area was 403 ha in 1990 and 356 ha for the later period, a decrease of 47 ha or 12%. Corrected losses were 70 ha and corrected gains were 24 ha (Figure 21).

The relative drying index for the period was –0.13 (Table 14), showing that, overall, wetlands in 1996–1997 were slightly wetter than in 1990–1991. When changes linked to open water are excluded, however, a trend towards more terrestrial environments is observed.

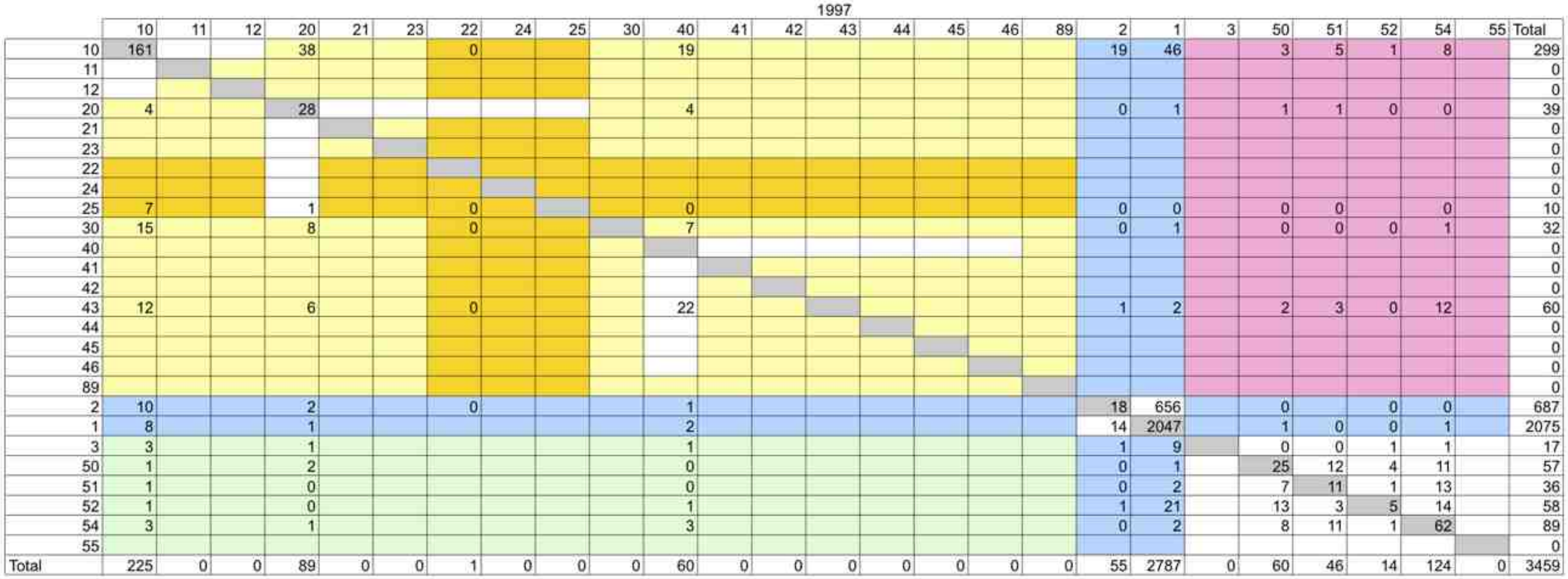
The only losses retained (70 ha) are the result of the appearance of areas of open water around the Îles de la Paix, Saint-Bernard Island and along the shore of the western side of the Kahnawake Mohawk Reserve. Fluctuating water levels and the late date of image acquisition in 1996–1997 may be the reason for this phenomenon on the Îles de la Paix (Pointe-Claire hydrometric station – 02OA039: 21.12 m on August 21, 1990, and 21.38 m on October 17, 1996; source: HYDAT 2001). However, geometric problems observed on the 1990–1991 map for Saint-Bernard Island could also explain part of these changes.

The gains retained (24 ha) can be attributed to the disappearance of areas of open water in scattered areas around the Îles de la Paix, Saint-Bernard Island and the western part of the Kahnawake Mohawk Reserve. Although geometric problems could be the cause in the case of Saint-Bernard Island, we have no evidence to indicate that these changes are not plausible.

Losses and gains not retained in the analysis are described in Appendix 19.

The main progressive changes observed within wetlands concern the transformation of over 38 ha of low marshes to high marshes, observed on the Îles de la Paix and Saint-Bernard Island. Of these 38 ha, barely 1 ha is dominated by *Phragmites australis*. At these same sites, other low marshes (19 ha) were replaced by forested swamps.

Sector: Lac Saint-Louis



														1997														
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
	10	161			38			0				19								19	46		3	5	1	8		299
	11																											0
	12																											0
	20	4			28							4								0	1		1	1	0	0		39
	21																											0
	23																											0
	22																											0
	24																											0
	25	7			1			0				0								0	0		0	0		0		10
	30	15			8			0				7								0	1		0	0	0	1		32
	40																											0
	41																											0
	42																											0
1990	43	12			6			0				22								1	2		2	3	0	12		60
	44																											0
	45																											0
	46																											0
	89																											0
	2	10			2			0				1								18	656		0		0	0		687
	1	8			1							2								14	2047		1	0	0	1		2075
	3	3			1							1								1	9		0	0	1	1		17
	50	1			2							0								0	1		25	12	4	11		57
	51	1			0							0								0	2		7	11	1	13		36
	52	1			0							1								1	21		13	3	5	14		58
	54	3			1							3								0	2		8	11	1	62		89
	55																											0
Total		225	0	0	89	0	0	1	0	0	0	60	0	0	0	0	0	0	0	55	2787	0	60	46	14	124	0	3459

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 20 Transition matrix for the portion of the Lake Saint-Louis sector covered between 1990–1991 and 1996–1997

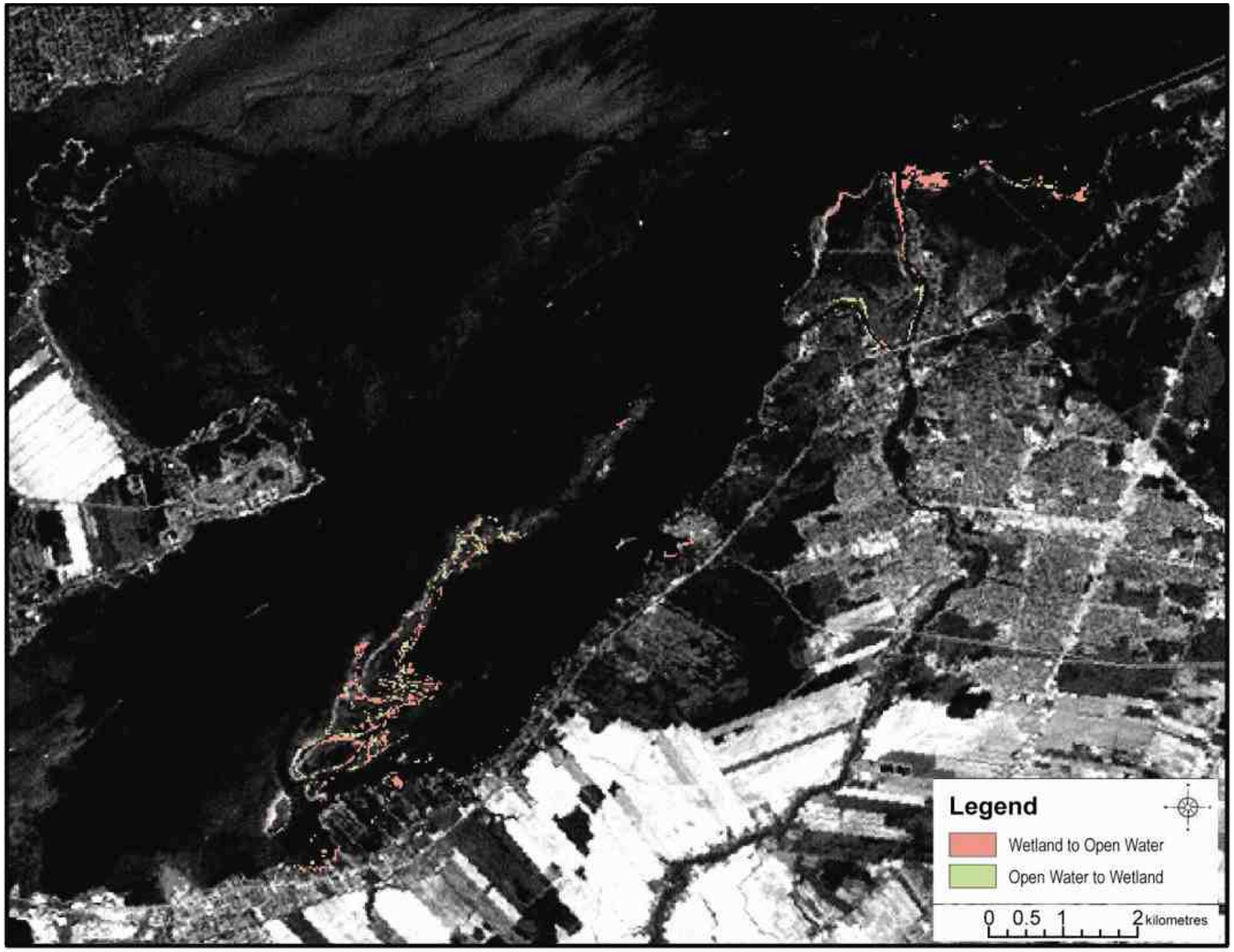


Figure 21 Losses and gains of marshes and swamps in the portion of the Lake Saint-Louis sector covered between 1990–1991 and 1996–1997

In addition, forested swamps seem to have increased, as shown by the transformation of 4 ha of high marshes and 7 ha of shrub swamps into this type of habitat. On the other hand, less than 1 ha of high marsh dominated by *Lythrum salicaria* became forested swamp.

Regressive changes observed within wetlands included 15 ha of shrub swamps that became low marshes, mainly on Saint-Bernard Island. In addition, 12 ha of forested swamps dominated by *Acer saccharinum* reverted to low marshes, mainly around the edge of Saint-Bernard Island and in the Kahnawake Mohawk Reserve. Lastly, 11 ha of high marshes reverted to low marshes, as observed on the Îles de la Paix and Saint-Bernard Island; 7 ha of these former high marshes were dominated by *Lythrum salicaria*.

4.4.4 Partial changes between 1996–1997 and 2000–2002

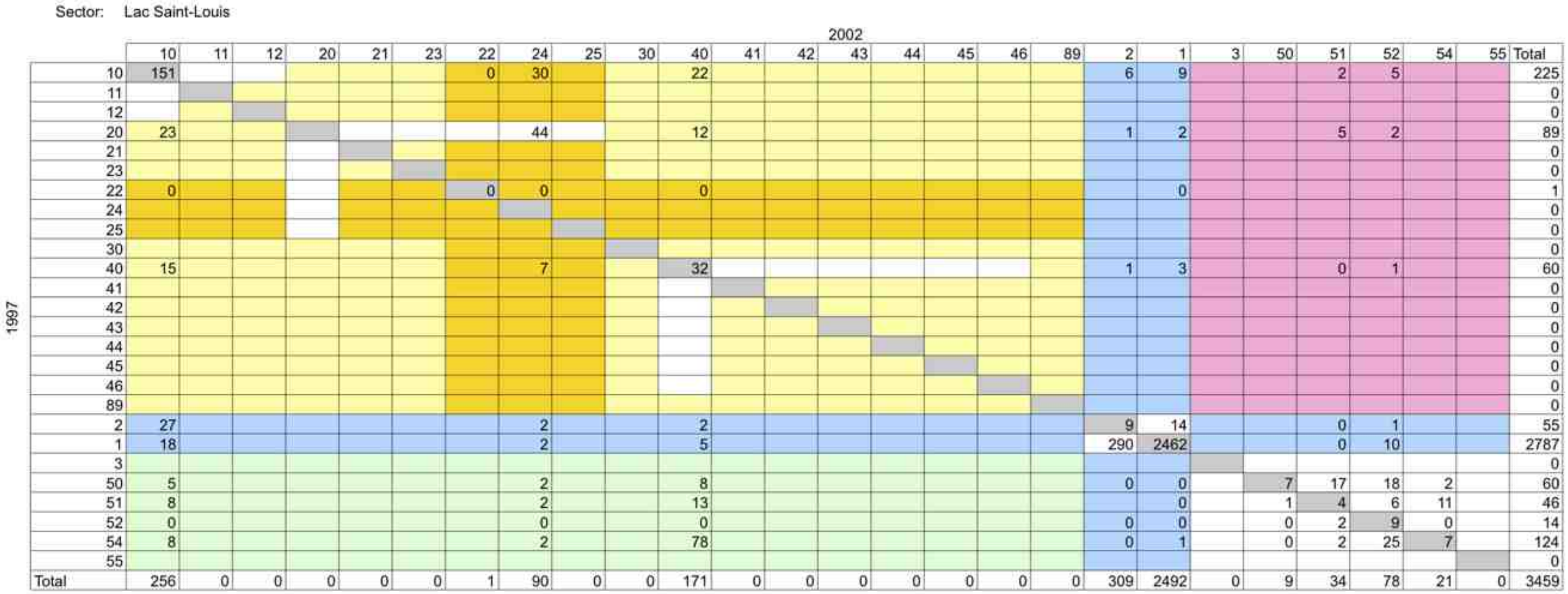
Wetlands increased from 374 ha in 1996 to 517 ha in 2000–2002, an increase of 143 ha or 38% (Figure 22). Losses totalled 38 ha and gains totalled 181 ha. When inconsistencies were excluded, the corrected wetland area was 344 ha in 1996 and 390 ha in 2000–2002, representing an increase of 46 ha or 13.4%. Corrected losses totalled 8 ha and gains, 54 ha (Figure 23).

The relative drying index for the period was 0.24 (Table 14), illustrating that, overall, there was a drying trend in wetlands during this period. When changes related to open water were excluded, the same trend towards more terrestrial environments was observed, albeit a less pronounced one.

Of the losses observed, only the conversion of 8 ha of wetlands to built-up area is plausible. This transformation can be seen along the shores of and in the middle of Saint-Bernard Island, where wildlife habitat development was carried out in 2000, among other things.

The only gains taken into account in this analysis were the transformation of 54 ha of open water into wetlands, mainly on the eastern shore of the Îles de la Paix. This could be due to changes in water level (see section 4.4.3 above for water levels recorded).

Losses and gains not retained in the analysis are described in Appendix 19.



Sector: Lac Saint-Louis

2002

1997

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	151						0	30			22								6	9			2	5			225
11																											0
12																											0
20	23							44			12								1	2			5	2			89
21																											0
23																											0
22	0						0	0			0									0							1
24																											0
25																											0
30																											0
40	15							7			32								1	3			0	1			60
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	27							2			2								9	14			0	1			55
1	18							2			5								290	2462			0	10			2787
3																											0
50	5							2			8								0	0		7	17	18	2		60
51	8							2			13									0		1	4	6	11		46
52	0							0			0								0	0		0	2	9	0		14
54	8							2			78								0	1		0	2	25	7		124
55																											0
Total	256	0	0	0	0	0	1	90	0	0	171	0	0	0	0	0	0	0	309	2492	0	9	34	78	21	0	3459

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 22 Transition matrix for the portion of the Lake Saint-Louis sector covered between 1996–1997 and 2000–2002

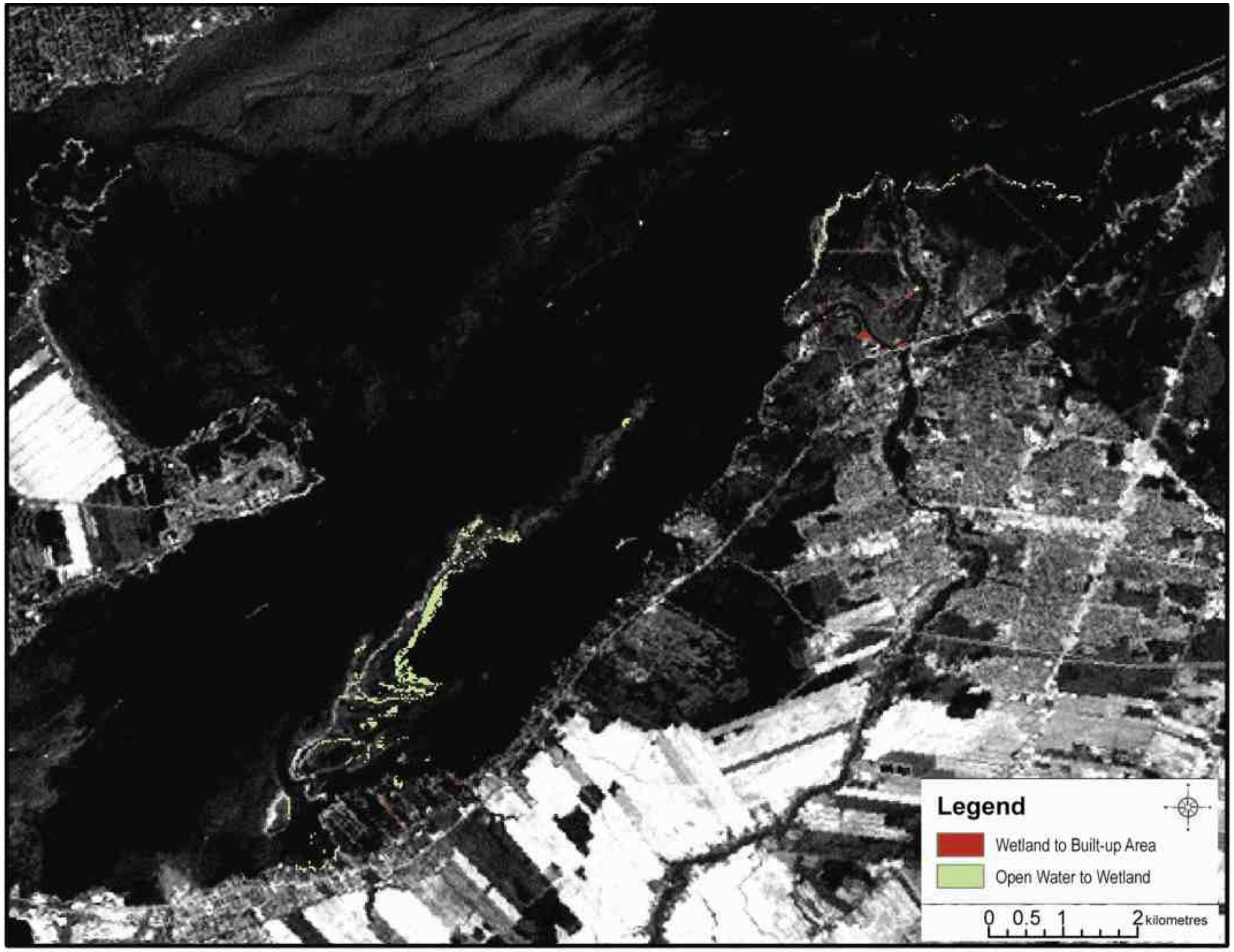


Figure 23 Losses and gains of marshes and swamps in the portion of the Lake Saint-Louis sector covered between 1996–1997 and 2000–2002

Progressive changes within wetlands included 30 ha of low marshes converted to high marshes dominated by *Phalaris arundinacea,* observed on the Îles de la Paix and Saint-Bernard Island. These made up the bulk of the 39 ha of high marshes that appeared between 1990 and 1996. In addition, 22 ha of low marshes were transformed into forested swamps, mainly on the northern point of Saint-Bernard Island and in the Kahnawake Mohawk Reserve. Lastly, 12 ha of high marshes located mainly on Saint-Bernard Island were transformed into forested swamps.

Regressive changes within wetlands included 23 ha of high marshes that reverted to low marshes in 2000–2002, concentrated mainly on Saint-Bernard Island and possibly resulting from wildlife habitat developments constructed on this site. On the same island, 15 ha of forested swamps were transformed into low marshes. Lastly, 7 ha of forested swamps were converted to high marshes dominated by *Phalaris arundinacea*, located mainly on Saint-Bernard Island and the Îles de la Paix.

Lastly, in terms of invasive plant species, a total of 90 ha of high marshes dominated by *Phalaris arundinacea* were identified in the sector.

4.5 LA PRAIRIE BASINS

A total of 14 464 ha were analyzed in the La Prairie Basins sector between 1990–1991 and 2000–2002, including open water and adjacent terrestrial habitats (Appendices 21 and 22). Since the southeast part of the sector was not analyzed, the areal extent of wetlands was underestimated. An analysis of the differences between the 1970s and 2000 was not carried out for the sector, nor were the relative drying indices calculated.

4.5.1 Overall changes between 1990–1991 and 2000–2002

The areal extent of wetlands increased from 0 ha to 2 ha during this period (Figure 24). There were no losses, and gains totalled only 2 ha.

We have no data from fieldwork in this sector, which presents a problem in identifying wetlands. The gains observed were due to the presence of high marshes dominated by *Phragmites australis* in 2000–2002.

Sector: La Prairie Basins (maximum coverage)

	2002																									
1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12																											0
20																											0
21																											0
23																											0
22																											0
24																											0
25																											0
30																											0
40																											0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2							0												116	781		7	7	10	23		945
1							1												20	3681		20	12	52	55		3841
3																											0
50							0													4		47	43	42	44		179
51							0													24		69	106	153	129		482
52							1												0	106		172	240	1528	472		2518
54																				8		14	37	18	197		273
55																											0
Total	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	136	4604	0	328	445	1803	920	0	8237

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 24 Transition matrix for the La Prairie Basins sector between 1990–1991 and 2000–2002

4.6 MONTRÉAL–LONGUEUIL

A total of 24 977 ha in the Montréal–Longueuil sector were analyzed between 1990–1991 and 2000–2002, including open water and adjacent terrestrial habitats. Coverage of the sector was complete (Appendices 24 and 25).

However, the only area covered consistently in all four time periods (1970-1978, 1990-1991, 1996-1997 and 2000-2002) was the Boucherville Islands and the area downstream; it is estimated at 12 705 ha (Appendices 26 to 29).

The relative drying indices calculated for the Montréal–Longueuil sector are shown in Table 15. An analysis of the statistics shows that a slight drying trend occurred during the study period as a whole.

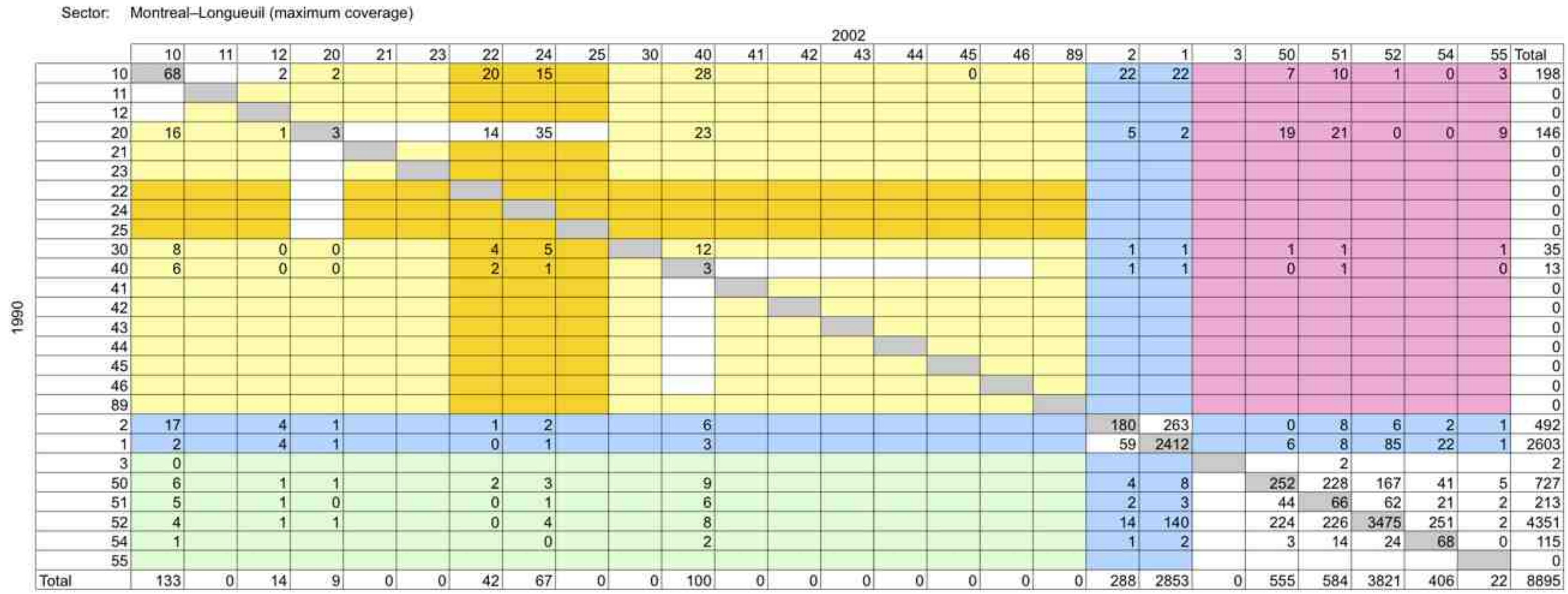
Table 15 Relative drying indices for the Montréal–Longueuil sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	–0.02
Between 1990–1991 and 1996–1997	0.04
Between 1996–1997 and 2000–2002	0.20
Between 1990–1991 and 2000–2002	0.17

4.6.1 Overall changes between 1990–1991 and 2000–2002

Wetlands in the sector as a whole decreased from 393 ha in 1990–1991 to 365 ha in 2000–2002, representing a loss of 28 ha or roughly 7% (Figure 25). Losses were estimated to be 125 ha and gains were estimated at 98 ha. When inconsistencies are excluded, losses totalled 55 ha and gains totalled 42 ha (Figure 26), resulting in a corrected wetland area of 322 ha in 1990–1991 and 309 ha in 2000–2002, for a decrease of 13 ha or 4%.

The relative drying index for the period was 0.17, showing a drying trend in wetlands in the sector (Table 15). This is consistent with the trend observed in the indices calculated for the period between 1970–1978 and 2000–2002. When changes involving open water were excluded, a stronger trend towards more terrestrial environments was observed.



Sector: Montreal–Longueuil (maximum coverage)

2002

1990

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	68		2	2			20	15			28					0			22	22		7	10	1	0	3	198
11																											0
12																											0
20	16		1	3			14	35			23								5	2		19	21	0	0	9	146
21																											0
23																											0
22																											0
24																											0
25																											0
30	8		0	0			4	5			12								1	1		1	1			1	35
40	6		0	0			2	1			3								1	1		0	1			0	13
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	17		4	1			1	2			6								180	263		0	8	6	2	1	492
1	2		4	1			0	1			3								59	2412		6	8	85	22	1	2603
3	0																						2				2
50	6		1	1			2	3			9								4	8		252	228	167	41	5	727
51	5		1	0			0	1			6								2	3		44	66	62	21	2	213
52	4		1	1			0	4			8								14	140		224	226	3475	251	2	4351
54	1							0			2								1	2		3	14	24	68	0	115
55																											0
Total	133	0	14	9	0	0	42	67	0	0	100	0	0	0	0	0	0	0	288	2853	0	555	584	3821	406	22	8895

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 25 Transition matrix for the Montréal–Longueuil sector between 1990–1991 and 2000–2002

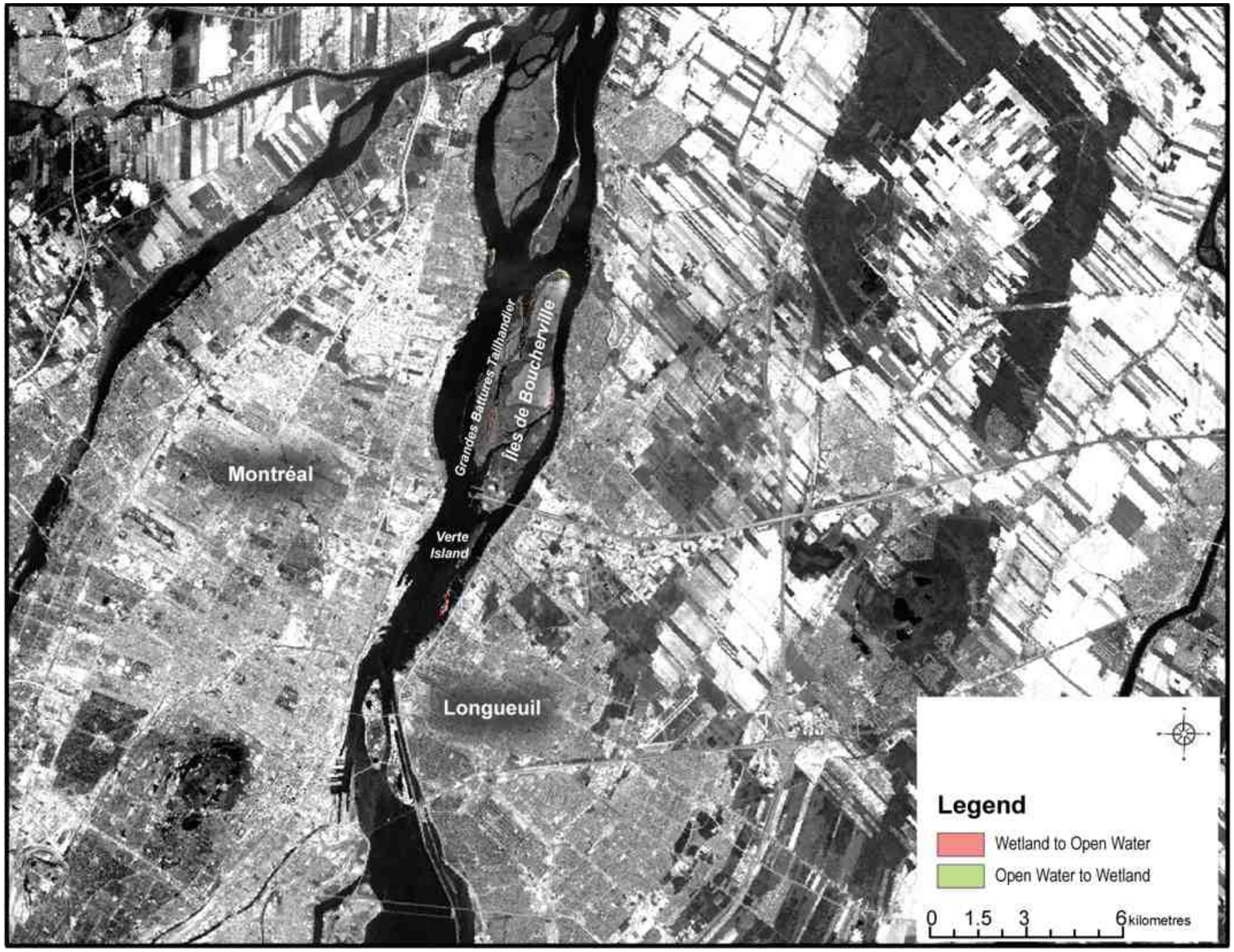


Figure 26 Losses and gains of marshes and swamps in the Montréal–Longueuil sector between 1990–1991 and 2000–2002

The only losses of wetlands retained involved conversions to open water (55 ha), involving the area around the Tailhandier Flats (Boucherville Islands) and on the shoreline of Verte Island. The wetlands that disappeared were mainly low marshes, except for an area of high marshes on the Tailhandier Flats, which was opened up for development as wildlife habitat. Setting aside this wildlife habitat development, water levels alone do not explain these changes, since levels dropped slightly during the study period (Montréal hydrometric station [Jetty No. 1] – 02OA046: 6.24 m on August 21, 1990, and 6.11 m on September 18, 2000; Montréal hydrometric station [Jetty No. 1] – 15520: 6.20 m on August 10, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). Despite this, these losses were retained given the differences in water levels between the Boucherville Islands and the hydrometric station at Jetty No. 1 (Jean Morin, personal communication).

Of the gains in wetland area observed, only those that occurred at the expense of open water were retained. A total of 42 ha of wetlands emerged from open water, in the Boucherville Islands and at Verte Island, comprising both low and high marshes and swamps. The slight drop in water levels is consistent with this observation and could in part account for this difference (see hydrometric data above).

Gains and losses not retained in the analysis are described in Appendix 30.

Several major changes within wetlands occurred in this sector. The most important progressive changes involved the conversion of 37 ha of low marshes to high marshes. The new high marshes were dominated by *Phragmites australis* (20 ha) and *Phalaris arundinacea* (15 ha), with the remaining 2 ha having no identified dominant species. The marshes in question are all found on the Tailhandier Flats. The expansion of *Phragmites australis* populations has been well documented in the literature (Hudon et al. 2005). Although *Phragmites australis* marshes can sometimes be confused with high marshes dominated by *Phalaris arundinacea*, *Phragmites* marshes were estimated to cover 42 ha in 2000–2002. In comparison, Hudon et al. (2005) estimated that 32.63 ha on the Tailhandier Flats alone were covered with this vegetation based on aerial photographs. In addition, on these same flats, 28 ha of low marshes and 23 ha of high marshes were transformed into forested swamps. Lastly, 12 ha of shrub swamps became forested swamps in 2002. The extent of the progressive changes within wetlands illustrates a trend towards more terrestrial environments, which is consistent with the relative drying index.

In terms of regressive changes within wetlands, 17 ha of high marshes, 8 ha of shrub swamps and 6 ha of forested swamps reverted to low marshes. The latter changes could be attributable to geometric problems. In addition, 12 ha of shrub and forested swamps became high marshes, half dominated by *Phragmites australis* and half by *Phalaris arundinacea*.

In 2000–2002, among the areas dominated by invasive species, a total of 67 ha of high marshes were dominated by *Phalaris arundinacea* and 42 ha by *Phragmites australis*.

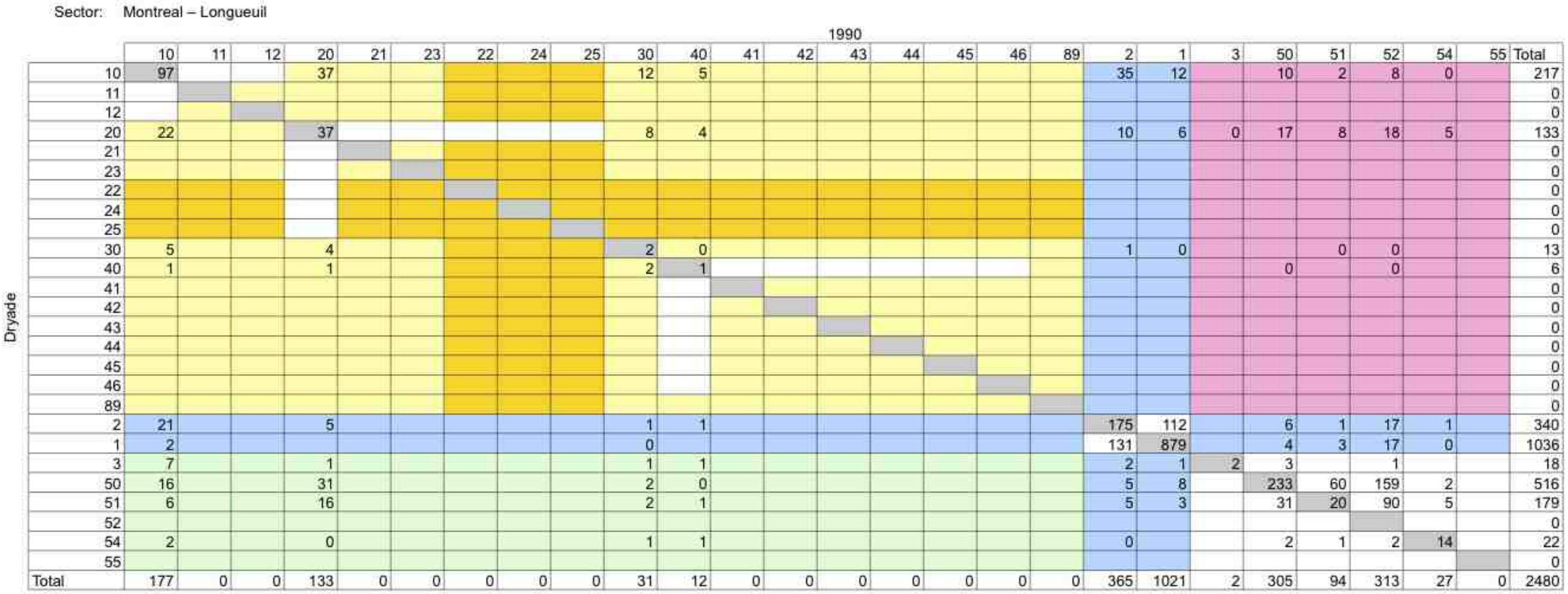
4.6.2 Partial changes between 1970–1978 and 1990–1991

During this period, the area of wetlands decreased by 17 ha from 369 ha to 352 ha, or by roughly 5% (Figure 27). Losses totalled 132 ha and gains, 115 ha. When inconsistencies are eliminated, wetland area decreased from 278 ha in the late 1970s to 237 ha in 1991. Corrected losses amounted to 41 ha and gains, zero, for a net loss of 41 ha or 15% (Figure 28).

The relative drying index for the period (Table 15) was –0.02, showing that overall only a very slight trend toward more aquatic environments occurred during the period. When changes involving open water are excluded, a moderate trend towards more terrestrial environments can be observed, however.

The most significant losses retained involved 27 ha of wetlands identified as built-up area in 1990. Although built-up areas can be confused with denuded substrate, here we are dealing with the conversion of wetlands to terrestrial environments in general. These losses occurred on the shoreline of the Boucherville Islands, Charron Island and along the channels in the Boucherville Islands. Moreover, 9 ha of wetlands were transformed into fallow land and 5 ha into forests.

Losses and gains not retained in the analysis are described in Appendix 30.



Sector: Montreal – Longueuil

1990

Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	97			37						12	5								35	12		10	2	8	0		217
11																											0
12																											0
20	22			37						8	4								10	6	0	17	8	18	5		133
21																											0
23																											0
22																											0
24																											0
25																											0
30	5			4						2	0								1	0			0	0			13
40	1			1						2	1											0		0			6
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	21			5						1	1								175	112		6	1	17	1		340
1	2									0									131	879		4	3	17	0		1036
3	7			1						1	1								2	1	2	3		1			18
50	16			31						2	0								5	8		233	60	159	2		516
51	6			16						2	1								5	3		31	20	90	5		179
52																											0
54	2			0						1	1								0			2	1	2	14		22
55																											0
Total	177	0	0	133	0	0	0	0	0	31	12	0	0	0	0	0	0	0	365	1021	2	305	94	313	27	0	2480

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 27 Transition matrix for the portion of the Montréal–Longueuil sector covered between 1970–1978 and 1990–1991

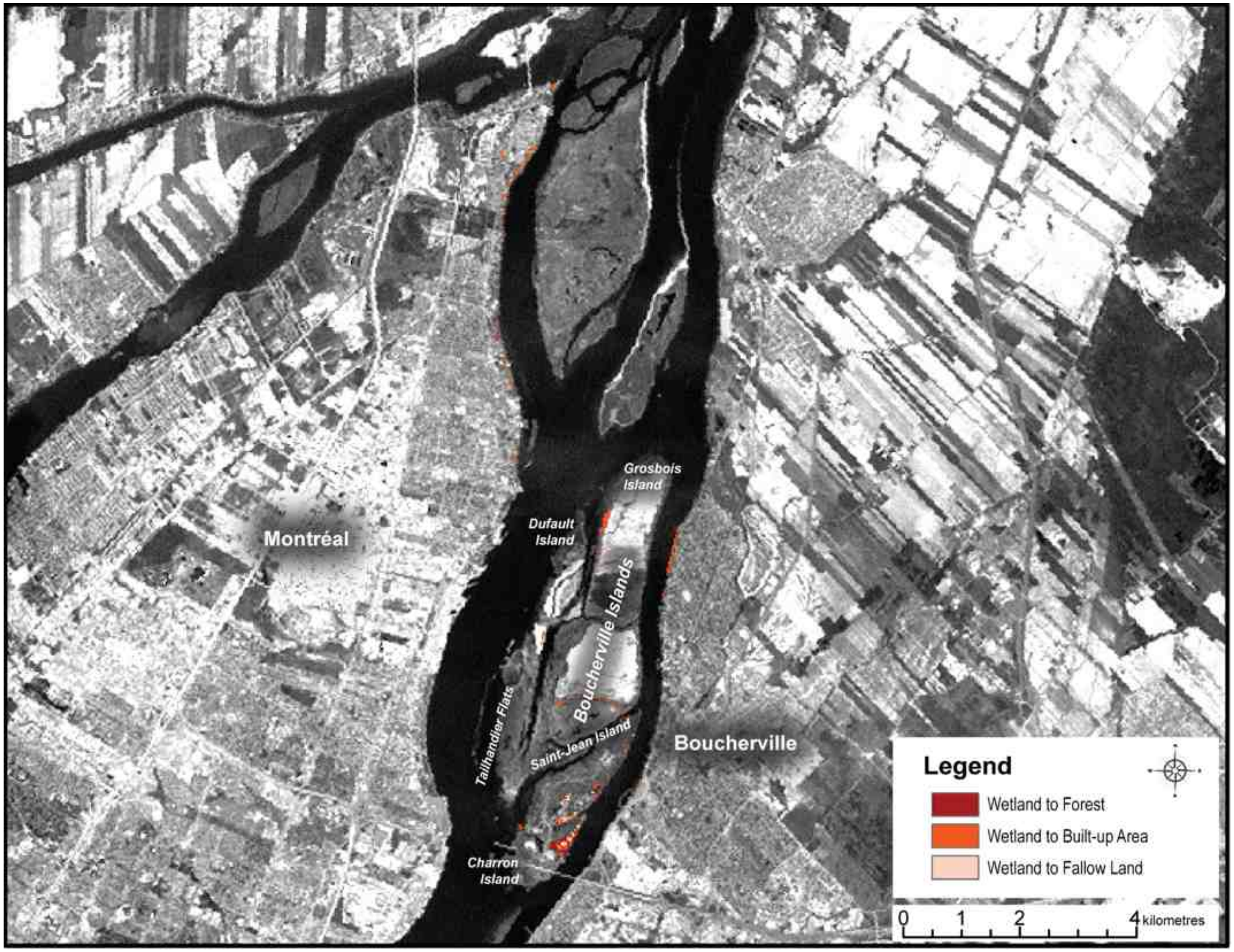


Figure 28 Losses and gains of marshes and swamps for the portion of the Montréal–Longueuil sector covered between 1970–1978 and 1990–1991

Some progressive changes within wetlands stand out, the main one being the conversion of 37 ha of low marshes to high marshes on the Tailhandier Flats. In addition, 12 ha of low marshes became shrub swamps in the same location. Lastly, 8 ha of high marshes were transformed into shrub swamps. Other internal changes involved 6 ha or less.

The only significant regressive change observed within wetlands was the transformation of 22 ha of high marshes to low marshes, mainly on the Tailhandier Flats.

4.6.3 Partial changes between 1990–1991 and 1996–1997

During this six-year period, the area of wetlands decreased from 352 ha in 1990–1991 to 278 ha in 1996–1997 (Figure 29). Gains totalled 47 ha and losses totalled 122 ha. When inconsistencies are eliminated, wetland area totalled 311 ha in 1990 and 257 ha in 1996, for a net loss of 54 ha or 17%. Retained losses and gains were 83 ha and 26 ha, respectively (Figure 30).

The relative drying index for the period (Table 15) was 0.04, showing that, overall, only a slight drying of wetlands occurred during the period. When changes linked to open water are excluded, this trend towards more terrestrial environments is accentuated.

Of the losses retained during this period, the most significant were 76 ha of wetland transformed into open water. These changes may be due to water levels (Montréal hydrometric station [Jetty No. 1] – 02OA046: 6.24 m on August 21, 1990, and 6.37 m on October 17, 1996; source: HYDAT 2001). In addition, a loss of 7 ha of wetlands to fallow land occurred in three specific locations in the Boucherville Islands: the western point of Saint-Jean Island, near the area of dredge spoil deposits on the Tailhandier Flats, and on the southeastern side of Grosbois Island.

The only gains retained involved the transformation of 26 ha of open water into wetlands on the northernmost end of the Boucherville Islands. This change cannot be explained by water levels (Montréal hydrometric station [Jetty No. 1] – 02OA046: 6.24 m on August 21, 1990, and 6.37 m on October 17, 1996; source: HYDAT 2001).

Sector: Montreal – Longueuil

	1997																										
1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	41			1			10	21		32									46	5	0	8	4	1	7		177
11																											0
12																											0
20	10			1			3	53		26									15	0	0	18	3	1	2		133
21																											0
23																											0
22																											0
24																											0
25																											0
30	5			1			2	5		10									6	0		1	0		1		31
40	3			0			1	1		3									3	0		0	0	0	1		12
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	4			3			1	4		6									147	179	1	3	3	3	12		365
1	3			0			0	4		3									44	951	1	3	1	3	9		1021
3										0												0	0	0	2		2
50	3			0			0	4		2									9	7	0	155	69	7	48		305
51	0			0				1		0									3	1		31	32	3	23		94
52	3			1				4		3									15	22	1	147	16	27	76		313
54				0				0											1	0		0	6	0	19		27
55																											0
Total	72	0	0	8	0	0	16	96	0	85	0	0	0	0	0	0	0	0	289	1165	3	366	134	45	199	0	2480

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 29 **Transition matrix for the portion of the Montréal–Longueuil sector covered between 1990–1991 and 1996–1997**

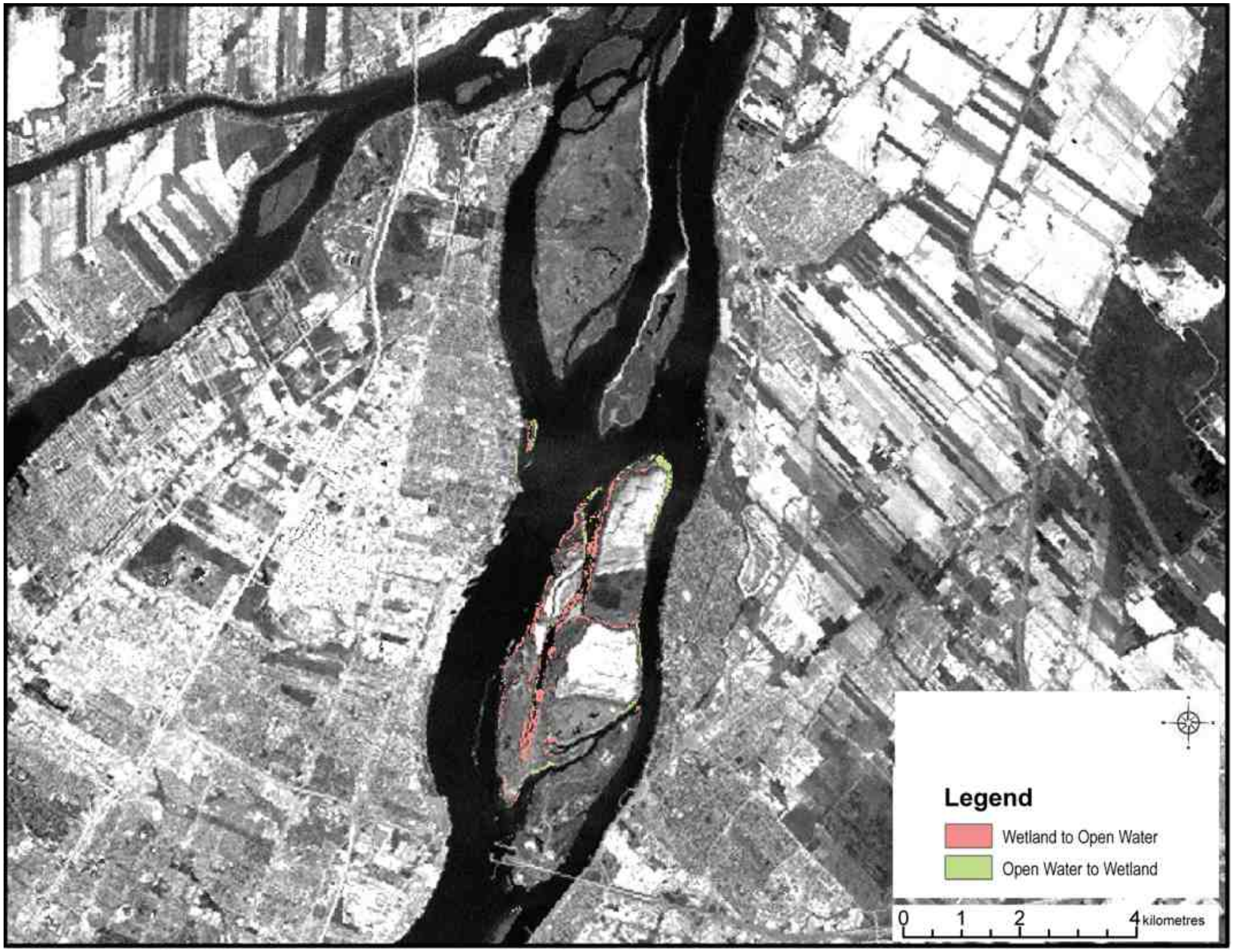


Figure 30 Losses and gains of marshes and swamps in the portion of the Montréal–Longueuil sector covered between 1990–1991 and 1996–1997

This change was retained, however, due to the significant hydrometric differences in the values recorded at the Jetty No. 1 station and those observed in the Boucherville Islands (Jean Morin, personal communication).

Gains and losses not retained in the analysis are described in Appendix 30.

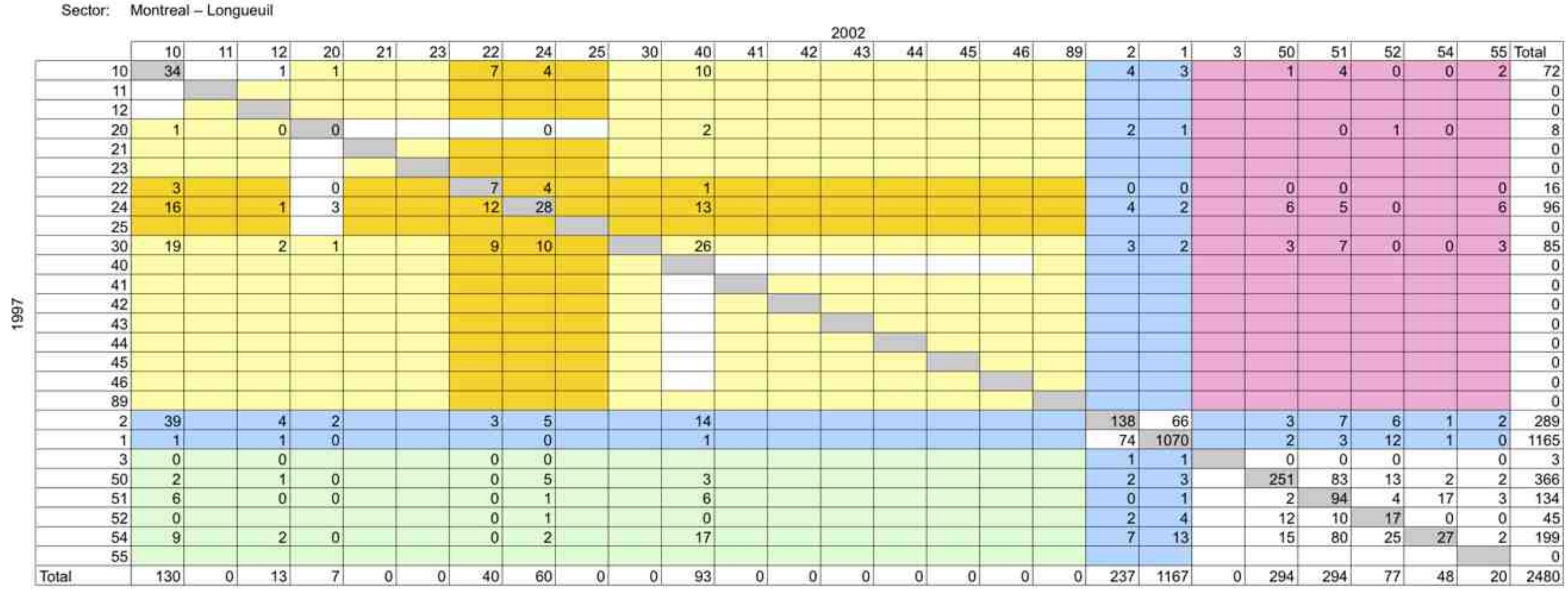
In terms of progressive changes within wetlands, the most significant involved 32 ha of low marshes converted to high marshes; 21 ha of the new high marshes were dominated by *Phalaris arundinacea*, and 10 ha by *Phragmites australis*, both on the Tailhandier Flats. In addition, 32 ha of low marshes on these flats and on Dufault Island (Boucherville Islands) were transformed into shrub swamps. Lastly, 26 ha of high marshes became shrub swamps, mainly on and around the Tailhandier Flats (particularly on Île aux Raisins).

Among the regressive changes observed within wetlands, the most significant was 10 ha of high marshes that reverted to low marshes, mainly on the Tailhandier Flats. In addition, 10 ha of shrub and forested swamps were converted to high marshes, 6 ha of which were dominated by *Phalaris arundinacea* and 3 ha by *Phragmites australis.*

In 1996–1997, marsh areas dominated by invasive species consisted of an estimated 306 ha of high marshes dominated by *Phalaris arundinacea* and 18 ha by *Phragmites australis*.

4.6.4 Partial changes between 1996–1997 and 2000–2002

During this period, the area of wetlands increased from 278 ha in 1996–1997 to 342 ha in 2000–2002, an increase of 64 ha or roughly 23% (Figure 31). Losses totalled 62 ha and gains, 126 ha. When inconsistencies are excluded, corrected wetland area totalled 240 ha in 1996–1997 and 285 ha in 2002, representing an increase of 45 ha or 19%. Corrected values for losses and gains amounted to 23 ha and 70 ha, respectively (Figure 32).



Sector: Montreal – Longueuil

		2002																									
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1997	10	34		1	1			7	4			10								4	3		1	4	0	0	2	72
	11																											0
	12																											0
	20	1		0	0				0			2								2	1			0	1	0		8
	21																											0
	23																											0
	22	3			0			7	4			1								0	0		0	0			0	16
	24	16		1	3			12	28			13								4	2		6	5	0		6	96
	25																											0
	30	19		2	1			9	10			26								3	2		3	7	0	0	3	85
	40																											0
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2	39		4	2			3	5			14								138	66		3	7	6	1	2	289
	1	1		1	0				0			1								74	1070		2	3	12	1	0	1165
	3	0		0				0	0											1	1		0	0	0		0	3
	50	2		1	0			0	5			3								2	3		251	83	13	2	2	366
	51	6		0	0			0	1			6								0	1		2	94	4	17	3	134
	52	0						0	1			0								2	4		12	10	17	0	0	45
	54	9		2	0			0	2			17								7	13		15	80	25	27	2	199
	55																											0
Total		130	0	13	7	0	0	40	60	0	0	93	0	0	0	0	0	0	0	237	1167	0	294	294	77	48	20	2480

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 31 Transition matrix for the portion of the Montréal–Longueuil sector covered between 1996–1997 and 2000–2002

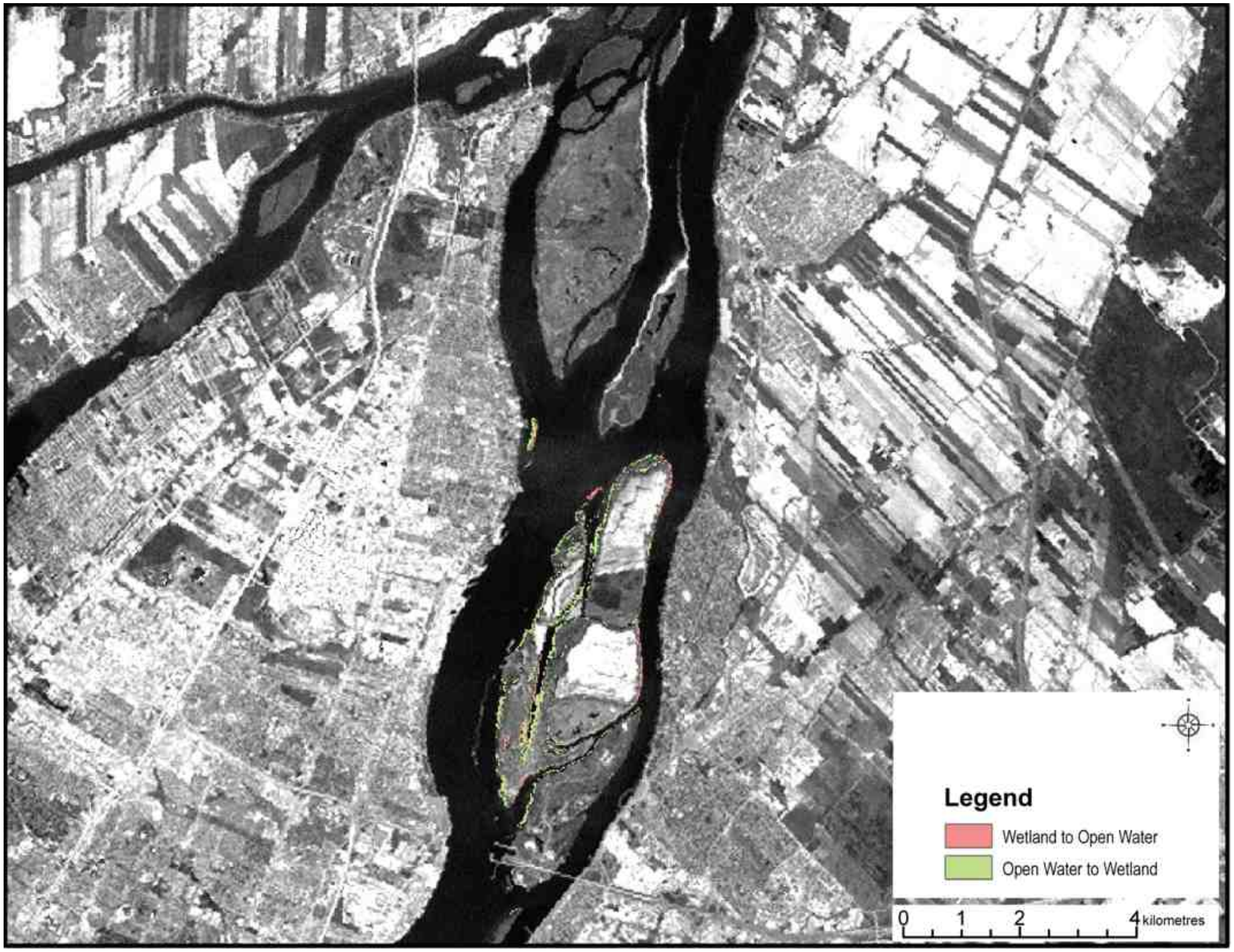


Figure 32 Losses and gains of marshes and swamps in the portion of the Montréal–Longueuil sector covered between 1996–1997 and 2000–2002

The relative drying index for the period (Table 15) was 0.20, illustrating, overall, a moderate drying trend during the period. When changes involving open water are excluded, a null result is obtained, indicating the absence of a trend in wetland changes.

The only losses retained for the purposes of our analysis were 23 ha of wetlands around the Boucherville Islands which were lost to open water. However, recorded water levels cannot explain this loss since they decreased from 6.37 m to 6.20 m (Montréal hydrometric station [Jetty No. 1] – 02OA046: 6.37 m on October 17, 1996, and 6.20 m on August 10, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). This loss was nonetheless retained due to the significant differences between hydrometric readings at the Jetty No. 1 station and the Boucherville Islands (Jean Morin, personal communication).

The only gains retained for this period involved 70 ha of open water that were transformed into wetlands, mainly on the Tailhandier Flats. They could be linked to the 17-cm drop in water levels that occurred after the image was acquired in 1997 (see above).

Losses and gains not retained in the analysis are described in Appendix 30.

Among changes within wetlands, several progressive changes are apparent, including 26 ha of shrub swamps that became forested swamps on the Tailhandier Flats (Île aux Raisins and Dufault Island). Similarly, on the Tailhandier Flats, 12 ha of low marshes and 18 ha of high marshes were transformed into forested swamps, and 12 ha of low marshes became high marshes (7 ha dominated by *Phragmites australis* and 4 ha by *Phalaris arundinacea*).

Regressive changes observed within wetlands included 21 ha of high marsh that reverted to low marsh; 16 ha were dominated by *Phalaris arundinacea* (dispersed over the sector) and 3 ha by *Phragmites australis* (on the Tailhandier Flats). In addition, 21 ha of shrub swamps reverted to low marshes (mainly on Dufault Island). Lastly, 20 ha of shrub swamps were replaced by high marshes, 10 ha dominated by *Phalaris arundinacea* and 9 ha by *Phragmites australis*.

The area dominated by invasive plant species decreased from 324 ha to 174 ha, or by 150 ha. High marshes dominated by *Phalaris arundinacea* shrank from 306 ha to 126 ha, a loss largely due to the confusion between this class and fallow land. Lastly, the area of high marshes dominated by *Phragmites australis* rose from 18 ha to 48 ha.

4.7 VARENNES–CONTRECŒUR

A total of 18 815 ha (including open water and adjacent terrestrial habitats) in the Varennes–Contrecœur sector were analyzed in both 1990–1991 and 2000–2002 (Appendices 32 and 33). Coverage of the sector was complete, except for an area masked by cloud cover near the Contrecœur Islands.

In addition, two subsectors—Sainte-Thérèse Island and the Varennes Islands—were analyzed in all four time periods (1970-1978, 1990-1991, 1996-1997 and 2000-2002). The total area of these sectors was estimated to be 2759 ha (Appendices 34 to 37). An area of roughly 4442 ha around the Contrecoeur Islands was also examined in all time periods (Appendices 38 to 41).

Relative wetland drying indices for the Varennes–Contrecœur sector are shown in Table 16. An examination of these statistics shows that a slight relative drying trend occurred during the entire study period.

Table 16 Relative drying indices for the Varennes–Contrecœur sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991 (Sainte-Thérèse Island and Varennes Islands)	0.09
Between 1990–1991 and 1996–1997 (Sainte-Thérèse Island and Varennes Islands)	0.15
Between 1996–1997 and 2000–2002 (Sainte-Thérèse Island and Varennes Islands)	–0.18
Between 1970–1978 and 1990–1991 (Contrecœur Islands)	0.73
Between 1990–1991 and 1996–1997 (Contrecœur Islands)	–0.21
Between 1996–1997 and 2000–2002 (Contrecœur Islands)	0.62
Between 1990–1991 and 2000–2002	0.19

4.7.1 Overall changes between 1990–1991 and 2000–2002

Between 1990–1991 and 2000–2002, wetlands in the sector increased from 1038 ha to 1143 ha, an increase of 105 ha or roughly 10% (Figure 33). Estimated losses were 259 ha and gains, 364 ha. When inconsistencies are excluded, losses total 80 ha and gains total 155 ha

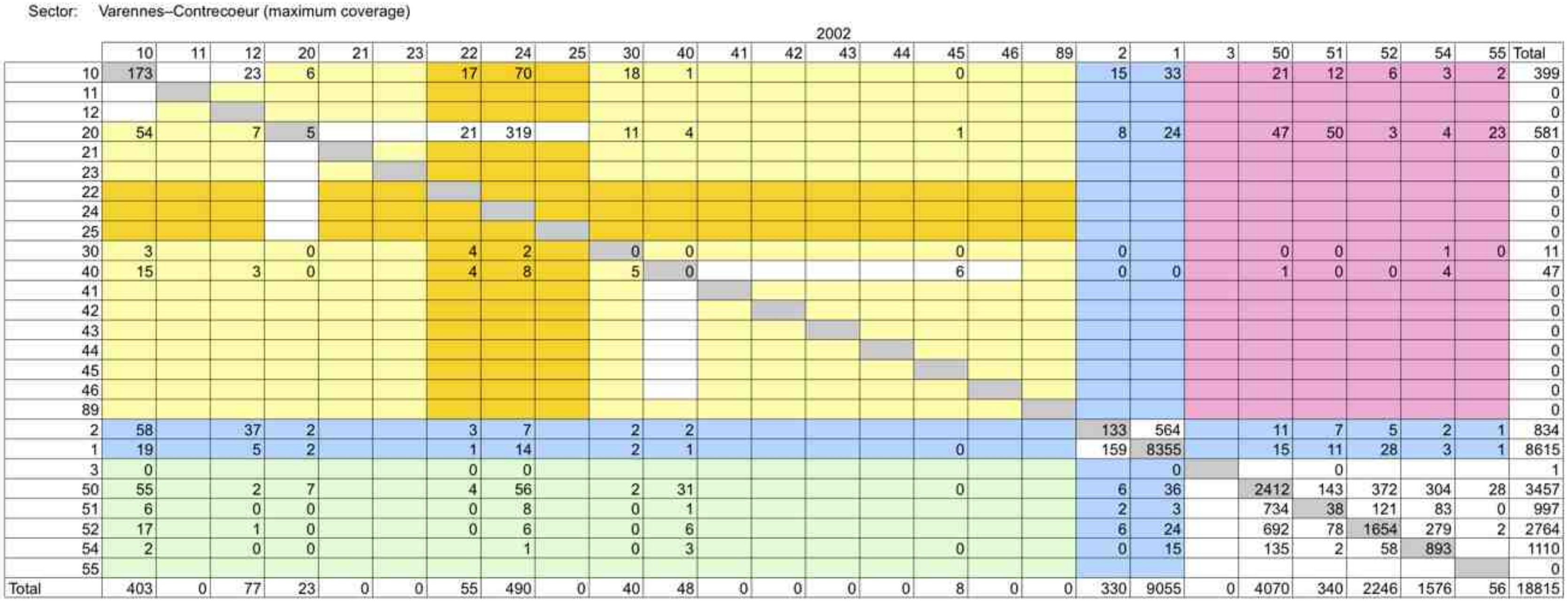
(Figure 34). The corrected area of wetland was 860 ha for 1990 and 934 ha for 2000–2002, representing an increase of 74 ha or 9%.

The relative drying index for the period is 0.19, showing a drying trend in the sector (Table 16). This is consistent with the trend observed in the indices for the analysis involving all four datasets to maximize temporal coverage—which was moderately negative in the Contrecœur Islands subsector for the period between 1990–1991 and 1996–1997, but strongly positive for the period between 1996–1997 and 2000–2002. When changes involving open water are excluded, a trend towards more terrestrial environments was observed.

The only losses retained involved 80 ha of low marshes lost to open water, which occurred on several islands, along channels between islands and along shorelines. The slight differences between water levels measured when the images were captured do not allow these changes to be clearly explained (Contrecœur hydrometric stations 02OJ021 and IOC – 02OJ034: 4.93 m on August 21, 1990; source: HYDAT 2001; Contrecœur hydrometric station IOC – 15780: 4.90 m on August 13, 2002; source: Marine Environmental Data Service, Fisheries and Oceans Canada). Erosion phenomena, among other possibilities, could help explain some of these differences at least partially.

Gains in wetlands retained during the period totalled 155 ha and occurred at the expense of open water (which sometimes includes submerged vegetation). This phenomenon was observed around islands and along shorelines throughout the sector. In addition, several ponds seemed to be filling in with vegetation on Bouchard Island and in closed-off bays in the Îles de Contrecœur National Wildlife Area. As stated earlier, differences in water levels between the two periods are too small to allow these changes in wetlands to be linked to water level fluctuations in the St. Lawrence River, and other factors are very likely at play.

Losses and gains not retained in the analysis are described in Appendix 42.



Sector: Varennes–Contrecoeur (maximum coverage)

	2002																										
1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	173		23	6			17	70		18	1					0			15	33		21	12	6	3	2	399
11																											0
12																											0
20	54		7	5			21	319		11	4					1			8	24		47	50	3	4	23	581
21																											0
23																											0
22																											0
24																											0
25																											0
30	3			0			4	2		0	0					0			0			0	0		1	0	11
40	15		3	0			4	8		5	0					6			0	0		1	0	0	4		47
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	58		37	2			3	7		2	2								133	564		11	7	5	2	1	834
1	19		5	2			1	14		2	1					0			159	8355		15	11	28	3	1	8615
3	0						0	0												0			0				1
50	55		2	7			4	56		2	31					0			6	36		2412	143	372	304	28	3457
51	6		0	0			0	8		0	1								2	3		734	38	121	83	0	997
52	17		1	0			0	6		0	6								6	24		692	78	1654	279	2	2764
54	2		0	0				1		0	3					0			0	15		135	2	58	893		1110
55																											0
Total	403	0	77	23	0	0	55	490	0	40	48	0	0	0	0	8	0	0	330	9055	0	4070	340	2246	1576	56	18815

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 33 Transition matrix for the Varennes–Contrecoeur sector between 1990–1991 and 2000–2002

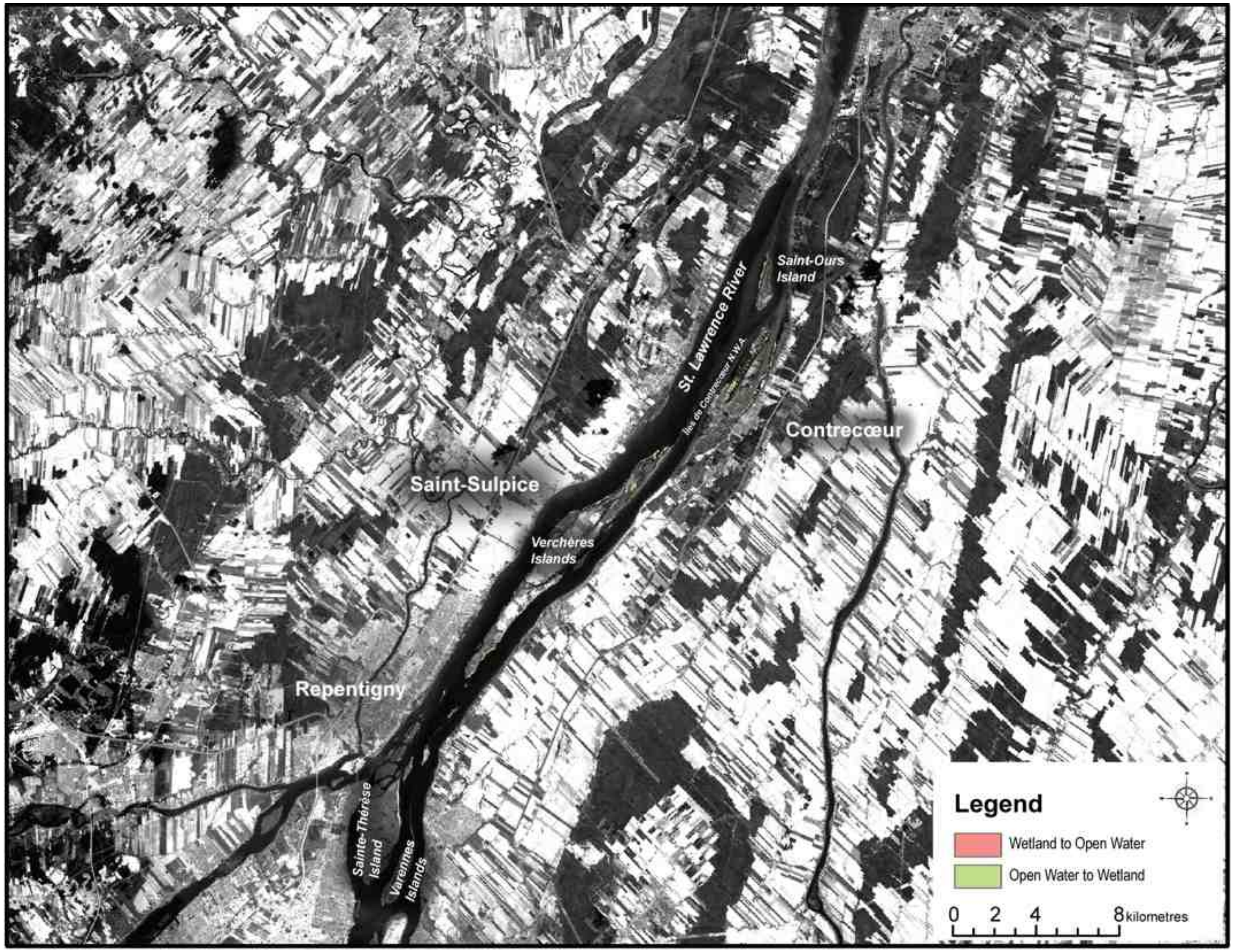


Figure 34 **Losses and gains of marshes and swamps in the Varennes–Contrecœur sector between 1990–1991 and 2000–2002**

A number of changes within wetlands were observed. Progressive changes included 93 ha of low marshes that were transformed into high marshes. Of these high marshes, an area of 70 ha is dominated by *Phalaris arundinacea* (in the Îles de Contrecœur National Wildlife Area and on the north shore of the St. Lawrence River between Repentigny and Saint-Sulpice) A 17-ha area is dominated by P*hragmites australis* (concentrated in the Îles de Contrecœur National Wildlife Area); no dominant species was identified in the remaining 6 ha. In addition, 18 ha of low marshes became shrub swamps; this type of change occurred in scattered locations with some concentration in the Îles de Contrecœur National Wildlife Area. Lastly, in the Verchères Islands, 11 ha of high marshes became shrub swamps.

Regressive changes included 61 ha of high marshes that reverted to low marshes, found in small concentrations throughout the territory (except on Grande Île). In addition, 18 ha of forested swamps reverted to low marshes, on Saint-Ours Island and Bouchard Island. On the same two islands, 12 ha of forested swamps became high marshes (8 ha dominated by *Phalaris arundinacea* and 4 ha by *Phragmites australis*). Additionally, 6 ha of shrub swamps were converted to high marshes (2 ha dominated by *Phalaris arundinacea* and 4 ha by *Phragmites australis*).

In 2000–2002, *Phalaris arundinacea* occupied 490 ha, while *Phragmites australis* was dominant on 55 ha.

4.7.2 Partial changes on Sainte-Thérèse Island and the Varennes Islands

4.7.2.1 Between 1970–1978 and 1990–1991

During this period, the area of wetlands on Sainte-Thérèse Island and the Varennes Islands went from from 196 ha to 187 ha, a decrease of 9 ha or roughly 5% (Figure 35). Estimated losses totalled 108 ha and gains, 99 ha. When inconsistencies were eliminated, wetland area during the period decreased from 99 ha to 88, for a net loss of 11 ha or 11%. An estimated 11 ha were retained as losses, but there were no gains (Figure 36).

Sector: Sainte-Thérèse Island and Varennes Islands

	1990																										
Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	15			36						1	0								17	19		14	1	4			108
11																											0
12																											0
20	3			29						1									3	4	0	36	3	5	1		84
21																											0
23																											0
22																											0
24																											0
25																											0
30				2						0												2					4
40																				0							0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	11			7						0	0								80	184	0	9	1	4	1		298
1	3			1															114	1452		2	0	2	0		1573
3				3															0	11		3		0	1		18
50	1			2						0									1	1		225	1	18	1		249
51	12			59															8	18	0	264	11	47	6		425
52																											0
54																							0	0			0
55																											0
Total	44	0	0	140	0	0	0	0	0	2	0	0	0	0	0	0	0	0	223	1689	0	554	16	80	10	0	2759

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 35 Transition matrix for the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1970–1978 and 1990–1991

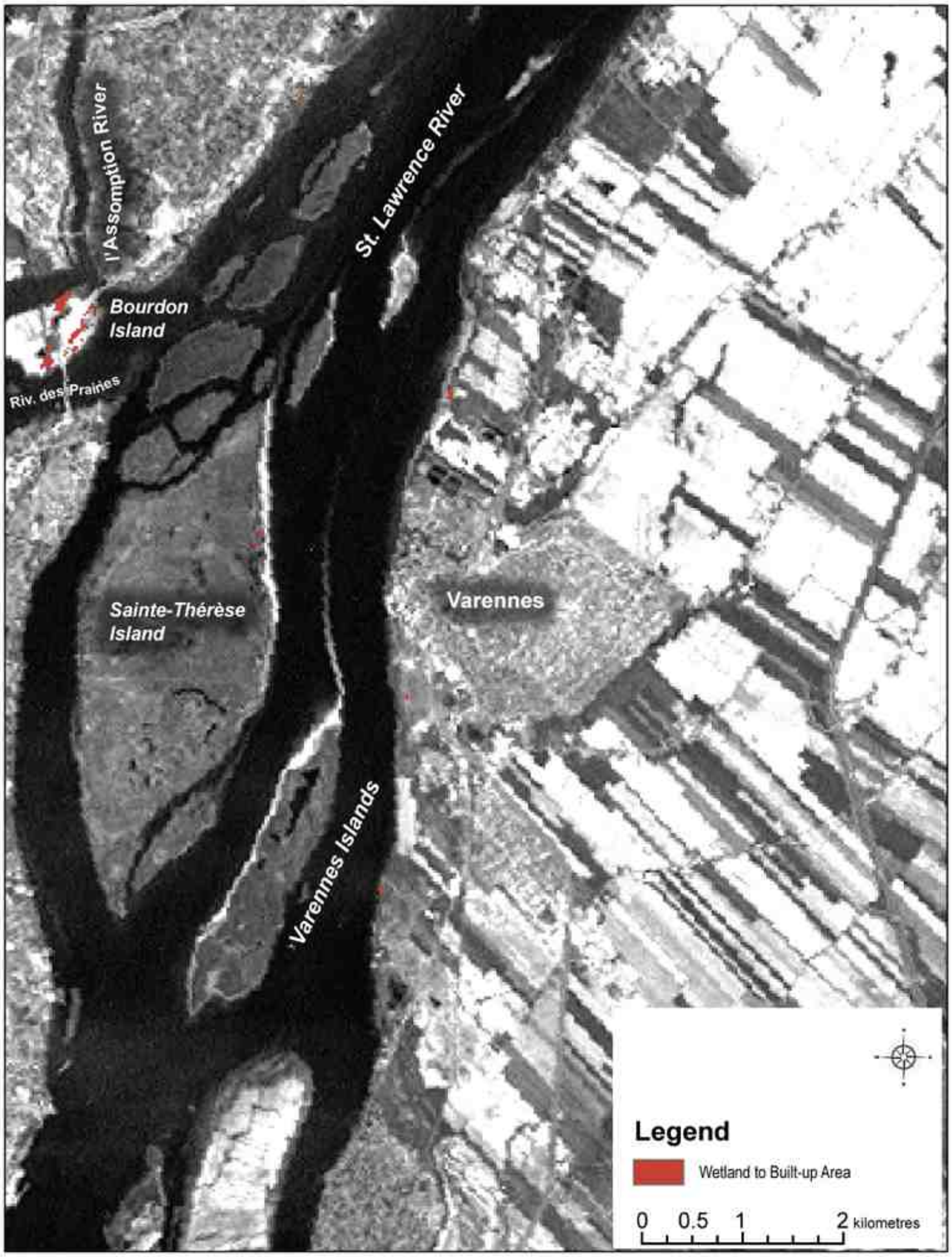


Figure 36 **Losses and gains of marshes and swamps in the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1970–1978 and 1990–1991**

The relative drying index for the period was 0.09 (Table 16), indicating the absence of any general trend in changes within wetlands. When changes involving open water are excluded, a strong drying trend is observed in the sectors' marshes.

Although losses retained totalled 11 ha, no single type exceeded the 10-ha limit set for the analysis. The greatest losses (8 ha) involved wetlands replaced by built-up areas (including roads); they are concentrated mainly on Bourdon Island, at the confluence of the Rivière des Prairies and L'Assomption River. The other losses retained, observed in Varennes, were wetlands converted to fallow land (3 ha).

Losses and gains not retained in the analysis are described in Appendix 42.

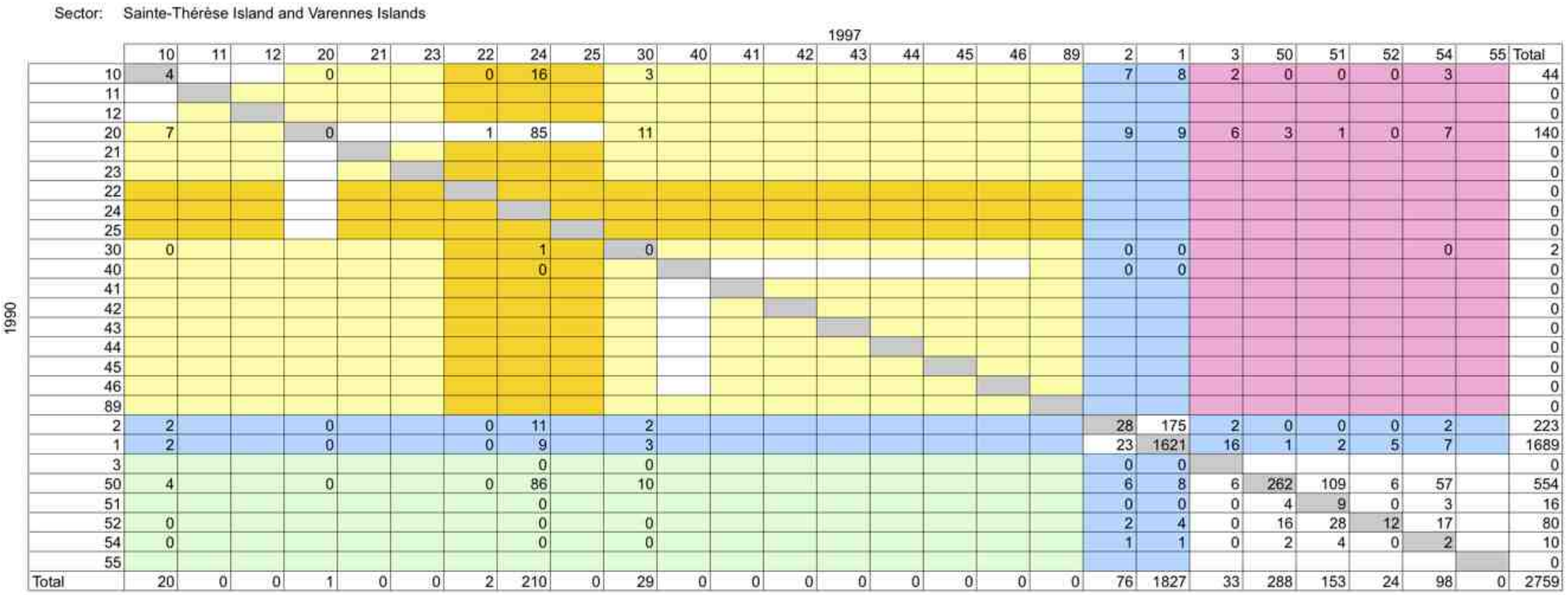
Changes within wetlands during this period involved only a small area. Progressive changes included 37 ha of low marshes replaced by high marshes (36 ha) and shrub swamps (1 ha), which occurred on various islands. In addition, 1 ha of high marsh became shrub swamp.

Regressive changes between wetland categories were small, as indicated by the value of the relative drying index for the period. On both ends of Sainte-Thérèse Island, 3 ha of high marshes reverted to low marshes and, in the southern part of the island, 2 ha of shrub swamps were transformed into high marshes.

No areas dominated by invasive species were identified during the period.

4.7.2.2 Between 1990–1991 and 1996–1997

During this period, the area of wetlands increased from 187 ha to 261 ha, an increase of 74 ha or 40% (Figure 37). Estimated losses totalled 57 ha and gains, 131 ha. When inconsistencies are eliminated, wetland area decreased from 172 ha in 1990–1991 to 160 ha in 1996–1997, for a net loss of 12 ha or 7%. Losses retained totalled 42 ha and gains, 29 ha (Figure 38).



Sector: Sainte-Thérèse Island and Varennes Islands

													1997													
1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	4			0			0	16		3									7	8	2	0	0	0	3		44
11																											0
12																											0
20	7			0			1	85		11									9	9	6	3	1	0	7		140
21																											0
23																											0
22																											0
24																											0
25																											0
30	0							1		0									0	0					0		2
40								0											0	0							0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	2			0			0	11		2									28	175	2	0	0	0	2		223
1	2			0			0	9		3									23	1621	16	1	2	5	7		1689
3								0		0									0	0							0
50	4			0			0	86		10									6	8	6	262	109	6	57		554
51								0											0	0	0	4	9	0	3		16
52	0							0		0									2	4	0	16	28	12	17		80
54	0							0		0									1	1	0	2	4	0	2		10
55																											0
Total	20	0	0	1	0	0	2	210	0	29	0	0	0	0	0	0	0	0	76	1827	33	288	153	24	98	0	2759

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 37 Transition matrix for the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1990–1991 and 1996–1997

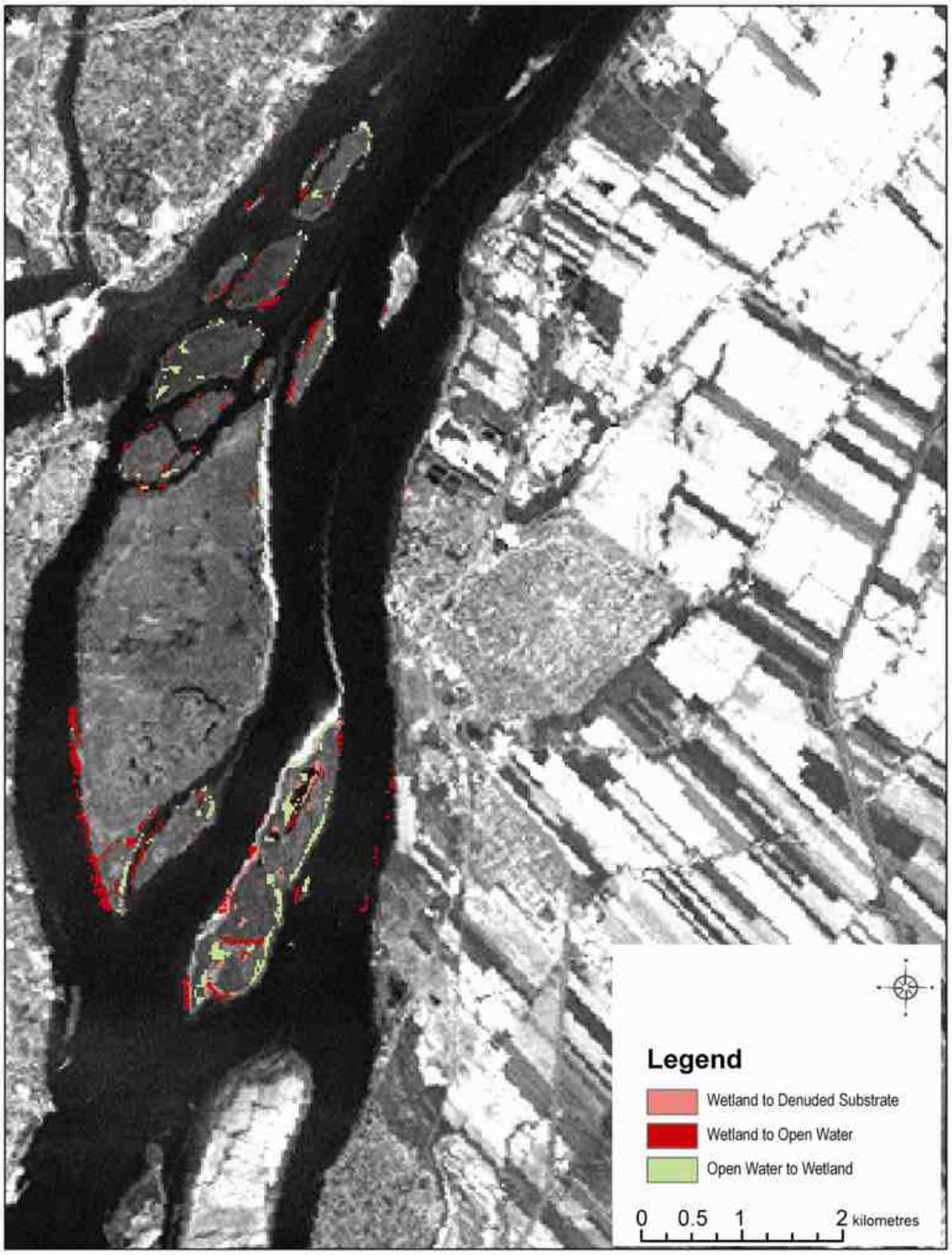


Figure 38 Losses and gains of marshes and swamps in the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1990–1991 and 1996–1997

The relative drying index for the period (Table 16) was 0.15, showing a slight overall drying trend during the period. When changes involving open water are excluded, a stronger trend towards more terrestrial environments is observed.

The most significant losses retained involved 34 ha lost to open water. Water levels could be responsible for these changes (hydrometric station no. 02OA046 [Jetty No. 1]: 6.24 m on August 21, 1990, and 6.37 m on October 17, 1996; source: HYDAT 2001). In addition, 8 ha of wetlands on the Varennes Islands were replaced by denuded substrate.

The only gains retained (29 ha) occurred at the expense of open water. They were observed around the edge and in the interior of several islands. Differences in water levels cannot explain these gains (see above). They were retained, however, due to the significant hydrometric differences between the values recorded at the Jetty No. 1 station and those recorded southeast of the St. Lawrence Seaway (Jean Morin, personal communication).

Losses and gains not retained in the analysis are described in Appendix 42.

Changes within wetlands included 30 ha of progressive changes. They included 19 ha of low marshes that were transformed into high marshes dominated by *Phalaris arundinacea* (16 ha) and shrub swamps (3 ha). In addition, 11 ha of high marshes became shrub swamps.

The most significant regressive changes involved the transformation of 7 ha of high marshes into low marshes, while 1 ha of shrub swamp reverted to high marsh dominated by *Phalaris arundinacea*.

The area dominated by invasive species (almost exclusively *Phalaris arundinacea*) was estimated at 212 ha in 1996–1997; of this, 86 ha seem to be used for agriculture.

4.7.2.3 Between 1996–1997 and 2000–2002

During this period, the area of wetlands decreased from 261 ha in 1996–1997 to 251 ha in 2000–2002, representing a decline of 10 ha or 4%. Losses totalled 179 ha and gains, 169 ha. When inconsistencies are eliminated, the corrected wetland area was 103 ha in 1996–1997 and 107 ha in 2000–2002, representing an increase of 4 ha or 4%. The corrected losses were estimated at 20 ha and gains at 24 ha (Figure 40).

The relative wetland drying index for the period (Table 16) is –0.18, showing that wetlands became slightly wetter overall during the period. When changes involving open water are excluded, this trend becomes accentuated and can be described as moderate.

The only losses retained (20 ha) involved conversions to open water. However, water levels cannot explain these losses since levels decreased from 6.37 m to 6.20 m (hydrometric station no. 02OA046 [Jetty No. 1]: 6.37 m on October 17, 1996, and 6.20 m on August 10, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). This loss was nonetheless retained owing to the significant hydrometric differences between the Jetty No. 1 station and the analyzed portion (Jean Morin, personal communication).

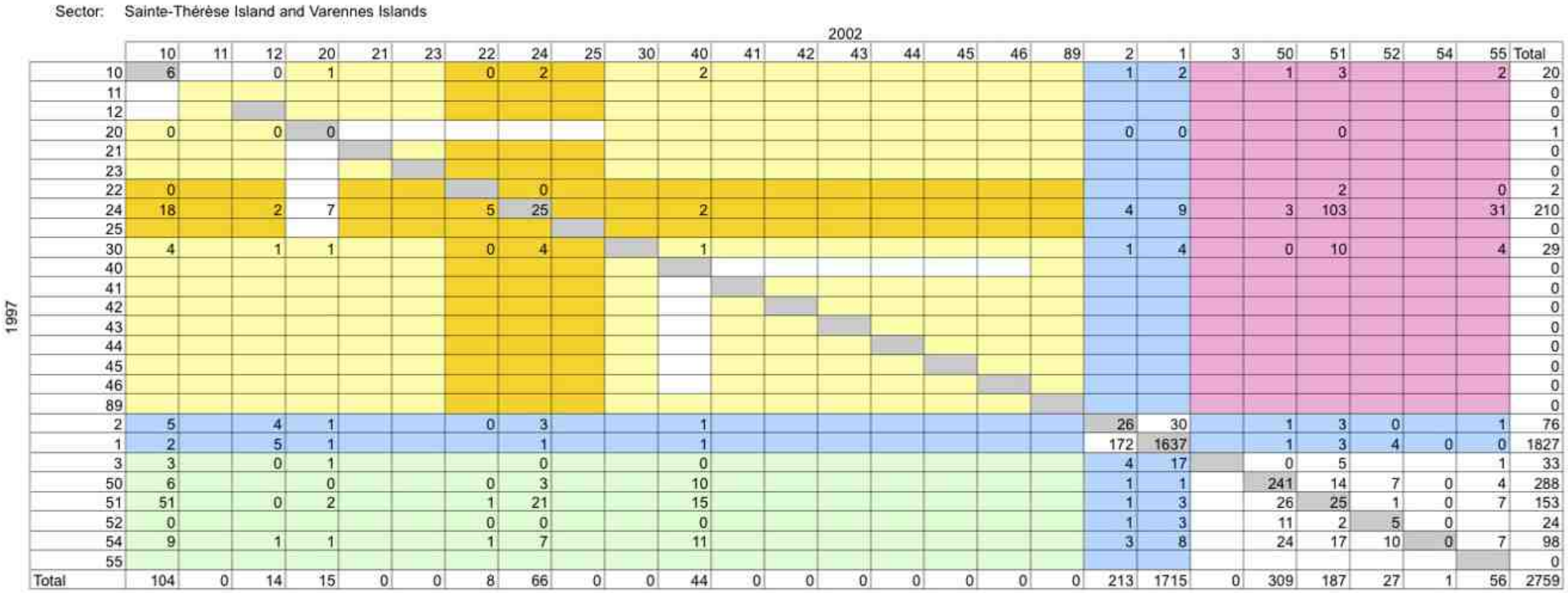
The only gains retained for the period involved 24 ha of wetlands gained at the expense of open water. They may be related to the 17-cm drop in water levels in relation to those recorded when the image was acquired in 1997 (see above).

Losses and gains not retained in the analysis are described in Appendix 42.

Among changes within wetlands, very few progressive changes can be seen. A total of 5 ha of low marshes were transformed into either high marshes (3 ha, 2 ha of which were dominated by *Phalaris arundinacea*) or forested swamps (2 ha). In addition, 2 ha of high marshes and 1 ha of shrub swamps became forested swamps.

Regressive changes were a little more significant. A total of 25 ha of low marshes were formed at the expense of high marshes (20 ha) and shrub swamps (5 ha). In addition, 5 ha of shrub swamps reverted to high marshes, 4 ha of which are dominated by *Phalaris arundinacea.*

The area of wetlands dominated by invasive species decreased from 212 ha to 74 ha during the period. The 1996–1997 estimates were strongly biased by the overestimation of wetlands at this time.



Sector: Sainte-Thérèse Island and Varennes Islands

	2002																										
1997	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	6		0	1			0	2			2								1	2		1	3			2	20
11																											0
12																											0
20	0		0	0															0	0			0				1
21																											0
23																											0
22	0							0															2			0	2
24	18		2	7			5	25			2								4	9		3	103			31	210
25																											0
30	4		1	1			0	4			1								1	4		0	10			4	29
40																											0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	5		4	1			0	3			1								26	30		1	3	0		1	76
1	2		5	1				1			1								172	1637		1	3	4	0	0	1827
3	3		0	1				0			0								4	17		0	5			1	33
50	6			0			0	3			10								1	1		241	14	7	0	4	288
51	51		0	2			1	21			15								1	3		26	25	1	0	7	153
52	0						0	0			0								1	3		11	2	5	0		24
54	9		1	1			1	7			11								3	8		24	17	10	0	7	98
55																											0
Total	104	0	14	15	0	0	8	66	0	0	44	0	0	0	0	0	0	0	213	1715	0	309	187	27	1	56	2759

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 39 Transition matrix for the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1996–1997 and 2000–2002

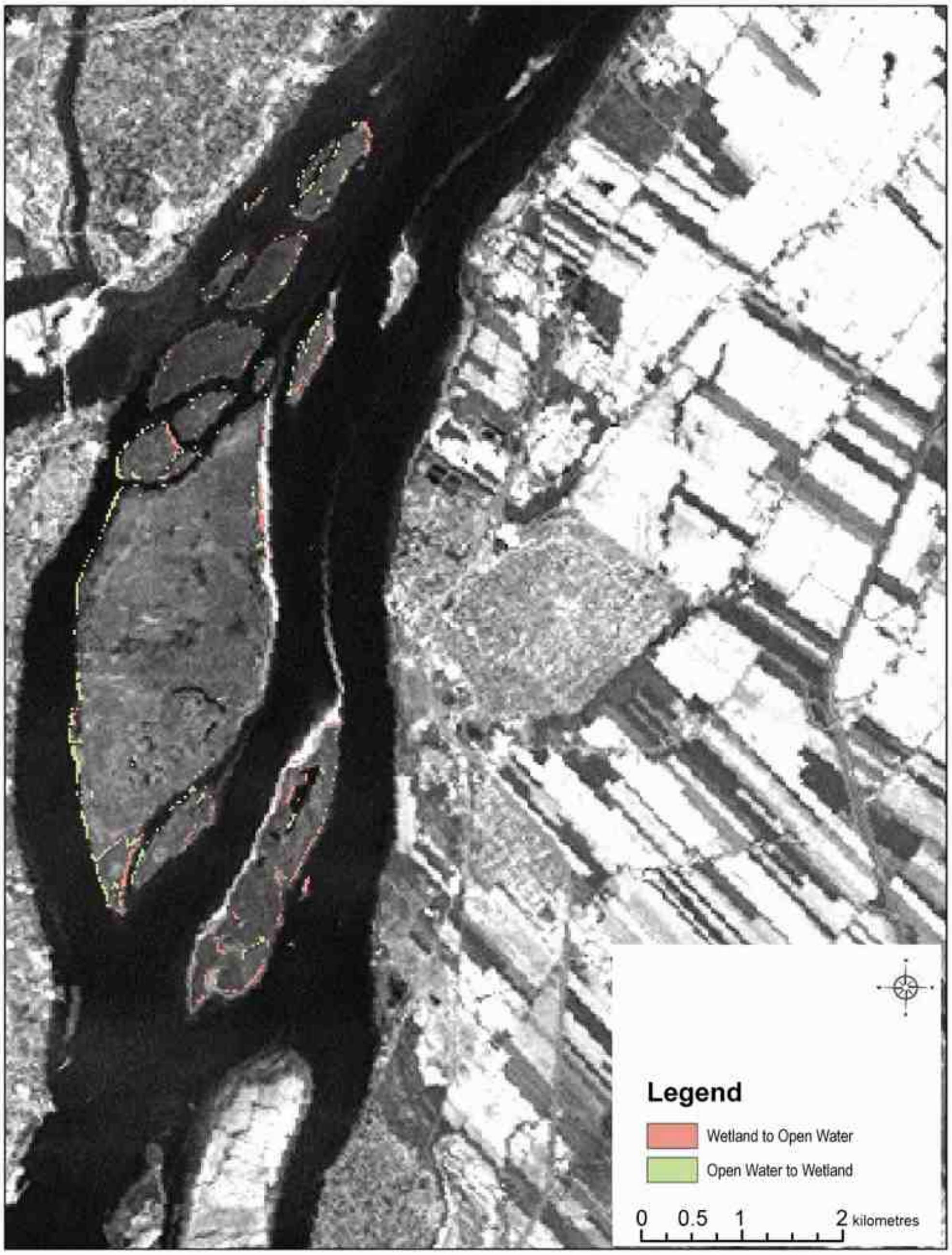


Figure 40 Losses and gains of marshes and swamps in the Sainte-Thérèse Island and Varennes Islands subsector analyzed between 1996–1997 and 2000–2002

4.7.3 Partial changes in the Contrecœur Islands subsector

4.7.3.1 Between 1970–1978 and 1990–1991

During this period, the area of wetlands increased from 211 ha to 377 ha, a gain of 166 ha or roughly 79% (Figure 41). Losses totalled 42 ha and gains, 208 ha. When inconsistencies are excluded, wetland area increased from 200 ha to 368 ha, a net gain of 168 ha or 84%. Losses retained totalled 31 ha, while totalled gains, 199 ha (Figure 42).

The relative drying index for the period (Table 16) was 0.73, illustrating that overall a significant drying trend occurred during this period. When changes involving open water are excluded, a trend toward wetter environments was still observed, albeit a less pronounced one.

The main losses of wetland area, although minimal, involved open water (31 ha). These changes were observed in the northeastern portion of the Contrecœur Islands (Îlet à Lefebvre). This appears to be an actual transformation possibly involving erosion processes. The other losses, totalling 10 ha, were not retained.

Gains retained (199 ha) involved the transformation of open water into wetlands, with large areas of this type of change observed in the western part of the Contrecœur Islands. Although differences in water levels could possibly be responsible, these changes persisted through 2000–2002, leading us to favour the explanation that a succession to marsh was actually occurring in this sector.

Gains not retained consisted of 9 ha of fallow land that were incorrectly classified as wetlands in 1990.

Progressive changes within wetlands included 37 ha of low marshes that were transformed into high marshes, mainly in the Contrecœur Islands and on Saint-Ours Island. In addition, 9 ha of low marshes became swamps, divided into shrub (3 ha) and forested (6 ha) formations. Furthermore, 3 ha of high marshes were classified as shrub swamps in 1990–1991. Lastly, 2 ha of shrub swamps were transformed into forested swamps.

Sector: Contrecoeur

1990

Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	64			37						3	6								19	6		1	2	0	0		137
11																											0
12																											0
20	13			37						3	0								2	4	1	1	3	1			65
21																											0
23																											0
22																											0
24																											0
25																											0
30	0			1						1	2											1	1	0			6
40	0			0						1	1											0	0		0		3
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	32			12						1	1								149	119		0			0		314
1	121			32							1								87	1766		1	2	3	1		2013
3				0															1	2	0						4
50																			1	1		2	1	1	6		12
51	1			8							0								3	0		1	2	0	1		16
52																											0
54																						0	0	0	2		3
55																											0
Total	231	0	0	127	0	0	0	0	0	8	11	0	0	0	0	0	0	0	262	1898	1	8	10	6	10	0	2572

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 41 Transition matrix for the Contrecoeur subsector analyzed between 1970–1978 and 1990–1991

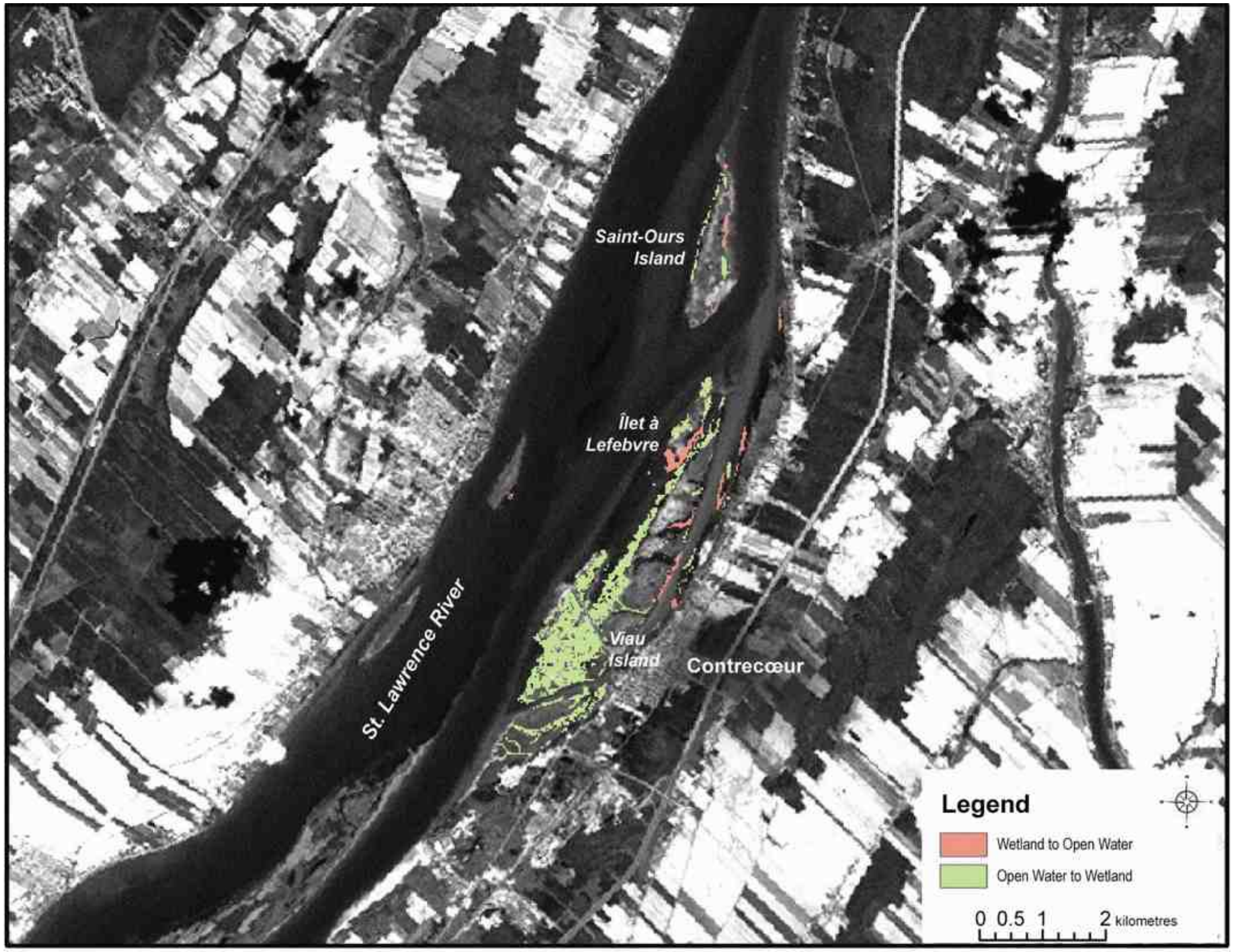


Figure 42 Losses and gains of marshes and swamps in the Contrecœur subsector analyzed between 1970–1978 and 1990–1991

Only two regressive changes within wetlands were observed during the period: 13 ha of high marshes reverted to low marshes and 1 ha of shrub swamps reverted to high marshes.

4.7.3.2 Between 1990–1991 and 1996–1997

During this period, the area of wetlands decreased from 377 ha to 290 ha, a loss of 87 ha or roughly 23% (Figure 43). Losses totalled 109 ha and gains, 22 ha. When inconsistencies are eliminated, the corrected figures show that wetland area decreased from 355 ha in 1990–1991 to 284 ha in 1996–1997, a loss of 71 ha or 20%. Corrected losses were 87 ha, while and gains totalled 16 ha (Figure 44).

The relative drying index for the period (Table 16) was –0.21, showing that, overall, wetlands became wetter during this period. When changes involving open water are excluded, however, a slight trend towards more terrestrial environments is observed.

The main losses (59 ha) occurred in the Contrecœur Islands (not including Saint-Ours Island) and involved conversions to open water. Higher water levels in 1996 than in 1990 could explain these differences (Contrecœur – 02OJ021 and Contrecœur IOC – 02OJ034 hydrometric stations: 4.93 m on August 21, 1990, and 5.03 m on October 17, 1996; source: HYDAT 2001). In addition, 28 ha of wetlands were transformed into denuded substrate, mainly on Saint-Ours Island and in the marsh west of Viau Island, in the southern part of the Contrecœur Islands. These appear to be real modifications in the vegetation cover. Losses not retained in the analysis are described in Appendix 42.

Retained gains, totalling 16 ha and observed in very scattered locations around the islands, including Saint-Ours Island, occurred at the expense of open water. Although these may be areas of sediment accumulation, this is not borne out by erosion data from the sector (Louis–Fillip Richard, personal communication). Other unidentified causes are therefore at play.

Sector: Contrecoeur

		1997																									
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10	149						0	21		3									35	11	10	1			0		231
	11																											0
	12																											0
	20	19						3	38		17									4	9	17	17	0		1		127
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	1						1	2		4											1						8
	40	2							2		6											0	0			0		11
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2	10							1		0									56	195	0	0		0	0		262
	1	1							2		2									2	1889	3			0	0		1898
	3							0	0		0										0	1						1
	50	2							1											0	2		2	0	1	1		8
	51	2							1												1		4	0	0	2		10
	52	0																		0	1		1	0	1	2		6
	54	0																		0	1		1	0	0	8		10
	55																											0
Total		186	0	0	0	0	0	4	68	0	32	0	0	0	0	0	0	0	0	96	2109	32	26	1	2	15	0	2572

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 43 **Transition matrix for the Contrecœur subsector analyzed between 1990–1991 and 1996–1997**

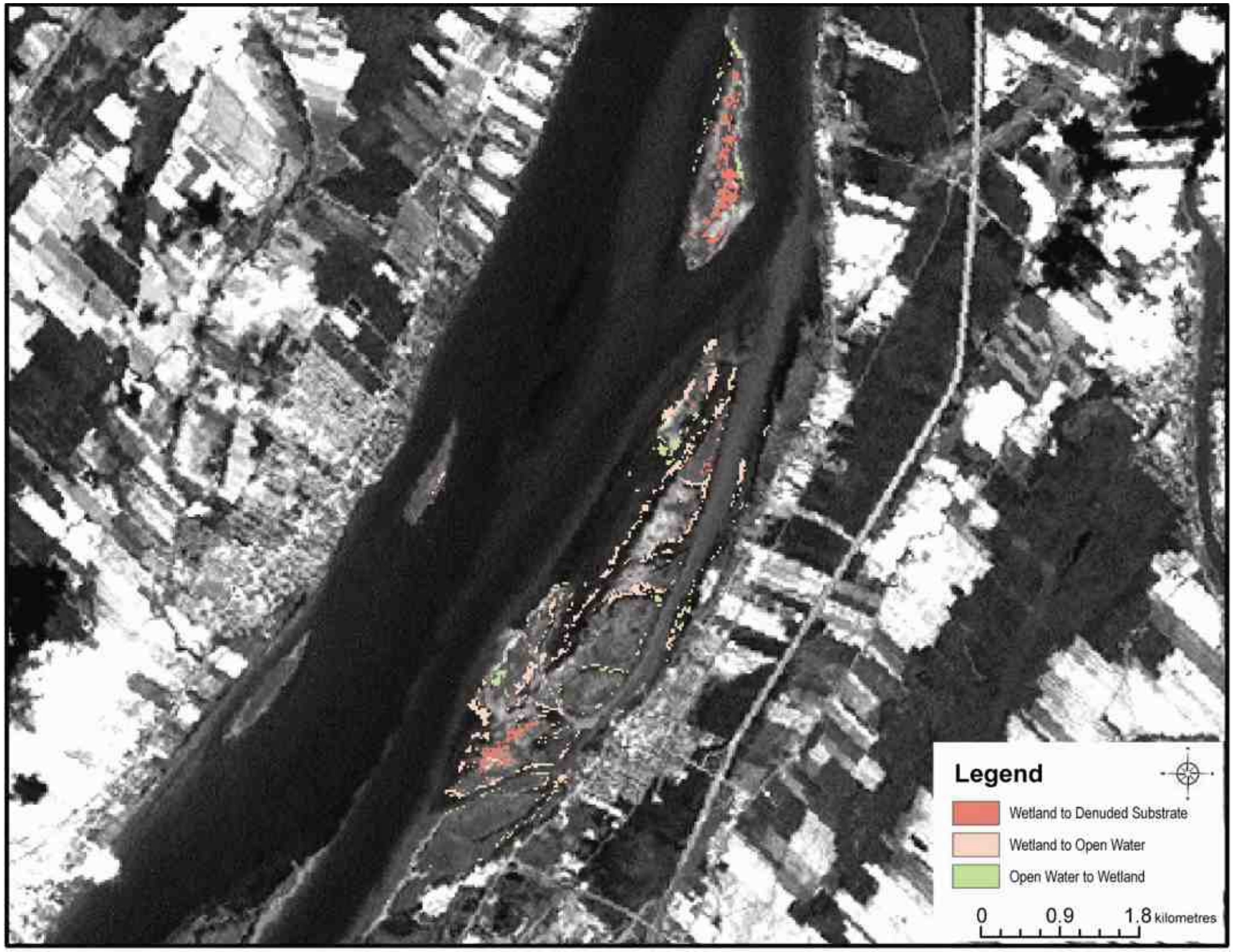


Figure 44 Losses and gains of marshes and swamps in the Contrecœur subsector analyzed between 1990–1991 and 1996–1997

Among changes within wetlands, progressive changes totalled 56 ha; 21 ha were low marshes transformed into high marshes dominated by *Phalaris arundinacea,* with these changes observed nearly everywhere in the Contrecœur Islands. In addition, 17 ha of high marshes were transformed into shrub swamps, as were 3 ha of low marshes.

Conversely, regressive changes totalled 90 ha during the period. Aside from losses to open water, most of these changes (19 ha) in the Contrecœur Islands involved high marshes reverting to low marshes. In addition, 6 ha of forested swamps were transformed into shrub swamps.

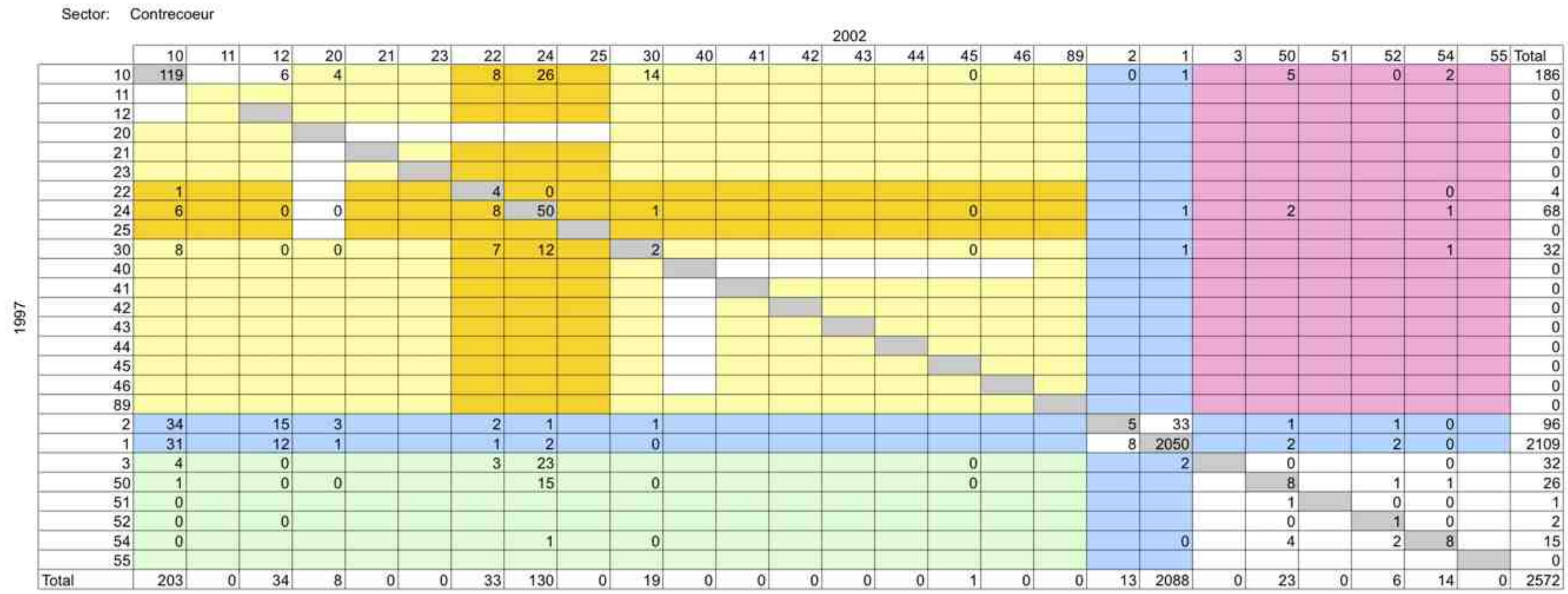
High marshes dominated by invasive plant species during the period are estimated to total over 72 ha, with 68 ha dominated by *Phalaris arundinacea* and 4 ha by *Phragmites australis*.

4.7.3.3 Between 1996–1997 and 2000–2002

During this period, the area of wetlands increased from 290 ha in 1996 to 427 ha in 2002, an increase of 137 ha or 47% (Figure 45). Losses totalled 14 ha and gains, 152 ha. When inconsistencies were eliminated, the corrected wetland area totalled 283 ha in 1996 and 409 ha in 2002, an increase of 126 ha or 45%. Corrected losses were 7 ha and gains, 133 ha (Figure 46).

The relative drying index for the period (Table 16) was 0.62, showing that, overall, there was a drying trend in wetlands during the period. When changes involving open water are excluded, the same trend—albeit a weaker one—towards more terrestrial environments was observed.

No significant losses (over 10 ha) were noted in a single class of wetland. The greatest losses were 7 ha of wetlands that were converted to agriculture (on the south shore, in the northern part of Contrecœur).



Sector: Contrecoeur

	2002																										
1997	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	119		6	4			8	26		14						0			0	1		5		0	2		186
11																											0
12																											0
20																											0
21																											0
23																											0
22	1						4	0																	0		4
24	6		0	0			8	50		1						0				1		2			1		68
25																											0
30	8		0	0			7	12		2						0				1					1		32
40																											0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	34		15	3			2	1		1									5	33		1		1	0		96
1	31		12	1			1	2		0									8	2050		2		2	0		2109
3	4		0				3	23								0				2		0			0		32
50	1		0	0				15		0						0						8		1	1		26
51	0																					1		0	0		1
52	0		0																			0		1	0		2
54	0							1		0										0		4		2	8		15
55																											0
Total	203	0	34	8	0	0	33	130	0	19	0	0	0	0	0	1	0	0	13	2088	0	23	0	6	14	0	2572

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 45 Transition matrix for the Contrecœur subsector analyzed between 1996–1997 and 2000–2002

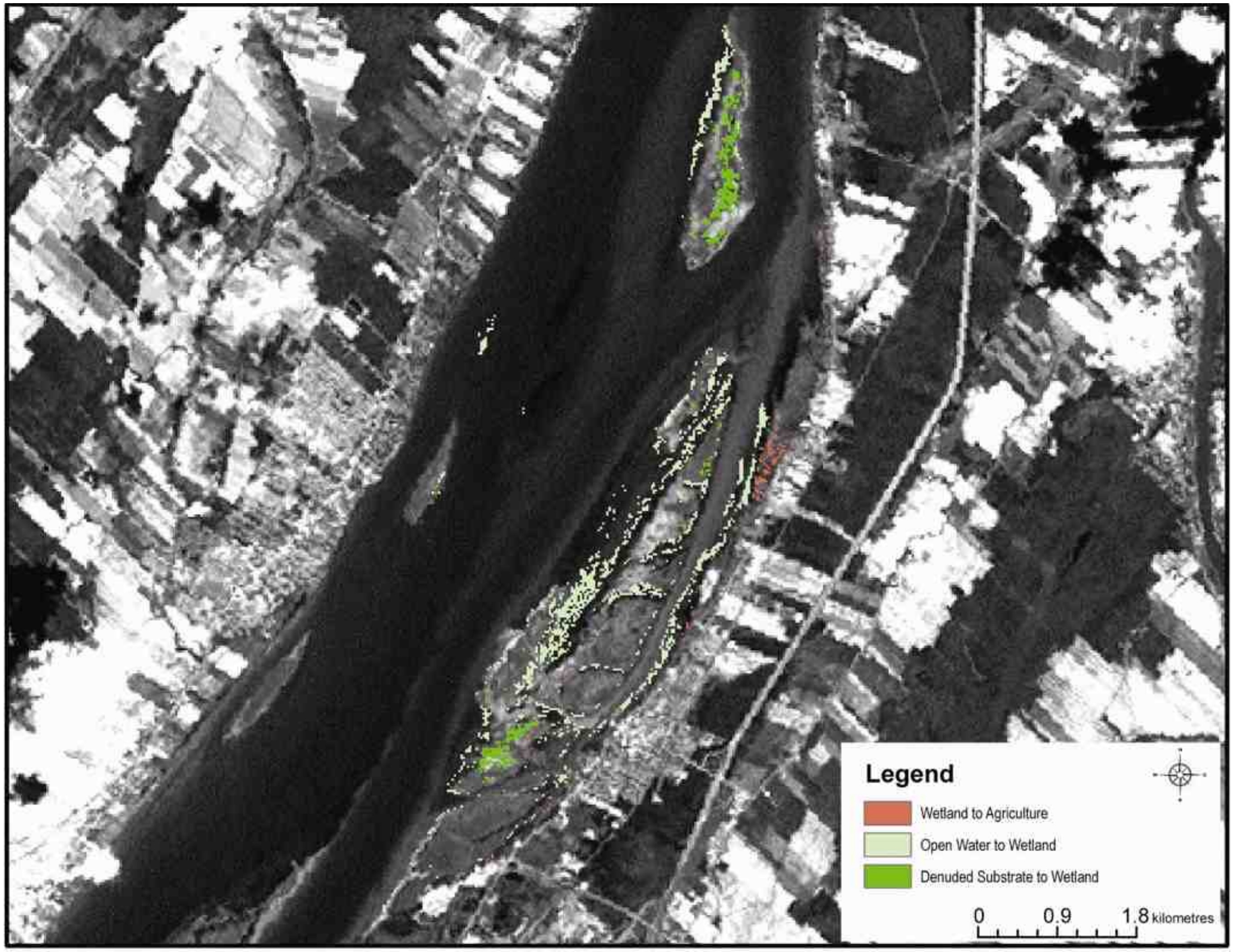


Figure 46 Losses and gains of marshes and swamps in the Contrecœur subsector analyzed between 1996–1997 and 2000–2002

The primary gains (103 ha) occurred at the expense of open water. This phenomenon was encountered mainly in the Contrecœur Islands and on the western shoreline of Saint-Ours Island. Differences in water levels appear to be associated with the aforementioned changes (Contrecœur IOC – 15780 hydrometric station: 5.04 m on October 17, 1996, and 4.90 m on August 13, 2002; source: Marine Environmental Data Service, Fisheries and Oceans Canada). In addition, 30 ha identified as substrate in 1996–1997 were classified as wetlands in 2000–2002, on Saint-Ours Island and in the marsh west of Viau Island. Gains not retained in the analysis are described in Appendix 42.

In terms of changes within wetlands, there were visible progressive changes in low marshes. A total of 38 ha of low marshes were transformed into high marshes; 26 ha of these new high marshes were dominated by *Phalaris arundinacea* and 8 ha by *Phragmites australis*. These marshes are found in the Contrecœur Islands and in a more scattered fashion on Saint-Ours Island. Furthermore, 14 ha of low marshes were converted to shrub swamps, almost all in the Contrecœur Islands.

The most significant regressive changes involved shrub swamps that reverted to high marshes (19 ha, 12 ha of which were dominated by *Phalaris arundinacea*) and to low marshes (8 ha). Among these regressive changes, what is believed to be the appearance of high marshes on Saint-Ours Island seems to be the result of an overestimation of swamps in 1996–1997. Lastly, 7 ha of high marshes reverted to low marshes.

Wetlands dominated by invasive plant species increased from 72 ha in 1996–1997 to 163 ha in 2000–2002. Part of the reason for this difference is the more effective detection of these species.

4.8 LAKE SAINT-PIERRE

A total of 58 132 ha (including open water and adjacent terrestrial habitats) were analyzed in the Lake Saint-Pierre sector in both 1990–1991 and 2000–2002. Coverage of the sector was complete, except for a missing area on the southwest side of the lake (Appendices 44 and 45).

In addition, a portion of the islands in Lake Saint-Pierre (Berthier–Sorel Islands) was examined in all four time periods (1970-1978, 1990-1992, 1996-1997 and 2000-2002). The area was estimated at 25 847 ha (Appendices 46 to 49).

Relative drying indices for the Lake Saint-Pierre sector are shown in Table 17. An examination of these statistics seems to show fluctuations in the wetness of wetlands, with a slight drying trend occurring between 1990–1991 and 2000–2002.

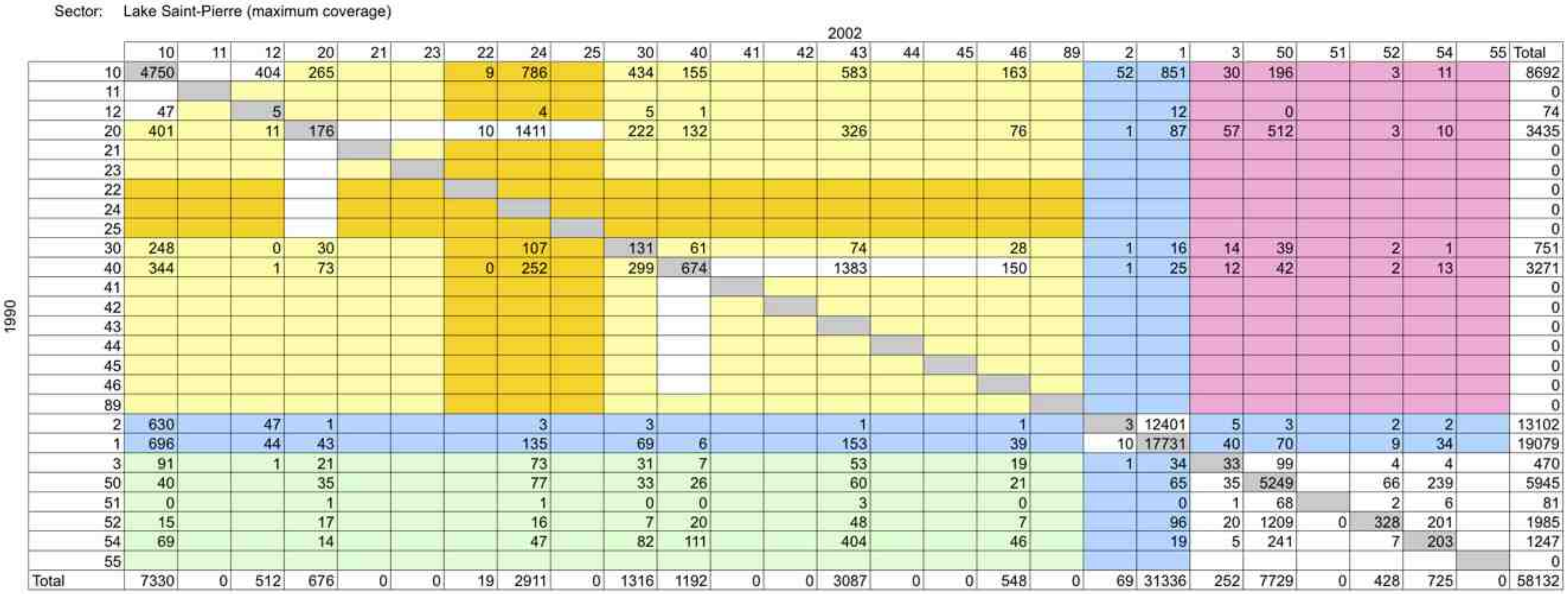
Table 17 Relative drying indices for the Lake St. Pierre sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	–0.40
Between 1990–1991 and 1996–1997	0.61
Between 1996–1997 and 2000–2002	–0.49
Between 1990–1991 and 2000–2002	0.27

4.8.1 Overall changes between 1990–1991 and 2000–2002

Between 1990–1991 and 2000–2002, Lake Saint Pierre gained 1368 ha of wetlands. The total area of wetlands in the sector increased from 16 224 ha to 17 592 ha, or roughly 8% (Figure 47). During this period, losses of marshes and swamps totalled 1994 ha, while gains totalled 3363 ha. When inconsistencies are eliminated, losses totalled 1949 ha and gains, 1873 ha (Figure 48). The corrected total area was 16 180 ha in 1990–1991 and 16 098 ha in 2000–2002, representing a net loss of 82 ha or 0.5%.

The relative drying index for the period was 0.27, pointing to a drying trend in the sector's wetlands (Table 17). This supports the trend observed in the indices for the analysis involving all four datasets to maximize temporal coverage, which shows a strongly positive value for the period between 1990–1991 and 1996–1997, but a moderately negative value for the period between 1996–1997 and 2000–2002. Excluding changes involving open water, a trend of similar magnitude towards more terrestrial environments was observed.



Sector: Lake Saint-Pierre (maximum coverage)

2002

1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	4750		404	265			9	786		434	155			583			163		52	851	30	196		3	11		8692
11																											0
12	47		5					4		5	1									12		0					74
20	401		11	176			10	1411		222	132			326			76		1	87	57	512		3	10		3435
21																											0
23																											0
22																											0
24																											0
25																											0
30	248		0	30				107		131	61			74			28		1	16	14	39		2	1		751
40	344		1	73			0	252		299	674			1383			150		1	25	12	42		2	13		3271
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	630		47	1				3		3				1			1		3	12401	5	3		2	2		13102
1	696		44	43				135		69	6			153			39		10	17731	40	70		9	34		19079
3	91		1	21				73		31	7			53			19		1	34	33	99		4	4		470
50	40			35				77		33	26			60			21			65	35	5249		66	239		5945
51	0			1				1		0	0			3			0			0	1	68		2	6		81
52	15			17				16		7	20			48			7			96	20	1209	0	328	201		1985
54	69			14				47		82	111			404			46			19	5	241		7	203		1247
55																											0
Total	7330	0	512	676	0	0	19	2911	0	1316	1192	0	0	3087	0	0	548	0	69	31336	252	7729	0	428	725	0	58132

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 47 Transition matrix for the Lake Saint-Pierre sector between 1990–1991 and 2000–2002

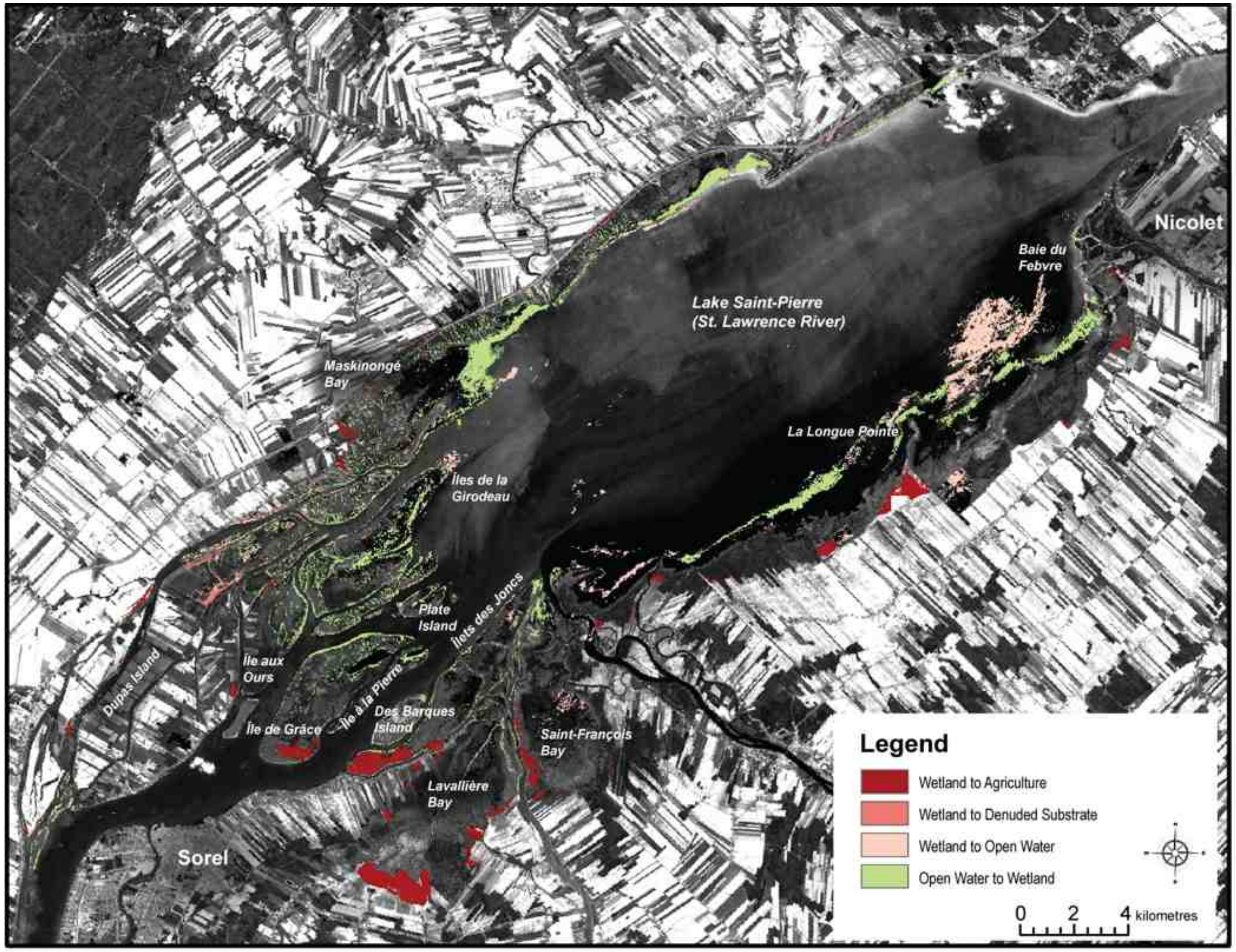


Figure 48 **Losses and gains of marshes and swamps in the Lake Saint-Pierre sector between 1990–1991 and 2000–2002**

The vast majority of wetland losses observed during the period were retained. In all, 1046 ha of wetlands were lost to open water in various locations around Lake Saint-Pierre, in Saint-François Bay, around certain of the Lake Saint-Pierre islands and most significantly, in the Baie du Febvre. Based on the historical data, these changes cannot be linked to rising water levels (Lake Saint-Pierre curb no. 2 hydrometric station – 02OC016: 4.47 m on July 26, 1990, 4.23 m on August 21, 1990, 4.06 m on September 18, 2000; Lake Saint-Pierre curb no. 2 hydrometric station – 15975: 4.20 m on July 25, 2002, and 4.12 m on August 13, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). Some of these losses could be explained by the creation of structures to maintain high water levels locally, and the remainder could be due to the disappearance of vegetation. In addition, 789 ha of wetlands, found mainly on the south shore of the lake, were converted to agricultural land. Based on the information we have, these appear to be actual losses. Furthermore, 113 ha of wetlands were converted to denuded substrate, mainly on the eastern end of Dupas Island. Several wildlife management structures are located in this area and they could very likely be the reason for this type of change.

Over half the gains in wetlands were retained for this analysis. Gains occurred at the expense of open water (1871 ha) and were scattered around several of the Lake Saint-Pierre islands and along both shores of the lake itself. These are very likely changes caused by lower water levels (see the hydrometric data above, particularly the levels for July 26, 1990, and August 13, 2002, when the remote sensing images were acquired for most of the lake).

Losses and gains not retained in the analysis are described in Appendix 50.

Many progressive changes within wetlands occurred during this period. The most significant was the conversion of 1064 ha of low marshes to high marshes, of which 790 ha are dominated by *Phalaris arundinacea* and 9 ha by *Phragmites australis*. These changes are mainly seen along Lavallière and Saint-François bays, as well as on some nearby islands, particularly Plate and Des Barques islands. The presence of cloud cover on the 1990–1991 image calls these types of changes into question, however. In addition, 902 ha of low marshes became forested swamps in 2000–2002; of these, 583 ha were dominated by *Acer saccharinum*, 163 ha by *Salix* sp. and 156 ha by other species. These forested swamps were found mainly near Lavallière and Saint-François bays, on Île de Grâce and the Îles de la Girodeau and on the south shore of the lake itself. A possible overestimation of low marshes on the 1990–1991 map should be taken into account here, as well as geometric differences between the two maps. On the south shore of the lake and on certain islands, 439 ha of low marshes were converted to shrub swamps. In terms of high marshes, other than the changes mentioned above, 534 ha present in 1990–1991 were transformed into forested swamps in 2000–2002: 326 ha dominated by *Acer saccharinum*, 76 ha by *Salix* sp. and 132 ha by other species. These forested swamps are dispersed over the islands, with a concentration on the eastern shore of Saint-François Bay and the south shore of Lake Saint-Pierre. Furthermore, 222 ha of high marshes became shrub swamps in 2000–2002, mainly on the south shore of the lake with a few traces on the islands. Lastly, 163 ha of shrub swamps were transformed into forested swamps, 74 ha dominated by *Acer saccharinum*, 28 ha by *Salix* sp. and 61 ha by other species. These changes are scattered throughout the sector, with a concentration upstream of the Baie du Febvre.

Regressive changes within wetlands include the reversion of 412 ha of high marshes to low marshes at the head of Lavallière and Saint-François bays, near the Dupas Island wildlife developments and in some other areas. In addition, 345 ha of forested swamps reverted to low marshes in areas where swamps are less dense, such as Dupas Island, Maskinongé Bay and some parts of Île aux Ours. Moreover, 248 ha of shrub swamps were replaced by low marshes, mostly in Lavallière and Saint-François bays. Furthermore, 325 ha of forested swamps reverted to high marshes; these are particularly visible around some of the islands in the southern part of the Lake Saint-Pierre archipelago (for example, the Îlets des Joncs and Île à la Pierre). In addition, 137 ha of shrub swamps reverted to high marshes on the south shore as well as on Île des Barques; of these, 107 ha are dominated by *Phalaris arundinacea*. Finally, 299 ha of forested swamps reverted to shrub swamps around the Baie du Febvre as well as on the islands north of the Lake Saint-Pierre archipelago.

We used the 2000–2002 maps to estimate the area of dense populations of *Phragmites australis* and *Phalaris arundinacea*. High marshes dominated by *Phragmites australis* totalled 19 ha and were found mainly in Lavallière Bay. Field checks showed that the species is also present elsewhere in the Lake Saint-Pierre sector. A total of 2911 ha of high marshes dominated by *Phalaris arundinacea* were found, but this figure would no doubt be higher if terrestrial environments where it occurs were also taken into account.

4.8.2 Partial changes between 1970–1978 and 1990–1991

During this period, the area of wetlands decreased from 9764 ha to 9426 ha, a loss of 338 ha or roughly 3.5% (Figure 49). Losses totalled 1914 ha and gains totalled 1576 ha. When inconsistencies are eliminated, wetland area decreased from 9285 ha in the late 1970s to 8964 ha in 1990, representing a net loss of 321 ha or 22%. Based on the corrected figures, losses totalled 1435 ha and gains totalled 1114 ha (Figure 50).

The relative drying index for the period (Table 17) is –0.40, showing an overall moderate trend toward wetter habitats. When changes involving open water are excluded, a trend of similar magnitude towards wetter environments is observed.

Most of the losses observed in this period are considered valid. The main losses of wetlands consisted of conversions to open water (904 ha). Such losses occurred mainly around the Îles de la Girodeau, in the eastern part of Île aux Grues and the Baie des Ouines, as well as at the mouth of the Yamaska River. Fluctuations in water levels may be the cause. In addition, 398 ha of wetlands were identified as agricultural land in 1990–1991. This phenomenon can be found throughout the Lake Saint-Pierre islands, particularly on the Îles de la Girodeau, Île aux Ours and Île du Mitan.

Sector: Lake Saint-Pierre

1990

Dryade

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10	2212			259						104	180								129	345	69	160		43	25		3526
11																											0
12																											0
20	405			554						60	160								2	122	32	131		14	25		1506
21																											0
23																											0
22																											0
24																											0
25																											0
30	1041			351						113	255								3	71	44	43		10	41		1971
40	719			277						97	1063								7	225	27	64		20	262		2762
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2	324			16						5	18								994	586	11	9		8	3		1974
1	117			15						2	3								2544	6784	8	23		47	6		9549
3	7			1						0	1								0	5	0						15
50	134			88						14	57								1	49	16	2169		193	59		2780
51	86			248						11	91								4	55	27	249		30	18		819
52																											0
54	95			97						13	133								2	57	29	137		46	338		947
55																											0
Total	5141	0	0	1906	0	0	0	0	0	420	1960	0	0	0	0	0	0	0	3687	8298	264	2984	0	410	777	0	25847

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 49 Transition matrix for the portion of the Lake Saint-Pierre sector analyzed between 1970–1978 and 1990–1991

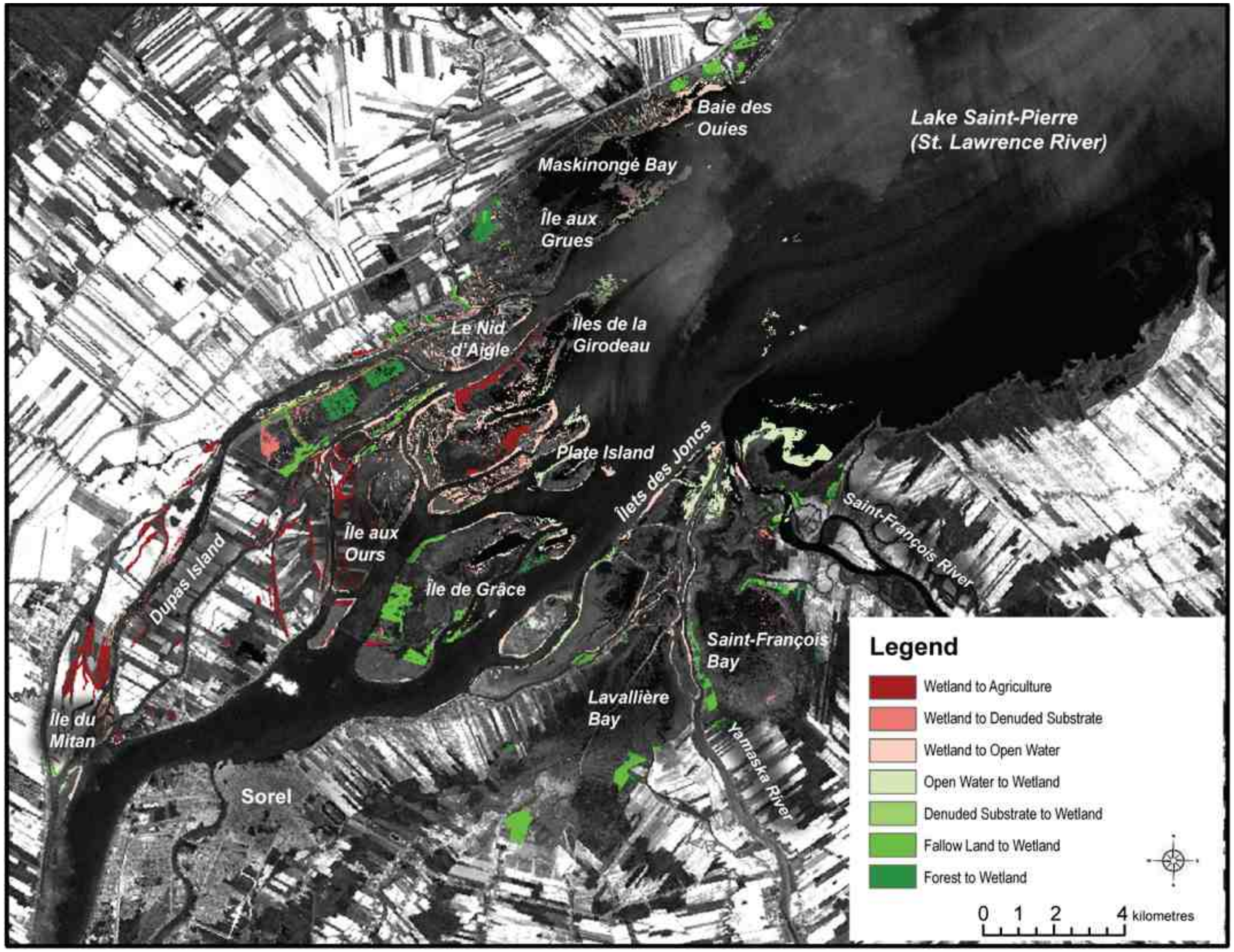


Figure 50 Losses and gains of marshes and swamps in the portion of the Lake Saint-Pierre sector analyzed between 1970–1978 and 1990–1991

Although it is possible that these sites were flooded during the spring freshet, their intensive use in agriculture (and the clear distinction between the two classes [wetland and agriculture]) suggests that these changes are real. In addition, 132 ha of wetlands on Dupas Island were transformed into denuded substrate in 1990–1991. The recent conversion of such land to agricultural use could explain this difference.

The primary wetland gains retained involve those that occurred at the expense of open water (500 ha). Large expanses of these wetlands can be seen at the mouths of the Yamaska and Saint-François rivers, as well as on the eastern portion of the Îles de la Girodeau and in Île aux Grues bay. Water level fluctuations and vegetation succession (particularly the denser growth of vegetation in shallow-water zones) could be responsible for this change. In addition, 436 ha of fallow land were classified as wetlands in 1990–1991, on Île de Grâce and Dupas Island and inland from Lavallière and Saint-François bays. Furthermore, 169 ha of upland forests, out of a total of 337 ha, became wetlands in 1990–1991. These gains, which were concentrated on Dupas Island (in two areas managed for wildlife), in Maskinongé Bay and further inland, were retained owing to their plausibility. Lastly, 9 ha of denuded substrate were colonized by wetlands. Vegetation can clearly be seen in these areas on the raw images, which prompted us to retain these changes in the analysis.

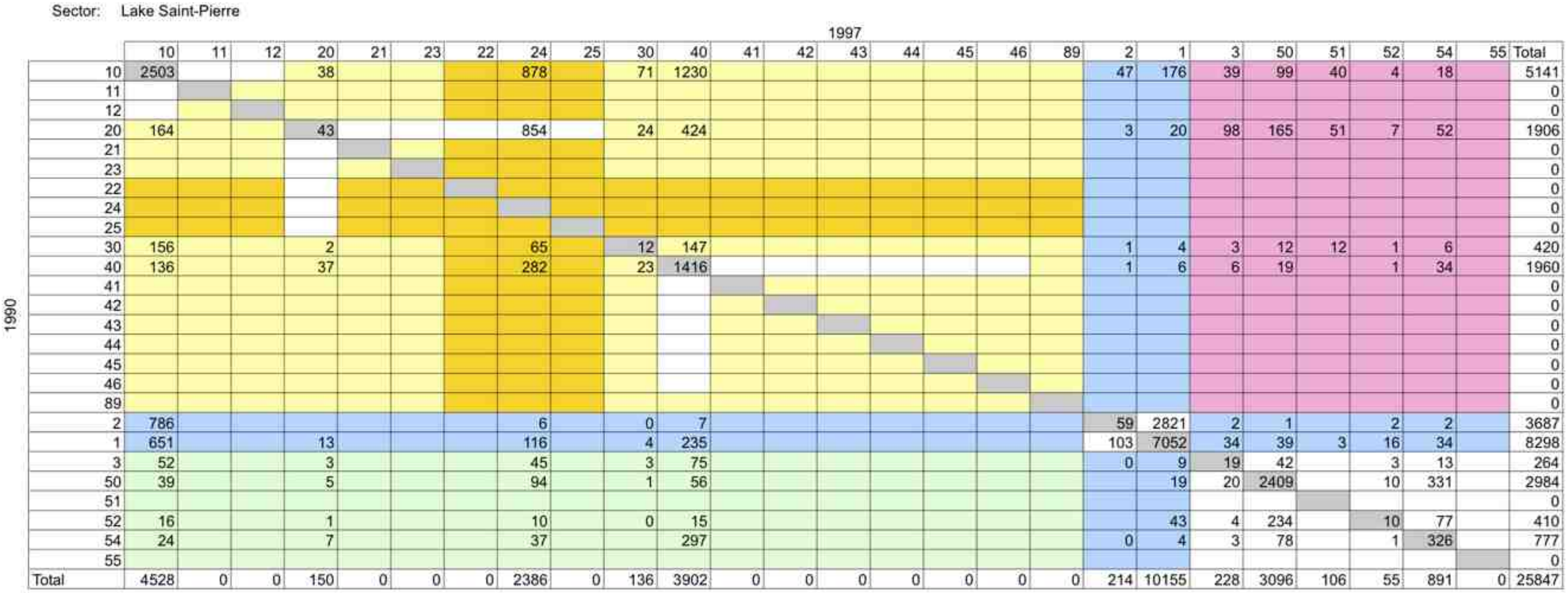
Losses and gains not retained are described in Appendix 50.

Significant changes within wetlands were observed during this period. Progressive changes within wetlands included the transformation of 180 ha of low marshes into forested swamps. However, forested swamps were likely overestimated in 1990–1991. Similarly, 104 ha of low marshes in Saint-François Bay were converted to shrub swamps; this again appears to be due to an overestimation of the latter habitats in 1990–1991. The conversion of 259 ha of low marshes to high marshes was considered plausible, however. In addition, 160 ha of high marshes were converted to forested swamps—a plausible change, particularly on Le Nid d'Aigle Island. At the same time, 60 ha of high marshes were converted to shrub swamps; in this case, the change appears to be the result of an overestimation of shrub swamps in 1990–1991. Lastly, 255 ha of shrub swamps were transformed into forested swamps in 1990–1991. These new forested formations are scattered over the sector, but are particularly concentrated on Dupas Island. Nonetheless, these two classes can be confused to some extent.

Regressive transformations within wetlands to wetter environments were somewhat more significant. First, 405 ha of high marshes reverted to low marshes, probably due in part to the overestimation of low marshes in 1990–1991, although the trend seems plausible in Lavallière Bay. The transformation of 1041 ha of shrub swamps and 719 ha of forested swamps into low marshes is probably due to development for wildlife habitat. Although the latter transformations can primarily be seen in Lavallière Bay, they also occur at the head of Saint-François Bay and on the Îles de la Girodeau. In addition, 351 ha of shrub swamps, primarily in Lavallière and Saint-François bays, reverted to high marshes, as did 277 ha of forested swamps, mainly on Île de Grâce. An overestimation of high marshes in 1990–1991 could be the cause. Lastly, 97 ha of forested swamps reverted to shrub swamps.

4.8.3 Partial changes between 1990–1991 and 1996–1997

During this period, the area of wetlands increased from 9426 ha to 11 102 ha, a difference of 1676 ha or roughly 18% (Figure 51). Losses totalled 923 ha and gains totalled 2599 ha. When inconsistencies are eliminated, the corrected wetland area increased from 9010 ha in 1990–1991 to 10 499 ha in 1996–1997, a net gain of 1489 ha or 17%. The corrected losses were 507 ha and gains, 1996 ha (Figure 52).



Sector: Lake Saint-Pierre

		1997																									
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10	2503			38				878		71	1230								47	176	39	99	40	4	18		5141
	11																											0
	12																											0
	20	164			43				854		24	424								3	20	98	165	51	7	52		1906
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	156			2				65		12	147								1	4	3	12	12	1	6		420
	40	136			37				282		23	1416								1	6	6	19		1	34		1960
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2	786							6		0	7								59	2821	2	1		2	2		3687
	1	651			13				116		4	235								103	7052	34	39	3	16	34		8298
	3	52			3				45		3	75								0	9	19	42		3	13		264
	50	39			5				94		1	56									19	20	2409		10	331		2984
	51																											0
	52	16			1				10		0	15									43	4	234		10	77		410
	54	24			7				37			297								0	4	3	78		1	326		777
	55																											0
	Total	4528	0	0	150	0	0	0	2386	0	136	3902	0	0	0	0	0	0	0	214	10155	228	3096	106	55	891	0	25847

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 51 **Transition matrix for the portion of the Lake Saint-Pierre sector analyzed between 1990–1991 and 1996–1997**

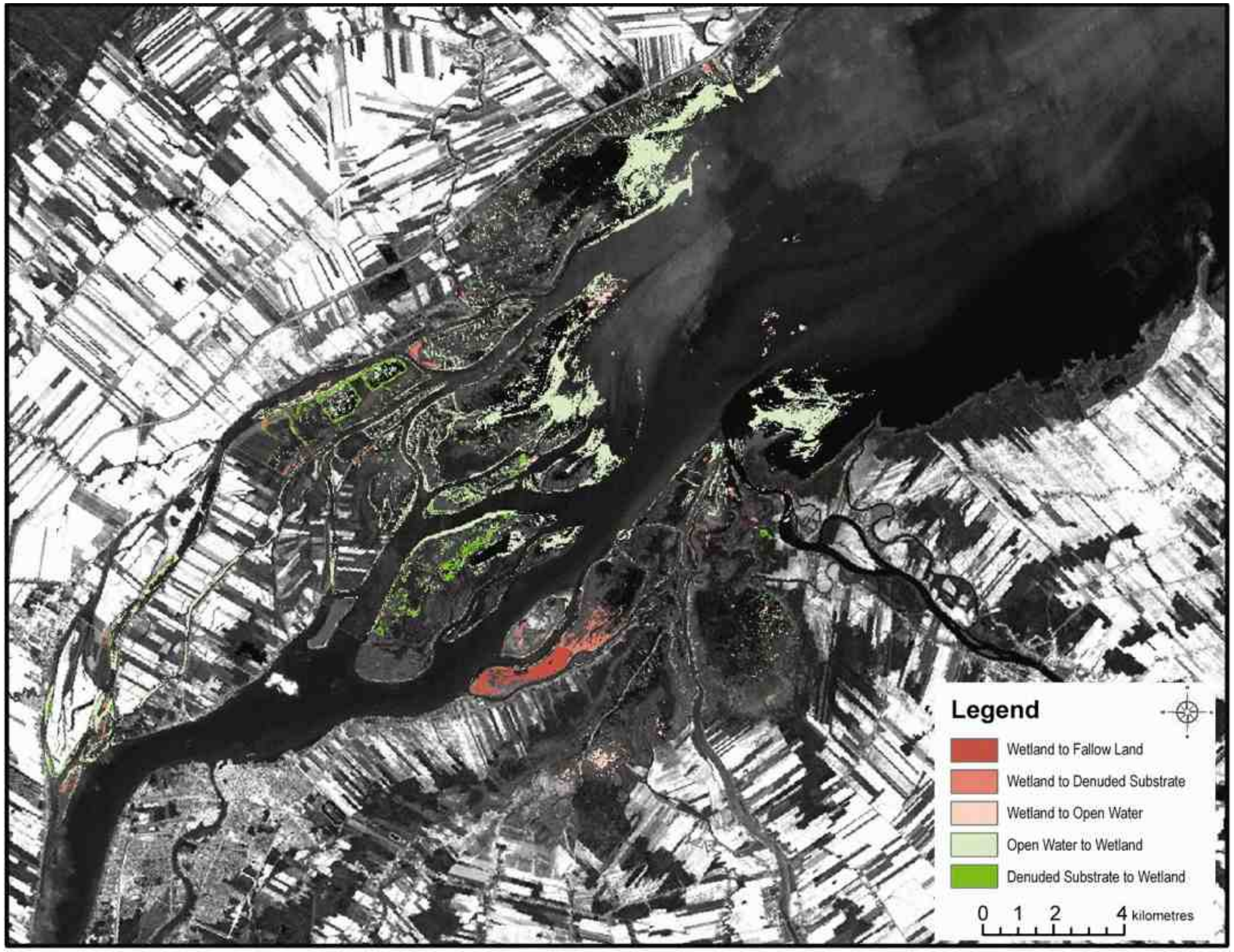


Figure 52 **Losses and gains of marshes and swamps in the portion of the Lake Saint-Pierre sector analyzed between 1990–1991 and 1996–1997**

The relative drying index for the period (Table 17) was 0.61, showing a strong overall trend towards the drying of wetlands. When changes involving open water are excluded, a trend of similar magnitude towards more terrestrial environments can be observed.

Among the losses retained for the period, 258 ha of wetlands were lost to open water, which can be seen in Lavallière and Saint-François bays as well as on the north shore of Dupas Island. The finer resolution of the 1997 image may have allowed the ponds in the two bays to be more visible. However, we believe that these could be real transformations within wetlands. In addition, 146 ha of wetlands became denuded substrate in 1996–1997, in the western part of Le Nid d'Aigle Island and the centre of Île du Moine. On the latter, 104 ha of wetlands were transformed into fallow land; on this site over a period of about 20 years there has been a gradual loss of high marshes to agriculture.

Most of the gains retained (1817 ha) occurred at the expense of open water. The new wetlands were scattered widely around the Lake Saint-Pierre islands, with greater concentrations in the eastern part (Maskinongé Bay, Îles de la Girodeau, Plate Island and the mouth of the Saint-François River). Fluctuating water levels or growth of vegetation could be responsible for these changes (Sorel hydrometric station – 02OJ022: 4.69 m on August 21, 1990, and 4.56 m on August 10, 1997; source: HYDAT 2001). In addition, 178 ha of substratum were classified as wetlands in 1996–1997, particularly around the areas developed for wildlife on Dupas Island. This could be attributable to the growth of vegetation after these development efforts.

Losses and gains not retained are described in Appendix 50.

Significant changes within wetlands can be observed. In terms of progressive changes, 1230 ha of low marshes were transformed into forested swamps. However, we believe this is due to low marshes being greatly overestimated on the 1990–1991 maps at the expense of forested swamps. In addition, 71 ha of low marshes, located at the head of Saint-François Bay, were converted to shrub swamps, and 878 ha of low marshes became high marshes dominated by *Phalaris arundinacea,* mainly around Lavallière and Saint-François bays as well as on Plate Island, Île des Barques and the Îlets des Joncs. Also, 38 ha of low marshes (with no dominant species identified) became high marshes. Furthermore, 424 ha of high marshes likely were converted to forested swamps, and 24 ha of high marshes were identified in 1996–1997 as shrub swamps. In the case of swamps, 147 ha of shrubby wetland formations around Lavallière Bay and on Île de Grâce and Dupas Island became forested in 1996–1997.

In terms of regressive changes, 164 ha of high marshes reverted to low marshes; most are located in the zones developed for wildlife on Dupas Island. In addition, 156 ha of shrub swamps were transformed into low marshes, including a portion in the same wildlife areas. At the same time, 136 ha of forested swamps reverted to low marshes, while 319 ha of forested swamps reverted to high marshes and 23 ha to shrub swamps. Lastly, 67 ha of shrub swamps were replaced by high marshes.

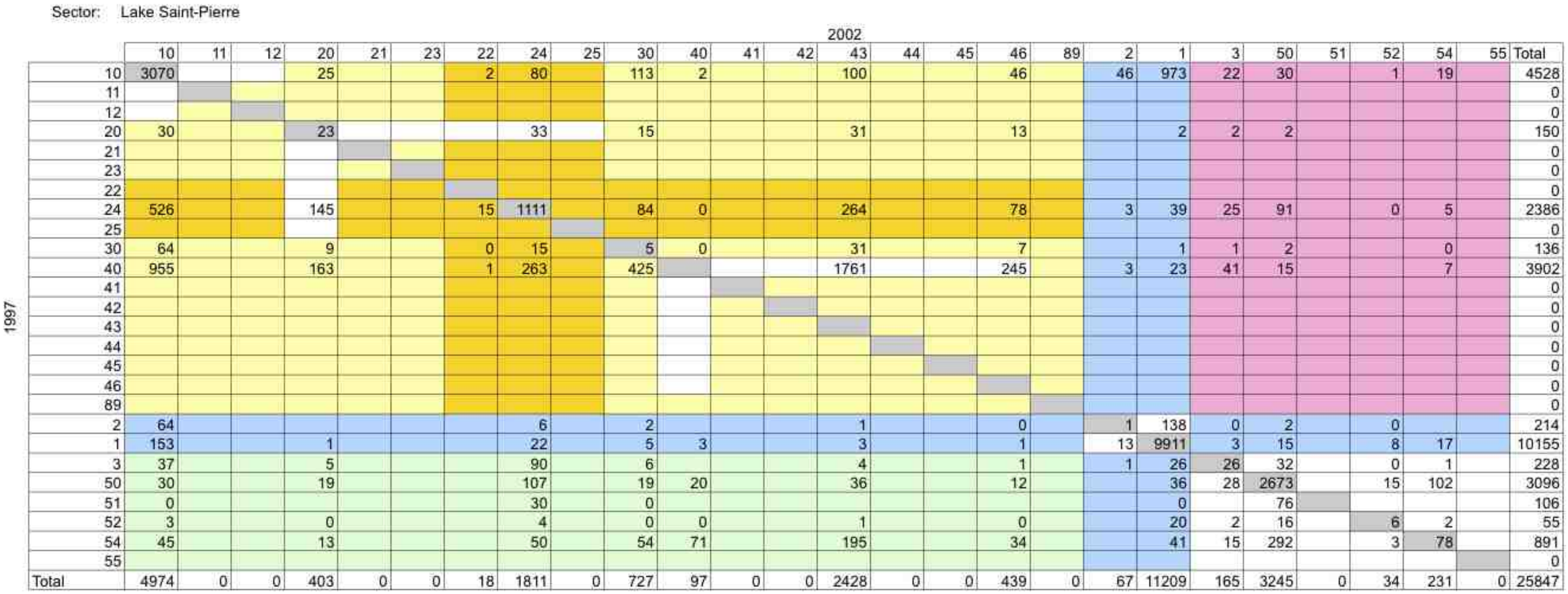
A total of 2386 ha of high marshes dominated by a single invasive plant species—*Phalaris arundinacea*—were identified in 1996–1997.

4.8.4 Partial changes between 1996–1997 and 2000–2002

During this period, the area of wetlands decreased from 11 102 ha in 1997 to 10 896 ha in 2002, a decrease of 206 ha or 2% (Figure 53). Losses totalled 1353 ha and gains, 1146 ha. When inconsistencies are eliminated, losses totalled 1321 ha, while gains totalled 404 ha, for a net loss of 916 ha or 8% (Figure 54). Corrected wetland area decreased from 11 070 ha in 1996 to 10 154 ha in 2002.

The relative drying index for the period (Table 17) was –0.49, showing a strong general trend towards wetter environments. When changes involving open water are excluded, a trend of similar magnitude towards more aquatic environments was observed.

Most of the losses observed during the period were retained. Most wetlands in question were lost to open water (1090 ha), specifically in the eastern part of the Lake Saint-Pierre islands (Maskinongé Bay, Îles de la Girodeau, Plate Island and the mouth of the Saint-François River).



Sector: Lake Saint-Pierre

														2002													
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1997	10	3070			25			2	80		113	2			100			46		46	973	22	30		1	19		4528
	11																											0
	12																											0
	20	30			23				33		15				31			13			2	2	2					150
	21																											0
	23																											0
	22																											0
	24	526			145			15	1111		84	0			264			78		3	39	25	91		0	5		2386
	25																											0
	30	64			9			0	15		5	0			31			7			1	1	2			0		136
	40	955			163			1	263		425				1761			245		3	23	41	15			7		3902
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2	64							6		2				1			0		1	138	0	2		0			214
	1	153			1				22		5	3			3			1		13	9911	3	15		8	17		10155
	3	37			5				90		6				4			1		1	26	26	32		0	1		228
	50	30			19				107		19	20			36			12			36	28	2673		15	102		3096
	51	0							30		0										0		76					106
	52	3			0				4		0	0			1			0			20	2	16		6	2		55
	54	45			13				50		54	71			195			34			41	15	292		3	78		891
	55																											0
Total		4974	0	0	403	0	0	18	1811	0	727	97	0	0	2428	0	0	439	0	67	11209	165	3245	0	34	231	0	25847

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 53 Transition matrix for the portion of the Lake Saint-Pierre sector analyzed between 1996–1997 and 2000–2002

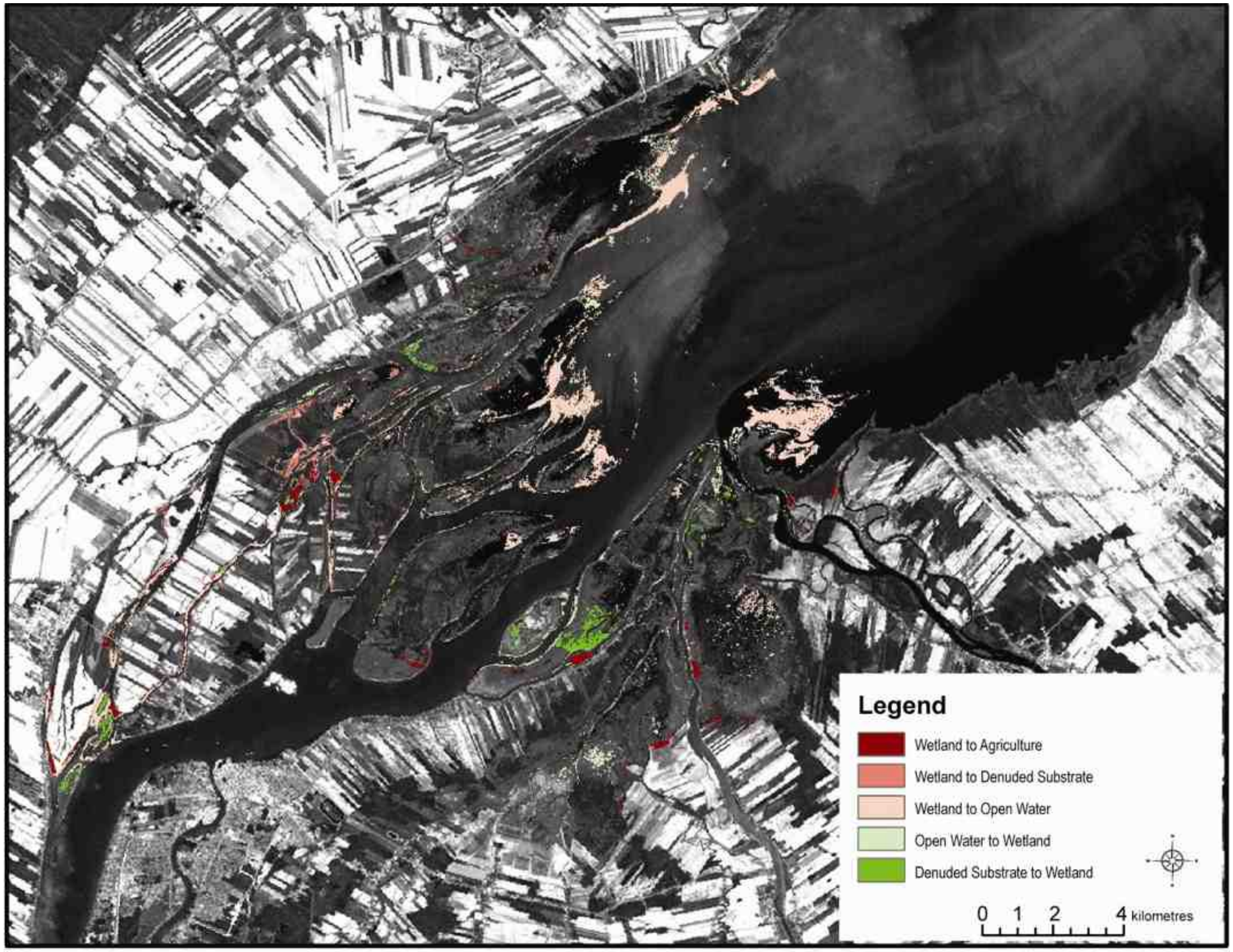


Figure 54 **Losses and gains of marshes and swamps in the portion of the Lake Saint-Pierre sector analyzed between 1996–1997 and 2000–2002**

These changes were probably not caused by water level fluctuations (Sorel hydrometric station – 02OJ022: 4.56 m on August 10, 1997, and 4.52 m on August 13, 2002; source: HYDAT 2001). In addition, 140 ha of wetlands were classified as agricultural land. Lastly, 91 ha of wetlands appeared as substratum on the 2000–2002 images, mainly on Dupas Island.

In the case of gains retained for the period, 261 ha of open water became wetlands in 2000–2002. This was seen in Lavallière and Saint-François bays, as well as around some islands. Although historical water level data do not allow this change to be corroborated directly, the hydrometric variations are weak enough to make them plausible. In addition, 143 ha of denuded substrate were converted to wetlands on Île du Moine and Le Nid d'Aigle Island.

Losses and gains not retained in the analysis are described in Appendix 50.

Within wetlands, a significant number of progressive changes were observed. First, 46 ha of low marshes became forested swamps dominated by *Salix;* this may be due to an overestimation of swamps, however. Also, 100 ha of forested swamps dominated by *Acer saccharinum* replaced low marshes. This appears to be a plausible change. Furthermore, 113 ha of low marshes were transformed into shrub swamps, but this change is probably due to an overestimation of swamps. In addition, 80 ha of low marshes are now high marshes dominated by *Phalaris arundinacea* and 25 ha of low marshes were transformed to high marshes, but without a dominant invasive species. With respect to high marshes, 91 ha became *Salix*-dominated forested swamps; here, too, an overestimation of swamps in 2000–2002 appears to be responsible. In addition, 295 ha of high marshes were transformed into forested swamps dominated by *Acer saccharinum* and 99 ha were transformed into shrub swamps. In the case of swamps, 31 ha of shrub swamps were reclassified as forested swamps dominated by *Acer saccharinum*.

Regressive changes within wetlands included 30 ha of high marshes which became low marshes. A large area, 526 ha, of high marshes dominated by *Phalaris arundinacea* reverted to low marshes, as did 64 ha of shrub swamps. The latter are located at the head of Saint-François Bay and probably stem from the overestimation of swamps in 1996–1997. An impressive 955 ha of forested swamps reverted to low marshes; here, too, the overestimation of swamps in 1996–1997 seems to be the cause. In addition, 24 ha of shrub swamps and 427 ha of forested swamps reverted to high marshes, again probably partially due to the overestimation of swamps in 1996–

1997. Lastly, 425 ha of forested swamps reverted to shrub swamps, a change also linked to the overestimation of forested swamps in 1996–1997.

During this period, the area occupied by invasive plant species decreased from 2386 ha to 1829 ha, a decrease of 557 ha or 23%. It should be noted that agricultural areas and swamps may have been confused here with high marshes dominated by *Phalaris arundinacea*; this could explain the decrease.

4.9 FLUVIAL ESTUARY

A total of 66 727 ha (including open water and adjacent terrestrial habitats) in the fluvial estuary were analyzed between 1990–1991 and 2000–2002 (Appendices 52 and 53). Coverage of the sector was complete.

In addition, the Gentilly portion (7324 ha) was also examined in the other time periods (1970-1978 and 1996-1997), making comparisons possible across all time periods only in this subsector (Appendices 54 to 57).

Relative drying indices for the fluvial estuary are shown in Table 18. An examination of these statistics shows an apparently strong trend toward wetter habitats, particularly around Gentilly, as well as in the sector as a whole between 1990–1991 and 2000–2002.

Table 18 Relative drying indices for the fluvial estuary

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	0.06
Between 1990–1991 and 1996–1997	–0.58
Between 1996–1997 and 2000–2002	–0.09
Between 1990–1991 and 2000–2002	–0.71

4.9.1 Overall changes between 1990–1991 and 2000–2002

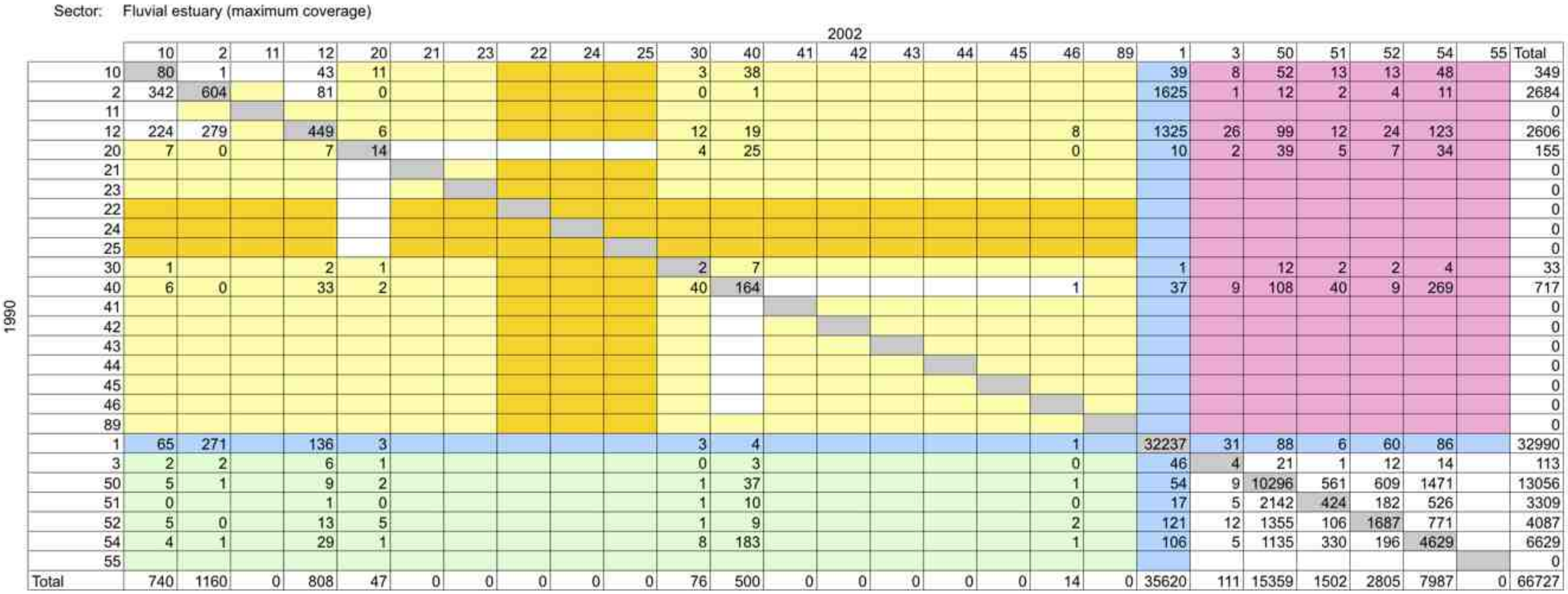
During this period, the area of wetlands in the fluvial estuary upstream of Quebec City decreased from 6544 ha to 3344, a drop of 3200 ha or close to 49% (Figure 55). Estimated losses totalled 4027 ha and gains, 827 ha. When inconsistencies are eliminated, gains totalled 482 ha and losses, 35 ha, for a net gain of 447 ha (Figure 56). The corrected wetland area was therefore 5589 in 1991 and 6036 ha in 2000–2002, representing an increase of 447 ha or 8%.

The relative wetland drying index for the period was –0.71, showing a significant trend towards wetter conditions in the sector's marshes and swamps (Table 18). When changes involving open water are excluded, however, a moderate trend toward more terrestrial environments can be observed.

Of the 322 ha of wetland that were converted to agricultural land, 35 ha were retained as actual losses. These losses occurred in the Sainte-Anne-de-la-Pérade sector. However, due to the lack of field data, we cannot confirm if these formerly forested areas (visible on the raw images) are really and truly swamps.

The gains retained (482 ha, or over half of the total gains observed) occurred at the expense of open water. They were observed over most of the south shore of the river with concentrations in Bécancour, near the Laviolette Bridge (due to the presence of submerged vegetation in 2000–2002), near the mouth of the Bécancour River (presence of new areas of submerged vegetation in 2000–2002), on the Gentilly Flats (different vegetation configuration), east of the flats, on the Saint-Pierre Flats downstream of Pointe de la Rivière aux Orignaux (consolidation of submerged vegetation beds in 2000–2002), downstream of Deschambault to Lotbinière (distribution of submerged vegetation and marshes between the two time periods), and in the stretch between Sainte-Croix and Saint-Antoine-de-Tilly (different distribution of marshes). Tidal levels do not explain these changes.

Losses and gains not retained in the analysis are described in Appendix 58.



Sector: Fluvial estuary (maximum coverage)

	2002																										
1990	10	2	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	1	3	50	51	52	54	55	Total
10	80	1		43	11						3	38								39	8	52	13	13	48		349
2	342	604		81	0						0	1								1625	1	12	2	4	11		2684
11																											0
12	224	279		449	6						12	19						8		1325	26	99	12	24	123		2606
20	7	0		7	14						4	25						0		10	2	39	5	7	34		155
21																											0
23																											0
22																											0
24																											0
25																											0
30	1			2	1						2	7								1		12	2	2	4		33
40	6	0		33	2						40	164						1		37	9	108	40	9	269		717
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
1	65	271		136	3						3	4						1		32237	31	88	6	60	86		32990
3	2	2		6	1						0	3						0		46	4	21	1	12	14		113
50	5	1		9	2						1	37						1		54	9	10296	561	609	1471		13056
51	0			1	0						1	10						0		17	5	2142	424	182	526		3309
52	5	0		13	5						1	9						2		121	12	1355	106	1687	771		4087
54	4	1		29	1						8	183						1		106	5	1135	330	196	4629		6629
55																											0
Total	740	1160	0	808	47	0	0	0	0	0	76	500	0	0	0	0	0	14	0	35620	111	15359	1502	2805	7987	0	66727

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 55 Transition matrix for the fluvial estuary between 1990–1991 and 2000–2002

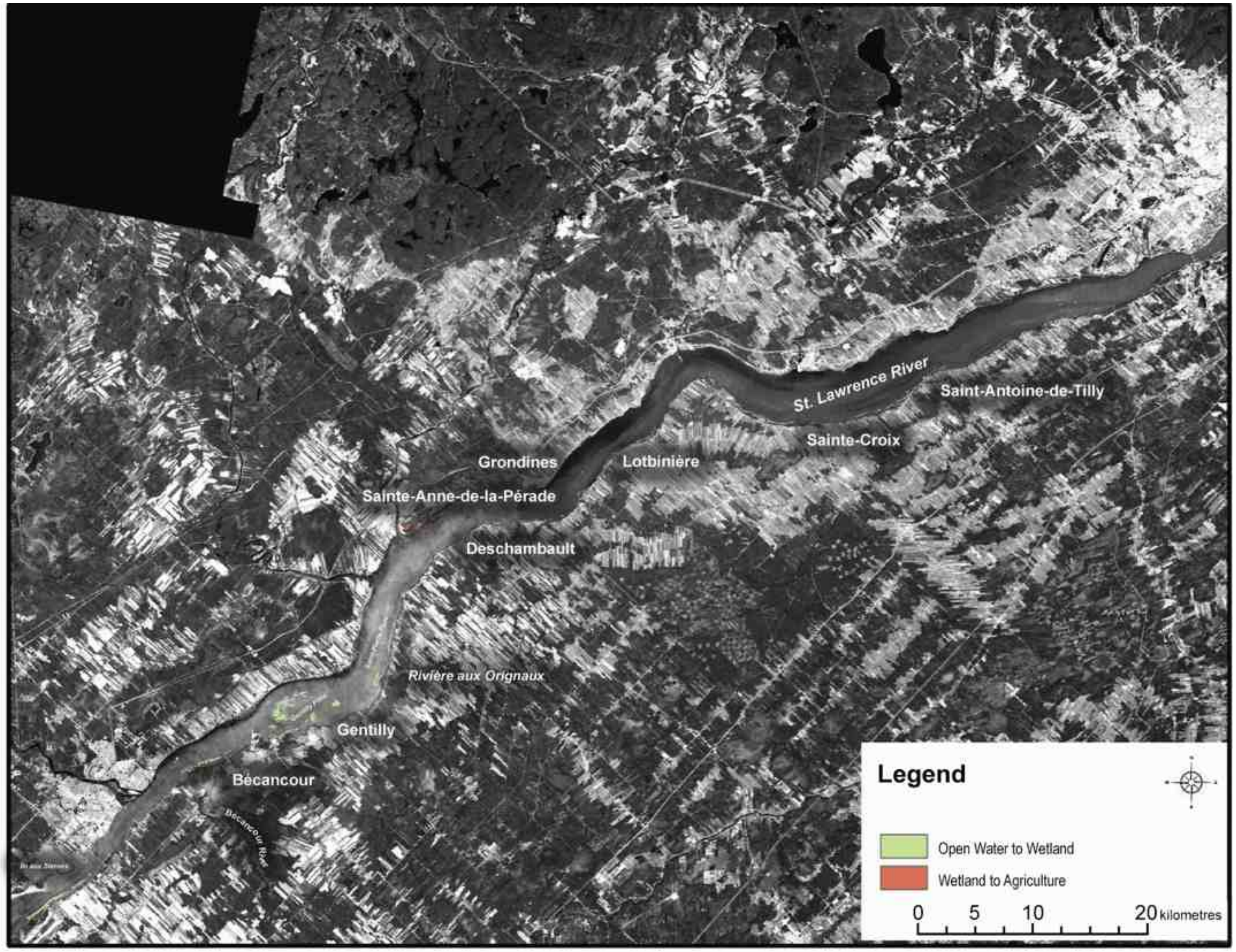


Figure 56 **Losses and gains of marshes and swamps in the fluvial estuary between 1990–1991 and 2000–2002**

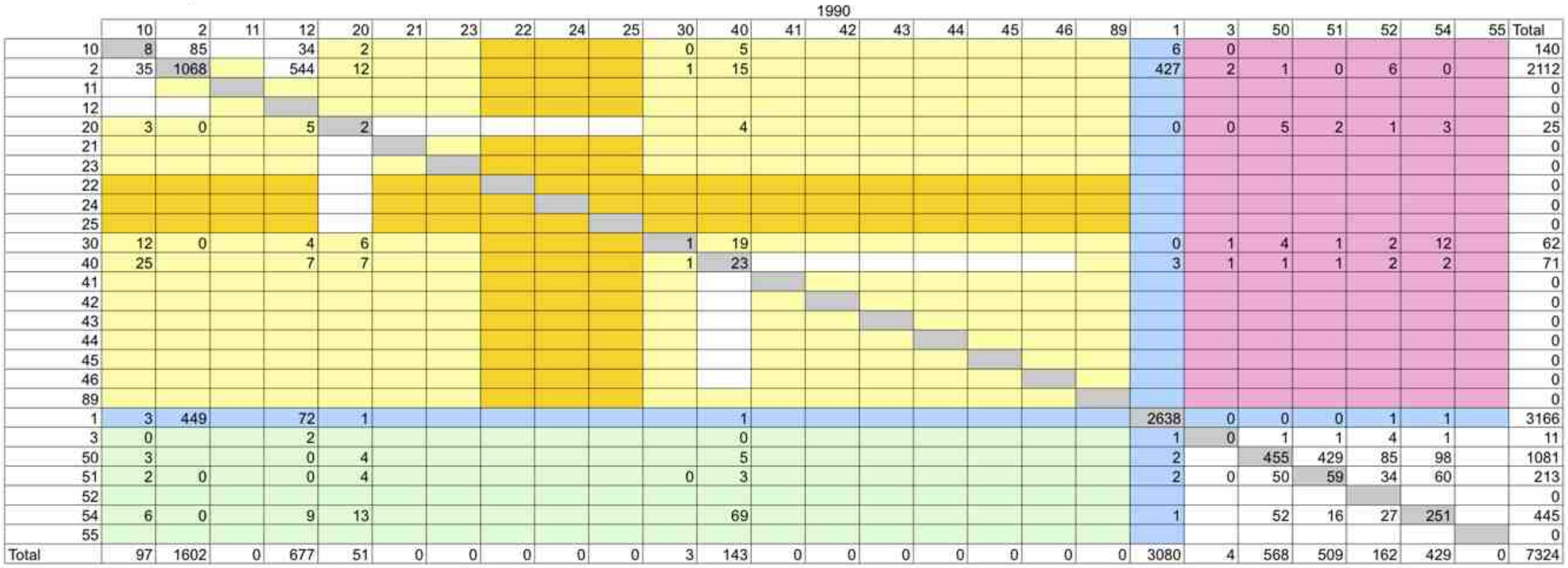
Progressive changes found within wetlands include 65 ha of low marshes (38 ha without an identified dominant species and 27 ha dominated by *Schoenoplectus pungens*) in 1990–1991 which became forested swamps in 2000–2002 (8 ha of which are dominated by *Salix* sp.). This habitat is found mainly around the Port of Gentilly, and an examination of the raw images suggests that this is a real transformation. However, this type of change is debatable for Île aux Sternes (error in 1990–1991) and Grondines (differences caused by geometry or masks used to define upland areas). In addition, 17 ha of low marshes became high marshes and 15 ha of low marshes became shrub swamps. High marshes were transformed into shrub swamps (4 ha) and forested swamps (26 ha), and 7 ha of shrub swamps were replaced by forested swamps.

In the case of regressive changes, 40 ha of forested swamps in 1990–1991 were classified as shrub swamps in 2000–2002, mostly located at Grondines. An examination of the raw images suggests, however, that they were probably shrub swamps in 1990–1991. In addition, 39 ha of forested swamps reverted to low marshes, which can be seen in a number of locations including Gentilly, Grondines and Sainte-Anne-de-la-Pérade. Furthermore, 14 ha of high marshes became low marshes, and a small area (4 ha) of shrub swamps became low marshes. Only 1 ha of shrub swamps reverted to high marshes, while 2 ha of forested swamps were converted to high marshes.

No plant community dominated by invasive plants was identified in the sector.

4.9.2 Partial changes between 1970–1978 and 1990–1991

During this period, the area of wetlands in Gentilly increased from 2408 ha to 2573 ha, an increase of 163 ha or roughly 7% (Figure 57). Losses totalled 482 ha and gains, 647 ha. When inconsistencies are eliminated, wetland area decreased from 2916 ha in the late 1970s to 2887 ha in 1990–1991. When the corrected figures are used, losses totalled 28 ha and gains were zero, for a net loss of 28 ha or 1% (Figure 58).



Sector: Fluvial estuary

1990

	10	2	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	1	3	50	51	52	54	55	Total
10	8	85		34	2						0	5								6	0						140
2	35	1068		544	12						1	15								427	2	1	0	6	0		2112
11																											0
12																											0
20	3	0		5	2							4								0	0	5	2	1	3		25
21																											0
23																											0
22																											0
24																											0
25																											0
30	12	0		4	6						1	19								0	1	4	1	2	12		62
40	25			7	7						1	23								3	1	1	1	2	2		71
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
1	3	449		72	1							1								2638	0	0	0	1	1		3166
3	0			2								0								1	0	1	1	4	1		11
50	3			0	4							5								2		455	429	85	98		1081
51	2	0		0	4						0	3								2	0	50	59	34	60		213
52																											0
54	6	0		9	13							69								1		52	16	27	251		445
55																											0
Total	97	1602	0	677	51	0	0	0	0	0	3	143	0	0	0	0	0	0	0	3080	4	568	509	162	429	0	7324

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 57 Transition matrix for the portion of the fluvial estuary analyzed between 1970–1978 and 1990–1991

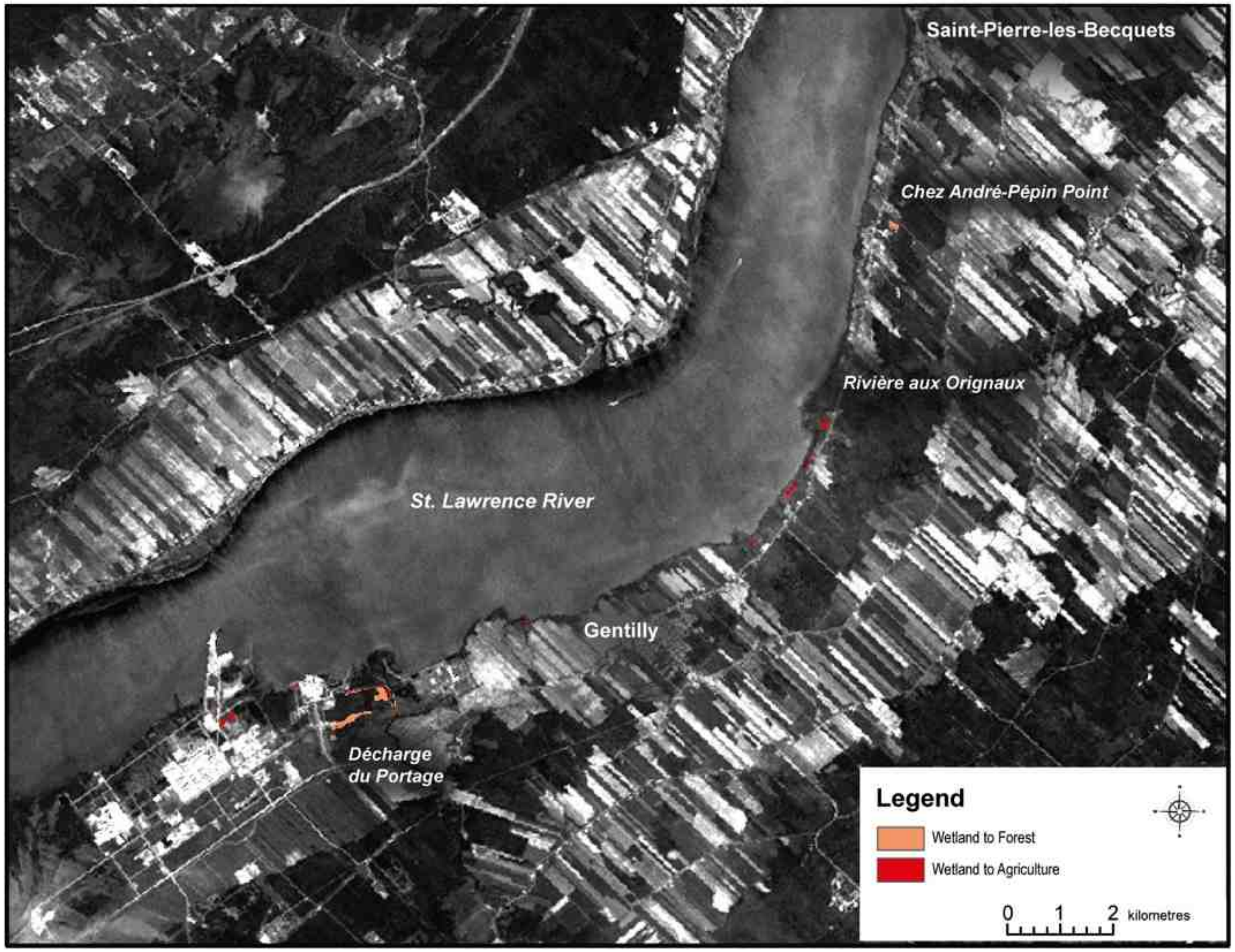


Figure 58 Losses and gains of marshes and swamps in the portion of the fluvial estuary analyzed between 1970–1978 and 1990–1991

The relative drying index for the period (Table 18) was 0.06, illustrating that overall, wetlands in the Gentilly sector showed a slight trend towards more terrestrial environments. The tidal effect is significant and, when it is excluded, an inverse but very slight trend toward wetter environments, with water being increasingly present, was observed.

Of all the losses observed during this period, those that were retained included 17 ha of wetlands that were identified as forests in 1991. This phenomenon was encountered around Décharge du Portage (east of the Gentilly nuclear power station) and at a small site in Saint-Pierre-les-Becquets, east of Chez André-Pépin Point. Although we consider these areas to be upland in nature, owing to the lack of field data we could not call into question the classification by Groupe Dryade. In addition, 11 ha of wetlands were converted to agricultural land along the banks of the river. These seem to be plausible changes.

Losses and gains not retained in the analysis are described in Appendix 58.

Progressive changes within wetlands included 20 ha of low marshes and 4 ha of high marshes that became shrub swamps. Furthermore, 19 ha of shrub swamps became forested swamps (mainly at the mouth of the Rivière aux Orignaux and near the Gentilly nuclear power station). In addition, 14 ha of low marshes became filled in with vegetation and were transformed into high marshes.

Regressive changes within wetlands included the transformation of 32 ha of forested swamps into low marshes, mainly in the wooded area west of the Gentilly nuclear power station. In addition, 7 ha of forested swamps reverted to high marshes, 16 ha of shrub swamps to low marshes, and 6 ha of shrub swamps to high marshes. Lastly, 8 ha of high marshes reverted to low marshes.

No invasive plant species were found during the period.

4.9.3 Partial changes between 1990–1991 and 1996–1997

During this period, the area of wetlands in the Gentilly subsector decreased from 2573 ha to 1537 ha, a drop of 1036 ha or roughly 40% (Figure 59). Losses totalled 1300 ha, and gains totalled 264 ha. When inconsistencies are eliminated, losses totalled 5 ha and gains, 254 ha, for a net gain of 249 ha or 0.4% (Figure 60). The corrected area of wetlands was 2339 ha in 1990–1991 and 2588 ha in 2006–2007.

The relative drying index for the period (Table 18) was –0.58, showing that wetlands in the Gentilly sector became moderately wetter overall during the period. When changes involving open water are excluded, however, the trend is towards more terrestrial environments.

The only wetland losses retained, although small, can be attributed to urbanization. Therefore, 5 ha of the 23 ha of transformations into built-up area are considered plausible. These changes occurred mainly around the Gentilly nuclear power station. The remainder are attributable to classification problems.

The great majority of gains observed were retained, including the conversion of 254 ha of open water to wetlands. They are concentrated mainly on the Gentilly Flats. Tidal level differences do not explain this change.

Losses and gains not retained in the analysis are described in Appendix 58.

Several changes within wetlands were observed during this period. Progressive changes included 10 ha of low marshes that became high marshes in 1996–1997 and 14 ha of low marshes and 3 ha of high marshes that became shrub swamps. In addition, 5 ha of low marshes and 1 ha of high marshes were converted to forested swamps. All of these changes were concentrated in the Gentilly nuclear power station sector.

Regressive changes within wetlands included 10 ha of forested swamps that were reclassified as shrub swamps (again in the sector west of the Gentilly nuclear power station). Other forested swamps apparently also reverted to an earlier stage: 3 ha to high marshes and 2 ha to low marshes. Lastly, 4 ha of high marshes reverted to low marshes.

No plant communities dominated by invasive species were identified during the period.

Sector: Fluvial estuary fluvial

1997

1990

	10	2	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	1	3	50	51	52	54	55	Total
10	24	0			8						12	3								6	8	14	0	4	17		97
2	17	843			0						0	0								738	1	0		2	1		1602
11																											0
12	73	230			2						2	2								315	5	8	0	11	28		677
20	4				7						3	1								1	3	12	0	4	17		51
21																											0
23																											0
22																											0
24																											0
25																											0
30	0				0						0	0								0	0	0		0	1		3
40	2				3						10	25								2	1	28	0	2	70		143
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
1	1	253			0						0									2814	1	4	0	4	3		3080
3	0				0						0	0								1	1	0		0	0		4
50	0				1						1	1								0	3	428	10	22	102		568
51	0				0						0									0	1	438	11	19	39		509
52	0	0			0						1	1								3	2	75	3	52	24		162
54					1						2	1								1	0	76	1	8	338		429
55																											0
Total	121	1327	0	0	23	0	0	0	0	0	33	34	0	0	0	0	0	0	0	3881	26	1085	26	129	640	0	7324

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 59 Transition matrix for the portion of the fluvial estuary analyzed between 1990–1991 and 1996–1997

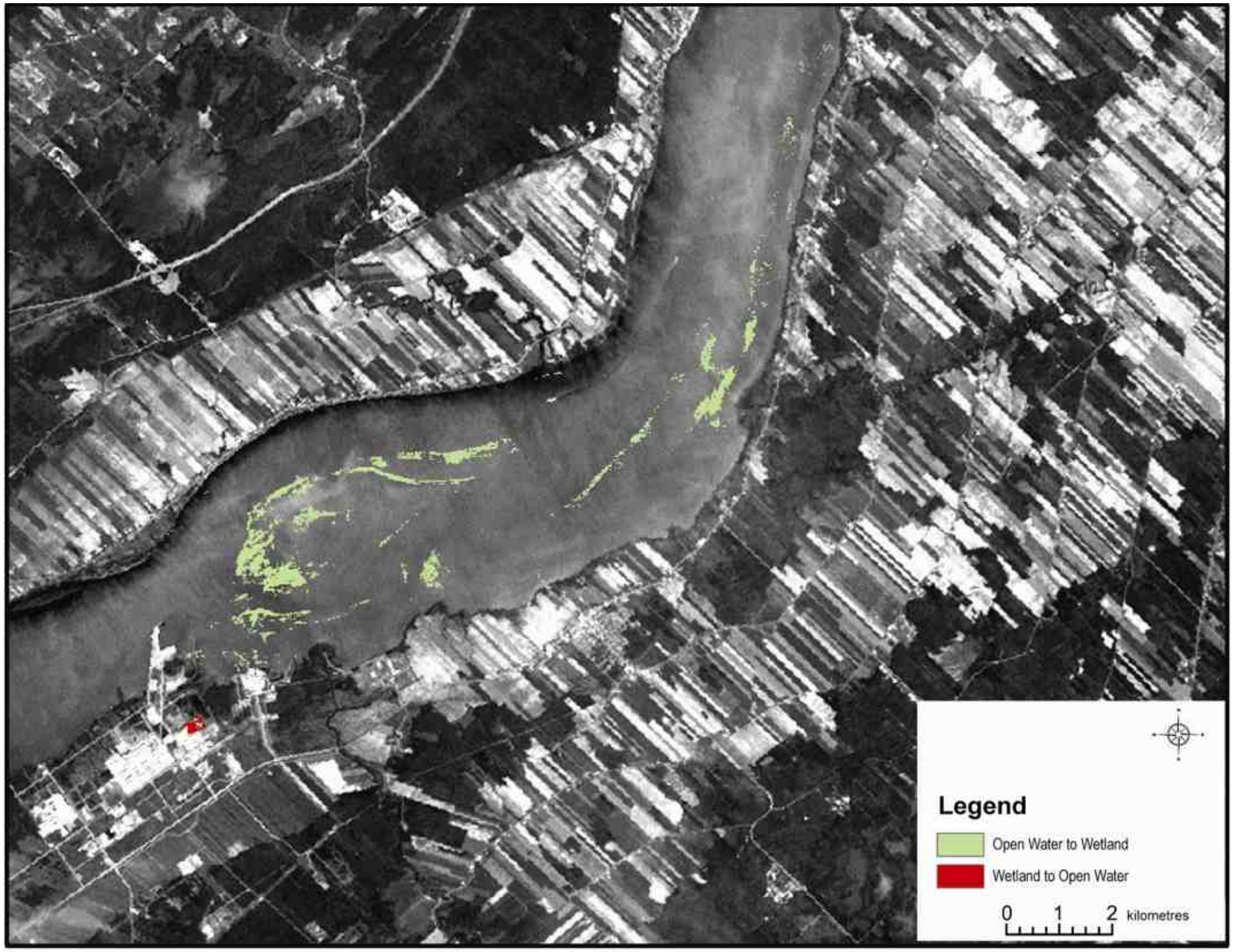


Figure 60 Losses and gains of marshes and swamps in the portion of the fluvial estuary analyzed between 1990–1991 and 1996–1997

4.9.4 Partial changes between 1996–1997 and 2000–2002

During this period, the area of wetlands in the Gentilly subsector increased from 1537 ha to 1666 ha, an increase of 129 ha or 8% (Figure 61). Losses totalled 554 ha, while gains totalled 683 ha. When inconsistencies are eliminated, corrected wetland losses totalled 528 ha and gains were zero (Figure 62). Conservative estimates totalled 2133 ha in 1996–1997 and 1604 ha in 2000–2002.

The relative drying index for the period (Table 18) was –0.09, showing that, overall, there was a very slight trend towards more terrestrial environments in the Gentilly subsector during this period. When changes involving open water are excluded, the index shows a moderate trend in the same direction, although it was not very dominant in terms of the surface area affected.

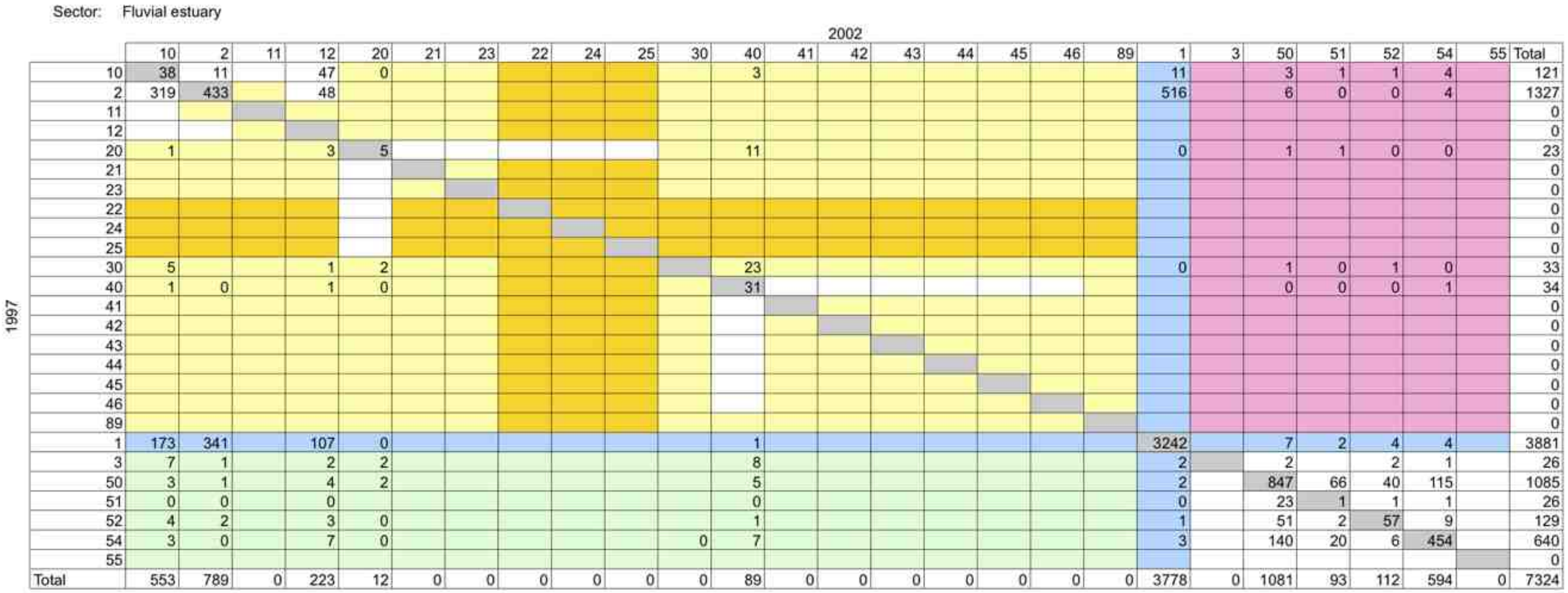
The only losses retained show that 527 ha of wetlands were lost to open water. Tidal differences cannot explain this change (Champlain hydrometric station: 0.815 m on August 10, 1997, at 10:10 a.m. EDT; 0.740 m on September 20, 2000, at 11:40 a.m. EDT). Although we have no information that would explain this difference between the two maps, the difference is too great to be due to inconsistencies alone.

Gains not retained in the analysis are described in Appendix 58.

Few changes within wetlands are observed. Progressive changes include slightly over 3 ha of low marshes that were transformed mainly into forested swamps. Similarly, 11 ha of high marshes and 23 ha of shrub swamps became forested swamps, possibly due to an overestimation of swamps in 1996–1997.

Regressive changes within wetlands were even less significant: 6 ha of shrub swamps, 2 ha of forested swamps and 4 ha of high marshes all reverted to low marshes.

No plant communities dominated by invasive species were identified during the period.



Sector: Fluvial estuary

		2002																									
		10	2	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	1	3	50	51	52	54	55	Total
1997	10	38	11		47	0							3								11		3	1	1	4		121
	2	319	433		48																516		6	0	0	4		1327
	11																											0
	12																											0
	20	1			3	5							11								0		1	1	0	0		23
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	5			1	2							23								0		1	0	1	0		33
	40	1	0		1	0							31										0	0	0	1		34
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	1	173	341		107	0							1								3242		7	2	4	4		3881
	3	7	1		2	2							8								2		2		2	1		26
	50	3	1		4	2							5								2		847	66	40	115		1085
	51	0	0		0								0								0		23	1	1	1		26
	52	4	2		3	0							1								1		51	2	57	9		129
	54	3	0		7	0						0	7								3		140	20	6	454		640
	55																											0
Total		553	789	0	223	12	0	0	0	0	0	0	89	0	0	0	0	0	0	0	3778	0	1081	93	112	594	0	7324

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 61 Transition matrix for the portion of the fluvial estuary analyzed between 1996–1997 and 2000–2002

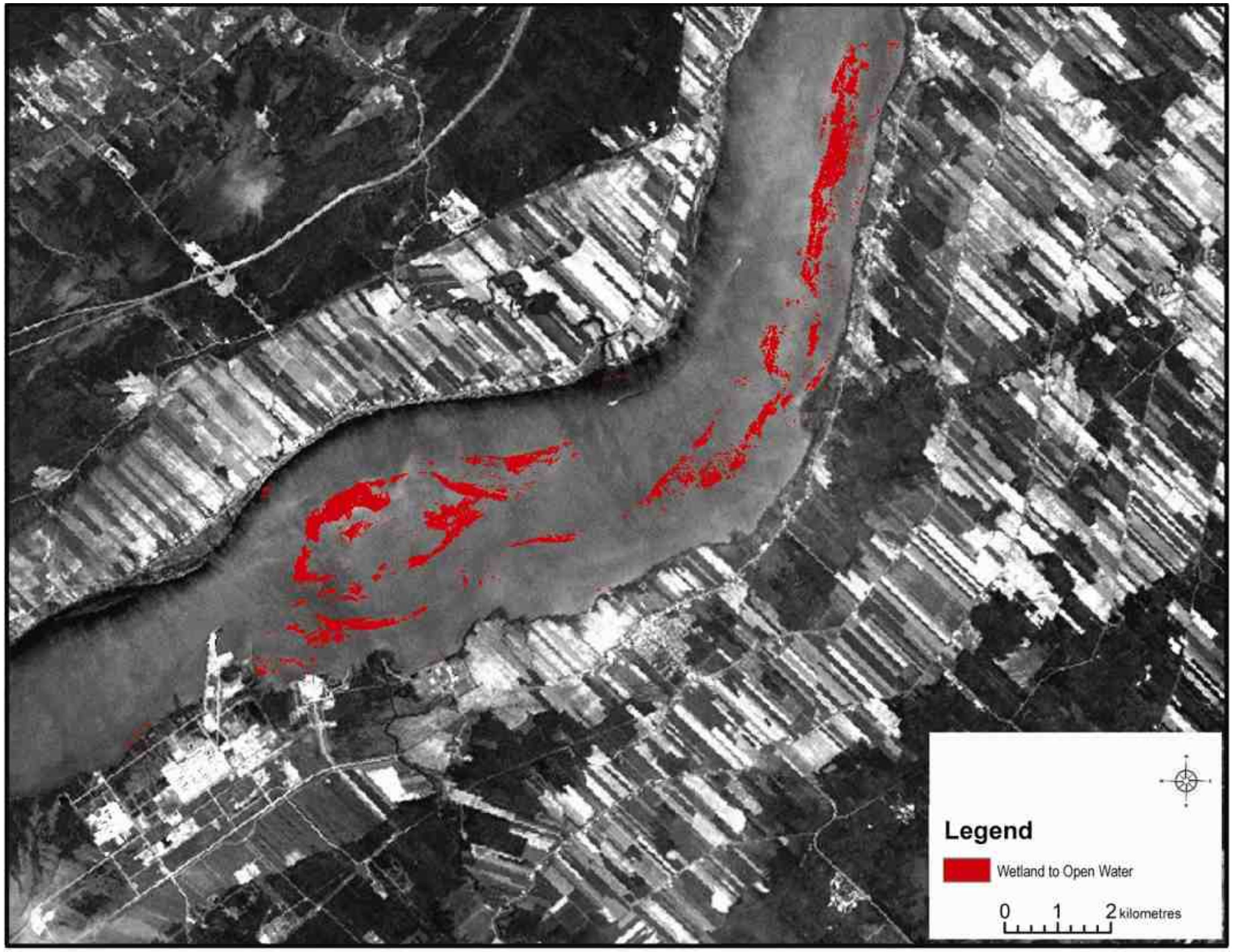


Figure 62 Losses and gains of marshes and swamps in the portion of the fluvial estuary analyzed between 1996–1997 and 2000–2002

4.10 QUEBEC CITY–LÉVIS

A total of 45 165 ha (including open water and adjacent terrestrial habitats) were analyzed in the Quebec City–Lévis sector in both 1990–1991 and 2000–2002. Coverage of the sector was complete (Appendices 60 and 61).

However, only one subsector, the Côte-de-Beaupré region, was examined in all four time periods (1970-1978, 1990-1991, 1996-1997 and 2000-2002). The area is estimated at 3292 ha (Appendices 62 to 65).

The relative drying indices for the Quebec City–Lévis sector, shown in Table 19, appear to show a moderate trend towards wetter environments, particularly before 1996–1997.

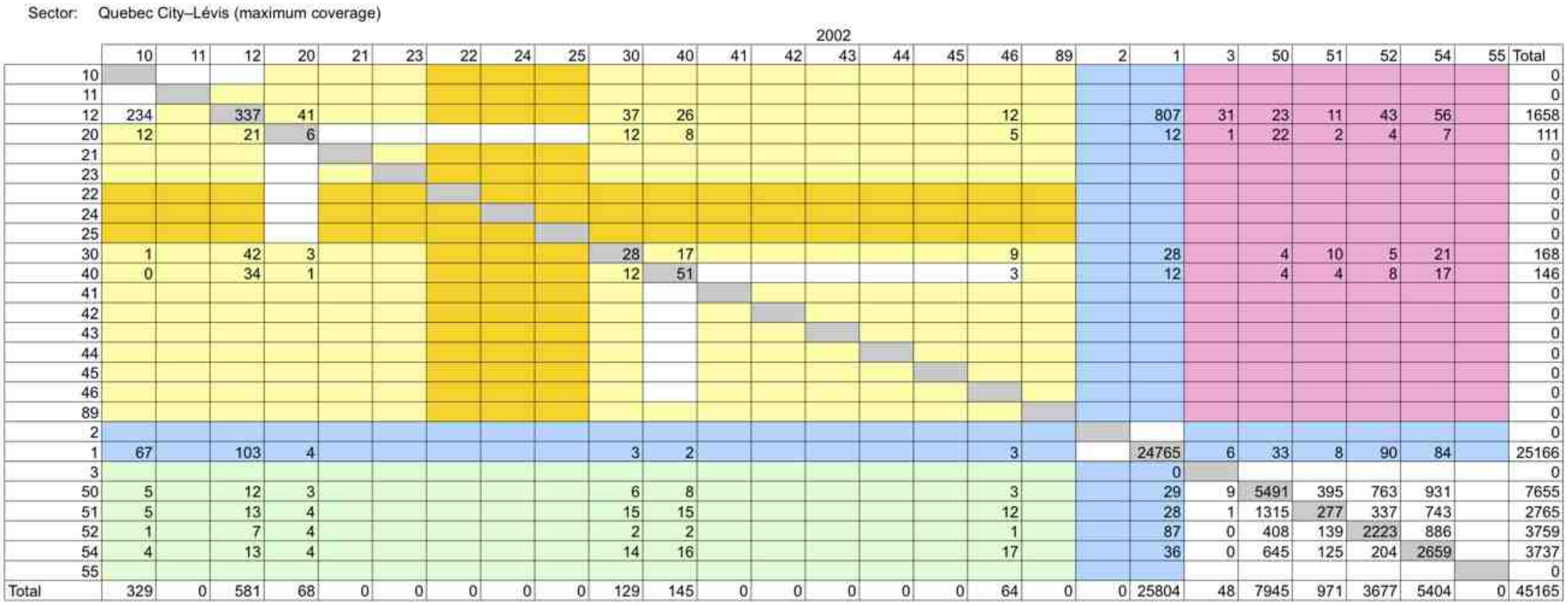
Table 19 Relative drying indices for the Quebec City–Lévis sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991 (Côte-de-Beaupré)	–0.20
Between 1990–1991 and 1996–1997 (Côte-de-Beaupré)	–0.55
Between 1996–1997 and 2000–2002 (Côte-de-Beaupré)	0.06
Between 1990–1991 and 2000–2002	–0.45

4.10.1 Overall changes between 1990–1991 and 2000–2002

Wetlands in the Quebec City–Lévis sector declined from 2083 ha in 1990–1991 to 1317 ha in 2000–2002, a decrease of 766 ha or roughly 37% (Figure 63). Losses were estimated at 1132 ha and gains at 365 ha. When inconsistencies are eliminated, the balance was zero, with neither gains nor losses. The corrected area of wetlands was 951 ha for both periods.

The relative drying index for the period was –0.45, showing a significant trend towards more aquatic environments in the sector's wetlands (Table 19). This is consistent with the trend observed in the indices for the analysis involving all four datasets to maximize temporal coverage, particularly between 1990–1991 and 1996–1997. When changes linked to tides are excluded, the opposite trend is found, albeit a slight one—towards more terrestrial environments.



Sector: Quebec City–Lévis (maximum coverage)

		2002																									
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1991	10																											0
	11																											0
	12	234		337	41						37	26						12			807	31	23	11	43	56		1658
	20	12		21	6						12	8						5			12	1	22	2	4	7		111
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	1		42	3						28	17						9			28		4	10	5	21		168
	40	0		34	1						12	51						3			12		4	4	8	17		146
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2																											0
	1	67		103	4						3	2						3			24765	6	33	8	90	84		25166
	3																				0							0
	50	5		12	3						6	8						3			29	9	5491	395	763	931		7655
	51	5		13	4						15	15						12			28	1	1315	277	337	743		2765
	52	1		7	4						2	2						1			87	0	408	139	2223	886		3759
	54	4		13	4						14	16						17			36	0	645	125	204	2659		3737
	55																											0
	Total	329	0	581	68	0	0	0	0	0	129	145	0	0	0	0	0	64	0	0	25804	48	7945	971	3677	5404	0	45165

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 63 Transition matrix for the Quebec City–Lévis sector between 1990–1991 and 2000–2002

No losses or gains were retained (Appendix 66).

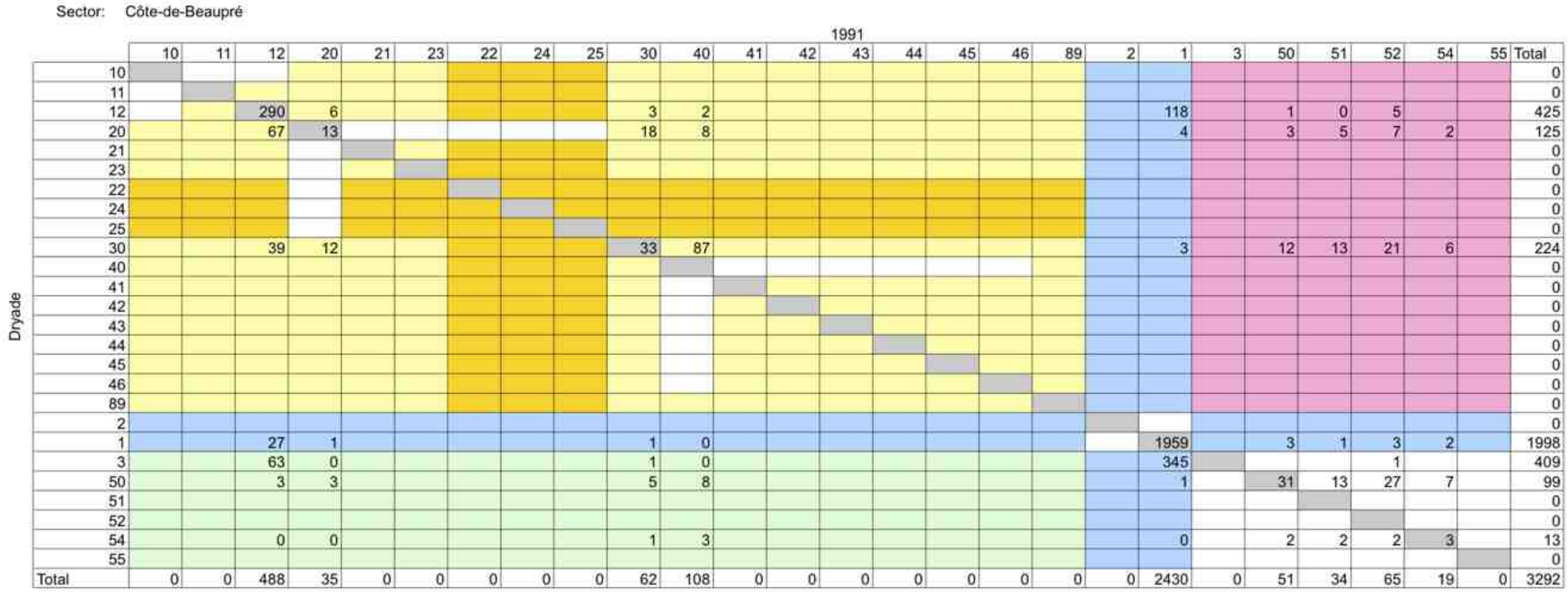
Multiple changes occurred within wetlands. The most significant progressive changes involved 41 ha of low marshes that were converted to high marshes, mainly on the north shore of Île d’Orléans. In addition, 37 ha of low marshes and 12 ha of high marshes were transformed into shrub swamps; this occurred in scattered locations in the sector, with a slightly greater occurrence at Beaupré, upstream of the mouth of the Sainte-Anne River. Also, 38 ha of low marshes became forested swamps, 12 ha of them dominated by *Salix* sp. and the other 26 ha without a dominant species identified. This occurred in scattered locations on the Côte-de-Beaupré and on the north shore of Île d’Orléans. Lastly, forested swamps replaced 13 ha of high marshes and 26 ha of shrub swamps.

Regressive changes include certain forested swamps that reverted to shrub swamps (12 ha), high marshes (1 ha) and low marshes (a little over 34 ha). These low marshes are found on the Côte-de-Beaupré, near Périgny. In addition, 3 ha of shrub swamps reverted to high marshes and 43 ha reverted to low marshes (almost all dominated by *Schoenoplectus pungens*). This phenomenon was concentrated around Le Moyne on the Côte-de-Beaupré as well as on the opposite side of the river, in the southwest part of Sainte-Famille on Île d’Orléans. Lastly, 33 ha of high marshes were converted to low marshes (most dominated by *Schoenoplectus pungens*).

No plant communities dominated by invasive species were identified in the sector.

4.10.2 Partial changes between 1970–1978 and 1990–1991

During this period, the area of wetlands on the Côte-de-Beaupré decreased from 774 ha to 693 ha, a drop of 81 ha or 10.5% (Figure 64). Losses totalled 197 ha, and gains were estimated at 117 ha. When inconsistencies are excluded, wetland area totalled 867 ha in the late 1970s and 814 ha in 1990–1991, for a decrease of 53 ha or 6%. Applying these corrections, losses are estimated at 73 ha and gains at 20 ha (Figure 65).



Sector: Côte-de-Beaupré

1991

Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12			290	6						3	2									118		1	0	5			425
20			67	13						18	8									4		3	5	7	2		125
21																											0
23																											0
22																											0
24																											0
25																											0
30			39	12						33	87									3		12	13	21	6		224
40																											0
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1			27	1						1	0									1959		3	1	3	2		1998
3			63	0						1	0									345				1			409
50			3	3						5	8									1		31	13	27	7		99
51																											0
52																											0
54			0	0						1	3									0		2	2	2	3		13
55																											0
Total	0	0	488	35	0	0	0	0	0	62	108	0	0	0	0	0	0	0	0	2430	0	51	34	65	19	0	3292

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 64 Transition matrix for the Côte-de-Beaupré subsector analyzed between 1970–1978 and 1990–1991

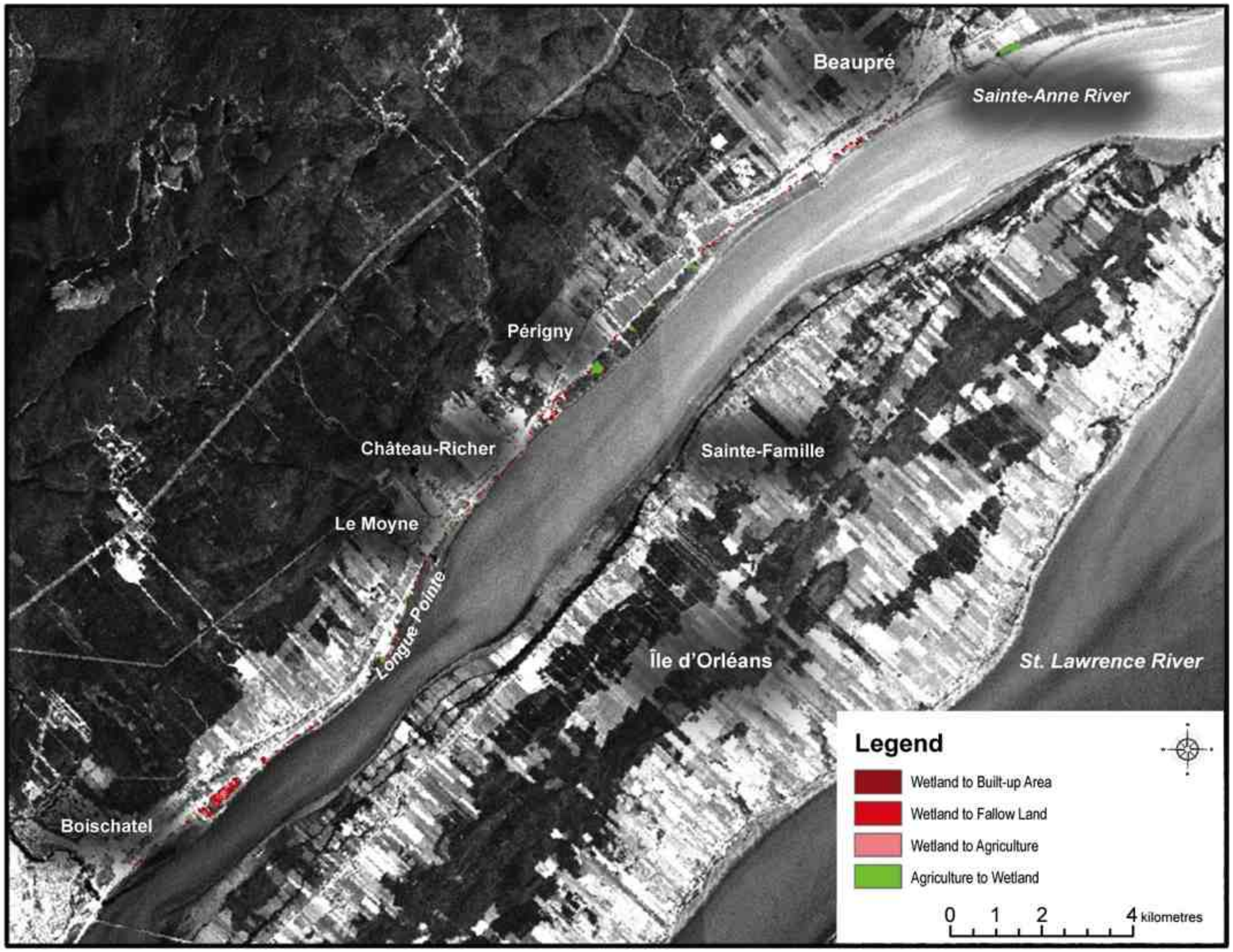


Figure 65 **Losses and gains of marshes and swamps in the Côte-de-Beaupré subsector analyzed between 1970–1978 and 1990–1991**

The relative drying index for the period (Table 19) is –0.20, showing an overall trend toward slightly wetter environments in wetlands on the Côte-de-Beaupré. When tide-related changes are excluded, no significant trend in changes within wetlands is observed.

Many wetland losses were retained for this period. These include 32 ha of wetlands that were converted to built-up area. They can be found in various locations along highway 138, with concentrations in the Boischatel, Château-Richer and Sainte-Anne-de-Beaupré areas. In general, these constitute genuine wetland losses. In addition, 18 ha of wetlands were converted to fallow land, concentrated around the transmission lines at Boischatel. Furthermore, 15 ha of wetlands scattered throughout the sector but concentrated to some degree near the transmission line corridor were converted to agricultural land.

Since we do not have any data demonstrating that wetlands are overestimated on the Groupe Dryade maps, we can only describe these changes as plausible. Lastly, in the Boischatel area, 8 ha of wetlands became forest.

Only one type of gain was retained for the period: 20 ha of agricultural land that were converted to wetlands on the 1990–1991 map. These wetlands can be seen downstream from the Donohue company wharf at Beaupré and in Périgny.

Losses and gains not retained are described in Appendix 66.

Changes within wetlands included several progressive changes. The largest change involved 87 ha of shrub swamps that became forested swamps; however, forested swamps seem to have been overestimated on the 1990–1991 map. In addition, 26 ha of high marshes became shrub swamps (18 ha) and forested swamps (8 ha). Lastly, 11 ha of low marshes dominated by *Schoenoplectus pungens* became high marshes (6 ha), shrub swamps (3 ha) and forested swamps (2 ha).

The most significant regressive changes included 67 ha of high marshes and 39 ha of shrub swamps that reverted to low marshes. In addition, 12 ha of shrub swamps reverted to high marshes.

No invasive plant species were identified during this period.

4.10.3 Partial changes between 1990–1991 and 1996–1997

During this period, the area of wetlands decreased from 693 ha to 451 ha, a drop of 242 ha or 35% (Figure 66). Estimated losses totalled 297 ha and gains totalled 55 ha. When inconsistencies are eliminated, wetland area totalled 679 ha in 1991 and 702 ha in 1996–97, representing an increase of 23 ha or 3%. When these corrected figures are used, there are no losses and 23 ha in gains (Figure 67).

The relative wetland drying index for the period (Table 19) is –0.55, showing that, overall, the wetlands in the Côte-de-Beaupré subsector showed a moderate trend towards wetter environments during the period, which is mainly attributable to tidal effects. When tide-related changes are excluded, a slight trend towards more terrestrial environments can be seen.

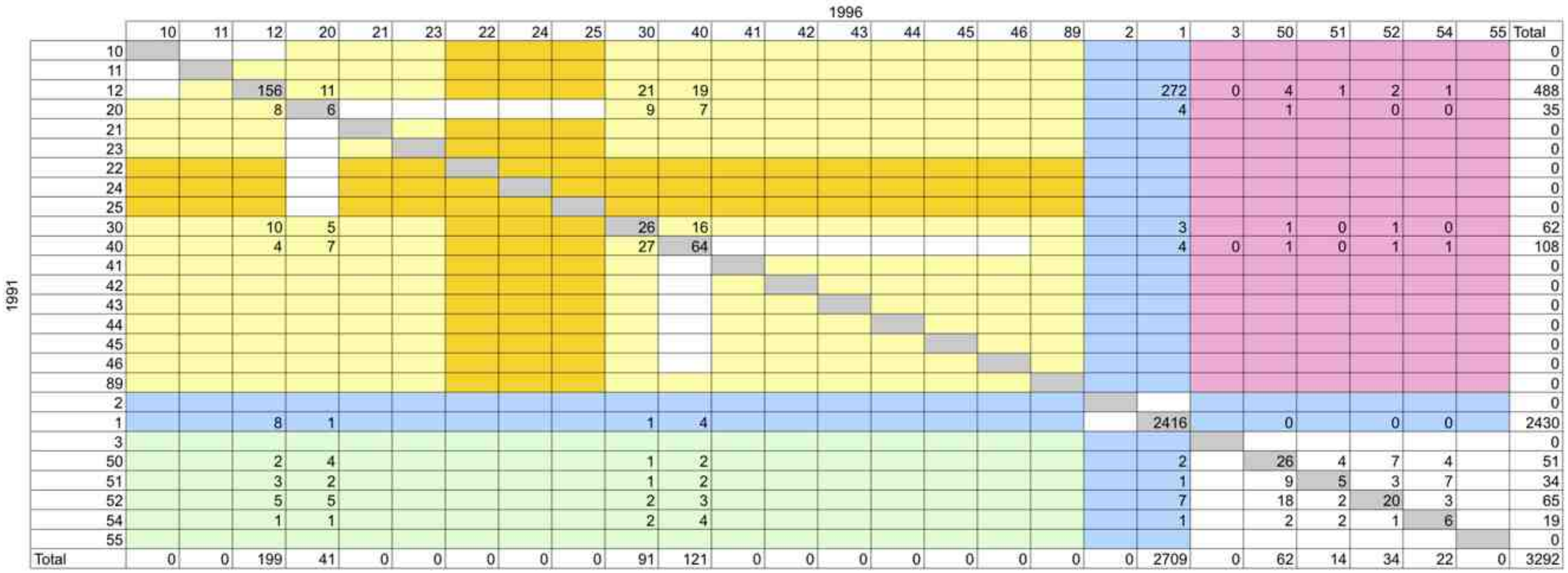
In the case of the gains retained, 14 ha of open water were replaced by wetlands. This occurred in areas along the St. Lawrence shoreline at Périgny and Le Moyne. The great majority of these differences appear valid. In addition, 9 ha of agricultural lands were converted to marshes and swamps. These changes are very well dispersed over the sector and an examination of the raw images suggests that they are actual changes in the landscape.

Losses and gains not retained are described in Appendix 66.

It is difficult to reach a conclusion on the overall changes observed within wetlands during the period. There is a geometric shift between the maps, which seems to have produced a whole series of incorrect transformations. Progressive changes within wetlands include 51 ha of low marshes dominated by *Schoenoplectus pungens,* which seem to have been transformed into high marshes (11 ha), shrub swamps (21 ha) and forested swamps (19 ha). In addition, 16 ha of high marshes were classified on the 1996–1997 maps as shrub swamps (9 ha) and forested swamps (7 ha). Lastly, 16 ha of shrub swamps became forested swamps.

The most extensive regressive change observed within wetlands was the conversion of 27 ha of forested swamps to shrub swamps. In addition, 5 ha of shrub swamps and 7 ha of forested swamps reverted to high marshes. Also, 8 ha of high marshes, 10 ha of shrub swamps and 4 ha of forested swamps reverted to low marshes.

No invasive plant species were identified during the period.



Sector: Côte-de-Beaupré

1996

1991	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12			156	11						21	19									272	0	4	1	2	1		488
20			8	6						9	7									4		1		0	0		35
21																											0
23																											0
22																											0
24																											0
25																											0
30			10	5						26	16									3		1	0	1	0		62
40			4	7						27	64									4	0	1	0	1	1		108
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1			8	1						1	4									2416		0		0	0		2430
3																											0
50			2	4						1	2									2		26	4	7	4		51
51			3	2						1	2									1		9	5	3	7		34
52			5	5						2	3									7		18	2	20	3		65
54			1	1						2	4									1		2	2	1	6		19
55																											0
Total	0	0	199	41	0	0	0	0	0	91	121	0	0	0	0	0	0	0	0	2709	0	62	14	34	22	0	3292

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 66 Transition matrix for the Côte-de-Beaupré subsector analyzed between 1990–1991 and 1996–1997

Figure 67 Losses and gains of marshes and swamps in the Côte-de-Beaupré subsector analyzed between 1990–1991 and 1996–1997

4.10.4 Partial changes betwen 1996–1997 and 2000–2002

During this period, the area of wetlands increased by 16 ha from 451 ha to 467 ha, an increase of 3% (Figure 68). Estimated losses were 139 ha and gains, 154 ha. When inconsistencies are excluded, wetland area totalled 405 ha in 1996–1997 and 374 ha in 2000–2002, a net decrease of 31 ha or 8%. Corrected losses totalled 31 ha and gains were zero (Figure 69).

The relative drying index for the period (Table 19) is 0.06, showing that, overall, there was a very slight trend toward more terrestrial wetlands in the Côte-de-Beaupré sector. When changes linked to tides are excluded, however, a slight trend towards more aquatic habitats is observed.

Interpretation of these maps was complicated since the 2000–2002 map consisted of a mosaic of four images taken on different dates (Tables 6 and 7). The only losses that were retained were 31 ha of a total 92 ha lost to open water. The raw images show that such losses were real in the area east of the mouth of the Saint-Anne River.

Losses and gains not retained in the analysis are described in Appendix 66.

Several changes can be observed within wetlands. Some of the progressive changes appear to have resulted from incorrect identification of wetland type on one of the maps. These include low marshes transformed into high marshes (5 ha), into shrub swamps (18 ha upstream from the mouth of the Saint-Anne River) and into forested swamps (5 ha). In addition, 3 ha of low marshes were converted to shrub swamps and 8 ha to forested swamps. Lastly, 24 ha of shrub swamps became forested swamps (downstream of the Donohue plant in Beaupré and along the wooded shoreline of Périgny).

Sector: Côte-de-Beaupré

	2002																										
1996	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12	50		45	5						18	4						1			63		1	2	5	5		199
20	1		3	2						4	8						0			5		4	2	6	4		41
21																											0
23																											0
22																											0
24																											0
25																											0
30	1		30	1						19	21						3			11		1	1	2	2		91
40	1		42	1						9	43						1			13		1	1	4	5		121
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1	91		50	1						2	3						0			2554		2	0	5	2		2709
3			0																	0				0			0
50	1		0							1	1									3		11	7	30	9		62
51			1							0	0									1		2	3	3	5		14
52	0		0	0						0	1									2		2	1	25	2		34
54	0		2								0						0			1		2	4	2	12		22
55																											0
Total	146	0	173	10	0	0	0	0	0	53	80	0	0	0	0	0	5	0	0	2653	0	25	22	81	45	0	3292

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 68 Transition matrix for the Côte-de-Beaupré subsector analyzed between 1996–1997 and 2000–2002

Figure 69 **Losses and gains of marshes and swamps in the Côte-de-Beaupré subsector analyzed between 1996–1997 and 2000–2002**

The most significant regressive change within wetlands was the transformation of 31 ha of shrub swamps and 43 ha of forested swamps into low marshes, on Longue Pointe (Giguère) and the wooded shoreline of Périgny. Lastly, 9 ha of forested swamps scattered over the sector became shrub swamps.

No invasive plant species were identified during the period.

4.11 UPPER ESTUARY

A total of 66 727 ha, including open water and adjacent terrestrial habitats, were analyzed in the upper estuary both in 1990–1991 and 2000–2002. Coverage of the sector was complete (Appendices 68 and 69).

In addition two subsectors were also examined in the other time periods (1970-1978 and 1996-1997), allowing for a comparison of these subsectors across all four time periods. The areas studies were 1250 ha in the Cap Toumente subsector (Appendices 70 to 73) and 3366 ha in the Kamouraska subsector (Appendices 74 to 77).

Relative drying indices for the upper estuary are shown in Table 20. An examination of these statistics appears to show a trend toward more aquatic habitats, particularly in the Kamouraska region, and in the sector as a whole between 1990–1991 and 2000–2002. However, the trend is less clear for the Cap Tourmente region.

Table 20 Relative drying indices for the upper estuary

Period	Relative Drying Index
Between 1970–1978 and 1990–1991 (Cap Tourmente)	0.02
Between 1990–1991 and 1996–1997 (Cap Tourmente)	–0.57
Between 1996–1997 and 2000–2002 (Cap Tourmente)	0.33
Between 1970–1978 and 1990–1991 (Kamouraska)	–0.56
Between 1990–1991 and 1996–1997 (Kamouraska)	0.23
Between 1996–1997 and 2000–2002 (Kamouraska)	–0.39
Between 1990–1991 and 2000–2002	–0.56

4.11.1 Overall changes between 1990–1991 and 2000–2002

During this period, the area of wetlands in the portion of the upper estuary analyzed decreased by 1113 ha or roughly 20%, from 5481 ha in 1991 to 4368 ha in 2000–2002

(Figure 70). Estimated losses totalled 2387 ha and gains, 1274 ha. After inconsistencies were eliminated, the corrected area totalled 5189 ha in 1991 and 5223 ha in 2000–2002, representing an increase of 34 ha or 0.7%. Corrected losses totalled 29 ha and gains, 63 ha (Figure 71).

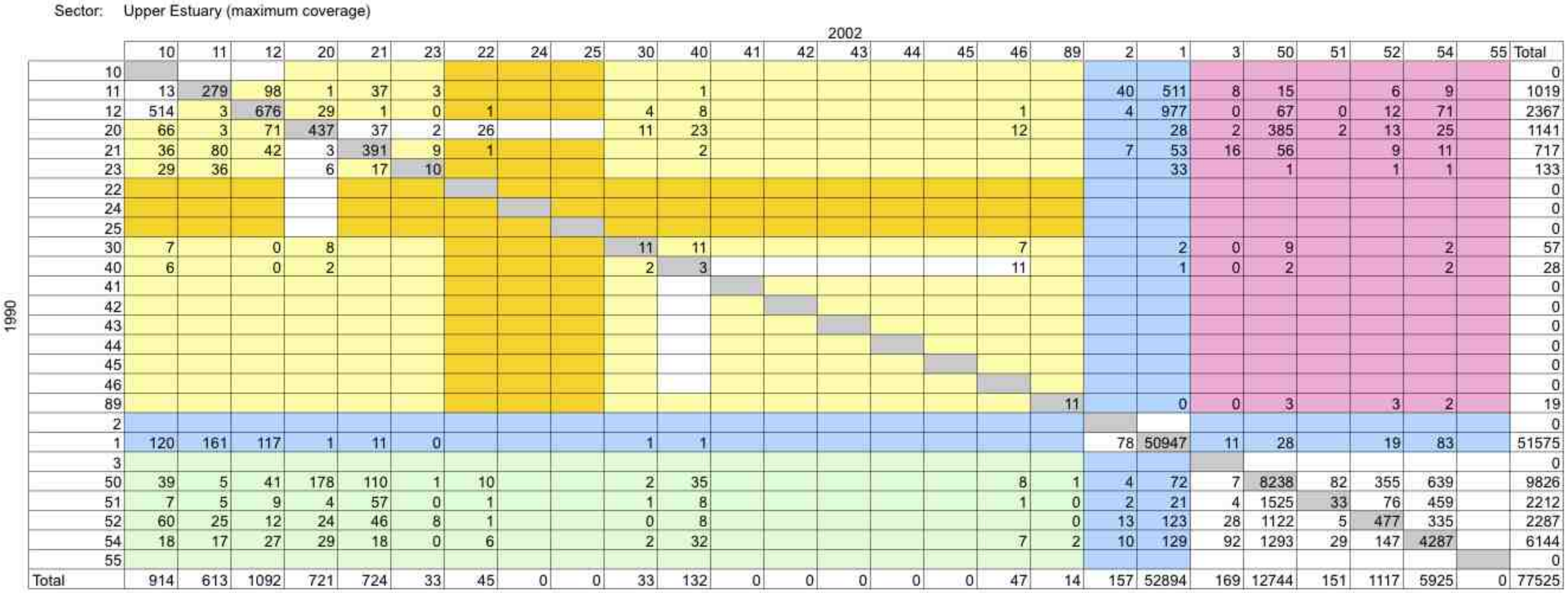
The relative drying index for the period is –0.56, illustrating a strong trend toward more aquatic environments in wetlands between the two periods (Table 20). When changes related to tides are excluded, a trend in the same direction is noted, albeit a slightly weaker one.

Losses retained totalled 29 ha, 27 ha of which were identified as substrate in 2000–2002. This transformation was observed very locally, particularly in the Kamouraska region, and affected saltmeadows as well as low marshes dominated by *Spartina alterniflora* that may have been subject to shoreline erosion in the sector. In addition, 2 ha of high marshes were lost to fallow land.

Gains observed included 185 ha that were identified as built-up area in 1990–1991 but classified as wetlands in 2000–2002. The largest portion (63 ha) of the 185 ha was located at the Gros-Cacouna marsh, a birding site, and the change is considered to be a genuine change. However, some confusion occurred in 1990–1991, since the site was likely covered with denuded substrate. The conversion of this site into bird habitat in the mid-1990s led to the creation of wetlands in this location. The rest of the gains, which were scattered over the sector, seem to have resulted from confusion between classes.

Losses and gains not retained in the analysis are described in Appendix 78.

Several changes within wetland categories were observed during the period. Most notably, 72 ha of low marshes (dominated mainly by *Spartina alterniflora* or *Schoenoplectus pungens*) became high marshes (mainly saltmeadows with no dominant plant species observed or, to a lesser degree, dominated by *Spartina patens* or *Phragmites australis*). These changes can be observed in the Cap Tourmente National Wildlife Area and at La Pocatière.



Sector: Upper Estuary (maximum coverage)

2002

1990

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11	13	279	98	1	37	3					1								40	511	8	15		6	9		1019
12	514	3	676	29	1	0	1			4	8						1		4	977	0	67	0	12	71		2367
20	66	3	71	437	37	2	26			11	23						12			28	2	385	2	13	25		1141
21	36	80	42	3	391	9	1				2								7	53	16	56		9	11		717
23	29	36		6	17	10														33		1		1	1		133
22																											0
24																											0
25																											0
30	7		0	8						11	11						7			2	0	9			2		57
40	6		0	2						2	3						11			1	0	2			2		28
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																		11		0	0	3		3	2		19
2																											0
1	120	161	117	1	11	0				1	1								78	50947	11	28		19	83		51575
3																											0
50	39	5	41	178	110	1	10			2	35						8	1	4	72	7	8238	82	355	639		9826
51	7	5	9	4	57	0	1			1	8						1	0	2	21	4	1525	33	76	459		2212
52	60	25	12	24	46	8	1			0	8							0	13	123	28	1122	5	477	335		2287
54	18	17	27	29	18	0	6			2	32						7	2	10	129	92	1293	29	147	4287		6144
55																											0
Total	914	613	1092	721	724	33	45	0	0	33	132	0	0	0	0	0	47	14	157	52894	169	12744	151	1117	5925	0	77525

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 70 Transition matrix for the portion of the upper estuary analyzed between 1990–1991 and 2000–2002

Figure 71 **Losses and gains of marshes and swamps in the portion of the upper estuary analyzed between 1990–1991 and 2000–2002**

In addition, during this period low marshes were transformed into shrub swamps (4 ha) and forested swamps (10 ha), and a slightly greater area of high marshes was transformed into swamp, either shrub swamps (11 ha) or forested swamps (37 ha). This phenomenon was observed in the Cap Tourmente National Wildlife Area and in Montmagny. Lastly, 18 ha of shrub swamps were transformed into forested swamps (including 7 ha dominated by *Salix* sp., with the rest having no identified dominant species). These changes again are concentrated in the Cap Tourmente National Wildlife Area.

The most significant regressive changes within wetlands involved 363 ha of high marshes (divided into saltmeadow, high marshes dominated by *Spartina patens* and high marshes with no identified dominant species) transformed into low marshes (dominated by *Schoenoplectus pungens*, *Spartina alterniflora* or with no identified dominant species). These changes, which may have resulted from erosion, were concentrated near the Cap Tourmente National Wildlife Area and on Île du Gros Cacouna, but were also observed in more scattered fashion on the south shore opposite the Montmagny Islands, La Pocatière and Notre-Dame-du-Portage. In addition, small areas of shrub swamps reverted to low marshes (7 ha) or high marshes (8 ha), and some forested swamps reverted to low marshes (6 ha), high marshes (2 ha) or shrub swamps (2 ha).

In terms of invasive species, 46 ha of high marshes dominated by *Phragmites australis* were tallied in 2000–2002, on Île aux Grues and in the area between Saint-Roch-des-Aulnaies and La Pocatière. The species was present in the sector before 1925 and has continued its expansion ever since (Delisle 2002).

In addition, even though this class was completely eliminated after modifications to the 2000–2002 map (to a 25-m resolution), 18 ha of low marshes dominated by *Lythrum salicaria* were identified in the La Pocatière area (Létourneau and Jean 2006b, 2006c).

Since invasive species were not detected on the 1991 map, no comments can be made on their possible expansion.

4.11.2 Partial changes in the Cap Tourmente region

4.11.2.1 Between 1970–1978 and 1990–1991

During this period, the area of wetlands in the Cap Tourmente region increased from 452 ha to 472 ha, an increase of 20 ha or 4% (Figure 72). Estimated losses were 62 ha and gains, 82 ha. When inconsistencies were eliminated, wetland area totalled 507 ha in the late 1970s and 459 ha in 1990–1991, a decrease of 48 ha or 10%. Taking the corrections into account, losses totalled 48 ha and gains, zero (Figure 73).

The relative drying index for the period (Table 20) was 0.02, showing no overall trend in changes within wetland categories. When changes related to tides are excluded, a slight trend towards more terrestrial environments can be observed.

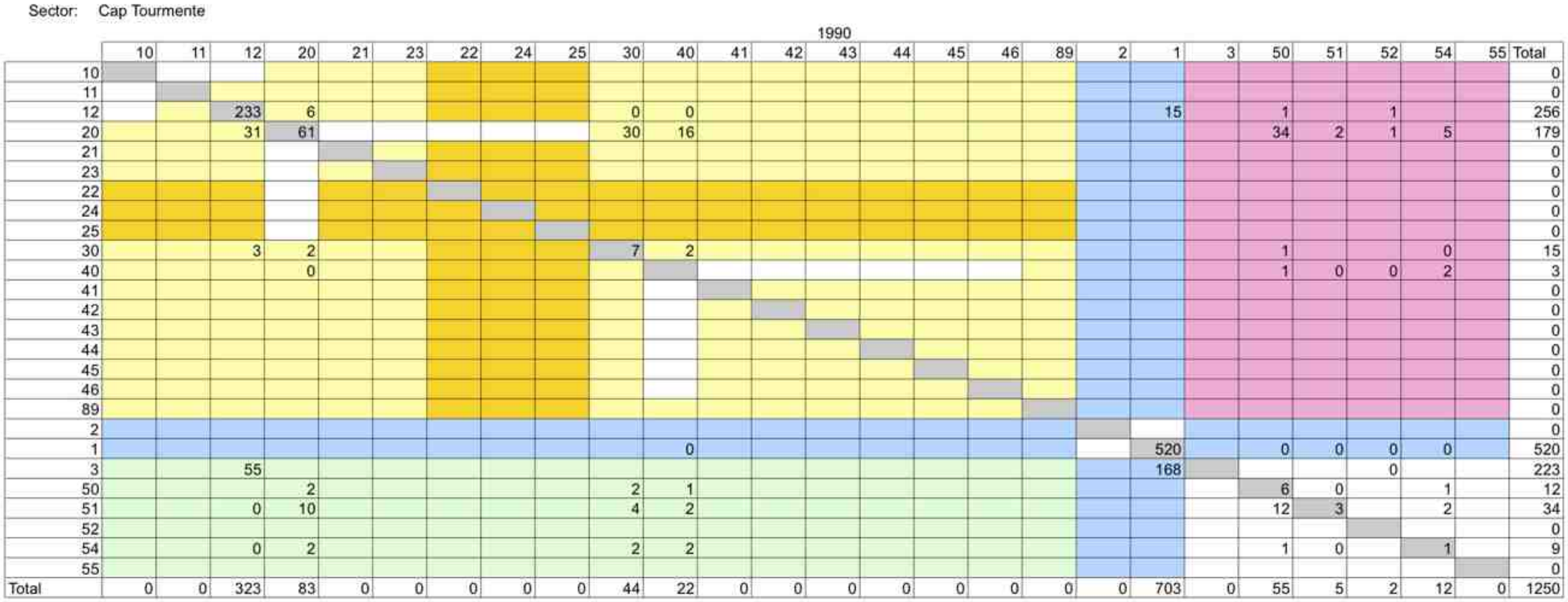
A number of losses of wetlands during the period were retained. The only ones of real significance involved 36 ha of wetlands that were transformed into agricultural land. Small areas of this can be identified, including areas in the Cap Tourmente National Wildlife Area (east of the Bois-sent-bon trail) and in Saint-Joachim, between the village and the shoreline of the St. Lawrence. Since we do not have any data demonstrating that wetlands were overestimated on the Groupe Dryade maps, we consider these changes to be plausible. In addition, there was a loss of 7 ha of wetlands that were transformed into forest south of the village of Saint-Joachim. Lastly, two small losses to fallow land and built-up area occurred, each involving 2 ha.

Losses and gains not retained in the analysis are described in Appendix 78.

Several progressive changes within wetlands during the period can be observed. First, 6 ha of low marshes dominated by *Schoenoplectus pungens* were transformed into high marshes, and 46 ha of high marshes became shrub swamps (30 ha) and forested swamps (16 ha). Lastly, 2 ha of shrub swamps became forested swamps. Forested swamps appear to be overestimated on the 1990–1991 map.

The most significant regressive changes within wetlands were 31 ha of high marshes and 3 ha of shrub swamps that reverted to low marshes dominated by *Schoenoplectus pungens*. In addition, 2 ha of shrub swamps reverted to high marshes.

No invasive plant species were identified during the period.



Sector: Cap Tourmente

1990

Dryade

	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12			233	6						0	0									15		1		1			256
20			31	61						30	16											34	2	1	5		179
21																											0
23																											0
22																											0
24																											0
25																											0
30			3	2						7	2											1			0		15
40				0																		1	0	0	2		3
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1											0									520		0	0	0	0		520
3			55																	168				0			223
50				2						2	1											6	0		1		12
51			0	10						4	2											12	3		2		34
52																											0
54			0	2						2	2											1	0		1		9
55																											0
Total	0	0	323	83	0	0	0	0	0	44	22	0	0	0	0	0	0	0	0	703	0	55	5	2	12	0	1250

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 72 Transition matrix for the Cap Tourmente subsector analyzed between 1970–1978 and 1990–1991

Figure 73 Losses and gains of marshes and swamps in the Cap Tourmente subsector analyzed between 1970–1978 and 1990–1991

4.11.2.2 Between 1990–1991 and 1996–1997

During this period, the area of wetlands decreased from 472 ha to 388 ha, a decrease of 84 ha or 18% (Figure 74). Estimated losses totalled 126 ha and gains, 41 ha. When inconsistencies are eliminated, wetlands totalled 456 ha in 1990–1991 and 486 ha in 1996–1997, an increase of 30 ha or 5%. When corrections are applied, losses were zero and gains totalled 30 ha (Figure 75).

The relative drying index for the period (Table 20) was –0.57, showing an overall moderate trend among wetlands in the Cap Tourmente sector towards wetter environments. When changes related to tides are excluded, a trend toward wetter environments in marshes and swamps still stands, although it is significantly diminished.

Gains retained include 25 ha of agricultural land that were transformed into wetlands, which occurred mainly in two locations on either side of Petit-Cap. An examination of the raw images appears to confirm that these changes in the landscape are real ones. In addition, the transformation of 6 ha of open water into wetlands was retained; this change was observed along the St. Lawrence shoreline, near the low marshes in the Cap Tourmente National Wildlife Area.

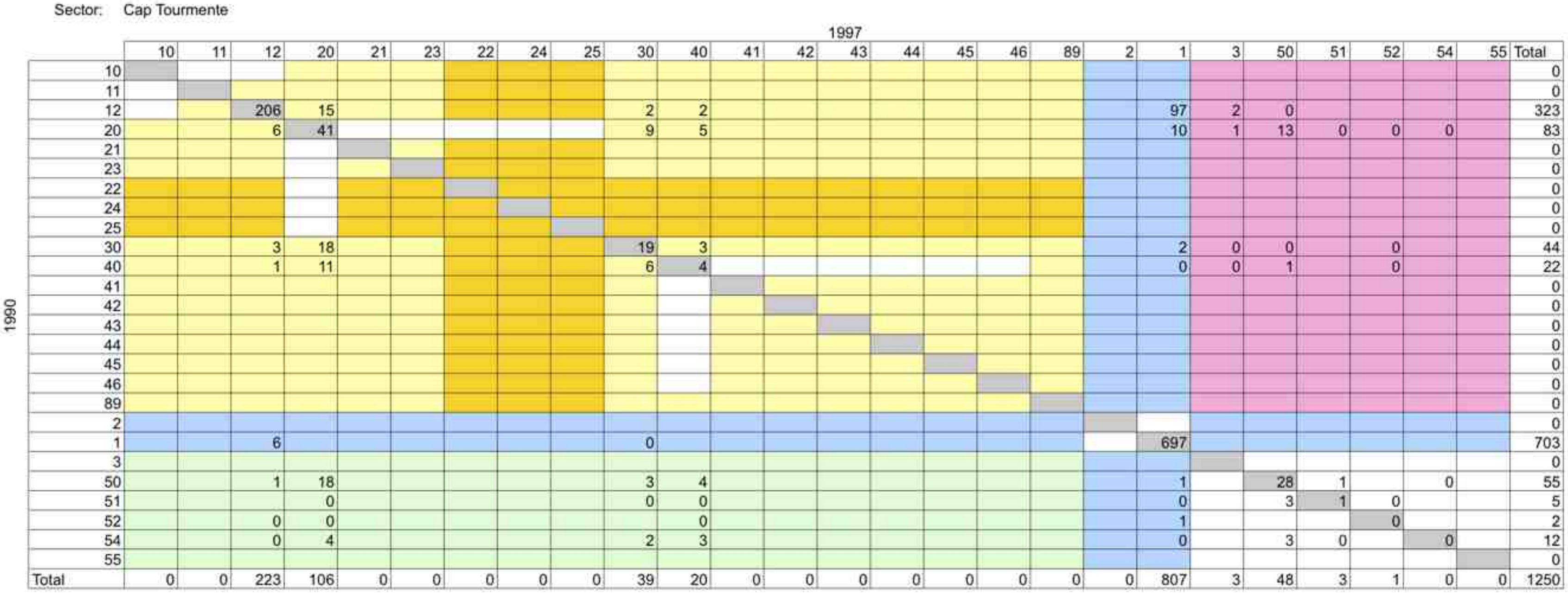
Losses and gains not retained are described in Appendix 78.

It is difficult to comment on the overall changes occurring within wetlands. A geometric shift between maps may have generated an entire series of false internal changes. Possible progressive changes include 15 ha of low marshes dominated by *Schoenoplectus pungens* that seem to have evolved into high marshes. In addition, 2 ha of low marshes and 9 ha of high marshes were classified as shrub swamps on the 1996–1997 map. Lastly, 2 ha of low marshes, 5 ha of high marshes and 3 ha of shrub swamps were transformed into forested swamps.

The most significant regressive change within wetlands in terms of area was the replacement of 18 ha of shrub swamps and 11 ha of forested swamps by high marshes.

Furthermore, 10 ha of low marshes dominated by *Schoenoplectus pungens* appeared in the later photos, replacing high marshes (6 ha), shrub swamps (3 ha) and forested swamps (1 ha). Lastly, 6 ha of forested swamps were classified in 1996–1997 as shrub swamps.

No invasive plant species were identified during the period.



Sector: Cap Tourmente

	1997																										
1990	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11																											0
12			206	15						2	2									97	2	0					323
20			6	41						9	5									10	1	13	0	0	0		83
21																											0
23																											0
22																											0
24																											0
25																											0
30			3	18						19	3									2	0	0		0			44
40			1	11						6	4									0	0	1		0			22
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1			6							0										697							703
3																											0
50			1	18						3	4									1		28	1		0		55
51				0						0	0									0		3	1	0			5
52			0	0							0									1				0			2
54			0	4						2	3									0		3	0		0		12
55																											0
Total	0	0	223	106	0	0	0	0	0	39	20	0	0	0	0	0	0	0	0	807	3	48	3	1	0	0	1250

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 74 Transition matrix for the Cap Tourmente subsector analyzed between 1990–1991 and 1996–1997

Figure 75 Losses and gains of marshes and swamps in the Cap Tourmente subsector analyzed between 1990–1991 and 1996–1997

4.11.2.3 Between 1996–1997 and 2000–2002

During this period, the area of wetlands increased from 388 ha to 480 ha, an increase of 92 ha or 24% (Figure 76). Estimated losses totalled 29 ha and gains, 120 ha. When inconsistencies are eliminated, the area of wetlands rose from 468 ha in 1996–1997 to 496 ha in 2000–2002, for an increase of 28 ha or 6%. After corrections were applied, losses were zero while gains totalled 27 ha (Figure 77).

The relative drying index for the period (Table 20) was 0.33, showing that overall, wetlands in the Cap Tourmente subsector displayed a moderate trend toward more terrestrial environments. When changes linked to tides are excluded, this trend disappears almost completely, however.

Interpreting this period is complex, since the 2000–2002 map is a mosaic of four images taken on different dates (Tables 6 and 7).

The only significant gains retained involved the conversion of 24 ha of agricultural land into wetlands south of Petit–Cap. Although this type of change is somewhat unusual, it did actually occur (Serge Labonté, personal communication). In addition, 3 ha of denuded substrate along the shoreline near Petit–Cap were covered with vegetation in 2000–2002.

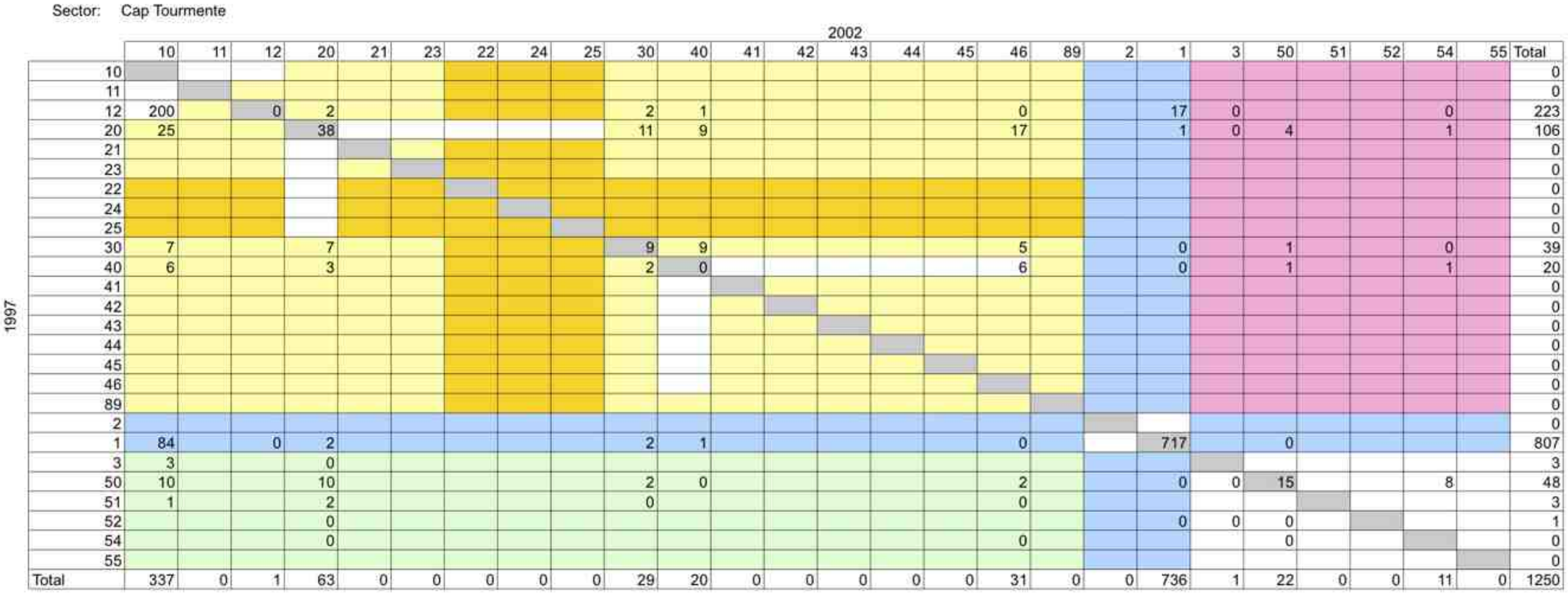
Losses and gains not retained in the analysis are described in Appendix 78.

Some changes within wetlands can be seen, although many seem to be the result of incorrect identification of the wetland type in one of the maps. The most significant progressive changes involve the replacement of 37 ha of high marshes by shrub swamps (11 ha) and forested swamps (26 ha). In addition, 5 ha of low marshes were transformed into high marshes (2 ha), shrub swamps (2 ha) and forested swamps (1 ha).

Lastly, 14 ha of shrub swamps became forested swamps; however, the latter appear to be overestimated on the 1990–1991 map.

The most important regressive changes within wetlands involved the creation of 38 ha of low marshes, which replaced high marshes (25 ha), shrub swamps (7 ha) and forested swamps (6 ha). In addition, 7 ha of shrub swamps and 3 ha of forested swamps reverted to high marshes, and 2 ha of forested swamps reverted to shrub swamps.

No invasive species were identified during this period.



Sector: Cap Tourmente

		2002																										
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1997	10																											0
	11																											0
	12	200		0	2						2	1						0			17	0				0		223
	20	25			38						11	9						17			1	0	4			1		106
	21																											0
	23																											0
	22																											0
	24																											0
	25																											0
	30	7			7						9	9						5			0		1			0		39
	40	6			3						2	0						6			0		1			1		20
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2																											0
	1	84		0	2						2	1						0			717		0					807
	3	3			0																							3
	50	10			10						2	0						2			0	0	15			8		48
	51	1			2						0							0										3
	52				0																0	0	0					1
	54				0													0					0					0
	55																											0
Total		337	0	1	63	0	0	0	0	0	29	20	0	0	0	0	0	31	0	0	736	1	22	0	0	11	0	1250

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 76 Transition matrix for the Cap Tourmente subsector analyzed between 1996–1997 and 2000–2002

Figure 77 Losses and gains of marshes and swamps in the Cap Tourmente subsector analyzed between 1996–1997 and 2000–2002

4.11.3 Partial changes in the Kamouraska subsector

4.11.3.1 Between 1970–1978 and 1990–1991

During this period, the area of wetlands in the Kamouraska region decreased from 632 ha to 297 ha, a drop of 335 ha or roughly 53% (Figure 78). Losses totalled 372 ha and gains, 38 ha. After inconsistencies were eliminated, wetland area went from 596 ha in the late 1970s to 289 ha in 1990–1991. Corrected losses were 337 ha and corrected gains were 30 ha, for a negative difference of 307 ha or 52% (Figure 79).

The relative drying index for the period (Table 20) is –0.56, showing that, overall, there was a significant trend towards wetter environments in the Kamouraska region's wetlands. When tidal effects are excluded, a slight trend is seen in the opposite direction, toward more terrestrial environments.

Most of the losses observed during the period were retained. The main losses, which involved the conversion of wetlands into agricultural lands (169 ha) in Kamouraska Bay, were related to the construction of aboiteaux (tide gates). In addition, 75 ha of wetlands reverted to open water. Owing to the lack of accurate data on tidal levels, it is prudent to retain this change. A further 62 ha of wetlands were classified as built-up area. Although we could call into question the identification of built-up areas on the 1990–1991 map, an examination of the raw images suggests that real losses of wetlands occurred. Lastly, 31 ha of wetlands were transformed into fallow land in 1990–1991, an occurrence observed around farm fields throughout the subsector.

Sector: Kamouraska

	1990																										
Dryade	10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
10																											0
11		72			22															61		4	1	4	1		166
12																											0
20		0																		5		0		1	1		7
21		3			113															1		129	24	37	1		307
23		12			36															6		35	5	13	0		106
22																											0
24																											0
25																											0
30																											0
40		1			1															2		1	1	7	33		45
41																											0
42																											0
43																											0
44																											0
45																											0
46																											0
89																											0
2																											0
1		2			1															8		1	0	4	0		16
3		25			5															2311		0		5	1		2348
50		0			5																	285	30	28	4		352
51																						1	2	1	5		9
52																											0
54		0																		1		2	0	0	6		10
55																											0
Total	0	115	0	0	182	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2395	0	459	61	102	53	0	3366

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 78 Transition matrix for the Kamouraska subsector analyzed between 1970–1978 and 1990–1991

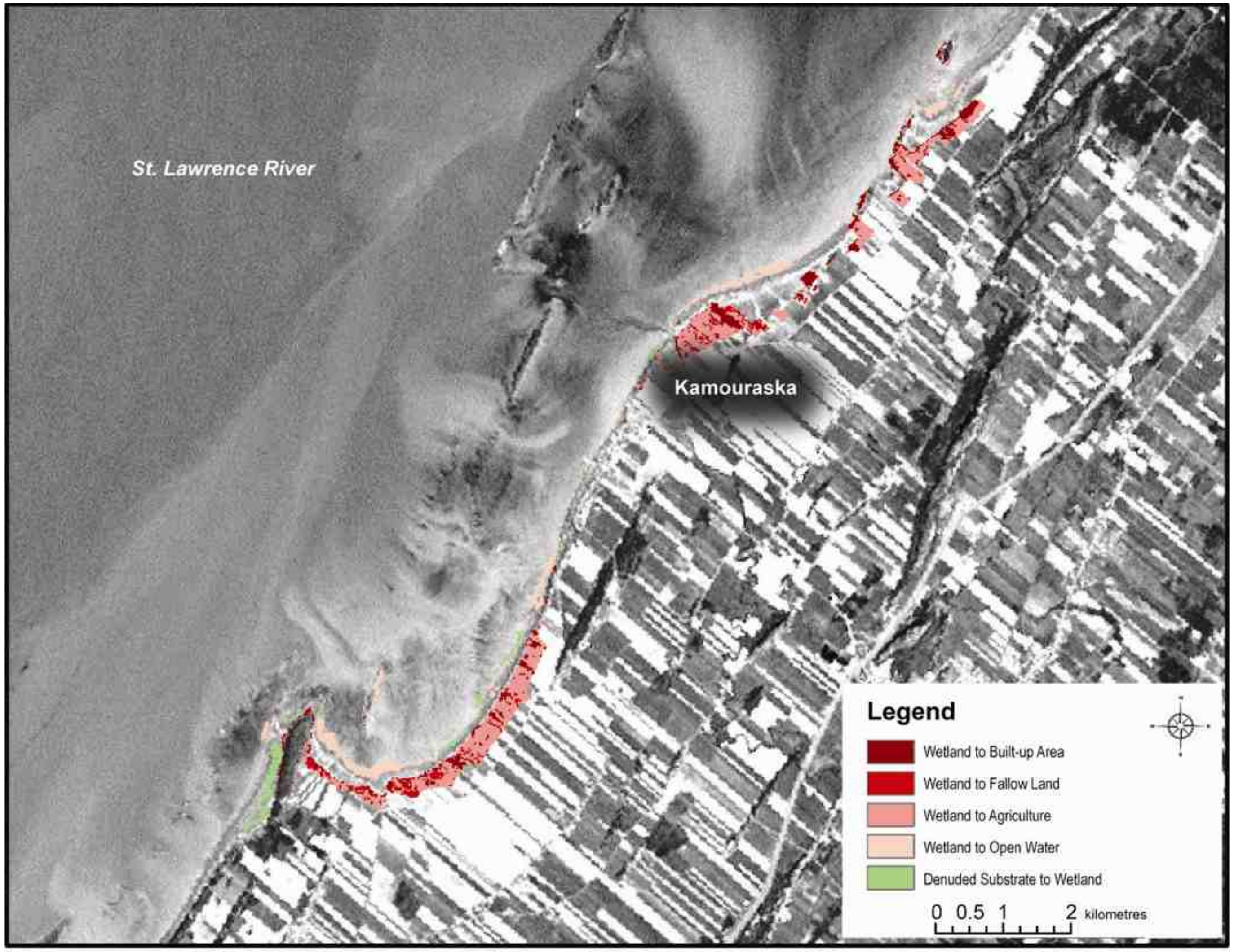


Figure 79 Losses and gains of marshes and swamps in the Kamouraska subsector analyzed between 1970–1978 and 1990–1991

The only gain retained was the transformation of 30 ha of denuded substrate into wetlands.

Losses and gains not retained in the analysis are described in Appendix 78.

Few changes within wetlands were observed in the Kamouraska region during the period. The transformation of 22 ha of low marshes dominated by *Spartina alterniflora* into high salt marshes was the only progressive internal change. Regressive changes involved 15 ha of high marshes (including 12 ha dominated by *Spartina patens*) and 1 ha of shrub swamps that reverted to low marshes. In addition, 36 ha of high marshes dominated by *Spartina patens* and 1 ha of shrub swamps became saltmeadows.

No invasive plant species were identified during the period.

4.11.3.2 Between 1990–1991 and 1996–1997

During this period, the area of wetlands increased from 297 ha to 383 ha, an increase of 86 ha or 29% (Figure 80). Estimated losses totalled 69 ha and gains, 155 ha. After inconsistencies are eliminated, the corrected area is 320 ha in both 1991 and 1997, for a zero net balance, with neither losses nor gains retained.

The relative drying index for the period (Table 20) is 0.23, showing an overall moderate trend towards more terrestrial habitats in the wetlands of the Kamouraska region. When tidal effects are eliminated, a moderate trend towards wetter habitats is observed, however.

The losses and gains not retained, which comprised all losses and gains, are described in Appendix 78.

Wetlands changed little during the period. The only progressive changes within wetlands were 11 ha of low marshes that became high marshes. Conversely, 21 ha of high marshes reverted to low marshes.

4.11.3.3 Between 1996–1997 and 2001–2002

During this period, the area of wetlands in the Kamouraska region decreased from 383 ha to 291 ha, a loss of 92 ha or 24% (Figure 81). Estimated losses totalled 140 ha and gains, 48 ha. When inconsistencies are eliminated, the net balance is zero, with the area of wetlands remaining constant throughout the period at 337 ha.

Sector: Kamouraska

		1997																										
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10																											0
	11		63			11															28	12	1		1	0		115
	12																											0
	20																											0
	21		21			134															13	7	7	0	0	1		182
	23																											0
	22																											0
	24																											0
	25																											0
	30																											0
	40																											0
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2																											0
	1		88			4															2272	28	2	0	2	0		2395
	3																											0
	50		2			26															1	1	424	1	2	3		459
	51		0			7																0	52		0	2		61
	52		4			19															7	3	62	1	3	4		102
	54		4			2															2	1	9	0	1	33		53
	55																											0
Total		0	181	0	0	202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2322	51	557	2	8	43	0	3366

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 80 Transition matrix for the Kamouraska subsector analyzed between 1990–1991 and 1996–1997

Sector: Kamouraska

		2002																										
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1997	10																											0
	11		56			19															91	11	2		0	1		181
	12																											0
	20																											0
	21		5			162															3	7	22		0	2		202
	23																											0
	22																											0
	24																											0
	25																											0
	30																											0
	40																											0
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																											0
	2																											0
	1		18			4															2286	11	2		1	1		2322
	3		5			5															33	4	1		1	2		51
	50		0			14															1	3	519		8	11		557
	51					0															0		2			0		2
	52		0			1															1	2	2		1	1		8
	54		0			1															0	1	11		0	29		43
	55																											0
Total		0	85	0	0	206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2416	40	560	0	12	48	0	3366

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 81 Transition matrix for the Kamouraska subsector analyzed between 1990–1997 and 2000–2002

The relative drying index for the period (Table 20) is –0.39, showing a general moderate trend towards wetter environments in Kamouraska wetlands. When tidal effects are excluded, the opposite trend (more terrestrial environments) was found, although it is insignificant in terms of the area affected.

Losses and gains not retained in the analysis are described in Appendix 78.

The only notable changes within wetlands were the transformation of 19 ha of low marshes dominated by *Spartina alterniflora* into high marshes and the reversion of 5 ha of saltmeadows to low marshes.

No invasive plant species were identified during the period.

4.12 LOWER ESTUARY

The area analyzed in the small portion of the lower estuary covered in the study between 1990–1991 and 2000–2002 totalled 77 525 ha, including open water and adjacent terrestrial habitats (Appendices 80 and 81). No analysis was carried out in 1970-1978 and 1996-1997, so no comparison with other time periods is possible.

The relative drying index for the lower estuary is shown in Table 21. An examination of these statistics between 1990 and 2002 shows a significant trend toward more aquatic habitats.

Table 21 Relative drying indices for the lower estuary sector

Period	Relative Drying Index
Between 1970–1978 and 1990–1991	—
Between 1990–1991 and 1996–1997	—
Between 1996–1997 and 2000–2002	—
Between 1990–1991 and 2000–2002	–0.63

4.12.1 Overall changes between 1990–1991 and 2000–2002

In this very small portion of the lower estuary, the area of wetlands decreased from 1617 ha to 1319 ha, a loss of 298 ha or roughly 18% (Figure 82). Estimated losses totalled 624 ha and gains, 326 ha. When inconsistencies are excluded, the corrected area totalled 1458 ha in 1990–1991 and 1632 ha in 2000–2002, representing an increase of 174 ha or 12%. Corrected losses were zero and gains, 174 ha (Figure 83).

The relative drying index for the period was –0.63, showing a significant trend toward wetter environments in the sector's wetlands (Table 21). When changes likely due to tidal effects are excluded, an even more significant trend towards wetter environments was observed.

The only gains retained involved the creation of 174 ha of wetlands at the expense of open water, concentrated upstream and downstream of the mouth of the Trois Pistoles River, and in the bay adjoining the Trois-Pistoles wharf. Since these changes cannot be attributed to tidal effects, they are probably real increases in the area of marshes dominated by *Spartina alterniflora*.

Gains and losses not retained in the analysis are described in Appendix 82.

Progressive changes within wetlands were limited to 6 ha of low marshes which became high marshes. Regressive changes were more significant, with 298 ha of high marshes reverting to low marshes (168 ha with no dominant species identified and 130 ha dominated by *Spartina alterniflora)*. These changes were concentrated mainly within and around the Baie de l'Isle-Verte National Wildlife Area and could be the result of shoreline erosion.

No plant communities dominated by invasive species were identified in the sector.

Secteur: Estuaire maritime (couverture partielle)

		2002																										
		10	11	12	20	21	23	22	24	25	30	40	41	42	43	44	45	46	89	2	1	3	50	51	52	54	55	Total
1990	10																											0
	11	63	337		0	1	5														385	7	29		9	18		853
	12																											0
	20	51	17		45	60	50														4	1	9		0	4		241
	21	10	1		4	9	10														1	1	15		0	2		53
	23	107	112		14	15	68														75	4	25		3	13		436
	22																											0
	24																											0
	25																											0
	30																											0
	40																											0
	41																											0
	42																											0
	43																											0
	44																											0
	45																											0
	46																											0
	89																		14			0	8			12		34
	2																											0
	1	5	158		0	1	10														14419	32	11		14	65		14715
	3																											0
	50	2	1		13	64	5												1		7	8	1124	2	28	171		1425
	51	1	2		1	12	1												1		4	5	355	6	28	369		785
	52	6	8		2	8	2												1		71	52	614	2	177	400		1342
	54	0	8		1	12	1												1		7	15	278	3	29	1986		2339
	55																											0
	Total	245	644	0	81	182	150	0	0	0	0	0	0	0	0	0	0	0	17	0	14973	123	2468	13	287	3040	0	22222

Note: Line and column headings correspond to classes in the standardized legend (see Table 10); values in the table are shown in hectares.

Figure 82 Transition matrix for the portion of the lower estuary analyzed between 1990–1991 and 2000–2002

Figure 83 Losses and gains of marshes and swamps in the portion of the lower estuary analyzed between 1990–1991 and 2000–2002

5 Discussion: an outline of recent changes to wetlands

The change analysis produced a large number of results, which include a multitude of details that could obscure the overall portrait of the St. Lawrence wetlands situation. This section will attempt to highlight the salient facts emerging from the study, supplemented by a discussion of the results published by Robitaille et al. (1988) and taken up again by more recent authors (Marquis et al. 1991; Gosselin 2003). The goal is to provide a synthesis of the changes that have occurred in wetlands during the last 60 years.

Each of the mapping projects has some weaknesses, showing that no exercise of this type is perfect. However, these maps are the best tools available to portray the situation of the wetlands along the St. Lawrence, which are such an important component of the river ecosystem.

5.1 FROM 1945 TO 1990: MAJOR UPHEAVALS TO WETLANDS

There is a consensus among authors that, during the period between 1945 and 1984, wetlands in the St. Lawrence River underwent profound changes. Most of these changes occurred during the first half of this period (Groupe Dryade 1981) or, according to Gosselin (2003), up until 1976. Most of the wetlands affected were located near large urban centres, highway corridors and agricultural areas.

The area of wetlands affected is impressive: over 6000 ha of riparian habitats were likely modified (Gosselin 2003), including more than 3600 ha of wetlands (Groupe Dryade 1981), with the rest consisting of open water zones. The area of riparian habitats lost along the St. Lawrence is equivalent to nearly 8450 soccer fields, 5000 of which represent wetlands.

A cursory examination of the changes that occurred during this period of nearly 40 years quickly reveals the multiple pressures affecting wetlands.

5.1.1 Lake Saint-François: a unique sector

The construction of various, hydroelectric facilities, dams and the St. Lawrence Seaway (1954–1958) profoundly modified the appearance of Lake Saint-François (Gosselin 2003). The management of water levels on the lake led to the disappearance of marshes and the expansion of shallow-water areas with their submerged vegetation beds. According to Auclair (1995a), the area of wetlands has not changed significantly since 1970, remaining around 10 100 ha and consisting mainly of submerged vegetation beds (7616 ha).

According to our results, marshes and swamps in the southwestern part of the lake totalled 1392 ha in 1990–1991, making up 56% of the lake's swamps and marshes and 14% of its wetlands. Between 1978 and 1990–1991, a net loss of 510 ha of wetlands occurred in this southwestern section. Such losses conceal, however, a finer dynamic that may not be as negative. The conversion of marshes into open-water zones (including perhaps submerged vegetation beds) following wildlife habitat development can be observed in the Saint-Régis–Akwesasne Mohawk Reserve, for example. Such transformations had a major impact on the relative drying index, which shows a trend towards wetter environments in wetlands for the period between 1970–1978 and 1990–1991. Furthermore, just as many losses as gains in marshes, involving a transition to or from open water, were observed. However, it is difficult to link this phenomenon to water levels on the lake, which show very little variation. Such changes could be due to differences in the time of the year data were acquired. Spring, when lake levels are at their lowest, is when most of the aerial photos used by Groupe Dryade (1981) were acquired.

5.1.2 Valleyfield–Beauharnois: a totally artificial shoreline

The construction of the Beauharnois dam and canal (1921–1931) resulted in higher water levels upstream, favouring the expansion of marshes (Gosselin 2003). Subsequently, the shoreline of the canal was backfilled to support industrial development and the construction of settling basins (impoundments). This work resulted in the almost complete disappearance of the sector's natural vegetation; only 78 ha of wetland remained, including 22 ha of shallow water zones (Robitaille 1998a). Over the last few decades, the impoundments have been colonized by *Phragmites australis*, an invasive species.

This section of the St. Lawrence was not analyzed for the period between 1978 and 1990–1991.

5.1.3 Lake Saint-Louis: a heavily disturbed floodplain

An estimated 4700 ha or more of prime riparian habitats have been strongly altered by urban development and natural disturbances in this sector (Auclair 1994). Artificial shorelines were already present in the 1970s.

According to our results, in 1990–1991, the area of marshes and swamps totalled 344 ha, or 40% of the sector's known marshes and swamps, and 7% of all known wetlands. The pressures mentioned above were apparent between 1978 and 1990–1991, particularly on the Asselin peninsula and in the Kahnawake Mohawk Reserve. In addition, the high water levels recorded between 1972 and 1976 modified wetlands, particularly on the Îles de la Paix, where the swamps were transformed into meadows dominated by *Phalaris arundinacea*, which is considered an invasive species. Swamps also disappeared in the low-lying land in the middle of Saint-Bernard Island. Aside from this natural hydrological event, water level variations also caused fluctuations in the areas of marshes and swamps in the sector. Between 1970–1978 and 1990–1991, Lake Saint-Louis therefore saw a significant trend toward wetter environments in wetlands.

5.1.4 La Prairie Basins: a sector still not adequately surveyed

The La Prairie Basins sector has roughly 1700 ha of wetlands, 96% of which are shallow water zones (Robitaille 1997). Between 1945 and 1988, the construction of highway 132 and the Bonaventure Expressway, the development of the former Adacport site, the development of the Brossard main trunk sewer and the backfilling of Île des Soeurs eliminated close to 800 ha of riparian habitats, most of which were shallow water zones (Gosselin 2003).

Owing to our poor coverage of the sector, we cannot verify whether this trend continues. We did observe *Phragmites australis* colonies along the shoreline of the Island of Montreal.

5.1.5 Montréal–Longueuil: a depleted sector

The Montréal–Longueuil sector is the portion of the St. Lawrence between Lake Ontario and the sea with the largest amount of artificial shoreline (Auclair 1995b). Port activities, backfilling, dredging and erosion are the main pressures on riparian habitats in the sector. Between 1945 and 1984, at least 1590 ha of natural habitats, including 503 ha of wetlands, disappeared due to these pressures. Backfilling and draining are the main causes of wetland alteration. Not only the river banks but also the riparian zones of a number of islands (Verte, Charron, Sainte-Marguerite, Sainte-Hélène, Notre-Dame) were affected.

Today, 945 ha of wetlands remain, primarily around the Boucherville Islands (Auclair 1995b); of this total amount, 537 ha are covered by shallow water, leaving 408 ha of marshes and swamps.

In the current study, we tallied at least 325 ha of marshes and swamps (making up 34% of the sector's wetlands), which corresponds to 80% of the estimate derived by Auclair (1995b). We observed a net loss of 54 ha of wetlands on Charron Island and a slight trend towards more terrestrial environments during this period.

5.1.6 Varennes–Contrecœur: a sector in flux

The Varennes–Contrecœur sector is a dynamic portion of the St. Lawrence in many respects. Shoreline and island erosion is a major problem in the sector (Gosselin 2003). The erosion is caused by wave action from passing boats and storm-induced waves, flooding, ice scour and freeze-thaw cycles (Louis-Filip Richard, personal communication).

In addition, the sector has been subject to dredging and draining which have directly modified wetlands. Between 1946 and 1984, an estimated 326 ha of aquatic vegetation beds were buried by dredge spoil deposits around Contrecœur (Robitaille 1998b). Furthermore, 178 ha of marshes in Varennes were destroyed by draining or the dredging of the St. Lawrence Seaway. Wetlands in the sector are estimated at 2000 ha, divided into 881 ha of shallow water zones, 1500 ha of marshes and 65 ha of swamps (Robitaille 1998b).

In the Contrecœur region, our results show that between the 1970s and 1990–1991, a net gain of 157 ha of wetlands occurred, for a total of 368 ha, representing 33% of marshes and swamps and 18% of all wetlands in the sector. The losses of 31 ha that were observed could be attributable to erosion in the northwest portion of the Contrecœur Islands. Conversely, significant gains totalling 199 ha were observed in the southwestern part of these islands. The net balance shows relative drying of wetlands in the sector.

5.1.7 Lake Saint-Pierre: heart of the St. Lawrence wetlands

The greatest expanses of wetlands in the St. Lawrence are found in Lake Saint-Pierre: an estimated 39 900 ha, 19 000 ha of which are shallow water zones (beds of aquatic vegetation)

(Burton 1991). These vast beds are accompanied by 5900 ha of marshes and 8000 ha of swamps. The sector contains the greatest concentration of swamps in the St. Lawrence by far, and is one of the last major refuges of these wooded wetlands.

Except for the lake's floodplains, which have been largely converted into agricultural land, the wetlands in Lake Saint-Pierre have undergone relatively few modifications (Burton 1991; Gosselin 2003). However, between 1945 and 1984, dredging activities and the disposal of dredge spoil resulting from the construction and maintenance of the shipping channel had a significant impact on the lake, affecting close to 2900 ha, particularly areas of deeper water (Burton 1991). Dredging also affected a small area of shallow water (38 ha). Some marshes (324 ha) and swamps (123 ha) also disappeared due to backfilling or draining.

The area of swamps and marshes in the portion of Lake Saint-Pierre analyzed between the 1970s and 1990–1991 is estimated to be at least 8964 ha, or 67% of the marshes and swamps identified and 22% of all the wetlands in the sector. For the period between the 1970s and 1990–1991 for the southern portion of the lake our results give a net loss, with total losses of 1435 ha and gains of 1114 ha. Water level modifications seem to explain a good portion of the losses (904 ha) and gains (500 ha) observed. Other losses recorded (530 ha) seem to be linked to agricultural activities while the remaining gains can be attributed to the development of wildlife habitat, which involved the conversion of fallow land and forest to wetlands. The objective of some of this work was to open up wetlands; it therefore influenced the relative drying index in the direction of wetter environments in riparian habitats.

5.1.8 The fluvial estuary: an increasing tidal influence

This section of the St. Lawrence is characterized by the presence of both non-tidal (3345 ha) and tidal (2032 ha) wetlands (Gosselin 2003; Robitaille 1998c, 1999).

Over 360 ha of wetlands in the sector were modified between 1945 and 1984 (Robitaille 1998c, 1999). Backfilling to develop industrial infrastructures played the greatest role (Gosselin 2003). These projects included the construction of the Bécancour industrial park and the Gentilly nuclear power station. In addition, the results of the draining of wetlands for agricultural and residential purposes can be seen in the municipalities of Cap-de-la-Madeleine and Champlain. Other factors include the construction of bridges, wharves and dikes, as well as the discharge of warm water from the Gentilly nuclear power station (Gosselin 2003). Lastly, the St. Lawrence Seaway may have had an impact on aquatic vegetation beds in the sector (Gosselin 2003).

The area of marshes and swamps analyzed in the Gentilly subsector between the 1970s and 1990–1991 totalled 2887 ha, or 54% of all the sector's wetlands. Curiously, our estimate of the area of swamps and marshes is higher than the published estimates for the entire fluvial estuary. This difference may be due to tidal effects and the absence of swamps in previous estimates (Gosselin 2003). Between the 1970s and 1990, we recorded a net loss of 28 ha of swamps and marshes.

5.1.9 Quebec City–Lévis: a very dynamic sector

The Quebec City–Lévis sector has an estimated 2033 ha of wetlands, 1576 ha of which are marshes dominated by *Schoenoplectus pungens* (Mousseau and Armellin 1995). Swamps are thought to cover 315 ha.

Nearly 270 ha of wetlands and 207 ha of mudflats were modified between 1945 and 1988 (Gosselin 2003). Extensive backfilling occurred in the sector before the 1980s, particularly on the north shore of the river. Examples include the expansion of Quebec City's port area, the construction of Champlain Boulevard in the late 1960s and the Dufferin–Montmorency expressway in the early 1970s, and the widening of Sainte-Anne Boulevard in 1964–1965 (Gosselin 2003). Erosion also played a major role in the sector (Mousseau and Armellin 1995).

In this analysis, the estimated area of marshes and swamps in the Côte-de-Beaupré subsector was 1286 ha in 1990–1991, or 63% of the wetlands identified in the sector. Our results give a net loss of wetlands in this portion of the sector. Losses of 94 ha, attributable to agriculture, urbanization and conversion to fallow land, were observed. Gains (24 ha) were also recorded in Beaupré and Périgny. Lastly, changes within wetlands were relatively minor, showing a slight trend towards more terrestrial habitats.

5.1.10 The upper estuary: from fresh water to salt water

Altogether, the upper estuary contains 4854 ha of wetlands (Mousseau et al. 1998). Nearly half (2388 ha) are low marshes dominated by *Schoenoplectus pungens,* located in the Cap Tourmente National Wildlife Area, Montmagny, Cap Saint-Ignace, the Montmagny islands and Islet-sur-Mer. In addition, there is a sizeable area of salt marshes—dominated by S*partina* *alterniflora* (953 ha) or *Spartina patens* (232 ha)—and saltmeadows (777 ha), which are associated with the transition to a marine environment.

Over 500 ha of wetlands were modified between 1945 and 1988 (Gosselin 2003). These changes were due mainly to shipping, port and agricultural activities, and were concentrated on Île aux Oies and Île aux Grues, as well as in the Kamouraska region. In addition, erosion affected the high marshes in Cap Tourmente and Rivière-du-Loup (Gosselin 2003).

The estimated area of marshes and swamps in the Cap Tourmente region in 1990–1991 was 459 ha, or 10% of the wetlands recorded in the upper estuary. Losses of 48 ha, attributable mainly to expanding agricultural activities in the region, were observed between the 1970s and 1990–1991.

In comparison, in the Kamouraska region, the estimated area of swamps and marshes in 1990–1991 was 289 ha, or 6% of the sector's wetlands. Losses of 337 ha and gains of 30 ha were observed between the late 1970s and 1990–1991. The greatest losses involved 169 ha of marshland, which was caused by the construction of aboiteaux (tide gates). In addition, urbanization and the draining of wetlands for farmland resulted in the loss of 93 ha. Conversely, some areas (30 ha) which consisted of denuded substrate in the 1970s were colonized by vegetation in 1990–1991.

5.1.11 The lower estuary: sketchy coverage

The lower estuary contains an estimated 4386 ha of wetlands (Létourneau 1996). They comprise saltmeadows (1072 ha), marshes dominated by *Spartina patens* (285 ha) or *Spartina alterniflora* (1487 ha) and roughly 2300 ha of eelgrass beds dominated by *Zostera maritima* (Gagnon 1996).

Between 1945 and 1988, physical modifications affected close to 400 ha of wetlands, mainly tidal flats, marshes and river estuaries (Gosselin 2003). Backfilling and flow modifications constituted the greatest pressures on riparian habitats.

Our poor coverage of the sector does not allow us to provide a representative picture of the situation of wetlands.

5.2 FROM 1990 TO 2002: A CERTAIN DEGREE OF STABILIZATION

The results of this study provide an updated portrait of changes to wetlands in the St. Lawrence. In particular, the two major coverages of 1990–1991 and 2000–2002 allow us to document recent dynamics in wetlands.

5.2.1 Lake Saint-François

According to our analysis, the area of wetlands in Lake Saint-François has remained stable since 1990–1991 and is estimated to be at least 2043 ha. A slight trend toward more terrestrial environments can be observed, explained mainly by the continuing increase in shrub swamps at the expense of marshes in the Lac Saint-François National Wildlife Area. However, high marshes have reverted to low marshes at Leblanc Point.

In terms of invasive species, areas dominated by *Lythrum salicaria* were identified. *Phragmites australis*, *Myriophyllum spicatum* and *Hydrocharis morsus-ranae* are also present but their range was not estimated due to the detection limits of the sensors.

5.2.2 Valleyfield–Beauharnois

The area of wetlands in the Valleyfield–Beauharnois sector in 2000–2002 was estimated at 102 ha, which represents a slight increase over 1990–1991 (96 ha). Estimating the area of wetlands in the sector is difficult, however; less than 70% of the marshes and swamps identified on the 1990–1991 and 2000–2002 maps were retained, with the rest showing inconsistencies, particularly in agricultural areas.

Losses of wetlands to open water can be seen around Pointe du Buisson and Pointe-des-Cascades, while gains are observed around the settling basins (impoundments) on the north shore of the Beauharnois Canal; however, the abundant *Phragmites australis* is a major problem in these basins.

5.2.3 Lake Saint-Louis

Wetlands in the Lake Saint-Louis sector in 2000–2002 were estimated to cover at least 685 ha, or only 41 ha more than in 1990–1991. Only 67% of the wetlands identified were retained in the analysis, however. Areas difficult to classify included Dowker Island and the Kahnawake Mohawk Reserve.

Gains occurred mostly on the south shore of the Îles de la Paix, at the expense of open water. In addition, invasive species are present and expanding in the sector. Both *Phalaris arundinacea* and *Phragmites australis* continue to make inroads, the former in the Îles de la Paix National Wildlife Area and Saint-Bernard Island and the latter in the western part of the Kahnawake Mohawk Reserve.

5.2.4 La Prairie Basins

Although Groupe Dryade (1980) estimated wetlands in the La Prairie Basins sector at 82 ha, we only identified 2 ha, dominated by *Phragmites australis*, near the La Prairie golf course. However, wetlands are underestimated in the most recent maps of the sector.

5.2.5 Montréal–Longueuil

In 2000–2002, the Montréal–Longueuil sector had at least 309 ha of wetlands, representing a net loss of 13 ha compared with 1990–1991. Most of the changes observed—gains as well as losses—were caused by water level fluctuations and are concentrated in the Boucherville Islands. A slight trend towards more terrestrial environments was observed during this period, with relative drying of low marshes, which are being invaded increasingly by *Phalaris arundinacea*. In addition, *Phragmites australis* is still gaining ground on the Tailhandier Flats.

5.2.6 Varennes–Contrecœur

In the Varennes–Contrecœur sector, wetlands were estimated to total 934 ha in 2000–2002, a net gain of 74 ha over 1990–1991. Both losses and gains occurred in favour of or at the expense of open water, although they cannot be linked to water-level fluctuations. Gains were concentrated mainly in the Îles de Contrecoeur National Wildlife Area and on the edge of Bouchard Island.

The most abundant invasive plant species in the area is *Phalaris arundinacea* (490 ha), transforming low marshes and swamps into high marshes completely dominated by this species. *Phragmites australis* is also present in the sector.

5.2.7 Lake Saint-Pierre

The Lake Saint-Pierre sector contained an estimated 16 098 ha of marshes and swamps in 2000–2002. Between 1990–1991 and 2000–2002, the sector suffered net losses of approximately 82 ha. However, this figure obscures wetlands that are greatly in flux, with losses of 1949 ha involving conversion to open water zones, agricultural land and denuded substrate. Conversely, gains of 1873 ha of wetlands were observed and can be attributed to lower water levels in the lake.

In addition, a trend towards more terrestrial habitats was observed in the sector's wetlands. Although regressive changes were observed, changes to drier wetlands predominated, including the appearance of swamps and high marshes dominated by *Phalaris arundinacea.* Consequently, this invasive species occupies at least 2911 ha. In addition, *Phragmites australis* is present in several locations, notably Lavallière Bay.

5.2.8 Fluvial estuary

The greatest increase in wetland (swamps and marshes) area between 1990–1991 and 2000–2002 occurred in the fluvial estuary. A remarkable 447 ha of new marshes appeared around Bécancour, the Gentilly and Saint-Pierre flats, Deschambault, and Sainte-Croix. There were also losses of 35 ha of wetlands to agriculture in the Sainte-Anne-de-la-Pérade region. Gains occurred at the expense of open water and cannot be explained by fluctuating water levels or tidal effects.

A slight trend towards more terrestrial environments can be observed but it only involves a small area. No marshes dominated by invasive species were detected during the period.

5.2.9 Quebec City–Lévis

In the Quebec City–Lévis sector, the total area of wetlands remained the same, at 951 ha. Owing to the multiple image acquisition dates, a number of inconsistencies were found and wetlands are likely underestimated. The presence of tides and other sources of confusion complicate data interpretation in the sector.

Despite this, changes within wetlands can be seen in the sector. Two major trends emerge. First, an additional 126 ha of swamps appeared, replacing mainly marshes, which contributed to the slight trend towards more terrestrial environments during this period.

Conversely, 110 ha of high marshes and swamps were transformed into low marshes; erosion, which is significant in the sector, could be one of the causes.

5.2.10 Upper estuary

Wetlands in the upper estuary were estimated to total 5223 ha in 2000–2002, a net increase of 34 ha over 1990–1991. The gains observed, attributable in large part to the creation of bird habitat in the Gros-Cacouna marsh, exceeded the losses observed, which were scattered along the south shore.

The most striking changes to the sector's wetlands were the transformation of 363 ha of high marshes to low marshes, which was observed in locations such as Cap Tourmente, the Montmagny islands and Gros-Cacouna, places where an erosion problem has been identified (Dionne 1999).

Aside from erosion problems, the sector also contains several sites with significant populations of invasive plant species. A total of 46 ha marshes dominated by *Phragmites australis* are present in the Montmagny islands and along the south shore, between Saint-Roch-des-Aulnaies and La Pocatière. In addition, *Lythrum salicaria* is present in the La Pocatière region.

5.2.11 Lower estuary

Due to the very poor coverage of wetlands in the lower estuary in this study, no conclusions could be reached on the situation of wetlands in the sector. Wetlands on the south shore between L'Isle-Verte and Trois-Pistoles were estimated to total 1632 ha in 2000–2002, an increase of 174 ha over 1990–1991. Gains were concentrated around the Trois-Pistoles wharf and at the mouth of the Rivière des Trois Pistoles. The difference between the two periods cannot be explained by water level fluctuations or tidal effects.

As was seen in the upper estuary, erosion appears to be a potential factor in explaining the conversion of 298 ha of high marshes into low marshes, which occurred particularly in the Baie de l'Isle-Verte National Wildlife Area.

6 Conclusion

The primary goal of this study was to contribute to the State of the St. Lawrence Monitoring Program by establishing a recurring mechanism for tracking changes in the wetlands of the St. Lawrence. Our objective was to take account of the dynamics of these wetlands and to examine the results of recent pressures on these crucial ecosystems.

The project was inspired by major studies whose goal was to quantify wetland losses along the St. Lawrence River, including work by Groupe Dryade (1981), Environment Canada (1985), Robitaille et al. (1988) and Marquis et al. (1991).

A more recent study attempted to provide an updated portrait of wetlands along the St. Lawrence (Gosselin 2003). However, for technical reasons, the goals of the study could not be achieved and the author had to limit himself to re-examining the period between 1945 and 1988.

We overcame numerous technical constraints in order to compare previous results with the most recent data. We harmonized the legends of maps published by Groupe Dryade (1980) and by Létourneau and Jean (2005, 2006a, 2006b, 2006c) and documented changes in marshes and swamps between the 1970s and 2000–2002. Our results show that the area of wetlands evolved very differently between the 1970s and 2000–2002 than it did between 1945 and the 1970s. Specifically, the area of marshes and swamps (excluding shallow water zones) increased slightly between 1990–1991 and 2000–2002 (28 228 ha in 1990–1991 and 28 992 ha in 2000–2002, an increase of 764 ha or 2.7%). Results by sector reveal different dynamics, however. Net losses of wetlands were observed in the Montréal–Longueuil and Lake Saint-Pierre sectors, whereas significant gains were recorded in the fluvial estuary, the upper estuary and part of the lower estuary.

The distinctiveness of this study, as compared to previous studies, lies in the fact that it takes account of wetland gains as well as losses. We did not emphasize, as previous comparative studies did, the identification of wetland losses alone. Instead, our perspective elucidates the major dynamics of the different components of the St. Lawrence wetlands, and reveals that several factors, including water levels and tides, strongly influence the estimation of wetland area. In addition, numerous changes occurring within wetlands themselves make these ecosystems all the more dynamic. In several sectors, a trend towards more terrestrial environments in wetlands was observed: wetlands became relatively drier. Although this may be a natural trend, we can postulate that the drop in water levels recorded during the last decade, as well as eutrophication, may have accelerated this phenomenon.

Results from the last ten years appear to be encouraging. In our opinion, conservation and restoration efforts by multiple organizations along the St. Lawrence have been successful. Among such efforts, the creation of national wildlife areas and migratory bird sanctuaries along the river has been a crucial step in preserving the area of remaining wetlands. This does not diminish in any way the need to realize that these wetlands are still under significant pressure. Although the decreasing trend in wetland area along the St. Lawrence has been halted at least for the time being, this is not the case in the St. Lawrence Valley where wetlands are under enormous pressure and are continually losing ground, particularly due to urban sprawl. Vigilance is therefore essential, and only a long-term commitment to protect and monitor the river's riparian habitats will allow these habitats to be preserved and will provide the necessary information for reporting on habitat conditions and guiding future conservation efforts.

To improve our assessment of wetlands and more accurately evaluate and monitor the contribution of wetlands to the long-term survival and sustainability of the St. Lawrence River, further reflection is necessary. Such reflection could begin with the addition of other relevant dimensions to the simple measurement of area. One possible avenue would be to carry out a recurring long-term analysis of the pressures on, as well as the ecological functions and services provided by, the wetlands of the St. Lawrence, in addition to monitoring the area of wetlands.

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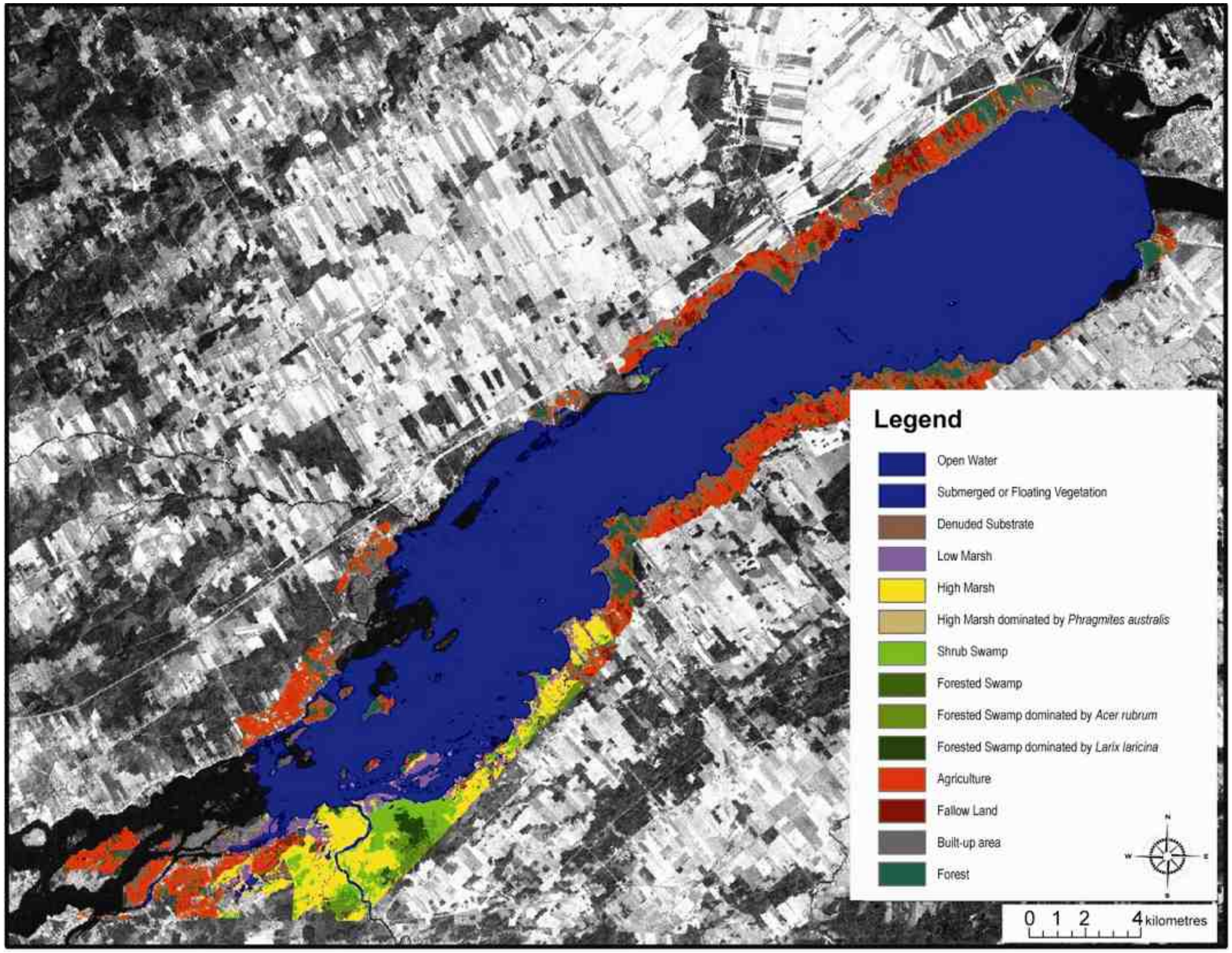
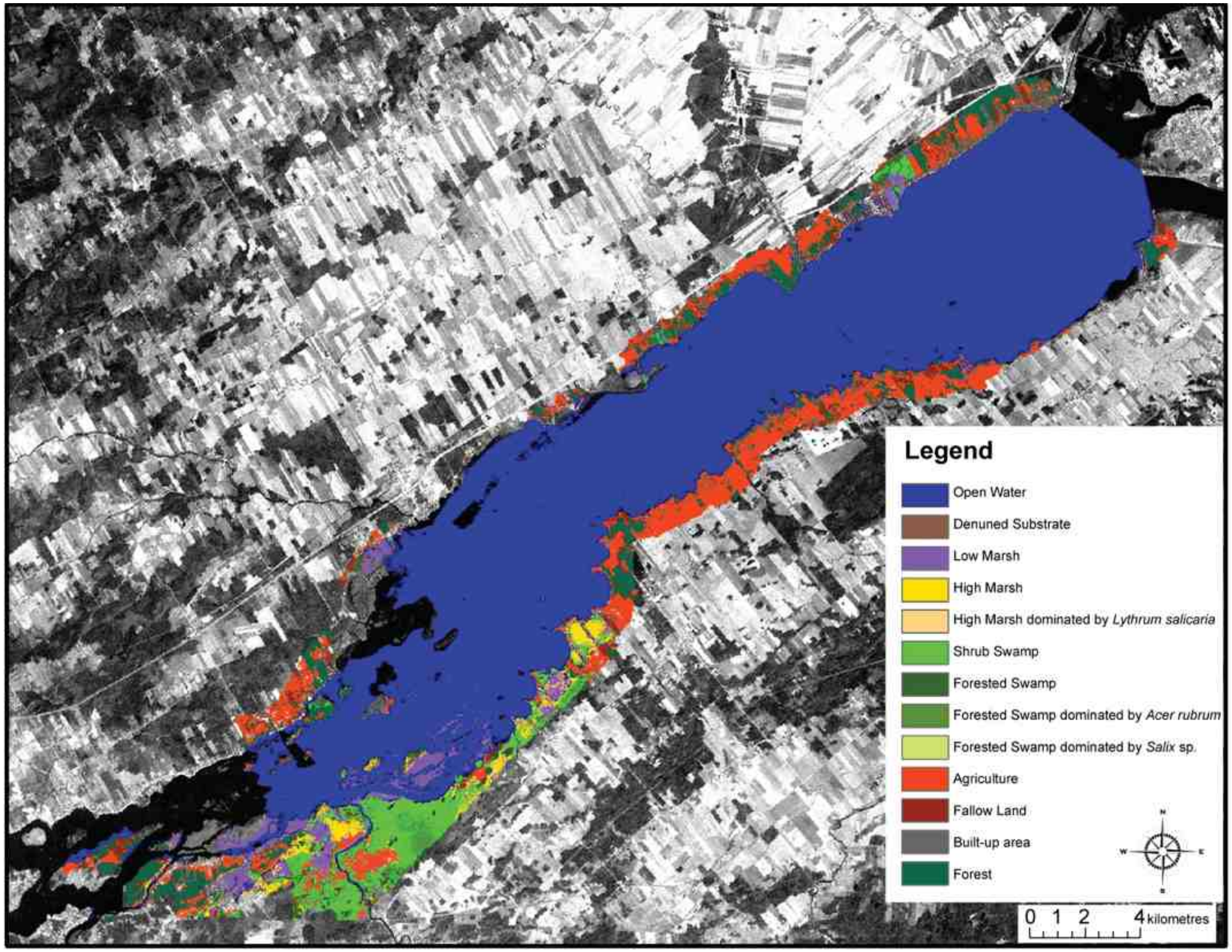
Appendices

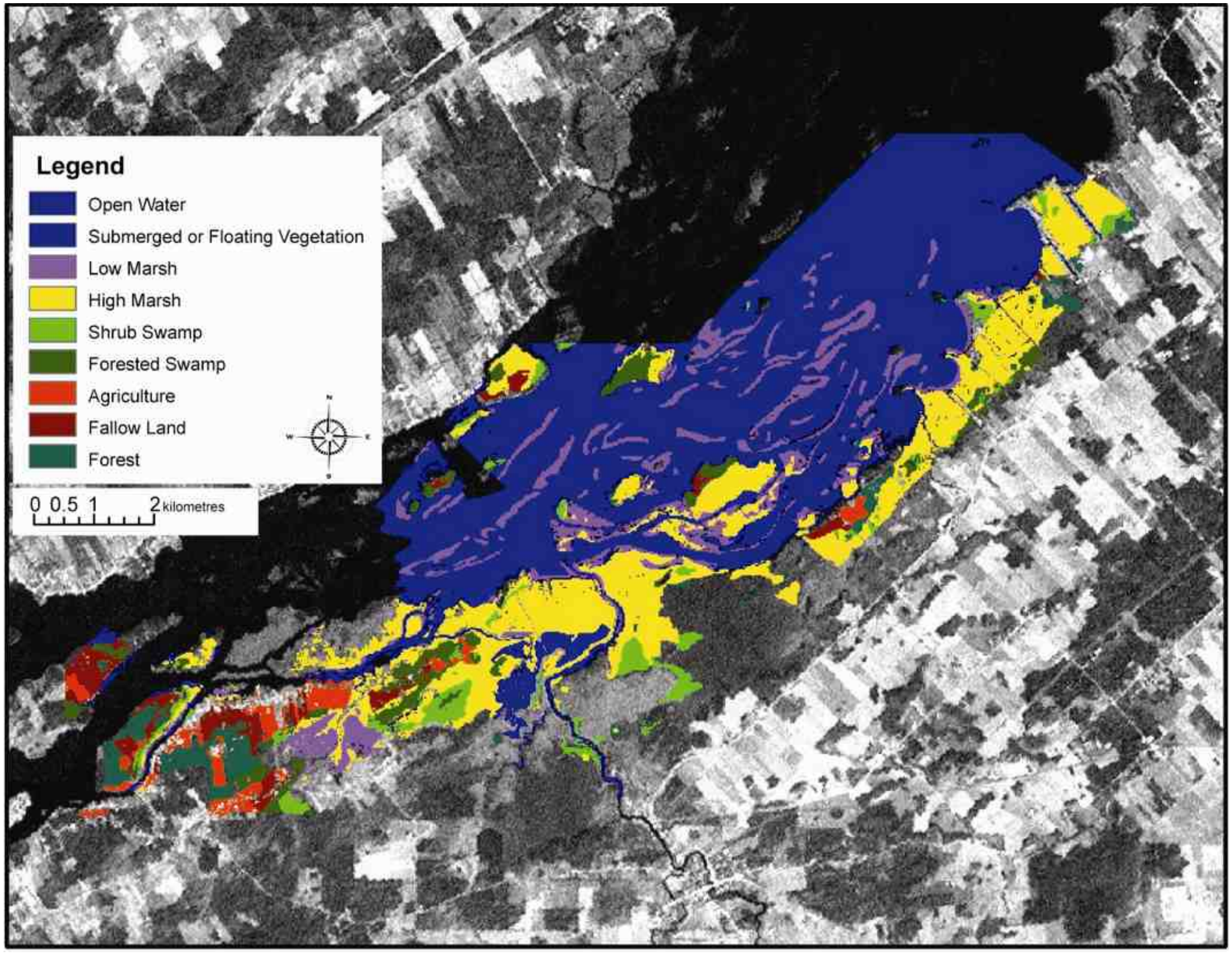
1 Wetlands in Lake Saint-François in 1990–1991



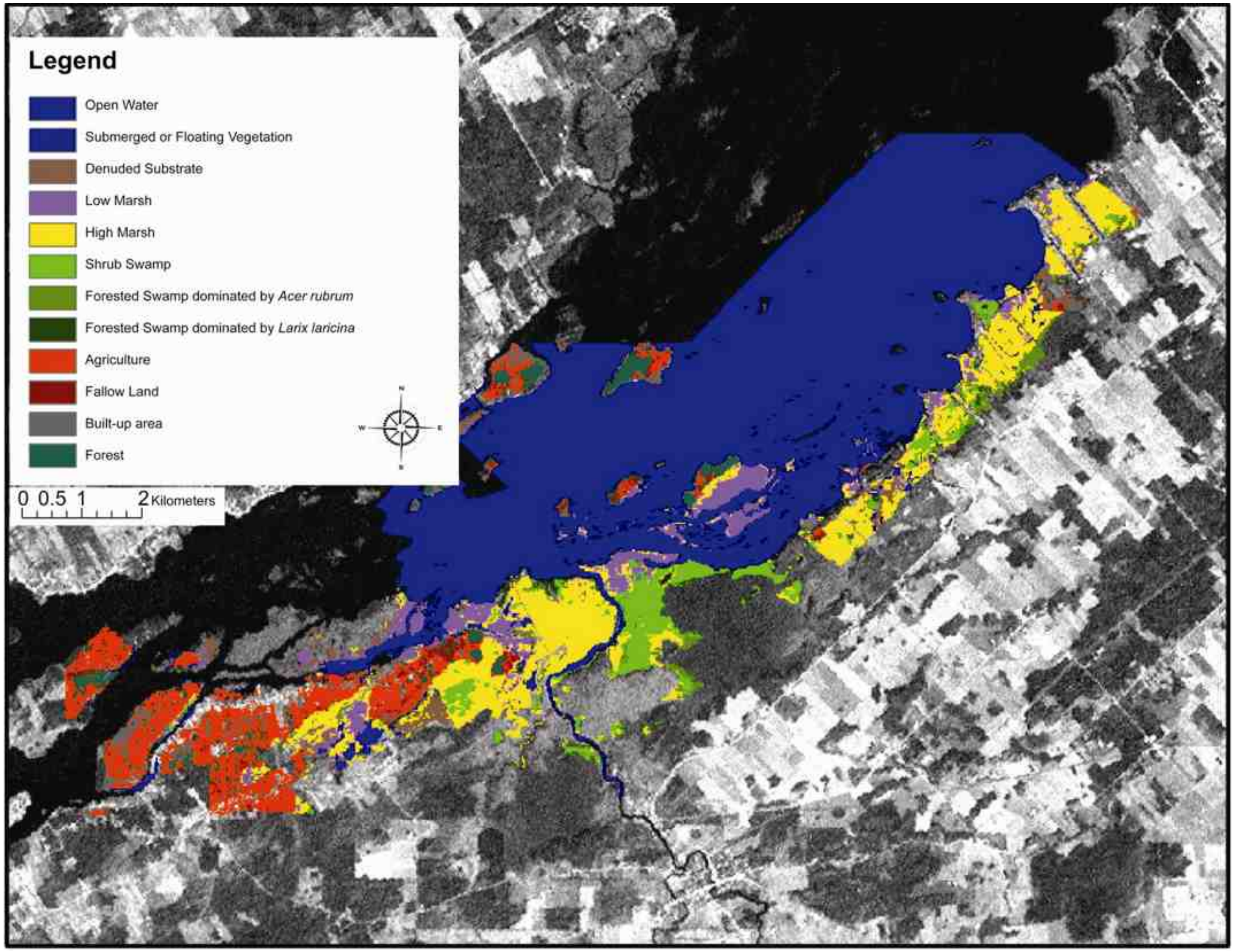
2 Wetlands in Lake Saint-François in 2000–2002



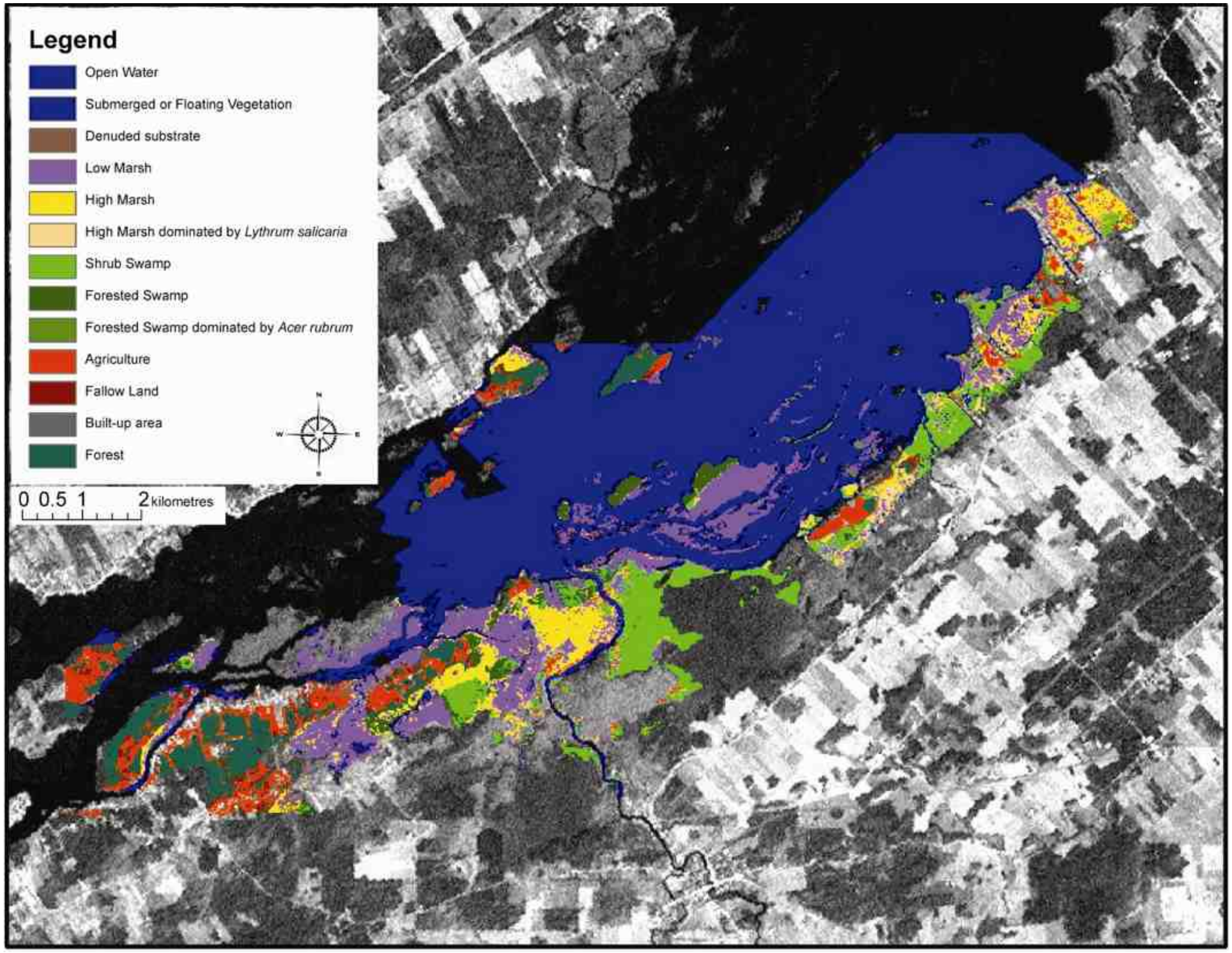
3 Wetlands in the portion of Lake Saint-François analyzed in 1970–1978



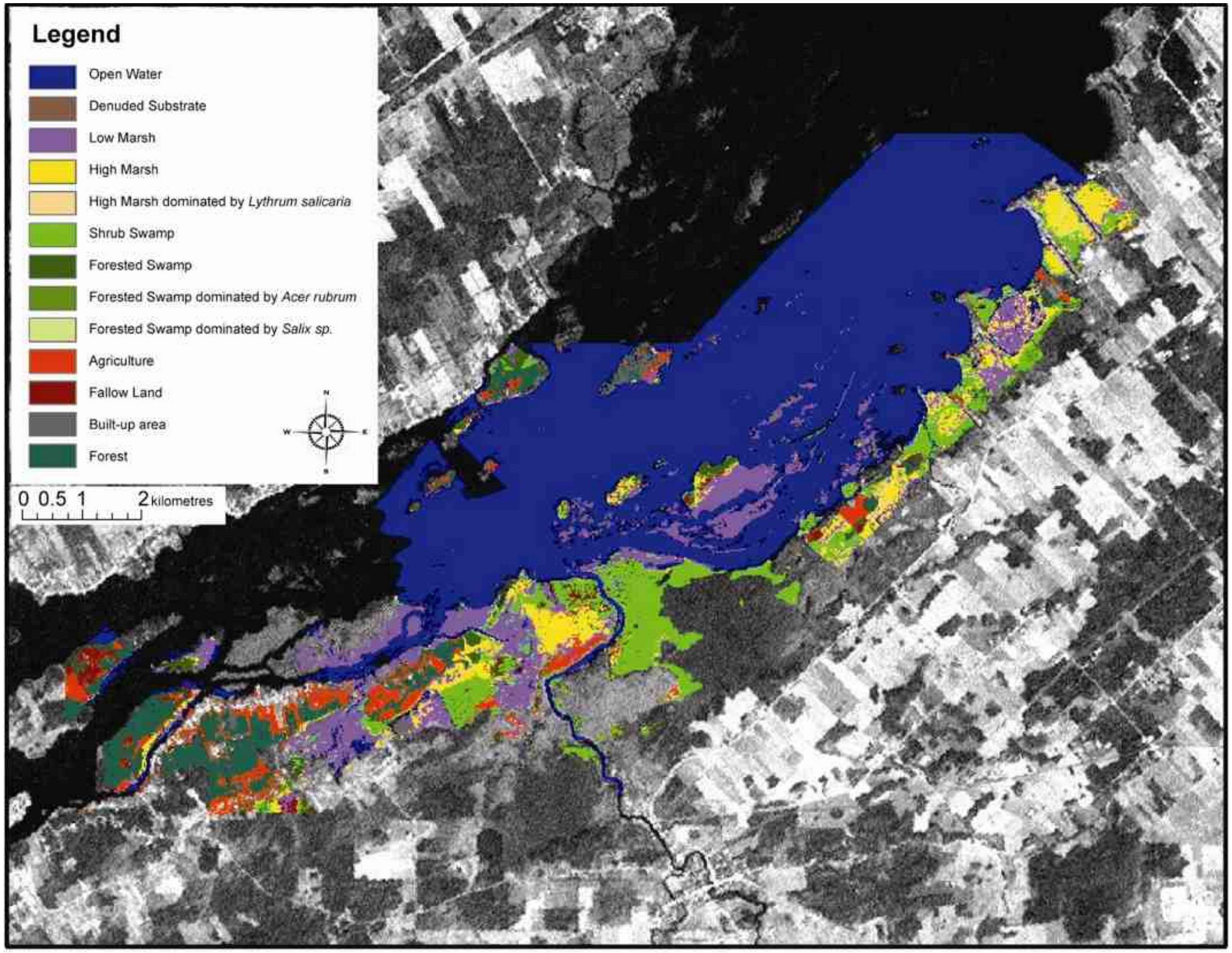
4 Wetlands in the portion of Lake Saint-François analyzed in 1990–1991



5 Wetlands in the portion of Lake Saint-François analyzed in 1996–1997



6 Wetlands in the portion of Lake Saint-François analyzed in 2000–2002



7 Gains and losses in the Lake Saint-François sector not retained in the analysis

Between 1990–1991 and 2000–2002

The main losses not retained in the analysis (267 ha) involve high marshes transformed into cropland and pastureland, with these changes occurring in the open portion of the Lac Saint-François National Wildlife Area, in the Saint-Regis–Akwesasne Mohawk Reserve and in the Fraser Point area. These changes are probably due to confusion between pastureland and high marshes, which are relatively dry and dense. In addition, 114 ha of wetlands in 1990–1991, mostly marshes, were identified as fallow land in 2000–2002, very likely for the same reasons as explained above.

Furthermore, 78 ha identified as wetlands in 1990–1991 were classified as open water in 2000–2002. These changes were observed along the south shore of the lake and along certain streams. Since the water levels remained fairly constant on the lake (Summerstown, Ontario, hydrometric station – 02MC023: 46.71 m on July 26, 1990; 46.76 m on September 18, 2000; 46.81 m on September 19, 2000; and 46.79 m on August 8, 2002; sources: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada), these changes are unlikely to be linked to water level fluctuations. On the other hand, differences could have resulted from geometric problems in the two images.

A total of 55 ha of wetlands were identified as upland forests in the sector in 2000–2002. These changes were scattered along the south shore of the lake, particularly on either side of the Rivière aux Saumons, in the Saint-Regis–Akwesasne Mohawk Reserve and on Fraser Point. Most are due to the overestimation of wetlands in 1990–1991 (mainly swamps), while the remainder fit in more with an overestimation of forests in 2000–2002. Lastly, 44 ha of wetlands were identified as built-up area in 2000–2002; the changes were not concentrated in specific sectors but were distributed along certain highways. Some type of confusion seems to be to blame, probably produced by geometric problems in the two maps.

No gains were retained in the analysis. Gains rejected can be divided into six types. First, 192 ha of open water in 1990–1991 were identified as wetlands in 2000–2002, mainly around the islands off Fraser Point and in the Saint-Regis–Akwesasne Mohawk Reserve. In these areas, open water was identified as giving way to forested swamps, a change that is very unlikely in the space of a decade. An overestimation of swamps on the 2000–2002 map is a more likely explanation.

In addition, 160 ha of farmland were identified as wetlands in 2000–2002, mainly on the north shore of the river at Lancaster and Notre-Dame-des-Rivières (near Saint-Zotique) and in the Saint-Regis–Akwesasne Mohawk Reserve. The new wetlands ranged from low marshes to forested swamps and appear to have resulted from an underestimation of wetlands on the 1990–1991 map.

Furthermore, 102 ha of built-up area, mainly on the north shore of Lake Saint-François, were identified as wetlands, around Beaudette Point, Mouillée Point and Lancaster on the north shore as well as near Latreille Point and, to a lesser extent, Fraser Point. These new wetlands ranged from low marshes to shrub swamps. A plausible explanation would be an overestimation of built-up area in 1990–1991. A total of 92 ha of denuded substrate were identified as wetlands in 2000–2002, in the Saint-Regis–Akwesasne Mohawk Reserve, around Fraser Point and in the Charlottenburgh Marsh. These changes seem to have resulted from an overestimation of denuded substrate in 1990–1991. In addition, 63 ha identified as fallow land in 1990–1991 were transformed into wetlands, mainly shrub swamps, in 2000–2002, mainly around Notre-Dame-des-Rivières. This likely resulted from, as it did in the case of cropland and pastureland, the underestimation of wetlands on the 1990–1991 map. Lastly, 47 ha of upland forests in 1990–1991 were classified as wetlands in 2000–2002. These changes were observed around Notre-Dame-des-Rivières, the Saint-Regis–Akwesasne Mohawk Reserve and Christatie Island. This is probably again due to confusion with upland forests (for Christatie Island) or the underestimation of wetlands in 1990–1991 (for Notre-Dame-des-Rivières).

Between 1970–1978 and 1990–1991

A total of 172 ha of wetlands identified by Groupe Dryade (1981) were classified in 1990–1991 as agricultural land. This appears to involve the overestimation of wetlands in the Groupe Dryade study, particularly around islands. Owing to the lack of information on the territory in the Saint-Regis–Akwesasne Mohawk Reserve, we are unable to draw any conclusions on the changes that occurred there, and we therefore cannot include these losses in our analysis.

Furthermore, 85 ha of wetlands were classified as denuded substrate in 1990–1991, in the Fraser Point area and the Saint-Regis–Akwesasne Mohawk Reserve. Once again, owing to the lack of information on the land in the reserve, we are unable to draw any conclusions on these changes, although the presence of cloud cover nearby suggests that there was confusion between classes.

Next, 68 ha of wetlands were transformed into forests in 1990–1991, found on certain islands (Christatie, Thompson and Hamilton islands, for example) and in the reserve. Since these sectors are higher in elevation than the lake (according to the contour lines on the topographic maps), this appears to be an issue of the overestimation of wetlands on the older map coverage.

In addition, 50 ha of wetlands were incorrectly classified as built-up area in 1990–1991. These changes were not retained, since the 1990–1991 coverage seems to contain confusion between classes, particularly between built-up areas and open water.

Lastly, 35 ha of wetlands were identified as fallow land in 1990–1991, primarily in the Saint-Regis–Akwesasne Mohawk Reserve. This appears to be due to an overestimation of swamps by Groupe Dryade (the main wetlands involved in the comparison) and an overestimation of fallow land in the 1990–1991 coverage, although in the latter, fallow land was correctly identified as upland areas.

Among gains not retained in the analysis, 35 ha of upland forests were classified as wetlands in the 1990–1991 coverage. The areas concerned were moraine mounds in the Lac Saint-François National Wildlife Area. This is mainly a case of confusion between forested swamps and mesic forest. In addition, upland forests were flooded due to the introduction of water level control structures in the Fraser Point sector, which was probably covered by forests previously (Melançon and Lethiecq 1981).

Finally, 16 ha of agricultural land were classified as wetlands in 1990–1991, on Fraser Point and in the Saint-Regis–Akwesasne Mohawk Reserve. Wetlands seem to have been overestimated in the 1990–1991 coverage.

Between 1990–1991 and 1996–1997

The greatest losses of wetlands not retained in the analysis involve the appearance in 1996–1997 of 102 ha of cropland and pastureland around Fraser Point, Hopkins Point, Leblanc

Point and Somerville Beach. The 1990–1991 coverage appears to have confused agricultural land use with wetlands. The second-biggest losses involved the appearance of open water (72 ha). The overestimation of open water in 1996–1997, along with geometric anomalies, explains the differences between the maps, which were not taken into account in the analysis.

In addition, 19 ha of wetlands were classified as upland forests, scattered in small areas in the Saint-Regis–Akwesasne Mohawk Reserve, the Lac Saint-François National Wildlife Area and Fraser Point. A confusion with forests is probably responsible. Lastly, 11 ha of wetlands became denuded substrate in 1996–1997 in very scattered locations, probably attributable to various classification problems.

Most of the gains observed, 200 ha, involved the transformation of open water into wetlands, a phenomenon observed in the Saint-Regis–Akwesasne Mohawk Reserve, along the Rivière aux Saumons and around the islands off the Lac Saint-François National Wildlife Area. Since water levels rarely vary in Lake Saint-François, water level fluctuations cannot be considered responsible here. Confusion between submerged or floating aquatic vegetation and low marshes is probably involved.

In addition, 76 ha of denuded substrate were classified as wetlands in 1996–1997. The classification problem in 1990–1991 is probably due to sun glitter on the water. In addition, 72 ha of agricultural land were classified as wetlands in 1996–1997 in the Saint-Regis–Akwesasne Mohawk Reserve and on certain islands (such as Christatie Island). Since there are known gaps in the 1990–1991 coverage of the Saint-Regis–Akwesasne Mohawk Reserve, we believe that these are not actual changes. In addition, there was very likely an overestimation of wetlands on the islands in the southwestern part of the lake in the 1996–1997 maps.

A total of 31 ha of built-up area were classified as wetlands in 1996–1997, mainly on Hamilton Island. An overestimation of built-up area on the islands probably occurred in 1990–1991. In the case of forests, 28 ha were classified as wetlands (particularly swamps), probably due to the difficulty of identifying moraine mounds surrounded by wetlands. In addition, 18 ha of fallow land situated on moraine mounds were erroneously classified as wetlands.

Between 1996–1997 and 2000–2002

The main losses not retained in the analysis involved open water (95 ha) along the shoreline. Geometric problems are probably to blame. In addition, 60 ha of wetlands appeared as agricultural areas in the 2000–2002 maps, mainly in the Saint-Regis–Akwesasne Mohawk Reserve. These differences, which do not represent real changes, can be attributed to better field checks of the earlier maps and some inconsistencies.

A total of 56 ha of wetlands were classified as fallow land in 2000–2002 in the Saint-Regis–Akwesasne Mohawk Reserve, the Lac Saint-François National Wildlife Area and the Fraser Point area. This inconsistency is probably due to classification problems involving fallow land (overestimation of wetlands in 1996–1997 and fallow land in 2000–2002).

In addition, 41 ha of wetlands were classified as built-up areas. The 2000–2002 coverage probably overestimates built-up areas. Furthermore, 16 ha of wetlands scattered over the sector were identified as upland forests in 2000–2001; this is probably due to classification confusion and the difficulty of discriminating between forested swamps and upland forests. Lastly, the reclassification of 2.5 ha of wetlands as substratum is probably the result of various confusions.

The primary gains observed (none were retained in the analysis) were scattered throughout the sector and occurred at the expense of open water (83 ha). Although they could involve an actual change in the vegetation cover (for example, from floating vegetation to low marshes), they are more likely due to mixed pixels or a geometric shift.

In addition, 76 ha identified as crops and pastureland in 1996–1997 were classified as wetlands in 2000–2002 in portions of the Saint-Regis–Akwesasne Mohawk Reserve, around some moraine mounds in the Lac Saint-François National Wildlife Area, at Somerville Beach and around Fraser, Leblanc and Latreille points. This seems to be the result of an overestimation of agricultural land in 1996–1997.

Furthermore, 14 ha that were classified as denuded substrate in 1996–1997 were classified as wetlands in 2000–2002, found in scattered locations in the Saint-Regis–Akwesasne Mohawk Reserve and around some islands (such as Christatie Island). The difference appears to be due in part to sun glitter on the water, resulting in an overestimation of denuded substrate in 1996–1997.

Also, 12 ha of fallow land scattered throughout the image (and concentrated somewhat in the Saint-Régis–Akwesasne Mohawk Reserve) were classified as wetlands in 2000–2002, apparently the result of confusion between shrubby fallow land and shrub swamps.

Lastly, 11 ha of upland forests were classified as wetlands in 2000–2002, found mainly in the Saint-Regis–Akwesasne Mohawk Reserve and around some moraine mounds in the Lac Saint-François National Wildlife Area. Here again, the difficulty of distinguishing between forested swamps and more upland forests is probably involved.

8 Results of Kappa agreement analyses for Lake Saint-François

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.78
KHisto	0.89
KLoc	0.88
Fraction correct	0.90
Fuzzy Kappa	0.64
Fuzzy fraction correct	0.91

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.52
KHisto	0.75
KLoc	0.70
Fraction correct	0.71
Fuzzy Kappa	0.14
Fuzzy fraction correct	0.73

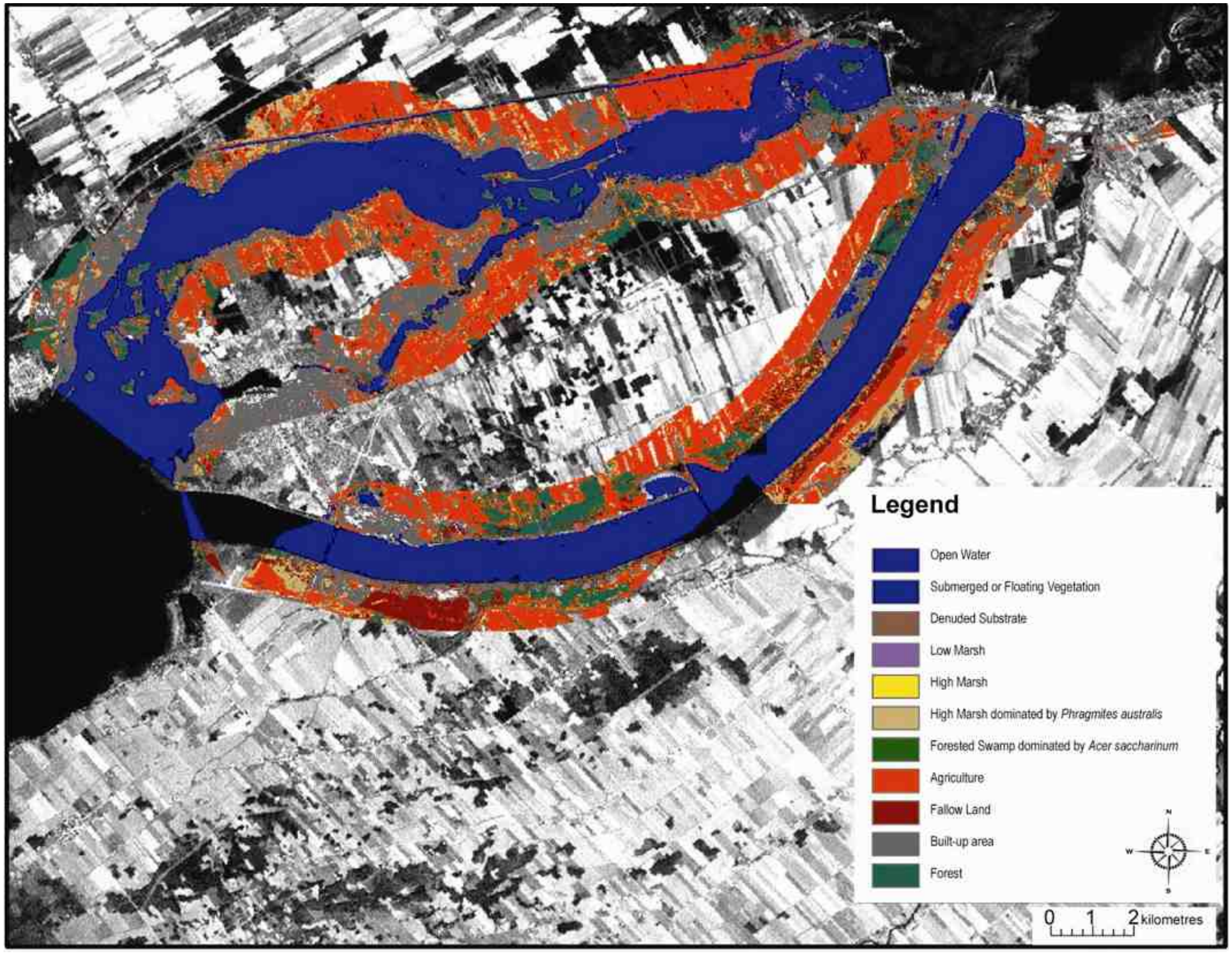
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.78
KHisto	0.89
KLoc	0.88
Fraction correct	0.90
Fuzzy Kappa	0.64
Fuzzy fraction correct	0.91

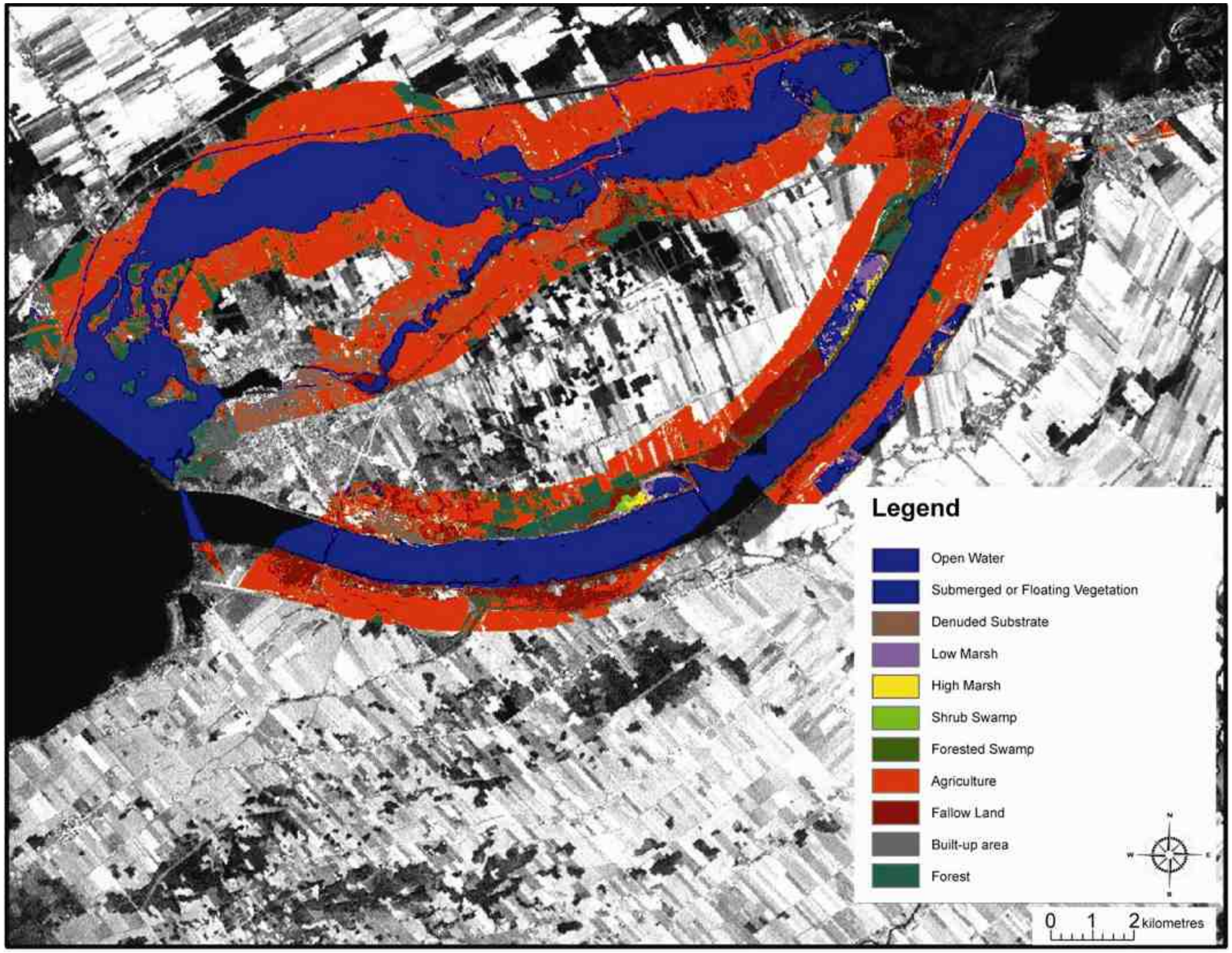
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.78
KHisto	0.89
KLoc	0.88
Fraction correct	0.90
Fuzzy Kappa	0.64
Fuzzy fraction correct	0.91

9 Wetlands in the Valleyfield–Beauharnois sector in 1990–1991



10 Wetlands in the Valleyfield–Beauharnois sector in 2000–2002



11 Gains and losses in the Valleyfield–Beauharnois sector not retained in the analysis

Between 1990–1991 and 2000–2002

Almost all of the rejected gains (467 ha out of 737 ha, or 63%) can be attributed to the conversion of wetlands (including 455 ha dominated by *Phragmites australis*) to agricultural land. A major overestimation of the area occupied by *Phragmites australis* on the 1990–1991 map is very likely responsible, although the species' presence along the Beauharnois Canal is well known. Another possibility is that *Phragmites australis* populations were underestimated in 2000–2002, given the lack of field data in this sector. Regardless of the cause, these transformations were not retained.

Similarly, 113 ha identified as wetlands in 1990–1991 (mainly high marshes dominated by *Phragmites australis*) were classified as fallow land in 2000–2002. These are located mainly inland from and along the Beauharnois Canal. These changes were not retained since they appear to be due to an overestimation of wetlands on the 1990–1991 map. In addition, 60 ha previously classified as wetlands (mainly high marshes dominated by *Phragmites australis*) were identified as forests in 2000–2002; this again is probably due to an overestimation of high marshes dominated by *Phragmites australis* in 1990–1991.

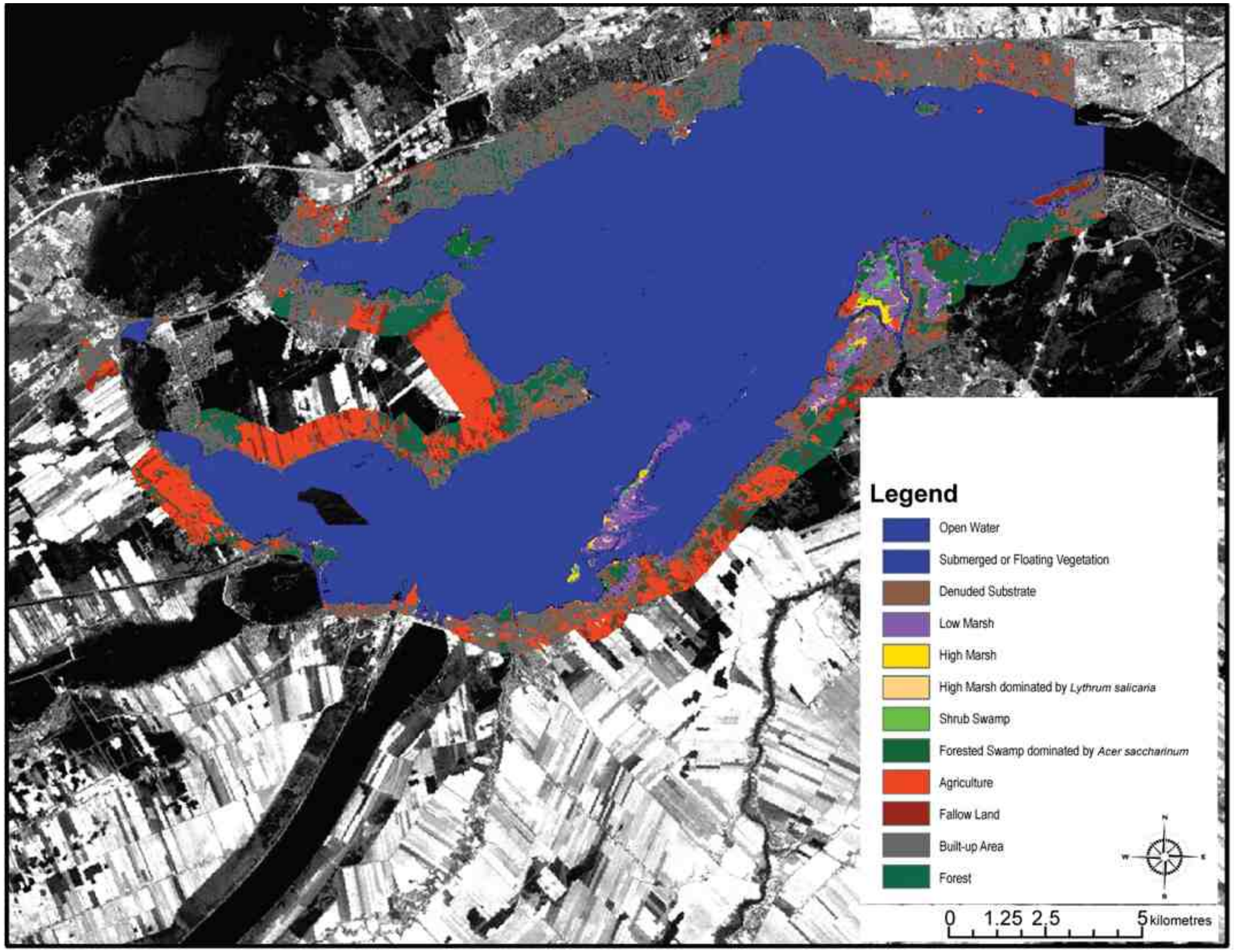
Gains not retained consist first of all of 28 ha of agricultural lands along the Beauharnois Canal in 1990–1991, which were identified as wetlands in 2000–2002. This can be explained by the better classification of the sector in the more recent map. In addition, 15 ha of fallow land were transformed into wetlands, again around the settling basins (impoundments) on the north side of the Beauharnois Canal. These transformations probably result from confusion in identifying the "fallow land" class in 1990–1991.

12 Results of Kappa agreement analyses for the Valleyfield–Beauharnois sector

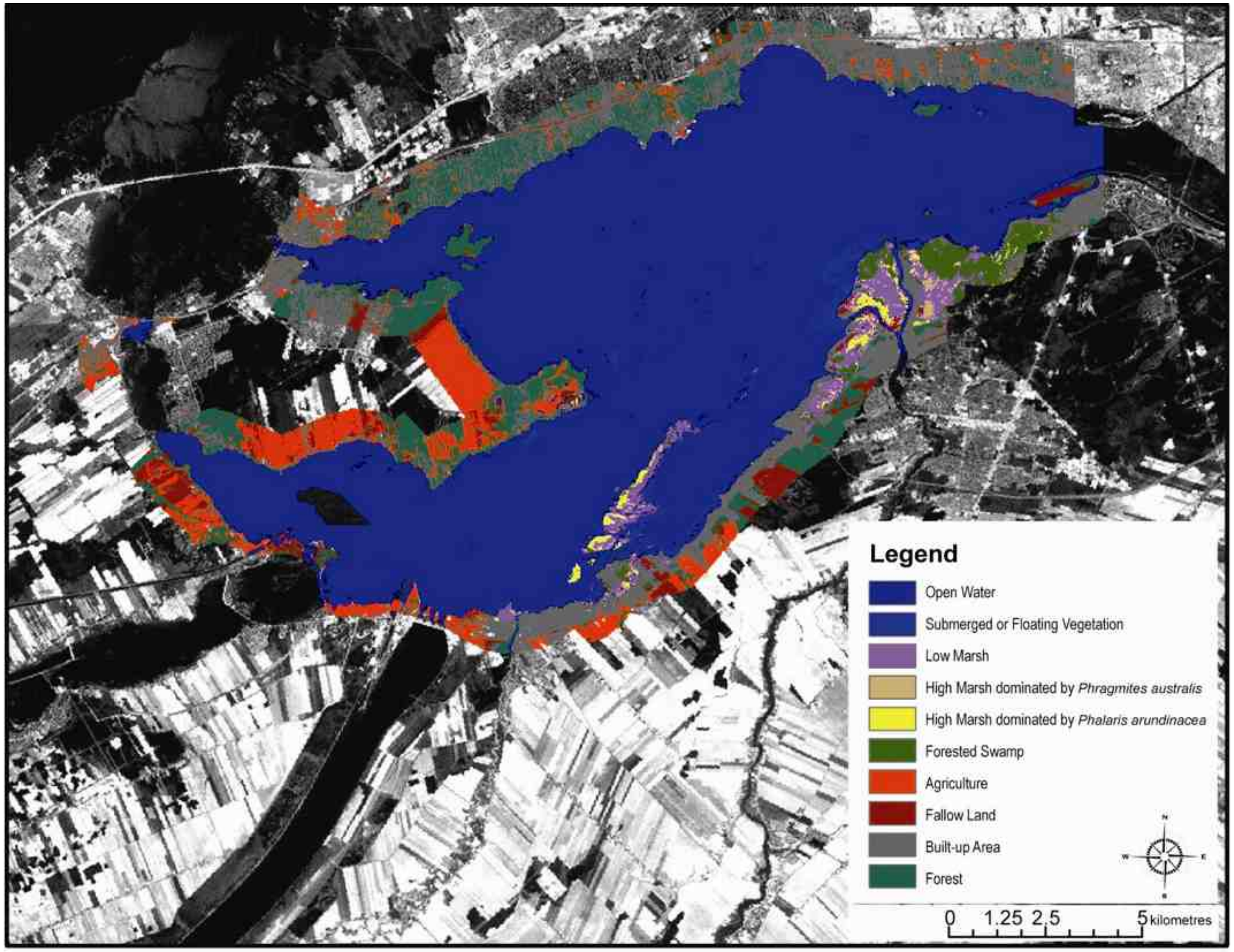
Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.80
KHisto	0.90
KLoc	0.88
Fraction correct	0.90
Fuzzy Kappa	0.56
Fuzzy fraction correct	0.91

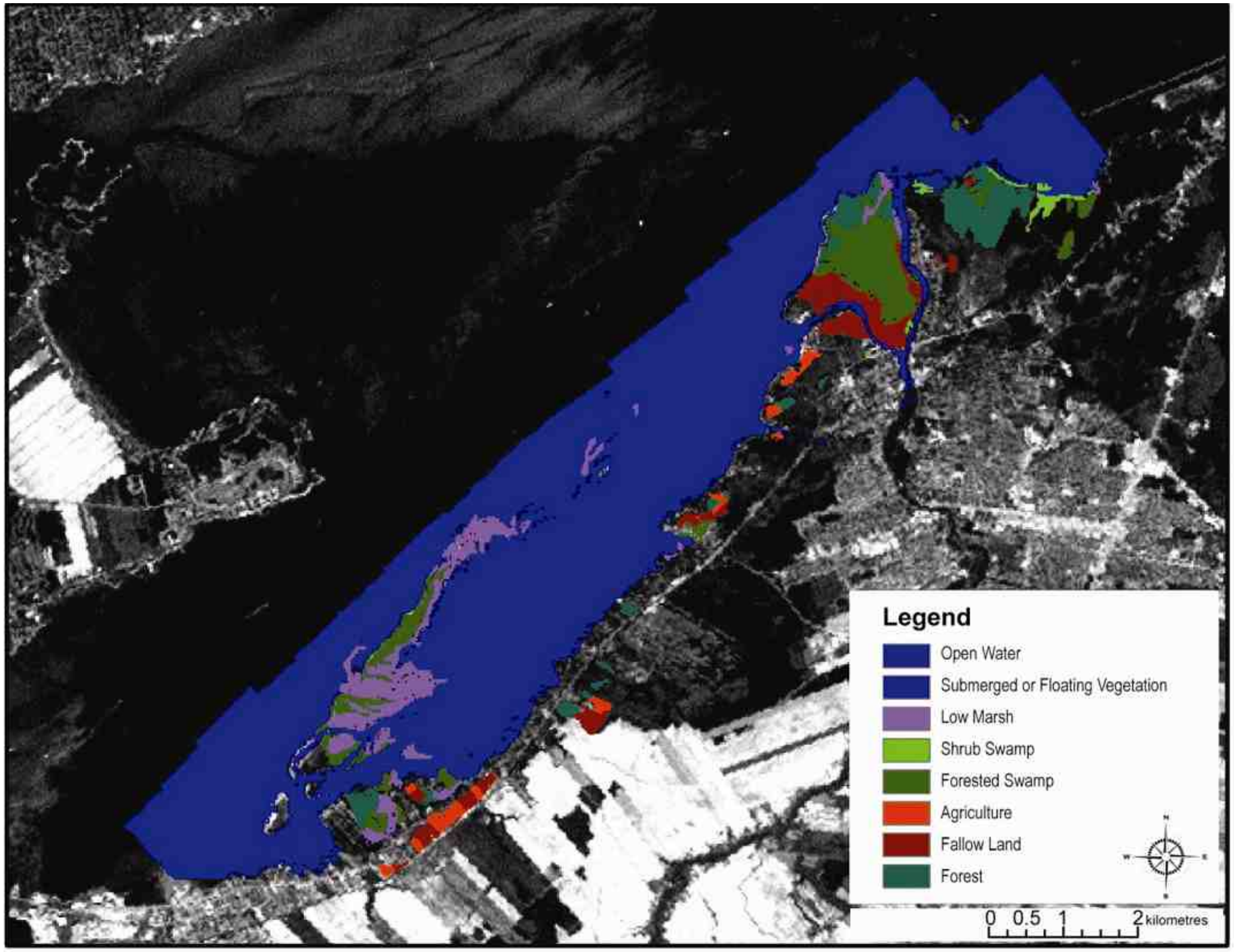
13 Wetlands in Lake Saint-Louis in 1990–1991



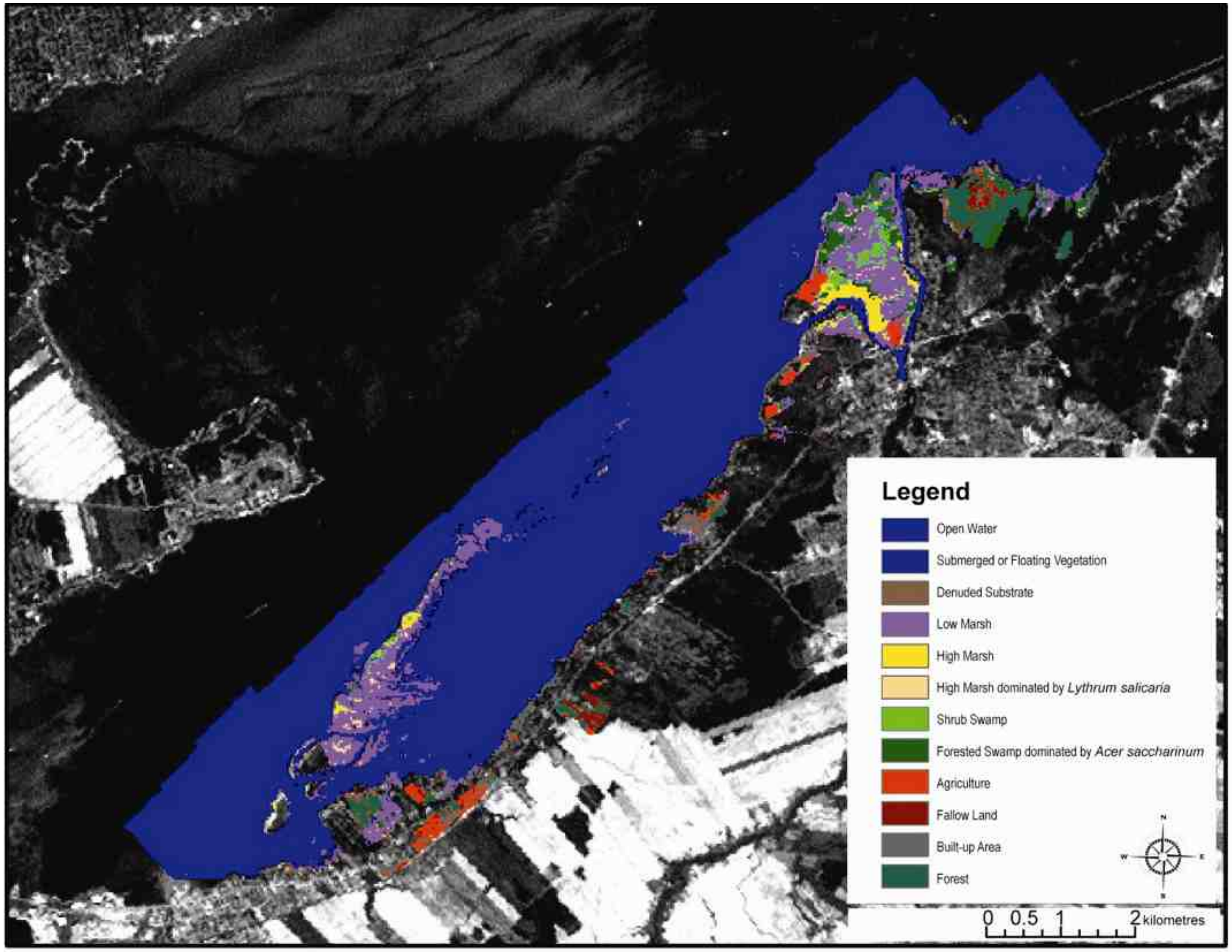
14 Wetlands in Lake Saint-Louis in 2000–2002



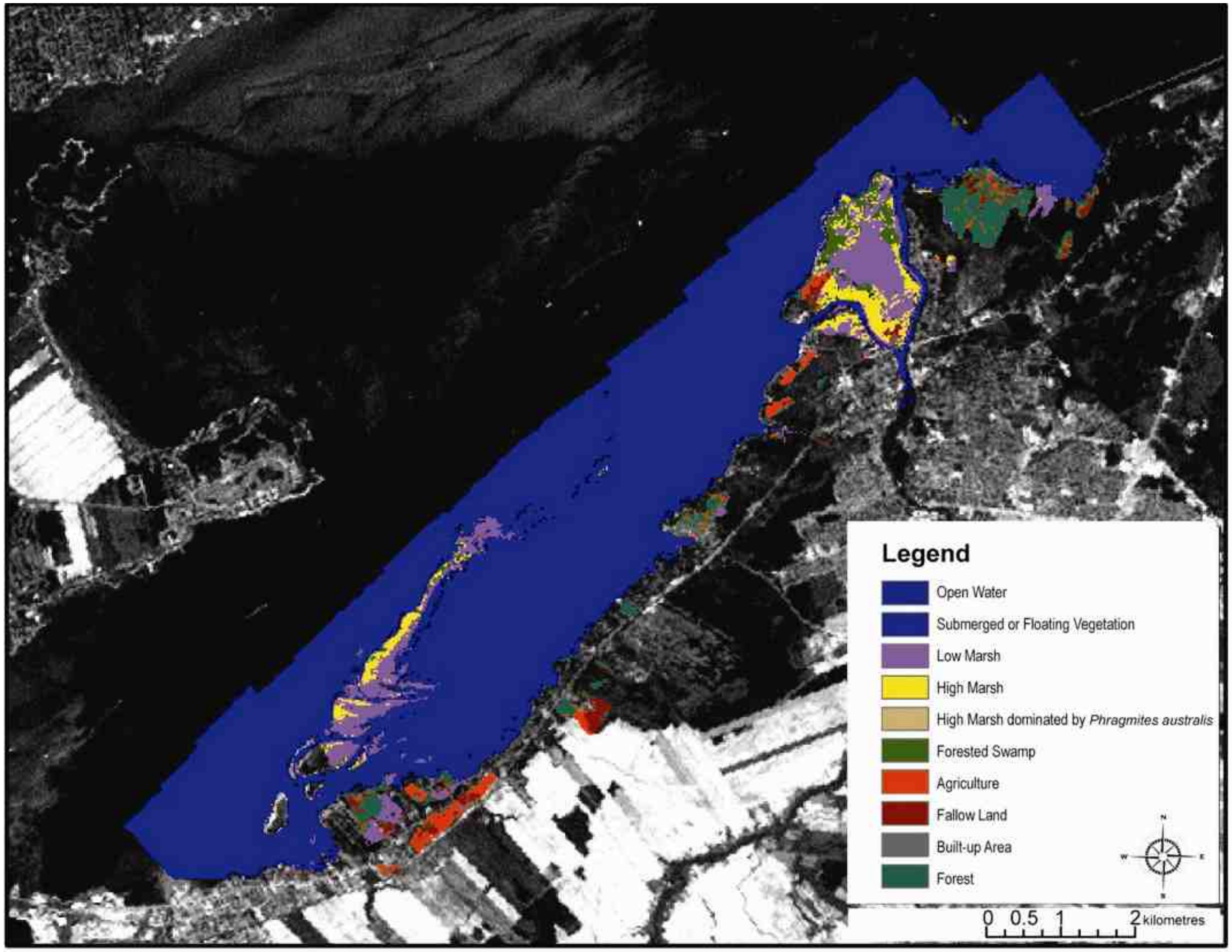
15 Wetlands in the portion of Lake Saint-Louis analyzed in 1970–1978



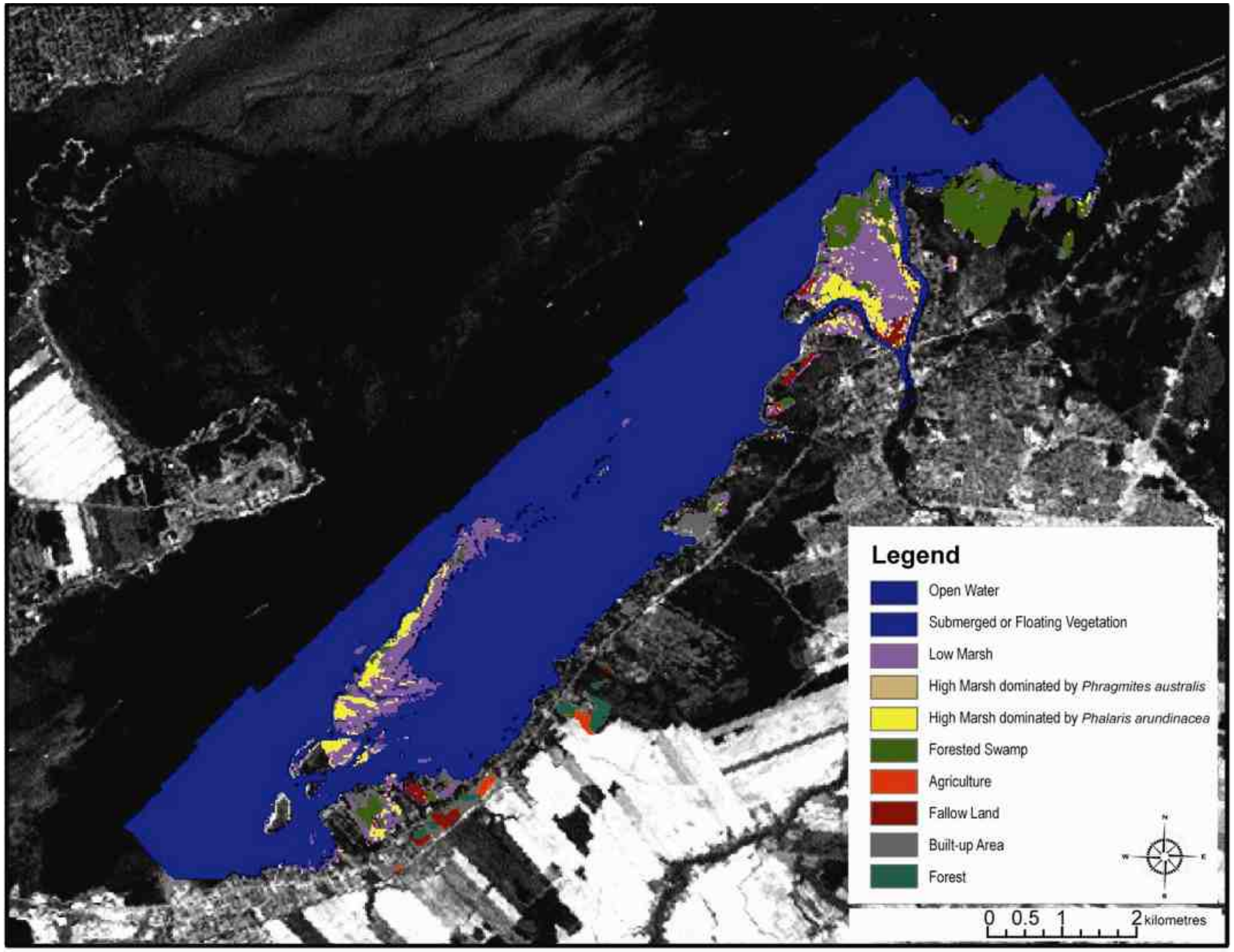
16 Wetlands in the portion of Lake Saint-Louis analyzed in 1990–1991



17 Wetlands in the portion of Lake Saint-Louis analyzed in 1996–1997



18 Wetlands in the portion of Lake Saint-Louis analyzed in 2000–2002



19 Gains and losses in the Lake Saint-Louis sector not retained in the analysis

Between 1990–1991 and 2000–2002

All the losses of wetlands tallied during this period involve, in our opinion, various problems rather than actual changes. Among these losses, 95 ha involved conversions of wetlands to open water zones; these occurred in several locations, including Pointe du Moulin (Windmill Point) on Île Perrot, around the Îles de la Paix National Wildlife Area, on the eastern shore of Saint-Bernard Island, at the mouth of the Châteauguay River and in the bays adjacent to the Kahnawake Mohawk Reserve. This difference between the two time periods cannot be attributed to water level fluctuations (Pointe-Claire hydrometric station – 02OA039: 21.12 m on August 21, 1990, 21.13 m on September 18, 2000, and 21.09 m on September 19, 2000; Pointe-Claire hydrometric station – 15330: 21.14 m on August 11, 2002, and 21.01 m on August 21, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). It may have resulted from geometric problems with the two maps.

In addition, a total of 53 ha of wetlands were transformed into upland forests, concentrated on Dowker Island and in the Châteauguay area. An overestimation of forested swamps in 1990–1991 could explain this difference. Furthermore, 36 ha of wetlands (mainly low marshes and forested swamps) were converted to built-up areas around populated areas in Châteauguay and seem to be linked more to confusion between classes as well as the use of corridors to determine the boundaries of built-up areas in 2000–2002. Lastly, 16 ha of wetlands were transformed into fallow land on Dowker Island and in the Châteauguay area. This may involve the overestimation of wetlands in 1990–1991.

The great majority of gains observed during the period seem to be the result of inconsistencies. The most abundant gains (240 ha) result from confusion between upland forests and wetlands. Large areas of swamp were correctly identified in 2000–2002 in the Kahnawake Mohawk Reserve. Between the two periods, 33 ha previously identified as built-up areas were subsequently incorrectly classified as wetlands in areas throughout the sector (for example, on Pointe du Moulin on Île Perrot, in Châteauguay and in the Kahnawake Mohawk Reserve). This difference could be caused by confusion between classes. In addition, 27 ha of fallow land in 1990–1991 were identified as wetlands (mainly forested swamps) in 2000–2002, concentrated around Johnson Point in the Kahnawake Mohawk Reserve. There is strong evidence that an underestimation of wetlands in 1990–1991 is to blame.

Lastly, 24 ha classified as agricultural land in 1990–1991 were incorrectly identified as wetlands in 2000–2002; although this occurred in the Johnson Point area again, the greatest concentration was on the western tip of Saint-Bernard Island. This again may be due to an underestimation of wetlands in 1990–1991.

Between 1970–1978 and 1990–1991

Wetland losses during the period that were not retained in the analysis include 12 ha classified as upland forests in 1990–1991, located in the western part of the Kahnawake Mohawk Reserve and at Maple Grove Point. The probable cause is confusion resulting from the definition of masks for upland areas. The rest of the transformations observed (losses to denuded substrate, agricultural areas and fallow land, for a total of 9 ha) seem to be the result of various problems rather than real changes in wetlands.

Two types of gains were not retained. Of the 115 ha of fallow land identified by Dryade in 1970-1978, 54 ha were transformed into wetlands in 1990–1991. This fallow land was located on and around Saint-Bernard Island. The 1990–1991 maps appear to overestimate wetlands in this sector. Also in the Saint-Bernard Island area, 42 ha of forests were transformed into wetlands in 1990–1991; again an overestimation of wetlands in 1990–1991 appears to be responsible.

Between 1990–1991 and 1996–1997

Losses that were not retained included over 21 ha of wetlands that were classified as forests in 1996–1997, located in the western part of Kahnawake Mohawk Reserve and on Maple Grove Point. Given the short period of time between coverages, it is unlikely that these are real changes. In the same areas, 9 ha of wetlands were converted to fallow land in 1996–1997. Differences in the upland masks used are probably responsible for this difference. The rest of the losses not retained in the analysis total 7 ha.

In all, 18 ha of presumed gains (at the expense of denuded substrate, agricultural land, fallow land, built-up area and forest) were not retained. They seem to be the result of inconsistencies, mainly in the Saint-Bernard Island area.

Between 1996–1997 and 2000–2002

Among the wetland losses observed that, in our opinion, represent inconsistencies, 22 ha of wetlands appeared in 2000–2002 as open water around Saint-Bernard Island and, to a lesser extent, the Îles de la Paix. Water levels recorded when the images were acquired in 1996 were higher than those in 2000–2002 (Pointe-Claire hydrometric station – 02OA039: 21.38 m on October 17, 1996, 21.13 m on September 18, 2000, 21.09 m on September 19, 2000; Pointe-Claire hydrometric station – 15330: 21.14 m on August 11, 2002 and 21.01 m on August 21, 2002; source: HYDAT 2001 and Marine Environmental Data Service, Fisheries and Oceans Canada). Therefore, it is very unlikely that these changes are real ones; it is more likely that they are the result of geometric problems. The remaining losses (totalling 8 ha) seem to be associated with confusions between wetlands and upland areas.

Most of the gains observed during this period probably result from various classification problems. The main change of this type (87 ha) occurred at the expense of forests and was observed primarily in the western part of the Kahnawake Mohawk Reserve. In our opinion, it is due to the confusion between classes (forested swamps and upland forests). In addition, 23 ha of fallow land were classified as wetlands in 2000–2002 on Maple Grove Point, Saint-Bernard Island and the western side of the Kahnawake Mohawk Reserve. Again, this appears to result from confusion between classes, as is the case for 15 ha of agricultural lands observed in the same locations that were classified as wetlands.

20 Results of Kappa agreement analyses for Lake Saint-Louis

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.88
KHisto	0.94
KLoc	0.94
Fraction correct	0.94
Fuzzy Kappa	0.75
Fuzzy fraction correct	0.95

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.58
KHisto	0.77
KLoc	0.76
Fraction correct	0.85
Fuzzy Kappa	0.40
Fuzzy fraction correct	0.86

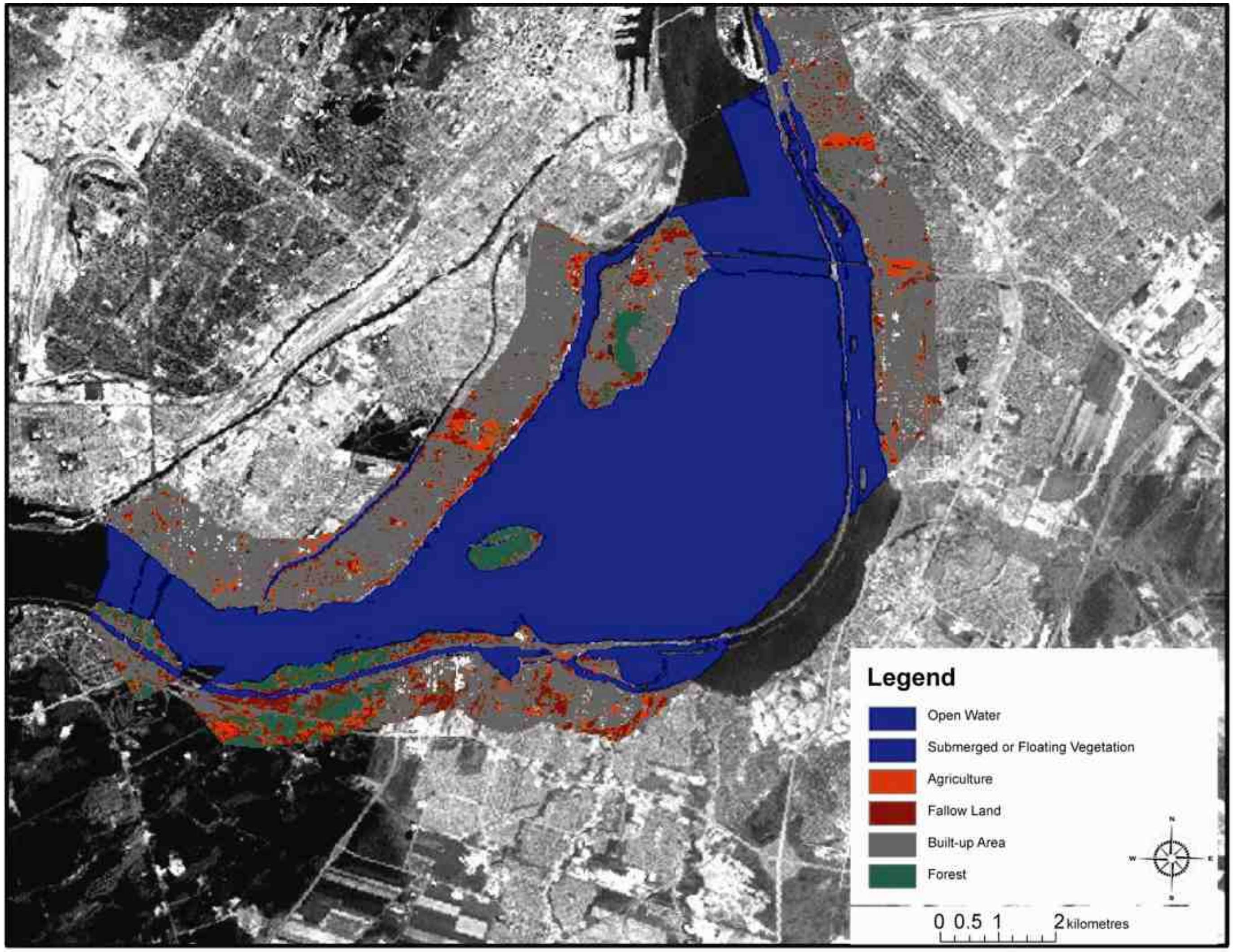
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.71
KHisto	0.83
KLoc	0.85
Fraction correct	0.90
Fuzzy Kappa	0.60
Fuzzy fraction correct	0.92

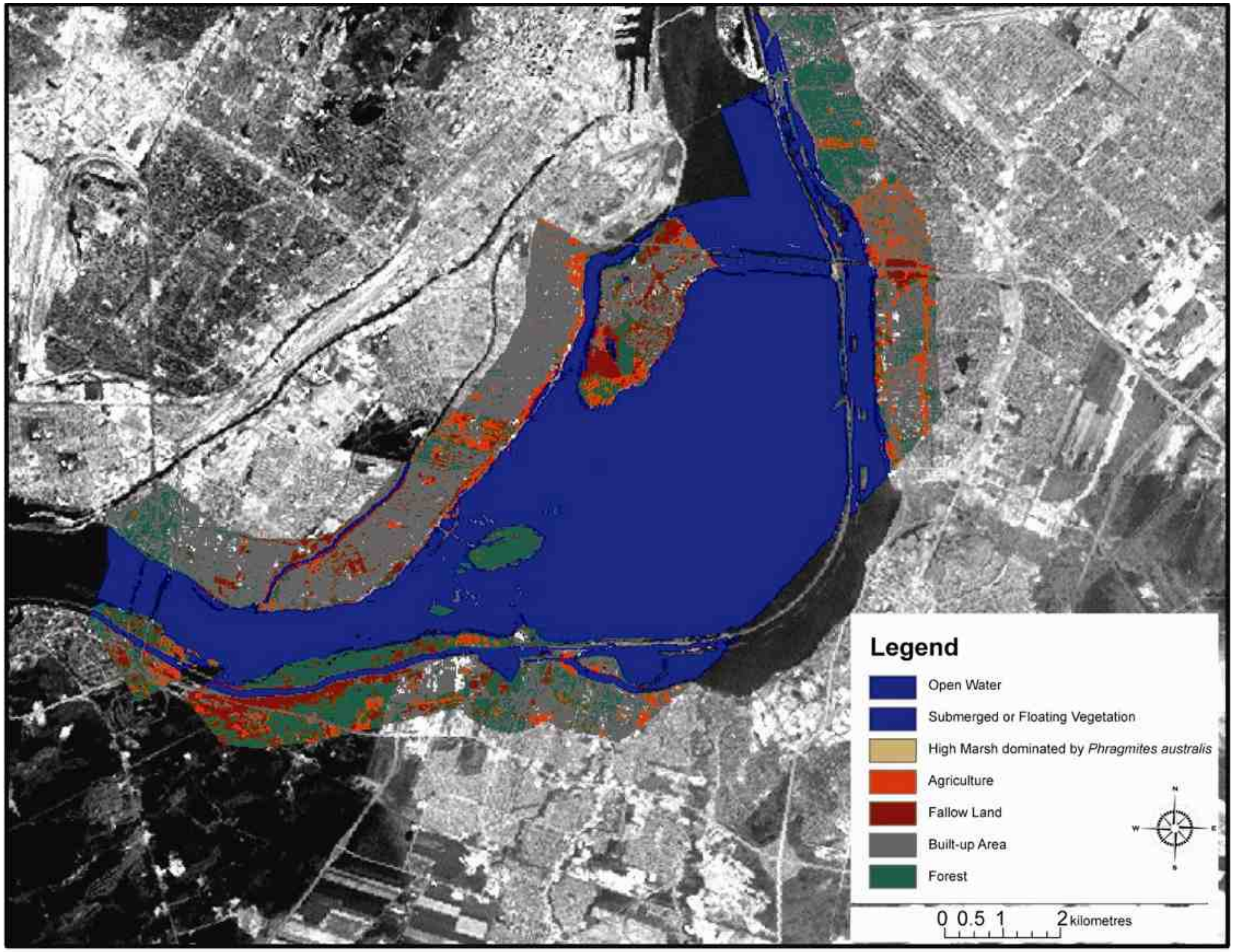
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.66
KHisto	0.79
KLoc	0.83
Fraction correct	0.89
Fuzzy Kappa	0.54
Fuzzy fraction correct	0.91

21 Wetlands in the La Prairie Basins sector in 1990–1991



22 Wetlands in the La Prairie Basins sector in 2000-2002

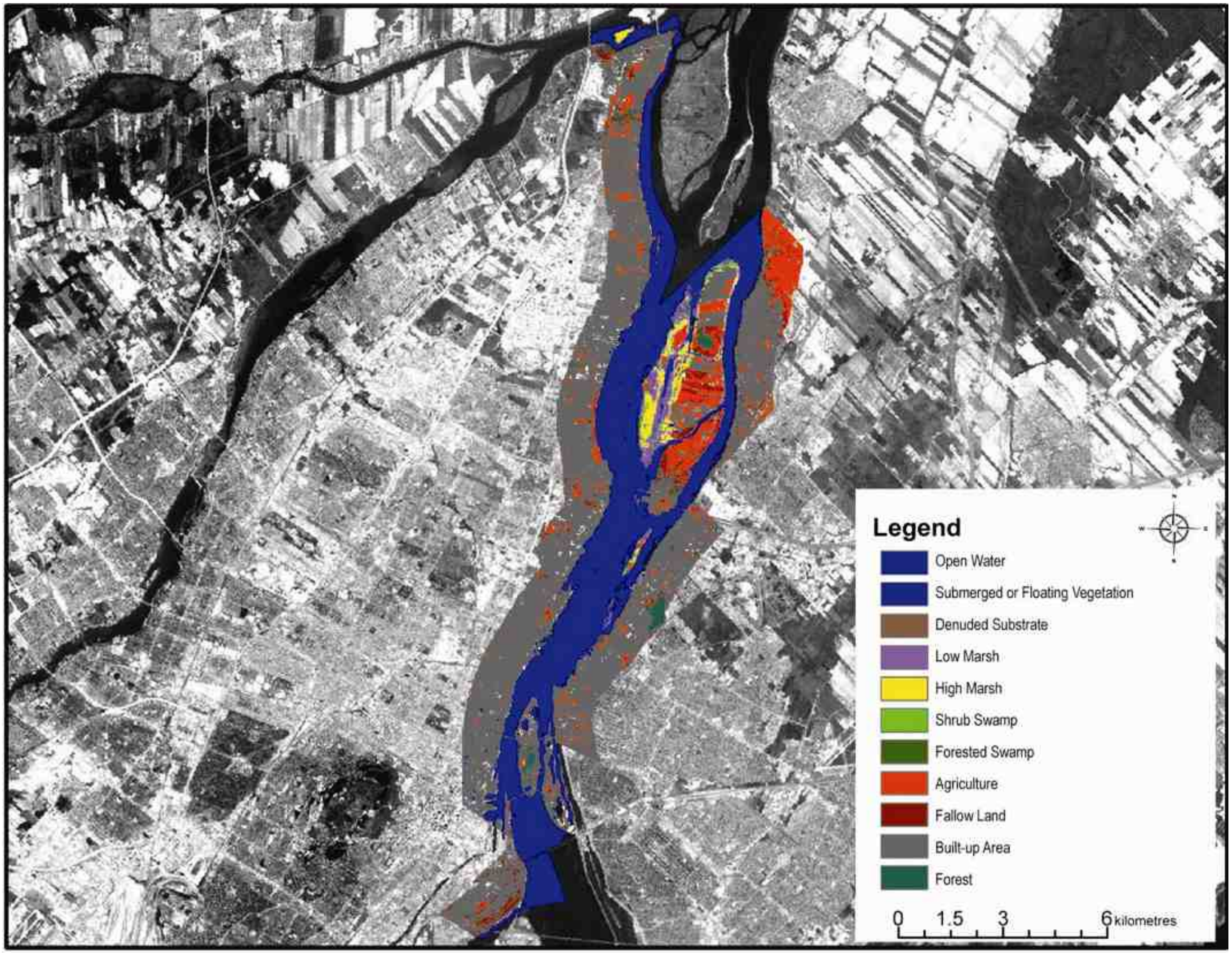


23 Results of Kappa agreement analyses for the La Prairie Basins sector

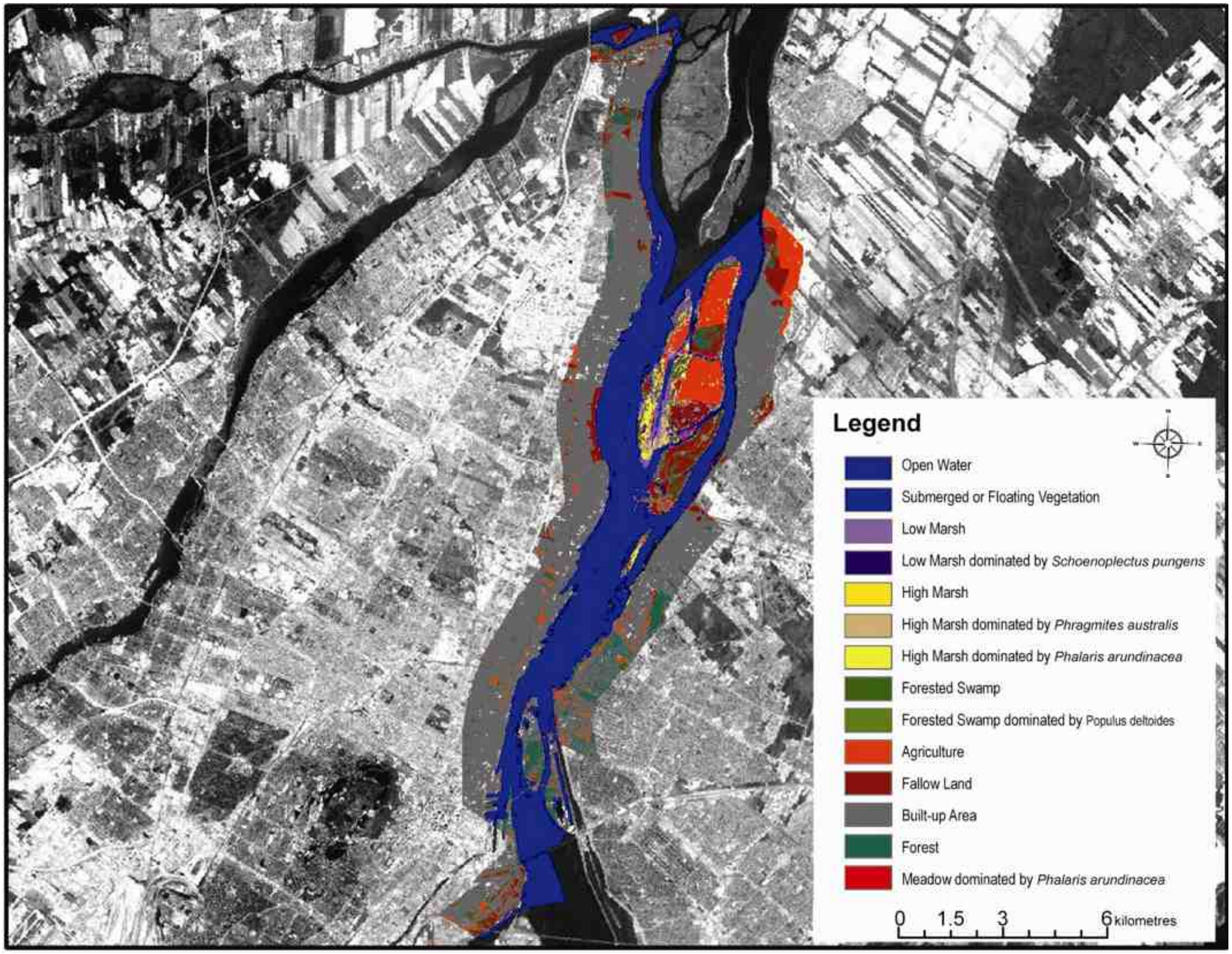
Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.92
KHisto	0.99
KLoc	0.93
Fraction correct	0.96
Fuzzy Kappa	0.83
Fuzzy fraction correct	0.97

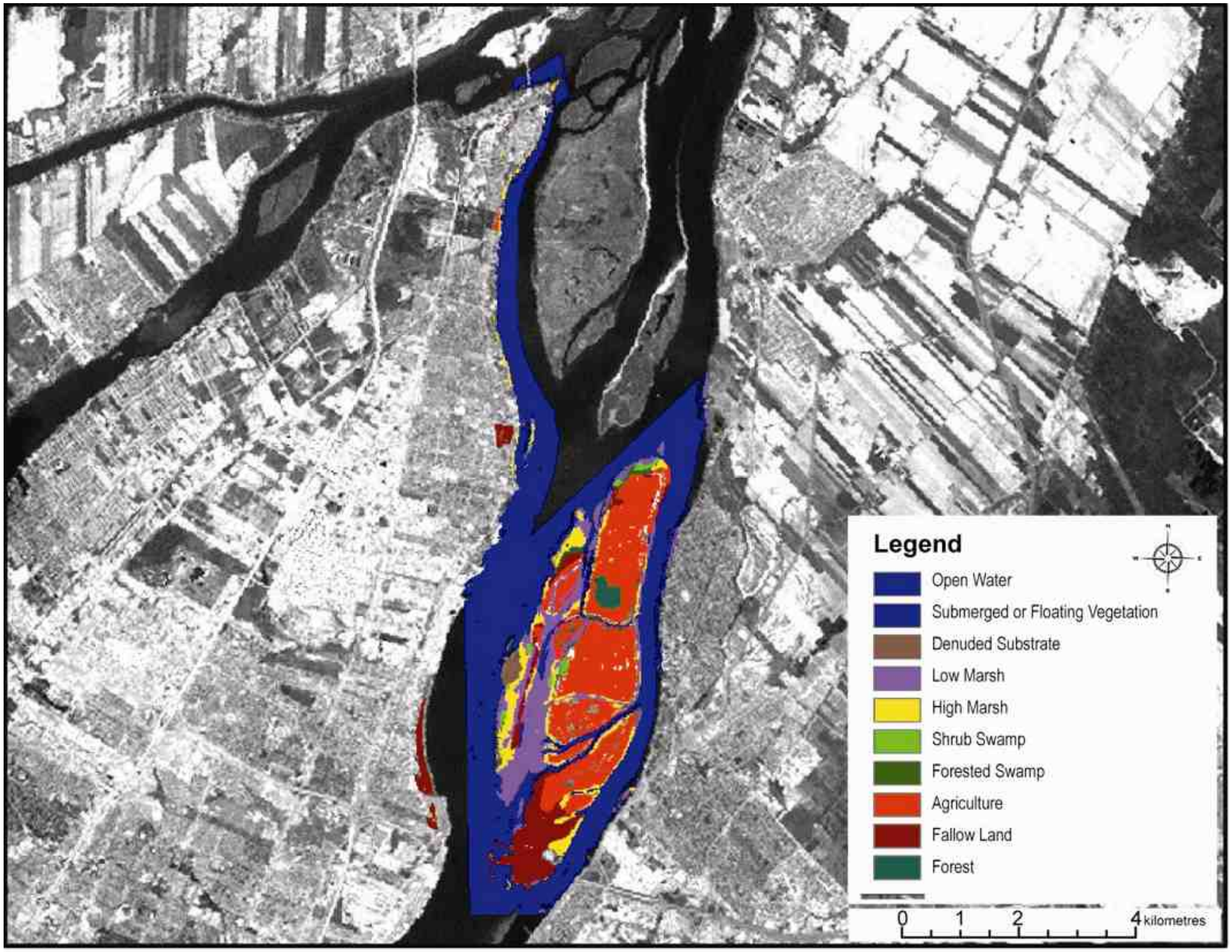
24 Wetlands in the Montréal–Longueuil sector in 1990–1991



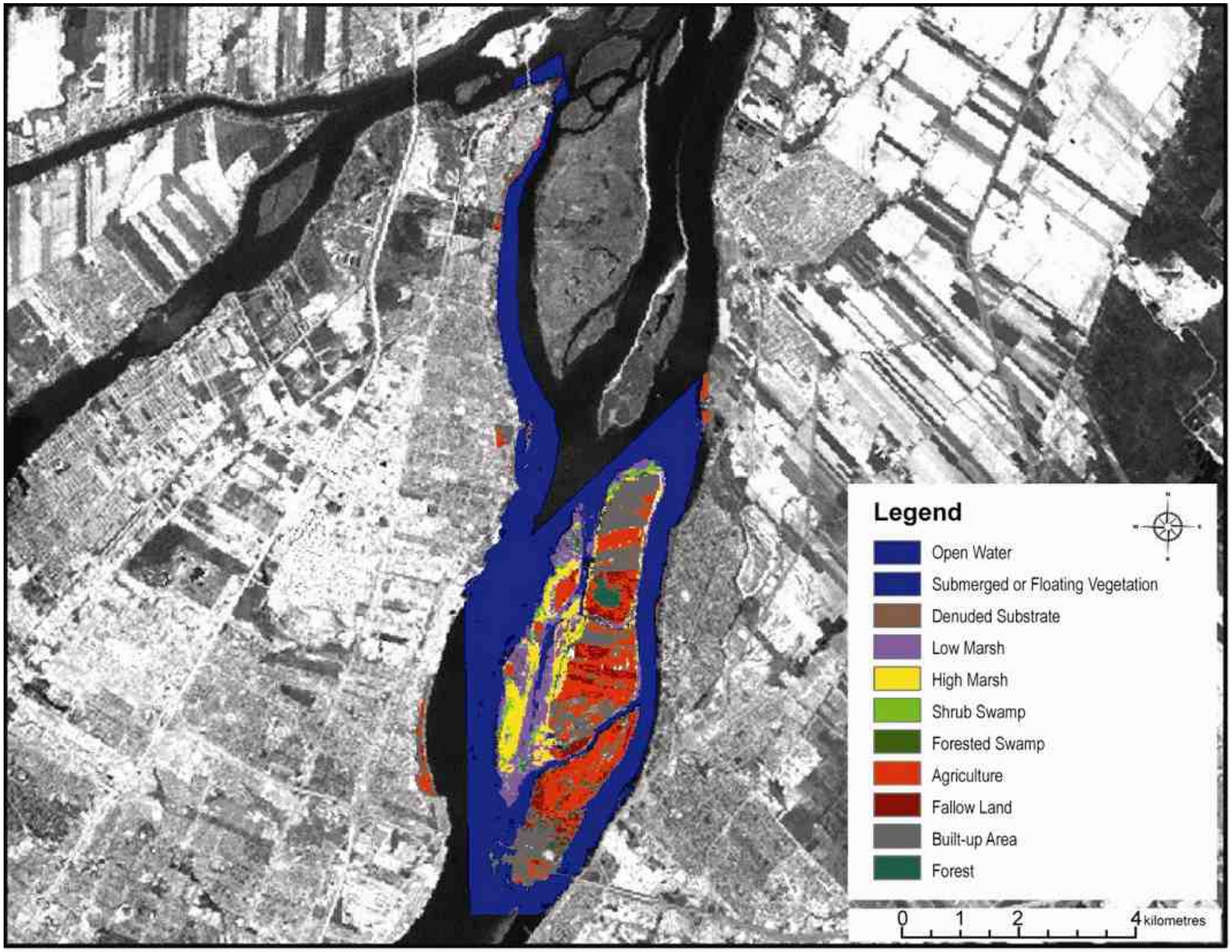
25 Wetlands in the Montréal–Longueuil sector in 2000–2002



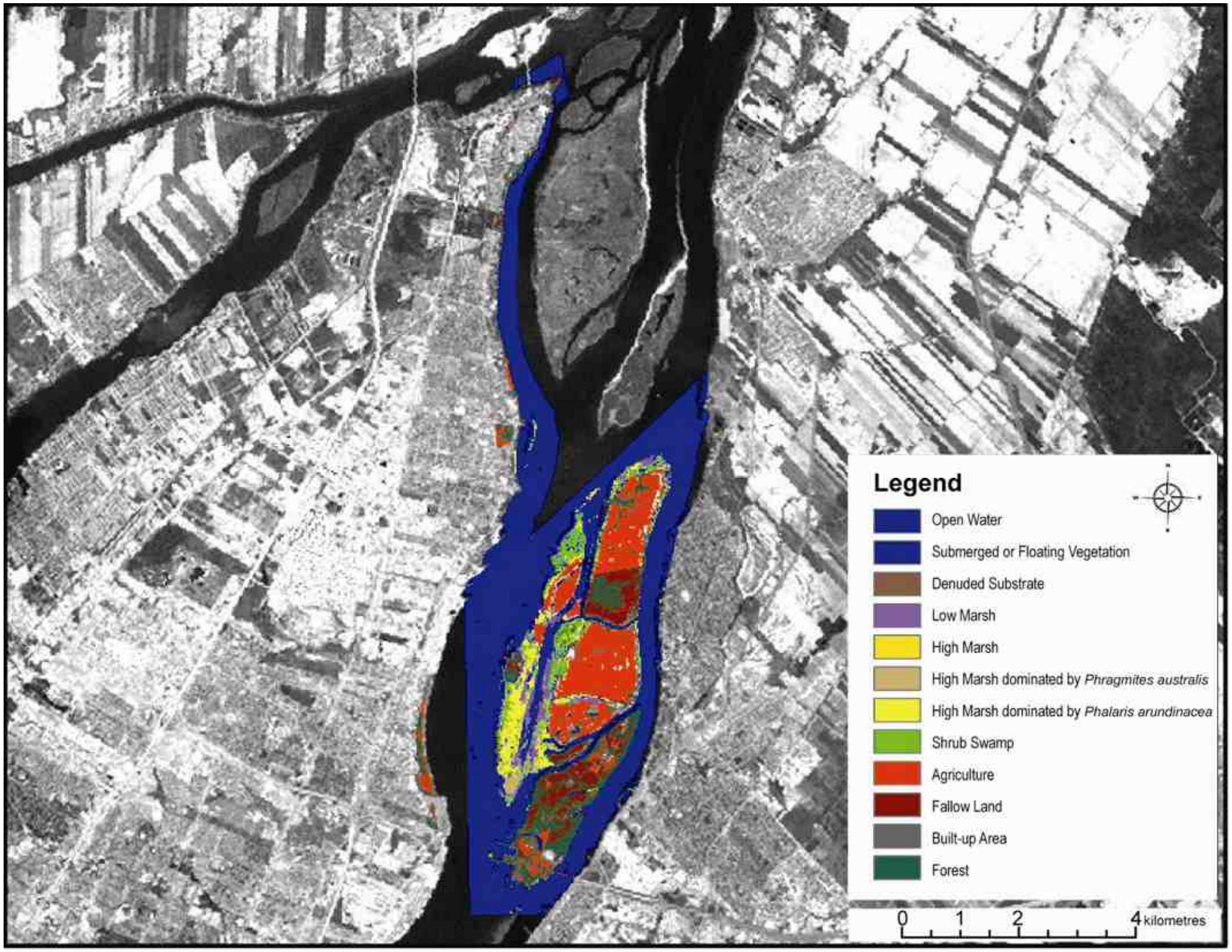
26 Wetlands in the portion of the Montréal–Longueuil sector analyzed in 1970–1978



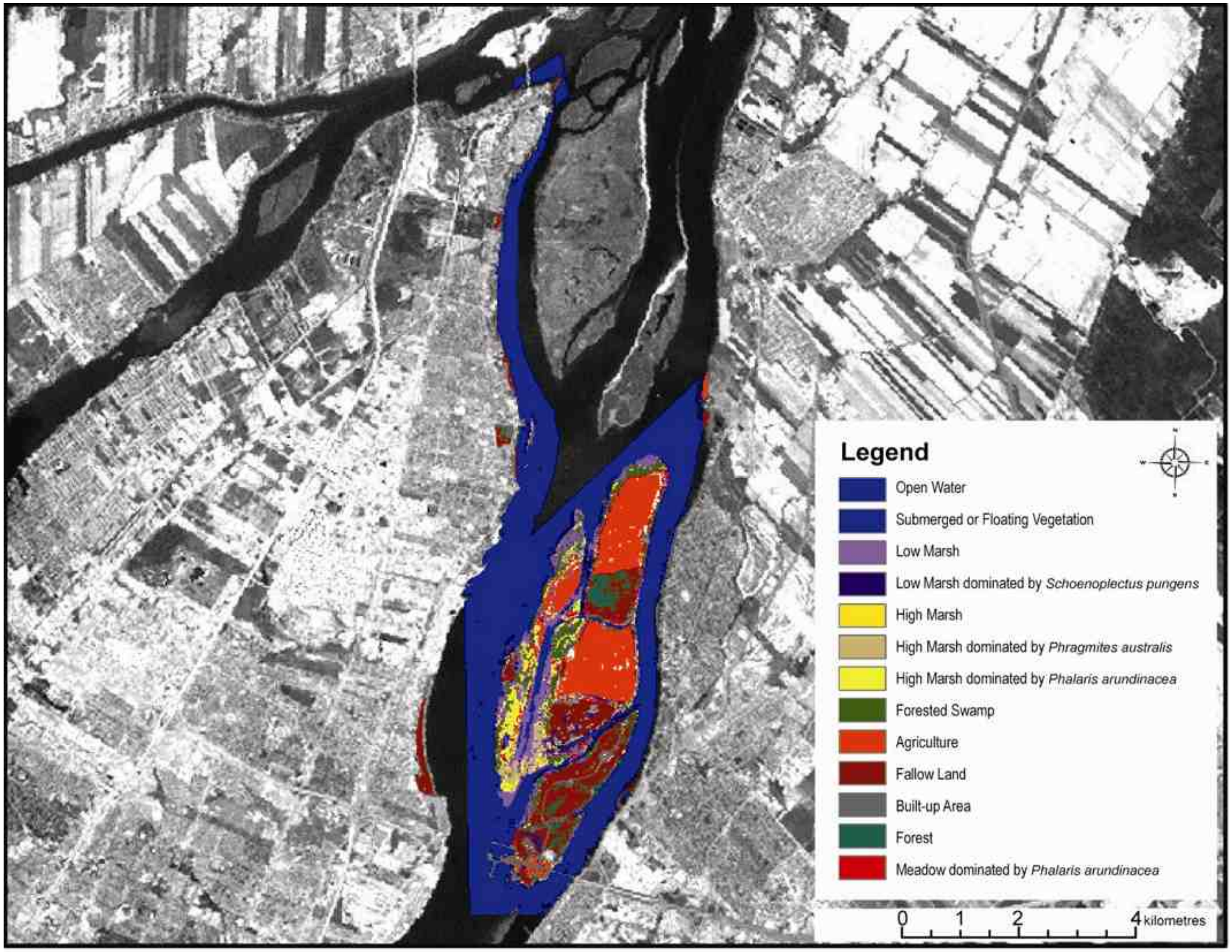
27 Wetlands in the portion of the Montréal–Longueuil sector analyzed in 1990–1991



28 Wetlands in the portion of the Montréal–Longueuil sector analyzed in 1996–1997



29 Wetlands in the portion of the Montréal–Longueuil sector analyzed in 2000–2002



30 Gains and losses in the Montréal–Longueuil sector not retained in the analysis

Between 1990–1991 and 2000–2002

The losses of wetlands observed during this period but not retained in our analysis are probably due to a significant overestimation of wetlands in the 1990–1991 map. A total of 33 ha of wetlands were classified as fallow land in the 2000–2002 map, located around Grosbois Island in the Tailhandier Flats (Boucherville Islands) as well as on Bonfoin Island (at the confluence of the Rivière des Mille Îles and Rivière des Prairies). In addition, 27 ha classified as wetlands in 1990–1991 were classified as agricultural land in 2000–2002. This is probably due to confusion problems as well as the overestimation of wetlands in 1990–1991. Lastly, 13 ha of wetlands were classified as dry meadows dominated by *Phalaris arundinacea*, all on the Tailhandier Flats. This is probably due to the more accurate identification of dry meadows in 2000–2002, which previously were confused with high marshes (a problem difficult to resolve because the species is also present in wetlands).

Three types of gains were excluded. First, a total of 22 ha classified initially as agricultural land were identified as wetlands, located mainly in the Boucherville Islands. This can probably be explained by differences between the geometry of the two images. In addition, 18 ha of land initially identified as built-up area (including denuded substrate), also in the Boucherville Islands, were classified as wetlands (low marshes and forested swamps); the difference again seems to be explained by geometry. Lastly, 12 ha of fallow land were incorrectly classified as wetlands, all located in the southern part of the Boucherville Islands. This may be due to the overestimation of upland riparian habitats in 2000–2002.

Between 1970–1978 and 1990–1991

Two types of losses observed in the analysis of the two maps were not included in the present analysis. First, close to 64 ha of wetlands were lost to open water in various spots around the islands. This change cannot be explained by differences in water levels and, out of caution, we did not retain it. Similarly, 27 ha of wetlands were converted to agricultural land, mainly along certain channels in the Boucherville Islands. Differences in interpreting wetlands in the two mapping projects are probably to blame.

All the gains observed were deemed unlikely and were rejected. The main ones totalled 48 ha and involved agricultural land that was transformed into wetlands, mainly on the Tailhandier Flats. An overestimation of wetlands in 1990–1991 is in all likelihood the origin of this difference. In addition, 30 ha of open water were converted to wetlands. As is it not possible to verify water levels on the Groupe Dryade maps, no conclusions can be drawn about the veracity of this change and we preferred not to retain it. Furthermore, 25 ha of wetlands were gained at the expense of fallow land on the Tailhandier Flats and Boucherville Islands. Differences in upland masks are probably the reason for this discrepancy. Lastly, 9 ha of denuded substrate were incorrectly classified as wetlands in 1990–1991.

Between 1990–1991 and 1996–1997

Two major types of wetland losses (over 10 ha each) were not retained in the analysis of this period. First, 27 ha of wetlands were lost to agriculture; this can be explained by the overestimation of wetlands in 1990–1991. In addition, 11 ha of wetlands were classified as upland forests in the dredge spoil deposit area on the Tailhandier Flats, probably the result of the overestimation of wetlands in 1990-1991.

Two types of gains were not retained. First of all, 11 ha of built-up area were classified as wetlands, mainly around the Île à Pinard and Île de la Commune (Boucherville Islands), in all likelihood due to an overestimation of wetlands in 1996–1997. Similarly, 9 ha of wetlands appeared at the expense of agricultural land along certain channels in the Boucherville Islands; this can probably be explained by an overestimation of wetlands in 1996–1997.

Between 1996–1997 and 2000–2002

Among wetland losses not retained in the analysis, 16 ha were lost to fallow land, located mainly on the Tailhandier Flats, Île de la Commune and Grosbois Island. This loss, which was rejected, can be explained by overestimation of wetlands in 1996–1997 (due partially to an absence of field data). In addition, 21 ha of wetlands were classified as agricultural land (10 ha) and dry meadows dominated by *Phalaris arundinacea* (11 ha), found in the same areas as the previous losses. The difficulty of distinguishing dry meadows from high marshes, both of which may be dominated by the same species, is at the root of this confusion.

Many of the gains observed were not retained due to an overestimation of wetlands in 2000–2002. First, 31 ha of upland forests on Sainte-Marguerite Island were incorrectly identified in 2000–2002 as wetlands. Furthermore, 13 ha of fallow land were erroneously classified as wetlands on Charron and Saint-Jean islands in the Boucherville Islands. Lastly, 11 ha of cropland were classified in 2000–2002 as wetlands on the islands north of the Tailhandier Flats (Tourte Blanche Island, Montbrun Island and Dufault Island).

31 Results of Kappa agreement analyses for the Montréal–Longueuil sector

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.84
KHisto	0.94
KLoc	0.89
Fraction correct	0.92
Fuzzy Kappa	0.70
Fuzzy fraction correct	0.94

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.89
KHisto	0.99
KLoc	0.90
Fraction correct	0.94
Fuzzy Kappa	0.80
Fuzzy fraction correct	0.95

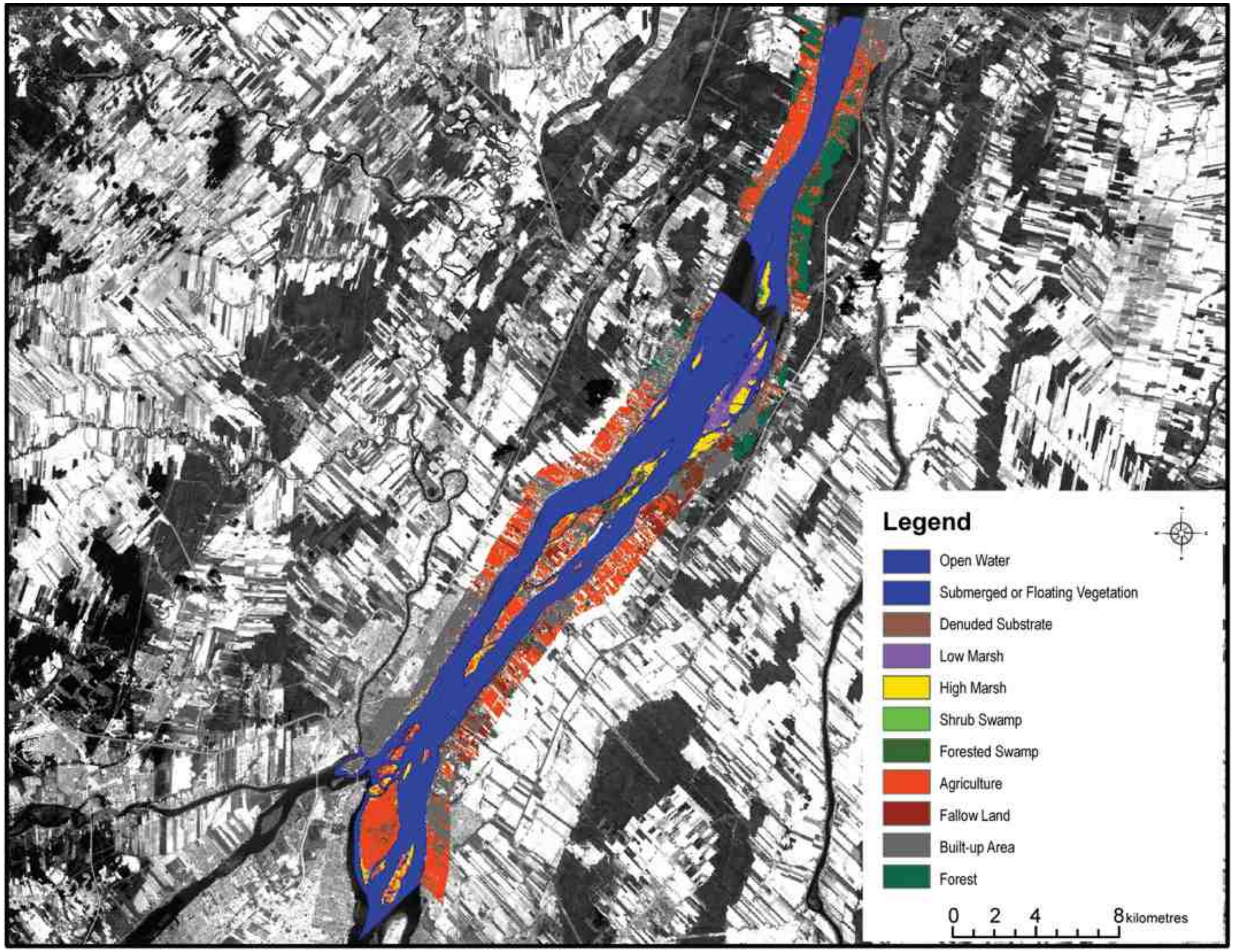
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.88
KHisto	0.94
KLoc	0.94
Fraction correct	0.94
Fuzzy Kappa	0.79
Fuzzy fraction correct	0.95

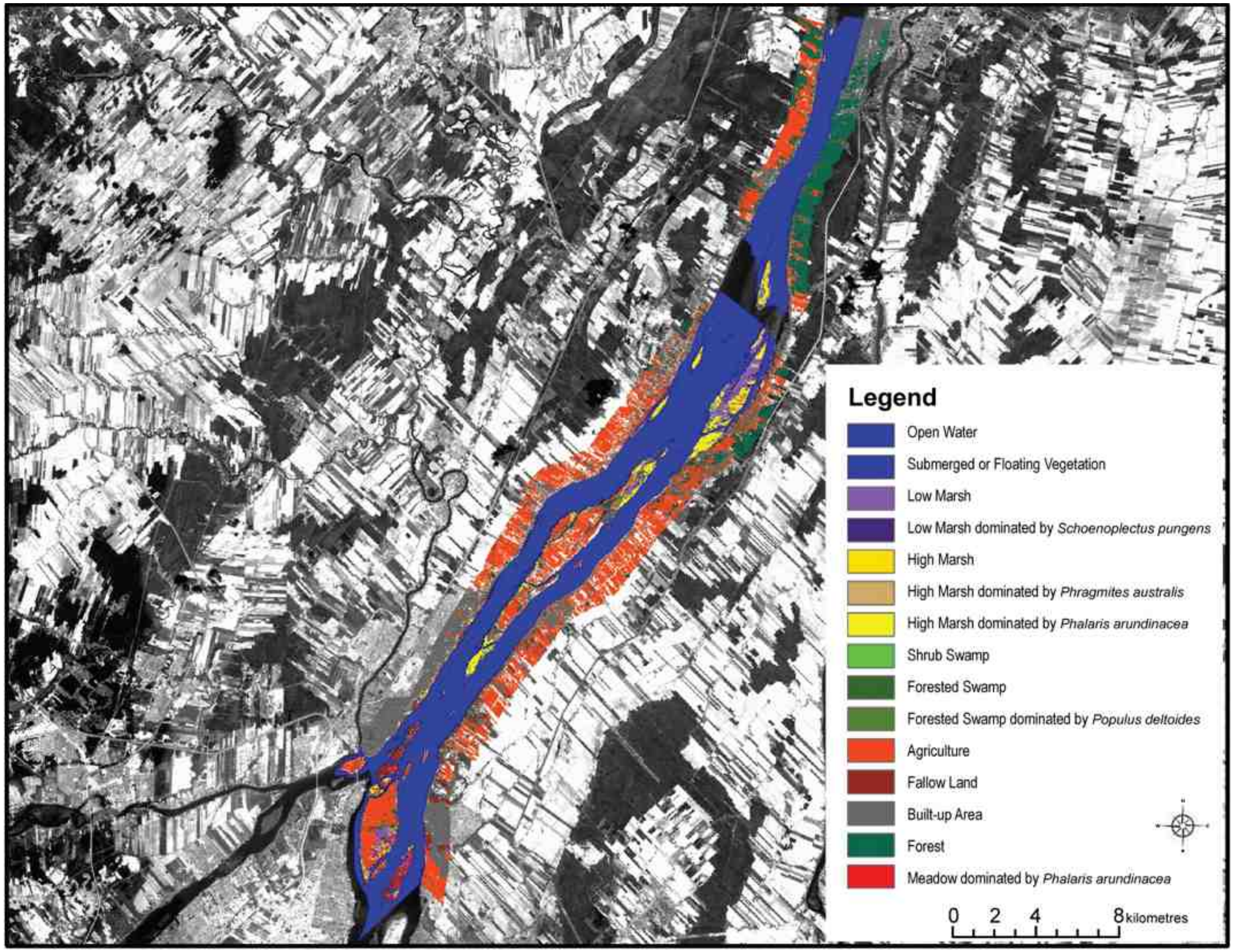
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.84
KHisto	0.89
KLoc	0.94
Fraction correct	0.92
Fuzzy Kappa	0.72
Fuzzy fraction correct	0.93

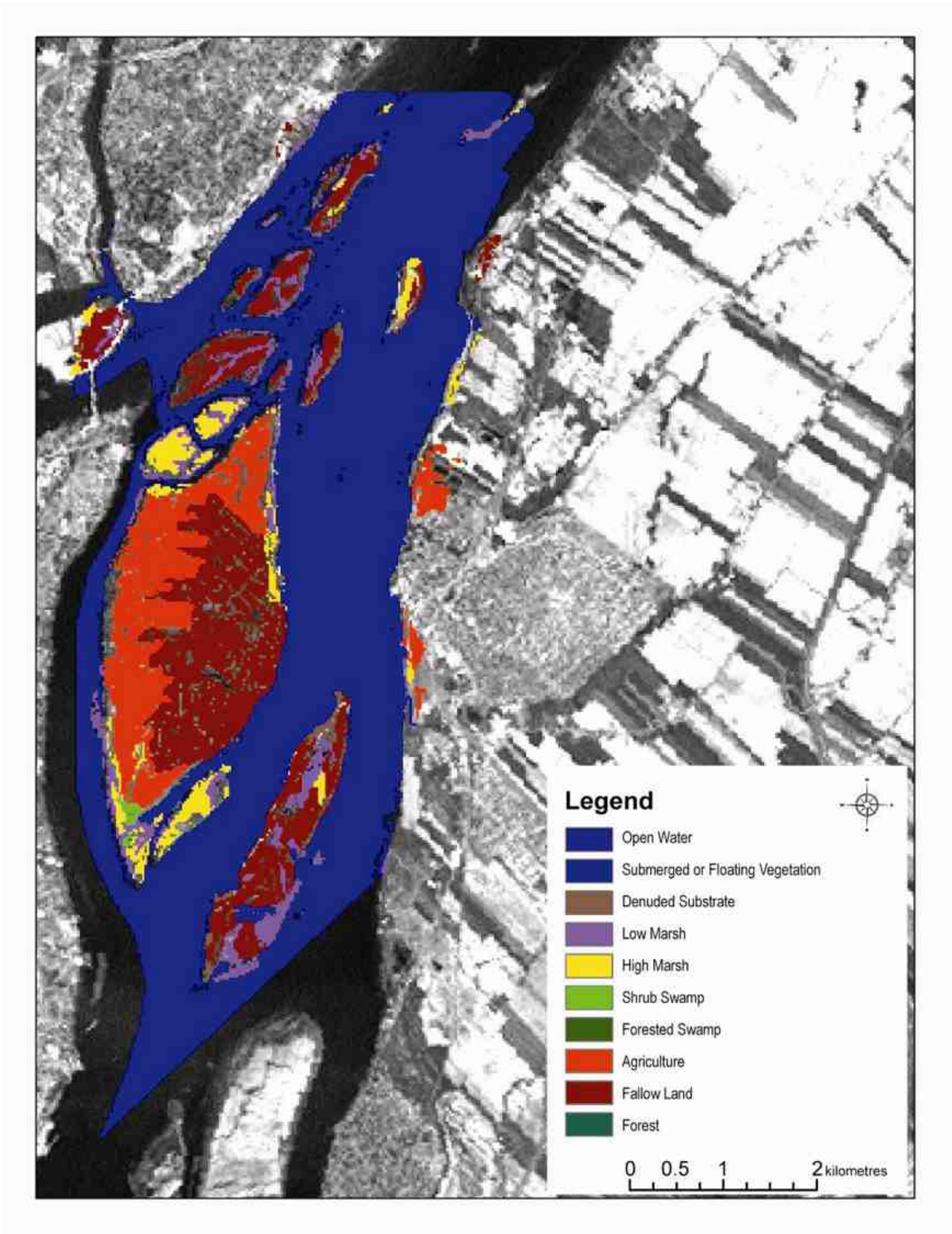
32 Wetlands in the Varennes–Contrecœur sector in 1990–1991



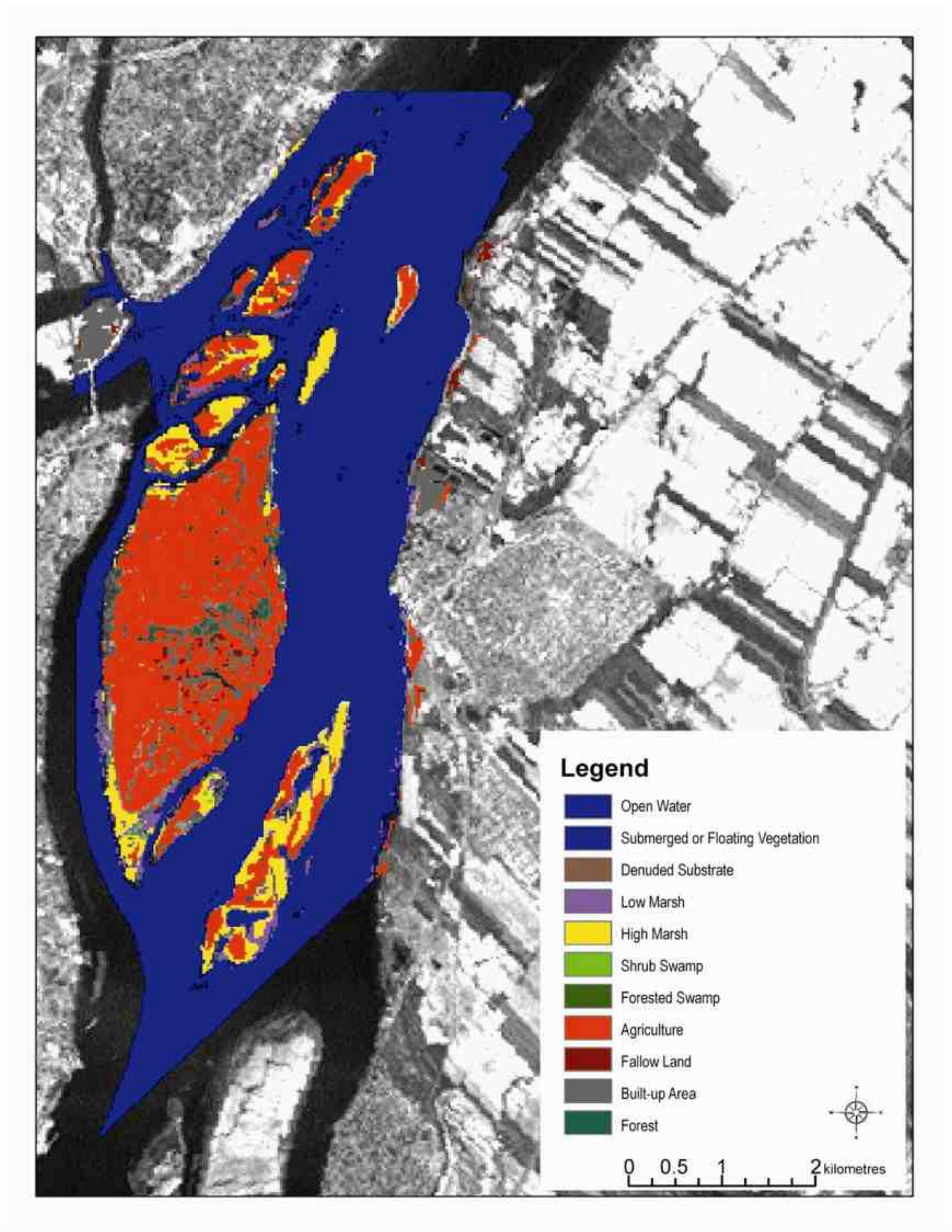
33 Wetlands in the Varennes–Contrecœur sector in 2000–2002



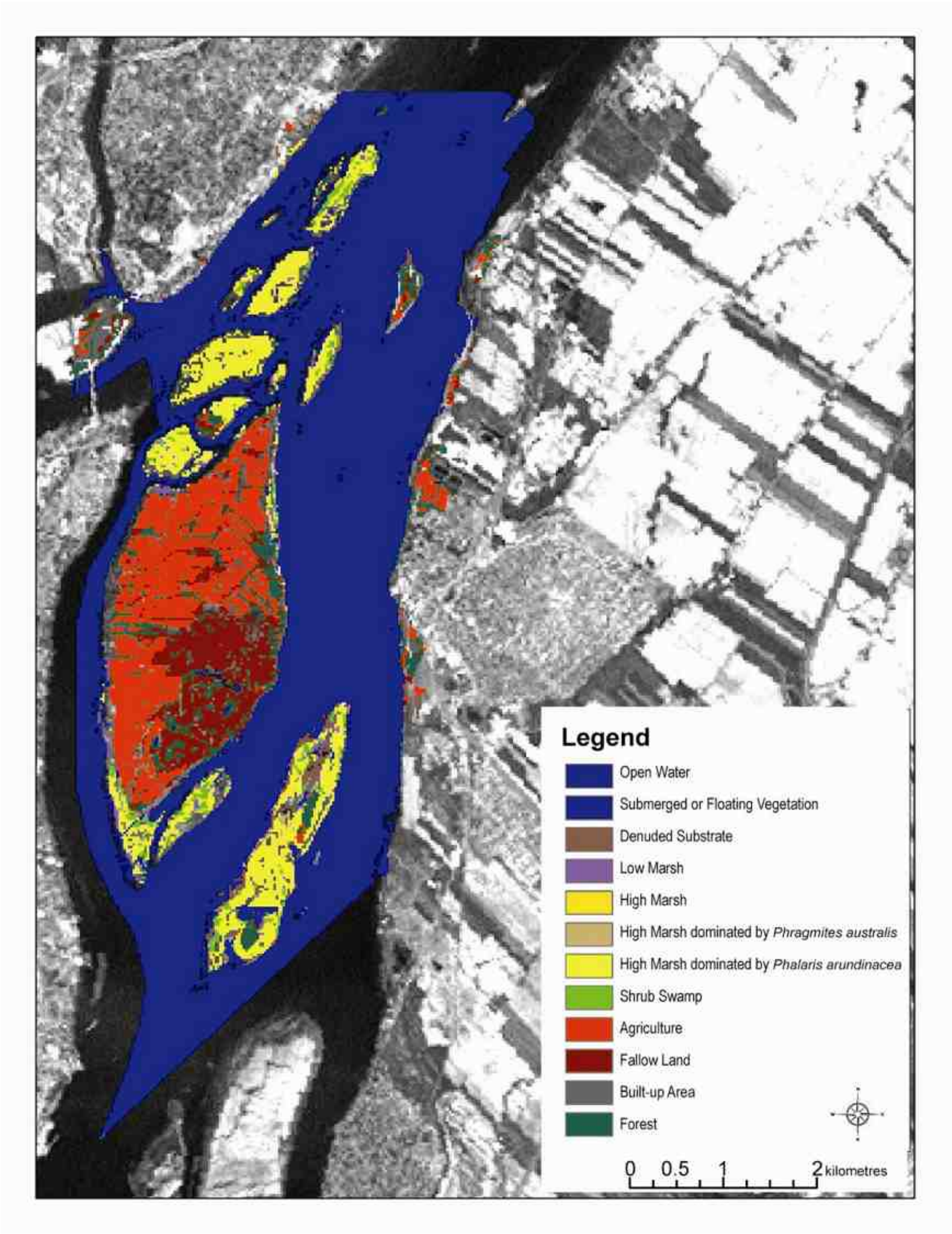
34 Wetlands in the Sainte-Thérèse Island and Varennes Islands subsector analyzed in 1970–1978



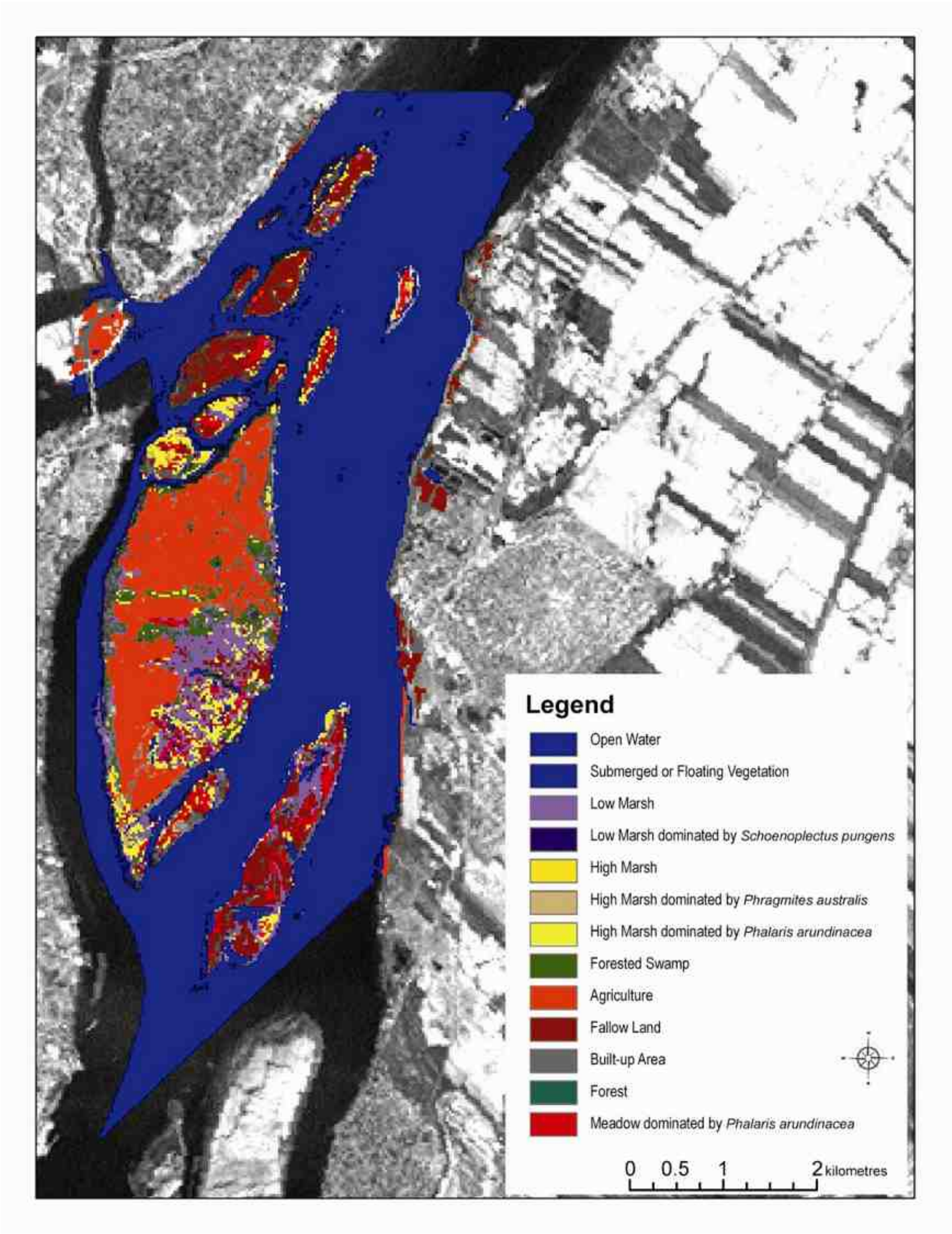
35 Wetlands in the Sainte-Thérèse Island and Varennes Islands subsector analyzed in 1990–1991



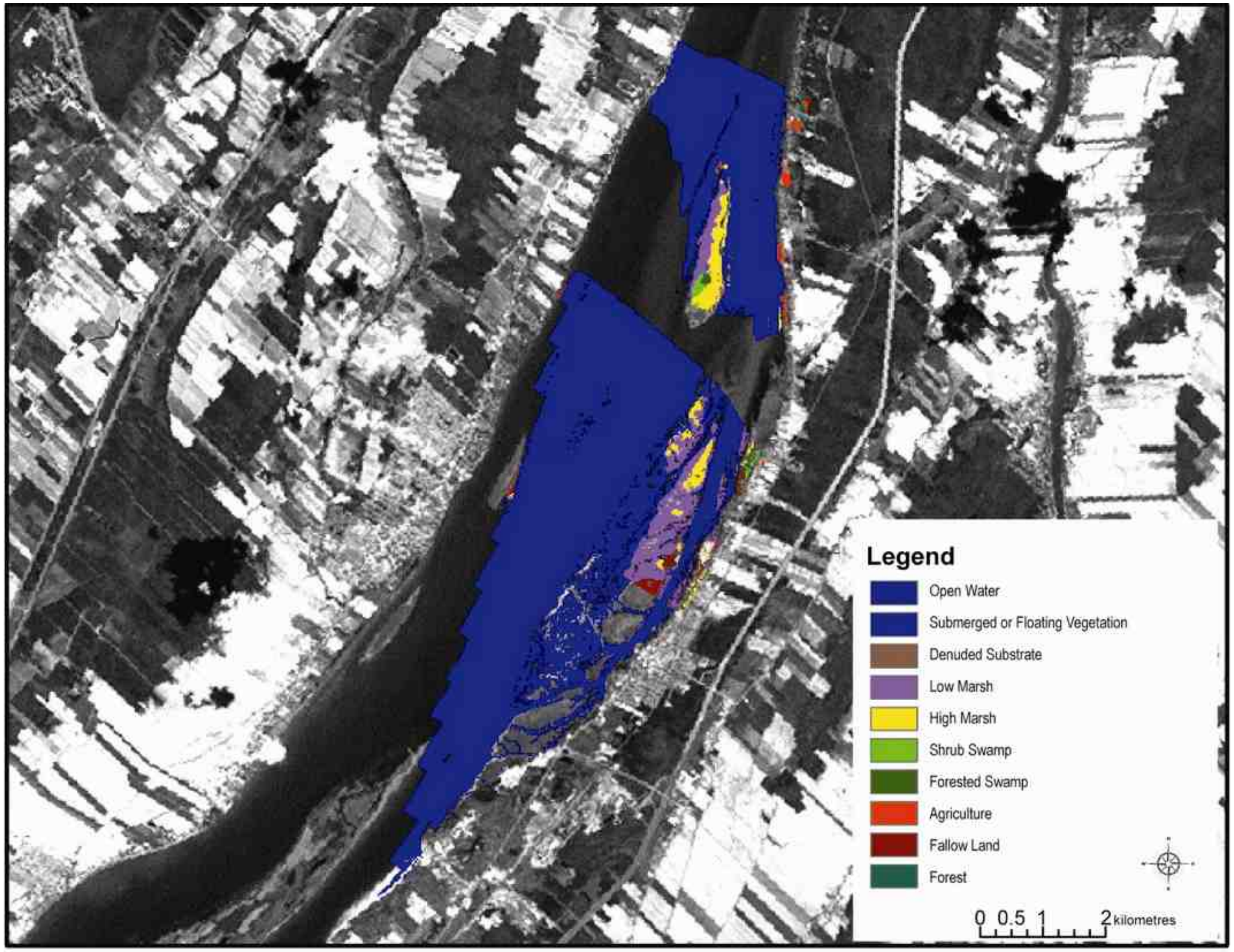
36 Wetlands in the Sainte-Thérèse Island and Varennes Islands subsector analyzed in 1996–1997



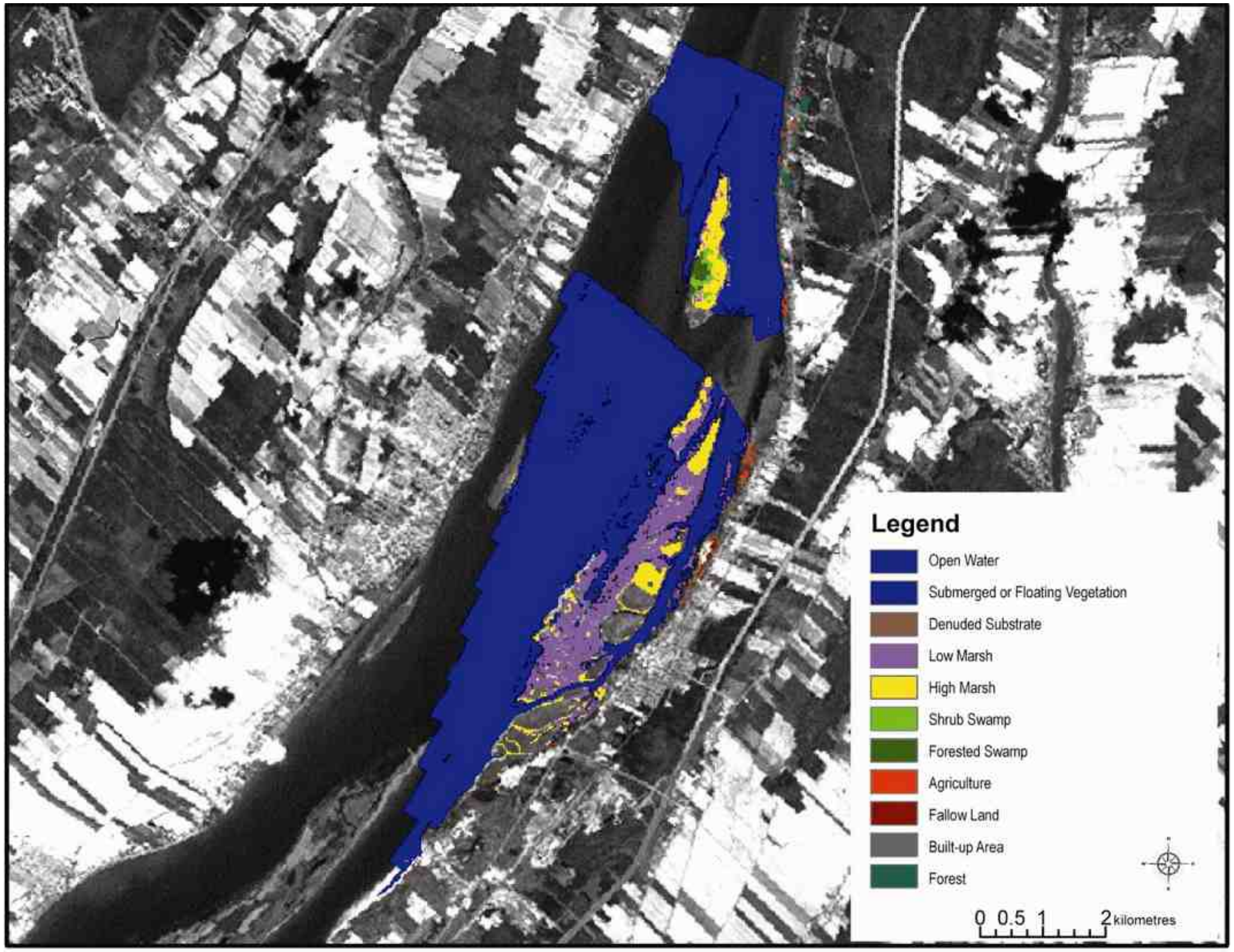
37 Wetlands in the Sainte-Thérèse Island and Varennes Islands subsector analyzed in 2000–2002



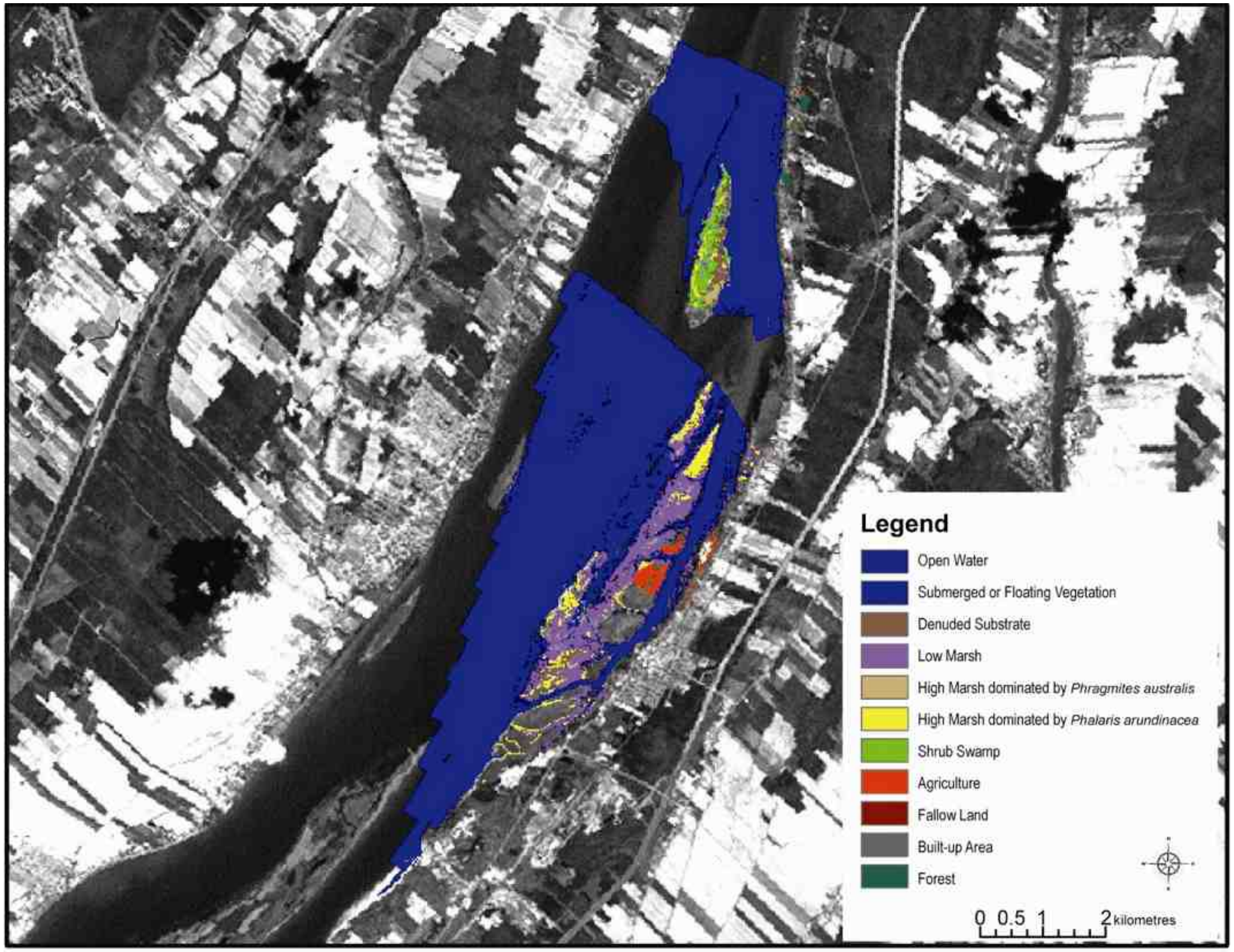
38 Wetlands in the Contrecœur Islands subsector analyzed in 1970–1978



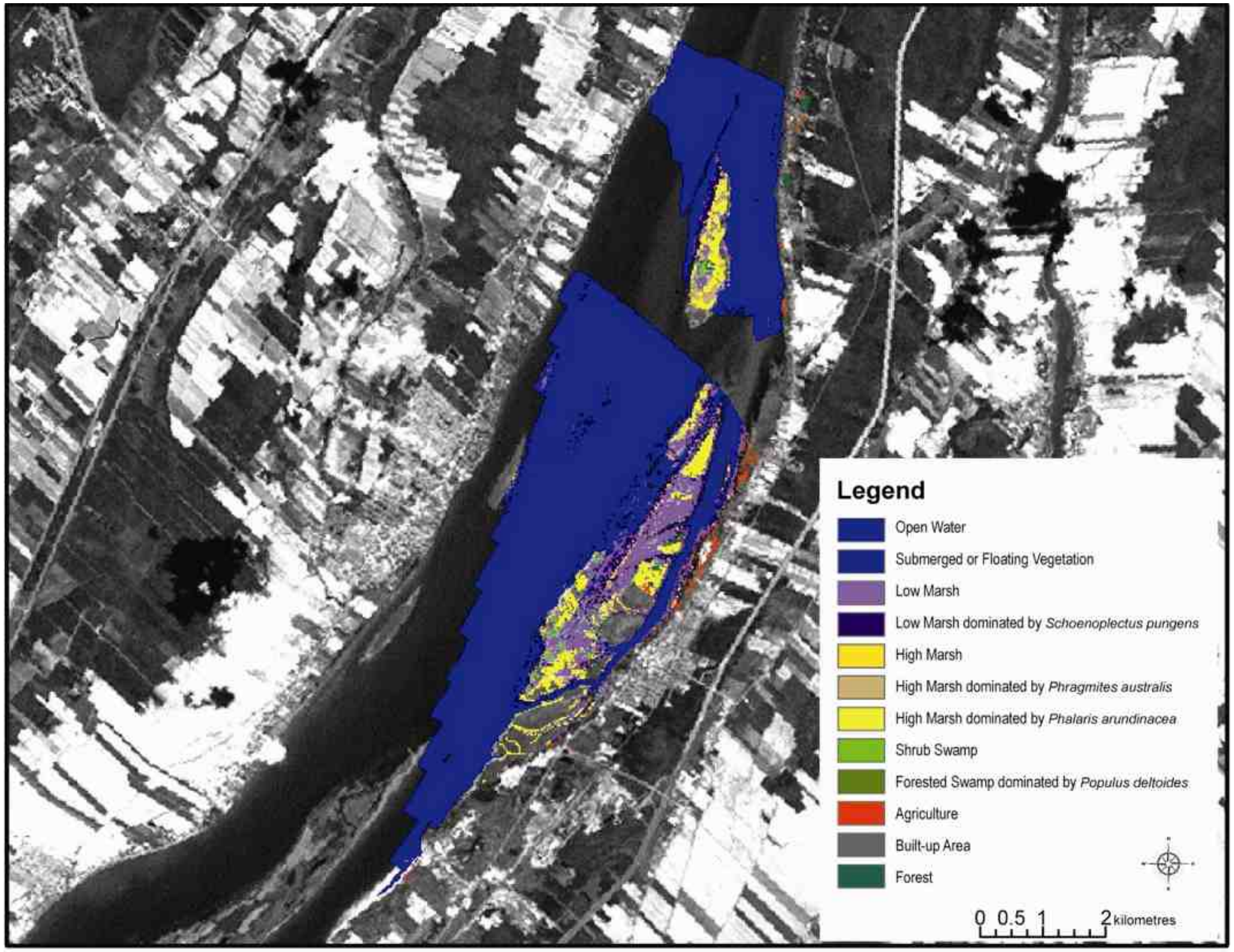
39 Wetlands in the Contrecœur Islands subsector analyzed in 1990–1991



40 Wetlands in the Contrecœur Islands subsector analyzed in 1996–1997



41 Wetlands in the Contrecœur Islands subsector analyzed in 2000–2002



42 Gains and losses in the Varennes–Contrecœur sector not retained in the analysis

Between 1990–1991 and 2000–2002 (complete coverage)

A total of 69 ha identified as wetlands (mainly high marshes) in 1990–1991 were classified as farmland in 2000–2002. The changes, observed primarily in the Contrecœur region, are attributable to differences in identifying the boundaries of upland areas, as well as to overestimations of wetlands in 1990–1991. Also, 62 ha identified as wetlands (mostly high marshes) in 1990–1991 were classified as fallow land in 2000–2002. These changes are concentrated on Grande Île, southeast of Île Sainte-Thérèse and in the Repentigny–Varennes islands. It is difficult to determine whether they represent actual wetland losses, because the sectors involved are very heterogeneous and it is difficult to distinguish between wetlands and upland areas.

Similarly, 25 ha identified as high marshes in 1990–1991 were subsequently classified as meadows dominated by *Phalaris arundinacea*. Although this species may be present in wetlands, field surveys indicate that the meadows in which it grows should be considered upland areas. The areas concerned are concentrated in the Repentigny–Varennes islands, as well as on Grande Île and Sainte-Thérèse Island.

In addition, 12 ha of wetlands, mostly forested swamps, were classified as upland forests in 2000–2002. The difference can be explained by an overestimation of swamps in 1990–1991 in some cases, and by the masks used for upland areas in other cases.

Lastly, 9 ha of wetlands were lost to built-up areas, which are scattered throughout the sector. We were unable to confirm the changes from an examination of the raw images.

The gains not retained for this period include 157 ha identified as farmland in 1990–1991 that were classified as wetlands in 2000–2002. Most of the areas concerned are located on Sainte-Thérèse Island and at the southern point of Île Beauregard. It appears that this can be explained by an underestimation of wetlands in 1990–1991, particularly habitats developed for wildlife.

In addition, 30 ha of built-up areas were converted into wetlands. This is the case on Sainte-Thérèse Island and on the north shore upstream of Contrecœur. Geometry problems and confusion between denuded substrate and built-up areas are probably the reason for the differences. Lastly, 15 ha classified as fallow land in 1990 became wetlands in 2000–2002, mainly in well-defined areas on the Verchères Islands, although the same phenomenon is observed on Sainte-Thérèse Island. We do not have accurate data enabling us to ascertain the veracity of these changes and so we prefer not to take them into account.

Between 1970–1978 and 1990–1991 (Sainte-Thérèse Island and Varennes Islands)

The largest losses not retained relate to 52 ha of wetlands that were converted to cropland and pastureland on several islands. Differences in wetland classification between the two mapping periods are probably to blame.

A further 44 ha of wetlands were lost to open water in many locations scattered around the islands. Owing to the lack of data there is no way to ascertain whether water level variations could be responsible for the difference.

None of the gains in wetlands observed during this period were retained. The main gains (71 ha) occurred at the expense of fallow land; they were observed on a few islands close to Repentigny. Variations in upland masks are probably the reason for this discrepancy.

In addition, 22 ha of open water were transformed into wetlands. Since it was not possible to verify water levels on the Groupe Dryade maps, we cannot draw any conclusions about the veracity of this change and we decided to err on the side of caution and reject it.

Between 1990–1991 and 1996–1997 (Sainte-Thérèse Island and Varennes Islands)

The only losses exceeding 10 ha that were not retained relate to the expansion of forests, primarily on the Varennes Islands.

Only one type of gain was not retained during this period; this gain consisted of 101 ha and occurred at the expense of farmland. An overestimation of wetlands in 1996–1997, particularly on the islands downstream of Sainte-Thérèse Island, is probably responsible for this difference.

Between 1996–1997 and 2000–2002 (Sainte-Thérèse Island and Varennes Islands)

The largest losses not retained concern the conversion of 118 ha of wetlands into fallow land, scattered on the Varennes Islands and on the islands downstream of Sainte-Thérèse Island. An overestimation of wetlands in 1996–1997 explains this difference. A further 36 ha identified as wetlands in 1996–1997 were classified as dry meadows dominated by *Phalaris arundinacea* in 2000–2002. Difficulty in differentiating between dry meadows and high marshes, especially when they are dominated by the same species, is the reason for this confusion.

A number of the gains observed were not retained owing to the overestimation of wetlands in 2000–2002. First, 90 ha of fallow land on Sainte-Thérèse Island appear to have been incorrectly identified as wetlands. On the same island, 29 ha of upland forests were incorrectly identified as wetlands in 2000–2002. Lastly, 19 ha of farmland were classified as wetlands in 2000–2002. This difference is also observed on Sainte-Thérèse Island.

Between 1990–1991 and 1996–1997 (Contrecoeur Islands)

The only wetland losses not retained during this period (18 ha) consist of agricultural areas. They are on Grande Île and Île Ronde. Confusion between the two classes is the reason for this difference.

Between 1996–1997 and 2000–2002 (Contrecoeur Islands)

Only one gain was not retained during the period. It concerns the conversion of 17 ha of agricultural land on Grande Île and Île Ronde, which appeared to have become wetlands. The same confusion as that identified between 1990–1991 and 1996–1997 seems to explain this difference.

43 Results of Kappa agreement analyses for the Varennes–Contrecœur sector

Between 1990–1991 and 2000–2002 (complete coverage)

Index	Value
Kappa	0.59
KHisto	0.72
KLoc	0.82
Fraction correct	0.88
Fuzzy Kappa	0.47
Fuzzy fraction correct	0.88

Between 1970–1978 and 1990–1991 (Sainte-Thérèse Island and Varennes Islands)

Index	Value
Kappa	0.89
KHisto	0.97
KLoc	0.92
Fraction correct	0.87
Fuzzy Kappa	0.77
Fuzzy fraction correct	0.94

Between 1990–1991 and 1996–1997 (Sainte-Thérèse Island and Varennes Islands)

Index	Value
Kappa	0.87
KHisto	0.91
KLoc	0.96
Fraction correct	0.91
Fuzzy Kappa	0.72
Fuzzy fraction correct	0.92

Between 1996–1997 and 2000–2002 (Sainte-Thérèse Island and Varennes Islands)

Index	Value
Kappa	0.84
KHisto	0.93
KLoc	0.90
Fraction correct	0.90
Fuzzy Kappa	0.66
Fuzzy fraction correct	0.90

Between 1970–1978 and 1990–1991 (Contrecoeur Islands)

Index	Value
Kappa	0.45
KHisto	0.72
KLoc	0.63
Fraction correct	0.87
Fuzzy Kappa	0.17
Fuzzy fraction correct	0.88

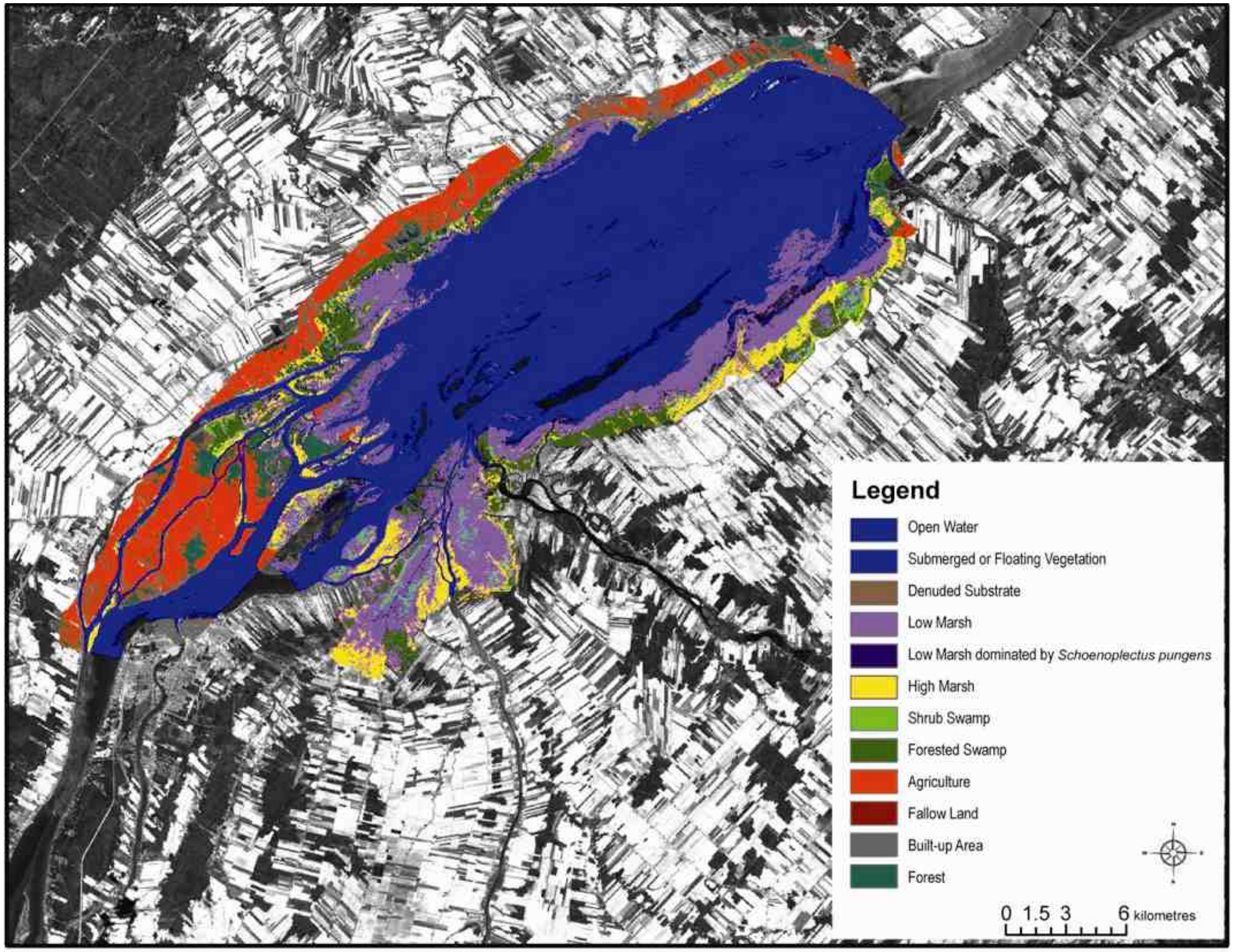
Between 1990–1991 and 1996–1997 (Contrecoeur Islands)

Index	Value
Kappa	0.64
KHisto	0.74
KLoc	0.86
Fraction correct	0.90
Fuzzy Kappa	0.53
Fuzzy fraction correct	0.91

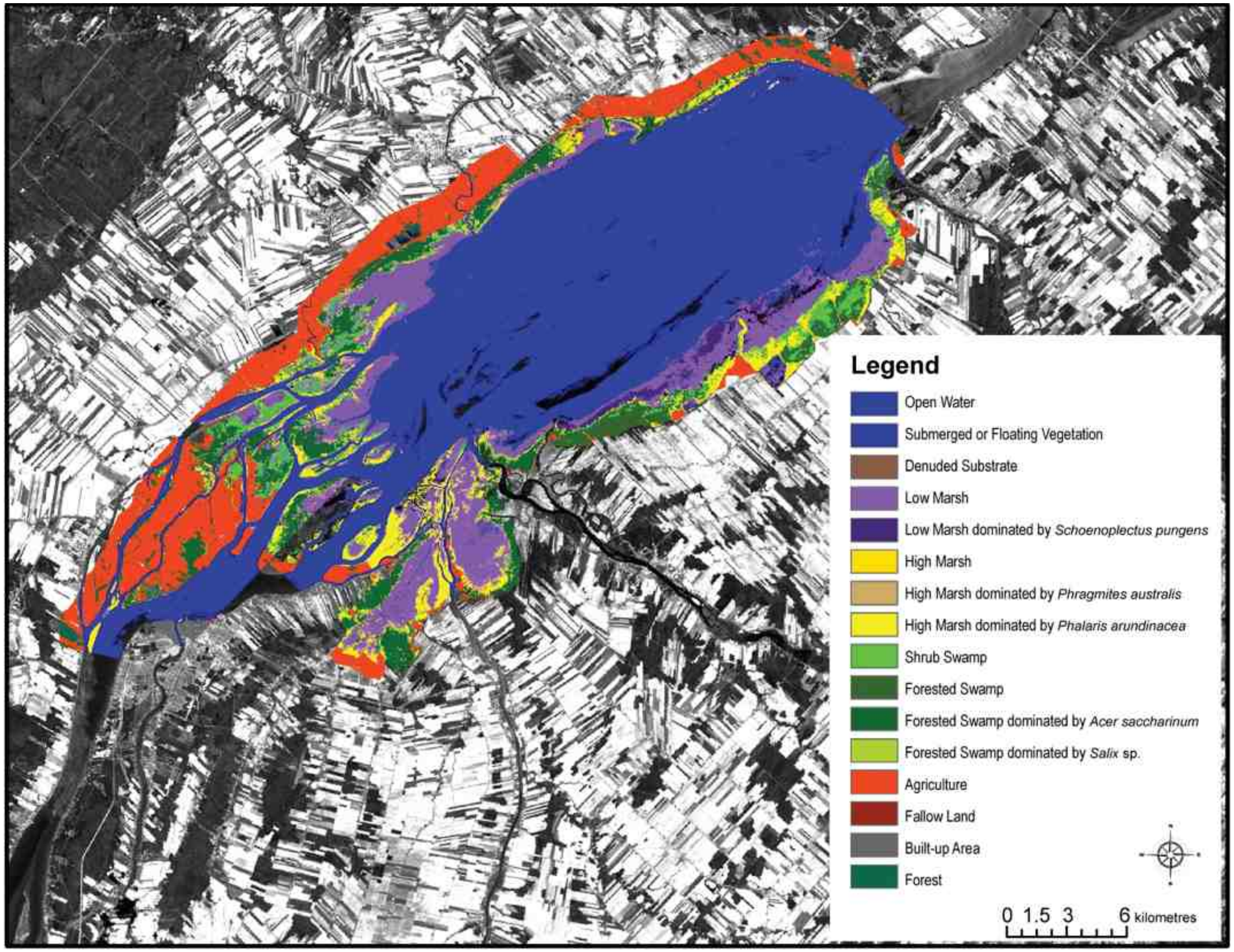
Between 1996–1997 and 2000–2002 (Contrecoeur Islands)

Index	Value
Kappa	0.63
KHisto	0.80
KLoc	0.79
Fraction correct	0.89
Fuzzy Kappa	0.51
Fuzzy fraction correct	0.91

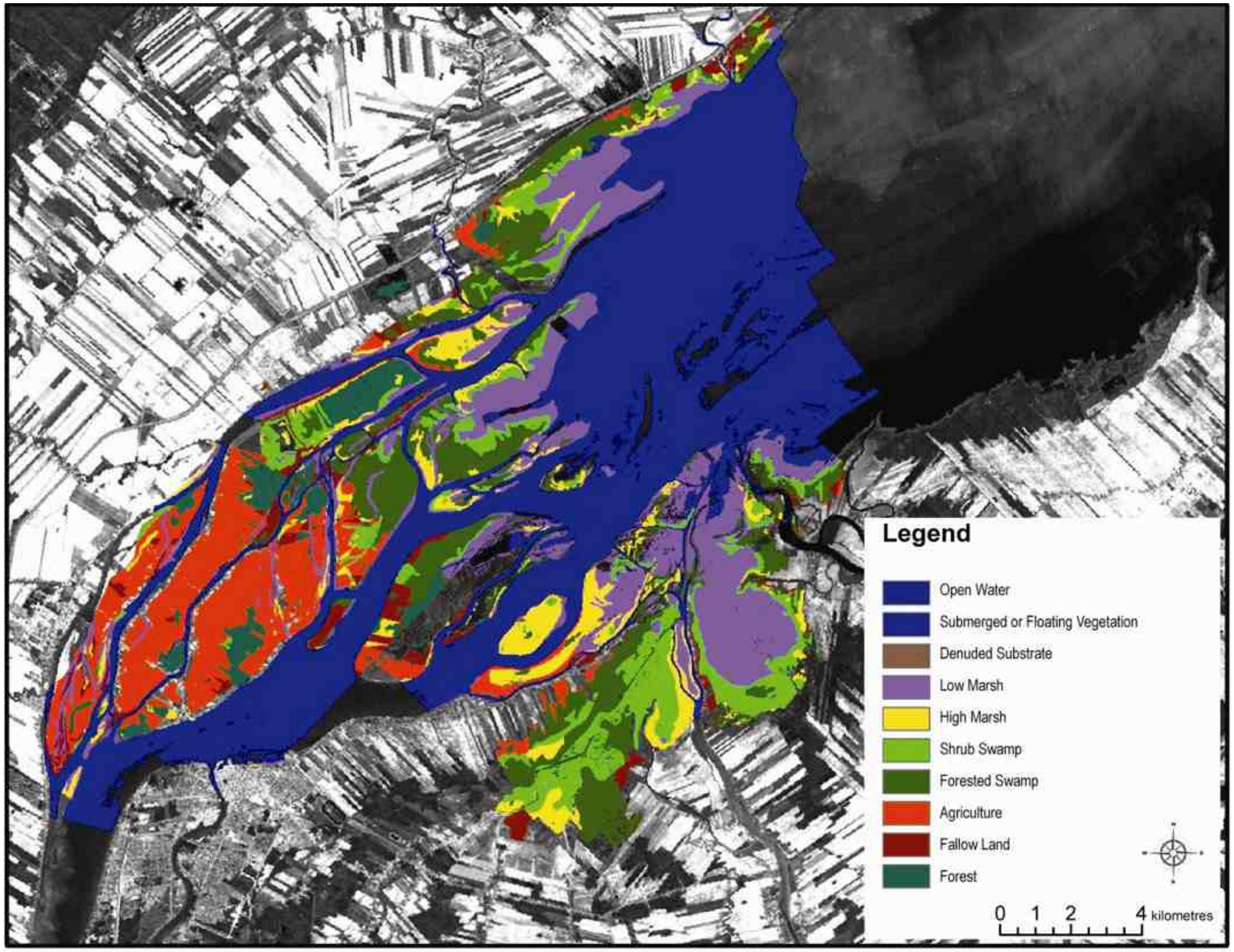
44 Wetlands in the Lake Saint-Pierre sector in 1990–1991



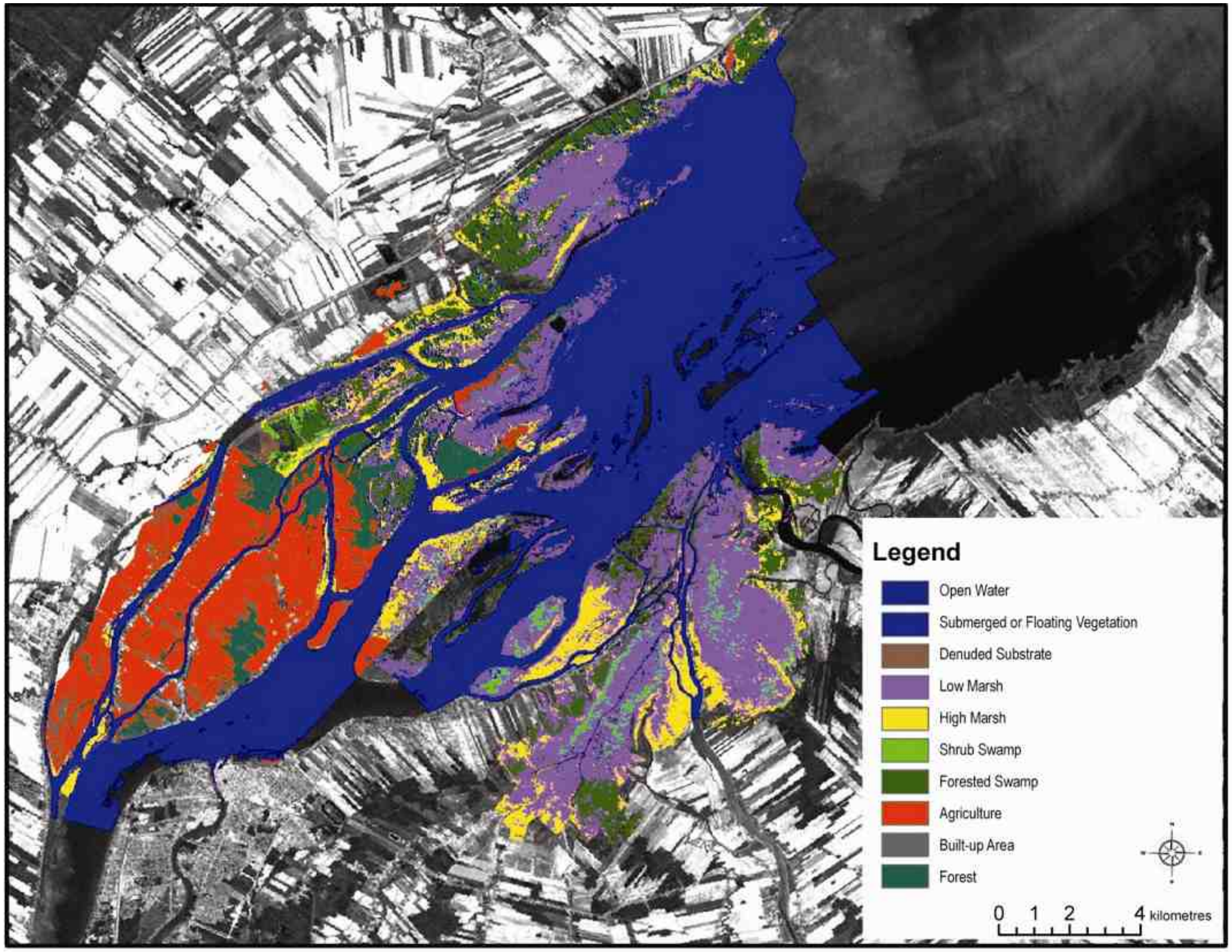
45 Wetlands in the Lake Saint-Pierre sector in 2000–2002



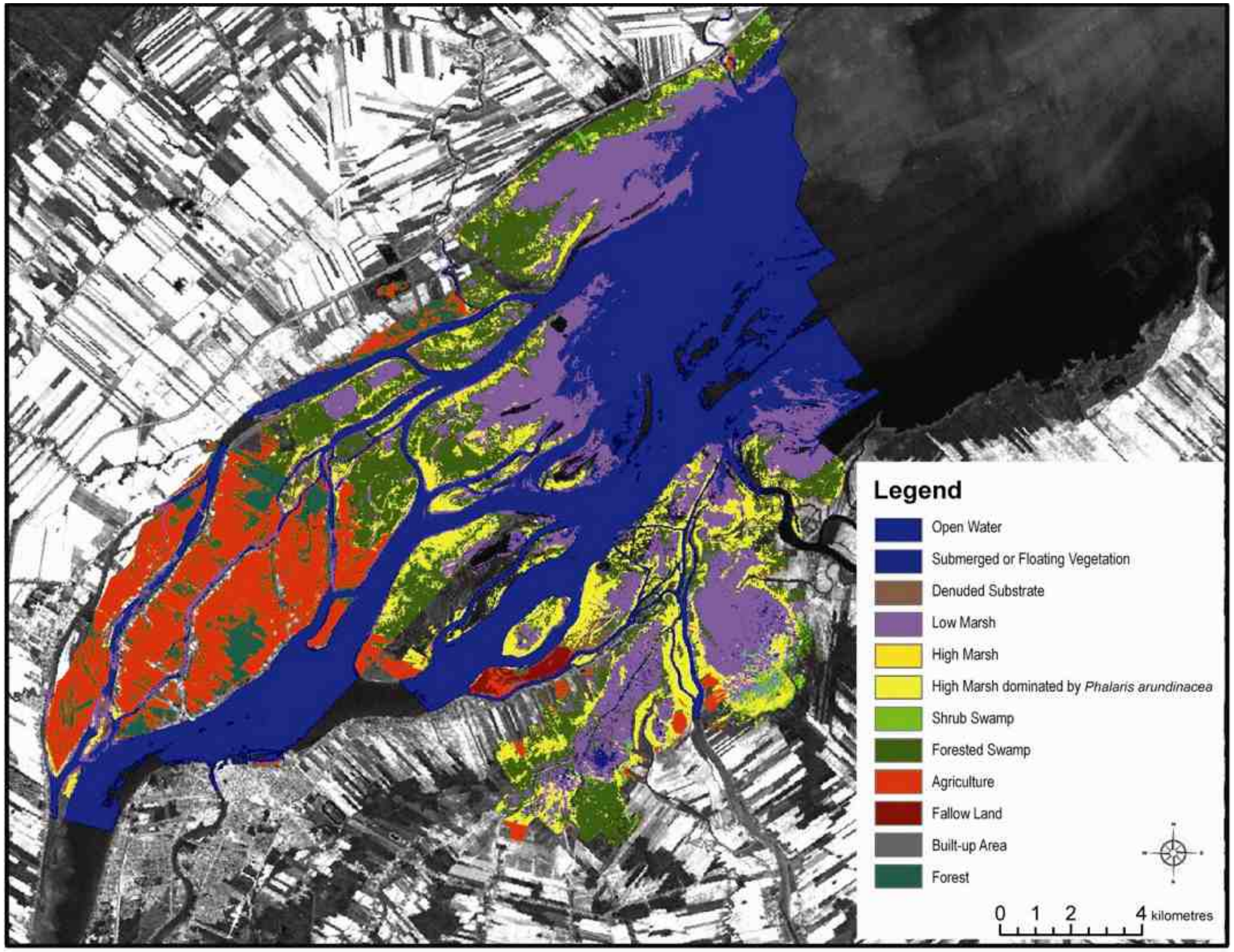
46 Wetlands in the portion of Lake Saint-Pierre analyzed in 1970–1978



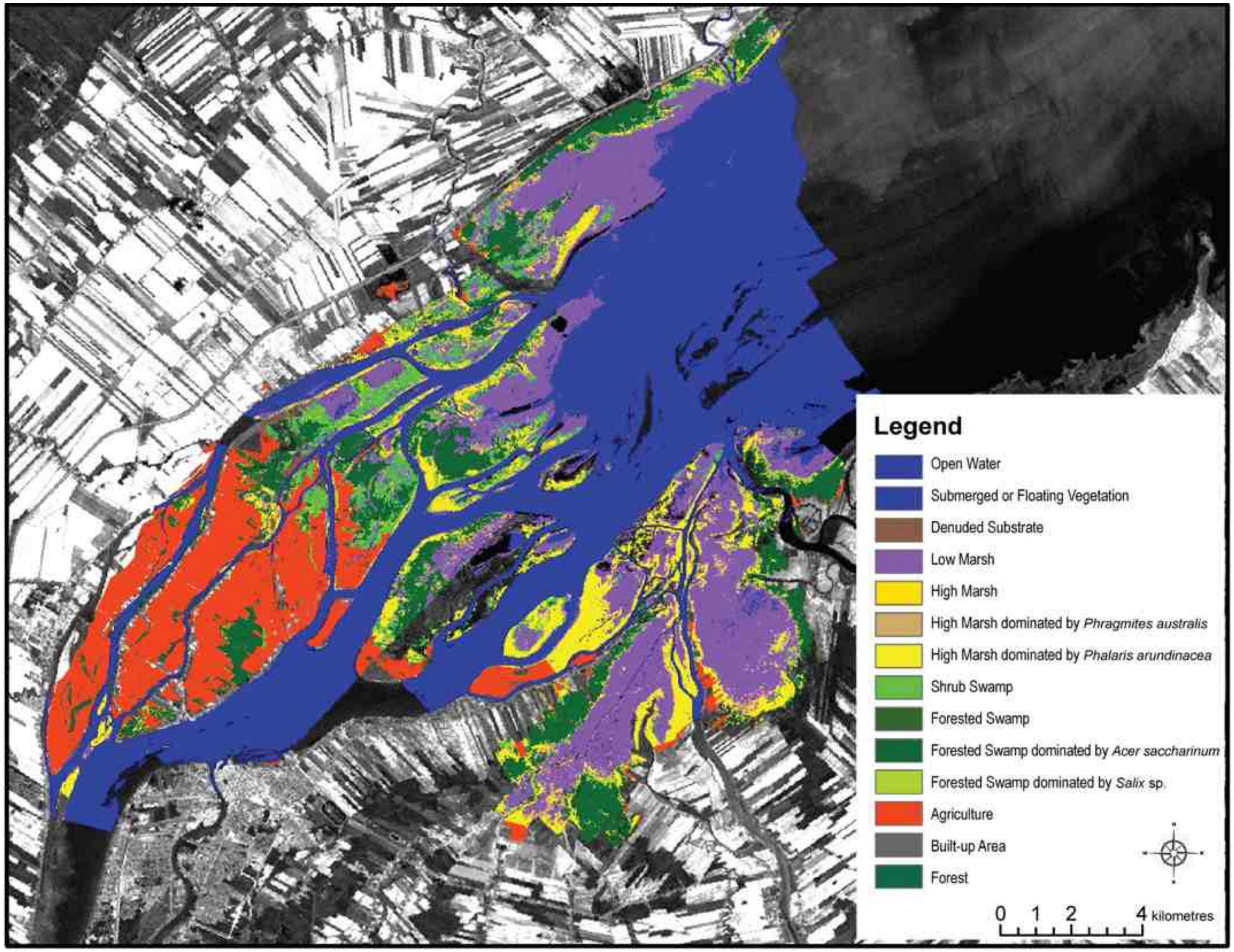
47 Wetlands in the portion of Lake Saint-Pierre analyzed in 1990–1991



48 Wetlands in the portion of Lake Saint-Pierre analyzed in 1996–1997



49 Wetlands in the portion of Lake Saint-Pierre analyzed in 2000–2002



50 Gains and losses in the Lake Saint-Pierre sector not retained in the analysis

Between 1990–1991 and 2000–2002

The only losses not retained during the period consist of 34 ha classified as wetlands (forested swamps) in 1990–1991 but identified as upland forests in 2000–2002. The cause appears to be confusion between the two classes. In addition, 10 ha of wetlands were classified as built-up areas in 2000–2002; they are located along highway 40 and a few places on the south shore. The cause appears to be a geometry problem affecting two images or confusion between the two classes.

The gains that were rejected include a classification error in 1990–1991 whereby 773 ha were classified as forests; the same areas were identified as wetlands in 2000–2002. They are located in the Lake Saint-Pierre islands and in the Nicolet area. In addition, 296 ha described as denuded substrate in 1990–1991 were classified as wetlands in 2000–2002. The areas are located in the islands, along highway 40 and near Longue Pointe and Nicolet. These changes are probably due to geometry problems and confusion between classes. Farmland covering an area of 292 ha appears to have been transformed into wetlands, primarily around the Lake Saint-Pierre islands; however, confusion related to the definition of agricultural areas in 1990–1991 is probably the reason. Lastly, 130 ha of built-up areas in 1990–1991 were classified as wetlands in 2000–2002. These changes can be explained by an overestimation of urban areas in 1990–1991.

Between 1970–1978 and 1990–1991

Wetland losses to denuded substrate (40 ha) on Île de Grâce actually represent an artefact caused by the presence of clouds.

Also, 353 ha of wetlands were classified as upland forests; these areas are on La Grande Île, Île aux Ours, Île Noyer and Île Lamarche. Because it is difficult to differentiate between these two classes, these were not considered to be real changes.

Lastly, 87 ha of wetlands were converted into built-up areas. Their scattered distribution suggests that there is an underlying classification problem (overestimation of built-up areas in 1990–1991).

Two types of gains were not retained. The most significant gain is 294 ha of farmland identified as wetlands in 1990–1991. The areas are located in Maskinongé Bay, in the western part of Le Nid d'Aigle Island, in the southern part of Île de Grâce, in the western section of Île du Moine and along the western shore of Baie de Lavallière. An overestimation of wetlands in 1990–1991 is likely to blame for this difference.

In addition, 168 ha of the 337 ha of upland forests transformed into wetlands in 1990–1991 were not retained. The areas concerned are in the southern part of Île de Grâce and around the managed habitats on Dupas Island. This is probably a case of incorrectly assigned classes.

Between 1990–1991 and 1996–1997

The largest loss not retained, 295 ha, involves the conversion of wetlands to farmland. This change is observed primarily at Langue-de-Terre (north of Le Nid d'Aigle Island), at the southern tip of Île de Grâce, on Île du Moine and around Lavallière and Saint-François bays. An overestimation of wetlands in 1990–1991 appears to be the cause.

In addition, 109 ha of wetlands were converted to upland forests near Langue-de-Terre (north of Le Nid d'Aigle Island). This is likely attributable to the overestimation of forests in 1996–1997. Lastly, 12 ha of wetlands were incorrectly classified as built-up areas in 1996–1997.

Three types of gains were rejected during the period. First, 366 ha of upland forests were classified as wetlands. It appears that these two classes were confused on the 1990–1991 map. Also, 195 ha of cropland and pastureland were classified as wetlands owing to confusion between high marsh and farmland. Lastly, 42 ha of built-up areas were classified as wetlands in 1996–1997, but the built-up areas were likely overestimated in 1990–1991.

Between 1996–1997 and 2000–2002

The only sizeable losses that were not retained involve 31 ha of wetlands that were incorrectly identified as upland forests. These are mainly woodlands that were incorrectly identified as upland areas in spite of the field data obtained for validation purposes which show that the areas are actually swamps.

The gains not retained include some of the largest gains of wetlands (462 ha); these occurred at the expense of upland forests. This phenomenon is observed primarily in the western part of the archipelago. Differences in the ability to distinguish between upland and wetland areas between the two dates are likely the reason.

In addition, 243 ha of agricultural areas were transformed into wetlands. This difference appears to stem from an overestimation of wetlands in 2000–2002. Lastly, a little over 30 ha of fallow land on Île du Moine reverted to wetlands. This is attributable to differences in the way upland areas and wetlands are differentiated.

51 Results of Kappa agreement analyses for Lake Saint-Pierre

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.54
KHisto	0.74
KLoc	0.73
Fraction correct	0.66
Fuzzy Kappa	0.33
Fuzzy fraction correct	0.68

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.59
KHisto	0.85
KLoc	0.69
Fraction correct	0.70
Fuzzy Kappa	0.18
Fuzzy fraction correct	0.72

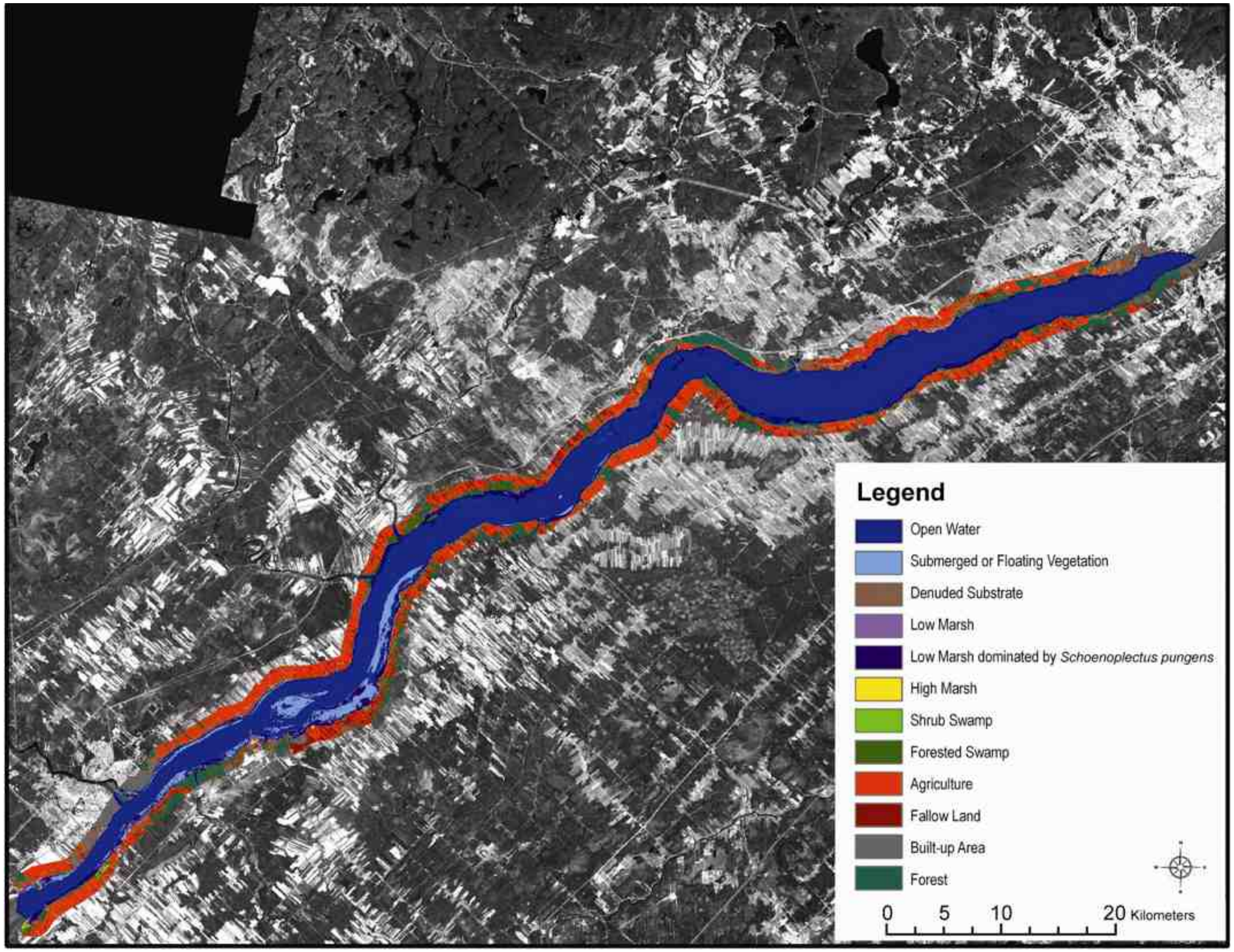
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.56
KHisto	0.77
KLoc	0.73
Fraction correct	0.68
Fuzzy Kappa	0.27
Fuzzy fraction correct	0.70

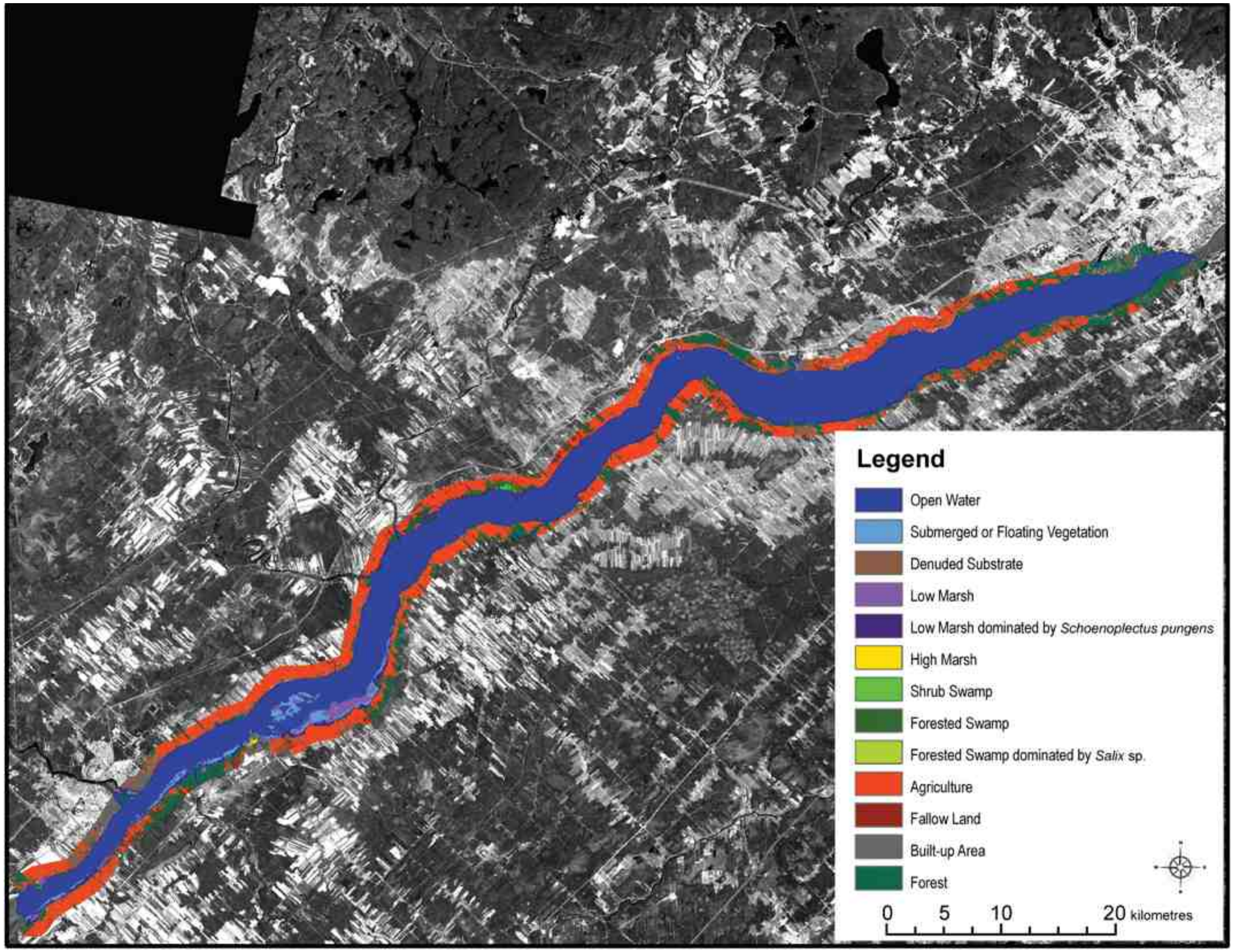
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.58
KHisto	0.74
KLoc	0.78
Fraction correct	0.68
Fuzzy Kappa	0.37
Fuzzy fraction correct	0.70

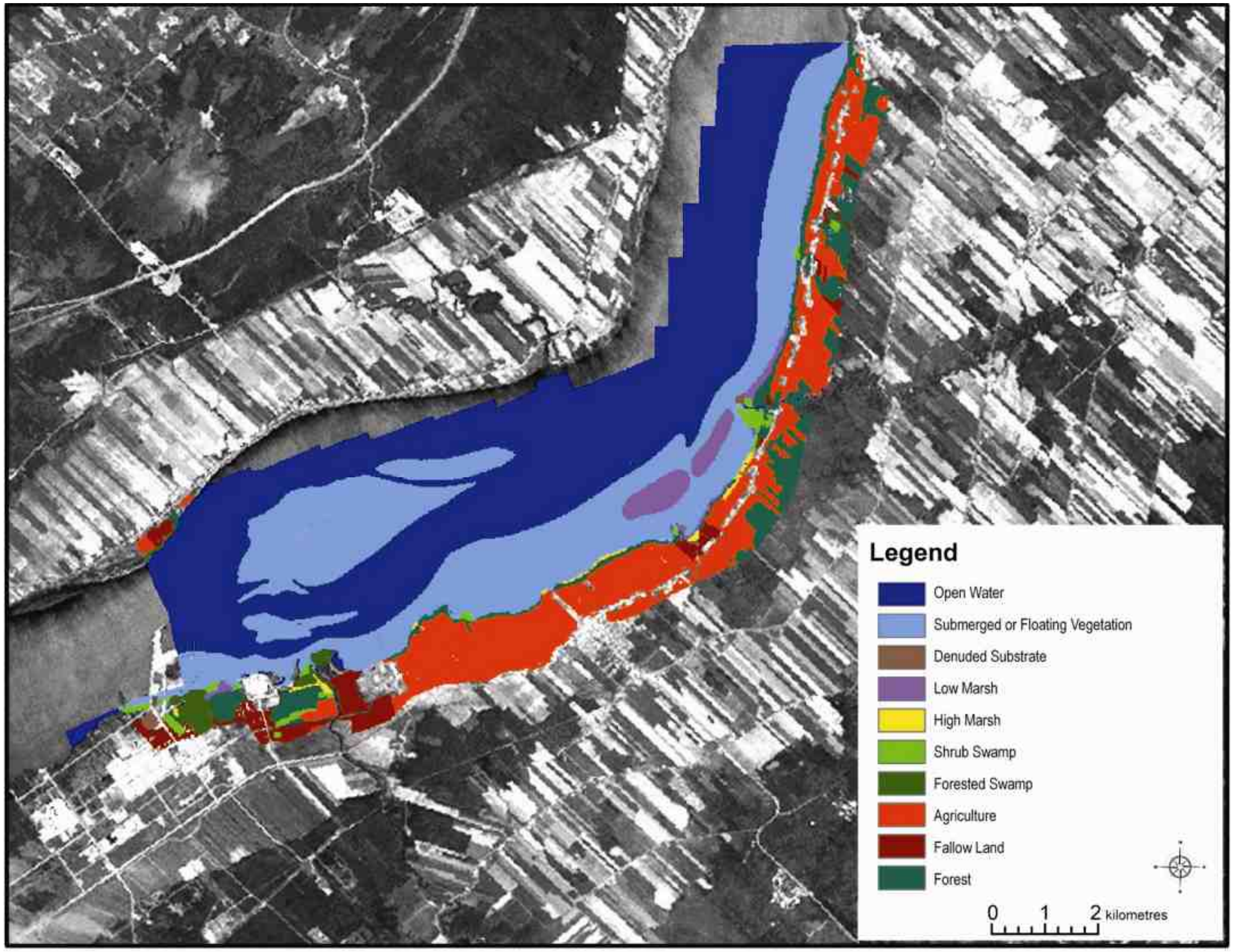
52 Wetlands of the fluvial estuary in 1990–1991



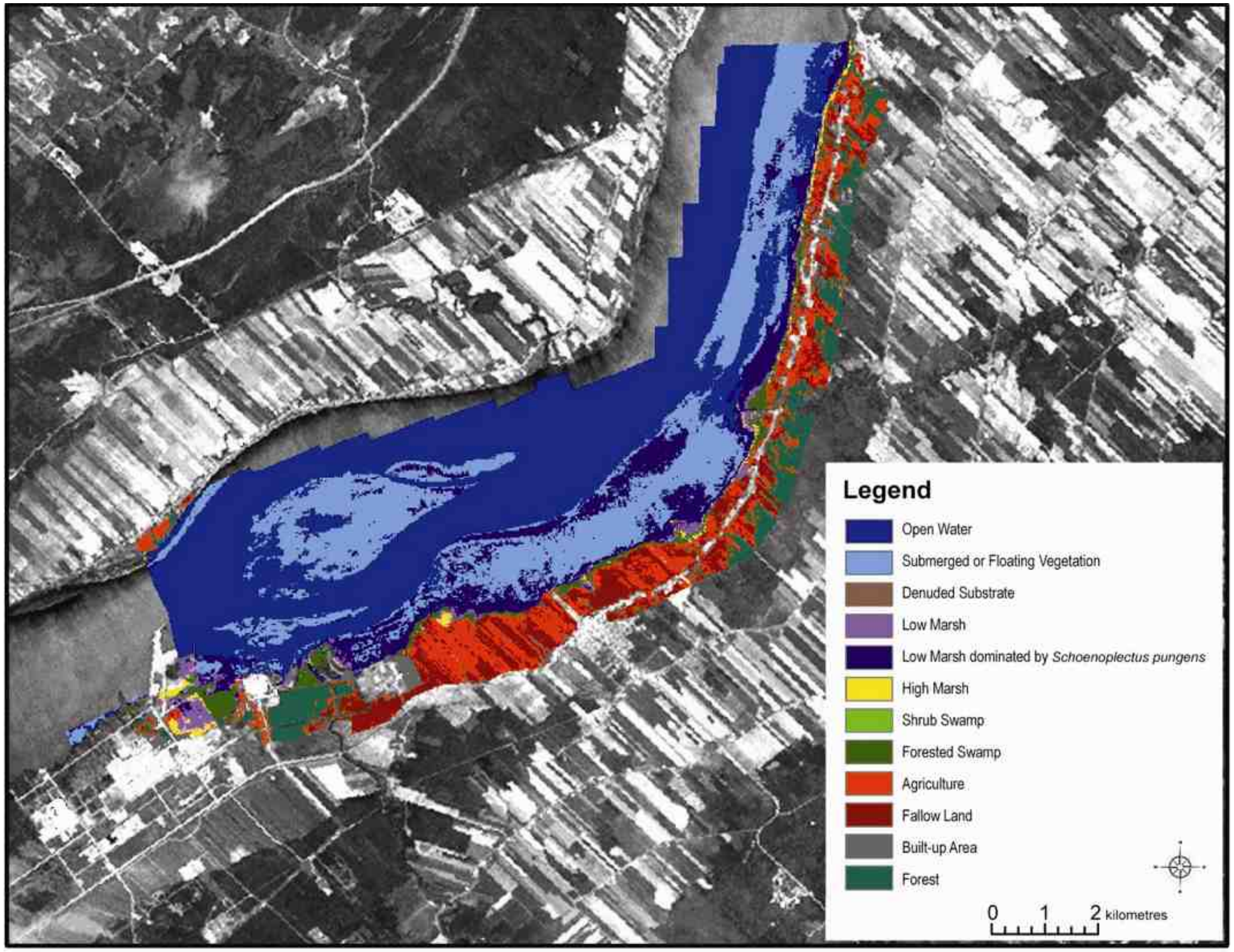
53 Wetlands of the fluvial estuary in 2000–2002



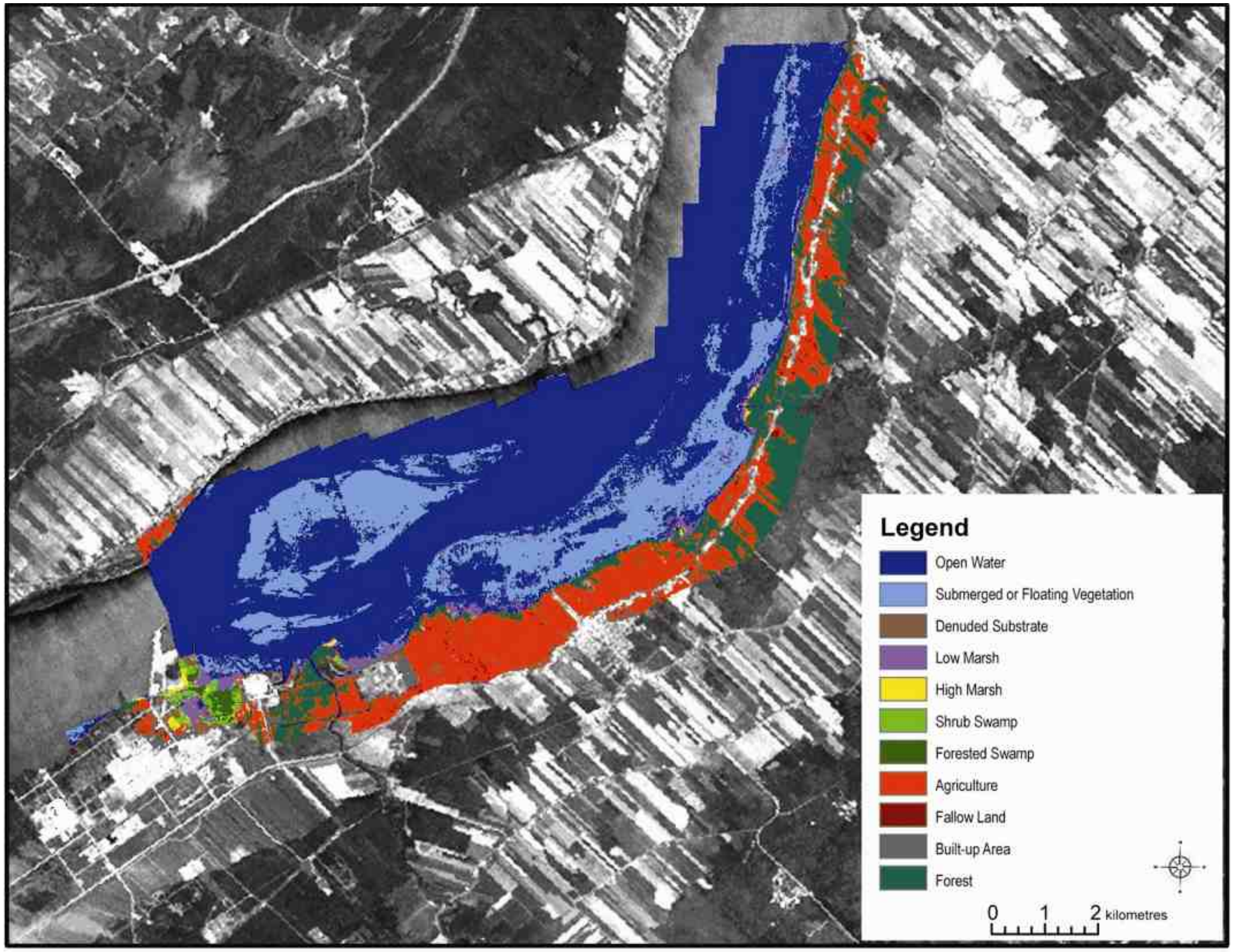
54 Wetlands in the portion of the fluvial estuary analyzed in 1970–1978



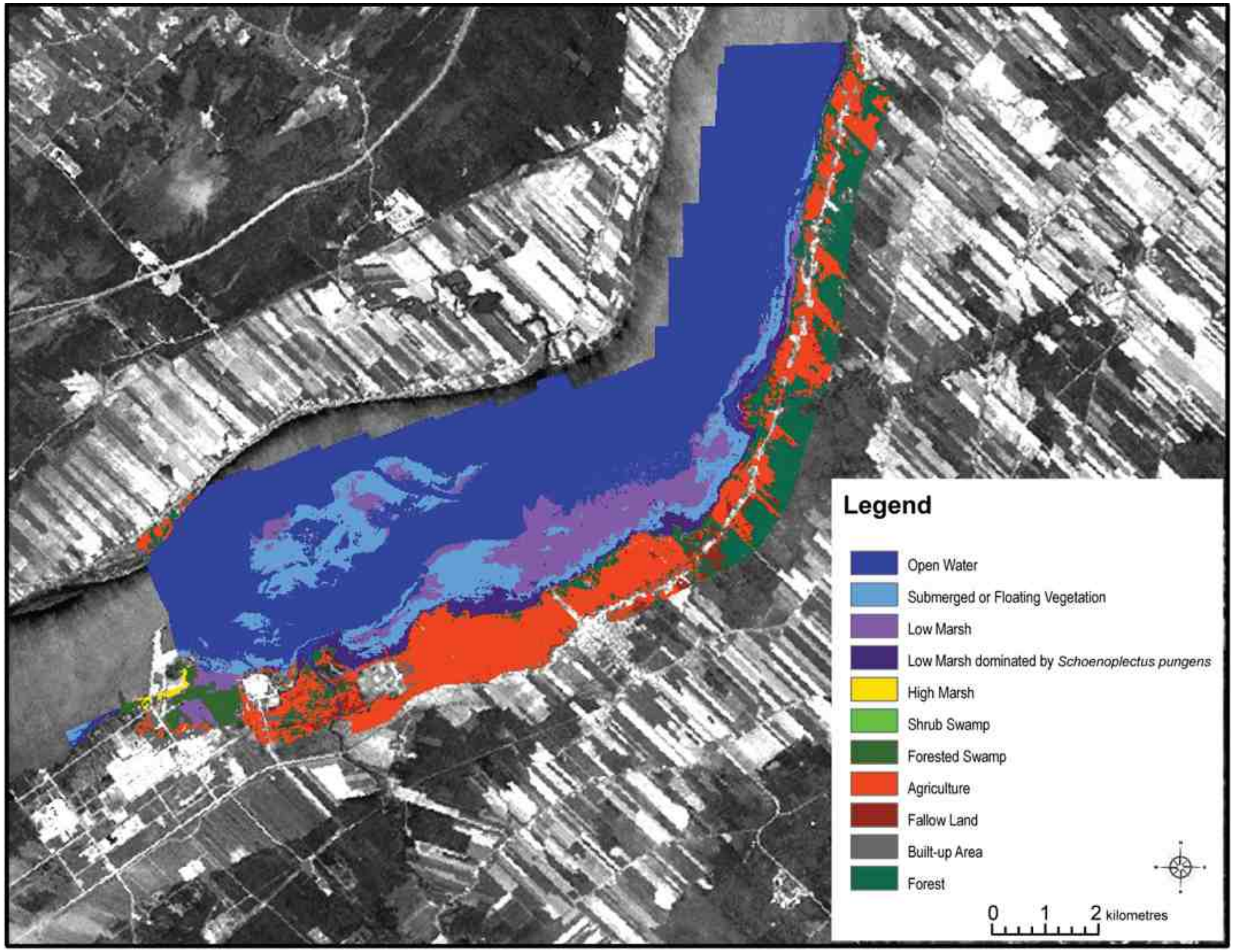
55 Wetlands in the portion of the fluvial estuary analyzed in 1990–1991



56 Wetlands in the portion of the fluvial estuary analyzed in 1996–1997



57 Wetlands in the portion of the fluvial estuary analyzed in 2000–2002



58 Gains and losses in the fluvial estuary not retained in the analysis

Between 1990–1991 and 2000–2002

The bulk of the wetland losses that were not retained involve conversions to open water (3037 ha). This situation is observed along the entire length of the fluvial estuary, with a certain concentration in the Gentilly area, and it appears to stem from differences in the tides (Champlain hydrometric station, between 0.579 m and 0.691 m in 1991, between 0.720 m and 1.278 m in 2000 and 0.787 m in 2002).

An additional 489 ha of wetlands were classified as forests in 2000–2002. This change is observed mainly in the Sainte-Anne-de-la-Pérade area, although it is visible in other areas of the sector as well. It appears that this discrepancy between the two maps can be attributed to uncertainty over the identification of forest areas (swamps or upland forests).

A total of 322 ha of wetlands were converted to farmland, but 287 ha of this change were not retained. The areas concerned are concentrated around Sainte-Anne-de-la-Pérade, Gentilly and Bécancour (near Laviolette Bridge). An overestimation of farmland in 2000–2002, particularly on the south shore of the St. Lawrence River, appears to be the cause. Conversely, it appears that the area of swamps was underestimated in 2000–2002 in the Gentilly area. It is clear from an examination of the raw images that the narrow forest zone concerned did not actually change.

In addition, 75 ha of fallow land appeared in 2000–2002 replacing wetlands (mostly marsh). These changes are concentrated in three sectors: Bécancour, Gentilly and Sainte-Anne-de-la-Pérade. In the first case, it appears that the area of wetlands was overestimated in 1990–1991. With respect to Gentilly, confusion between forest classes (forests or swamps) and fallow land is clearly responsible for the difference. Lastly, at Sainte-Anne-de-la-Pérade, forested areas (forests or swamps) were overestimated in 1990–1991.

Also, 58 ha classified as wetlands in 1990–1991 were replaced by built-up areas in 2000–2002. These changes involve small areas scattered throughout the region, with concentrations near the Gentilly nuclear power station. This difference likely stems from a geometry problem or the definition of built-up areas used for the two maps.

Lastly, 46 ha identified as wetlands in 1990–1991 were classified as denuded substrate in 2000. Various areas are involved: near the mouth of the Batiscan River, at Sainte-Anne-de-la-Pérade and near Grondines (probably caused by an overestimation of marshes in 1990–1991), near the town of Lotbinière and near the Deschambault experimental farm (confusion caused by a plume of suspended matter, identified as marshes dominated by *Schoenoplectus pungens* in 1990–1991).

The main gains that were not retained consist of 227 ha classified as forests in 1990–1991 but identified as wetlands (mostly swamps) in 2000–2002. This situation is observed mainly around Grondines and at Île aux Sternes as well as in the area at the mouth of the Batiscan River (caused by confusion between forests and forested swamps). Also, 56 ha of agricultural lands were classified as wetlands in 2000–2002. The Grondines area is where most of these changes were observed; they appear to stem from a major geometry problem, which could be confirmed by changes observed farther inland. The change is also seen at Gentilly, but it appears that confusion between classes is to blame in that case.

In addition, 35 ha identified as built-up areas in 1990–1991 were classified as wetlands in 2000–2002. These are scattered areas, with concentrations around Gentilly and Grondines. Differences between the masks used for upland areas, combined with the above-mentioned geometry problems, appear to be the reason for these changes. Also, 14 ha classified as denuded substrate in 1990–1991 were classified as wetlands in 2000–2002. No major concentration can be seen on the maps.

Lastly, 13 ha of fallow land were identified as wetlands in 2000–2002. This phenomenon is encountered on Île aux Sternes, at Gentilly and at Grondines. Owing to a lack of accurate data, we cannot determine whether these changes are real.

Between 1970–1978 and 1990–1991

The main losses that were not retained involved conversions to open water (436 ha). Two major concentrations are observed to the east of Gentilly (clearly identified on the Groupe Dryade map). It appears that these changes are attributable to tidal effects. The remaining changes (total of 8 ha) appear to be the result of inconsistencies.

Upon examinaton, all the observed gains were rejected in the analysis. The main gains (684 ha) show a transition from open water to wetlands. These changes involve extensive areas along the south shore of this part of the St. Lawrence. The difference is attributable to tidal effects, a factor that explains why Groupe Dryade identified flooded marshes dominated by *Schoenoplectus pungens* as shallow water zones.

In addition, 98 ha of upland forests were classified as wetlands in 1990–1991. This relates to problems in classifying riparian forests, which, on recent maps, have been identified mainly as upland forests. Small parcels of agricultural land (total of 12 ha) were considered to be wetlands in 1990–1991. It appears that this is due partly to an overestimation of riparian forests (incorrectly identified as wetlands in 1990–1991). The remaining gains (total of 12 ha) were not retained.

Between 1990–1991 and 1996–1997

The largest loss not retained (1062 ha) represents a conversion from wetlands to open water. This phenomenon is observed primarily along the south shore and appears to be attributable to tidal effects (Champlain hydrometric station: 0.616 m on September 3, 1991, at 3:53 p.m. EDT; 0.815 m on August 10, 1997, at 10:00 a.m. EDT). In addition, 134 ha of wetlands were incorrectly classified as upland forests (as was the case between 1970–1978 and 1990–1991). Furthermore, 62 ha of wetlands became cropland or pastureland in 1996–1997, with this change being scattered in many locations along the south shore. This is likely attributable to an overestimation of wetlands (swamps) on the 1990–1991 map. Lastly, 18 ha of denuded substrate were incorrectly identified as replacing wetlands, primarily around the Gentilly nuclear power station. An overestimation of substrate in 1996–1997 is probably to blame.

A total of 10 ha of gains occurring at the expense of upland areas were not retained.

Between 1996–1997 and 2000–2002

No gains were retained. The largest totalled 622 ha and involved conversions from open water. Differences in tide levels may explain this large variation (Champlain hydrometric station: 0.815 m on August 10, 1997, at 10:10 a.m. EDT; 0.740 m on September 20, 2000, at 11:40 a.m. EDT). In addition, 20 ha of denuded substrate were classified as wetlands. It appears nonetheless that an overestimation of denuded substrate on the 1996–1997 map is the reason for this difference. Also, 17 ha of upland forests were converted to wetlands in 2000–2002. This could relate to geometry problems affecting the image taken at that time. Similarly, 14 ha of farmland and 10 ha of built-up areas identified in 1996–1997 were incorrectly classified as wetlands in 2000–2002.

59 Results of Kappa agreement analyses for the fluvial estuary

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.82
KHisto	0.90
KLoc	0.91
Fraction correct	0.90
Fuzzy Kappa	0.64
Fuzzy fraction correct	0.91

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.62
KHisto	0.85
KLoc	0.73
Fraction correct	0.73
Fuzzy Kappa	0.25
Fuzzy fraction correct	0.74

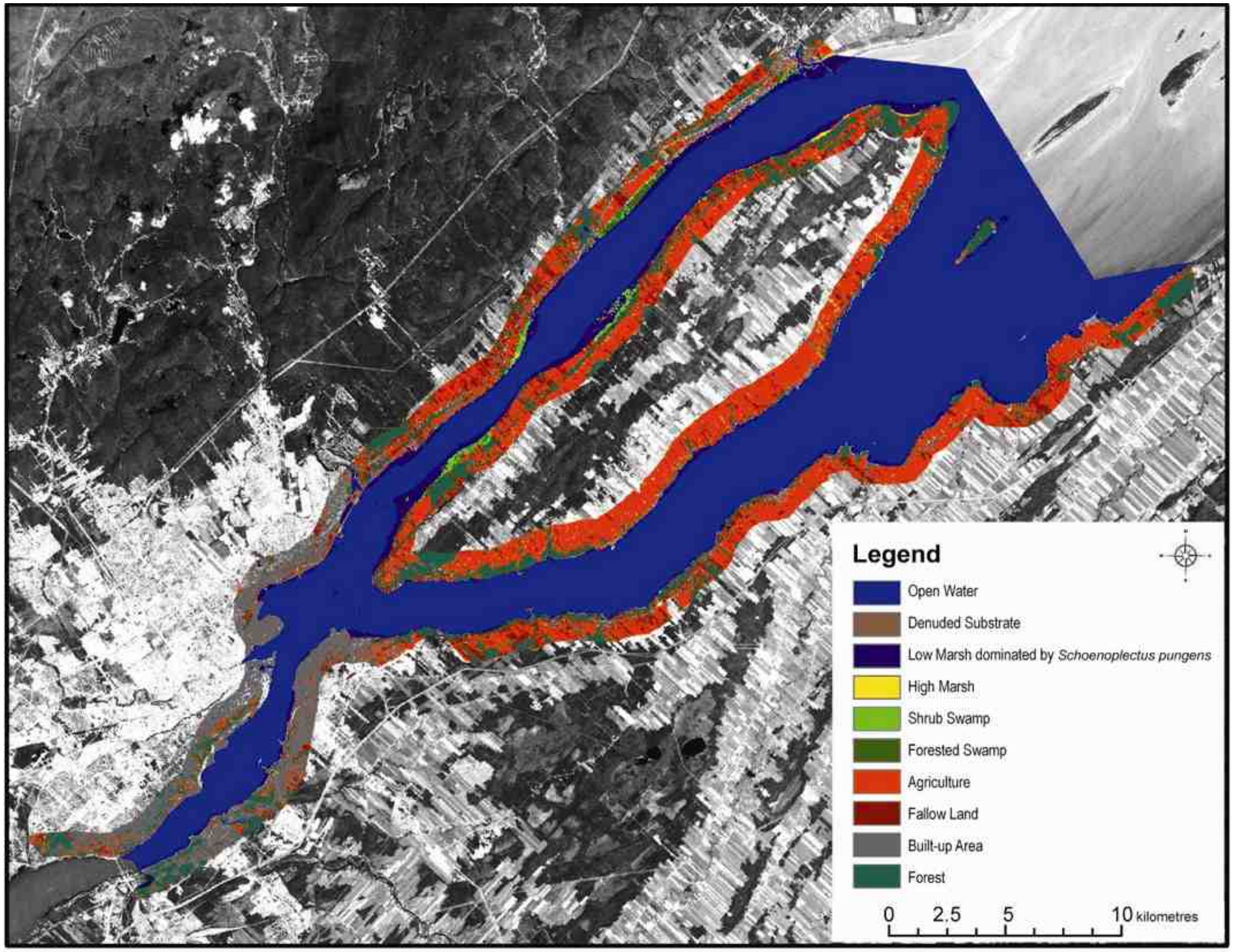
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.61
KHisto	0.78
KLoc	0.78
Fraction correct	0.73
Fuzzy Kappa	0.30
Fuzzy fraction correct	0.76

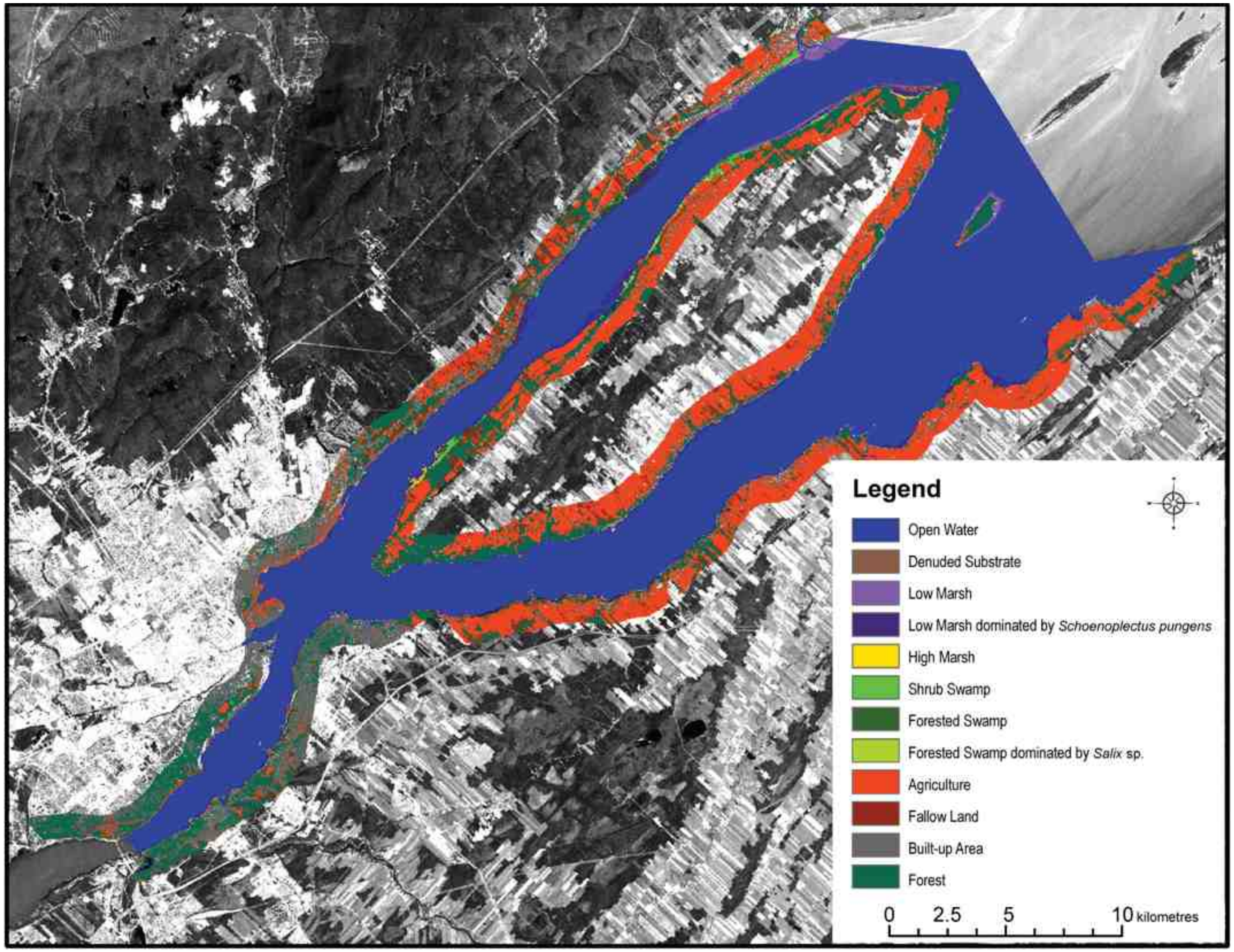
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.63
KHisto	0.85
KLoc	0.74
Fraction correct	0.76
Fuzzy Kappa	0.29
Fuzzy fraction correct	0.79

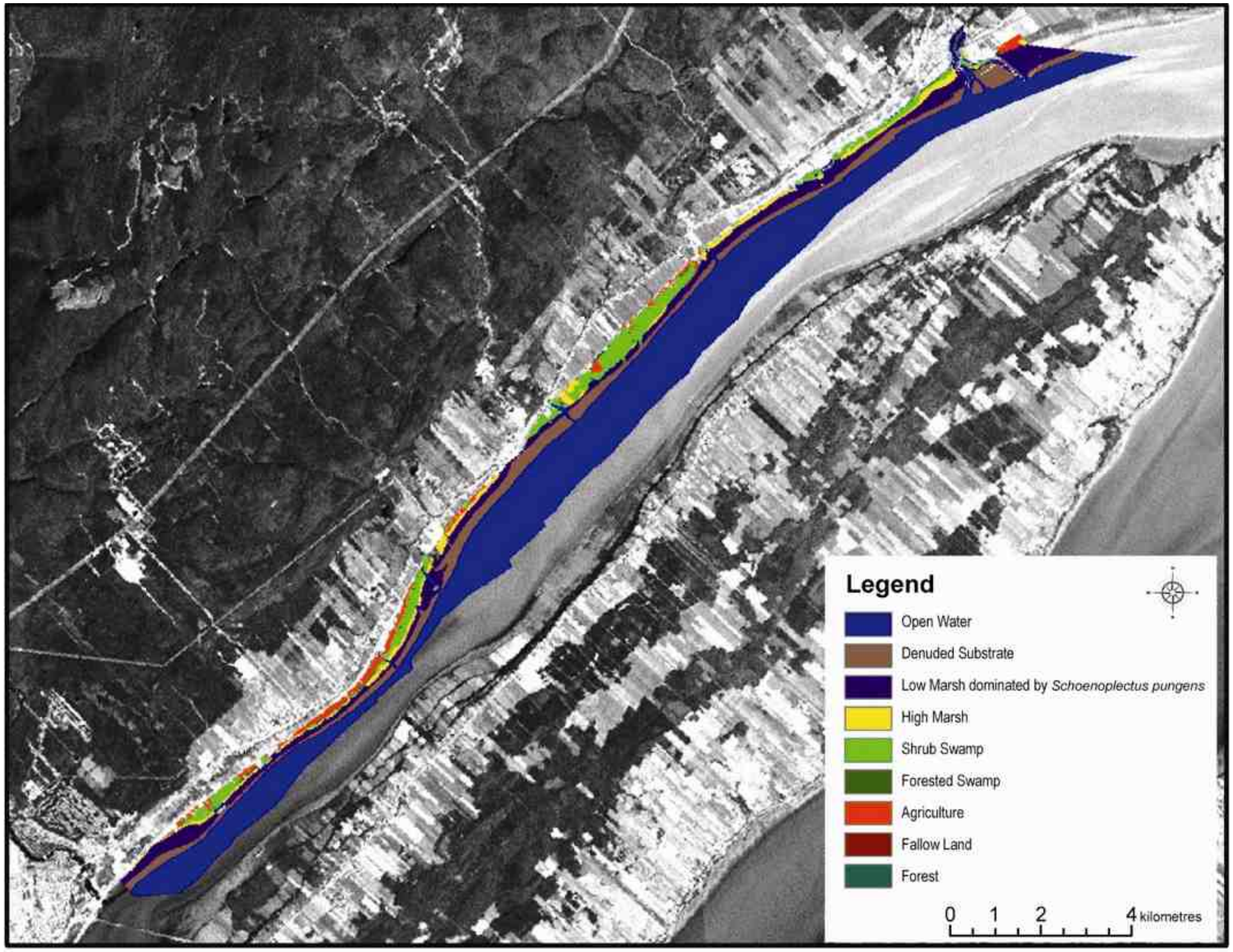
60 Wetlands in the Quebec City–Lévis sector in 1990–1991



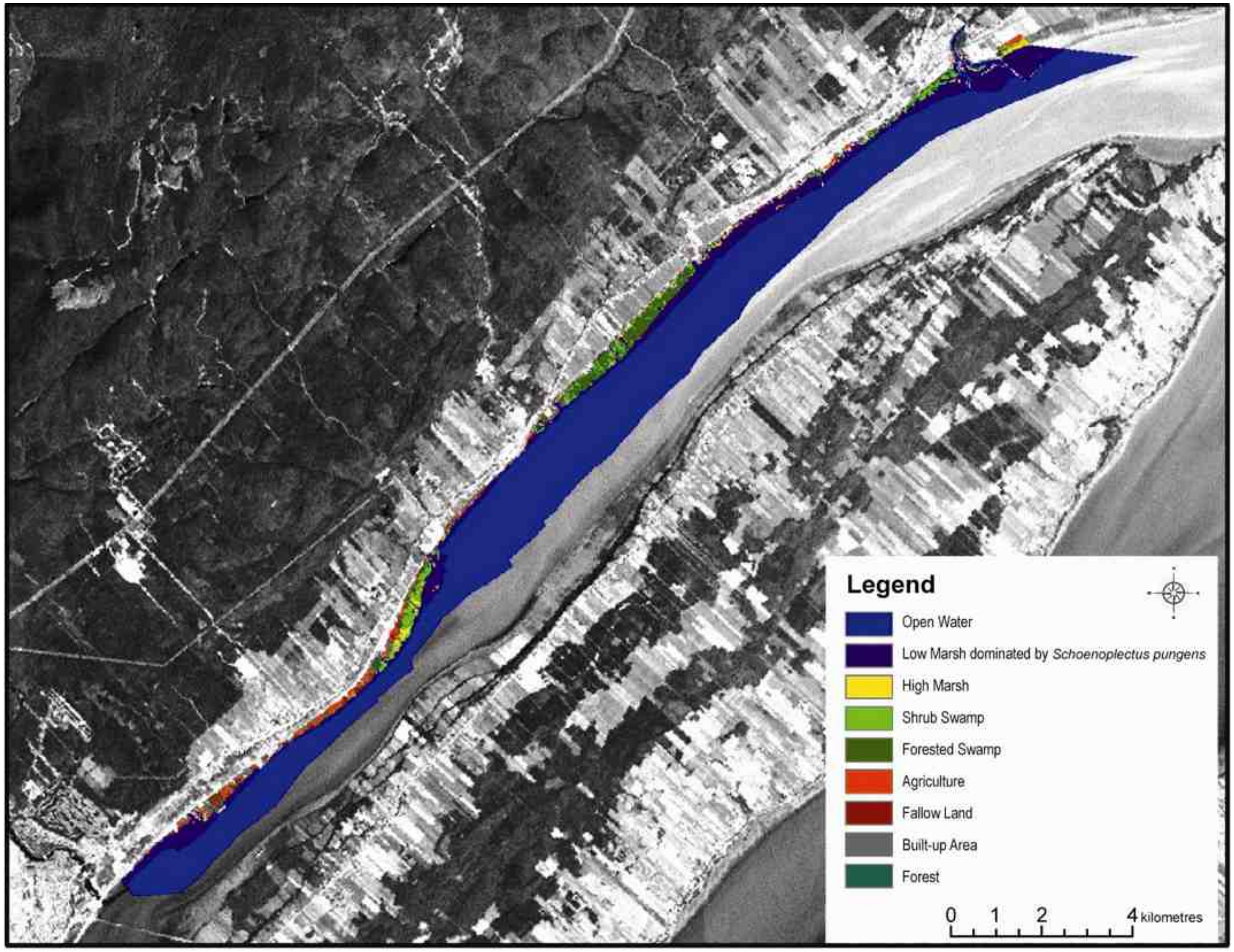
61 Wetlands in the Quebec City–Lévis sector in 2000–2002



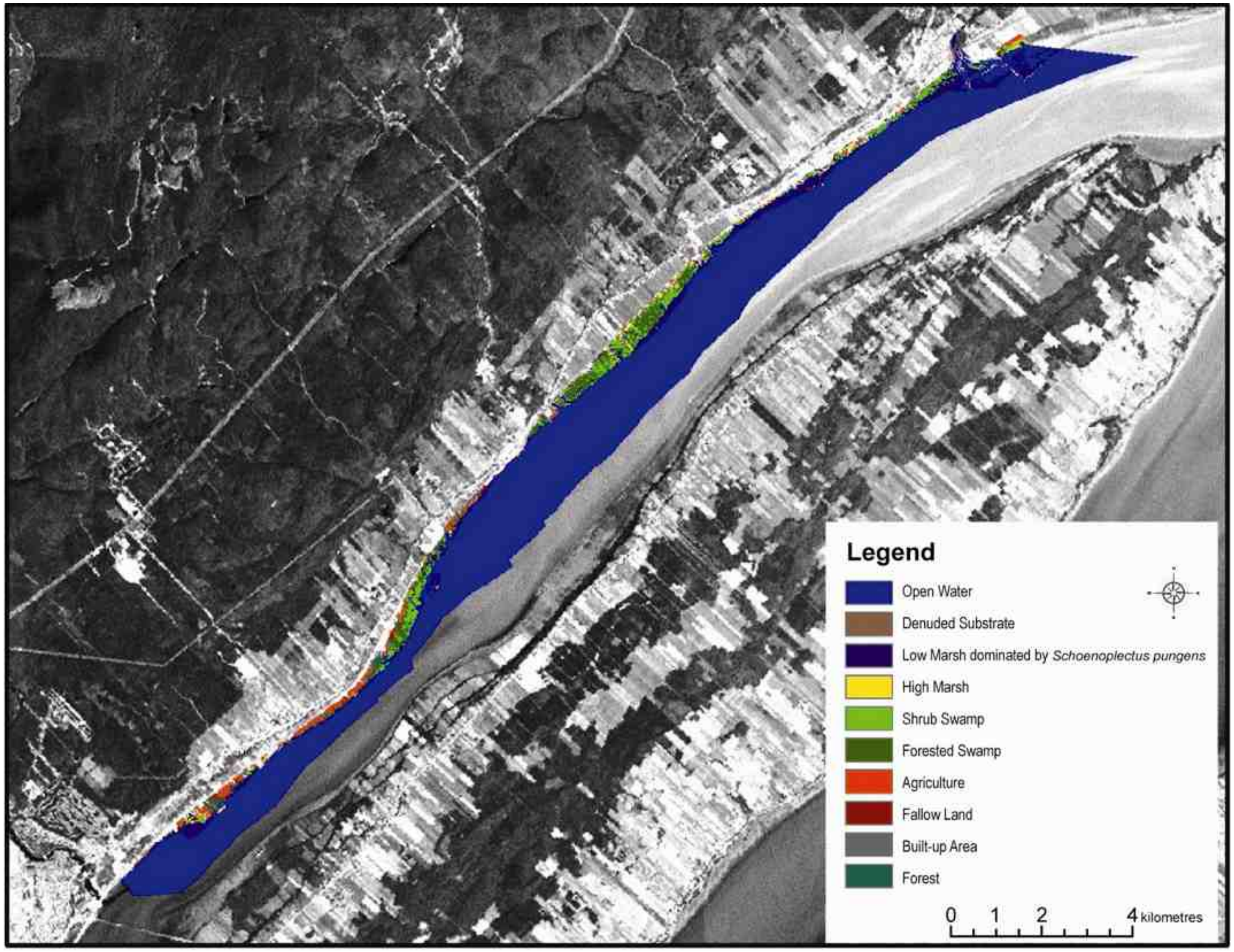
62 Wetlands in the portion of the Quebec City–Lévis sector analyzed in 1970–1978



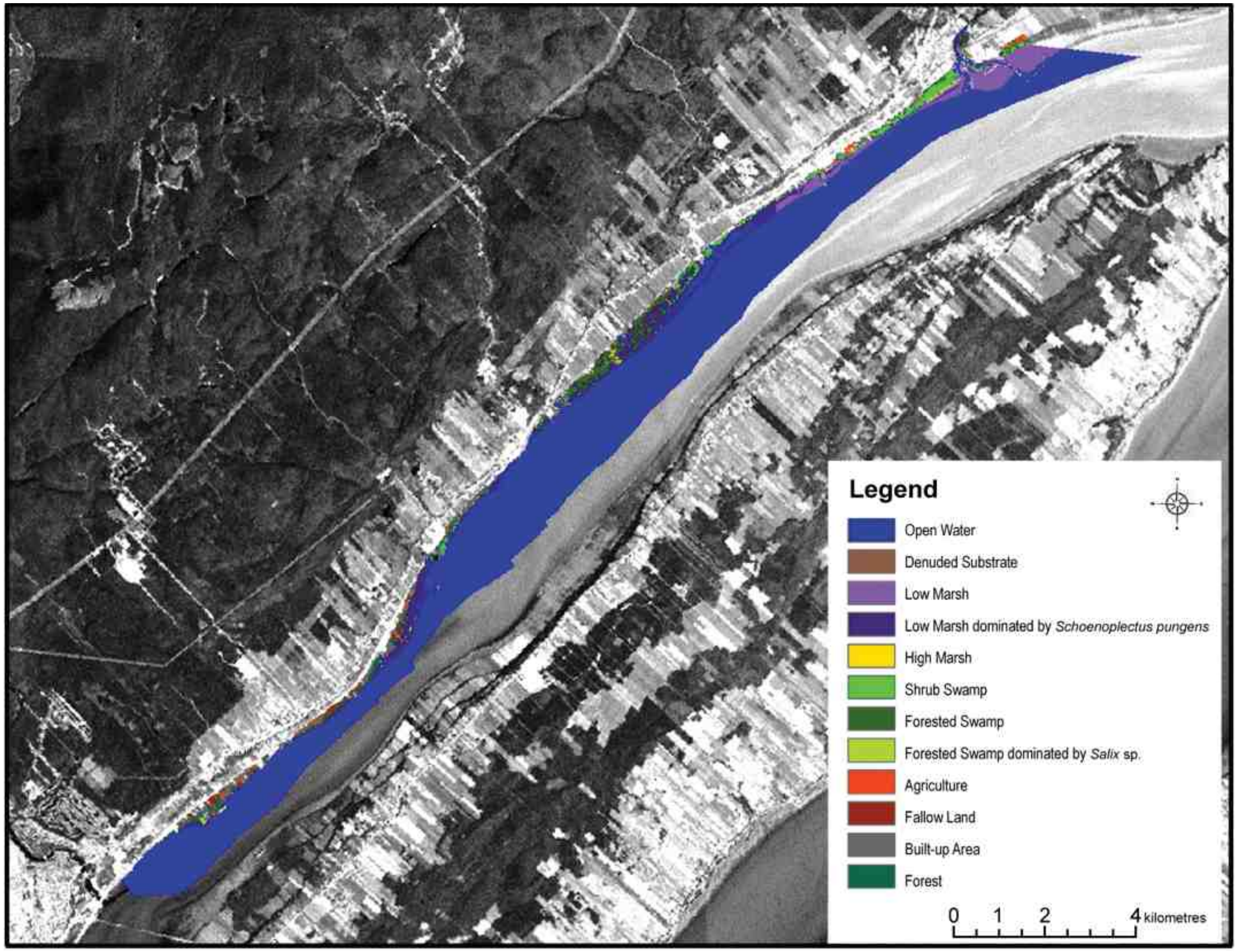
63 Wetlands in the portion of the Quebec City–Lévis sector analyzed in 1990–1991



64 Wetlands in the portion of the Quebec City–Lévis sector analyzed in 1996–1997



65 Wetlands in the portion of the Quebec City–Lévis sector analyzed in 2000–2002



66 Gains and losses in the Quebec City–Lévis sector not retained in the analysis

Between 1990–1991 and 2000–2002

None of the losses observed during this period were retained. The main losses (859 ha) involved conversions of wetlands to open water. This phenomenon is observed in shoreline areas throughout the study region, particularly downstream of Quebec City. This finding may be attributable to the effect of the multi-date mosaic used and differences in tide levels.

In addition, 101 ha identified as wetlands in 1990–1991 were classified as upland forests in 2000–2002. This phenomenon is observed throughout the Côte-de-Beaupré sector and along the north shore of Île d'Orléans. It appears that confusion between the two classes is responsible for the difference. In addition, 60 ha of wetlands were replaced by built-up areas in 2000–2002, which are located mainly along the Côte-de-Beaupré downstream of Beauport. A geometry problem affecting the image from 2000–2002 may be responsible for the difference.

Also, 53 ha of wetlands were transformed into agricultural areas, on the north and south shores of Île d'Orléans. The cause is undoubtedly an overestimation of wetlands in 1990–1991. In addition, 32 ha identified as wetlands in 1990–1991 were classified as denuded substrate in 2000–2002. These areas are located at the northwestern tip of Île d'Orléans. Tidal effects likely explain this difference. Lastly, 27 ha of wetlands were identified as fallow land on the 2000–2002 maps. These areas are situated on the Côte-de-Beaupré and on the north shore of Île d'Orléans. Although we have no specific validation data for these areas, it appears that the changes are due to confusion between the two classes.

All of the observed gains were rejected. Conversions of open water zones into wetlands (including low marshes dominated by *Schoenoplectus pungens*, low marshes and forested swamps) encompassed 182 ha, on the Côte-de-Beaupré, at the head of certain bays on the south shore, and around Île Madame. This change cannot be attributed to tidal effects since tides were higher in 2000 than in 1991 for the affected sections of the map (Île aux Grues hydrometric station, 2.444 m on September 3, 1991, at 4:11 p.m. EDT; 3.860 m on September 24, 2000, at 4:50 p.m. EDT). An examination of the raw images did not reveal major changes. In addition, 68 ha of forests, 64 ha of fallow land and 37 ha of agricultural land according to the 1990–1991 map were converted to wetlands (primarily swamps) in 2000–2002. These changes are located near the middle of the north shore of Île d'Orléans and are likely attributable to confusion between classes. Lastly, 17 ha of built-up areas in 1990–1991 were incorrectly classified as wetlands in 2000–2002; the areas concerned are on the south shore of the St. Lawrence and on the south shore of Île d'Orléans. The difference is probably due to geometry problems affecting the two maps.

Between 1970–1978 and 1990–1991

The main wetland losses during the period, all involving a transformation to open water (125 ha), were not retained. The areas concerned are scattered all along the Côte-de-Beaupré. Since the Groupe Dryade map was produced using aerial photographs taken on two separate dates, differences in tide levels provide a plausible explanation for this difference.

The wetland gains that were not retained include 64 ha of substrate classified as wetlands in 1990–1991. They mirror the transition from wetlands to open water at the mouth of the Saint-Anne River and along the shoreline at Sainte-Anne-de-Beaupré. The same cause (different tide levels between the two dates) appears to explain this phenomenon. Similarly, 29 ha of open water became wetlands primarily at the mouth of the Saint-Anne River. Tidal effects could explain this difference as well.

Between 1990–1991 and 1996–1997

All of the losses observed during this period were rejected. For example, 283 ha of wetlands disappeared and were replaced by open water; this phenomenon was observed along most of the Côte-de-Beaupré. Tidal effects (Saint-Joachim hydrometric station: 2.468 m on September 3, 1991, and 2.960 m on September 6, 1996) appear to explain the difference. The other changes consist of less than 10 ha each and are not taken into consideration.

Among the gains that were not retained, 16 ha of built-up areas were converted to wetlands. This difference appears to be linked to mixed pixels associated with highway 138. In addition, 9 ha of fallow land were classified as wetlands in 1996–1997. Since these differences are widely scattered in the region, they are more likely the result of classification problems than actual changes. Lastly, 8 ha of upland forests were classified as wetlands, with small portions in the southern part of the Côte-de-Beaupré. A variation in the definition of the masks used to delimit upland areas is probably responsible for these differences.

Between 1996–1997 and 2000–2002

Of the 92 ha of wetlands lost to open water, 61 ha were not retained. In the Périgny area, an overestimation of open water zones on the image from 2000 appears to explain 37 ha of these incorrect losses. The remaining amount appears to be associated with tide levels, particularly south of Le Moyne (Saint-Joachim hydrometric station: 3.907 m, September 20, 2000, at 12:15 p.m. EDT, 0.718 m on September 25 at 9:50 a.m. EDT, 1.128 m on July 25, 2002, at 12:00 p.m. EDT and 2.751 m on July 28, 2002, at 12:10 p.m. EDT).

In addition, 16 ha of wetlands were classified as upland forests. Classification inconsistencies are the reason for this difference. Also, 16 ha of wetlands are now identified as built-up areas. This appears to be the result of mixed pixels associated with highway 138.

All of the gains were rejected. The only significant ones, attributed to conversion from open water (148 ha), are downstream of Le Moyne, where different acquisition dates and the tidal effects recorded on the images from 2000 and 2002 are particularly obvious.

67 Results of Kappa agreement analyses for the Quebec City–Lévis sector

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.90
KHisto	0.95
KLoc	0.94
Fraction correct	0.95
Fuzzy Kappa	0.78
Fuzzy fraction correct	0.96

Between 1970–1978 and 1990–1991

Index	Value
Kappa	0.82
KHisto	0.85
KLoc	0.96
Fraction correct	0.98
Fuzzy Kappa	0.73
Fuzzy fraction correct	0.98

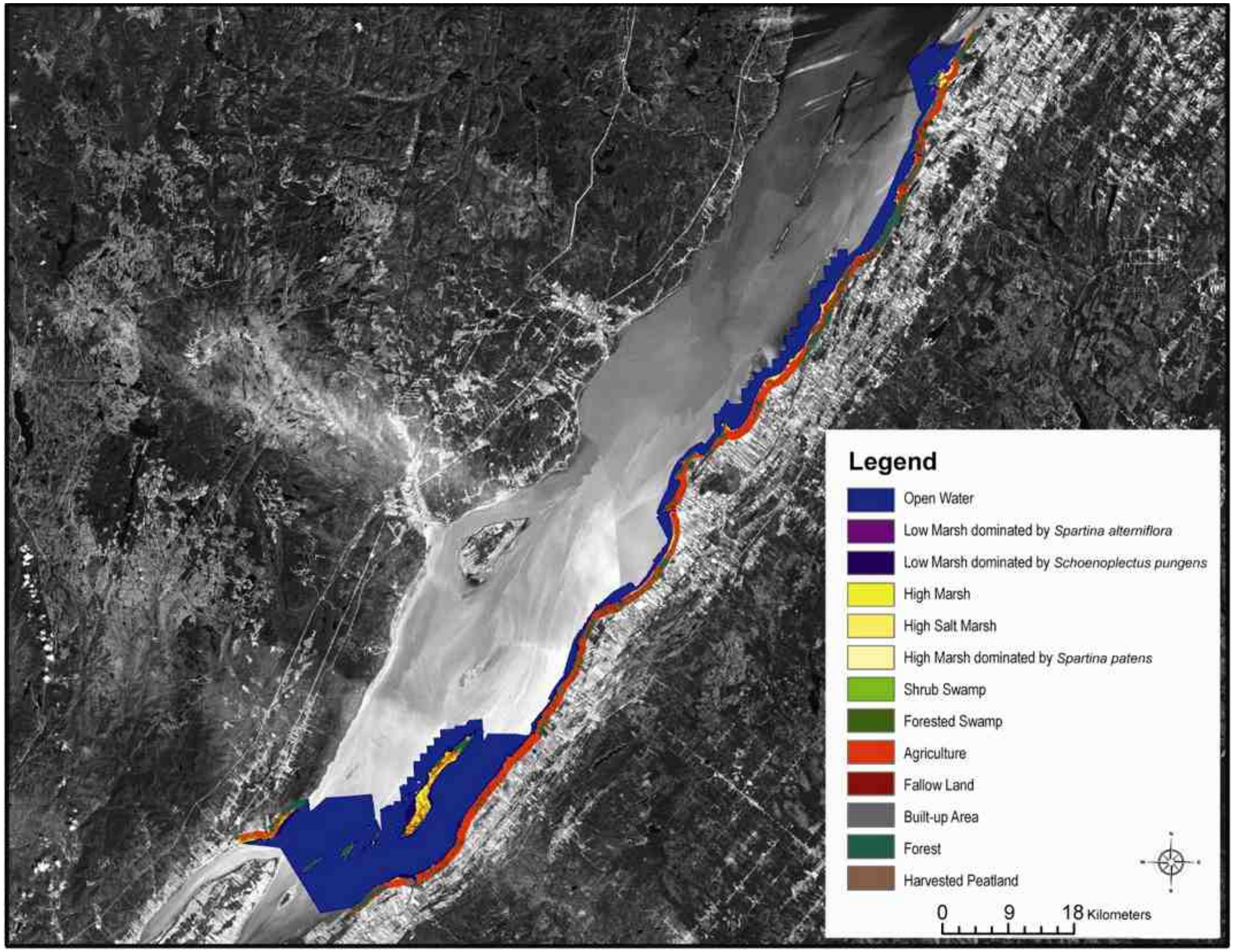
Between 1990–1991 and 1996–1997

Index	Value
Kappa	0.92
KHisto	0.95
KLoc	0.97
Fraction correct	0.99
Fuzzy Kappa	0.91
Fuzzy fraction correct	0.99

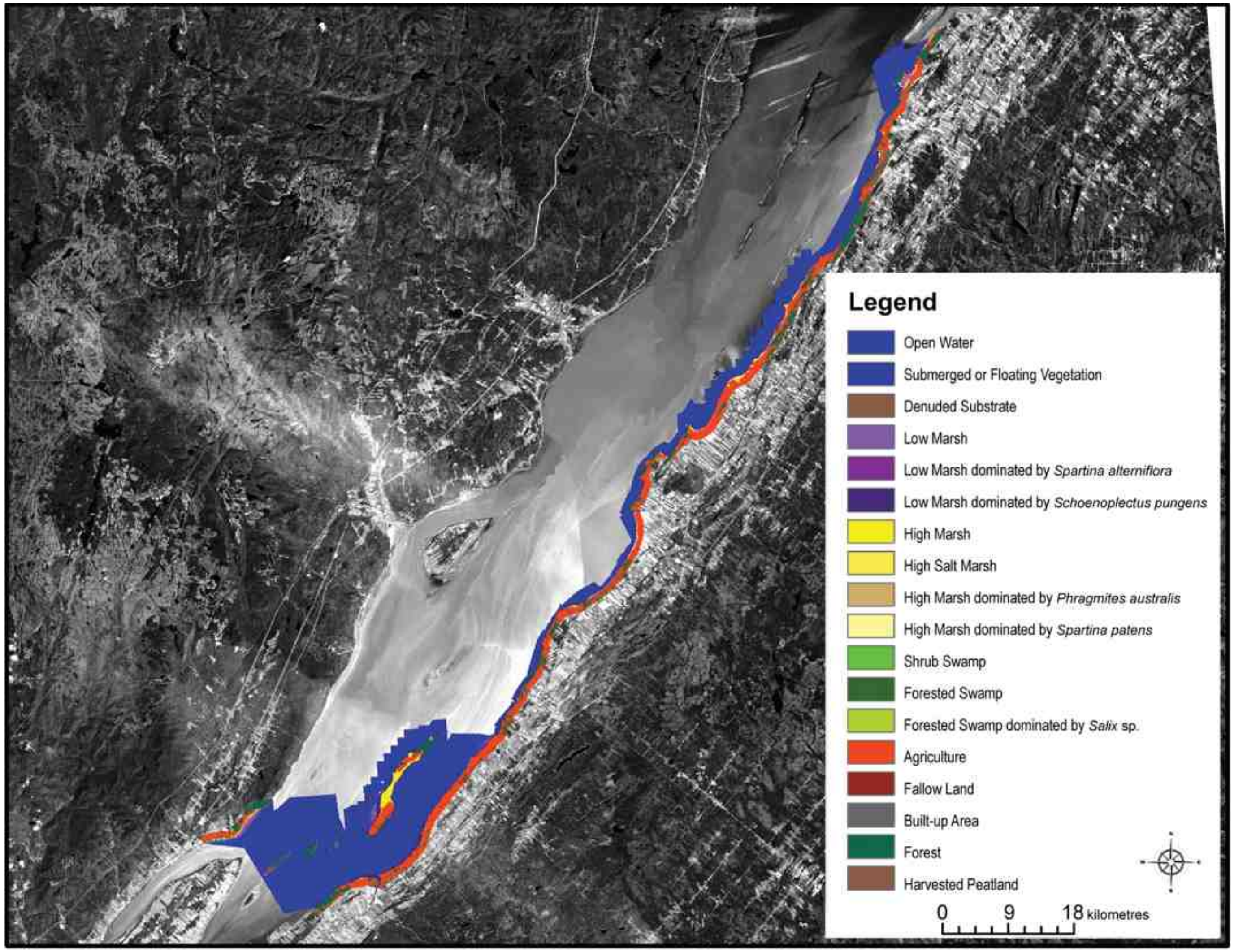
Between 1996–1997 and 2000–2002

Index	Value
Kappa	0.92
KHisto	0.97
KLoc	0.95
Fraction correct	0.99
Fuzzy Kappa	0.89
Fuzzy fraction correct	0.99

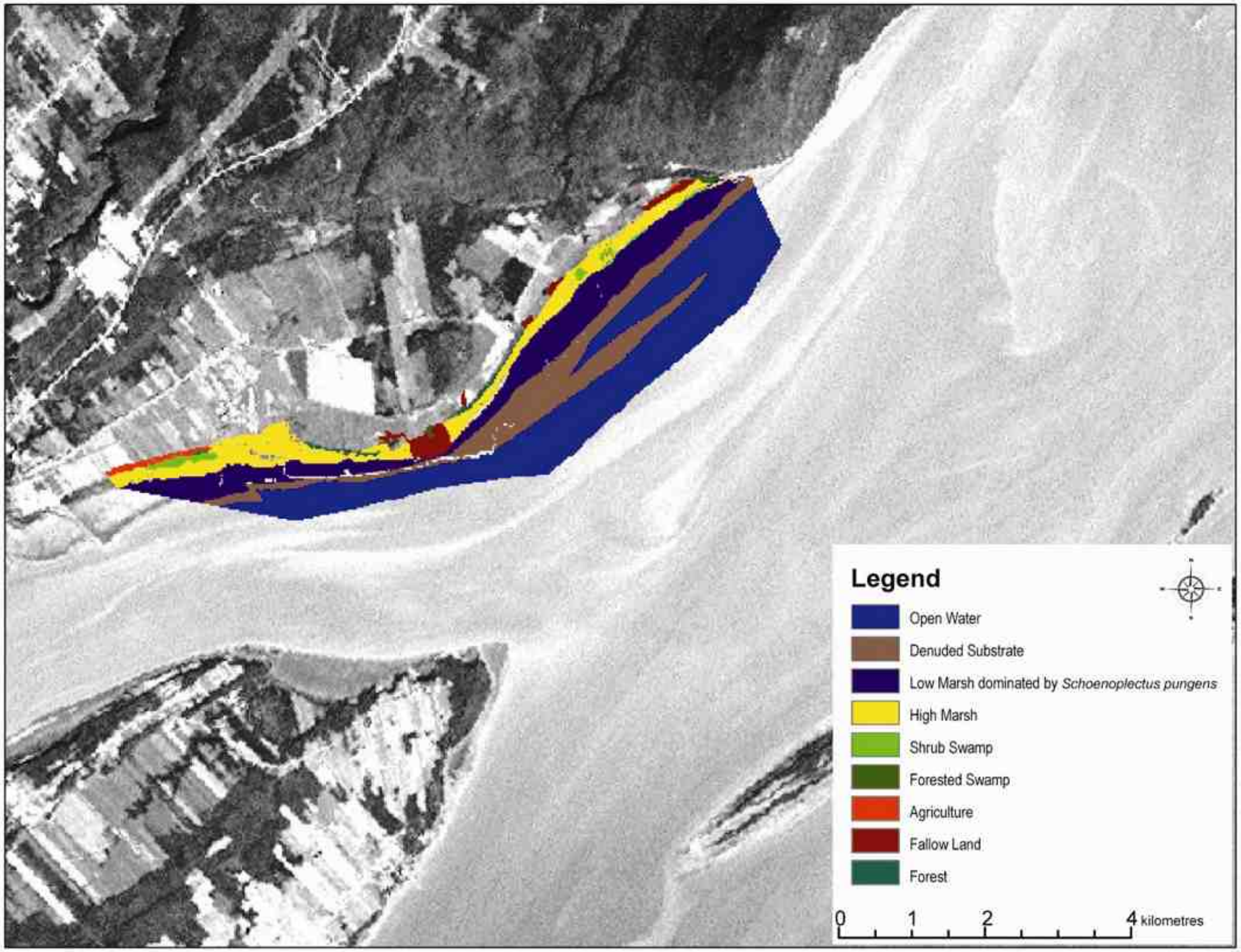
68 Wetlands in the portion of the upper estuary analyzed in 1990–1991



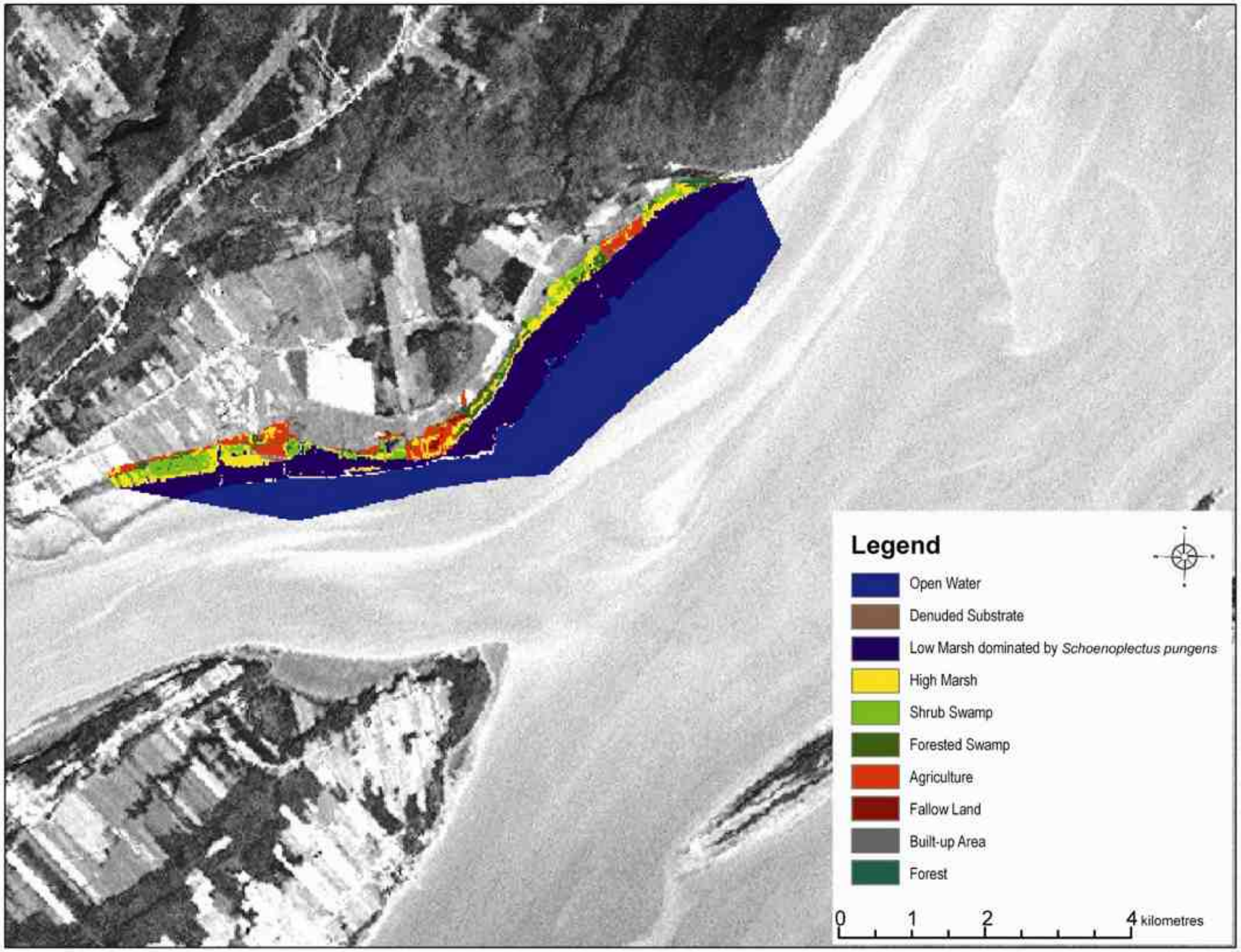
69 Wetlands in the portion of the upper estuary analyzed in 2000–2002



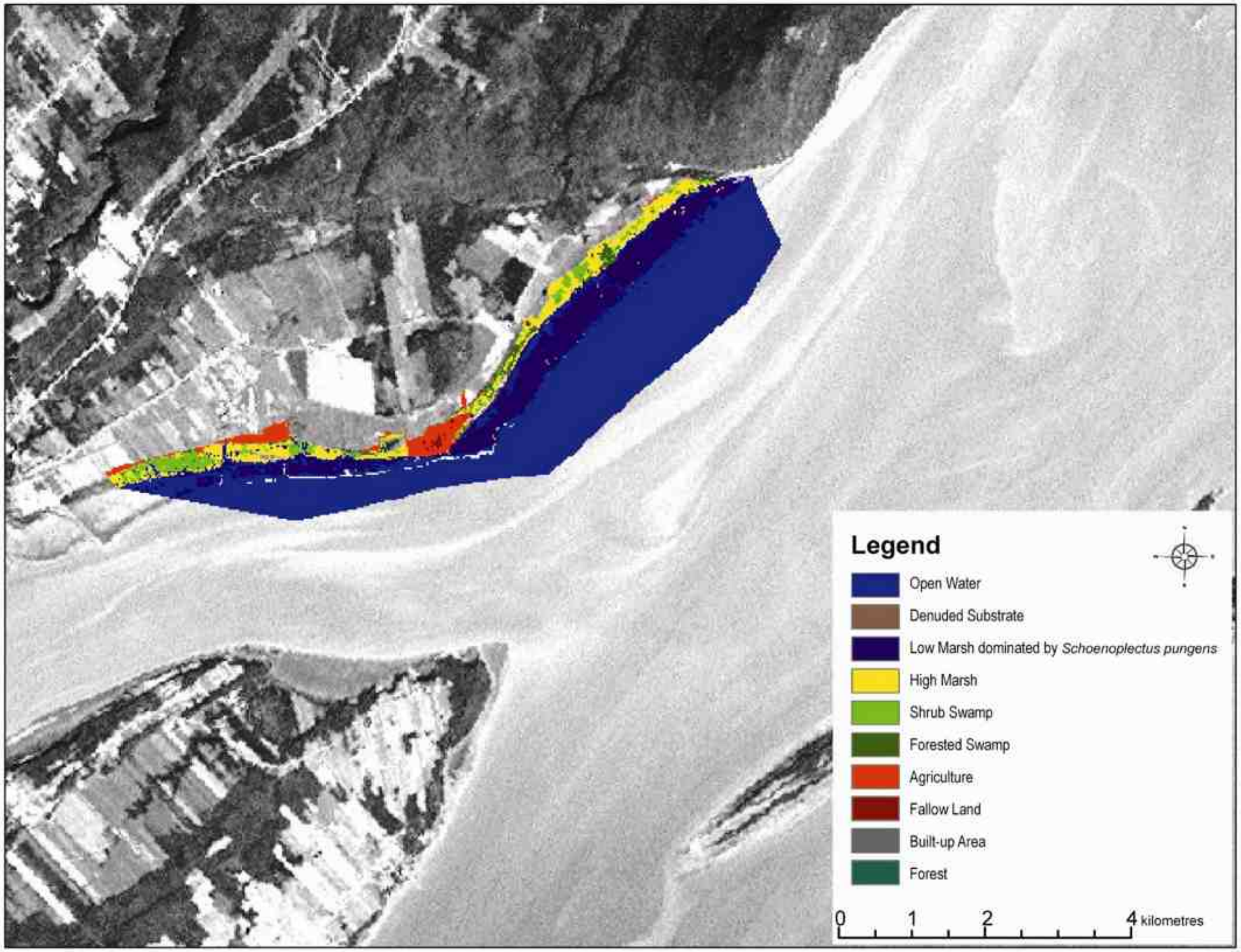
70 Wetlands in the Cap Tourmente (upper estuary) subsector analyzed in 1970–1978



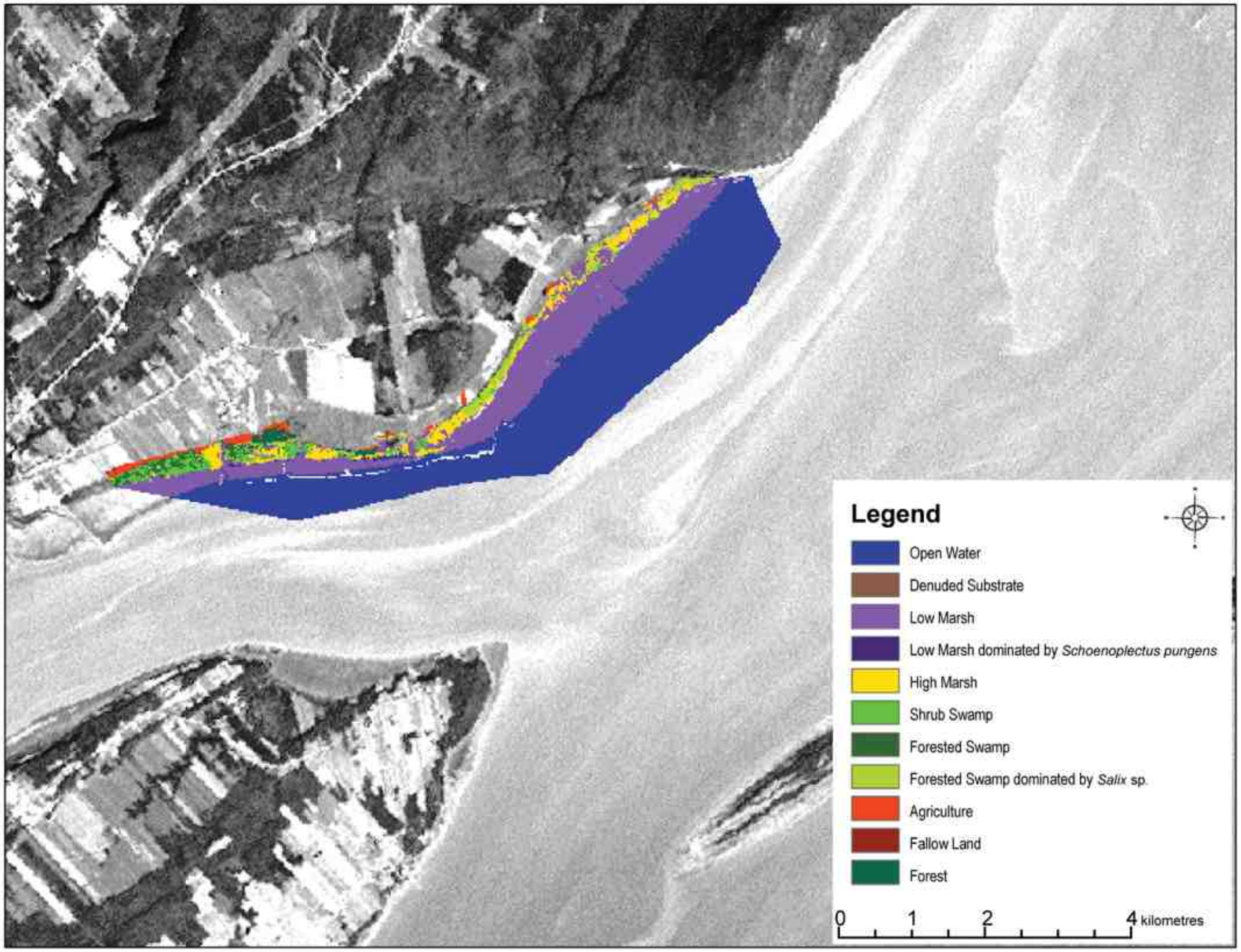
71 Wetlands in the Cap Tourmente (upper estuary) subsector analyzed in 1990–1991



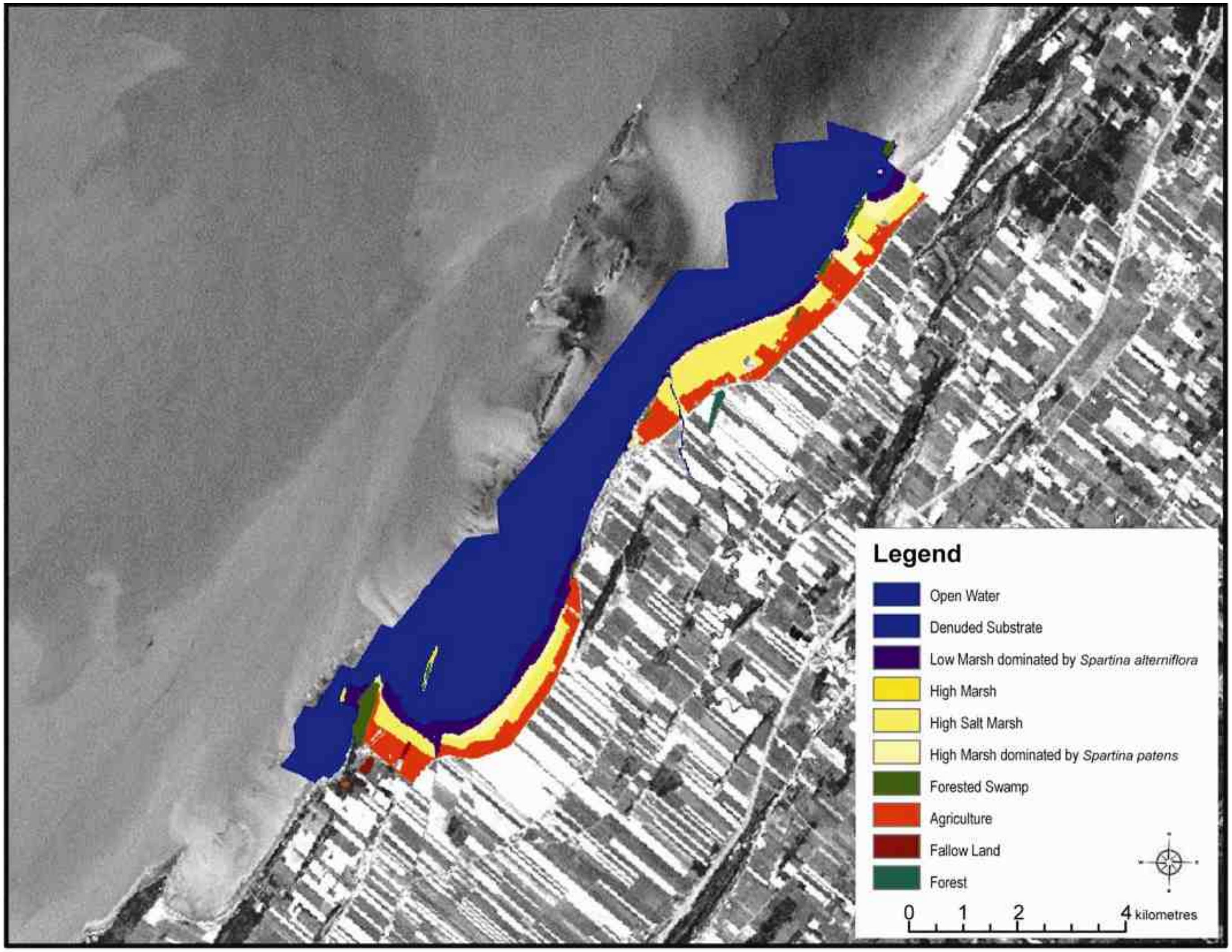
72 Wetlands in the Cap Tourmente (upper estuary) subsector analyzed in 1996–1997



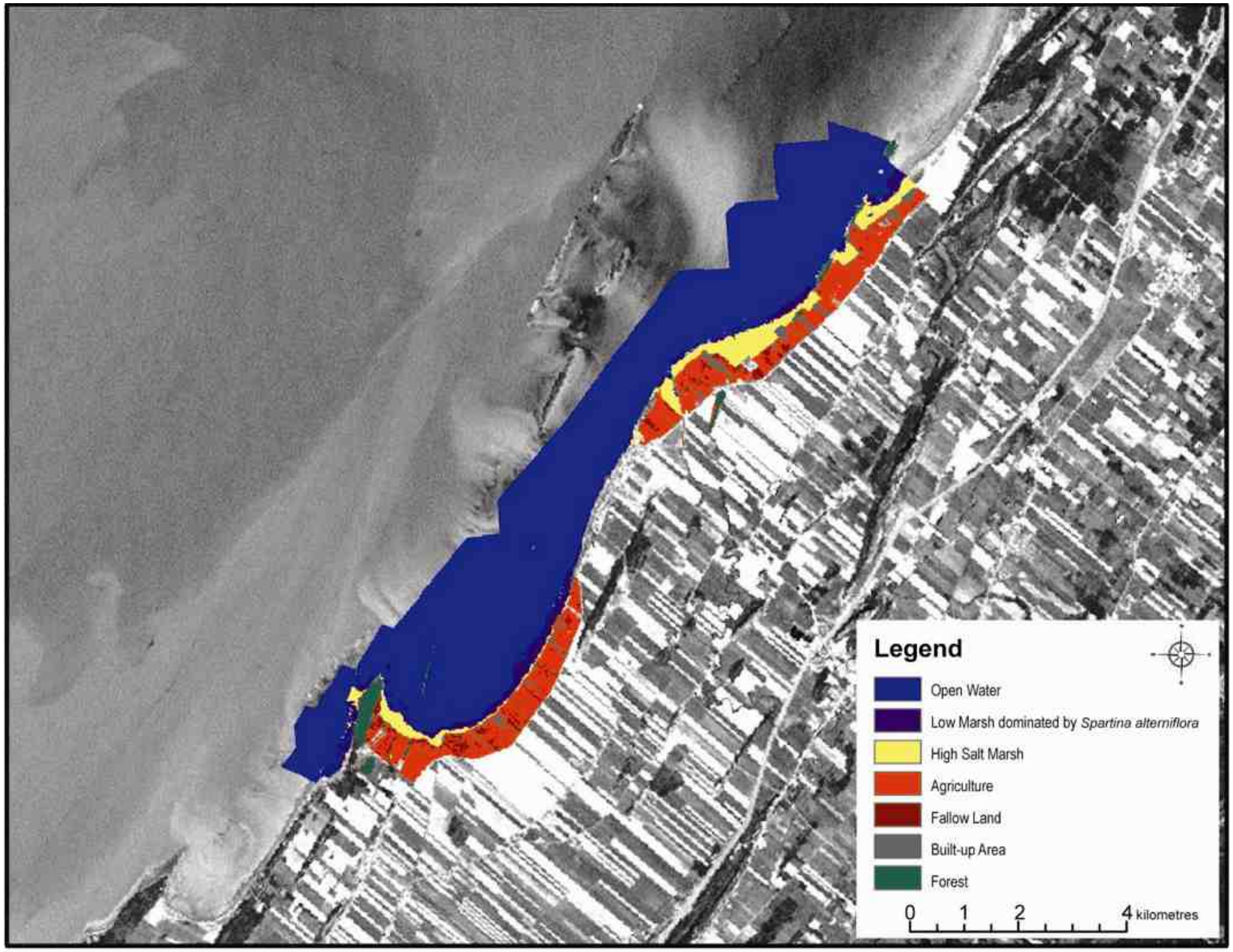
73 Wetlands in the Cap Tourmente (upper estuary) subsector analyzed in 2000–2002



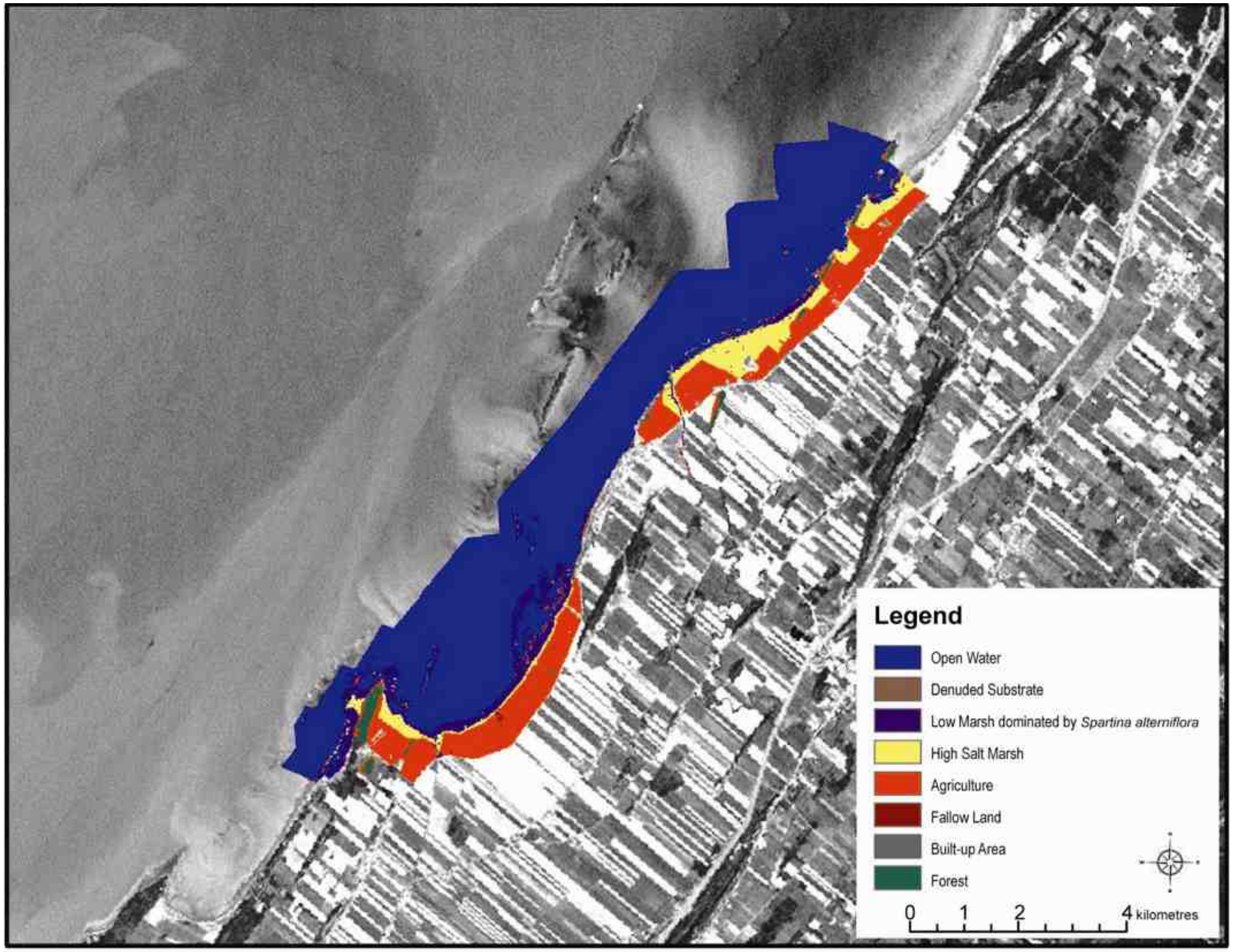
74 Wetlands in the Kamouraska (upper estuary) subsector analyzed in 1970–1978



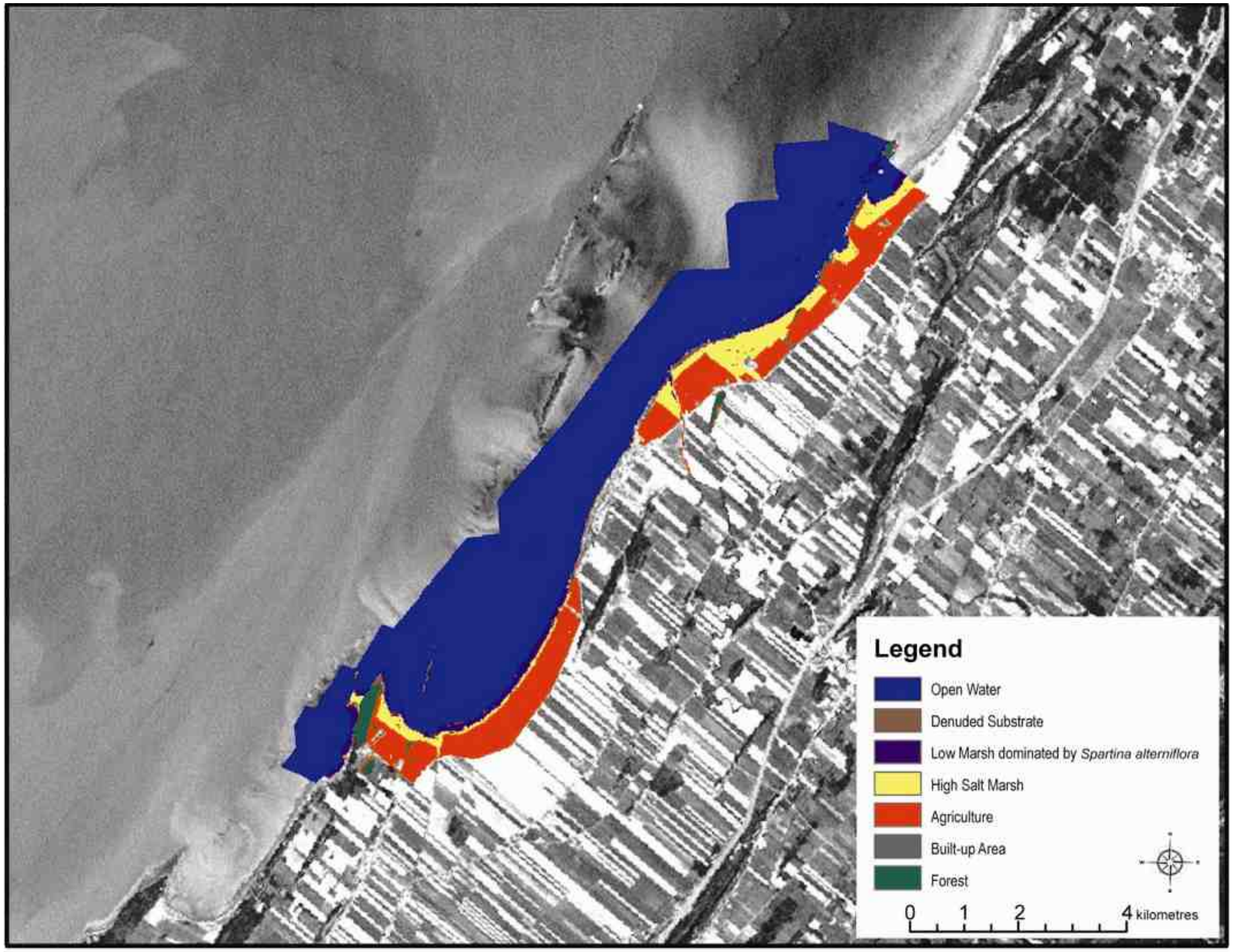
75 Wetlands in the Kamouraska (upper estuary) subsector analyzed in 1990–1991



76 Wetlands in the Kamouraska (upper estuary) subsector analyzed in 1996–1997



77 Wetlands in the Kamouraska (upper estuary) subsector analyzed in 2000–2002



78 Gains and losses in the upper estuary not retained in the analysis

Between 1990–1991 and 2000–2002 (complete coverage)

The main losses that were not retained relate to the advent of open water areas. In fact, 1656 ha classified as wetlands in 1990–1991 were replaced by open water in 2000–2002; these changes are scattered along the shoreline throughout the region. Given the use of multi-temporal mosaics, it is difficult to confirm whether these differences are entirely due to tidal effects. However, the sizeable areas affected indicate that that is the case. In addition, 538 ha of wetlands were classified as farmland in 2000–2002. These changes are located in the Cap Tourmente subsector and on Île aux Grues, Île aux Oies, and Île aux Ruaux. A variety of wetlands are affected, ranging from low marshes dominated by *Schoenoplectus pungens* to high marshes and swamps. These differences may be the result of an overestimation of wetlands in 1990–1991, although it is possible that, in some locations, wetland areas were actually wiped out by agricultural activities.

Added to this is the transformation of 123 ha of wetlands (low marshes, high marshes and swamps) into forests in 2000–2002. These changes concern small, widely scattered areas and appear to stem from confusion between classes. Lastly, 44 ha of wetlands were transformed into built-up areas, scattered on Île aux Grues, along Rivière du Sud, around Anse de Trois–Saumons, in the Pointe-aux-Orignaux bog and along the Rivière du Loup. Problems of geometry and confusion between classes appear to explain these differences.

Many of the observed gains were not retained. A comparison of the two maps shows what appear to be wetlands gained from open water (412 ha). The analysis comparing 1970–1978 and 2000–2002 (see below) indicates that the changes involving open water are not persistent and appear instead to be linked to tidal effects or various other problems. Large gains that were not retained (430 ha) consist of areas that were formerly farmland, on Île aux Grues and along the south shore of the St. Lawrence, particularly at Montmagny, Cap-Saint-Ignace, Saint-Roch-des-Aulnaies, Village-des-Aulnaies, Kamouraska, Rivière-du-Loup, Cacouna and Cacouna-Est. The differences are mainly attributable to confusion between wetlands and farmland. In addition, 158 ha identified as forests in 1990–1991 were classified as wetlands in 2000–2002. These wetlands, consisting of saltmeadows, bogs, low marshes dominated by *Spartina alterniflora*, forested swamps dominated by *Salix* sp., or high marshes, are located at Cap Tourmente, Île aux

Grues, Saint-Roch-des-Aulnaies, Rivière-des-Caps, Rivière-du-Loup and Cacouna. This situation is likely due to geometry differences between the two maps or confusion between swamps and more upland forest areas.

Lastly, 93 ha identified as fallow land in 1990–1991 were classified as wetlands in 2000–2002 at Cap Tourmente, Saint-Roch-de-Aulnaies, Rivière-du-Loup and L'Anse-au-Persil. More specifically, the new wetlands were classified as low marshes and high marshes in the Cap Tourmente National Wildlife Area. Farther downstream, the wetlands are actually low marshes dominated by *Schoenoplectus pungens* and saltmeadows. These differences can be explained by confusion between the two classes.

Between 1970–1978 and 1990–1991 (Cap Tourmente)

The only wetland losses during the period that were not retained consist of 15 ha of wetlands converted to open water. Since the Groupe Dryade map was produced using aerial photographs taken on two separate dates, differences in tide levels might explain this discrepancy.

The wetland gains not retained include 55 ha of substrate classified as wetlands in 1990–1991. They appear to mirror the transition from wetlands to open water described above, on the tidal flats in the Cap Tourmente National Wildlife Area. A difference in tide levels between two dates could explain this phenomenon. In addition, 17 ha of fallow land became wetlands, with these changes occurring in the Cap Tourmente National Wildlife Area and in scattered locations between Petit-Cap and Cap Tourmente. A detailed examination of the raw images suggests that wetlands were overestimated in 1990–1991. The other gains concern areas of less than 10 ha and are considered to be inconsistencies.

Between 1990–1991 and 1996–1997 (Cap Tourmente)

None of the losses noted during this period were retained. For example, 108 ha of wetlands were lost to open water, a phenomenon observed along much of the shoreline. Tidal effects (Saint-Joachim hydrometric station: 2.468 m on September 3, 1991, and 2.960 m on September 6, 1996) seem to be responsible for the difference. In addition, 13 ha of wetlands were classified as agricultural areas, including some located in and near the Cap Tourmente National

Wildlife Area. This appears to be due to an overestimation of wetlands in 1990–1991. The other changes (less than 5 ha apiece) represent inconsistencies.

The remaining gains, totalling 10 ha, were not retained. They include 8 ha of upland forests that were classified as wetlands. Most of them are located at the eastern end of the plain in the Cap Tourmente National Wildlife Area. A difference in the masks used to define upland areas is probably the reason for the discrepancy.

Between 1996–1997 and 2000–2002 (Cap Tourmente)

No losses were retained. The largest wetland losses, or about 19 ha, involved a transition to open water and appear to be linked to differences in tide levels (Saint-Joachim hydrometric station: 3.907 m on September 20, 2000, at 12:15 p.m. EDT, 0.718 m on September 25, 2000 at 9:50 a.m. EDT, 1.128 m on July 25, 2002, at 12:00 p.m. EDT and 2.751 m on July 28, 2002, at 12:10 p.m. EDT). The other types of losses (less than 10 ha each) are likely the result of classification problems.

The largest gains considered to be inconsistencies concern 90 ha of wetlands that were formerly open water. Different image acquisition dates and tide levels recorded on the images from 2000 and 2002 are likely responsible for this difference.

Between 1970–1978 and 1990–1991 (Kamouraska)

Only one type of loss was not retained: 36 ha of wetlands replaced in 1990–1991 by upland forests. The areas concerned are located at Pointe du Cap (Saint-Denis-sur-Mer) and on a few islands. An overestimation of wetlands by Groupe Dryade at the time appears to explain this difference.

The gains that were rejected are small (8 ha) and involve farmland and open water.

Between 1990–1991 and 1996–1997 (Kamouraska)

None of the losses were retained. The main losses were to open water (41 ha), a phenomenon encountered primarily along the shoreline near the Kamouraska Islands. Geometry problems appear to be the reason for the discrepancy. In addition, 19 ha of wetlands became denuded substrate. Geometry problems, or erosion, may be responsible for this difference. The other losses, totalling 10 ha, are considered inconsistencies.

The largest gains observed (92 ha) but not retained are conversions from open water. The effect of the tides is likely to blame for the difference (Grande Île hydrometric station: between 2.671 m and 2.898 m on September 3, 1991; between 2.077 m and 2.103 m on August 10, 1997). In addition, 28 ha of farmland were classified as wetlands in 1996–1997, a situation that appears to be attributable to geometry differences between the two maps along with inaccurate identification of classes. The same is true for the 23 ha of built-up areas that became wetlands according to the 1996–1997 map. The other changes, totalling 12 ha, are also considered to represent inconsistencies.

Between 1996–1997 and 2000–2002 (Kamouraska)

The main losses observed during the period, which were not retained, amount to 94 ha and represent a transformation to open water. Tidal effects appear to explain the difference (Grande Île hydrometric station: between 2.077 m and 2.103 m on August 10, 1997; between 3.989 m and 4.297 m on August 16 and 21, 2002). Also, 24 ha of wetlands appear to have been converted to farmland. The geometry of the 1996–1997 map, together with variations in upland masks, is probably the reason for this discrepancy. Lastly, 18 ha of wetlands became denuded substrate. Although a decrease in the density of the vegetation cover may have occurred, we do not have any information to support such an assumption. The other losses, totalling 4 ha, are considered to be inconsistencies.

Nearly half of the gains that were not retained (22 ha out of 48 ha) are areas formerly identified as open water. The geometry of the 1996–1997 map, combined with an overestimation of wetlands in 2000–2002, are likely responsible. In addition, 14 ha of agricultural land became wetlands. Geometry, together with confusion with certain upland areas (tide gates, for example), are probably to blame for this difference. Lastly, 10 ha of substrate became wetlands. It seems inappropriate, given the geometry problems in 1996–1997, to retain this change. The other gains, totalling 2 ha, are considered to be inconsistencies.

79 Results of Kappa agreement analyses for the upper estuary

Between 1990–1991 and 2000–2002 (complete coverage)

Index	Value
Kappa	0.85
KHisto	0.93
KLoc	0.92
Fraction correct	0.93
Fuzzy Kappa	0.73
Fuzzy fraction correct	0.94

Between 1970–1978 and 1990–1991 (Cap Tourmente)

Index	Value
Kappa	0.82
KHisto	0.86
KLoc	0.96
Fraction correct	0.94
Fuzzy Kappa	0.72
Fuzzy fraction correct	0.94

Between 1990–1991 and 1996–1997 (Cap Tourmente)

Index	Value
Kappa	0.89
KHisto	0.94
KLoc	0.94
Fraction correct	0.96
Fuzzy Kappa	0.85
Fuzzy fraction correct	0.97

Between 1996–1997 and 2000–2002 (Cap Tourmente)

Index	Value
Kappa	0.79
KHisto	0.83
KLoc	0.95
Fraction correct	0.93
Fuzzy Kappa	0.68
Fuzzy fraction correct	0.93

Between 1970–1978 and 1990–1991 (Kamouraska)

Index	Value
Kappa	0.69
KHisto	0.79
KLoc	0.87
Fraction correct	0.85
Fuzzy Kappa	0.45
Fuzzy fraction correct	0.87

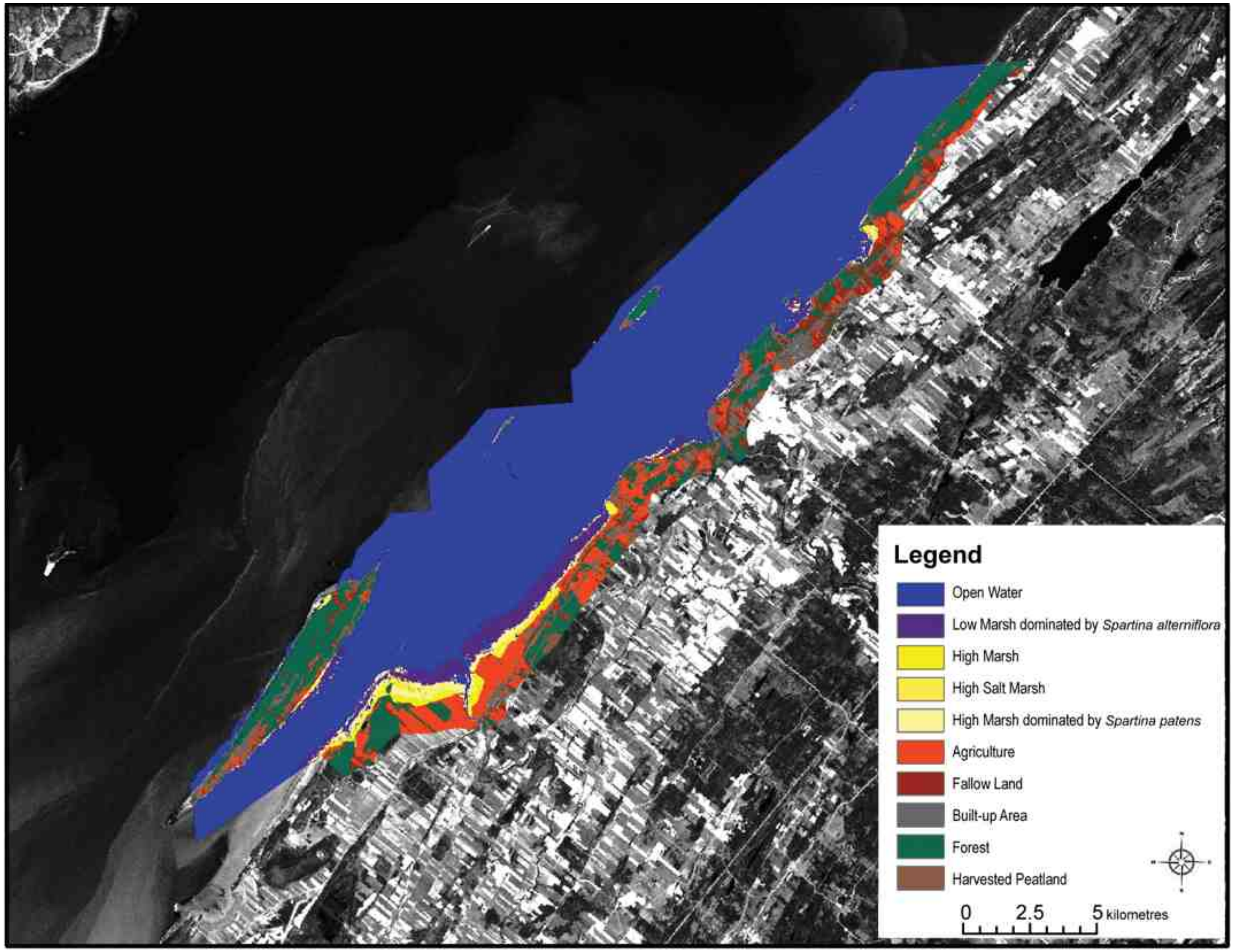
Between 1990–1991 and 1996–1997 (Kamouraska)

Index	Value
Kappa	0.81
KHisto	0.91
KLoc	0.89
Fraction correct	0.91
Fuzzy Kappa	0.69
Fuzzy fraction correct	0.93

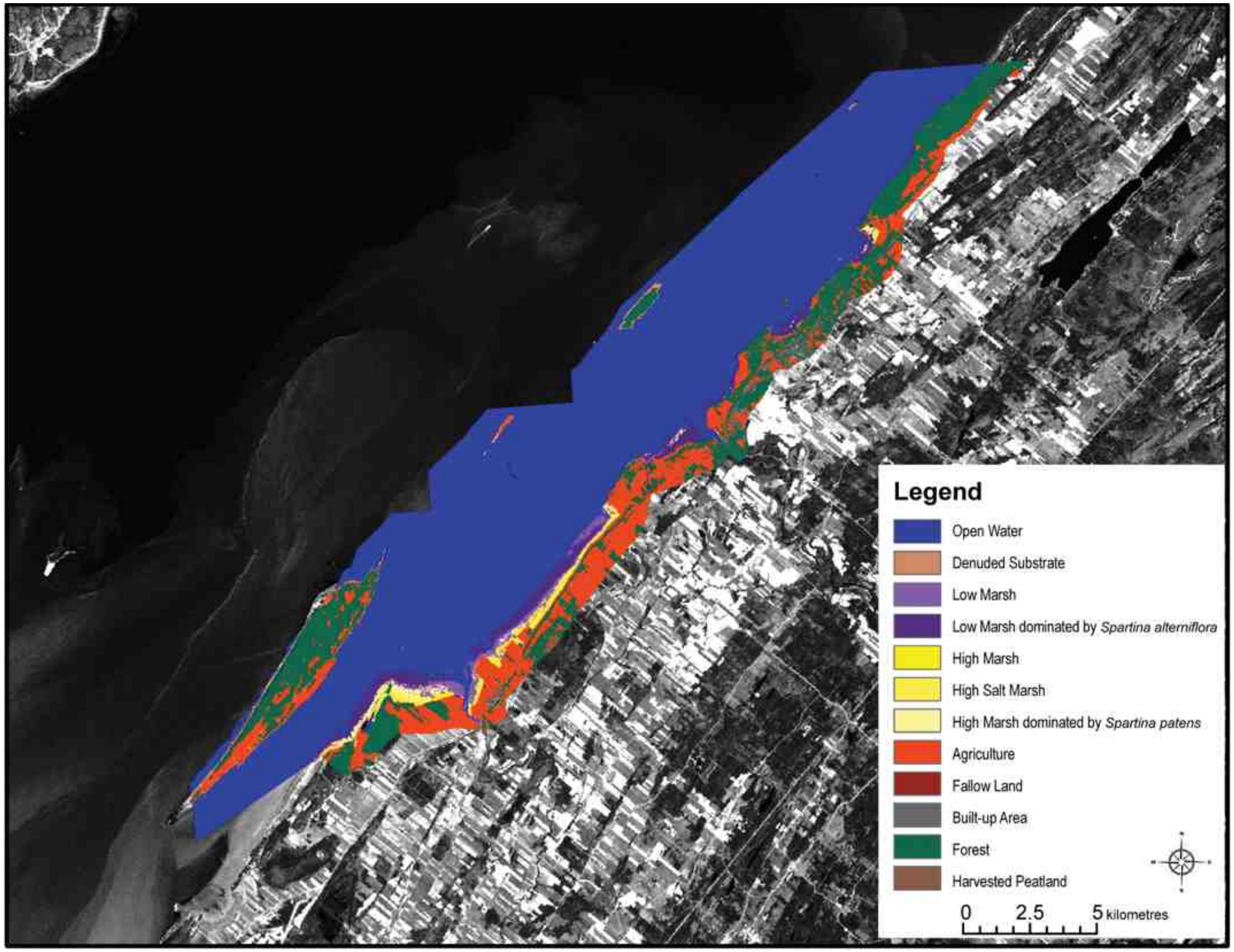
Between 1996–1997 and 2000–2002 (Kamouraska)

Index	Value
Kappa	0.83
KHisto	0.93
KLoc	0.89
Fraction correct	0.92
Fuzzy Kappa	0.74
Fuzzy fraction correct	0.94

80 Wetlands in the portion of the lower estuary analyzed in 1990–1991



81 Wetlands in the portion of the lower estuary analyzed in 2000–2002



82 Gains and losses in the lower estuary not retained in the analysis

Between 1990–1991 and 2000–2002

All of the losses during this period were rejected. The biggest loss consisted of some 465 ha of wetlands (mostly low marshes dominated by *Spartina alterniflora*), which were classified as open water in 2000–2002. The areas are distributed on the south shore of Verte Island and in the bay adjacent to the Trois-Pistoles wharf (region mapped in 2000), as well as in L'Isle-Verte cove (mapped using the images from 2002). Tide levels in 2000 and 2002 were at least one metre higher than those recorded in 1991 (Trois-Pistoles hydrometric station: between 1.431 m and 1.444 m on September 3, 1991; between 2.774 m and 2.916 m on September 22, 2000; 1.732 m on September 26, 2000; 2.327 m on August 16, 2002). It is therefore conceivable that the observed changes are mainly due to tidal effects. Lastly, in the case of the bay adjacent to the Trois-Pistoles wharf, it appears that the area of the wetlands was overestimated on the 1990–1991 map.

In addition, 86 ha of wetlands (including bogs, saltmeadows and low marshes dominated by *Spartina alterniflora*) became agricultural land in 2000–2002. The areas concerned are primarily on the north and south shores of Verte Island and in a bog east of the town of L'Isle–Verte. This difference is probably due to an overestimation of farmland in 2000–2002.

Also, 50 ha identified as wetlands in 1990–1991 were classified as forests in 2000–2002. This change is observed around Verte Island and around the bog east of the town of L'Isle–Verte. In the latter case, confusion between the forest and the wooded part of the bog appears to be responsible. However, a geometry problem affecting the images seems to be the reason for the changes observed on Verte Island.

In addition, 12 ha identified as wetlands in 1990–1991 were classified as built-up areas in 2000–2002 around Verte Island and at the head of certain bays. Confusion may have affected the 2000–2002 classification exercise, with sun glitter or strong turbidity possibly interpreted as built-up areas.

Lastly, 13 ha identified as wetlands in 1990–1991 were classified as denuded substrate. A geometry problem affecting the images appears to be the reason.

The gains that were not retained include 86 ha classified as farmland in 1990–1991 which were classified as wetlands (high marshes and saltmeadows) in 2000–2002, with most of the areas concerned situated in the L'Isle-Verte cove. These changes are probably due to an overestimation of cropland in 1990–1991.

Also, 27 ha classified as built-up areas in 1990–1991 are identified as wetlands in 2000–2002. This is clearly due to an overestimation of built-up areas in 1990–1991. In addition, 22 ha classified as forests in 1990–1991 became wetlands in 2000–2002. The wetlands in question (low marshes, saltmeadows and bogs) are concentrated on the point near Île Ronde. A classification error on the 2000–2002 map appears to be the reason for this discrepancy.

Lastly, 18 ha of fallow land were transformed into wetlands (low marshes and saltmeadows) in an area east of the mouth of Rivière Verte. An incorrect classification in 1990–1991 may be responsible.

83 Results of Kappa agreement analyses for the lower estuary

Between 1990–1991 and 2000–2002

Index	Value
Kappa	0.84
KHisto	0.93
KLoc	0.90
Fraction correct	0.92
Fuzzy Kappa	0.69
Fuzzy fraction correct	0.93

Environment Canada Environnement Canada