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Denis Lehoux

Use of various habitat types by nesting ducks on islands in the St. Lawrence River between Montréal and Trois-Rivières

Occasional Paper
Number 87
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Environment Canada
Environnement Canada
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Service canadien de la faune

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Aussi disponible en français

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Cover photo: Gadwall nest (Luc Bélanger)

Published by Authority of the
Minister of Environment
Canadian Wildlife Service

Catalogue No. CW69-1/87E
ISBN 0-662-22982-7
ISSN 0576-6370

Canadian Cataloguing in Publication Data

Bélanger, Luc, 1958–

Use of various habitat types by nesting ducks on islands in the St. Lawrence River between Montréal and Trois-Rivières

(Occasional paper, ISSN 0576-6370; no. 87)
Issued also in French under title: L'utilisation de divers habitats par les anatinés en période de nidification, les îles du fleuve Saint-Laurent situées entre Montréal et Trois-Rivières.
Includes bibliographical references.
ISBN 0-662-22982-7
Cat. no. CW69-1/87E

1. Water birds — Habitat — Quebec (Province) — Saint Lawrence River.
2. Wetland conservation — Quebec (Province) — Saint Lawrence River.
3. Birds, Protection of — Quebec (Province) — Saint Lawrence River.
I. Lehoux, Denis.
II. Canadian Wildlife Service.
III. Title.
IV. Series: Occasional paper (Canadian Wildlife Service); no. 87.

QL685.5Q8B54 1995 598.29'24 C95-980078-6

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Occasional Papers report the results of original research carried out by members of the Canadian Wildlife Service or supported by the Canadian Wildlife Service. Occasional Papers have been subjected to external peer review.

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Publications
Canadian Wildlife Service
Environment Canada
Ottawa, Ontario
K1A 0H3
(819) 997-1095

Aussi disponible en français sous le titre *L'utilisation de divers habitats par les anatinés en période de nidification : les îles du fleuve Saint-Laurent situées entre Montréal et Trois-Rivières*

95-09

Abstract

Studies published in the late 1970s and early 1980s have provided us with a better understanding of waterfowl nesting on islands in the St. Lawrence River between Montréal and Trois-Rivières. The objective of our study was to describe the use of the islands by dabbling ducks and to assess the role of habitat characteristics (e.g., area, plant cover, human activities) in the selection of the islands by waterfowl. Our study was also designed to compare the value of the islands as waterfowl nesting sites and to identify those islands of highest priority for conservation efforts. Finally, we wished to develop management criteria (i.e., size, shape, plant cover, and location) for the construction of new islands in the St. Lawrence River using dredged material.

In total, 831 dabbling duck nests were inventoried on the islands where surveys had been conducted in the late 1970s. Gadwall *Anas strepera* and Northern Pintail *A. acuta* nests were the most numerous, accounting for 29% and 23%, respectively, of the total number of nests counted. An average of 8.9 nests was counted per island, for an average density of 1.3 nests/ha. However, as only one inventory was conducted at each site, this figure represents the minimum density. Nest density declined as the size of the islands increased ($p \leq 0.05$), with the most productive islands being smaller than 0.5 ha. In contrast, the shape of the islands had little impact ($p > 0.05$); as well, the location of the islands did not seem to be an important factor, as there was no correlation between the distance of the islands to the mainland or to the St. Lawrence shipping channel and density or total number of nests ($p > 0.05$).

Approximately 73% of the nests were found in tall grasslands, 11% in short grasslands, and 14% in forest areas. No nests were found in scrubland, although the total area of scrubland inventoried was very small. Most of the nests (>50%) were found in plant communities in which reed canary grass *Phalaris arundinacea* was the dominant species; the average density was 0.6 nests/ha. High nest densities were also found in a number of other tall grass communities, including Canada blue-joint grass *Calamagrostis canadensis*, goldenrod (*Solidago* spp.) and milkweed (*Asclepias* spp.). The lowest nest density was observed in common timothy (*Phleum pratense*). Both the total number of nests and nest density increased ($p \leq 0.05$) as the percentage of the island covered by tall grasses increased. Higher productivity was observed on islands where 75% or more of the total area was covered by tall grasses. The presence of marshes with emergent or submerged vegetation around the islands had little impact on habitat use by dabbling ducks ($p > 0.05$).

The size of the islands, the length of island shoreline, the proportion covered by tall grasses, and the presence of larid colonies had a positive impact on the selection of the islands for nesting ($p \leq 0.05$). In contrast, the proportion of the islands covered by short grasses and the presence of human activities (particularly agriculture) resulted in reduced use ($p \leq 0.05$). Four of these factors account for close to 65% ($r = 0.8$; $p \leq 0.0001$) of the variation in the number and density of nests on the islands in our study area.

Because more than 30% of the islands are privately owned, we classified them according to conservation priority. The index used was based on density of nests on each island in relation to the average nest density established for all the islands in the study area and for the islands of each archipelago or sector. Conservation efforts should focus on 68 of the 224 islands in the study area (for a total area of more than 2000 ha) during the waterfowl nesting season.

Finally, on the basis of our results, we suggest that any islands constructed in the St. Lawrence River using dredged material should be between 0.5 and 1.5 ha in size. We recommend that the smaller islands (0.5 ha) be round and that the larger islands (> 0.5 ha) be rectangular. The islands should be constructed more than 200 m from the mainland and at least 100 m from other islands. We recommend that tall grasses be the primary plant cover, covering more than 75% of the total area of the new islands, with reed canary grass being the dominant species.

Acknowledgements

We thank Alain Demers, Claude Grenier, André Lachance, Nathalie Poirier, and Monique Salat, who were involved in data entry, map planimetry, and interpretation of aerial photographs, and Alain Cossette and Claude Grenier, who prepared the figures for this paper.

We also wish to thank Jacques Bélanger (Environment Service, Quebec Department of Transport) and Sylvie Desjardins and Louis-Marc Soyez (Wildlife Management and Harvesting Service, Quebec Department of Environment and Wildlife, Montréal Region) for providing us with unpublished data on waterfowl nesting on a number of islands in the Montréal region.

Finally, we thank Daniel Bordage and Jean-Pierre Savard (Canadian Wildlife Service, Quebec Region) and André Breault (Canadian Wildlife Service, Western Region) for their comments on the preliminary draft of this paper. This study was made possible by a service contract awarded to Denis Lehoux by the St. Lawrence Centre (Environment Canada).

This publication was produced by the Scientific and Technical Documents Division of CWS. The following people were responsible: Pat Logan, Chief — coordination and supervision; Sylvie Larose, Computer Publishing Specialist — layout; Marla Sheffer, Contract Editor — scientific editing; and Mark Hickson, Acting/Production Officer — printing.

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1.0 Introduction

The use of natural and human-made islands as nesting sites is common in Canada Geese *Branta canadensis* (Vermeer 1970a; Giroux 1981; Giroux et al. 1983; Reese et al. 1987) and many species of dabbling ducks, particularly Gadwalls *Anas strepera* and Mallards *A. platyrhynchos* (Duebbert 1966; Young 1968; Drewien and Fredrickson 1970; Vermeer 1970b; Duebbert et al. 1983). This phenomenon is attributable to the expanse of open water around islands, which limits access to the islands by terrestrial predators (Hammond and Mann 1956). It is believed that the more distant spacing of nests on the mainland is an evolutionary mechanism that minimizes the impact of predation (see Hill 1984). Because such a mechanism is less critical on islands, nest density and nesting success are generally higher (Johnson et al. 1978; Hines and Mitchell 1983; Piest and Sowls 1985). Lokemoen and Woodward (1992), for example, reported that nesting success was four times higher on islands than on the mainland (62% and 16%, respectively).

It is not surprising, then, that the construction of islands is considered an important management tool for compensating for habitat losses in both Europe (Mihelsons et al. 1967) and North America (Hammond and Mann 1956; Bellrose and Low 1978; Giroux 1981), including Quebec (Bélanger and Tremblay 1989). However, owing to the high cost of constructing islands, one of the most effective approaches to habitat management, from both an environmental and economic perspective, is increasingly considered to be the conservation and restoration of natural islands (Lokemoen and Woodward 1992).

The St. Lawrence River, gulf, and estuary are a major migration route for ducks and geese. It is estimated that more than one million birds use this route at various times during the year (Lehoux et al. 1985). The St. Lawrence is also a very important breeding area for many species. For instance, it is estimated that more than 2000 broods of dabbling ducks are produced annually within a 100-km radius of Montréal (D. Lehoux, unpubl. data). The freshwater portion of the St. Lawrence River (from Cornwall to Trois-Rivières) contains several archipelagos totalling a few hundred islands (Fig. 1), many of which are used extensively by waterfowl during the breeding season. For example, more than 150 nests (primarily Gadwall nests) were inventoried on St-Ours Island in the Contrecoeur archipelago (Cantin and Ringuet 1978). Thompson (1974) reported heavy use of the Christatie islands in Lake Saint-François, particularly by Redheads *Aythya americana*, and Pilon et al. (1980, 1981) reported heavy use of several islands in the Berthier–Sorel, Boucherville, Varennes, and Sainte-Thérèse archipelagos as nesting sites by Northern Pintails *Anas acuta*, Mallards, and Gadwalls. Finally, inventories conducted on islands in the major bodies of water in the Montréal area (Lake Saint-Louis, Lake des Deux-Montagnes, and the LaPrairie basin) revealed that several of the islands, particularly the Paix Islands, generally had high potential as waterfowl nesting sites (Laperle 1974; Dimension Environnement Ltée. 1982).

Because the above data are taken from different studies, it is difficult to assess the relative importance of each of the islands and to develop a comprehensive conservation plan aimed at ensuring more effective protection of the islands. In addition, although the use of the islands by nesting waterfowl is determined by the biophysical characteristics of the islands themselves, the above studies often examined the relationship between the use of the islands by ducks and the characteristics of the islands only in a fragmented way.

In light of the need to focus conservation and management initiatives aimed at waterfowl habitat in this portion of the St. Lawrence River, the primary objective of this study was to describe the use of the islands by nesting waterfowl and to determine the biophysical characteristics of the islands (e.g., size, plant cover, human activities) influencing such use. The study was also designed (1) to compare the relative value of the various islands as waterfowl nesting sites and to inventory those islands of highest priority in terms of protection efforts; and (2) to define the management criteria (i.e., size, shape, plant cover, and location) for any islands that might be constructed using dredged material.

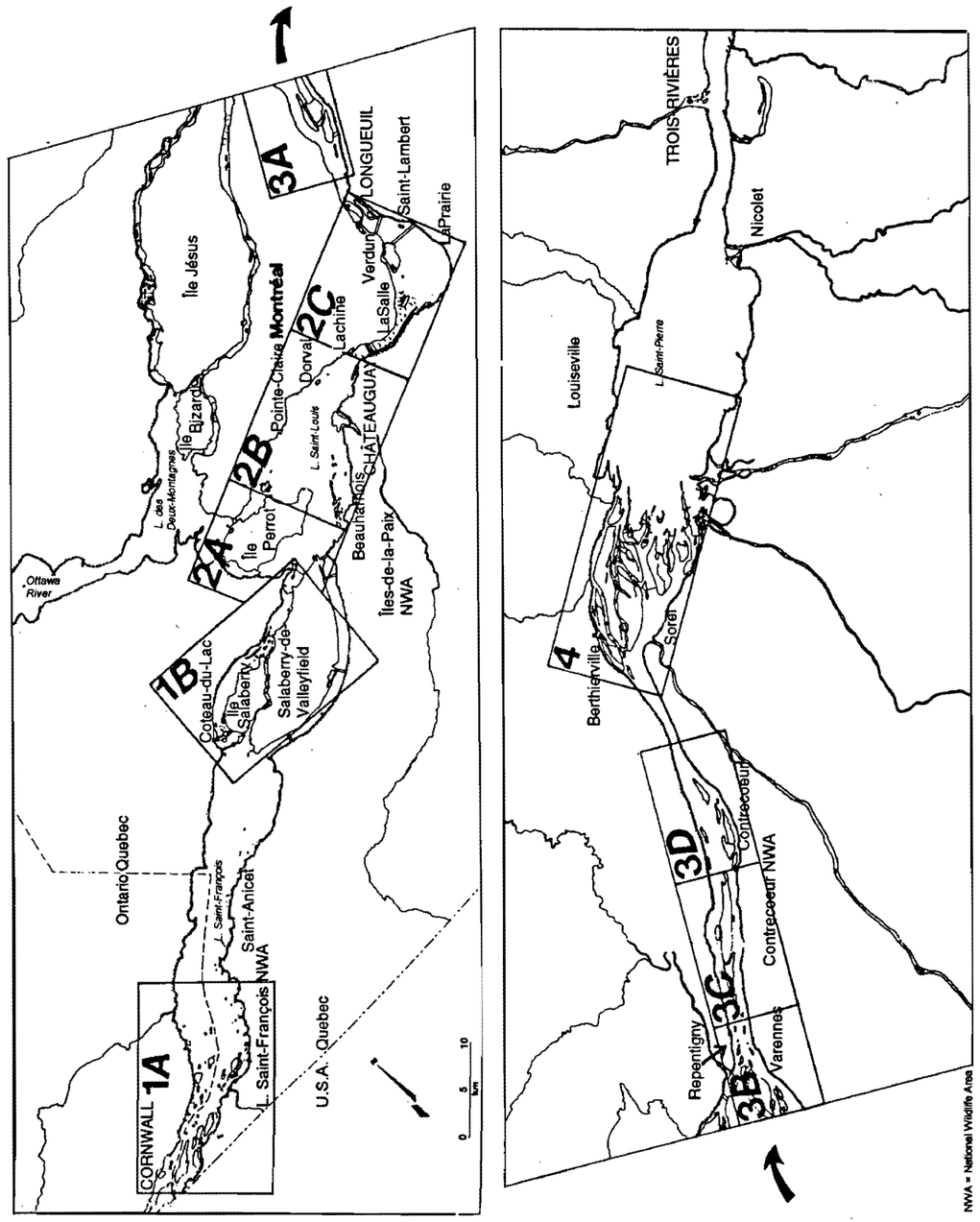


Figure 1
Location of the various archipelagos in the St. Lawrence River

2.0 Study area

The freshwater portion of the St. Lawrence River extends over 230 km in the province of Quebec (Fig. 1). It is unaffected by tides, and its salinity is only 0.1 mg/L. In the spring, the islands may be flooded, either totally or partially, depending on the year.

The study area is limited to that portion of the St. Lawrence River between Trois-Rivières and Montréal (Fig. 1). It contains 224 islands, which belong to six separate archipelagos: Boucherville (Sector 3A), Varennes and Sainte-Thérèse (Sector 3B), Verchères (Sector 3C), Contrecoeur (Sector 3D), and Berthier–Sorel (Sector 4). We also examined all islands in major bodies of water in the Montréal area — namely, Lake Saint-Louis (Sectors 2A–2B, which include the Paix Islands), the LaPrairie basin, and the Lachine rapids (Sector 2C). Given the lack of detailed ecological maps and data on the number of nests, the islands in Lake Saint-François (Sectors 1A–1B) and Lake des Deux-Montagnes (Sector 2A) were not included in the study.

Owing to the proximity of large urban centres and the presence of intensive agricultural practices on nearby shores, many of the islands in the study area have long been the site of human activity. Farming activities are carried out on 53 of the 224 islands, specifically the Boucherville, Varennes, Sainte-Thérèse, Verchères, and Berthier–Sorel islands. The most common agricultural use is community pasture. In addition, small cottages and fishing and hunting lodges have been built on many of the islands, and year-round residences have been constructed on islands that are accessible by road, such as the large islands located in the western part of the Berthier–Sorel archipelago.

The St. Lawrence shipping channel allows the passage of high-tonnage vessels to the Great Lakes. The rapid succession of vessel-generated waves results in the erosion of the most exposed shorelines (D'Agnolo 1978; Pilon et al. 1980, 1981; Bertrand et al. 1991). Ice movement, high spring water levels, and trampling by cattle (D'Agnolo 1978) also erode the shoreline.

3.0 Methods

The first step consisted of establishing the biophysical characteristics of the islands in the study area through the use of photo-interpretation. For only those islands on which nest inventories had already been conducted, we attempted to determine the habitat characteristics that seemed to influence the use of the islands by waterfowl. The biophysical characteristics considered included the size, shape, plant cover, and location of the islands, as well as the presence or absence of a gull or tern colony and the extent of human activity. A detailed list of the variables is presented in Table 1. For the islands in Sectors 3 (A–D) and 4, we used the ecological map (1:20 000) produced by the Centre de recherches écologiques de Montréal (Pilon et al. 1980, 1981). For Sector 2 (A–C), we used phytosociological maps (1:10 000) produced for Hydro-Québec and the former Quebec Department of Recreation, Fish and Game as part of Projet Archipel (Dryade 1983). Through the analysis of black and white 1983 photographs (1:20 000) of the entire river proper, (available from the Quebec Department of Energy and Resources), we were able to complete our information on some of the biophysical features of the islands, particularly the extent of human activity.

Table 1
Variables, abbreviations, and units of measurement used in the study

Characteristic	Variable	Unit of measurement
Physical description	Size of the island (SUPTOT)	ha
	Perimeter (PERIM)	km
	Exposed area (EXOND)	ha
	Area of an inside 100-m-wide strip (PRO100)	ha
	Coefficient of sinuosity (CS)	n.a.
Plant cover	Area of tall grasslands (HAUTE)	ha
	Area of short grasslands (BASSE)	ha
	Area of scrubland (ARBUS)	ha
	Area of forestland (ARBRE)	ha
	Area of bare ground (PLAGE)	ha
	Area of marshland with emergent vegetation within a 1-km radius (EMERG)	ha
	Area of marshland with submerged vegetation within a 1-km radius (SUBM)	ha
Location	Distance from mainland (DRIV)	km
	Distance from shipping channel (DVOIE)	km
Other	Presence of a gull or tern colony (COL)	n.a.
	Human disturbance (PERTUR)	n.a.
	Area of agricultural land (CULT)	ha
	Inhabited area (HAB)	ha

n.a. = not applicable.

3.1 Physical characteristics and location of the islands

Five variables were measured using the above-mentioned maps (Table 1) to determine the physical appearance of each island: total area at low-flow conditions, the perimeter (length of the shorelines), area exposed during floods, the area of an inside 100-m-wide strip around the edge of the entire island, and the sinuosity of the shoreline.

The last two variables mentioned are, in fact, different measurements or estimates of the shape of the islands, which indicate the portion that is likely to be the most attractive to nesting waterfowl. It is generally recognized that dabbling ducks build their nests less than 100 m from the shoreline (Bellrose 1976), which suggests that, for a given area, an elongated island will be more extensively used than a round or square island, for example. As a result, we determined the proportion of each island located less than 100 m from the water. Moreover, as Hammond and Mann (1956) reported that a higher shoreline length to land area ratio resulted in a larger number of nesting sites owing to increased visual isolation of waterfowl, we also calculated the coefficient of sinuosity of the shorelines. This coefficient is the ratio between the size and the perimeter of an island (see Lind 1979 for details on the calculation). It can be used to obtain a quantified indicator of the shape of the island. The closer the value is to zero, the rounder the island tends to be. Conversely, the farther the value is from zero, the more elongated the island tends to be.

The exposed area of the islands corresponds to the level of the two-year floods. It was calculated on the basis of maps produced by Pilon et al. (1980, 1981). We also examined two aspects of the location of the islands: their distance from the mainland and their distance from the shipping channel. In both cases, the shortest distance between the two was retained for purposes of analysis. Finally, given that we were interested in assessing the significance of the presence of marshes around the islands, we established the total area of marshland (with emergent and submerged vegetation) within a 1-km radius of the shoreline of each island in the study area.

It should be noted that the islands of the St. Lawrence are also used as nesting sites by other species of birds, particularly colonial nesters, such as gulls and terns (Lagrenade and Mousseau 1981; Mousseau 1984; P. Brousseau, Canadian Wildlife Service, pers. commun.) and herons (Black-crowned Night-Heron *Nycticorax nycticorax* and Great Blue Heron *Ardea herodias*) (Tremblay and Bélanger 1989). The presence or absence of a colony (i.e., at least five nests) of Ring-billed Gulls *Larus delawarensis* or Common Terns *Sterna hirundo* was noted for each island in the study area.

3.2 Nesting cover and vegetation

The proportion of each island covered by vegetation was established on the basis of the previously mentioned ecological and phytosociological maps. The designation of the cover types in the literature was based on dominant and codominant species within the plant communities, as determined using Braun-Blanquet's (1965) method. Vegetation on the islands was classified according to structure or physiognomy. The cover types considered were tall grasslands, short grasslands, scrubland, and forestland, which are defined in the literature as follows. *Tall grasslands* contain less than 10% shrubs, trees or stands of trees that are very isolated from one another or virtually lacking, and herbaceous plants that reach a height of over 50 cm. A *short grassland* is a plant community in which herbaceous plants are less than 50 cm in height. In our study area, the plant cover in most cases consisted of natural grasslands utilized by cattle for grazing. An area is said to be *scrubland* when shrubs cover 10–50% of the area. It is considered *forestland* when trees cover more than 10% of the area.

3.3 Human activity on the islands

Human activity on the islands was first assessed quantitatively. We determined the proportion of each island used for agricultural purposes and the proportion occupied by year-round residences (e.g., cities, towns, small centres). Using black and white 1983 aerial photographs (scale of 1:20 000) (available from the Quebec Department of Energy and Resources) and the description of the use of the islands provided by Pilon et al. (1980, 1981), we then assessed, with a qualitative index, the degree of disturbance associated with the various types of human activity observed on the islands. The following four categories were established: A — no human presence, i.e., no residential, industrial, or agricultural infrastructures or activities; B — presence of a few seasonal residences, i.e., cottages and/or hunting and fishing lodges; C — presence of many cottages or use of the island for pasture; and D — presence of year-round residences (cities, towns, etc.) or cropland.

3.4 Relative abundance of dabbling ducks and nest density

The data on waterfowl nesting on the islands in Sectors 3 and 4 were taken from Pilon et al. (1980, 1981) and, in the case of several of the Contrecoeur islands, from Cantin and Ringuet (1978). For Sector 2, we used the results of inventories conducted by Dimension Environnement Ltée. (1982). For islands in the LaPrairie basin, we used unpublished data (L.-M. Soyez and S. Desjardins, Wildlife Management and Harvesting Service, Quebec Department of Environment and Wildlife, Montréal Region) and the results of inventories conducted by Dimension Environnement Ltée. (1982).

Inventories were conducted between 1975 and 1980 on 104 of the 224 islands in the study area. However, only 77 of the islands were covered in their entirety. The same technique was used on all islands: observers conducted systematic searches for nests on foot, beating the vegetation with long stakes to frighten the females from the nests.

A bias is doubtless associated with the fact that we used data collected in different years, as the extent of

waterfowl use of certain islands may have varied depending on the annual conditions, such as the severity and duration of spring floods in relation to the nesting period of early nesters. In addition, in most of the studies consulted, the inventories involved only one visit to each island during the nesting season. However, given that flood conditions have been quite similar from one year to the next and there has been very little change in habitats, we believe that our results provide a fairly accurate picture of the relative use of the islands by waterfowl. This database clearly underestimates the actual number of nests on the various islands. Nonetheless, it provides a basis for comparing the relative value of the islands as waterfowl nesting sites.

3.5 Analysis of the data

The data were analyzed using SAS software (SAS Institute, version for microcomputers), in accordance with the method described by Scherrer (1984). The normality of the distribution of the different variables was verified using the Shapiro-Wilk test, and a logarithmic or hyperbolic transformation was used where needed. The degree of relationship between the dependent variable (total number of nests or nest density) and the independent variables (habitat characteristics) was determined using simple Pearson correlations, followed by multiple sequential regression analysis. The collinearity of the independent variables was verified using the correlation matrix (threshold of 0.9); correlated variables were then eliminated from the subsequent analyses. The validity of the regression model obtained was verified through a study of the residuals. Finally, the comparison of the categories or status of a given variable (e.g., the size of the islands) was performed using the Kruskal-Wallis test, followed by the Noether multiple comparison test (see Scherrer 1984).

4.0 Results

4.1 Habitat characteristics

The biophysical characteristics of the islands in the St. Lawrence River between Montréal and Trois-Rivières vary widely (Table 2). The islands range in size from 0.1 ha to more than 1800 ha, with the average being 57.9 ha. The plant cover is highly diversified and can differ significantly from one archipelago to another and from one island to another within the same archipelago. In general, the vegetation is composed primarily of tall grasslands, which cover on average 38% of the total area of the islands. The dominant species include reed canary grass *Phalaris arundinacea* and Canada blue-joint grass *Calamagrostis canadensis*. The short grasslands, which are composed primarily of Kentucky bluegrass *Poa pratensis*, redtop *Agrostis alba*, couch grass *Agropyron repens*, and red fescue *Festuca rubra*, cover 14% of the area of the islands on average. Finally, trees and shrubs cover approximately 41% of the total area of the islands (Table 2). The main species are silver maple *Acer saccharinum*, black willow *Salix nigra*, sandbar willow *S. interior*, and crack willow *S. fragilis*. The periodicity of floods and the accessibility of the islands by road (e.g., bridges, ferries, barges) largely affect both the type of vegetation present and the use of the islands for residential, agricultural, or other purposes. On average, 36% of the area of the islands is completely flooded every year. However, in some sectors, such as the LaPrairie basin, the water level is regulated by a system of locks. An average of close to 5% of the area of the islands is used for agricultural purposes, and less than 1% is occupied by year-round residences or cottages. These figures vary considerably from one island to another (Table 2).

4.2 Use of the islands by waterfowl

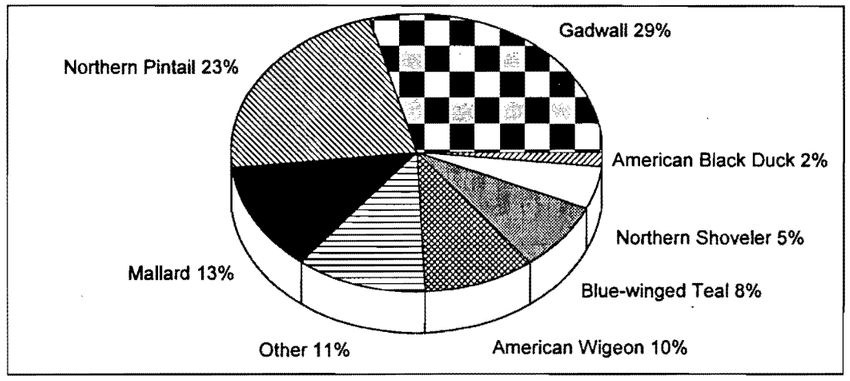
In our study, we inventoried 831 dabbling duck nests on all of the islands. However, the species and the location of the nest in relation to the shoreline were recorded for only 545 of the nests. Eleven species of dabbling ducks nest on the islands in the study area (Fig. 2). Gadwall and Northern Pintail nests were the most numerous, accounting for 29% and 23%, respectively, of the total number of nests counted. Mallard nests accounted for 13% of the total. The nests of the other

Table 2
Biophysical characteristics of islands in the St. Lawrence River between Montréal and Trois-Rivières, Sectors 2, 3, and 4 (see Fig. 1)

Characteristic	Average	Minimum	Maximum
Size and shape			
SUPTOT[a] (ha)	57.9	0.1	1816.0
PERIM (km)	2.9	0.1	33.7
Vegetation			
HAUTE (%)	38.3	0.0	100.0
BASSE (%)	14.0	0.0	100.0
ARBUS (%)	0.8	0.0	49.4
ARBRE (%)	39.9	0.0	100.0
PLAGE (%)	1.4	0.0	100.0
Human activity			
CULT (%)	4.7	0.0	92.2
HAB (%)	0.9	0.0	74.0

[a] For further details on the abbreviations and units of measurement, see Table 1.

Figure 2
Relative abundance of species for which nests were identified on islands in the St. Lawrence River between Montréal and Trois-Rivières



species each accounted for less than 10% of the total, and American Black Duck *Anas rubripes* nests accounted for only 2% of the total. The nests were generally located less than 100 m from the water (average of 75.8 m). This distance did not vary from one species to another ($p > 0.05$).

An average of 8.9 nests was counted on each island, or 1.3 nests/ha. This figure, which represents the average nest density, varied from sector to sector (Fig. 3). The Contrecoeur Islands (Sector 3D) had the highest nest density, with close to 3.3 nests/ha. The Boucherville and Sorel islands (Sectors 3A and 4, respectively) had the lowest nest densities, with 0.16 nests/ha.

4.3 Physical description and location of the islands

The size and perimeter of the islands and the area of marshes with emergent vegetation surrounding them had a positive influence on the use of the islands as breeding sites by waterfowl ($p \leq 0.05$) (Table 3). Although the total number of nests generally increased as the size of the islands increased, we did not observe significant differences among the various islands ($p > 0.05$) (Fig. 4), with some large islands being used to a small extent or not at all. In contrast, nest density decreased as the size of the islands increased ($p \leq 0.05$), with the most productive islands being smaller than 0.5 ha (Fig. 4). The location of the islands in relation to the mainland or the seaway did not seem to affect ($p > 0.05$) the use of the sites by waterfowl (Table 3), nor did the proportion of the total island area located less than 100 m from the water. Islands for which more than 60% of the total area was less than 100 m from the water did, however, appear to have a higher nest density. The same is true of islands with a coefficient of sinuosity less than or equal to 1.0.

4.4 Plant cover

The total number of nests and nest density increased as the proportion of tall grass cover increased ($p \leq 0.5$) and decreased as the percentage of short grass cover increased ($p \leq 0.05$) (Table 3). The islands for which more than 75% of the total area was covered by tall grassland were used more extensively than the others (Fig. 5). In fact, 73% of the nests inventoried were in tall grasslands, compared with only 11% in short grasslands and 14% in forestland (Table 4). No nests were inventoried in scrubland, although inventories in this type of cover were very limited in scope (14.5 ha, Table 4). Fewer than 1% of the nests were observed on farmland (ploughed fields and hay fields) or in emergent marshland

Figure 3
Average nest density in the various archipelagos in the St. Lawrence River between Montréal and Trois-Rivières

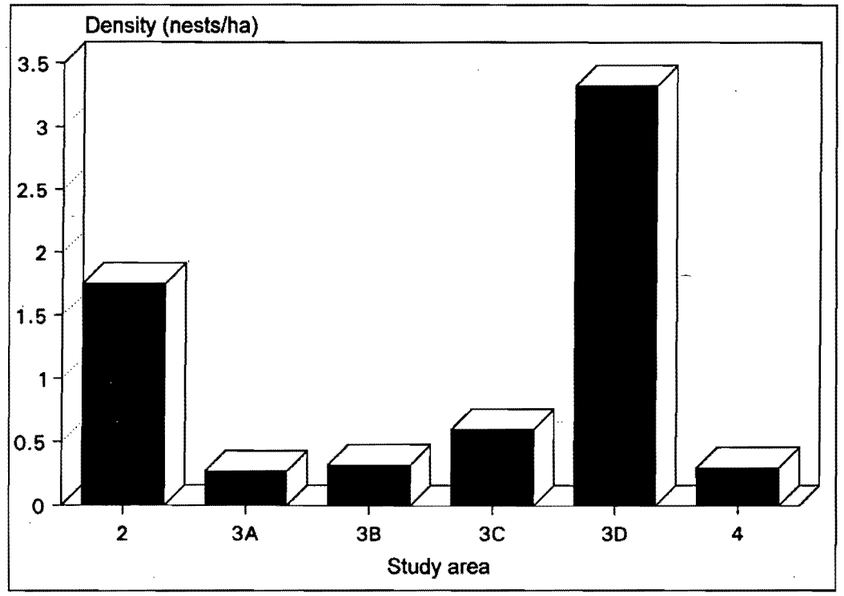


Figure 4
Total number and density of nests in relation to the size of the islands in the freshwater portion of the St. Lawrence River

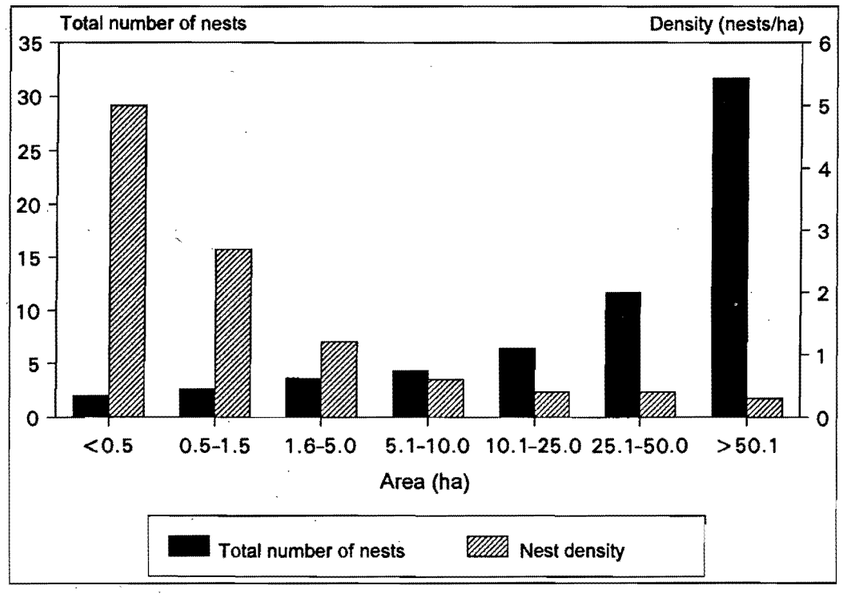


Figure 5
Total number and density of nests in relation to the proportion of the islands covered by tall grasslands

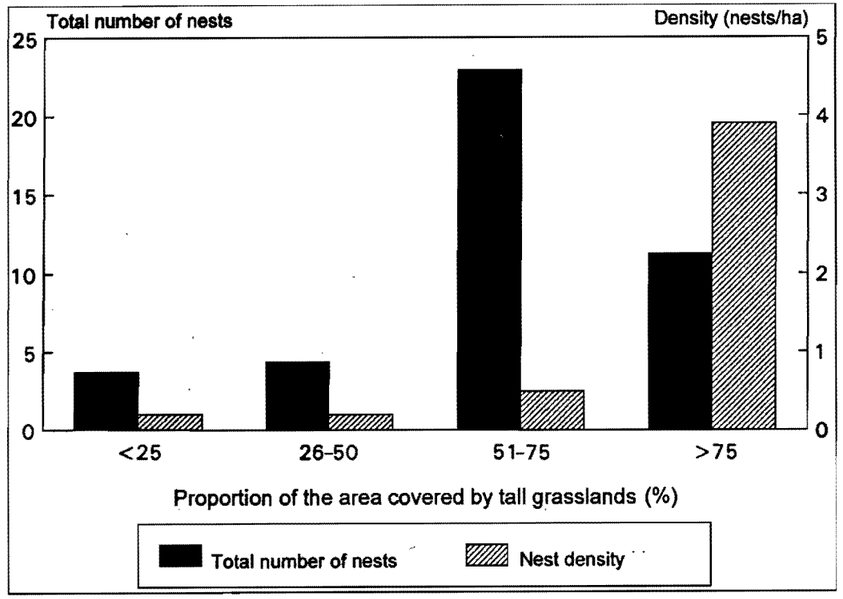


Table 3
Simple linear correlation between the use of the islands by dabbling ducks and the biophysical characteristics of the islands (n = 77)

Characteristic	Value of the coefficient: Total number of nests	Value of the coefficient: Nest density (nests/ha)
Physical description and location		
SUPTOT[a]	0.32[b]	−0.23[c]
PERIM	0.23[c]	−0.19[c]
EXOND	−0.09	−0.25[c]
CS	−0.04	−0.12
DRIV	−0.01	−0.04
DVOIE	−0.13	−0.20
Vegetation		
HAUTE[e]	0.62[d]	0.63[d]
BASSE[e]	−0.28[b]	−0.37[b]
ARBUS[e]	0.16	−0.02
ARBRE[e]	0.14	−0.06
PLAGE	0.15	0.01
EMERG	0.31[b]	0.03
SUBM	0.13	0.12
Human activity		
CULT	0.07	−0.03
HAB	0.06	0.05

[a] For further details on the abbreviations and units of measurement, see Table 1.
[b] $p \leq 0.01$.
[c] $p \leq 0.05$.
[d] $p \leq 0.001$.
[e] n = 62.

vegetation (Table 4), although only 19 ha of cropland were inventoried.

Most nests (> 50%) were observed in plant complexes in which reed canary grass was the dominant species, with an average nest density of 0.6 nests/ha (Table 4). Other tall grass communities, some in association with reed canary grass, also had high nest densities. They were composed primarily of Canada blue-joint and various species of goldenrod and milkweed, such as Canada goldenrod *Solidago canadensis* and common milkweed *Asclepias syriaca*. The inventories conducted in these communities covered a relatively small area (Table 4). The lowest nest density in tall grass communities was observed in common timothy *Phleum pratense* (Table 4).

Overall, the nest densities in short grasslands and forestland were much lower than in tall grasslands. However, in a number of individual communities, nest densities were comparable to and even higher than those in tall grasslands (Table 4). For example, in rice cutgrass *Leersia oryzoides* communities, which accounted for only 0.3% of the total area inventoried, the nest density was 1.6 nests/ha. Once again, too few inventories were conducted in the other short grass communities, such as communities dominated by switch grass *Panicum virgatum* and dandelion *Taraxacum officinale*, to allow us to draw definitive conclusions about their value as nesting cover (0.7 and 0.6 ha, respectively) (Table 4). In forestland, stands dominated by willow (*S. fragilis*, *S. amygdaloides*, and *S. nigra*) had nest densities of 0.3–0.6 nests/ha, whereas most stands dominated by other species had nest densities equal to or less than 0.2 nest/ha (Table 4).

4.5 Human activities and other factors

We observed no direct statistical relationship between the proportion of the islands used for agricultural purposes or occupied by year-round residences and the use of the islands by waterfowl ($p > 0.05$) (Table 3). However, using the index of disturbance mentioned previously, we observed that the islands on which there

Figure 6
Total number and density of nests in relation to the presence or absence of a gull or tern colony

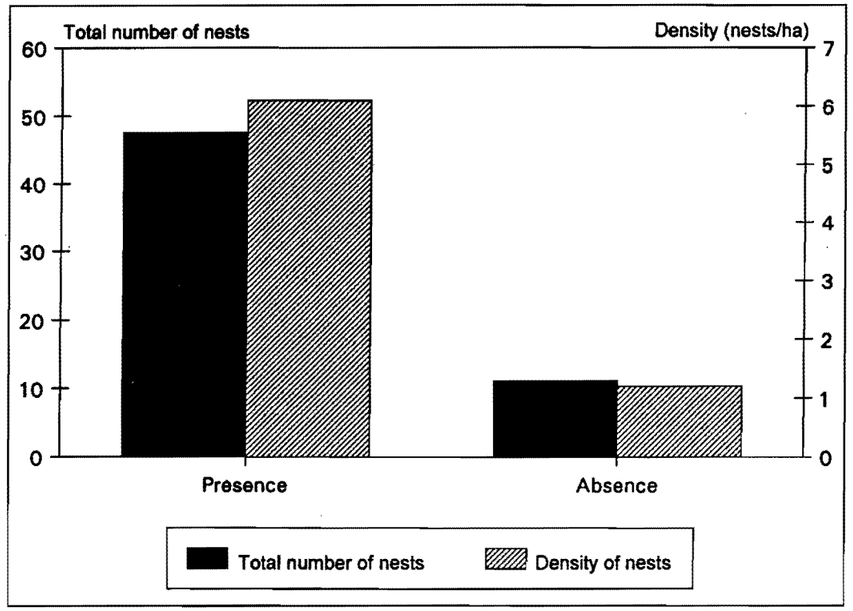


Table 4
Dabbling duck nest density according to the different cover types present on the islands in the study area

Community	Nests No.	Nests %	Areas inventoried ha	Areas inventoried %	Density nests/ha
Tall grassland	268	73.0	512.9	28.2	0.5
As[a]	11	3.0	8.7	0.5	1.3
Cc	18	4.9	19.0	1.1	1.0
Pa	185	50.4	327.5	18.0	0.6
Pa Cc	13	3.5	25.7	1.4	0.5
Ph Pop	2	0.5	45.5	2.5	<0.1
Pa So	2	0.5	0.8	0.1	2.5
Other	0	0.0	50.4	2.8	0.0
Short grassland	41	11.2	367.5	20.3	0.1
Aa	3	0.8	79.0	4.4	<0.1
Aa Pop Fr	16	4.4	85.9	4.7	0.2
Ar Pop	37	10.1	35.3	1.9	1.1
Lo	9	2.5	5.7	0.3	1.6
Pop	7	1.9	29.7	1.6	0.2
Pv	5	1.4	0.7	<0.1	7.1
To	1	0.3	0.6	<0.1	1.7
Other	0	0.0	165.9	9.1	0.0
Forestland	50	13.7	285.3	15.7	0.2
As Lc	1	0.3	11.5	0.6	<0.1
As Lc Pa	2	0.5	59.5	3.3	<0.1
As Pa	8	2.2	35.6	2.0	0.2
As Pa Lc	8	2.2	8.1	0.5	1.0
As Pa Lc Os	3	0.8	14.5	0.8	0.2
Fp	1	0.3	98.5	5.3	<0.1
Sfg	12	3.3	20.8	1.2	0.6
Smg	4	1.1	14.7	0.8	0.3
Sn	11	3.0	22.1	1.2	0.5
Scrubland	0	0.0	14.5	0.8	0.0
Marsh with emergent vegetation	6	1.6	615.4	33.9	0.1
Cropland	2	0.5	19.4	1.1	0.1

[a] For the codes of the plant species, see Appendix 1.

was little or no human activity were used more extensively by waterfowl than the islands on which there was heavier human activity ($p \leq 0.05$). We counted an average of 3.8 nests/ha on islands on which there was no human activity, compared with only 0.3 nests/ha (average of categories B, C, and D combined, as defined in Section 3.3) on the other islands. Finally, we observed that the number and density of nests were higher on islands that supported gull or tern colonies ($p \leq 0.05$) (Fig. 6).

4.6 Relative significance of the different variables

At this point in our analysis, we eliminated correlated variables and retained the following characteristics only: the size of the island, the proportion of the total area exposed during floods, the proportion of the island covered by tall grasslands, the area of marshes with emergent vegetation around the island, the presence of a gull or tern colony, and the index of human disturbance. These characteristics together account for close to 65% ($r = 0.8$; $p \leq 0.0001$) of the variation in both the number and density of nests on each island (Table 5), with tall grass cover having the most significant effect (39–40%; $p \leq 0.0001$). The other factors ($p \leq 0.05$) that most influence nest density are, in decreasing order of importance, the absence of human activity, the presence of a gull or tern colony, and the size of the island. In terms of the total number of nests, these variable are the size of the island, the absence of human activity, and the presence of a gull colony. The area of marshes with emergent vegetation and the area exposed had very little impact on the use of the islands by waterfowl.

Table 5
Principal biophysical features affecting the variation in the use of the island (n = 62) by nesting waterfowl

Dependent variable	Independent variable (% of variation)	r	p
Total number of nests	SUPTOT[a] (10)[b]	0.81	0.0001
	HAUTE (39)[b]		
	COL (4)[c]		
	PERTUR (9)[b]		
	EMERG (0)		
	EXOND (0)		
Nest density (nests/ha)	SUPTOT (3)[d]	0.80	0.0001
	HAUTE (40)[b]		
	COL (7)[b]		
	PERTUR (15)[b]		
	EMERG (1)		
	EXOND (0)		

[a] For abbreviations, see Table 1.
[b] $p \leq 0.0001$.
[c] $p \leq 0.01$.
[d] $p \leq 0.05$.

5.0 Discussion

5.1 Waterfowl species and nest density

Northern Pintails and Gadwalls were the two most abundant species nesting on the islands in the study area. Northern Pintails have long been recognized as a pioneering species — that is, they are opportunistic in their use of habitat (Hochbaum and Bossenmaier 1971; Johnson and Grier 1988). Lokemoen and Woodward (1992) observed no direct relationship between the nest density of this species and the features of insular habitats in North and South Dakota. This finding suggests that the species is not very demanding in selecting a nesting site. The Northern Pintail is one of the most abundant species in the Atlantic flyway (Bellrose 1976). In the spring and fall, it is found in very large numbers along the entire St. Lawrence River, or at least in the various sectors of our study area (Lehoux et al. 1985).

The heavy use of natural and human-made islands by Gadwalls and their tendency to nest in such habitats in large numbers are common phenomena in the prairies in western North America (Giroux 1981; Duebbert 1982; Duebbert et al. 1983; Wills and Crawford 1989; Lokemoen and Woodward 1992). This species is believed to be generally predominant on the islands because adult females and a few young females tend to return to their natal sites to nest (Lokemoen et al. 1990). It also has a large range and can travel large distances between its nesting sites and feeding areas.

Although Gadwalls arrived in Quebec less than 30 years ago (Cantin et al. 1976), the nest density of this species along the St. Lawrence River, particularly in the Contrecoeur islands (Cantin and Ringuet 1978), was already high by the late 1970s. The construction of islands in this area using dredged material is believed to have played a determining role in the spread of the species along the St. Lawrence valley (Cantin et al. 1976).

The low representation of American Black Ducks in our results indicates, as do other studies, that the population of this species or phenotypic race (see Ankney et al. 1986) is declining in eastern North America, particularly in southern Quebec and Ontario (Rogers and Patterson 1984). It may be that the habitats in our study area, in which grasses are the dominant species, are less attractive to species that seek forests for breeding (Bellrose 1976). It has, in fact, been demonstrated that American Black Ducks, like Mallards, nest in the stumps,

trunks, and forks of trees in flooded wooded areas (Cowardin et al. 1967; Laperle 1974; Dimension Environnement Ltée. 1982; Massé and Raymond 1988). The underrepresentation of that type of habitat (flooded forest areas and scrubland; see Table 4) in the inventories conducted on the islands may explain to some extent the underrepresentation of American Black Ducks in our results.

We also observed that several of the islands with high nest densities also supported colonies of gulls (*Larus* spp.) or terns (*Sterna* spp.). Duebbert (1982) reported that Gadwalls are very attracted to islands that support larid colonies. This phenomenon is believed to be attributable to the protection afforded by larids against predators, particularly avian predators, such as crows (*Corvus* spp.) (Dwernychuk and Boag 1972a; Schranck 1972; Sudgen and Beyersbergen 1987). Vermeer (1968) observed, in research in Alberta, that many other species, including Mallards, also tend to nest in close association with larid colonies. Duebbert (1982) advanced the theory that, although the nest density is probably highest at sites where this type of commensal relationship exists, nesting success is perhaps much lower, given the increased risk of egg and duckling predation by gulls. Vermeer (1968) observed California Gulls *Larus californicus* killing newly hatched ducklings. According to Dwernychuk and Boag (1972a), this commensal relationship is an ecological trap.

However, in a study of the diet of Ring-billed Gulls in the Couvée Island colony near Montréal (Sector 2C), Lagrenade and Mousseau (1981) observed no cases of egg or duckling predation by this species. More recent studies carried out in the Contrecoeur region (Sector 3D) confirmed that egg and duckling predation by Ring-billed Gulls was infrequent (J.-F. Giroux, University of Quebec at Montréal, pers. commun.). The same is true around Québec (P. Brosseau, Canadian Wildlife Service, Quebec Region, pers. commun.).

5.2 Physical description of the islands

On the basis of our study, we observed that nest density decreased as the size of the islands increased ($p \leq 0.05$), with the most productive islands being smaller than 0.5 ha (Fig. 4). Several studies carried out in western North America have also found that the size of islands is an important factor in the selection of nesting sites by waterfowl. They also showed that smaller islands generally have the highest nest densities. For example, the most productive islands in Alberta were 0.1 ha (Giroux 1981) and in North Dakota, 0.3 ha (Duebbert 1982). In Saskatchewan, Browne et al. (1983) reported heavy use of islands 0.4 ha in area, and Vermeer (1970b) reported a density of 4.6 nests/ha on islands in Alberta > 0.8 ha, and 24.4 nests/ha on islands ≤ 0.8 ha.

In a study of small human-made islands (0.1–0.5 ha) in the southern part of Lake Saint-Pierre (Quebec), Bélanger and Tremblay (1989) showed that islands over 0.2 ha in size attracted a larger number of dabbling ducks during the nesting period. In our own study, which included much larger islands (0.3–197 ha), we reached the conclusion that islands smaller than 5 ha were the most attractive to dabbling ducks owing to the virtual lack of predators. Duebbert (1982) reported that islands larger than 5 ha are more likely than smaller islands to support resident populations of predatory mammals. However, Lokemoen and Woodward (1992) and Wills and Crawford (1989) observed no significant correlation between the size of islands and the nest density of various species of ducks, with one exception: the nest density of Blue-winged Teals *Anas discors* increased as the size of the islands increased (Lokemoen and Woodward 1992).

The shape of the islands does not appear to have a significant impact on their use by waterfowl. Nonetheless, islands for which more than 60% of the total area is less than 100 m from the water do seem to have a higher nest density, as do islands whose coefficient of sinuosity is less than or equal to 1.0. On the basis of these findings, it is difficult to draw conclusions regarding the actual significance of this variable, as there is a close correlation between the shape and the size of the islands. In the case of a small island (≤ 0.5 ha), a larger proportion of the island is less than 100 m from the water, and the island is necessarily round in shape. The coefficient of sinuosity of its shoreline is low (<1.0). However, even after arbitrarily eliminating the smallest islands (< 1 ha) from our analysis to avoid this bias, we found no significant difference in the use of islands of various shapes ($p > 0.05$). Moreover, although some studies state that the shape of the island is an important factor in the selection of nesting sites by waterfowl (Hammond and Mann 1956; Giroux 1981; see also Section 5.3), to our knowledge there is little quantitative proof of this to date.

We observed that the location of the islands in relation to the mainland had no impact on their use by waterfowl. This phenomenon is clearly due to the fact that the majority of the islands in our study area are part of archipelagos — hence the lack of variation in the distance from the island to the mainland. However, Lokemoen and Woodward (1992) found more Gadwall nests on islands located farther from the mainland (average of 134 m) than on islands located close the mainland (average of 79 m). This phenomenon had previously been observed by Hammond and Mann (1956), Giroux (1981), and Duebbert et al. (1983).

Islands that are surrounded by marshes with emergent or submerged vegetation, and which are therefore suitable for the feeding and rearing of ducklings, are believed to be more desirable as nesting sites. For instance, Lokemoen and Woodward (1992) found a strong correlation between Gadwall and Mallard nest density and the presence of marshes around islands in North and South Dakota. In our study area, the insignificant impact of marshes around the islands on island use (only a low positive correlation was observed between the area of marshes with emergent vegetation and the use of the islands) (Table 3) could be attributable to the fact that the islands, which are part of archipelagos, are all located about the same distance from the largest marshes. We know that dabbling duck broods are mobile and can move about over distances of up to several kilometres (Thompson 1974). Gadwall and Northern Pintail broods are also known to cover distances of up to 1 km in the Contrecoeur islands (Sector 3D) (J.F. Giroux, University of Quebec at Montréal, unpubl. data).

5.3 Use of various cover types

It is well established that vegetation acts as a screen that protects female ducks and their eggs from terrestrial and avian predators and that isolates individuals from one another (Lokemoen et al. 1984). Dwernychuk and Boag (1972b), Schranck (1972), and Sudgen and Beyersbergen (1987) demonstrated that nesting success is highest in vegetative cover that provides the best camouflage. In all cases reported in the literature, camouflage is provided by grasses growing at a good height and in dense formations. It is not surprising, then, that the majority (73%) of the dabbling duck nests inventoried in our study were found in tall grasslands and that the area of the grasslands as a proportion of the total area had a significant impact on the use of the islands by waterfowl. Giroux (1981) also observed that duck nests on islands in Alberta were more numerous in tall grasslands than in other plant communities and that the larger the tall grasslands area, the higher the nest density.

Our study appears to indicate that scrubland in the study area is used to a very small extent by waterfowl as nesting sites. We should mention that the inventories conducted in scrubland covered a very small area, perhaps owing to the small area covered with scrubland (0.8% of the total area of the islands) and to the increased difficulty of conducting inventories in that type of vegetation. However, several authors (Townsend 1966; Drewien and Fredrickson 1970; Browne et al. 1983; Duebbert et al. 1983; Hines and Mitchell 1983; Lokemoen et al. 1984; Lokemoen and Woodward 1992) have described the value of scrubland as nesting sites for dabbling ducks, particularly if some of the shrubs are small.

5.4 Significance of human use of the islands

We have observed that waterfowl use islands on which there is little or no human activity (categories A and B, respectively, as defined in Section 3.3) more heavily than islands on which there is more extensive human activity (Categories C and D) and that, of all the different plant cover types studied — with the exception of scrubland, for which we have too few data — short grasslands are the least preferred by nesting waterfowl. On the islands in our study area, the vast majority of the grasslands are used as pasture (for cattle and sheep). The authors of studies conducted elsewhere in North America on the impact of cattle grazing during the waterfowl nesting period found that natural grasslands not utilized by cattle contain more nests than grazed pastures and that nesting success is higher in these grasslands (Glover 1956; Capel 1965; Kirsch 1969; Miller 1971; Higgins 1977; Kirsch et al. 1978; Kaiser et al. 1979; Klett et al. 1988). Burgess et al. (1965) were the only authors to find otherwise.

Contrary to the findings of Sayler (1962), the main explanation for the less extensive use of short grasslands by waterfowl is not believed to be related to the destruction of nests due to trampling by cattle, although nest losses may occur if the livestock density is too high (see Jensen et al. 1990). The major impact of the presence of cattle is more likely to be the degradation of nesting cover. Grazing alters species composition and reduces the abundance and height of annual vegetation and residual cover, which reduces the value of the nesting cover, particularly under conditions of very high grazing pressure (Kirsch 1969). Gjersing (1975) observed more abundant residual vegetation (or litter) and earlier spring growth in sectors that had not been grazed in the summer and fall prior to his study. He also found that breeding success, based on the number of breeding pairs and broods, was higher in these sectors. Finally, the presence of cattle is believed to have increased nest predation as an indirect effect. Capel (1965) observed that nests built near paths used by cattle suffered higher levels of predation than nests built at a distance from them.

5.5 Habitat features and use by waterfowl

The various biophysical features we examined for the islands in our study area can account for close to 65% of the variation in the total number of nests and in nest density. This result is similar to the 62–77%, depending on the type and location of the islands, obtained by Giroux (1981) in Alberta.

There are a number of factors that can explain why it is impossible to predict with 100% accuracy, using a multiple regression technique, the value of a dependent variable (in this case, the total number or density of nests) on the basis of independent descriptors related to habitat characteristics. The problem may be partially explained by the fact that there is some degree of imprecision in the various evaluation methods. By considering a given plant species to be part of a given physiognomic plant unit (within which all species have equal value as nesting cover), we may have introduced some degree of bias. Timothy, for example, is a tall grass, but it does not have significant value as nesting cover (see Table 4). Moreover, other less common cover types, such as woodlands composed of maple stands with a grass stratum composed of reed canary grass, form excellent nesting sites for waterfowl in our study area (L. Bélanger, pers. obs.). On the basis of the maps available, we were unable to distinguish between forests with clearings and dense forests or to determine the degree of vitality. Stands of dead trees, for example, represent better breeding sites than stand of healthy trees (see Dimension Environnement Ltée.1982), but such a distinction was not available for the entire study area. Similarly, the vegetation in a given community is seldom homogeneous, and small pockets of very different flora can exist alongside a particular microtopography. For example, in a number of short grasslands, clumps of tall grasses suitable for nesting were frequently found along small streams or in depressions.

Habitat degradation could have forced the birds to nest in alternative sites (stumps, branches, or forks of trees, artificial shelters, etc.) that are seldom, if ever, used when better habitats (i.e., tall grasslands) are available. Such a situation was observed at Lake Saint-Louis (see Laperle 1974; Dimension Environnement Ltée. 1982). Finally, the scarcity of good nesting sites in a given sector, combined with a high level of disturbance, may have forced the birds to use less suitable sites, which may or may not have been used in other sectors. In our view, this is what occurred on the islands in the LaPrairie basin (Sector 2C).

All things considered, a mathematical model, such as multiple regression, remains a simplified, relatively crude representation of reality. Particularly with applications in natural ecosystems, it is normal not to obtain a perfect representation, as too many factors are involved. In addition, many of the factors are difficult to assess or quantify (degree of accuracy of inventories, research effort in relation to the area or type of cover, and so on) or are, as in the present case, subject to a certain degree of bias inherent in the study framework itself (inventories conducted in different years, scale of precision of vegetation mapping, etc.). We are confident, however, that our study has clearly demonstrated the habitat characteristics that best explain the selection of the various islands in the St. Lawrence River by nesting waterfowl.

6.0 Conservation recommendations

In recent decades, more than 70% of the wetlands in the St. Lawrence system, from the Great Lakes to the gulf, have been destroyed or seriously degraded. In Quebec, wetland losses between 1945 and 1976 have been estimated to be more than 4000 ha (Environment Canada 1985b). This figure does not include the loss of several thousand hectares of upland habitats associated with the floodplain that are used as nesting sites by waterfowl and by many other bird species. Given the combined effects of urbanization, intensification of agricultural practices, and industrial expansion in this region, which is already the most heavily populated area in all of Quebec, the loss of these habitats is critical.

Only a few of the islands in the study area are accessible by road, such as the Boucherville and Berthier–Sorel islands (Sectors 3A and 4, respectively). As a result, habitats are less disturbed or degraded by human activity than the environments located along the shore of the St. Lawrence River. Their wildlife value, in terms of both fauna and flora, is undeniable. The objective of our study was to provide direction for the conservation efforts of various government and nongovernment organizations. More specifically, our review of the literature should serve the following purposes: (1) to compare the value of the various islands as waterfowl nesting sites and to identify those islands of highest priority in terms of protection efforts; and (2) to define the management criteria (i.e., size, shape, plant cover, and location) for any new islands that might be constructed using dredged material in order to compensate for habitat losses.

6.1 Conservation strategy for the islands

Aware of the significant ecological value of the islands in the St. Lawrence River, the Canadian Wildlife Service (Quebec Region) has focused its efforts in recent years on protecting the islands through its network of national wildlife areas and migratory bird sanctuaries. The Contrecoeur islands (Sector 3D) are a good example the Canadian Wildlife Service's protection efforts: the majority of the archipelago forms part of the Contrecoeur National Wildlife Area. However, more than 30% of the islands of the different archipelagos in our study area are privately owned. As a result, it is essential that immediate action be taken to promote the conservation of the plant and animal life on these islands, either through the acquisition of the land or through conservation agreements with the landowners (private stewardship programs, etc.).

To compare the value of the various islands as nesting sites for waterfowl, we began by using the multiple regression model described previously in order to predict, on the basis of the biophysical characteristics of the islands, the potential density of dabbling duck nests on islands that had never been inventoried (n = 120) or had been only partially inventoried (n = 27) (for the exact procedures, see Bélanger 1989). We then established criteria for classifying the various islands that had higher potential (i.e., higher nest density) than that of all islands (i.e., average nest density) in the study area. Average priority was given to the islands that had lower potential than all islands in the study area but higher potential than the islands in the archipelago or sector of which they were part. The conservation of the remaining islands was not considered to be a priority at this time owing to the low nest density found on them. It is important to bear in mind that our study focused specifically on waterfowl and that these "remaining islands" could have a high ecological value for other species of plants or animals.

Using this simple technique, we determined that 68 (30%) of the 224 islands in our study area should be given priority in terms of conservation. These islands account for 2026 ha of habitat and are located as follows: eight islands in Lake Saint-Louis and in the LaPrairie basin (Sector 2), six in the Boucherville archipelago (Sector 3A), eight in the Sainte-Thérèse archipelago and two in the Varennes archipelago (Sector 3B), three in the Verchères archipelago (Sector 3C), 21 in the Contrecoeur archipelago (Sector 3D), and 20 in the Berthier–Sorel region (Sector 4). A detailed list of the islands that should be given priority is presented in Bélanger (1989).

6.2 Integrated management of agricultural practices

The islands that have high waterfowl potential can be protected and conserved through such measures as the restoration of seriously degraded habitats. Human activities that do not have adverse effects on the natural resources present could be recommended for habitats that are sometimes considered marginal but which are very widespread in the area. In other words, habitat conservation would be implemented from an integrated resource management perspective. A number of changes could be made to agricultural practices to reduce their impact during the waterfowl nesting period. This approach, which was suggested by Holechek et al. (1982) and Lokemoen and Woodward (1992), has already been adopted in western North America, as described in other studies.

Reducing grazing intensity in the spring has been suggested as a way of minimizing both habitat losses due to trampling by cattle and the alteration of nesting cover (Bue et al. 1952; Glover 1956; Burgess et al. 1965; Kirsch 1969). Several authors have also suggested adopting an intensive grazing management system in natural grasslands (rest-rotation grazing) in order to maximize the potential of the grasslands for waterfowl nesting. Under such a system, some plots are farmed and others are left idle for a number of years on a rotating basis. Some authors have suggested annual rotation, whereas others have demonstrated that the interval should be several years in order to promote nesting of avifauna. The recommended period varies enormously from one study to another, with some authors suggesting a relatively long cycle of 5–10 years (Duebbert 1969; Duebbert and Kantrud 1974; Duebbert and Lokemoen 1976) and others suggesting a shorter cycle of 2–4 years (McFarlane 1977; Kirsch et al. 1978; Kaiser et al. 1979; Voorhees and Cassel 1980). Another grazing system that has recently been recommended consists of subdividing large pastures into several smaller areas and rotating the livestock from one area to another during the season (see Koerth et al. 1983; Jensen et al. 1990).

Between Montréal and Trois-Rivières, 53 islands are used for agricultural activities, particularly livestock grazing (community pasture). They account for 40% of the total area of the 224 islands in this area. An integrated wildlife–agriculture management program has recently been proposed under the Eastern Habitat Joint Venture. All of the management measures described above will be the subject of various studies in the next few years. We will then be able to assess their economic efficiency (cost per duck produced) and tailor them more effectively to the situation in Quebec, particularly on islands used for agricultural activities in the St. Lawrence.

6.3 Construction of islands using dredged material

Regular maintenance dredging of the St. Lawrence seaway shipping channel is carried out in order to allow the passage of deep-draught vessels. The disposal of the dredged material poses a problem (Levings 1983; Piette et al. 1984). The solution to the problem must take considerations other than economic or strictly technical ones into account (Rochon 1984). For example, the dredged material taken from the river, often in large quantities, could be used in the management or restoration of wildlife habitats along the St. Lawrence River, particularly for the construction of artificial islands (Vigneault et al. 1978).

Many wetland habitat construction projects have already been carried out using dredged material across North America, particularly in the United States. In the last 100 years, more than 2000 islands have been constructed and have become very important habitats for wildlife, especially colonial birds (see Soots and Landin 1978; Landin 1984). The different models tested involve the use of a wide variety of land areas, shapes, and shoreline slopes. However, they cannot be applied directly to the St. Lawrence owing to its very special ecological and hydrological characteristics (type of vegetation, spring floods, erosive action of ice, etc.) and to the presence of species that have very different requirements from those of the southern United States and other regions.

Quebec has little experience in the construction of islands for wildlife using dredged material. A number of islands were constructed in the 1970s, in the Contrecoeur archipelago for instance, but with no specific management plans. According to Landin (1984), before initiating construction activities with dredged material, it is

important to clearly identify the wildlife species to be helped and their ecological requirements. On the basis of the results of our study, we propose the following.

6.3.1 Physical description

Table 6 provides an overview of the recommendations of a number of authors regarding the construction of islands for waterfowl. Most authors recommend that islands be less than 0.5 ha, with the exception of Duebbert (1982), who suggests up to 5.0 ha. Keith (1961) and Bélanger and Tremblay (1989) believed that the islands should be larger than 0.1 ha, because smaller islands would not permit the establishment of several nests. However, Johnson et al. (1978) and Piest and Sowls (1985) reported, for North Dakota and Arizona, respectively, very high nest densities on islands smaller than 0.1 ha. On the basis of these studies and our own study results, we suggest that the islands to be constructed in the years ahead in the St. Lawrence using dredged material should be 0.5–1.5 ha. In our view, this would strike a good balance among construction costs, the amount of material required, and the loss of material due to erosion. In addition, the life of islands of this size would be sufficiently long to ensure economic efficiency (cost per fledged duck, amortized over 20 years; see Lokemoen 1984). The fact that few predatory mammals are generally found on islands smaller than 1.5 ha, or at least are not part of the resident population (Lokemoen and Woodward 1992), is a further justification for the recommended size range.

According to Hammond and Mann (1956), the islands should have the highest possible ratio shoreline to land area, which would result in a larger number of nesting sites owing to better visual isolation of individual waterfowl. To achieve this objective, Giroux (1981) suggested building rectangular islands. According to our findings, the size of the island tends to play a more significant role than its shape in its selection by waterfowl for nesting, at least in our study area. We recommend that the smallest islands be round (≤ 0.5 ha) and that the largest islands be rectangular (> 0.5 ha) (Hammond and Mann 1956; Giroux 1981). In areas where there are few marshes with emergent vegetation, horseshoe-shaped islands (≤ 1.5 ha) would also be recommended (Vigneault et al. 1978). This shape would promote the growth of emergent vegetation favourable to the rearing of ducklings. Bélanger and Couture (1988) have observed that artificial ponds larger than 0.5 ha were the most extensively used by dabbling duck broods in Quebec.

In our study area, the location of the islands in relation to the mainland did not appear to affect the use of the islands by dabbling ducks. However, an island located too close to the mainland or to other islands (particularly large islands) would clearly be more susceptible to human disturbance and more vulnerable to terrestrial predators. According to various authors, the distance likely to ensure the most safety for birds ranges from 10 m (Keith 1961) to 300 m (Wills and Crawford 1989) (Table 6). Reese et al. (1987) suggested a minimum distance of 125 m for islands used by Canada Geese. More recently, Lokemoen and Woodward (1992) suggested a distance of over 100 m. Given the particular characteristics of the St. Lawrence River (highly populated shorelines), we suggest that the new islands be located at least 200 m from the mainland. Of course, this distance could vary depending on local conditions, such as the presence of grass stands used as spawning grounds and the visual impact of the islands from the viewpoint of riparian landowners.

According to Hammond and Mann (1956), the distance between the human-made islands should be very small. Giroux (1981) stated that if the islands are located too close together, terrestrial predators would be able to move from one island to another, which would significantly reduce nesting success. He suggested that the islands be spaced at least 100 m apart, which in our view is reasonable.

6.3.2 Plant cover

Our study indicates that tall grasslands would provide the best nesting cover for dabbling ducks and that islands on which this type of vegetation is predominant are the most extensively used. As a result, we recommend that more than 75% of the total area of the new islands be covered with tall grasses. It would be preferable for reed canary grass to be the dominant species, given that it is native to the study area. If seeding is required, commercial supplies of this species are readily available.

Table 6
Summary of recommendations on the construction of artificial islands for waterfowl in North America

Reference	Size (ha)	Shape	Distance (m) Shore	Island	Marshe
Hammond and Mann (1956)	0.1–0.4	[a]	>30	[b]	P
Keith (1961)	≥0.2	—	10	—	—
Giroux (1981)	0.1	[c]	>170	>100	P
Duebbert (1982)	0.2–5.0	—	—	—	—
Duebbert et al. (1983)	—	—	200	—	—
Wills and Crawford (1989)	0.3–0.5	—	300	—	A
Lokemoen and Woodward (1992)	—	—	>100	>100	P

— = value not specified.
A = absent.
P = present.

[a] Highest possible ratio of shoreline to land area.
[b] Spaced close together.
[c] Rectangular.

7.0 Conclusions

Through our study, we have gained a better understanding of waterfowl nesting on islands in the St. Lawrence River between Montréal and Trois-Rivières. Gadwall and Northern Pintail nests were the most numerous, accounting for 29% and 23%, respectively, of the total number of nests inventoried. An average of 8.9 nests was counted on each island, for a average density of 1.3 nests/ha. Close to 73% of the nests were located in tall grasslands, in which reed canary grass was the dominant species.

The size of the island, the proportion of tall grass cover, and the presence of a colony of gulls or terns had a positive influence on the use of the islands as nesting sites, whereas the presence of human activity (year-round and seasonal residences, pasture, cropland) had a negative impact. Together, these criteria account for close to 65% ($r = 0.8$; $p \leq 0.0001$) of the variation in the number and density of nests on each island.

In order to ensure more effective management of the islands in our study area, it will be necessary, in our view, to conduct another series of inventories in the next few years. These inventories could serve as a basis for establishing the real nest density on the islands (three inventories for each island, rather than one), more effectively assessing changes in the composition of waterfowl populations over the last 10–15 years, and determining the impact of the changes that have occurred on some islands during that period (urbanization, intensification or modification of agricultural practices, wildlife habitat management initiatives) on duck populations in the study area.

Other studies are needed to gain a better understanding of (1) the effect of annual floods on the use of the islands by waterfowl; (2) the impact of livestock grazing on the vegetation of tall grasslands and the importance of this type of plant cover for nesting; and (3) the relationship between the aging of reed canary grass stands (accumulation of litter, stem density, etc.) and the selection of a nest site by female ducks. Finally, the selection of nesting cover types by dabbling ducks, particularly American Black Ducks, Blue-winged Teals, and Northern Pintails, whose declining populations are of concern throughout North America, should be examined in the next few years.

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Appendix 1
List of codes used for the plant species present

Community	Species	Code
Tall grassland	*Asclepias syriaca*	Asr
	Phalaris arundinacea	Pa
	Calamagrostis canadensis	Cc
	Phleum pratense	Ph
	Phragmites communis	Pc
	Solidago spp.	So
	Spartina pectinata	Sp
Short grassland	*Agropyron repens*	Ar
	Agrostis alba	Aa
	Bidens spp.	Bi
	Equisetum arvense	Ea
	Echinocystis lobata	Le
	Festuca rubra	Fr
	Leersia oryzoides	Lo
	Panicum virgatum	Pv
	Poa pratensis	Pr
	Poa palustris	Pop
	Taraxacum officinale	To
Scrubland and forestland	*Acer rubrum*	Acr
	Acer saccharinum	Acs
	Acer saccharum	As
	Alnus rugosa	Alr
	Betula populifolia	Bp
	Cornus canadensis	Coc
	Fraxinus pennsylvanica	Fp
	Laportea canadensis	Lc
	Onoclea sensibilis	Os
	Pinus strobus	Ps
	Populus deltoides	Pd
	Populus tremuloides	Pt
	Salix alba	Sa
	Salix amygdaloides	Smg
	Salix discolor	Sd
	Salix fragilis	Sfg
	Salix interior	Si
	Salix nigra	Sn
	Salix petiolaris	Sp
	Salix rigida	Sr
	Tilia americana	Tla
	Tsuga canadensis	Tc
	Ulmus americana	Ua

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