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Duck use of the coastal habitats of northeastern James Bay

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Cover photo: James Bay near Bay of Many Islands, August 1992 (Austin Reed)

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Abstract

We conducted aerial and ground surveys along the northeast coast of James Bay, from the Au Castor River to Point Louis-XIV, in 1990–92. Ducks were encountered in abundance throughout the spring, summer, and fall. Overall, 21 different duck species were recorded.

During fall and spring migration periods, the American Black Duck *Anas rubripes* was the most common dabbling duck, but appreciable numbers of Green-winged Teal *A. crecca*, Mallard *A. platyrhynchos*, Northern Pintail *A. acuta*, and American Wigeon *A. americana* were encountered frequently. American Black Ducks, like the other dabbling ducks, used mainly mud/sand tidal flats and low salt marshes. In fall, American Black Ducks also used heathland, where they fed on berries. Diving ducks, including Common Mergansers *Mergus merganser*, Red-breasted Mergansers *M. serrator*, Greater Scaup *Aythya marila*, Lesser Scaup *A. affinis*, Surf Scoters *Melanitta perspicillata*, Black Scoters *M. nigra*, White-winged Scoters *M. fusca*, and Common Goldeneyes *Bucephala clangula*, were also abundant; they were encountered most frequently in areas of open water, over eelgrass *Zostera marina* beds, over boulder-strewn tidal flats, and over mud/sand tidal flats.

In early summer, many ducks assembled in large premoult congregations. Common Goldeneyes and American Black Ducks were especially abundant, the former in eelgrass beds and the latter on mud/sand tidal flats.

Twelve species were recorded breeding in coastal habitats: American Black Duck, Mallard, Northern Pintail, Green-winged Teal, American Wigeon, Greater and Lesser scaups, Common Eider *Somateria mollissima*, Surf and White-winged scoters, Red-breasted Merganser, and Oldsquaw *Clangula hyemalis*. All nested in very low density except Common Eiders, for which a nesting population of >420 pairs was estimated. All Common Eider nests were found on islands, mainly near the shoreline in patches of sea lime-grass *Elymus mollis* or in low shrubs; eider broods were raised mainly in areas of open water or over boulder-strewn tidal flats.

During the wing moult in August, some American Black Ducks and Common Goldeneyes remained in coastal habitats, whereas others appeared to move elsewhere for the flightless period, probably to inland freshwater wetlands. Large flocks of flightless Black Scoters, Surf Scoters, White-winged Scoters, Common Mergansers, and Red-breasted Mergansers were present in open water areas near shoals around the outer islands, where they fed on abundant molluscs and other marine organisms. Heathland ponds on the islands were also used by some Green-winged Teal for moulting.

This abundant and diversified use of northeastern James Bay by ducks is explained by the complex mosaic of coastal habitats that occur along this irregular shoreline. The presence of salt marshes, eelgrass beds, mud/sand tidal flats, boulder-strewn shores fringed with vegetation, open water areas, and heath-covered islands offers a wide variety of conditions in which many species of ducks can meet their needs for food and cover, especially during migration and moulting.

ᓯᓯᐸᐤ ᐋᓐᑕ ᐃᑎᒪᐱᓰᐦ ᑮᔮ ᐧᐋᐱᓈᑖᐤ ᒋᒥᔅ ᐱ ᐊᔦᔦᐧᐊᔦᔮᐤ ᐊᑖᐤ
ᓅᐤ ᐧᐃᑎᒪᒫᐅᐣ

ᐃᔅᐱᒥᐤ ᑮᔮ ᐋᓈᔅᑳᒥᐤ ᓂ ᒋ ᐅᐤ ᓈᓐᑎᐧᐋᐱᑕᓈᐣ ᒫᐧᑳᐣ 1990 ᐱᔮᐦ 1992 ᑳ ᐃᑎᔅᑖᐤ ᐋᐱᔫᐤ ᐋᓐᑕ ᐃᑎᒪᐱᓰᐦ ᑮᔮ ᐧᐋᐱᓈᑖᐤ ᒋᒥᔅ ᐱ ᐧᐃᓐᐸᑯ ᐊᔦᔦᐧᐊᔦᐤ, ᐋᓐᑖ ᐊᒥᔅᑯᓐᑳᐸᐤ ᐅᐤ ᐋᓐᑕ ᒦᐣ ᐊᒥᒋᔅᑕᐧᐊᔦᐤ ᐃᐢ. ᓈᔅᑖᐧᐸ ᒋ ᒥᑳᐎᐤ ᓯᓯᐱᐤ ᒫᐧᑳᐤ ᐊᓯᑯᓂᔮᐤ ᑮᔮ ᐊᓂᐱᓂᔮᐤ, ᑮᔮ ᐊᑎᐧᑳᒋᓂᔮᐤ. 21 ᐊᐃᔑᓇᑯᓰᐦ ᓯᓯᐱᐤ ᒋ ᐧᐋᐱᒪᑭᓄᐅᐤ.

ᒫᐧᑳᐤ ᐊᐱᒥᔦᐦ ᐱᔫᓂᐤ ᐊᑎᐧᑳᒋᐤ ᑮᔮ ᐊᓯᑯᐤ, ᐋᐅᐦ ᒪᐅᐤ ᑳ ᐧᐋᐧᐃᑎᓰᐦ ᐊᑎᓰᐤ ᐃᔮᔮᔅᐸᐤ ᒥᑭᑖᓯᐦ ᑳ ᐧᐃᔮᐱᓰᐦ ᑮᔮ ᐃᔦᐹᐤ ᒥᑳᐧᑖᐤ ᒋ ᐧᐋᐱᒪᑭᓄᐅᐤ ᒌᔅᒋᓯᐦᓯᐤ, ᑮᔮ ᐅᒥᓂᑯᐤ, ᑮᔮ ᐋᐦᒋ ᑯᑕᑲᐤ ᒥᑭᑖᓯᐸᐤ. ᐋᐦ ᒥᑭᑖᓯᐦ ᑳ ᐧᐃᔮᐱᓰᐦ ᐊᑯᑕ ᐋᓐᑕ ᐅᔅ ᐊᑖᐦ ᐊᒍᔅᑎᑖᔦᔮᐤ ᐊᓯᓯᔅᒋᐧᐃᔮᐤ ᑮᔮ ᒦᐣ ᐊᔦᑳᐧᐃᔮᐤ, ᑮᔮ ᐋᓐᑕ ᓯᓰᐤ ᐊᒥᔅᑯᓯᐧᐃᔮᐤ ᐊᔅᑯ ᓯᐧᐊᔫᐧᐃᔮᐤ, ᐧᒦᐤ ᐊᑏᐤ ᑮᔮ ᐋᐦᒋ ᑯᑕᑲᐤ ᐃᔮᔮᓯᐸᐤ. ᐃᔦᐹᐤ ᐋᓐᑕ ᐊᔅᒌᐤ ᑖᐅᐤ ᐋᐦᒋ ᑳ ᐧᐃᔮᐱᓰᐤ ᒥᑭᑖᓯᐸᐤ ᐋᓐᑕ ᐊᓂᐱᓯᐧᐃᓯᔮᐤ ᒥᓂᔅ ᐊᒥᒌᐤ. ᒋ ᐧᐋᐧᐃᑎᓯᐅᐤ ᑯᑕᑲᐤ ᓯᓯᐸᐤ ᑳ ᓯᐱᑕᐸᐧᐊᐤ ᐧᒦᐤ ᐋᐦ ᐅᓯᐤ, ᑮᔮ ᑳ ᐅᔅᐦᐱᔅᐧᐊᐦ ᐅᓯᐤ, ᑮᔮ ᐊᐧᑳᐧᐊᑲᓇᔅ ᑳ ᒥᓯᒋᔅᑖᐤ ᑮᔮ ᑳ ᐊᐱᓯᔅᓰᐦ, ᐧᐊᐦᑰᐧᐃᐧᐊᑲᐣ. ᑮᔮ ᑰᔅᑯᓯᐸᑖᐦ, ᑮᔮ ᐊᐧᑳᐧᐊᑲᓇᔅ; ᐋᓐᑕ ᐊᒥᔅᔮᐤ ᓂᐱᐁ ᑮᔮ ᒦᐤ ᐋᓐᑕ ᓯᑳᐸᔅᑯ ᐊᓂᑖᐅᒋᓂᔮᐤ, ᑮᔮ ᒦᐤ ᐋᓐᑕ ᐊᒍᔅᑎᑖᔦᔮᐤ ᐊ ᐊᓯᓂᐧᐃᔮᐤ, ᑮᔮ ᒦᐤ ᐊᓯᓯᔅᒋᐧᐃᔮᐤ ᑮᔮ ᐊᔦᑳᐧᐃᔮᐤ ᐊᑯᑕ ᔫᔅ ᑳ ᐧᐋᐱᒥᐤ ᐅᒋ ᓯᓯᐸᐤ.

ᓈᓈᐧᑳ ᑳ ᐊᐦ ᓂᐱᓂᔮᐤ ᓈᔅᑖᐧᐸ ᒋ ᒪᒥᑳᐎᐤ ᓯᓯᐸᐤ ᐊᓇᓂᔅᑕᐧᐃᐤ ᐧᐊᒪᔦ ᐸᔅᑰᐤ, ᐊᐧᑳᐧᐊᑲᓐᓯᐤ ᑮᔮ ᑳ ᐧᐃᔮᐱᓰᐦ ᒥᑭᑖᓯᐦ ᐊᐅᑯᓐᐤ ᓈᐦᐤ ᑳ ᒥᑳᑖᐤ, ᐋᐦᒋ ᐊᐧᑳᐧᐊᑲᓐᓯᐤ ᐋᓐᑕ ᓯᑳᐸᔅᑯ ᐊᓂᑖᐅᒋᓂᔮᐤ ᐊᑰᐦ ᓈᐦᐤ ᑳ ᓯᔦᑳᐦᑖᐤ, ᑮᔮ ᐋᐦᒋ ᒥᑭᑖᓯᐸᐤ ᑳ ᐧᐃᔮᐱᓰᐤ ᐋᓐᑕ ᐊᒍᔅᑎᑖᔦᔮᐤ ᐊᓯᔅᓯᒋᐧᐃᔮᐤ ᑮᔮ ᒦᐤ ᐊᔦᑳᐧᐃᔮᐤ ᐊᑯᑕ ᓈᐦᐤ ᑳ ᓅᒋᑳᐤ.

12 ᐊᐃᔑᓇᑯᓰᐦ ᓯᓯᐦ ᒋ ᐧᐋᐅᐤ ᑮᔮ ᒋ ᓂᑖᐅᒋᐊᐤ ᐅᑰᐦ ᐋᓐᑕ ᓯᓰᐤ ᐧᐃᓐᐸᑰᐤ, ᐋᐅᐦ ᐋᐦ ᒥᑭᑖᓯᐦ ᑳ ᐧᐃᔮᐱᓰᐦ ᑮᔮ ᐋᐦ ᑯᑖᐤ ᒥᑲᑕᓯᐸᐤ, ᑮᔮ ᐅᒥᓂᑯᐤ, ᑮᔮ ᒌᔅᒋᓯᐸᓰᐤ, ᑮᔮ ᒫᐧᑳᑕᑯᓰ. ᐊᐧᑳᐧᐊᑲᓐᓯᐤ ᑳ ᒥᒥᓯᒋᔅᑖᐤ ᑮᔮ ᑳ ᐃᔦᐱᓯᓯᐤ. ᑮᔮ ᒥᓰᐸᐤ, ᑮᔮ ᐊᒥᔅᐧᑳᐸᐧᐊᐅᐤ, ᑮᔮ ᑳ ᐅᔅᐦᐱᔅᐧᐊᐤ ᐅᓯᑯᐤ, ᑮᔮ ᐊᐊᐧᐊᓰᓯᐤ. ᒥᓯᐧᐊ ᐋᐦᔦ ᐊᑎᓰᐤ ᐅᒋ ᓯᓯᐸᐤ ᓂᔫᐧᐃ ᐅᐤ ᐧᐋᔦᐤ ᓂᑖᐅᒌᐅᐤ, ᒥᐁ ᐋᐦᒋ ᒥᓰᐸᐤ ᐊᐅᑯᓐᐤ ᒥᐁ ᑳ ᒥᑳᑖᐤ ᐊᐧᐊᐅᐤ, ᐧᐊᐧᐃᓯᐧᐊ 420 ᐊᑎᓰᐤ ᐊᓈᓂᓰᐤ ᒋ ᐃᑎᒋᒫᑭᓄᐅᐤ. ᒥᓯᐧᐊ ᐋᐦᒋ ᒥᓰᐸᐤ ᑳ ᐧᐋᐱᒥᐤ ᐋᓐᑕ ᒥᓂᔅᑎᑰᐤ ᐊᑰᐦ ᑳ ᐧᐋᐱᒥᐤ ᑮᔮ ᐅᔅ ᐋᓐᑕ ᓯᓰᐤ ᐊᒥᔅᑯᓯᐧᐃᔮᐤ ᑮᔮ ᒦᐤ ᐊᓂᐱᓰᐅᓯᔮᐤ ᑮᔮ ᐋᐦᒋ ᒥᓰᐸᔅᐤ ᐋᓐᑕ ᓂᐱᐤ ᑮᔮ ᒦᐤ ᐋᓐᑕ ᐊᔅᑯ ᔫᔅᑎᑖᔦᔮᐤ ᐊ ᐊᓯᓂᐧᐃᔮᐤ ᐊᑯᑕ ᑳ ᑖᐤ.

ᒫᒀᒡ ᐊᐱᔅᑯᒡ ᓱᓱᐸᒡ ᐊᑳᔅᐦ ᐱᓲᐦ, ᐱᔅᒡ ᐊᓐᒋ ᑳ ᐐᔦᐱᓲᒡ ᒥᑭᑖᓱᐦ ᑭᔦ
ᐊᒁᐊᑳᓐᓲᒡ ᐊᓐᑕ ᓲᓲᒡ ᐊᔦᔦᐋᔦᒡ ᐍᓐᐸᑯᔫ ᐊᑯᑕ ᑳ ᑖᒡ; ᑯᑕᑳᒡ ᒫᑊ ᑭᔦ
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ᑰᔅᑯᓱᐸᑕᒎᒡ ᑭᔦ ᐙᐦᑰᐄᐘᑳᓐᒡ, ᑭᔦ ᐊᒥᔅᒃᐚᐹᐊᐅᒡ, ᑭᔦ ᐅᓱᑯᒡ, ᑭᔦ ᑳ

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ᐊᑰᐦ ᑳ ᑖᒡ ᐊᒎᐘᒡ ᐊᓐᔦ ᐊᐘᓐᔅ ᐊᓐᑕ ᓂᐲᒡ ᓇᑖᐅᒥᔦᒡ ᑭᔦ ᑯᑖᒡᔽᐤ
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ᐊᓐᑕ ᐊᓐᔦ ᔕᑳᐦᐃᑲᓇᔅ ᒥᓂᔅᑎᑯᒡ ᐊᑎᑯᓂᔦᒡ ᒫᒀᒡ ᐊᐱᔅᑯᒡ.

ᐊᔦᐅᐞ ᐘᒡ ᐘᔽᑎᓲᐦ ᓱᓱᐦ ᓇᓈᑯᐤ ᐊᐃᔑᓇᑯᓲᐦ ᐊᓐᑕ ᐃᑎᒪᐱᓱᐦ ᑭᔦ
ᐘᐱᓅᑖᒡ ᒋᒥᔅ ᐱ ᐍᓐᐸᑯᒡ ᐊᐘᔽᑎᓂᔦᒡ ᓈᓇᑯᐤ ᐊᓐᔦ ᐊᐃᔑᓇᑯᓂᔦᒡ ᐊᑕ
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ᐊᔦᑲᐅᒡ, ᑭᔦ ᒫᑊ ᐊ ᐊᓱᓂᐅᒡ ᐊᓂᑖᐅᒌᒡ ᒑᒀᓐ, ᑭᔦ ᐊᒥᔕᒡ ᓂᐲ ᑭᔦ
ᐊᓂᑕᐅᒌᒡ ᓂᐱᓱᔅ ᐊᓐᑕ ᒥᓂᔅᑎᑯᒡ ᐊᑰᐦ ᐍᔦᔽᑎᓂᔦᒡ ᓱᓱᐦ ᐊᑕ ᒑ ᒋ
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1. Introduction

The James Bay Energy Corporation initiated habitat studies of the northeast coast of James Bay in 1982. In 1989, the Canadian Wildlife Service joined the James Bay Energy Corporation in the study of those habitats and their use by waterfowl. This partnership resulted in the publication of a report describing the coastal habitats from the Au Castor River to Point Louis-XIV (Dignard et al. 1991) and the undertaking of a series of surveys and ecological observations from 1990 to 1994. The present report, intended to be the first in a series, describes duck use of coastal habitats. It will be followed by others describing goose use of coastal habitats and waterfowl use of freshwater wetlands on the lowland coastal plain.

This area was chosen for study because of the development of hydroelectric power on the La Grande River, which flows into James Bay along its northeast coast. Development began in 1973, and most generating stations were operative by 1984 (Messier et al. 1986). The main hydraulic effects on the coastline were a reduced flow of fresh water into James Bay through the Eastmain estuary (to the south of our study area) and a major increase in flow through the La Grande River estuary during winter (Messier et al. 1986). Given the magnitude of the development project, there was a clear need to gain an in-depth understanding of the ecological relationships between the coastal habitats and migratory waterfowl in that area.

Earlier studies had identified the east coast of James Bay as an important area for waterfowl, particularly during migration. Most of that information came from the expeditions of W.E.C. Todd (Todd 1963) and T.H. Manning (Manning 1952, 1981; Manning and Coates 1952; Manning and Macpherson 1952) and more recently from studies by Bourget (1973), Curtis and Allen (1976), Morrison and Gaston (1986), and Reed et al. (1990). That work provided a good background on the individual species present, their relative abundance, and their geographical distribution but (with the exception of the study by Curtis and Allen [1976]) gave little information on habitat use.

Many wildlife studies related to resource exploitation have focused on comparing the size of postdevelopment populations with those present prior to development. We did not take this approach for a variety of reasons, including 1) the incompleteness of certain earlier population assessments and 2) anticipated difficulties in conducting complete and systematic surveys (costs and, especially, restrictions on aerial and ground survey work) during the peak months of waterfowl migration. Furthermore, it was felt that any changes in numbers of birds would be difficult to link to events occurring in James Bay rather than to events occurring elsewhere along their extensive migratory routes.

Our approach was based on the premise that any eventual impacts from development would result from changes in habitats. We therefore focused primarily on identifying habitats used by the different species of ducks and showing how these habitats fulfilled their ecological requirements during various stages of their life cycles. This was facilitated by the existence of a detailed habitat map (Dignard et al. 1991), which allowed us to associate any given bird observation with a specific habitat. By using a combination of field techniques (surveys, behavioural observations, etc.), we sought to gain a sound understanding of how the ecological requirements of the various duck species were being met by the array of coastal habitats in the area. This richer ecological data base should allow more meaningful evaluations of the importance of various wetlands or wetland complexes, leading to more rational decisions regarding the protection and management of waterfowl populations on James Bay and elsewhere.

2. Study area

In 1990, we focused on one sector, the Bay of Many Islands, because of its wide range of habitats, representative of the entire northeast coast of James Bay. Subsequently, the study area was extended to include Dead Duck Bay and an area from Point Attikuan north to Point Louis-XIV, as well as an area around the mouth of the La Grande River (Fig. 1).

The following brief description of the coastal habitats summarizes the work of Dignard et al. (1991), to which readers are referred for detailed descriptions and a map of the habitats as well as a list of plant species. The northeast coast of James Bay is highly sinuous, punctuated by numerous bays, points, and peninsulas and fringed by many islands, islets, and reefs. There is a frequent alternation between flat, gradually sloping shorelines and rockier, hilly shores, but overall the area is low, with little relief. Vast expanses of boreal forest are found inland, but along the coast the vegetative cover is typically subarctic, with sparse tree cover and large expanses of heathland. In the Bay of Many Islands, vast stretches of mud/sand tidal flats are found on the shore of the mainland. Salt marshes often occur inshore from these flats. In protected bays along the coast and inshore from the islands, where the substrate, slope, and salinity are favourable, subtidal beds of eelgrass *Zostera marina* occur (Lalumière et al. 1994). Medium-sized and large islands are often covered by heath, with lichens, ericaceous shrubs, or black crowberry *Empetrum nigrum* dominating, and usually dotted with small ponds. A narrow strip of boulder-strewn shoreline fringed with sea lime-grass *Elymus mollis* or scaly sedge *Carex paleacea* is often found around the edges of these islands or along certain sections of the mainland coast. Islets and reefs generally have little vegetation.

The habitats to the south, in Dead Duck Bay, have similar profiles and floristic characteristics. Point Attikuan, to the north, has less extensive mud/sand tidal flats and marshes; eelgrass beds and large expanses of heath are present.

3. Methods

3.1 Data collection

During each of the three years of the study, we made several visits to the study area in spring, summer, and fall (Table 1). Aerial surveys were restricted to the period between the beginning of June and mid-August to avoid disturbance during the Crees' traditional spring and fall goose hunts (Reed 1991).

For this study, we considered 16 May to 13 June as the spring migration period, 22 June to 14 August as the breeding and moulting period, and 10 September to 1 October as the fall migration period. The middle period was further divided into the nesting and premoult period (22 June to 8 July) and the brood-rearing and moulting period (28 July to 14 August). The choice of these dates is somewhat arbitrary because of intra- and interspecific differences in the phenology of migratory and reproductive activities, but the dates chosen generally demarcate periods when most species were migrating, breeding, or moulting.

3.1.1 Survey of nesting on islands

Nests were located by ground crews of 3–5 observers searching systematically over randomly selected islands in five sectors of the coast (Fig. 1, Table 2). Smaller islands were generally covered more thoroughly than medium-sized and large ones. Access to the islands was by freighter canoe, except in Dead Duck Bay, where a helicopter was used. On the mainland and on islands connected to it at low tide, systematic nest searches were not conducted because of the presence of red foxes *Vulpes vulpes*; in areas accessible to foxes, ducks generally nest at low densities (Larson 1960; Quinlan and Lehnhausen 1982; Sargeant et al. 1984).

Nests were identified to species, usually by identifying the ducks as they flushed from their nests, although occasionally egg measurements and nest down were used. The number of eggs in each nest was recorded, along with a brief description of the habitat, following the terminology of Dignard et al. (1991). Only nests containing eggs were considered in the analyses, except for Common Eiders *Somateria mollissima* in 1992, a year of late nesting during which several well-formed, typical nest basins were found containing no eggs.

Figure 1
The northeast coast of James Bay, showing sectors surveyed in 1990, 1991, and 1992

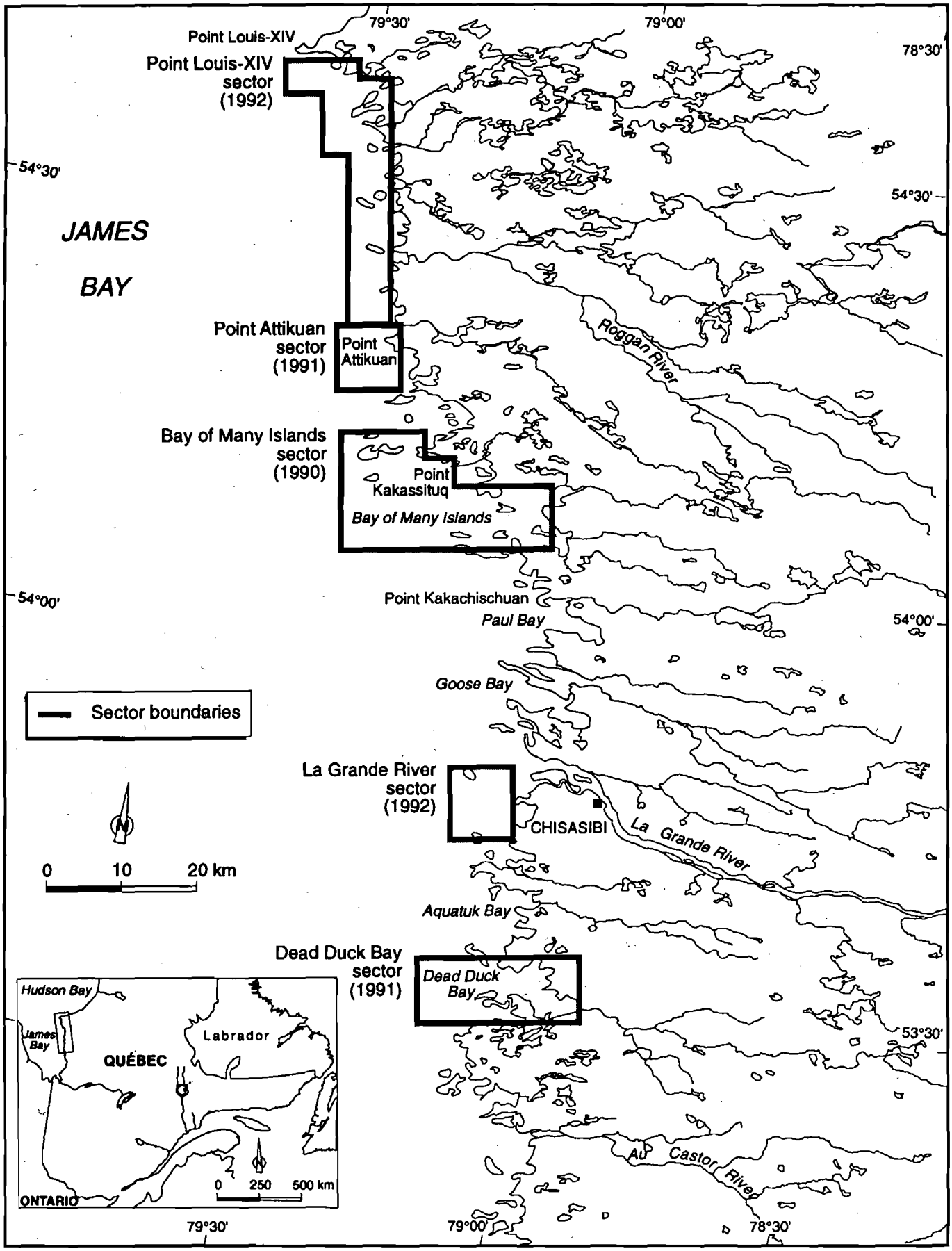


Table 1
Schedule of field activities on the northeast coast of James Bay, 1990–92

Year	Survey period	Field activities: Behavioural observations	Nest counts	Aerial surveys	Collection of benthic organisms or stomach contents
1990	4–13 June	✓		✓	
	25 June – 4 July	✓	✓	✓	
	30 July – 8 August	✓		✓	
	20 September – 1 October	✓			
1991	16–22 May	✓			
	25 June – 2 July	✓	✓		✓
	5–14 August			✓	✓
	10–16 September	✓			✓
1992	22 June – 4 July		✓		
	29 July – 1 August				✓

Table 2
Sampling schedule for nest counts on islands off the northeast coast of James Bay, 1990–92

Sector [a]	Survey year	Area of sector sampled (km^2)	Total no. of islands	No. of islands surveyed	% of islands surveyed
Dead Duck Bay	1991	100	54	24	44.4
La Grande River	1992	160	98	36	36.7
Bay of Many Islands	1990	235	150	51	34.0
Point Attikuan	1991	25	34	17	50.0
Point Louis-XIV	1992	160	112	58	51.8

[a] See Figure 1 for the location of survey sectors.

3.1.2 Aerial surveys

Aerial surveys were conducted in a Bell 206 L helicopter, flying at a speed of 50–100 km/h and an altitude of approximately 50 m, depending on the topography and type of habitat. An observer in the lefthand front seat acted as navigator and counted and identified the birds seen on the left side of the aircraft, whereas an observer in the righthand back seat counted birds on the right side. Usually an additional observer in the lefthand rear seat assisted the observer in the front. Data were recorded on standard forms by the navigator or the observer in the left rear seat. The location of birds was marked on a 1:50 000-scale map, and the species, sex (for species with sexual dimorphism), and age (adult, immature, etc.) were recorded. For broods, the number of ducklings and their approximate age (using the classification of Gollop and Marshall 1954) were recorded.

Three types of aerial surveys were conducted. In 1990, an 87-km transect following the coastline of the Bay of Many Islands and passing over some of the islands was flown on three different occasions — 6 and 28 June and 3 August (Fig. 2). This survey provided an initial assessment of the use of broad groupings of habitats by ducks in late spring and in summer. On 4 and 6 August of the same year, four quadrats, each 25 km^2 (5 km × 5 km), were thoroughly surveyed (Fig. 2); their locations were selected arbitrarily to reflect an inland-to-offshore gradient in habitat conditions in the Bay of Many Islands.

A third survey was carried out between 8 and 13 August 1991, covering 44 quadrats, each 4 km^2 (2 × 2 km). The quadrats were systematically distributed among three sectors (Bay of Many Islands, Dead Duck Bay, and Point Attikuan), allowing evaluation of both population densities and habitat use by ducks in late summer. The data were stratified by sector with the aim of increasing the accuracy of population estimates (see Rutherford and Hayes 1976).

3.1.3 Behavioural observations

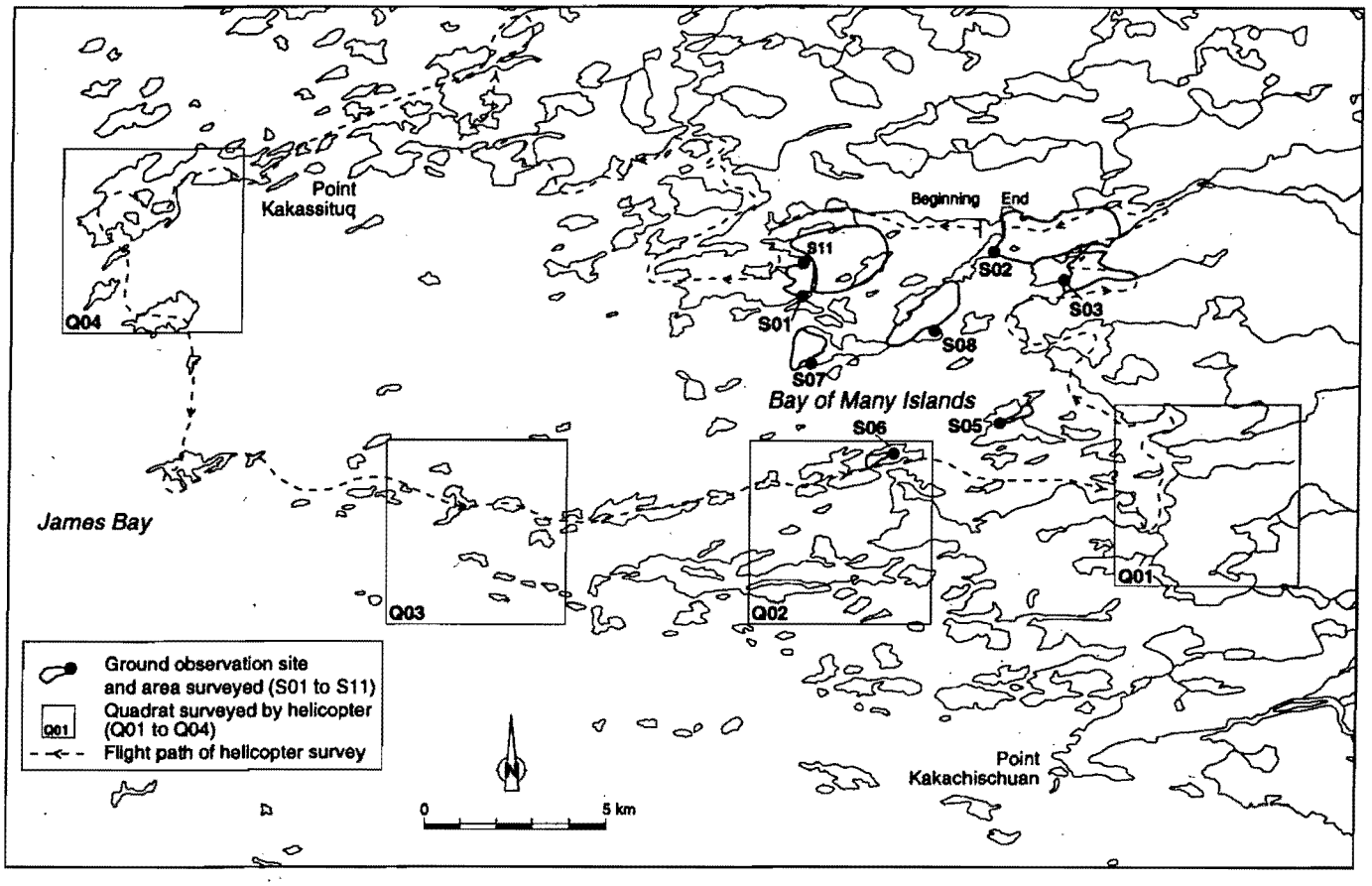
At the start of fieldwork in 1990, eight sites, each with a variety of habitats, were selected for behavioural observations (Fig. 2). These observations were aimed at establishing ecological links between ducks and their habitats. At three sites, repeated scans were performed every 30 or 45 minutes over six- or 12-hour periods. At the other five sites, a single instantaneous scan was carried out during each observation session (Table 3).

During each count, the location of all groups of ducks observed was plotted on an acetate sheet overlaying a 1:10 000-scale colour aerial photograph of the site; thus, the behaviour observed could be associated with a specific habitat. Simultaneously, the number of individuals in each group and their behaviour were recorded. The categories of behavioural activity used in our analyses included feeding, resting, flying, preening, vigilance, and social interaction. The repeated scans were used to examine habitat use in relation to time of day and tidal level. An electronic planimeter was used to measure the area of each habitat at each site.

3.1.4 Collection of benthic organisms and stomach contents of moulting diving ducks

In shoal areas off the Bay of Many Islands in early August 1991, 64 moulting diving ducks (mainly scoters,

Figure 2
Location of observation sites, survey quadrats, and survey transect in the Bay of Many Islands, 1990



Melanitta spp.) were shot and their esophagi, proventriculi, and gizzards removed and preserved in 70% methanol within 1–2 hours. The contents were later analyzed in the laboratory. In 1991, samples of benthic organisms were collected from the same shoals using a Ponar grab sampler; in 1992, further samples were taken by scuba divers.

3.1.5 Definitions

Under field conditions, it was not always possible to identify certain ducks at the individual species level. Thus, we have used the term "scaup" to refer to Greater Scaup *Aythya marila* and/or Lesser Scaup *A. affinis*, to designate both birds not identified to individual species as well as groups containing both species. Similarly, the term "mergansers" refers to Common Mergansers *Mergus merganser* and/or Red-breasted Mergansers *M. serrator*, and "scoters" refers to Black Scoters *Melanitta nigra* and/or Surf Scoters *M. perspicillata*.

3.2 Data analyses

3.2.1 Nesting surveys on islands

We estimated nesting populations of each species from the number of nests counted on surveyed islands, using a stratified random sampling procedure (Cochran 1977:91), the strata being the five survey zones (Fig. 1). This is the same approach used by Chapdelaine et al. (1986) to estimate the Common Eider population in Ungava Bay, Quebec.

All strata were not surveyed in the same year; we estimated the combined population of the five sectors assuming that in each sector the number and distribution of nests did not vary importantly between years.

3.2.2 Aerial surveys

3.2.2.1 Aerial transect surveys (1990)

Aerial transect surveys were divided into 1-km-long segments using the Universal Transverse Mercator (UTM) grid. Because of the patchiness of the habitat and the difficulty of associating a given bird (often seen in flight) with a specific habitat, we recognized groupings of two adjacent habitats, which we refer to as "macrohabitats." The four macrohabitats recognized were marsh–tidal flat, eelgrass bed–tidal flat, heath–tidal flat, and open water (Table 4).

The marsh–tidal flat macrohabitat is a section of shoreline containing a marsh (either fresh or salt) bordering on a mud/sand tidal flat and is found only along the mainland coastline. The eelgrass bed–tidal flat category includes dense or sparse eelgrass meadows and adjacent boulder-strewn tidal flats, either on islands or on the mainland, and mainly along the north shore of the Bay of Many Islands. The heath–tidal flat macrohabitat consists of *Empetrum* and lichen heath associated with tidal flats and occurs, in the Bay of Many Islands,

Table 3
Schedule of behavioural observations at eight sites in the Bay of Many Islands, 1990 and 1991

Site	Year	Date	Time[a]	No. of counts
S01	1990	6, 8, 10 June	7:15, 9:13, 15:11	3
		1 July	9:04	1
		1 August	17:24	1
		23 September	15:53	1
	1991	19 May	12:15	1
S02	1990	6 June	06:30–12:00	12
		8 June	15:30–21:00	13
		22 September	12:15–17:45	12
	1991	28 June	15:00–20:30	8
S03	1990	7 June	14:00–19:30	12
		11 June	08:00–13:00	11
		23 September	12:00–18:00	12
	1991	20 May	09:30–15:30	13
S05	1990	7, 9, 12 June	12:25, 11:00, 10:25	3
		30 June	12:24	1
		1 August	19:29	1
		23 September	13:50	1
S06	1990	7, 10, 12 June	11:42, 16:08, 10:53	3
		30 June	10:59	1
		1 August	18:05	1
		23 September	14:50	1
S07	1990	6, 9, 12 June	17:15, 11:58, 18:35	3
		1 July	7:25	1
		1 August	16:17	1
		23 September	16:15	1
S08	1990	8, 10, 12 June	7:39, 13:28, 7:58	3
		1 July	8:02	1
		1 August	16:45	1
		23 September	16:50	1
S11	1991	12 September	12:00–18:00	13
		13 September	07:30–12:30	11

[a] Eastern Daylight Saving Time (EDT).

primarily on islands (Dignard et al. 1991). The last macrohabitat, open water, includes mainly areas of marine water below the low tide line as well as reefs and rocky islands with little or no vegetation, but it excludes eelgrass beds, tidal flats, marshes, and heath. Segments of this macrohabitat were found mainly in the western and southern parts of the Bay of Many Islands.

Although some freshwater habitats along the mainland coast were covered during this survey, they were not included in the present analysis.

3.2.2.2 Aerial surveys of quadrats

Aerial surveys of quadrats involved exhaustive counts of ducks in all wetlands within 5 × 5 km (1990) or 2 × 2 km (1991) quadrats during the brood-rearing and moulting periods. The survey technique is adapted from that developed by Bordage (1987).

In 1990, four 5 × 5 km quadrats were surveyed to examine densities of ducks in an inland-to-offshore gradient in the Bay of Many Islands.

In 1991, 44 2 × 2 km quadrats were surveyed in three sectors (strata): Point Attikuan, Bay of Many Islands, and Dead Duck Bay (Fig. 3). We estimated populations and standard errors using the method described by Cochran (1977:91). These estimates were then expanded to densities per 100 km^2 by the formula $\bar{x} \pm s(\bar{x}_{st}) \times 25$, where $\bar{x}_{st}$ is the stratified mean and $s(\bar{x}_{st})$ is the standard error of the stratified mean. We examined habitat use by two methods. The first examined use by groups of species and covered all three sectors, whereas the second examined use on a species-by-species basis in the Bay of Many Islands. In the first analysis, each 2 × 2 km quadrat was divided into 16 equal squares, and the habitats in each square were identified (see Table 4). The total values assigned to each habitat in the 16 squares in each quadrat were calculated, and a percentage was assigned to reflect the importance of each habitat:

No. of habitats present in a square	Value assigned to each habitat
1	1.00
2	0.50
3	0.33
4	0.25
etc.	etc.

Two data matrices were then generated:

1) Habitat–quadrat matrix:
   - quadrat numbers on abscissa
   - types of habitats on ordinate
   - shows the relative importance of a given habitat in each survey quadrat.

2) Species–quadrat matrix:
   - quadrat numbers on abscissa
   - species on ordinate
   - shows the abundance of a given species in each survey quadrat.

A correspondence analysis (Benzécri and Benzécri 1980) was performed on the data in the species–quadrat matrix. This statistical method is used to measure the degree of association between species and to identify the quadrats and species that contribute most to data variability. Following the recommendations of Legendre and Legendre (1984), we also examined the intermediate tables produced in the correspondence analysis. Quadrats that contained no observations could not be used in the analysis. Subsequently, Kendall's coefficient of rank correlation was used to reveal associations between species and habitats.

In the second analysis, observations made in the Bay of Many Islands and recorded on a 1:50 000-scale map were overlaid on the habitat map produced by Dignard et al. (1991). For each species, the percentage of the population surveyed occupying each habitat was calculated. Each species' habitat preferences were then evaluated using Bonferroni's method (Byers et al. 1984). Preferences were calculated for species and habitats only when $np \geq 5$ for each habitat, where n is the number of individuals observed and p the proportion of the habitat in the sample.

Note that some of the innermost quadrats of this survey covered some freshwater mainland habitats; thus, exceptionally in this case, freshwater habitats have been included in the analysis.

3.2.3 Behavioural observations

To determine whether habitats at ground stations were selected or avoided, we compared the proportion of

Table 4
Categories of macrohabitats used in analysis of aerial survey data

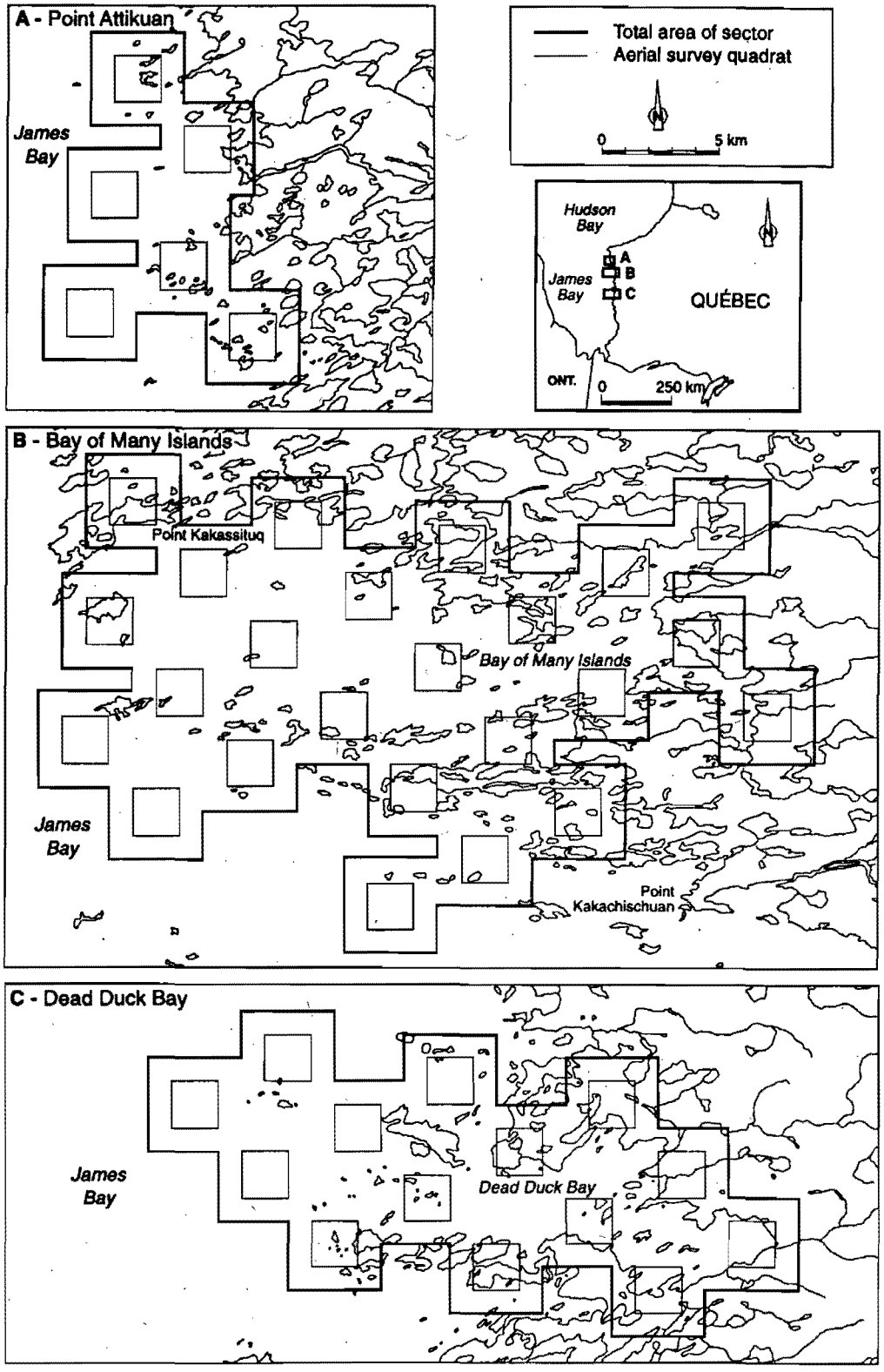
Aerial surveys		
Transect	Quadrat	Description[a]
Marsh–tidal flat	Marsh–mud/sand tidal flat	Main habitats are freshwater and salt marshes, mud/sand tidal flats, or a combination of the above.
Eelgrass bed–tidal flat	Eelgrass bed	Consists of eelgrass meadows with dense or sparse cover.
	Boulder-strewn tidal flat or boulder-strewn shore fringed with vegetation	Encompasses tidal flats strewn with rocks or boulders, boulder-strewn shoreline, and rocky islets fringed with vegetation.
Heath–tidal flat	Heath	Encompasses both *Empetrum* and lichen heaths.
	Offshore island	Includes boulder-strewn tidal flats without shoreline or submerged vegetation and barren rocky islands.
Open water	Open water	Areas of open water around islands.
	Freshwater habitats	Freshwater lakes, ponds, marshes, and bogs adjoining the coast.

[a] Adapted from Dignard et al. (1991).

the duck populations recorded in a given habitat with the proportional availability of that habitat; statistical inference followed Bonferroni's method (Byers et al. 1984) by examining the relationship between proportional availability and the 95% confidence interval of proportional use. If proportional availability falls below the confidence interval of proportional use, the habitat is considered to be significantly preferred; if it falls above the confidence interval, the habitat is significantly avoided; if it falls within the proportional use interval, the habitat is considered to be used in proportion to its availability (i.e., not significant at $P = 0.05$).

For abundant species at stations where repetitive scans were conducted over several hours, graphs were generated to show changes in habitat use for feeding and for other activities in relation to time of day and tidal level. Those data were compiled by species according to habitat and behaviour, and bird numbers were expressed in number of individuals per square kilometre.

Figure 3
Location of quadrats surveyed in Point Attikuan, Bay of Many Islands, and Dead Duck Bay sectors between 8 and 13 August 1991



4. Results

4.1 Habitat use during migration

4.1.1 Distribution by habitat

During an aerial survey towards the end of spring migration (6 June 1990) in the Bay of Many Islands, 13 species of ducks were observed, distributed across four macrohabitats (Fig. 4).

The American Black Duck *Anas rubripes* was the most abundant species and was found mainly in two macrohabitats: marsh–tidal flat and eelgrass bed–tidal flat. Other species of dabbling ducks were far less abundant; they also used macrohabitats containing tidal flats and generally occupied exposed portions of the tidal flats or portions covered by shallow water. Diving ducks were generally observed in deeper water, often over flooded tidal flats. Two of the most abundant diving ducks, the White-winged Scoter *Melanitta fusca* and the Common Eider, used open water areas, with the former also using tidal flats associated with eelgrass beds and the latter, tidal flats adjacent to heath (usually near offshore islands). Tidal flats associated with eelgrass meadows were also used by Surf and Black scoters, Common and Red-breasted mergansers, and Common Goldeneye *Bucephala clangula*; the mergansers also made considerable use of tidal flats associated with salt marshes.

Observations at the Bay of Many Islands ground stations provided additional information on habitats used during the spring and fall migrations (Figs. 5–8, Tables 5–7). Among the dabbling ducks, only American Black Ducks were observed in large numbers; in spring, the largest numbers were associated with mud/sand tidal flats, and their proportional abundance there was greater than expected, based on surface area (Fig. 5). That preferential use of mud/sand tidal flats was also statistically significant at site S02 (Table 5) and S03 (Table 6). Occasionally, the lower salt marsh and a saltwater pond were used in greater proportion than predicted by their relative surface areas (Fig. 5, Table 6), whereas the high salt marsh, open water areas, boulder-strewn shores, and eelgrass beds were generally avoided. In the fall, American Black Ducks also used mud/sand tidal flats preferentially (Fig. 6, Tables 5, 6), and, at one site, they were observed in large numbers on ericaceous heath (Fig. 6B). As in the spring, salt marshes, boulder-strewn tidal flats, eelgrass beds, and open water areas were not generally used intensively. For other species of dabbling ducks — Mallards *Anas platyrhynchos*, Green-winged Teal *A. crecca*, Northern Pintail *A. acuta*, and American Wigeon *A. americana* — small sample sizes hampered statistical treatment, but those species were generally observed in the same habitats as American Black Ducks.

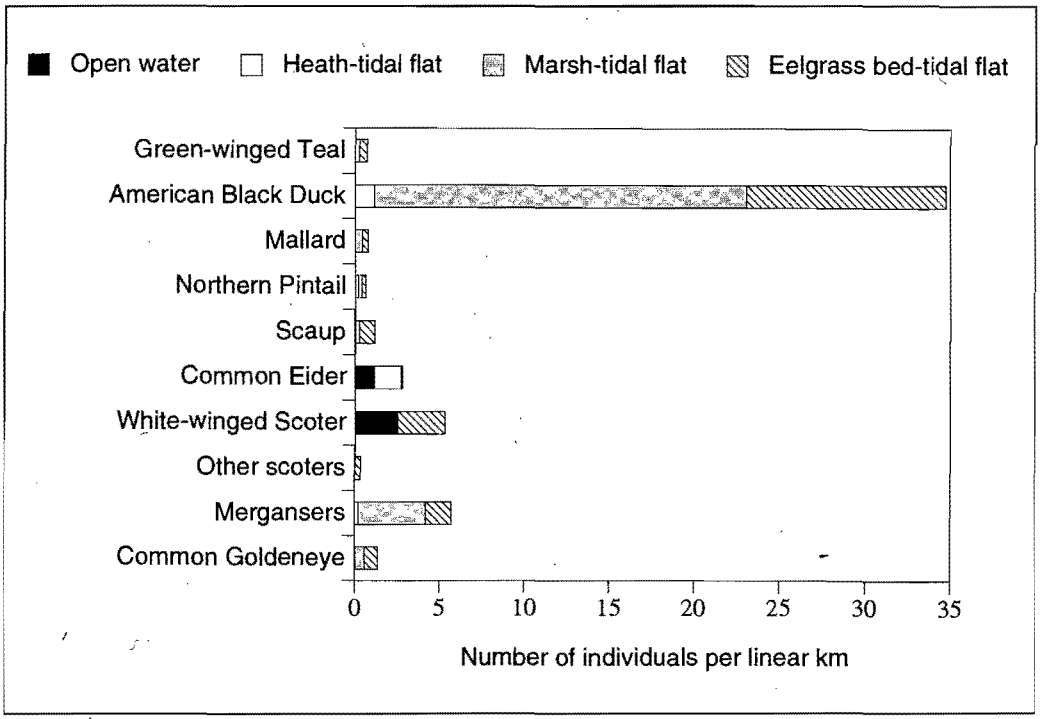
Scaup significantly favoured boulder-strewn tidal flats, eelgrass beds, and open water at site S02 on 6 and 8 June 1990 (Fig. 7A, Table 5). At the same site on 22 September 1990, scaup used eelgrass beds to a significant and almost exclusive degree (Fig. 8A, Table 5). The small number of White-winged Scoters present at site S02 used eelgrass beds and open water. Common Goldeneyes favoured eelgrass beds, open water, and rocky tidal flats at site S02 on 6 and 8 June 1990 (Table 5), while significantly avoiding mud/sand tidal flats. On 22 September 1990 at the same site, however, Common Goldeneyes used mud/sand tidal flats, open water, and eelgrass beds (Table 5). At site S03 on 7 and 11 June 1990, the same species frequented mud/sand tidal flats (Table 6), while at site S11 on 12–13 September 1991, it favoured eelgrass beds (Table 7).

Mergansers favoured eelgrass beds, open water, and boulder-strewn tidal flats at site S02 on 6 and 8 June 1990 (Fig. 7A, Table 5). On 22 September 1990, mergansers were observed on mud/sand tidal flats at the same site (Fig. 8A). On 7 and 11 June 1990, Common Mergansers also frequented mud/sand tidal flats at site S03 (Table 6). In autumn, mergansers were observed on boulder-strewn tidal flats and eelgrass beds at site S11 (Table 7).

4.1.2 Behavioural components of habitat use during migration

During spring migration, feeding was the most frequently observed activity. American Black Ducks fed primarily on mud/sand tidal flats (Figs. 9A, 9B), but the adjacent low salt marshes were also important (Fig. 9A); high salt marshes, boulder-strewn tidal flats, and dense eelgrass beds were used less regularly. Similarly, during fall migration, American Black Ducks fed in mud/sand tidal flats and adjacent low salt marshes (Figs. 10B, 10C). The species was less selective in its choice of habitats for other types of activities such as resting and preening,

Figure 4
Distribution by macrohabitat of ducks observed in an aerial transect survey on 6 June 1990 in the Bay of Many Islands (n = 1367)



frequenting low and high salt marshes, boulder-strewn tidal flats, open water, and mud/sand tidal flats.

Tidal levels did not appear to have a major influence on the foraging behaviour of American Black Ducks in their main feeding habitat; feeding in mud/sand tidal flats occurred both at low tide (Figs. 9B, 10C), when the flats were largely exposed, and at high tide (Figs. 9A, 10A, 10B), when the flats were largely flooded. However, most feeding in the second most important habitat, the low salt marsh, occurred at medium to high tide levels (Figs. 10A, 10C). Because low salt marshes generally occur immediately above mud/sand tidal flats, their use as a feeding site by dabbling ducks may be prompted, in part, by the temporary reduction in the availability of the tidal flats during high tide.

Generally, too few individuals of other duck species were observed during behavioural observations to warrant detailed analysis. However, the few other dabbling ducks observed (Mallards, American Wigeon, and Northern Pintails) also fed mainly on mud/sand tidal flats. The habitats used most often by mergansers (Fig. 9C), scaup (Fig. 9D), and Common Goldeneyes for feeding included sparsely vegetated eelgrass beds, open water, and boulder-strewn tidal flats.

4.2 Habitat use during the nesting and premoult periods

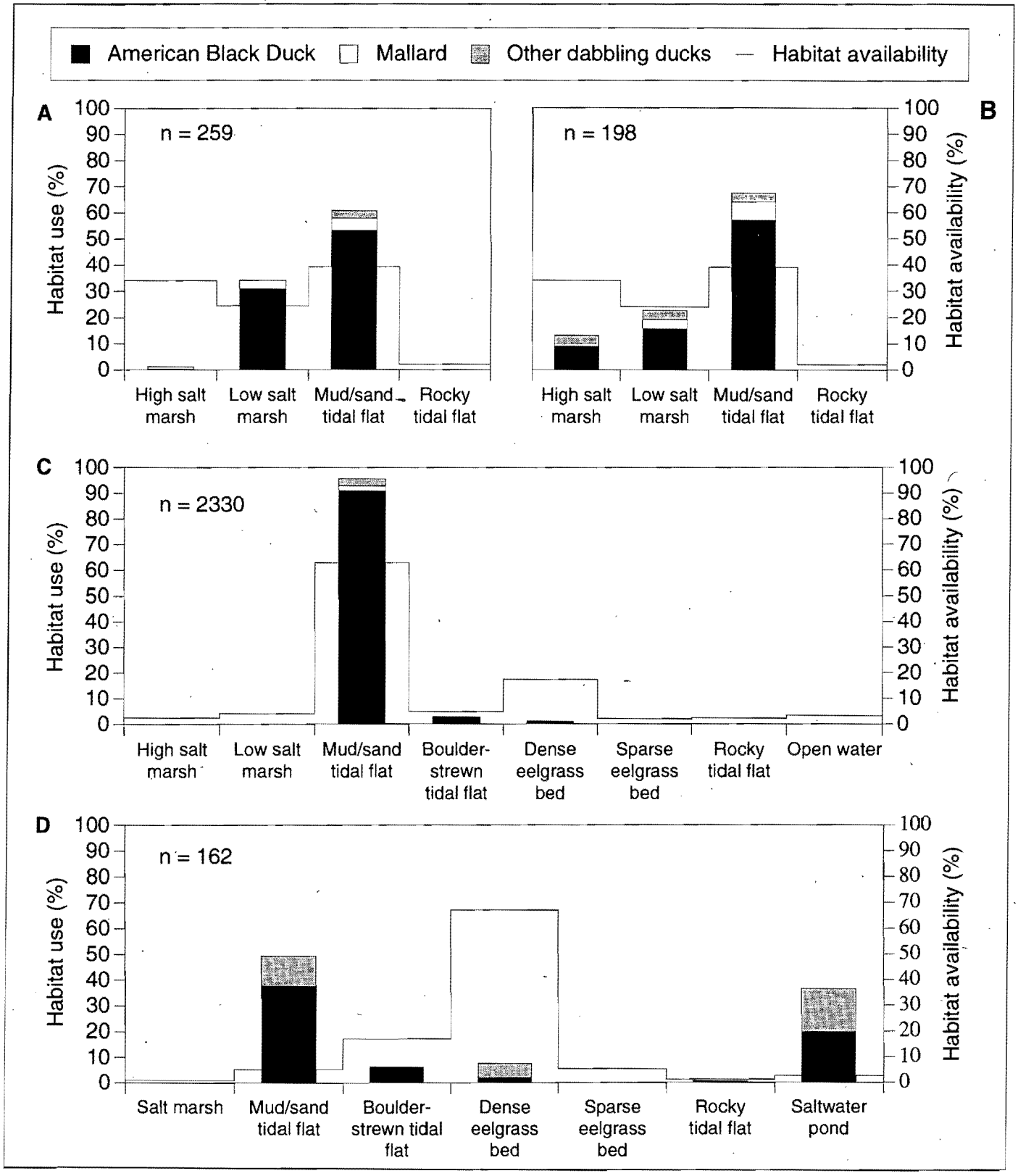
4.2.1 Distribution by habitat type (premoult congregations)

Observations to determine use of different habitat types during this period included an aerial survey of the Bay of Many Islands on 28 June 1990 and behavioural observations in the same area in late June 1990 and 1991. These and other observations, including nest searches on islands in this and other sections of the coast, indicated that the Common Eider was the only duck nesting in abundance in the coastal habitats in the study area; most (>98%) individuals of the other species were judged to be nonbreeders (e.g., yearling diving ducks still too young to breed) or postbreeders (e.g., adult males that had bred elsewhere and undergone a moult migration, and some adult females that had failed in their nesting attempts) congregating along this coast prior to the moult. This section of the report deals, therefore, mainly with habitat use by premoult congregations in the Bay of Many Islands; habitat use by breeding ducks is dealt with in Section 4.2.3.

The aerial survey showed the Common Goldeneye to be the most abundant species (Fig. 11), found mainly in the areas of open water and over tidal flats near islands (heath–tidal flat macrohabitat). American Black Ducks, second in abundance, used tidal flats, principally those associated with eelgrass beds and heath-covered islands, almost exclusively; Northern Pintails used essentially the same macrohabitats. Mallards were observed mainly in marsh–tidal flat macrohabitats, whereas Green-winged Teal were found in open water and eelgrass bed–tidal flat macrohabitats (Fig. 11). Surf and Black scoters, like Common Eiders, frequented open water exclusively, whereas White-winged Scoters were found over eelgrass bed–tidal flat macrohabitats. Mergansers were concentrated in heath–tidal flat and eelgrass bed–tidal flat macrohabitats.

At ground observation sites in the Bay of Many Islands, the vast majority of American Black Ducks, Mallards, and American Wigeon occurred in mud/sand tidal flats (Figs. 12A, 12B); at the one site where statistical tests could be conducted (S02), this use of

Figure 5
Distribution of dabbling ducks by habitat at site S03 on 20 May 1991 (A) and 7 and 10 June 1990 (B); at site S02 on 6 and 8 June 1990 (C); and at sites S01, S05, S06, S07, and S08 between 6 and 12 June 1990 (D)



mud/sand tidal flats proved to be significantly greater than expected, based on its proportional availability (Table 8), for all three species of dabbling ducks. Mergansers, Common Goldeneyes, and other diving ducks occurred in many habitats, but most frequently over flooded tidal flats and eelgrass beds (Figs. 12C, 12D); at site S02, Common Goldeneyes used eelgrass beds to a significantly greater degree than expected from the availability of that habitat, whereas mergansers showed a significant preference for boulder-strewn tidal flats (Table 8).

Figure 6
Distribution of dabbling ducks by habitat at site S03 on 23 September 1990 (A); at site S11 on 12 and 13 September 1991 (B); and at site S02 on 22 September 1990 (C)

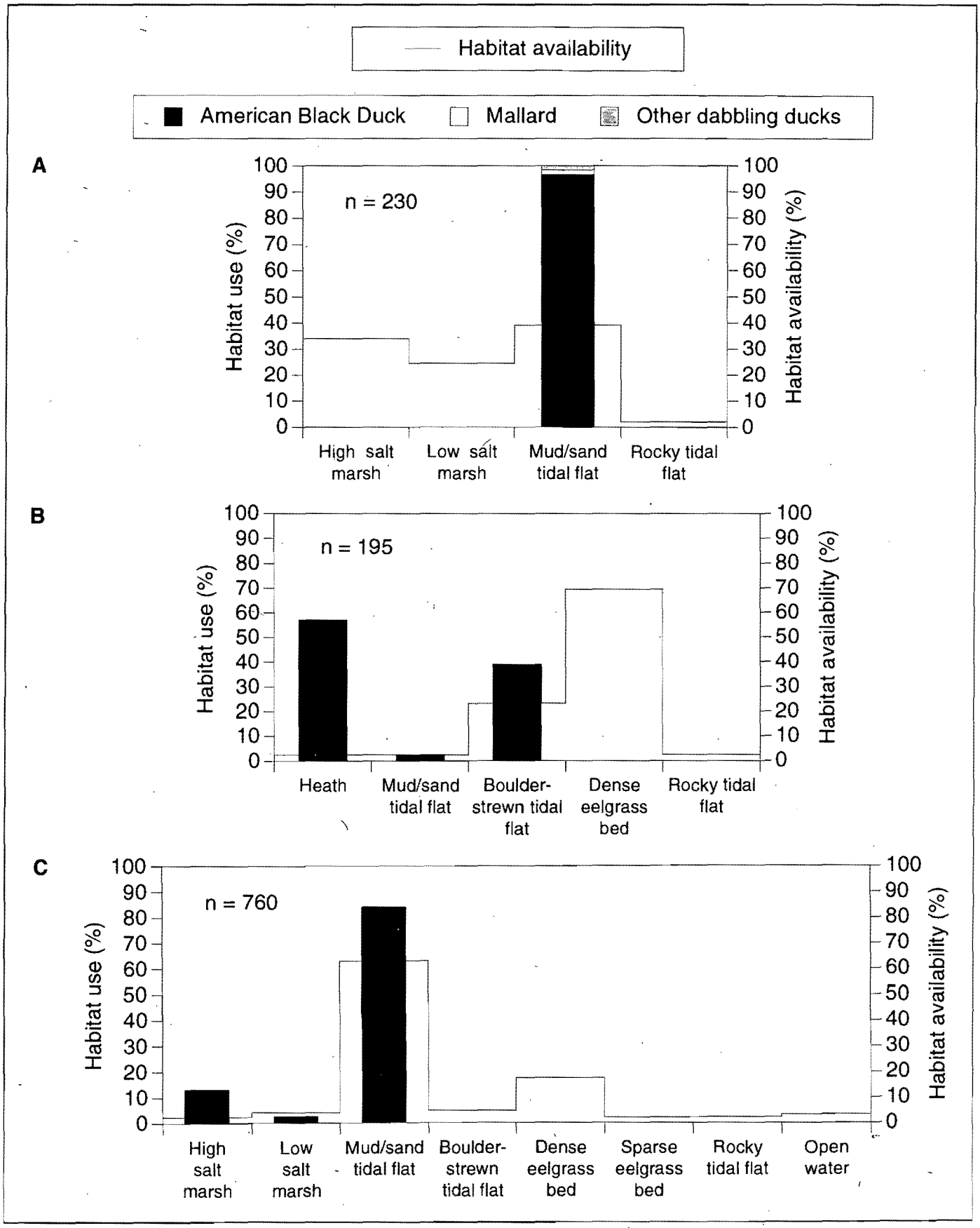
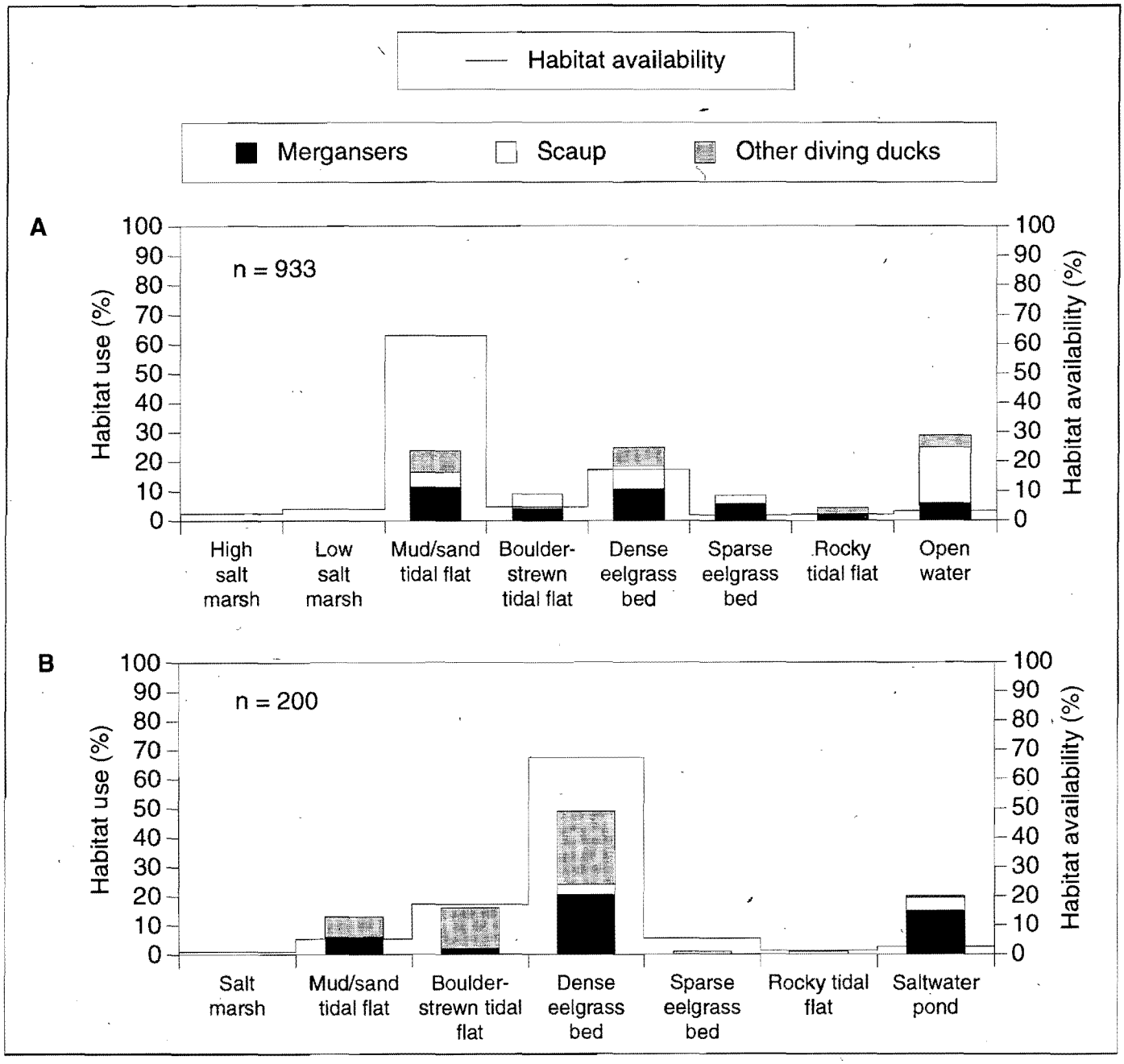


Figure 7
Distribution of diving ducks by habitat at site S02 on 6 and 8 June 1990 (A) and at sites S01, S05, S06, S07, and S08 between 6 and 12 June 1990 (B)



4.2.2 Behavioural components of habitat use (premoult congregations)

American Black Ducks devoted a smaller proportion of their time to feeding during this period than during migration (compare Figs. 9 and 10 with 13), but the bulk of their foraging occurred in the same habitat, namely the mud/sand tidal flat (Fig. 13A); other activities were performed mainly in boulder-strewn and rocky tidal flats.

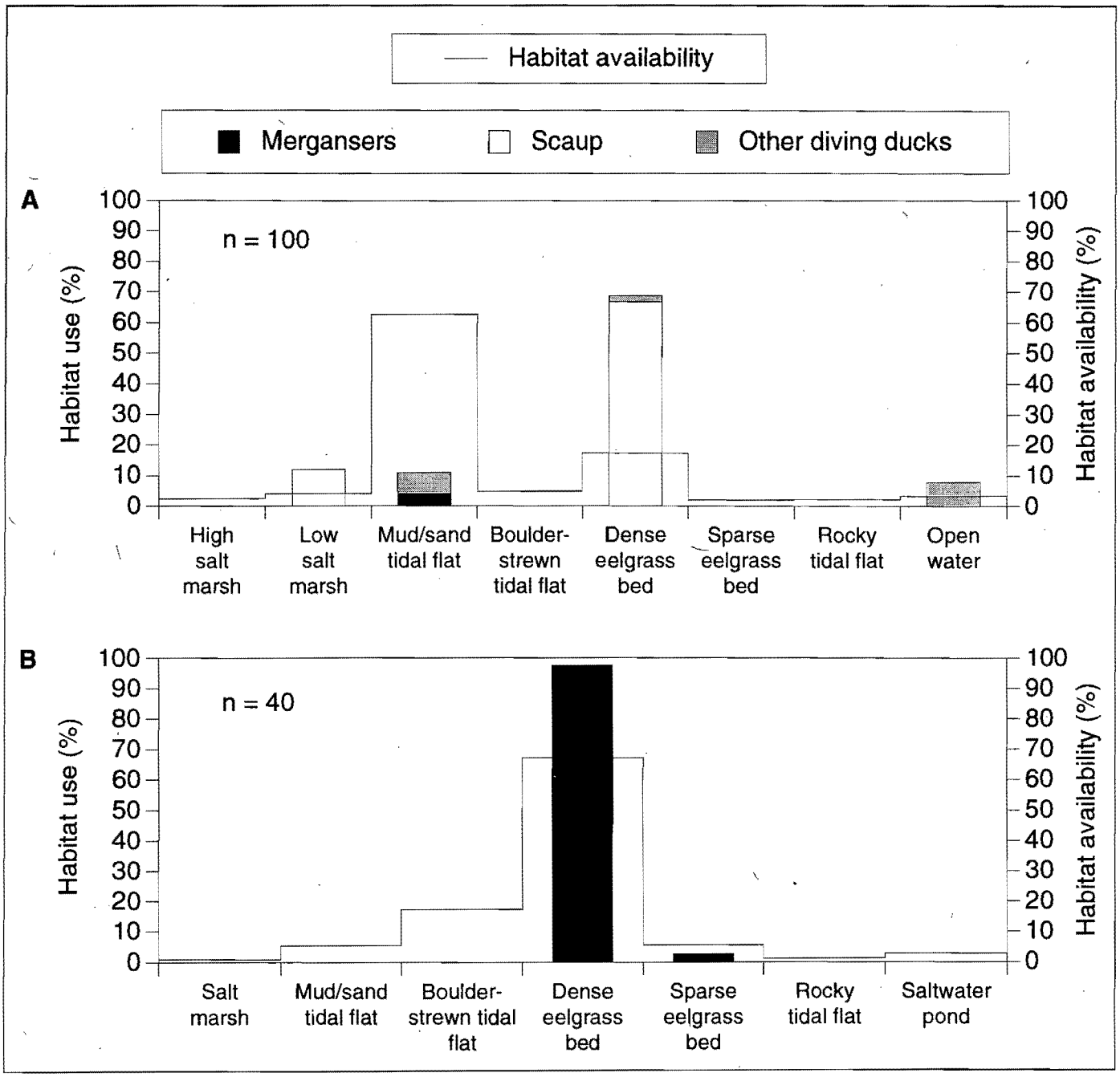
Other dabbling ducks, including Mallards and American Wigeon, fed mainly in the mud/sand and boulder-strewn tidal flats. Mergansers and Common Goldeneyes fed mainly in open water areas (Figs. 13B, 13C).

4.2.3 Habitat use by breeding ducks during the nesting period

During intensive searches in coastal habitats along the mainland of the Bay of Many Islands and near Point Attikuan, no duck nests were found. During behavioural observation sessions at coastal mainland sites in the Bay of Many Islands, pursuit flights and other manifestations of nesting activity (Seymour and Titman 1978) were rarely observed. These, along with more casual observations throughout the study area by us and our Cree guides, provide strong evidence that few ducks nest in coastal habitats on the mainland.

However, during searches on islands throughout the study area, the nests of seven different species were found, and young broods of five additional species were

Figure 8
Distribution of diving ducks by habitat at site S02 on 22 September 1990 (A) and at sites S01, S05, S06, S07, and S08 on 23 September 1990 (B)



observed (Table 9). Of the 12 species of duck for which at least one nest or brood was observed, only the Common Eider nested in any abundance; all others nested singly, widely distributed throughout the study area.

Common Eiders nested singly or, more commonly, in small colonies of 2–16 nests, with an average of 0.9 nests per island and an estimated combined population for the five survey sectors of 421 nests (Table 9). Ninety-three percent of the Common Eider nests were found in the northern portion of the study area, from the Bay of Many Islands to Point Louis-XIV (Table 10). Almost all were on the periphery of small islands. Nests were recorded in five different habitats, but almost half were in the vegetated fringe along boulder-strewn shorelines; other important habitats included the landward edge of rocky and boulder-strewn tidal flats and *Empetrum* heath (Table 11). Most nests (66%) were situated in grassy cover (of which >86% were in *Elymus mollis*), and most of the remainder in low shrubs (Table 11).

4.3 General distribution and abundance of ducks along the coast during brood-rearing and moulting periods

Of 6115 adult ducks observed during an aerial survey of three coastal sectors in August 1991 (Fig. 3, Table 12), only 76 individuals (1.2%) were associated with broods. Although at least 10 species were observed with broods, the Common Eider was the only abundant

Table 5
Proportional use of habitats by ducks at site S02 in the spring and autumn of 1990

Species	High salt marsh (0.025)[a]	Low salt marsh (0.041)	Mud/sand tidal flat (0.630)	Boulder-strewn tidal flat (0.048)	Eelgrass bed (0.194)	Rocky tidal flat (0.029)	Open water (0.033)
6 and 8 June 1990							
American Black Duck (2218)[b]	*0*	*0*	0.956 ± 0.012[c]	*0.030 ± 0.010*	*0.014 ± 0.007*	*0*	*0.000 ± 0.001*
Mallard (49)	[0][d]	[0]	0.959 ± 0.063	[2]	*0*	[0]	[0]
Northern Pintail (45)	[0]	[0]	1	[0]	*0*	[0]	[0]
American Wigeon (18)	[0]	[0]	1	[0]	[0]	[0]	[0]
Scaup (370)	*0*	*0*	*0.127 ± 0.047*	0.130 ± 0.047	0.262 ± 0.062	*0.003 ± 0.007*	0.478 ± 0.070
White-winged Scoter (4)	[0]	[0]	[0]	[0]	[2]	[0]	[2]
Common Goldeneye (181)	[0]	*0*	*0.370 ± 0.095*	*0*	0.315 ± 0.091	0.122 ± 0.064	0.193 ± 0.077
Mergansers (378)	*0*	*0*	*0.288 ± 0.063*	0.101 ± 0.042	0.415 ± 0.068	0.048 ± 0.029	0.148 ± 0.049
22 September 1990							
Green-winged Teal (1)	[0]	[0]	[1]	[0]	[0]	[0]	[0]
American Black Duck (757)	0.132 ± 0.033	0.026 ± 0.016	0.841 ± 0.036	*0*	*0*	*0*	*0*
Mallard (2)	[0]	[0]	[2]	[0]	[0]	[0]	[0]
Scaup (79)	[0]	[12]	*0*	[0]	0.848 ± 0.090	[0]	[0]
Common Goldeneye (17)	[0]	[0]	[7]	[0]	[2]	[0]	[8]
Mergansers (4)	[0]	[0]	[4]	[0]	[0]	[0]	[0]

[a] Proportional availability (relative area) of habitat at site.
[b] Total number of ducks observed during all counts.
[c] The 95% confidence interval of the proportional use of habitat, following the Bonferroni method (see Section 3.2.3). The underlined numbers (0.853 ± 0.136) indicate that the species used the habitat more than expected, whereas the numbers in italics (*0.407 ± 0.115*) indicate that the habitat was used less than expected. Numbers that are neither underlined nor in italics (0.242 ± 0.101) indicate that the species frequented the habitat in accordance with its relative area. In the case of total or zero frequentation, no confidence intervals are given.
[d] Number of individuals observed in habitat [2] but not included in statistics because np ≤ 5 (see Section 3.2.2.2).

Table 6
Proportional use of habitats by ducks at site S03 in the spring of 1990 and 1991 and autumn of 1990

Species	High salt marsh (0.340)[a]	Low salt marsh (0.246)	Mud/sand tidal flat (0.393)	Rocky tidal flat (0.021)
20 May 1991				
Green-winged Teal (1)[b]	[0][c]	[0]	[1]	[0]
American Black Duck (219)	*0.005 ± 0.011*[d]	0.365 ± 0.078	0.630 ± 0.078	[0]
Mallard (22)	*0.091 ± 0.147*	0.364 ± 0.246	0.545 ± 0.254	[0]
Northern Pintail (17)	*0*	[1]	0.941 ± 0.128	[0]
7 and 11 June 1990				
Green-winged Teal (5)	[5]	[0]	[0]	[0]
American Black Duck (162)	*0.111 ± 0.059*	0.191 ± 0.074	0.698 ± 0.086	[0]
Mallard (21)	[0]	0.333 ± 0.230	0.667 ± 0.230	[0]
Northern Pintail (7)	[3]	[0]	[4]	[0]
American Wigeon (3)	[0]	[0]	[3]	[0]
Common Goldeneye (2)	[0]	[0]	[2]	[0]
Common Merganser (10)	[1]	[0]	[9]	[0]
23 September 1990				
American Black Duck (222)	*0*	*0*	1	[0]
Mallard (4)	[0]	[0]	[4]	[0]
Northern Pintail (4)	[0]	[0]	[4]	[0]

[a] Proportional availability (relative area) of habitat at site.
[b] Total number of ducks observed during all counts.
[c] Number of individuals observed in habitat [2] but not included in statistics because np ≤ 5 (see Section 3.2.2.2).
[d] The 95% confidence interval of the proportional use of habitat, following the Bonferroni method (see Section 3.2.3). The underlined numbers (0.853 ± 0.136) indicate that the species used the habitat more than expected, whereas the numbers in italics (*0.407 ± 0.115*) indicate that the habitat was used less than expected. Numbers that are neither underlined nor in italics (0.242 ± 0.101) indicate that the species frequented the habitat in accordance with its relative area. In the case of total or zero frequentation, no confidence intervals are given.

breeding species, with a density of approximately 37 broods/100 km^2.

Therefore, most of the adult ducks present (>98% of the population surveyed) could not be considered as breeders. Rather, their presence seemed to be linked to the moulting of their flight feathers. Most groups observed included both flightless moulters and birds capable of flight, but for many individuals flight capability could not be determined. We nevertheless consider this group of nonbreeding adults as moulters, assuming that most of the variability in flight capabilities is attributable to individual differences in the schedule of the flightless period. This moulting population included 17 different species, with a total density of more than 3500 individuals/100 km^2 (Table 12). Scoters (Surf, Black, and White-winged combined) were most abundant, representing >60% of the total; large numbers of

Table 7
Proportional use of habitats by ducks at site S11 on 12 and 13 September 1991

Species	Heath (0.013)[a]	Mud/sand tidal flat (0.024)	Boulder-strewn tidal flat (0.244)	Eelgrass bed (0.695)	Rocky tidal flat (0.024)
American Black Duck (195)[b]	[20][c]	[5]	$\underline{0.872 \pm 0.054}$[d]	*0*	[0]
Scaup (1)	[0]	[0]	[0]	[1]	[0]
Common Goldeneye (28)	[0]	[0]	*0*	$\underline{1}$	[0]
Mergansers (3)	[0]	[0]	[2]	[1]	[0]

[a] Proportional availability (relative area) of habitat at site.
[b] Total number of ducks observed during all counts.
[c] Number of individuals observed in habitat [2] but not included in statistics because $np \leq 5$ (see Section 3.2.2.2).
[d] The 95% confidence interval of the proportional use of habitat, following the Bonferroni method (see Section 3.2.3). The underlined numbers ($\underline{0.853 \pm 0.136}$) indicate that the species used the habitat more than expected, whereas the numbers in italics ($\textit{0.407 \pm 0.115}$) indicate that the habitat was used less than expected. Numbers that are neither underlined nor in italics (0.242 ± 0.101) indicate that the species frequented the habitat in accordance with its relative area. In the case of total or zero frequentation, no confidence intervals are given.

American Black Ducks (20%) and Common Eiders (6%) were also present.

There were some interspecific differences in distribution in the study area. American Black Ducks, Mallards, Northern Pintails, and Common Eiders occurred in greater densities in the northern portion (Point Attikuan and Bay of Many Islands sectors), whereas Green-winged Teal were most abundant in the south (Dead Duck Bay sector). Scoters, in contrast, were concentrated in the Point Attikuan sector. Scaup and Common Goldeneye were significantly less abundant in general and were found almost exclusively in the Bay of Many Islands sector.

Based on correlations between habitat types within the aerial quadrats surveyed (Appendix 1), four habitats were retained for an analysis of the relations between species and habitats: marsh–tidal flats, freshwater habitats, heaths, and a fourth category consisting of boulder-strewn tidal flats and adjoining eelgrass beds. Open water areas were not retained, since they were correlated with the other habitats. Table 13 summarizes the correlations between habitats and main species present. No species was associated with heaths. Dabbling ducks were associated with marsh–tidal flats, whereas diving ducks such as the Red-breasted Merganser, Common Eider, and scoters were negatively correlated with this habitat. There was a negative correlation between the Common Eider and freshwater habitats, whereas scaup and dabbling ducks, other than the American Black Duck, were positively correlated with these habitats.

Among brood-rearing ducks, the most abundant, the Common Eider, raised its broods in areas of open water and over boulder-strewn tidal flats and eelgrass beds (Table 14). Dabbling ducks (Mallards, American Black Ducks, and American Wigeon), Ring-necked Ducks *Aythya collaris*, and White-winged Scoters used the marsh–tidal flat or freshwater habitats. A brood of Surf Scoters was observed in a heath pond.

4.4 Habitat use in the Bay of Many Islands during brood-rearing and moulting periods

Quadrat plots were surveyed in the Bay of Many Islands during August 1990 (Fig. 2) to appraise duck distribution along a gradient extending from the mainland shore to the offshore islands. The innermost quadrat consisted of a large salt marsh connected to extensive mud/sand tidal flats. The two central quadrats were located in the bay itself and included eelgrass beds and islands covered with heath or forest. The outermost quadrat consisted of heath-covered and barren islands and areas of open water. More than 50% of the ducks observed were American Black Ducks, which were present in large numbers in all quadrats (Fig. 14) and occupied mainly marsh–tidal flat and eelgrass bed–tidal flat macrohabitats (Fig. 15). Mallards were observed near the coast in marsh–tidal flat macrohabitat. Green-winged Teal were found mainly in the outer quadrat, using ponds on heath-covered islands. Among the diving ducks, scoters were most abundant, occurring almost exclusively over offshore shoal areas (outer quadrat, in open water habitat). Most other diving ducks were also observed at a certain distance from the coast, mainly in offshore shoal areas and over submerged tidal flats associated with heath-covered islands or eelgrass beds (heath–tidal flat and eelgrass bed–tidal flat macrohabitats); exceptions were Ringed-neck Ducks and Buffleheads *Bucephala albeola*, which were observed on small lakes just inland from the mainland coast.

Another quadrat survey in August 1991 (Fig. 3B) allowed further assessment of habitat selection in the Bay of Many Islands by the most numerous species (Fig. 16, Table 15). The most abundant species, the American Black Duck, was found in all macrohabitats but preferentially used heathland ponds, boulder-strewn tidal flats, and eelgrass beds, while significantly avoiding open water macrohabitat. Green-winged Teal, the second most abundant dabbling duck, occurred exclusively in two habitats, ponds on heath-covered islands and marsh–tidal flat macrohabitat. Similarly, Northern Pintails were found almost exclusively in two habitats: freshwater habitats and ponds on heath-covered islands. Mallards used all habitats except the marsh–tidal flat macrohabitat.

Scoters (three species combined) occurred almost exclusively in open water areas (Fig. 16, Table 15), as did Common Eiders. Scaup preferred eelgrass beds but also occurred frequently in freshwater habitats. Common Goldeneye used mainly open water, freshwater habitats, and eelgrass beds, but no statistically significant preference was detected (Table 15). Almost all the Hooded Mergansers *Lophodytes cucullatus* observed were in

Figure 9
Habitat use by American Black Ducks at sites S03 (A) and S02 (B) and by mergansers (C) and scaup (D) at site S02 between 6 and 11 June 1990

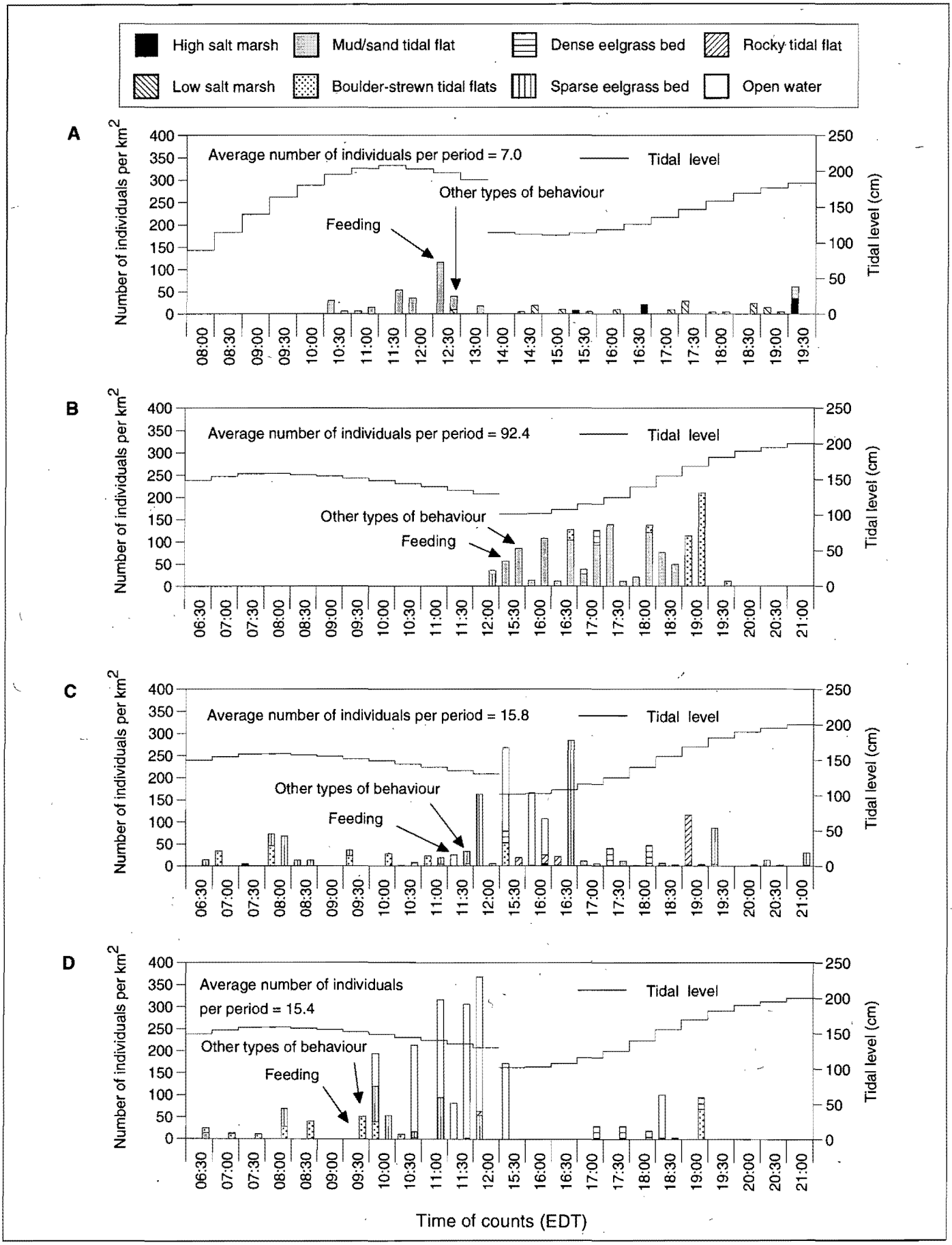
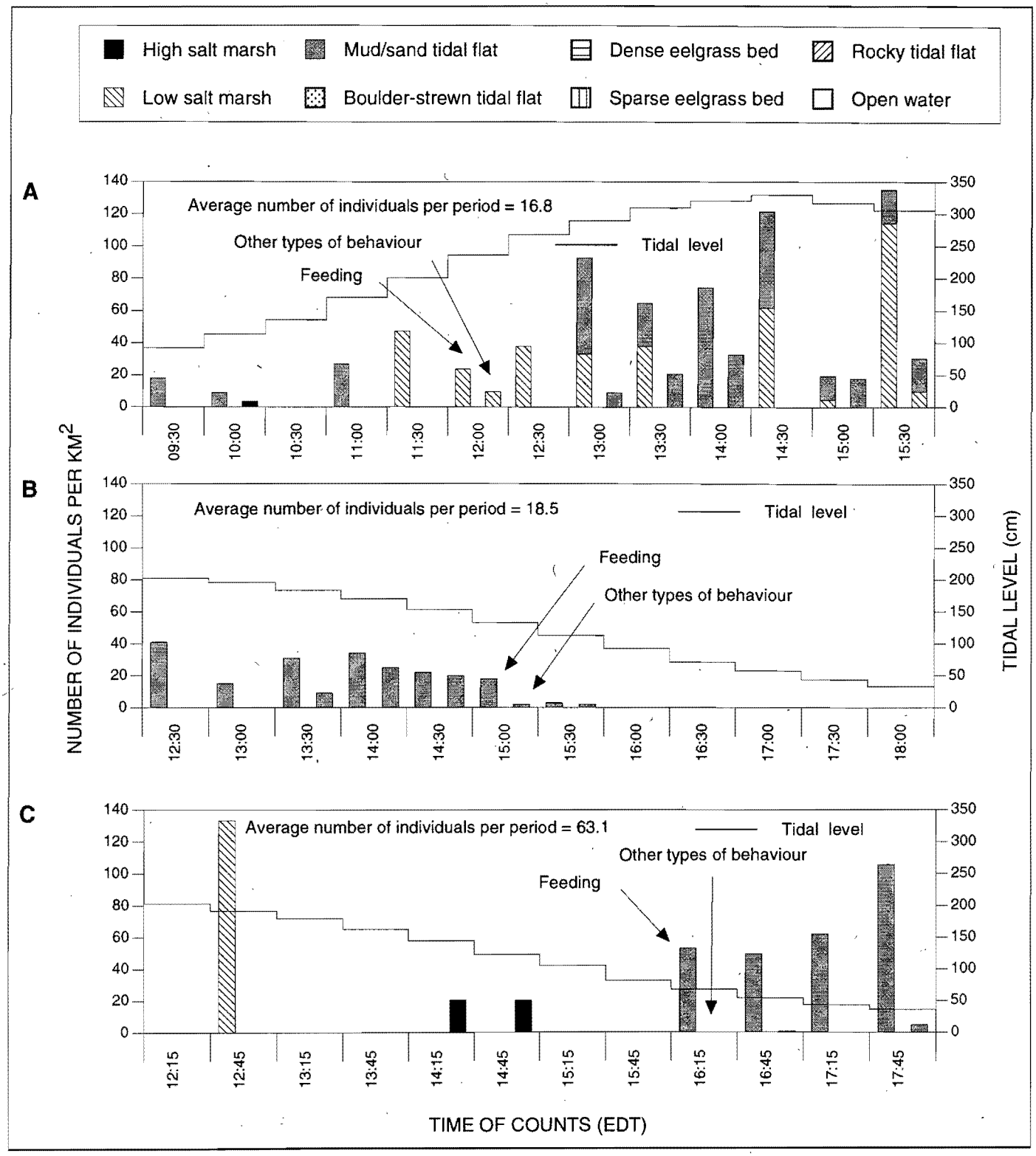


Figure 10
Habitat use by American Black Ducks at site S03 on 20 May 1991 (A) and 23 September 1990 (B) and at site S02 on 22 September 1990 (C)

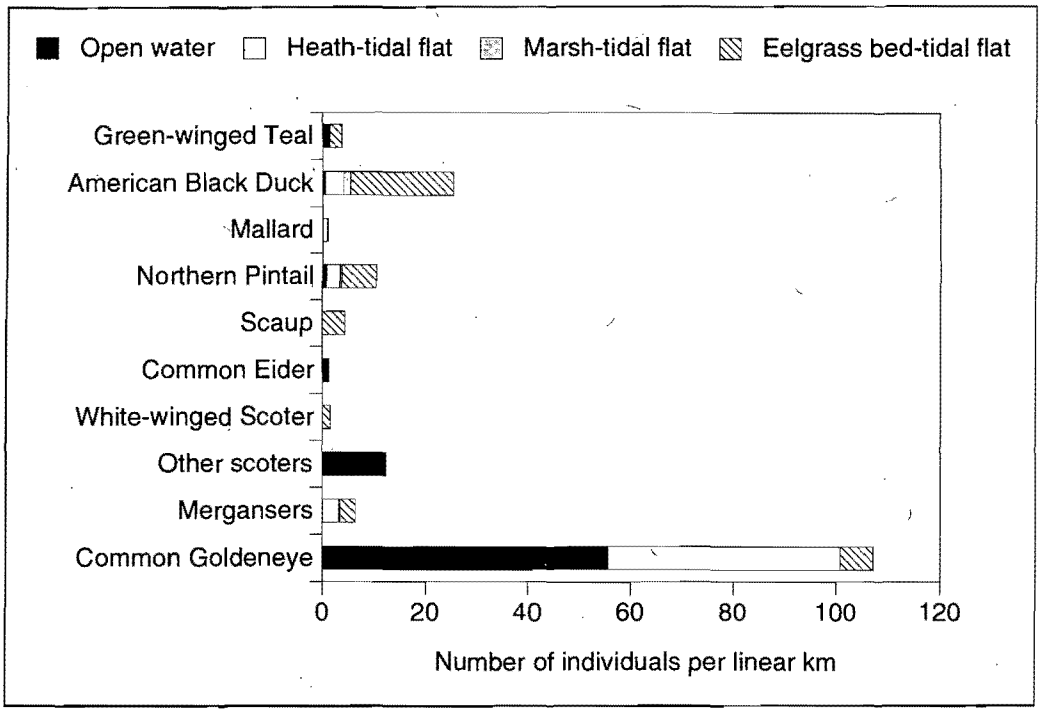


freshwater habitats, whereas the two other species of merganser selected open water.

4.5 Food resources and diet of certain ducks

To help explain the intensive use of some habitats, qualitative surveys of potential food organisms were conducted in mud/sand tidal flats, eelgrass beds (Lalumière 1987, 1988), and shoals near the islands in the outer edge of the Bay of Many Islands. We also collected moulting diving ducks (scoters, goldeneyes, and mergansers) to assess the relative importance of various organisms in their diet.

Figure 11
Distribution by macrohabitat of ducks observed in an aerial transect survey in the Bay of Many Islands on 28 June 1990 (n = 3561)



4.5.1 Benthic organisms collected from shoals or found in stomach contents of moulting diving ducks

Among the benthic organisms collected from shoals near the offshore islands in the Bay of Many Islands (Appendix 2.1), three groups of species predominated: the pelecypods, annelids, and amphipods. The most abundant species was the blue mussel *Mytilus edulis*.

Observations made during underwater dives suggested that the greatest concentrations of suprabenthic marine organisms are found on shoals where the water is between 1 and 6 m deep and where the hydrodynamics (currents and waves) are fairly strong. Sites at depths greater than 6 m were less productive and had weaker hydrodynamics. Productive locations were generally associated with coarser substrates and flourishing kelp (Laminariaceae) colonies; the blue mussel was the dominant species at the most productive sites.

The blue mussel was also the most abundant species found in the stomachs of the Black Scoter, Surf Scoter, and Common Goldeneye (Appendix 2.1). Other pelecypods that were absent from our benthic samples were also important in the diet of moulting scoters: bivalves of the genus *Astarte* were found in the stomachs of all three species of scoters, whereas *Nucula belloti* was the main species consumed by White-winged Scoters. Several species of insects were also found in the stomachs of Black Scoters, White-winged Scoters, and Common Mergansers. Mergansers had also fed on threespine sticklebacks *Gasterosteus aculeatus* and amphipods.

4.5.2 Benthic organisms in mud/sand tidal flats

In total, 24 taxa of benthic organisms were collected from a mud/sand tidal flat in August (Appendix 2.2), the most abundant being Chironomidae, particularly at high tide, when they represented 62.4% of the organisms collected, the annelid *Sabella crassicornis* (18.1% at high tide), the gastropod *Hydrobia minuta* (52.9% at low tide), and the bivalve *Macoma balthica* (22.5% at low tide). The organisms collected by us probably do not represent the full range of potential food items available to ducks; other animal organisms, plant detritus, and seeds probably flow into this habitat from adjacent communities with the ebb and flowing of the tide.

We were unable to make direct comparisons between this array of marine organisms and the food items eaten by ducks, because no birds were collected in this habitat. However, in subsequent sections, comparisons are made using published information on the diet of the most important duck species.

4.5.3 Benthic organisms in eelgrass beds

Eelgrass beds harboured 25 taxa of benthic organisms (Appendix 2.2). Annelid worms (especially Oligochaetes) constituted >66% of the organisms collected, followed by chironomids (insect larvae), with 23.8%. Although other taxa were less abundant, the bivalves *Macoma balthica* (2.7%) and *Mytilus edulis* (1.6%) deserve mention because of their large size and known importance in the diet of certain ducks (Cottam 1939; McGilvrey 1967).

Figure 12
Distribution of dabbling and diving ducks by habitat at site S02 on 28 June 1991 (A and C) and at sites S01, S05, S06, S07, and S08 between 28 and 30 June 1990 (B and D)

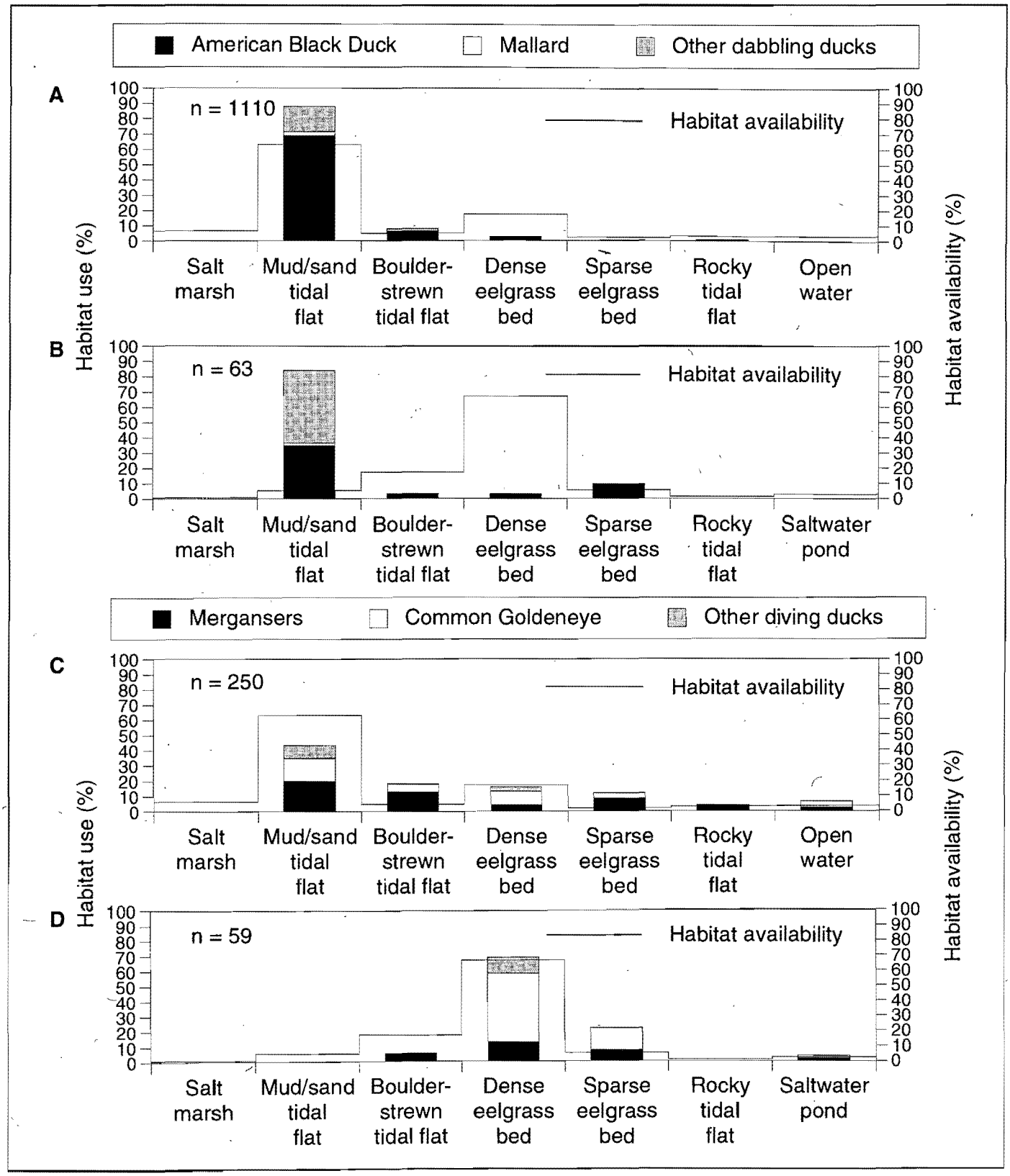


Table 8
Proportional use of habitats by ducks at site S02 on 28 June 1991

Species	High salt marsh (0.025)[a]	Low salt marsh (0.041)	Mud/sand tidal flat (0.630)	Boulder-strewn tidal flat (0.048)	Eelgrass bed (0.194)	Rocky tidal flat (0.029)	Open water (0.033)
American Black Duck (875)[b]	*0*	*0*	0.873 ± 0.030[c]	0.078 ± 0.024	*0.034 ± 0.017*	*0.010 ± 0.009*	*0.005 ± 0.006*
Mallard (34)	[0][d]	[0]	0.853 ± 0.014	[2]	*0.059 ± 0.004*	[1]	[0]
American Wigeon (52)	[0]	[0]	0.923 ± 0.083	[0]	*0.077 ± 0.083*	[0]	[0]
Scaup (7)	[0]	[0]	[4]	[1]	[2]	[0]	[0]
Common Goldeneye (91)	[0]	[0]	*0.407 ± 0.115*	[13]	0.341 ± 0.111	[0]	[10]
Mergansers (130)	[0]	*0*	*0.385 ± 0.096*	0.246 ± 0.085	0.246 ± 0.085	[10]	[6]

[a] Proportional availability (relative area) of habitat at site.
[b] Total number of ducks observed during all counts.
[c] The 95% confidence interval of the proportional use of habitat, following the Bonferroni method (see Section 3.2.3). The underlined numbers (0.853 ± 0.136) indicate that the species used the habitat more than expected, whereas the numbers in italics (*0.407 ± 0.115*) indicate that the habitat was used less than expected. Numbers that are neither underlined nor in italics (0.242 ± 0.101) indicate that the species frequented the habitat in accordance with its relative area. In the case of total or zero frequentation, no confidence intervals are given.
[d] Number of individuals observed in habitat [2] but not included in statistics because np ≤ 5 (see Section 3.2.2.2).

Table 9
Estimated number of duck nests on islands in the five coastal sectors surveyed in 1990, 1991, and 1992

Species	n[a]	Average no. of nests per island[b]	Estimated total no. of nests in five sectors studied
Green-winged Teal	p[c]	–	–
Mallard	p	–	–
American Black Duck	p	–	–
American Wigeon	p	–	–
Northern Pintail	1	–	–
Greater Scaup	1	–	–
Lesser Scaup	1	–	–
Common Eider	170[d]	0.9 (0.1)	421.2 (62.5)
Oldsquaw	3	–	–
White-winged Scoter	1	–	–
Surf Scoter	p	–	–
Red-breasted Merganser	2	–	–

[a] Number of nests or other evidence of nesting found.
[b] Average number of nests (standard error) per island using stratified means (Cochran 1977:91; see Section 3.2.1).
[c] p indicates that the species is present as a nesting species; no nest was found, but brood was observed.
[d] Includes some empty nests found in 1992 (see Section 3.1.1).

Table 10
Average density of Common Eider nests in the five sectors surveyed along the northeast coast of James Bay, 1990–92

Sector[a]	No. of islands in sector	No. of islands surveyed	No. of nests found	Average no. of nests per island (standard deviation)
Dead Duck Bay	54	24	6	0.3 (0.6)
La Grande River	98	36	6	0.2 (0.5)
Bay of Many Islands	150	51	84	1.6 (3.4)
Point Attikuan	34	17	21	1.2 (1.9)
Point Louis-XIV	112	58	53	0.9 (1.9)

[a] For sector location, see Figure 1.

Table 11
Habitats and cover used by nesting Common Eiders along the northeast coast of James Bay, 1990–92

Habitats	
Boulder-strewn shoreline fringed with vegetation	47
Empetrum heath	21
Rocky tidal flat	19
Boulder-strewn tidal flat	11
Lichen heath	2

Nesting cover	% of nests (n = 98 nests)
Grass	
Elymus mollis	57
Unspecified and others	9
Total grass	**66**
Shrub	
Willow	16
Ericaceous	13
Total shrub	**29**
Driftwood and other tidal debris	3
Rock crevice	2

Figure 13
Habitat use at site S02 in the Bay of Many Islands by American Black Ducks (A), mergansers (B), and Common Goldeneyes (C) on 28 June 1991

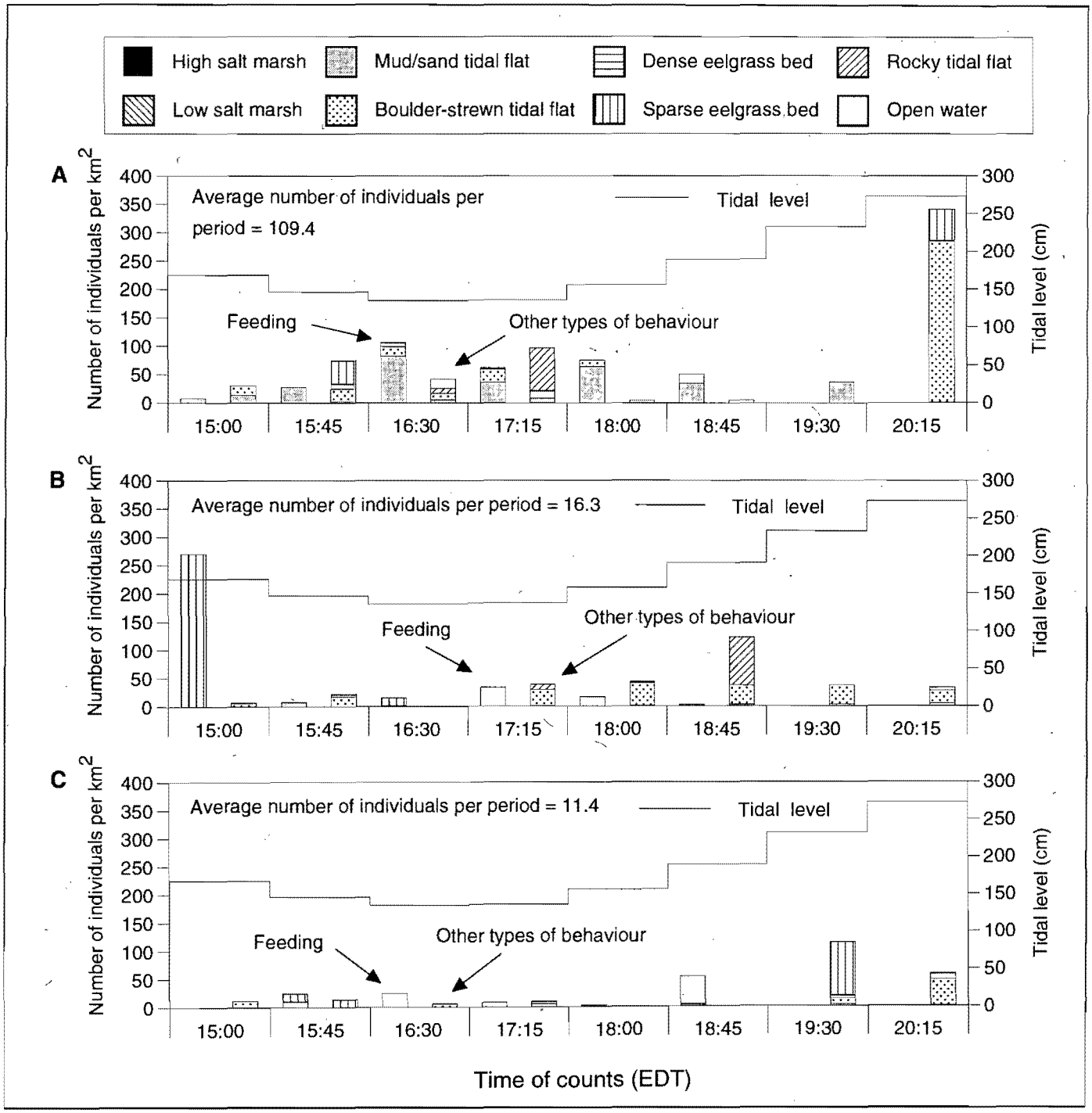


Table 12
Estimated size of adult duck populations and broods, based on aerial surveys on 8–13 August 1991 in the Bay of Many Islands, Dead Duck Bay, and Point Attikuan

	Adults		Broods	
Species	n[a]	No. of individuals per 100 km^2 [b]	n	No. of broods per 100 km^2
Green-winged Teal	184	103.4 (64.1)	1	–
American Black Duck	1210	689.5 (157.5)	2	–
Mallard	31	17.7 (6.2)	1	–
Northern Pintail	75	43.0 (19.1)	–	–
American Wigeon	–	–	1	–
Ring-necked Duck	–	–	1	–
Scaup	243	138.6 (81.2)	1	–
Common Eider	362	203.8 (109.4)	64	36.7 (8.2)
Oldsquaw	4	–	–	–
Scoters[c]	3716	2159.1 (1660.4)	4[d]	–
Hooded Merganser	39	22.1 (13.3)	–	–
Mergansers	179	100.6 (62.9)	2[e]	–
Common Goldeneye	67	38.3 (10.9)	–	–
Ducks (total)[f]	6115	3521.1 (1642.8)	77	43.5 (8.2)

[a] Number of individuals or broods observed in survey.
[b] Estimated density and standard error (see Section 3.2.2.2).
[c] All three species of scoters.
[d] One brood of White-winged Scoter and three broods of Surf Scoter.
[e] One brood of Red-breasted Merganser and one brood of an unidentified merganser species.
[f] All ducks, including unidentified species.

Table 13
Rank correlations between species and habitats, using Kendall's coefficient and the quadrats that contributed most to the formation of the three axes in the correspondence analysis

	Macrohabitats[a]			
Species	Freshwater habitats	Marsh–tidal flat	Eelgrass bed and boulder-strewn tidal flat	Heath
American Black Duck	–[b]	0.35	0.28	–
Other dabbling ducks	0.38	0.53	–	–
Scaup	0.50	–	–	–
Common Eider	-0.38	-0.40	–	–
Scoters[c]	–	-0.32	–	–
Red-breasted Merganser	–	-0.42	–	–

[a] See Table 4 for a description of habitat categories.
[b] – = not significant at $P \leq 0.05$.
[c] Includes all three species of scoters.

Table 14
Distribution by habitat of broods observed during an aerial survey in August 1991

	No. of broods					
Species	Freshwater habitats	Marsh–tidal flat	Boulder-strewn tidal flat	Eelgrass bed	Heath (ponds)	Open water
American Black Duck	1	1	–	–	–	–
Mallard	–	1	–	–	–	–
American Wigeon	–	1	–	–	–	–
Ring-necked Duck	1	–	–	–	–	–
Common Eider	–	–	8	2	–	11
White-winged Scoter	1	–	–	–	–	–
Surf Scoter	–	–	–	–	1	–

Figure 14
Distribution of ducks in four 5 × 5 km quadrats surveyed in the Bay of Many Islands between 3 and 6 August 1990 (n = 2008)

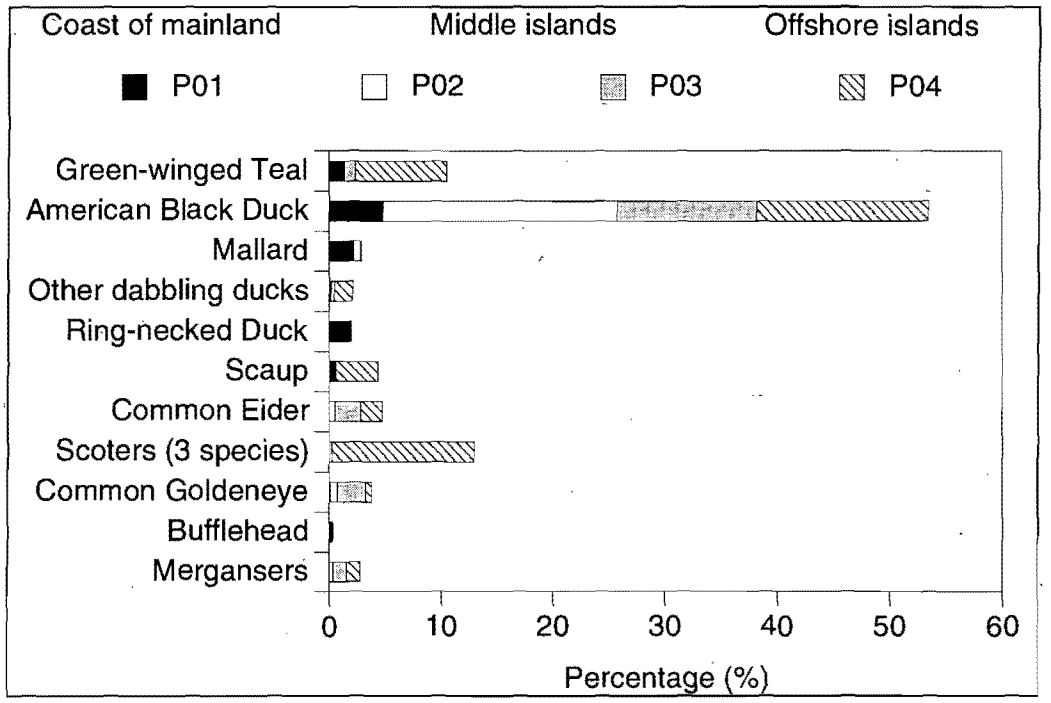


Figure 15
Distribution by macrohabitat of ducks observed during an aerial transect survey in the Bay of Many Islands on 3 August 1990 (n = 2303)

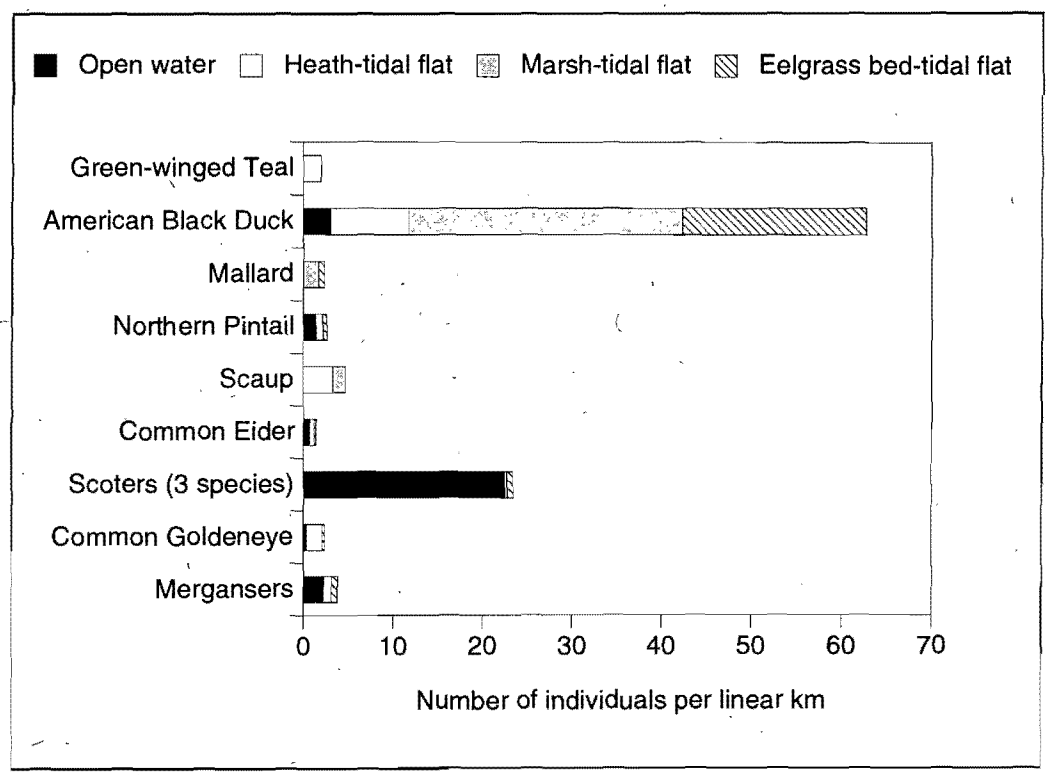


Figure 16
Distribution by habitat of main species of ducks observed in the Bay of Many Islands during aerial surveys of 2 × 2 km quadrats between 8 and 13 August 1991

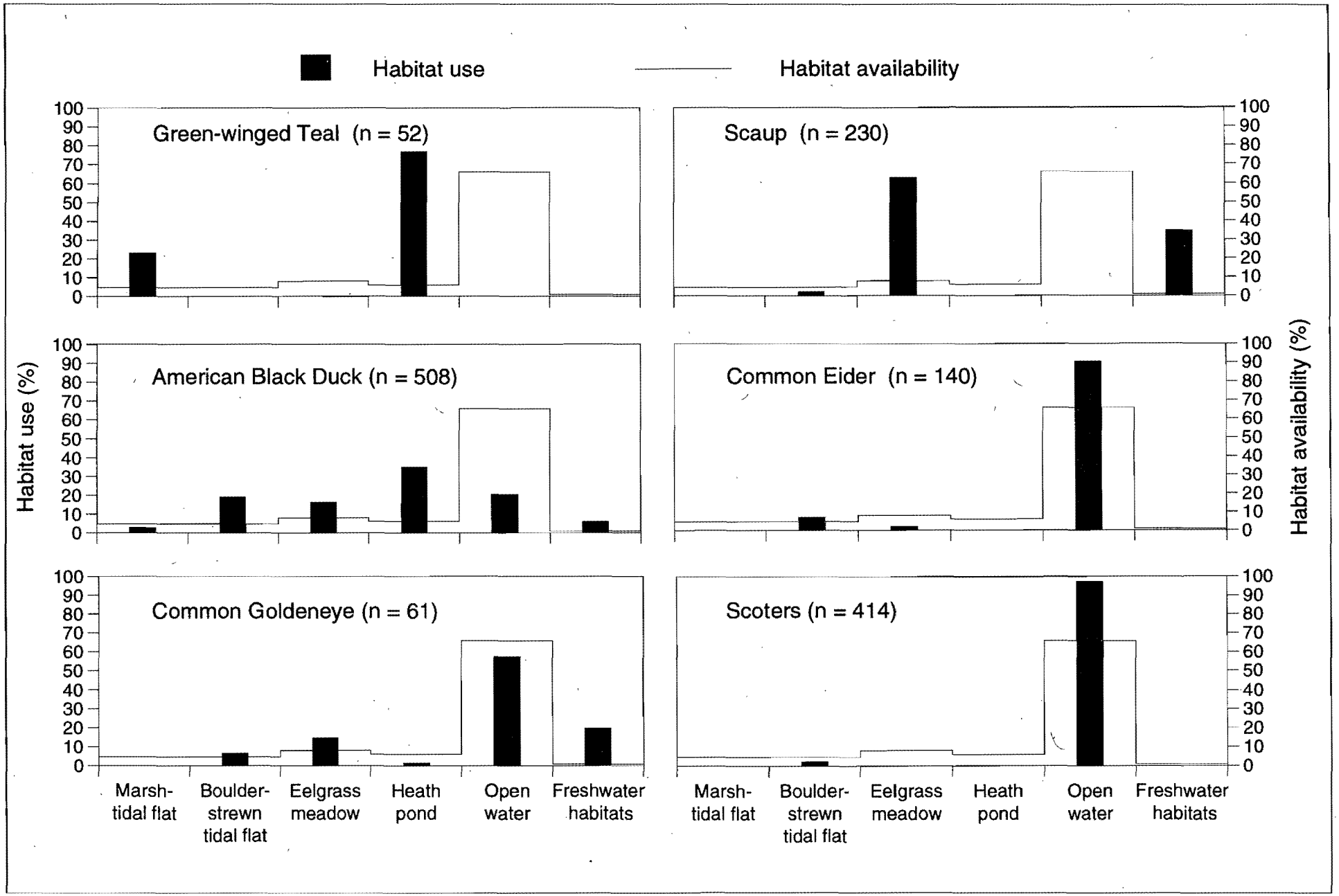


Table 15
Proportional use of habitats by ducks in the Bay of Many Islands during aerial surveys from 8 to 13 August 1991

Species	Marsh–tidal flat (0.047)[a]	Boulder-strewn tidal flat (0.047)	Eelgrass bed (0.080)	Heath (ponds) (0.060)	Open water (0.658)	Freshwater habitats (0.009)
Green-winged Teal (52)[b]	[12][c]	[0]	[0]	[40]	[0]	[0]
American Black Duck (508)	0.028 ± 0.019[d]	0.191 ± 0.046	0.163 ± 0.043	0.352 ± 0.056	*0.207 ± 0.047*	[30]
Mallard (15)	[0]	[4]	[1]	[6]	[3]	[1]
Northern Pintail (30)	[0]	[0]	[1]	[5]	[0]	[24]
Scaup (230)	*0*	0.022 ± 0.025	0.630 ± 0.082	*0*	*0*	[80]
Common Eider (140)	*0*	0.071 ± 0.057	*0.021 ± 0.032*	*0*	0.907 ± 0.065	[0]
Scoters (414)[e]	*0*	0.022 ± 0.019	*0.005 ± 0.009*	*0*	0.973 ± 0.021	[0]
Common Goldeneye (61)	[0]	[4]	[9]	[1]	0.574 ± 0.124	[12]
Hooded Merganser (27)	[0]	[1]	[0]	[0]	[0]	[26]
Mergansers (42)	[0]	[1]	[1]	[0]	0.952 ± 0.064	[0]

[a] Proportional availability (relative area) of habitat at site.
[b] Total number of ducks observed during all counts.
[c] Number of individuals observed in habitat [2] but not included in statistics because $np \leq 5$ (see Section 3.2.2.2).
[d] The 95% confidence interval of the proportional use of habitat, following the Bonferroni method (see Section 3.2.3). The underlined numbers (0.853 ± 0.136) indicate that the species used the habitat more than expected, whereas the numbers in italics (*0.407 ± 0.115*) indicate that the habitat was used less than expected. Numbers that are neither underlined nor in italics (0.242 ± 0.101) indicate that the species frequented the habitat in accordance with its relative area. In the case of total or zero frequentation, no confidence intervals are given.
[e] Includes all three species of scoters.

5. Discussion

5.1 Importance of coastal habitats to migrating, breeding, and moulting ducks

5.1.1 Salt marshes

Salt marshes were used by ducks principally during spring and fall migration. American Black Ducks and other dabbling ducks were the principal users (Figs. 5A, 6C, Tables 5, 6), notably in spring, when many other habitats were still ice or snow covered (Fig. 6C, Table 5). Use of salt marshes was influenced by tidal level. When the rising tide began to flood the lower salt marshes, dabbling ducks in adjacent mud/sand tidal flats often moved into the marshes and began to forage intensively in the partially flooded vegetation. At low tide, however, only a few low, wet areas and channels were used. In addition, during very high tides, some scaup were observed in the flooded salt marsh (Fig. 8A).

Few ducks used the salt marshes for breeding; the only evidence obtained in this study was the sighting of one brood each of American Black Duck, Mallard, and American Wigeon. Manning and Macpherson (1952) and Curtis and Allen (1976) also noted relatively few American Black Ducks and other dabbling ducks breeding in salt marshes along the coast. The limited use of salt marshes during the breeding season is surprising, given the richness of the flora (Dignard et al. 1991) and the fact that salt marshes farther south, such as those in the St. Lawrence estuary, support large concentrations of American Black Duck broods (Reed and Moisan 1971). This difference may be attributable to the presence in the St. Lawrence marshes of many small ponds that harbour large concentrations of invertebrate prey for ducklings; few ponds are found in the salt marshes in northeastern James Bay. The few broods noted in the study area salt marshes were located in streams.

Few ducks were present in salt marshes during the premoult or moulting periods, although some American Black Ducks and other dabbling ducks were observed during aerial surveys in macrohabitats that included salt marsh.

5.1.2 Mud/sand tidal flats

During both spring and autumn migrations, the mud/sand tidal flat was clearly the most important single habitat for the large populations of American Black Ducks and Mallards (Figs. 5, 6, 9, 10). The dominant daytime activity of American Black Ducks was feeding (Figs. 9, 10). Some diving ducks, notably mergansers and scaup, also used that habitat at high tide during migration (Figs. 7, 8).

Mud/sand tidal flats were not used by ducks for breeding. Tidal flooding makes this habitat unsuitable for nesting, as does the absence of escape cover for brood rearing.

This habitat was used extensively by premoulting groups of American Black Ducks and other dabbling species (Fig. 12, Table 8). The dominant daytime activity of American Black Ducks observed there was feeding. Some mergansers, Common Goldeneye, and scaup were observed when the tide was high.

During the moult period (August), few ducks were recorded on mud/sand tidal flats, but aerial surveys revealed the presence of American Black Ducks in macrohabitats that included tidal flats (Fig. 16); although some of this use may reflect use of mud/sand tidal flats, it appears that this habitat was used less extensively by moulting ducks than by premoulters and migrants.

The attraction of this habitat for migrating and premoulting ducks is undoubtedly linked to food resources. Sampling in the intertidal zone indicated a wide variety of organisms (Appendix 2.2), among which were taxa known to be important in the diet of American Black Ducks in marine and estuarine habitats elsewhere: *Gammarus* spp., *Macoma balthica*, and *Littorina* spp. (Mendall 1949; Hartman 1963; Savard 1990).

The attractiveness of mud/sand tidal flats to dabbling ducks may be influenced by adjacent habitats. Salt marshes often occur on the landward edge of mud/sand tidal flats and eelgrass meadows on the seaward border. We often observed intense foraging by dabbling ducks along the tide's edge as it moved from the upper mud/sand tidal flats into the adjacent salt marsh. Thus, some ducks recorded as occurring in mud/sand tidal flats at higher tidal levels might have been feeding on organisms more closely associated with the salt marsh community, and at lower levels, feeding on items from the eelgrass bed community. This suggests that these interfaces themselves may represent key feeding microhabitats for dabbling ducks.

5.1.3 Eelgrass beds

During spring and fall migrations, eelgrass beds were used almost exclusively by diving ducks (Figs. 7, 8); only a few dabbling ducks were noted (Fig. 5). Among the diving ducks, mergansers and scaup were the principal species, but Common Goldeneyes, White-winged Scoters, and Surf Scoters were also present. Most use was recorded in stands of dense eelgrass, but sparse stands were also used.

The only use of eelgrass beds by breeding ducks recorded in this study was for brood rearing by Common Eiders; 9.5% of eider broods observed were in this habitat (Table 14).

During the premoult period, mergansers and Common Goldeneyes were the principal users (Fig. 12); during a behavioural observation session (Fig. 13), almost all use by mergansers was for feeding, whereas goldeneyes used this habitat for feeding as well as for resting and other activities. Moderate numbers of American Black Ducks also used this subtidal habitat, mainly for resting but also for feeding at low tide levels. A few American Wigeon and Mallards were also present (Table 8).

During the moulting period, scaup, American Black Ducks, and Common Goldeneyes were the most abundant ducks in eelgrass beds, but a few scoters and Common Eiders were also present (Fig. 16, Table 15).

Eelgrass beds are habitats characterized by a high biomass of both green plant material (*Zostera marina*) and marine animals (McRoy and Helfferich 1977; Phillips 1984), and the eelgrass beds of the northeast coast of James Bay are no exception (Lalumière et al. 1994; Appendix 2.2). Although the blades of eelgrass provide the main attraction for the large flocks of Brant *Branta bernicla* that feed in this habitat in James Bay during migration (Curtis and Allen 1976), ducks are probably attracted mainly by the abundance and diversity of invertebrates and fish found there.

Eelgrass beds can be more efficiently exploited by diving ducks than by dabblers, because they are situated in deeper water than the previous habitats discussed in this section and are entirely subtidal. However, the blades of *Zostera marina* provide protective cover for invertebrates and fish, possibly reducing their availability as prey. This may explain cases of preference for sparse eelgrass beds by diving ducks (Figs. 9C, 12C, 12D), which may find it easier to capture prey in areas where the cover is less dense. Although dabbling ducks may be at a disadvantage in exploiting benthic organisms in these subtidal eelgrass beds, some nevertheless feed there (e.g., American Black Ducks, which feed at low tide; Figs. 9B, 13A) or occupy eelgrass bed–tidal flat macrohabitats (Figs. 4, 11, 16), where organisms from the eelgrass community may be available.

5.1.4 Boulder-strewn tidal flats and boulder-strewn shores fringed with vegetation

Boulder-strewn tidal flats were used rather sparingly by migrating ducks; American Black Ducks (Figs. 5C, 5D, 6B), mergansers, and scaup (Fig. 7A) were the principal users. American Black Ducks used these flats both for feeding and for other activities (Fig. 9B).

Many Common Eider nests were located along boulder-strewn shorelines fringed with sea lime-grass (47% of total) or along the upper edge of boulder-strewn tidal flats (11%), always on islands (Table 11). Also, 38% of Common Eider broods were observed in boulder-strewn tidal flats (Table 14). One Red-breasted Merganser brood was observed in this habitat.

During the premoult period, small numbers of American Black Ducks, mergansers, and Common Goldeneyes were recorded in boulder-strewn tidal flats (Fig. 12), usually engaged in activities other than feeding (Fig. 13). During the moult period, the same habitat was used by moderate numbers of American Black Ducks and by small numbers of other ducks, including scoters, scaup, Common Eiders, Common Goldeneyes, and mergansers (Fig. 16, Table 15).

5.1.5 Rocky tidal flats

Migrating ducks used rocky tidal flats infrequently and in small numbers (Figs. 5D, 7A). Approximately 20% of the Common Eider nests found were located on the upper edge of the rocky tidal flats surrounding some islands (Table 11).

5.1.6 Heaths

Heath occurred mainly on offshore islands (Dignard et al. 1991), where numerous freshwater ponds added to the attraction of this essentially terrestrial habitat to ducks. But heath cover as such was important, with low willow and ericaceous shrubs providing good nesting cover and *Vaccinium* spp. and *Empetrum nigrum* berries providing food.

During migration, heath ponds were used by ducks, particularly American Black Ducks and Green-winged Teal, but underrepresentation of heathland in our ground observation sites prevented detailed comparison with other habitats. Nevertheless, at one site during fall migration, many American Black Ducks frequented heath cover (Fig. 6B), apparently feeding intensively on berries. Manning and Macpherson (1952) also recorded American Black Ducks in heathland on the eastern shore of James Bay in late summer.

Over 20% of the Common Eider nests were found in this habitat (Table 11), and several broods of Surf Scoters were observed in heath ponds as well.

Little information is available for the premoult period, but during the moult period many Green-winged Teal and American Black Ducks and a few Mallards and Northern Pintails were present in heath ponds (Fig. 16, Table 15). Flightless adult Green-winged Teal were also observed in heath ponds.

5.1.7 Open water

Owing to the absence of detailed information on the bathymetry and the nature of substrates, we have included in this category all the marine waters in the study area except the intertidal zone (tidal flats and salt marshes) and submerged eelgrass beds. This category therefore comprises a wide range of ecological conditions and should be considered as a macrohabitat.

In May, the first patches of ice-free water appeared as polynyas in open water areas or at the mouths of streams flowing into tidal marshes. Polynyas were used intensively by the first flocks of ducks arriving from the south, including Oldsquaws *Clangula hyemalis*, White-winged Scoters, Mallards, American Black Ducks, and Greater and Lesser scaups. With diminishing ice cover in June, large numbers of migrating diving ducks, including Common and Red-breasted mergansers, Greater and Lesser scaups, Common Goldeneyes, White-winged Scoters, and Common Eiders, made extensive use of open water habitat (Figs. 4, 7, Table 5); during fall migration, this habitat was also used primarily by diving ducks.

Open water habitat was important for brood rearing by Common Eiders (52% of eider broods observed; Table 14), but no other duck species were observed with broods in this habitat.

During the premoult period, open water areas were used extensively by diving ducks, especially Common Goldeneyes, Black and Surf scoters, Common and Red-breasted mergansers, and Common Eiders (Figs. 11, 12C, 13B, 13C). During the moult, large mixed flocks of scoters (Black, Surf, and White-winged scoters) and smaller groups of Common Eiders, Common Goldeneyes, and Common and Red-breasted mergansers congregated in open water shoal areas near the offshore islands. The dominant prey organisms found in the digestive tracts of scoters and goldeneyes collected over these shoals (blue mussels and other molluscs) proved also to be abundant in benthic samples, suggesting a direct relationship between the availability of protein-rich prey and the nutritional needs of these sea ducks during the moult (Hohman et al. 1992).

5.2 Importance of coastal habitats to different duck species

5.2.1 American Black Duck

American Black Ducks were the most abundant dabbling duck species in the coastal habitats on the northeast coast of James Bay. They were abundant in all areas we surveyed but appeared to occur in somewhat greater concentrations in the northern sectors (Bay of Many Islands and Point Attikuan). They occurred along the mainland coast as well as on the islands, although they tended to be more abundant near the mainland. Thousands were present along the coast during spring and fall migration, as well as during the premoult period in early summer. Moderate numbers were present in late summer, but few of them appeared to spend the flightless period of the moult there. Relatively few American Black Ducks used the coastal habitats for breeding. This general summary is supported by the collective results of earlier investigators who found the species to be abundant in coastal habitats throughout most of the ice-free period (Manning and Macpherson 1952; Todd 1963; Bourget 1973; Curtis and Allen 1976). On the west coast of James Bay, the American Black Duck is also one of the most abundant ducks (Ross 1982).

American Black Ducks used primarily mud/sand tidal flats during both spring and fall migrations and in the premoult period. In seven of eight analyses of ground observation data, mud/sand tidal flats were used more frequently than any other habitat (Figs. 5, 6, 12); in five of those cases where statistical tests could be performed (three in spring, one in fall, one in early summer), this habitat was used at a significantly greater level than expected from its availability (Tables 5, 6, 8), and in another it was the only habitat used. Curtis and Allen (1976) also noted intensive use of mud flats along this coast. This habitat was used primarily for feeding (Figs. 9, 10, 13A), with most feeding occurring in shallow wet depressions or streams on the exposed flats at low tide or in shallow tidal waters flowing or ebbing over the flats. When tides reached higher levels and prevented feeding on tidal flats, American Black Ducks either ceased feeding or continued foraging in adjacent salt marshes. This extensive and preferential use of mud/sand tidal flats appeared to be linked to the abundance of intertidal invertebrates; such protein-rich food items are undoubtedly of special value in the laying down of nutrient reserves for the moult (Hohman et al. 1992). American Black Ducks remained abundant in tidal flat macrohabitats during the moult period in late summer (Fig. 16), but few were observed in flightless condition. For the flightless stage, most probably moved temporarily to other nearby habitats that provided better escape cover, including heathland ponds and, especially, freshwater lakes near the coast (Benoit et al. 1993, 1994).

Although mud/sand tidal flats were clearly the most important habitat type for American Black Ducks, many other habitats were used (e.g., Fig. 16). Boulder-strewn tidal flats were used in all periods (Figs. 5, 6, 12, 16). Salt marshes were used during migrations (Figs. 5A, 5B, 6C) but appeared especially important in early spring, when tidal flats were still partially ice covered (Fig. 5A). Part of this attraction to salt marshes may be explained by the probable availability of intertidal invertebrates along the seaward border that abuts on tidal flats (see Section 5.1.2), but marsh plants may provide additional food in the form of windrows of graminoid seeds (especially *Carex* spp.), which occur along the edge of marsh pools. Heath-covered areas were used by fall migrants in search of energy-rich berries (also reported by Manning and Macpherson 1952); heathland ponds were probably also important for the relatively few individuals that reared their broods or underwent the wing moult in the study area. Eelgrass beds were used moderately in late summer (Fig. 16) and sparingly in spring migration and in early summer (Figs. 5, 12), and no use was recorded during fall migration; most of the recorded use was for activities other than feeding (e.g., Fig. 13A), but Curtis and Allen (1976) reported American Black Ducks feeding there at very low tidal levels, and Manning and Macpherson (1952) observed them feeding on eelgrass washed ashore.

Although we found no American Black Duck nests, we suspected that a few nested on islands and used forest, shrub, or heath cover. Most brood rearing occurred on island ponds and in salt marshes. We conclude that the limited use of coastal habitats for breeding can be best explained by the lack of adequate brood-rearing habitat containing both an abundance of aquatic insects and good escape cover; Curtis and Allen (1976) suggested that frequent tidal flooding of otherwise attractive nest sites along the coast might also serve as a deterrent. Freshwater habitats near the coast provide more suitable breeding

habitat for the species (Curtis and Allen 1976; Benoit et al. 1993).

5.2.2 Other dabbling ducks

The other main species of dabbling ducks observed along the coast included, in approximate order of abundance, Green-winged Teal, Mallard, Northern Pintail, and American Wigeon. All were considerably less abundant than American Black Ducks.

Green-winged Teal occurred in relatively small numbers in all periods but were somewhat more abundant in late summer. They were present along the entire coast but occurred in greater concentration in Dead Duck Bay. The few individuals recorded on surveys during migration were all in salt marsh or mud/sand tidal flat habitat (Tables 5, 6). Those recorded on a survey in early summer (Fig. 11) were associated with open water and eelgrass bed–tidal flat macrohabitats (which generally occur in proximity to islands), whereas in a survey in late summer they were associated mainly with offshore islands (Fig. 14); another late summer survey (Fig. 16) and other observations suggested that this distribution reflected intensive use of ponds on heath-covered islands for brood rearing and the wing moult. Todd (1963), Manning and Macpherson (1952), and Curtis and Allen (1976) considered the Green-winged Teal to be a regular breeder in salt marshes and offshore islands in northeastern James Bay.

A small population of Mallards occurred through spring, summer, and autumn, and some individuals nested or moulted (Figs. 4, 5, 11). Their patterns of distribution and habitat use showed no obvious differences from those of American Black Ducks, with the possible exception of a tendency to use offshore islands less regularly (Fig. 14). Their relative scarcity along the northeast coast contrasts with the west coast of James Bay, where high densities occur (Ross 1984).

Northern Pintails occurred in all periods and in numbers similar to those of Mallards. Only a few nested in coastal habitats. They appeared to be somewhat more abundant in the Bay of Many Islands and Point Attikuan sectors. Many of those we observed were in freshwater ponds near the coast or on islands. Their relative scarcity along the northeast coast is in contrast with the situation on the south and west coasts, where they occur in large concentrations and are the most abundant dabbling duck (Manning 1952; Curtis and Allen 1976; Ross 1982, 1984). Todd (1963) also noted that Northern Pintails were less common as breeders on the coast north of Chisasibi (Fort George).

A small population of American Wigeon was also present in the region from spring to fall; somewhat higher densities appeared to occur in the northern portion of our study area. Brood sightings confirmed breeding (Manning and Macpherson 1952; Todd 1963; this study). During spring migration and early summer, most individuals were associated with mud/sand tidal flats (Tables 5, 6, 8). Broods were observed in a salt marsh and on an island pond. Although this species is known to feed on eelgrass (Bellrose 1980), we recorded it rarely in eelgrass beds (Table 8); indeed, it appeared to be more closely associated with freshwater wetlands a short distance inland from the coast (Benoit et al. 1993).

In addition, small numbers of Gadwall *Anas strepera*, Northern Shoveler *A. clypeata*, and Blue-winged Teal *A. discors* were observed.

5.2.3 Greater and Lesser scaups

We confidently identified both Greater and Lesser scaups on several occasions, but in many cases it was not possible to confirm specific identity. Todd (1963) stated that only Greater Scaup occurred on the northeast coast of James Bay, whereas Manning and Macpherson (1952) claimed that the Lesser Scaup predominated, although they did collect a few Greater Scaup there. Although we were not able to clearly establish the relative abundance of the two species, we believe that nonbreeders of both species were present in moderate numbers. Both breed in small numbers, as evidenced by the finding of a brood and a nest of each species on the islands.

Scaup were present during all periods, frequenting many coastal habitats (Figs. 7, 8, 16) but generally showing preference for eelgrass beds and open water areas (Tables 5, 15). Curtis and Allen (1976) suggested that scaup fed on crustaceans and molluscs from the eelgrass beds. During the moulting period, a few birds frequented offshore shoals (open water) in the company of scoters, but most chose freshwater habitats on the mainland for moulting (Curtis and Allen 1976; Benoit et al. 1993, 1994).

5.2.4 Common Eider

The Common Eider was the only duck that bred in abundance on the northeast coast of James Bay, occurring in largest concentrations north of the La Grande River. These eiders belong to the Hudson Bay subspecies *Somateria mollissima sedentaria*. Our survey, expanded to cover all of the northeast coast, indicates a population of >500 nesting pairs. Elsewhere in James Bay, >200 nests or broods were reported on islands in the middle of James Bay (Manning and Coates 1952; Manning 1981), and roughly 100 broods were noted in aerial surveys of the southeast coast (Consortium Gauthier & Guillemette–G.R.E.B.E. 1992). Thus, a total breeding population approaching 1000 pairs is indicated for all of James Bay, which is greater than an earlier estimate of 340–400 pairs (Abraham and Finney 1986). Nevertheless, the total population for James Bay is small in comparison with that of the east coast of Hudson Bay (Abraham and Finney 1986; Nakashima and Murray 1988).

On the northeast coast, Common Eiders nested on islands, usually in small colonies of fewer than 16 nests, and sometimes in association with the Herring Gull *Larus argentatus*. Most of the nests were located near the shoreline adjacent to rocky or boulder-strewn tidal flats, often in clumps of *Elymus*. Although some small crèches (multifamily broods) were seen, most ducklings were in single broods. Most broods were reared in open water, over boulder-strewn tidal flats, or over eelgrass beds (Table 14). The use of these marine subtidal habitats is probably linked to the availability of small marine organisms such as gastropods and amphipods that usually form the diet of young eider ducklings (Cantin et al. 1974).

In all periods, nonbreeding eiders were mainly found in open water areas or over tidal flats (Figs. 4, 11, 15, 16), usually near the offshore islands (Fig. 14). Blue mussels, a staple item in the diet of adult eiders in other areas (Cottam 1939; McGilvrey 1967; Bustnes and Erikstad 1988; Guillemette et al. 1992), were abundant in the open water (shoal) areas of our study area (Appendix 2.2), which probably explains the attractiveness of this habitat.

Eiders of this subspecies are believed to remain within Hudson and James bays throughout the year (Palmer 1976; Reed and Erskine 1986), making use of polynyas and open leads; therefore, some may remain in our study area into late fall and possibly through the winter.

5.2.5 White-winged Scoter

White-winged Scoters were present in all periods (Figs. 4, 11, 14). Several hundred pairs occurred along the coast in spring, and many moulted in shoal (open water) areas in late summer. Breeding was confirmed by the finding of a nest (Table 9) and the sighting of broods (Table 14). It was the most abundant scoter in spring but was outnumbered by both Surf and Black scoters in moulting flocks. Earlier, Todd (1963) and Curtis and Allen (1976) had reported it as common along the northeast coast in spring, summer, and fall, whereas Manning (1981) had confirmed breeding on the Twin Islands in central James Bay.

The nest we found was in a clump of dwarf birch *Betula glandulosa* on the edge of a clearing on a forested inner island. Most broods observed in coastal habitats were, however, on mainland lakes partially subject to tidal flooding; indeed, breeding individuals appeared more closely associated with inland freshwater lakes near the coast (Benoit et al. 1993) than with coastal habitats. The many pairs observed along the coast in spring were probably part of this inland breeding population, staging in marine areas close to their eventual nesting locations.

Nonbreeders occurred mainly in open water areas and eelgrass beds. During the moult, they joined large numbers of the other two scoters in shoal areas near the offshore islands; all three species fed on the abundant bivalve molluscs that occur there, but White-winged Scoters appeared to feed mainly on those of the genera *Nucula* and *Astarte*, rather than the *Mytilus* preferred by the other scoters. Bivalves form the bulk of the diet in wintering areas on both the Atlantic and Pacific coasts (Stott and Olson 1973; Sanger and Jones 1984; Vermeer and Bourne 1984).

5.2.6 Black and Surf scoters

In spring, Black and Surf scoters were less abundant than White-winged Scoters (Fig. 4), but by late June large groups of the two former species began to assemble in large rafts along the coast (Fig. 11), mainly to the north of the La Grande River. During the moult in summer, such rafts, dominated by Black and Surf scoters, numbered up to several thousand individuals, although a few dozen to a few hundred were more common (Benoit et al. 1994). Males dominated in these flocks, and Black Scoters were more numerous than Surf Scoters. Manning and Macpherson (1952) also reported the Black Scoter to be the most common scoter along the east coast of James Bay in summer. Surf Scoters were nevertheless abundant in these groups, which contrasts with the situation on the west coast of James Bay, where large moulting scoter flocks were composed almost entirely of Black Scoters (Ross 1982, 1983). In autumn, large mixed scoter flocks, totalling up to 100 000 individuals, have been observed along the east coast (Curtis and Allen 1976). Breeding by Surf Scoters was confirmed by the observation of a few broods, but no evidence of breeding by Black Scoters was obtained.

Almost all migrants, premoulters, and moulters were observed in open water habitat (Figs. 4, 11, 15) over shoals near the offshore islands (Fig. 14), where they fed chiefly on the pelecypods *Mytilus edulis* and *Astarte* spp. (Appendix 2.1). No nests were found, but several Surf Scoter broods were observed on coastal lakes subject to tidal influence and on island ponds.

5.2.7 Common and Red-breasted mergansers

Although many males of both merganser species were observed by us, difficulties in specifically identifying individuals in female or eclipse plumage prevented us from clearly establishing their relative abundance. Like Manning and Macpherson (1952), we believe that the Red-breasted Merganser was the more common during the moulting period, but the Common Merganser was also abundant. Both species were present in moderate numbers during spring migration (Fig. 4) and the premoult period (Fig. 11), with numbers increasing for the moult in August (Benoit et al. 1994). We obtained evidence of breeding only for the Red-breasted Merganser (two nests; Table 9), as did Todd (1963), but Manning and Macpherson (1952) collected downy young Common Mergansers just north of the La Grande River in 1950.

In spring, Common and Red-breasted mergansers frequented all habitats except salt marshes and heaths. In summer, they commonly fed in eelgrass beds and nearby areas of open water, showing an apparent preference for sparse eelgrass beds. This choice of feeding habitat may reflect a greater ease of capturing fish and other mobile prey (Appendix 2.1) where aquatic vegetation is less dense. In British Columbia, Common Mergansers were found to capture fewer smolt-size fish in river sections where fish had better shelter (Wood and Hand 1985). In summer, some mergansers were found among moulting flocks of scoters in shoal areas near the outer islands, but others occurred in open water even farther offshore (Benoit et al. 1995). Both Red-breasted Merganser nests were on islands.

5.2.8 Common Goldeneye

Common Goldeneyes were present in small numbers during spring migration (Fig. 4), but numbers built up during June, when flocks of several thousand premoulters assembled between the islands in the southern and southwestern portions of the Bay of Many Islands. During the moulting period, several hundred were still abundant among the middle and outer islands (Fig. 14),

some of which were observed in flightless moult (see also Manning and Macpherson 1952), sometimes associated with moulting scoters. However, fewer were observed than in June, probably because they became more secretive as they entered the wing moult, although some may have moved to other areas for the moult. Large concentrations occur along portions of the east coast of Hudson Bay and around the Belcher Islands during summer (Todd 1963); these and our own observations suggest that the east coasts of James and Hudson bays represent major moulting areas for this species. No evidence of breeding was obtained.

Common Goldeneyes occurred principally in open water and over eelgrass beds or tidal flats (Figs. 4, 11, 12, 17), usually in shallower water near islands or reefs; in late June, when peak numbers were recorded, they showed a marked preference for eelgrass beds (Fig. 12, Table 8; see also Curtis and Allen 1976). The blue mussel was the main species found in the digestive tracts of moulting goldeneyes.

5.2.9 Other diving ducks

A few Ring-necked Ducks were observed; they were associated mainly with mud/sand tidal flats or freshwater habitats. The only indication of breeding in coastal habitats was the sighting of a single brood in a lake partially subject to tidal action. This species appeared to be more closely associated with inland freshwater habitats south of the Bay of Many Islands (Benoit et al. 1993). Curtis and Allen (1976) and Manning and Macpherson (1952) noted its presence in small numbers along the northeast coast, but Todd (1963) suggested it was limited to southern James Bay.

Only a few Buffleheads were observed, and all were associated with freshwater lakes immediately inland from the mainland coast.

A few Hooded Mergansers were observed, mainly during the moult in August. They were associated primarily with freshwater habitats but also, occasionally, with mud/sand or boulder-strewn tidal flats at high tide. Several individuals were seen as far north as the Seal River (rivière au Phoque), which extends the northern limit of the range along the James Bay coast, which was previously reported to be Paul Bay (Todd 1963).

Individuals or small flocks of Oldsquaw were regularly observed, usually in open water areas. Curtis and Allen (1976) reported large flocks during fall migration. We found nests only on heath-covered islands north of Point Attikuan, but Todd (1963) reported nesting as far south as the La Grande River, and Manning (1981) found several nests on the Twin Islands.

5.3 Conclusions and considerations regarding northern development

This study, along with that of Curtis and Allen (1976), clearly shows that the northeast coast of James Bay is of special importance to migrating and moulting duck populations, in terms of both species diversity and overall numbers. Our study of habitat use establishes the importance of certain coastal habitats such as tidal flats, eelgrass beds, and shoal areas in supporting these duck populations.

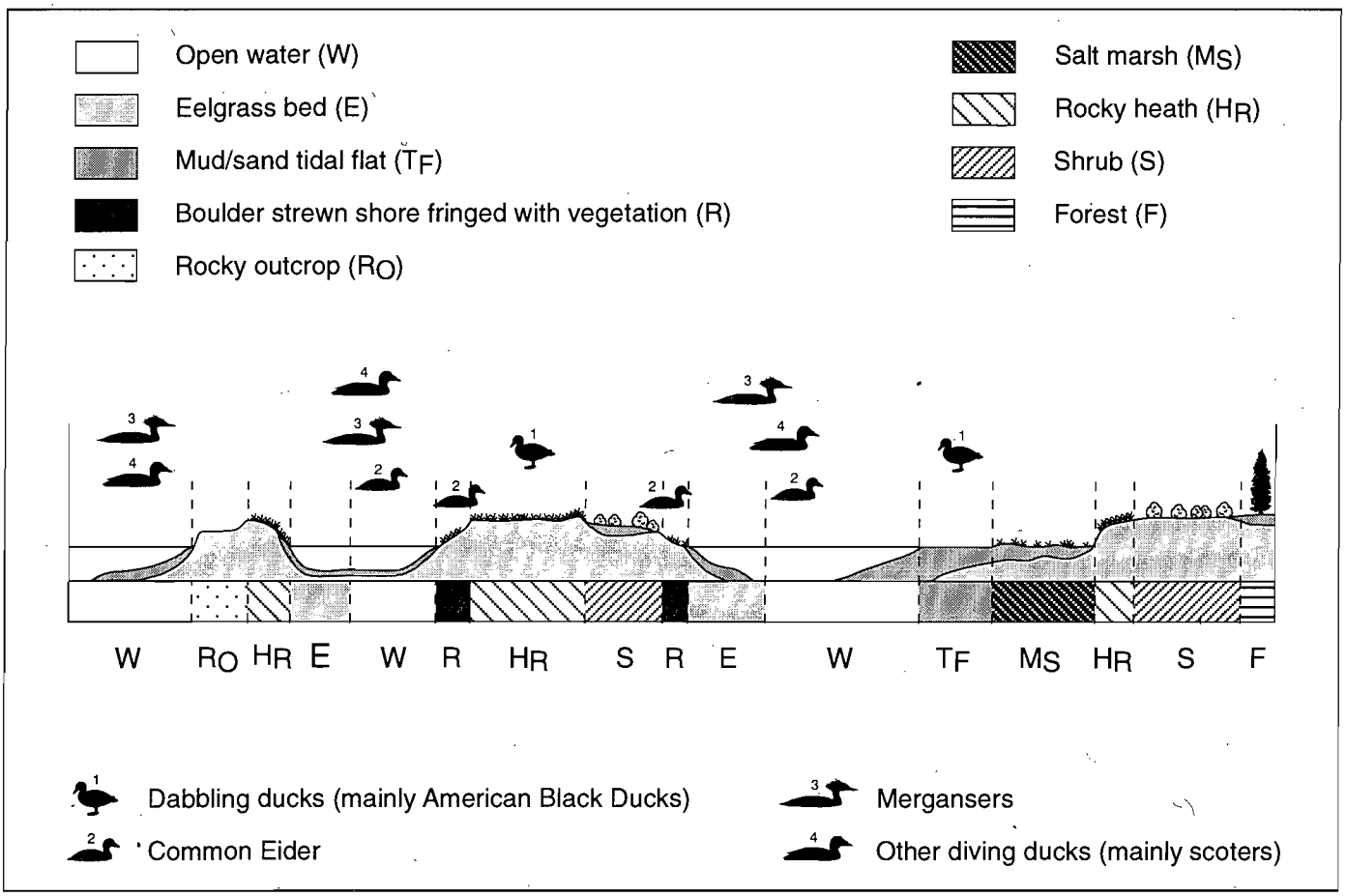
Dignard et al. (1991) suggested that the complex mosaic of different wetland habitats along that coast contributed importantly to its attractiveness to waterfowl. This complexity and diversity reflect the convergence of arctic, high-subarctic, and middle-subarctic biological zones within the study area (Ducruc et al. 1976), as well as the irregularity of the terrain, which imposes a certain degree of patchiness in habitat distribution. Many species appeared to benefit from the existence of different habitats within close proximity by using several. For example, although American Black Ducks used mainly mud/sand tidal flats, they made extensive use of adjacent salt marsh when ice cover or tidal level limited access to tidal flats, and they foraged on heath-covered islands when wild berries ripened in early fall. In addition to these diverse and rich coastal habitats, adjacent freshwater wetlands immediately inland from the mainland coast probably contributed to the area's diversity and attractiveness. Many American Black Ducks and scaup appeared to move from their coastal staging or premoulting areas to these nearby freshwater wetlands either to breed or to undergo the wing moult (use of these inland freshwater wetlands will be described in a future report in this series).

This diversity of habitat types and biological zones explains the wide range of species recorded, from typically arctic species such as Oldsquaw to low-boreal or temperate grassland species such as Blue-winged Teal. Most of the abundant species, the American Black Duck, Common Eider, Surf Scoter, Black Scoter, Common Goldeneye, and the mergansers, are of boreal or subarctic affinity, and all used the coastal habitats mainly for migration and moulting.

Although several species bred in the study area, the only abundant breeder was the Common Eider, one of the few waterfowl species that typically raise their young in open marine habitats. The very limited use of salt marshes by broods of American Black Ducks and other dabbling ducks was surprising but is probably explained by the scarcity in the James Bay salt marshes of permanent pools capable of supporting dense populations of soft-bodied invertebrate prey for young ducklings. Such feeding requirements are perhaps better met in adjacent mainland freshwater wetlands, where many broods of dabbling ducks, scaup, and White-winged Scoter are raised (Benoit et al. 1993, 1994, 1995); many of these brood-rearing females may have used nearby coastal habitats to lay down nutrient reserves prior to egg laying.

Hydro development could be a potential threat to the wetlands of coastal James Bay (Milko 1986; Gorrie 1990). Because of the current economic situation and present projections for energy needs, it appears unlikely that any additional development projects will be initiated in the James Bay territory in the immediate future. One major hydroelectric project, the La Grande Complex, was developed during the 1970s and 1980s (Messier et al. 1986), resulting in a reduced flow of fresh water into James Bay through the Eastmain estuary and a major increase in flow during winter through the La Grande River estuary. Several years after these changes had occurred, the few observable impacts on the coastal environment were largely limited to the two estuaries themselves (Messier et al. 1986).

Figure 17
Use of habitats of the northeast coast of James Bay by ducks (schematic profile of habitats adapted from Dignard et al. [1991]).



Changes in the freshwater plumes of the La Grande River resulted in a reduction in water salinity during winter along an increasing portion of the east coast of James Bay (Messier et al. 1986). The possible effects of these modifications on the coastal marine ecosystems are of considerable biological interest. Given the increased freshwater plume in winter since the early 1980s, it is likely that many eelgrass beds, open water areas, and possibly some mud/sand tidal flats of our study area have been subjected to a reduction in salinity during winter months. Detailed monitoring of certain eelgrass meadows from 1986 to 1991 revealed no overall trend in biomass and stem density of *Zostera marina* (Lalumière et al. 1994).

Isostatic rebound is considerable along the coasts of James and Hudson bays (roughly 1 m per century: Hunter 1970; Martini 1986) and undoubtedly exerts a powerful influence by continually subjecting emerging habitats to changing ecological conditions. Recently, changes in the vegetation of certain salt marshes and eelgrass meadows have been attributed to this factor (see Lalumière and Lemieux 1995). This suggests a continual natural process of change in the coastal habitats of James Bay; these changes could influence their use by waterfowl.

Although we have few comparative data on bird use before hydroelectric development, we observed intensive and abundant duck use of the eelgrass beds, mud/sand tidal flats, salt marshes, and shallow open water habitats during the course of the present study. Although there is little evidence of deterioration of the subtidal and intertidal duck habitats, it would, however, be premature to conclude that none has, or will, occur. Only long-term monitoring of these coastal habitats and their use by waterfowl will allow detection of changes attributable to natural and human-induced factors. Without such habitat-based monitoring, it will be difficult to attribute, with confidence, any changes in waterfowl numbers or behaviour to local (vs. distant) events.

This study provides a broad examination of the ecological relationships between the diverse and abundant population of duck and the complex mosaic of coastal habitats in northeastern James Bay. We have summarized the present extent of our understanding of these ecological relationships by a schematic illustration (Fig. 17). Given the complexity of these relationships, our analysis is unavoidably incomplete, but we hope we have provided both the background information and the inspiration for future investigators to delve more deeply into the study of the waterfowl ecology of this unique area.

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Appendices

Appendix 1
Rank correlations between habitats in quadrats covered in aerial surveys in the Bay of Many Islands, 8–13 August 1991

	Freshwater habitats	Marsh–tidal flat	Boulder-strewn tidal flat	Eelgrass bed	Heath	Open water
Freshwater habitats	1.0	0.49	–[a]	–	–	-0.54
Marsh–tidal flat		1.0	–	–	–	-0.60
Boulder-strewn tidal flat			1.0	0.59	0.47	-0.35
Eelgrass bed				1.0	0.49	-0.47
Heath					1.0	-0.34
Open water						1.0

[a] – = not significant at $P \leq 0.05$.

Appendix 2.1
List of benthic organisms identified in stomachs of diving ducks collected on shoals near offshore islands in the Bay of Many Islands in 1991 and 1992 or collected with a grab sampler

Taxa					Scoters				Mergansers		
					Black [25/6][a]	Surf [13/9]	White-winged [13/8]	Common Goldeneye [8/6]	Common [4/3]	Red-breasted [1/1]	Sampler
Mollusca											
	Gastropoda										
		Cephalaspidea	Scaphandridae	*Cylichna alba*							1
	Bivalvia										
		Heterodontida	Tellinidae	*Macoma balthica*							19
		"	Astartidae	*Astarte borealis*	1[b]	1	2				
		"	"	*Astarte* sp.	2	4	2				
		Pteroconchida	Mytilidae	*Mytilus edulis*	4	6	1	6			184
		Nuculoida	Nuculidae	*Nucula belloti*			5				
		"	Nuculanidae	*Portlandia arctica*			1				
Annelida											
	Polychaeta										
		Phyllodocida	Hesionidae	–							164
		"	Polynoidae	*Gattyana cirrosa*							4
		"	Sigalionidae	*Pholoe minuta*							24
		Terebellida	Terebellidae	*Terebellides stroemi*							59
Arthropoda											
	Crustacea				1	1			1		
		Calanoida	Calanoidae	*Calanus glacialis*							1
		Harpacticoida	–	–							1
		Amphipoda	Corophiidae	*Corophium* sp.							27
			Gammaridae	*Gammarus* sp.					1		
			"	*Gammarus oceanicus*							1
			"	*Gammaracanthus loricatus*						1	7
		"	"	*Weyprechtia pinguis*							2
		"	Haustoriidae	*Pontoporeia femorata*							32
		"	Ischyroceridae	*Ischyrocerus latipes*							2
		Cumacea	Diastylidae	*Diastylis rathkei*							2
	Insecta										
		Odonata	–	–					1		
		Diptera			1						2
			Chironomidae	–	1		1				1
Chordata											
	Pisces								3	1	
		Gasterosteiforma	Gasterosteidae	*Gasterosteus aculeatus*					1		

[a] [Total number of individuals collected/number of individuals with at least one item in stomach].
[b] Number of ducks containing that food item.

Appendix 2.2
Relative abundance of benthic organisms collected in early August from three habitats in the Bay of Many Islands

Taxa					Habitats			
					Mud/sand tidal flat			
					High tide	Low tide	Eelgrass bed	Shoal
Cnidaria								
	Hydrozoa		–	–	0.1			
	Scyphozoa							
		Stauromedusea	Eleutherocarpidae	*Haliclystus auricula*			0.1	
Aschelminthes								
	Priapulida		Priapulidae	*Halicryptus spinulosus*		0.9		
	Nematoda		–	–			0.2	
Mollusca								
	Gastropoda							
		Mesogastropoda	Hydrobiidae	*Hydrobia minuta*	0.1	52.9	0.2	
		"	Littorinidae	*Littorina saxatilis*	0.2		1.4	
		Cephalaspidea	Scaphandridae	*Cylichna alba*				0.2
	Bivalvia							
		Heterodontida	Tellinidae	*Macoma balthica*	0.4	22.5	2.7	3.6
		Pteroconchida	Mytilidae	*Mytilus edulis*			1.6	34.5
Annelida								
	Oligochaeta		–	–	0.5		48.7	
	Polychaeta							
		Phyllodocida	Phyllodocidae	*Eteona longa*	1.8	9.4	1.4	
		"	Nephtyidae	*Aglaophamus neotenus*			7.2	
		"	Hesionidae	–				30.7
		"	"	*Nereimyra punctata*			6.4	
		"	Polynoidae	*Harmothoe imbricata*			0.1	
		"	"	*Harmothoe extenuata*			+	
		"	"	*Gattuana cirrosa*				0.8
		"	Sigalionidae	*Pholoe minuta*			0.5	4.5
		Capitellida	Capitellidae	*Capitella capitata*			1.0	
		"	Arenicolidae	*Arenicola marina*			0.1	
		Spionida	Spionidae	*Spio filicornis*			0.5	
		"	"	*Polydora* sp.			0.2	
		Terebellida	Terebellidae	*Terebellides stroemi*				11.1
		Sabellida	Sabellidae	*Fabricia sabella*			0.6	
		"	"	*Euchone analis*			0.1	
		"	"	*Sabella crassicornis*	18.1			
Arthropoda								
	Crustacea							
		Calanoida	Calanoidae	*Calanus glacialis*	0.1			0.2
		Harpacticoida	–	–				0.2
		Amphipoda	Atylidae	*Atylus carinatus*			+	
		"	Corophiidae	*Corophium* sp.				5.1
		"	Gammaridae	*Gammarus* sp.	6.7			
		"	"	*Gammarus oceanicus*	3.0	2.9	2.0	0.4
		"	"	*Gammaracanthus loricatus*	0.1		0.9	1.3
		"	"	*Weyprechtia pinguis*				0.4
		"	Oedicerotidae	*Monoculodes* sp.	0.2	1.0		
		"	"	*Monoculodes intermedius*	0.7			
		"	Haustoriidae	*Pontoporeia femorata*				6.0
		"	Ischyroceridae	*Ischyrocerus latipes*				0.4
		"	Lysianassidae	*Onisimus glacialis*	0.2			
		"	"	*Onisimus litoralis*	0.2	0.1		
		Cumacea	Diastylidae	*Diastylis rathkei*				0.4
		Mysidacea	Mysidae	*Mysis stenolepis*	0.1			
	Insecta							
		Diptera	Ceratopogonidae	–	2.1	0.7		0.4
		"	Chironomidae	–	0.2			
		"	Psyllidae	–	62.4	9.7	23.8	0.2
		Hemiptera	–	–	2.6			
	Arachnida							
		Acarina	–	–	0.1			
Ectoprocta							+	
Chordata								
	Pisces							
		Gasterosteiforma	Gasterosteidae	*Pungitius pungitius*	0.1			
		"	"	*Gasterosteus aculeatus*	0.5			
		Fish eggs	–	–			0.3	

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