THE EFFECTS OF HERRING GULLS (*Larus argentatus*) ON THE VEGETATION AND SOILS OF THEIR NESTING SITES

Nathalie Bays
Natural Resource Sciences
McGill University, Montreal

March 1997

A Thesis submitted to the Faculty of Graduate Studies
and Research in partial fulfilment of the
requirements of the degree of
Master of Science

Department of Natural Resource Sciences
Macdonald Campus
McGill University
Ste-Anne-de-Bellevue
Québec

0-612-29651-2

ABSTRACT

MSc. Nathalie Bays Natural Resource Sciences

This study was initiated to determine the effects of Herring Gulls (*Larus argentatus*) on the vegetation and soils of their nesting sites within the Mingan Island National Park Reserve. Both vegetation (species composition, cover, density, growth) and soil characteristics (pH, N, P, K, Ca, Mg) were monitored throughout the 1995 breeding season. Exclosures were installed within the colonies as control sites to prevent gull activity and these were compared to "treatment plots" or areas where gulls were present. All plants located at the study sites were native perennials with the exception of *Stellaria*, a native annual. *Ledum groenlandicum* was the only plant species significantly affected by gull activities. Both % cover and shoot growth for *Ledum* were greater in the exclosures than in the treatment plots over the breeding season. The gulls were also found to significantly increase pH and phosphorous levels in the soil through the deposition of faeces. Gull roosting sites were found to have higher nutrient levels than the nesting areas (treatment plots). The gulls appear to have minor effects over the short term, however the increases in soil nutrients may lead to significant changes over the long term. It is therefore imperative the exclosures remain in place to monitor for any long term changes which may occur.

RÉSUMÉ

MSc. Nathalie Bays Natural Resource Sciences

Cette étude avait pour but de déterminer l'effet des goélands argentés (*Larus argentatus*) sur la végétation et les sols aux alentours de leurs sites de nidification à la Résèrve du Parc National de l'archipel de Mingan. La végétation (espèces, couverture, densité, croissance) ainsi que les nutriments du sol (pH, N, P, K, Ca, Mg) ont été suivis pendant la saison de reproduction 1995 dans des traitements (avec goélands) et des exclos contrôles excluant toute activité de reproduction des goélands argentés. Les éspèces végétales retrouvées dans les sites étaient toutes spontanées et vivaces avec l'exception de *Stellaria*, une plante annuelle. *Ledum groenlandicum* est la seul éspèce qui a été affectée par les goélands et dont le pourcentage de recouvrement et la croissance a été significativement ($P < 0.10$) plus elevés dans les exclos-contrôles que dans les traitements. Les goélands ont également eu un effet sur les sols en augmentant significativement ($P<0.10$) le pH ainsi que le taux de phosphore. Les lieux de repos des goélands avaient des niveaux de nutriments plus élevés que les périmetres (sites de nidification). Les goélands ont eu peut d'effet significatif à cour terme mais il est impératif que les exclos restent en place pour surveiller les changements possibles à long terme.

ACKNOWLEDGEMENTS

Transportation and funding for this project was provided by Parks Canada. Additional funding was provided by Fonds pour la formation de Chercheurs(euses) et Aide à la Recherche (FCAR), Ciment St-Laurent and la Societé pour la Protection des Oiseaux du Québec (PQSPB). Both Rodger Titman and Magella Guillemette made this project possible through negotiations with Parks Canada and provided valuable editorial comments for this manuscript. Thanks go to Dr. Pierre Dutilleuil for his statistical consulting, Michael Richardson for his editorial comments, Andrew Boyne for his eternal optimism both on the field and off and Steve Tinker for his willingness to help in all situations. Merci à Mamzi et toute la famille as well as the friends who kept me somewhat sane. A very special thanks goes to Dr. Jim Fyles for his expertise and patience, without which I would have not completed this project.

The following people provided personal comments used for this paper:

Andrew Boyne, McGill University, 1996.

Pierre Grondin, DRYADE Ltee., 1994.

Charles Kavanagh, Parks Canada, Mingan Island district, 1996.

Pierre J.H. Richard, University of Montreal, 1994.

Benoit Roberge, Parks Canada, Mingan Island district, 1996.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

This thesis deals with the effects of Herring Gulls (*Larus argentatus*) on the vegetation and soils of their nesting sites in the Mingan Island National Park Reserve and is presented in the traditional thesis format in two main sections. The first section is a general discussion of the literature pertaining to the fragility of maritime tundra vegetation and the effects of marine birds on vegetation. It also includes a brief discussion on the distribution and abundance of Herring Gulls, as well as the management of this species. The second section focuses more specific impacts of the Herring Gulls on the vegetation of their breeding sites. This section also includes information on the study site, materials and methods, results and final discussion/recommendations.

SECTION I:

LITERATURE REVIEW

Introduction

The attention given to the vascular flora of the Mingan Island National Park Reserve began when Frère Marie-Victorin performed an intensive study of the area between 1924 and 1928 (Belland *et al.* 1992). His detailed inventory (Marie-Victorin and Rolland Germain 1969) brought attention to the uniqueness of the island flora. The rare plants of the archipelago fall into one of five categories: a) Endemic - species confined to the gulf of St Lawrence; b) Cordilleran - species which are found in the Rockies but are rare in eastern Canada; c) Arctic-alpine - species at the southern limit of their distribution; d) Fragmented boreal - species which grow in the boreal zone but require limestone; e) Species at the northern limit of their distribution. Vegetative communities have been under the protection of Parks Canada since the opening of the park in 1984. Once threatened by intensive hunting and egg-collecting, the birds of the area are also protected within the park. A conflict becomes evident when protected gulls are believed to be a causal element in the destruction of the protected vegetation.

This study was therefore initiated at the request and with the collaboration of Parks Canada to determine the effects of the Herring Gulls (*Larus argentatus*) on the vegetation and soils of their nesting sites, as this was deemed imperative for any future management decisions for the area.

Tundra Vegetation

Maritime Tundra is an area with no trees present, dominated by low shrubs and herbaceous plants located on a coastline or adjacent to a body of salt water (Bliss 1971). This type of habitat is particularly sensitive to physical trampling, due to its slow growth rate (Pounder 1985, Gratton *et al.* 1988) and shows an extremely low recovery rate after disturbance. Visits by only 11-15 people on a trail can result in a loss of 50% of the vegetative cover (Gratton *et al.* 1988). This trampling by people kills plants directly and initiates an erosion process which allows soil particles to be washed away from unprotected soil during heavy rain (Willard and Marr 1971, Pounder 1985). The damaging effects of heavy trampling are long term and are not restored by seasonal growth (Babb and Bliss 1974, Pounder 1985). Trampling also causes indirect effects, such as changes in both the physical and chemical composition of the soil (Gouvernain 1996). Physically, soil porosity is decreased while bulk density increases, limiting soil aeration to plant roots. Compacted soils hold humidity for longer periods and have a higher temperature than non-compacted soils, making mineral uptake difficult for the plants (Gouvernain 1996). More extreme disturbance such as vehicle compaction results in significant decreases in species richness when compared to undisturbed sites (Chapin and Shaver 1981). The crushing effect on the vegetation increases decomposition due to the increased proximity of soil microbes (Rickard and Brown 1974) causing a thaw of the permafrost layer (Rickard and Brown 1974, Gersper and Challinor 1975). The improved nutrient status, as a result of this decomposition, in nutrient poor soil explains the increased resistance and productivity of those plants which can survive the trampling process. Light levels of disturbance can be beneficial, whereas heavy levels bring about irreversible damage to the vegetation (Challinor and Gersper 1975, Gersper and Chalinor 1975). Both the weight of the impact and the frequency of disturbance play a role in the impact on both the vegetation and soil of the affected area.

Marine Birds and Vegetation

Many marine bird species have been shown to alter vegetation in and around their nesting sites (Gillham 1960a, Soots and Parnell 1975). Most seabirds are colonial nesters, which intensifies effects on the ecological pattern of plant succession through defecation and trampling (Gillham 1977). Seabird faeces are considered to be the major contributors of nitrogen, phosphorous, potassium, and sometimes calcium and sulfur into the soil (Burger *et al.* 1978). The toxicity of the faeces leads to vegetation which is specialized, displacing native vegetation. However, in small quantities, seabird faeces can constitute a powerful fertilizer, and may enhance the vegetation when deposited onto the soil (Gillham 1977, Bosman and Hockey 1986).

Several different studies have looked at the effects of different marine bird species on the vegetation and soils on their breeding sites (Lewis 1929, Russell 1940, Gillham 1960b, Gillham 1963, Ishizuka 1966, Blakemore and Gibbs 1968, Weseloh and Brown 1970, Dusi 1977, Smith 1978, DesGranges *et al.* 1984, Bazely and Jefferies 1985, Grondin *et al.* 1986, Mizutani *et al.* 1986, Mizutani and Wada 1988, Moors *et al.* 1988, Mizutani *et al.* 1991, Gaston and Donaldson 1995, Hawke and Powell 1995, Headley 1996). The most damaging elements of bird activity are faeces deposition, and, to a lesser extent, trampling of vegetation. Some of these effects are summarized in Table 1.

The effects of birds on the soil and vegetation are therefore dependent on both the quantity and frequency of faeces deposited in a given area. The population of bird species on the breeding sites and the spacing between territories helps to determine these possible effects. The fragility of the plant species found within the colonies also determines how they will react to a moderate or high activity level by the birds. Tundra vegetation is extremely vulnerable to human trampling activities, however few studies have examined the effects of the birds on this type of vegetation.

Distribution and Abundance of Herring Gulls

The Herring Gull is the most common gull in Quebec (Gauthier et Aubry 1995). Herring Gulls have a circumpolar breeding range and can be found on most shorelines of either salt or freshwater. In winter, the gulls may also be found along the coastline from Canada to Mexico (Pierotti and Good 1994).

In the nineteenth century, egg collecting and reduction of fish stocks contributed to the decline of Herring Gull numbers to a point where they were considered rare by the Audubon Society (Furness and Monaghan 1987, Lloyd *et al.* 1991, Pierotti and Good 1994). However, by the turn of the century, Herring Gull populations had increased in size and distribution in many areas of the world (Thomas 1972, Sobey and Kenworthy 1979, Chapdelaine et Bourget 1981) either because of increases in food availability with the increase in garbage and landfill sites, or an increase in the availability of small fish due to a general decrease in piscivorous cetacean and pinniped populations (Pierotti and Good 1994). However, between 1988 and 1993, another turn-around occurred when a sharp decline (24%) (Chapdelaine 1995) in Herring Gull populations was documented in most sanctuaries along the north shore of the Gulf of St Lawrence. Similar declines have been noted in the Gaspé Peninsula with a 41% decrease from 1979 to 1989 (Chapdelaine and Brousseau 1992). It is suspected that the crash of Atlantic fish stocks due to overfishing influenced this decline, although other marine bird species (e.g. alcids) which specialize on fish actually increased during this period (Chapdelaine 1995). The decline of the fisheries also affects gulls indirectly because of the decrease of fishing boats on the water which provide a source of food. Fish preparation plants, another source of food, have closed down. One of the similarities between two declining species, Herring Gulls and Kittiwake Gulls (*Rissa tridactyla*), is that they feed on surface waters near the shore. The cooling of these waters in the early 1990's (Montevecchi and Myers 1996), may have decreased the availability of certain fish species, such as the capelin (*Mallotus villosus*). Because of the decreased surface temperature of the water, these fish remain at lower depths in the water, making them unavailable to surface-feeding birds, and thereby leading to the decreased reproductive success of both species (Montevecchi and Myers 1996).

In Britain and Ireland, Herring Gull populations are also declining according to censuses conducted in the mid and late 1980's. Western European colonies have shown the sharpest decline, where populations are estimated to have more than halved (Lloyd *et al.* 1991). The few populations which increased did not change the overall decline of 26% in the Irish breeding population (Lloyd *et al.* 1991). These declines are believed to be due in part to diseases such as salmonella and botulism contracted at refuse tips. Herring Gulls following fishing trawlers lose over half of the fish they have caught to stronger competitors such as Greater Black-backed Gulls (*Larus marinus*), Gannets (*Sula bassanus*) and Great Skuas (*Catharacta skua*) (Lloyd *et al.* 1991).

Although there has been an increase in *Larus* spp. in Gros Morne National Park in Newfoundland, whether Herring Gulls populations have changed is unknown (Howes and Montevecchi 1993).

Management of Gulls

When gulls are believed to cause damage to their breeding areas or displace other breeding birds, management techniques have been utilized to keep populations down. Techniques employed have included culling, egg smashing and spraying of eggs with oil (Thomas 1972, Pierotti and Good 1994). In Aberdeen, Scotland, thousands of gulls have been killed to keep the numbers down to a "satisfactory level" (Sobey 1976). This cull was initiated by the Nature Conservancy Council as part of a management plan for the Isle of May National Nature Reserve (Coulson *et al.* 1982). Similar culls have occurred in Britain and Ireland as well as several other European countries (Lloyd *et al.* 1991).

Gulls are not only considered a pest species due to their opportunistic feeding habits, but they also take over nesting areas which could be used by other more vulnerable marine species such as puffins (*Fratercula arctica*)(Thomas 1972), Common (*Sterna hirundo*) and Caspian Terns (*Hydroprogne caspia*), and Piping Plovers (*Charadrius melodus*) (Blokpoel and Tessier 1984). It is believed that large numbers of gulls may pose a hazard to human health when volatile faeces which harbour fungal and bacterial diseases may be inhaled. They also contribute to the bacterial degradation of recreational water (Blokpoel and Tessier 1984, Levesque *et al.* 1993). Along with other bird species, gulls have caused serious accidents near airfields by colliding with aircraft (Murton and Wright 1968, Wright 1980).

Monofilament cages have recently been used to keep gulls away from sensitive areas to prevent the negative public reaction associated with killing large numbers of animals (Blokpoel and Tessier 1983). In some areas, control structures such as exclosures have been built to keep whole areas free of gulls (Blokpoel and Tessier 1983, 1984, Robinson 1991). Small islands near a Hydro-electric plant in Beauharnois, Québec were covered with large exclosures made with monofilament to prevent the gulls from nesting. Monofilament wires have also been used at fish hatcheries as a control method to reduce predation on fish by gulls (Ostergaard 1981), and even to exclude gulls from areas where they are believed to exclude other marine bird species (Robinson 1991). Although the monofilament lines are effective and show immediate results, problems occur when the gulls have no alternative breeding sites. Exclosures need to be checked frequently to remove birds entangled in the wires (Blokpoel and Tessier 1983)

SECTION II:

The effects of Herring Gulls (*Larus argentatus*) on the vegetation and soils of their nesting sites.

INTRODUCTION

Nesting activities of Herring gulls (*Larus argentatus*) have been the subject of much interest in the past few years. This is in part due to the dramatic increase in population density and distribution of this species in many areas of the world at the turn of the century (Sobey and Kenworthy 1979). The other focus of attention is due to its opportunistic feeding habits having given it the reputation of being a "pest" species (Monaghan 1983).

One of the main reasons for people wishing to prevent gulls from nesting is concern over the drastic effects gulls have on vegetation where they nest (Gillham 1956a, 1956b, 1961, Géhu and Géhu-Frank 1961, Bernard *et al.* 1971, Shugart 1976, Sobey 1976, Sobey and Kenworthy 1979, Hogg and Morton 1983, Zelenskaya 1995).

Impacts of Gulls on Vegetation

Gulls usually return to the same nesting site in subsequent years (Tinbergen 1967) and most often nest on the ground, therefore they have a more direct impact on the vegetation than most other marine birds which use cliffs (Sobey and Kenworthy 1979).

Four different gull activities have been found to affect the vegetation at breeding sites. (1) Treading occurs when the birds stand or sit near their nesting sites, resulting in compaction of the vegetation. This mechanical trampling occurs throughout the breeding season and may have considerable impacts throughout the breeding colony, particularly for the growth of seedling plants (Ishizuka 1966). (2) Nest-building or collecting of material, requires the use of vascular plants and mosses while (3) boundary clashes between male gulls lead to the removal of vegetation (Tinbergen 1967). (4) The potentially longest lasting effect is created by defecation. Initially faeces may just diminish photosynthesis and respiration if they are deposited directly on the plant surface, however, with time repeated defecation will cause changes in soil nutrient levels (Gillham 1961, Sobey and Kenworthy 1979, Hogg and Morton 1983, Gillmore *et al.* 1984, Hogg *et al.* 1989). A single gull pair with three nestlings produces between 95-170 kg of faeces per breeding season (Zelenskaya 1995). When the faeces are deposited in one location, such as around the nest site, they alter the composition of the plant root medium, making the soil unsuitable for pre-existing plants and thereby altering the species composition (Gillham 1961). Although some nutrient levels (nitrates, potassium, pH and total salts) return to normal after abandonment of nesting sites, other long term changes (phosphorous, calcium and magnesium levels) may prevent the reestablishment of native plants (Sobey 1976, Sobey and Kenworthy 1979, Hogg and Morton 1983, Hogg *et al.* 1989). In small quantities, faeces deposition leads to an increase in the existing vegetation, although species composition may change (Bukasinski *et al.* 1994). In large quantities, however, the faeces become toxic, killing many plant species. Gulls may also increase soil depth through the accumulation of allochthonous organic matter (nesting material, dead birds, and eggs), and regurgitation pellets which may contain bones, feathers, shells and vegetative remains (Gillham 1956a, Ishhizuka 1966), causing a further increase in soil phosphorus levels (Hogg and Morton 1983, Bukacinski *et al.* 1994).

At gull-affected sites, there is a general increase in alien, annual and biennial plant species (resulting in a decrease in native and perennial plants), as well as a transition towards a more species-poor community (Sobey 1976, Sobey and Kenworthy 1979, Hogg *et al.* 1989). This alteration of the environment creates vacant niches which encourage the colonization of alien weeds, whose seeds are frequently dispersed by the gulls themselves (Gillham 1961, Hogg and Morton 1983, Hogg *et al.* 1989). This dispersal occurs both by endozoic dispersal, whereby the gull ingests the seeds only to later pass them with its faeces or regurgitation pellets; and ectozoic dispersal whereby plant propagules are carried externally with nesting material or adhere to feathers and feet (Morton and Hogg 1989).

While some studies have investigated effects caused by treading, nest-building, boundary clashes and defecation (Sobey and Kenworthy 1979, Hogg and Morton 1983), most have simply monitored the end effects of the gulls on vegetation and soils through the use of control sites, without looking at specific mechanisms.

Mingan Island Gull Population

Within the Mingan Archipelago in 1990, the Laridae (gulls and terns) accounted for 67% of marine birds (Roberge unpub.) as compared to 97% in the late seventies (Chapdelaine et Bourget 1981). Herring Gulls account for approximately 61% of gull species present in the Achipelago. Other gulls include the Kittiwake (*Rissa tridactyla*)(21%), Ring-billed Gull (*Larus delawarensis*)(16%), and the Greater Black-backed Gull (*Larus marinus*)(1%) (Grenier et Kavanagh 1993). Ile Nue, located in the western sector of the park (59°12'30"N 64°07'30'W)(Fig 2), contains the largest Herring Gull colony in the park (Brousseau 1984, Grenier et Kavanagh 1993). This colony increased from 1750 pairs in 1978 to over 6000 by 1991 (Grenier et Kavanagh 1993). Since the Mingan Island National Park Reserve was established in 1984, human access to marine bird colonies has been forbidden from mid April to the end of August during the nesting period. According to Parks Canada, marine birds within the park have benefited from the protection against uncontrolled hunting and egg collection.

The dramatic increase of nesting Herring Gulls on Ile Nue has raised questions concerning the resistance of the vegetation to the high level of gull activity. Herring Gulls begin to arrive in the Mingan Archipelago as early as March, and remain on their breeding sites until mid-September. According to a study by FORAMEC (Bouchard et Ouzilleau 1992) in the archipelago in 1991, areas in the tundra which experience no gull activity have remained fairly stable in terms of species composition. Concerns have been raised about the loss of native tundra vegetation followed by an invasion by species such as *Epilobium angustifolium* and *Poa pratensis* (Dryade Ltée 1986) in areas where gulls are present. Although it is believed that the disappearance of the more fragile species (e.g.*Cypripedum passerinum* var minganense) is due to the gulls because of its low tolerence to disturbance (Groupe Chardon pers. comm., 1995), no studies have been performed to validate this statement. The presence of other rare plants (*Dryas integrifolia, Diapensia laponica*), is usually restricted to lichen tundra where the gulls have not been nesting, however one species (*Erysimum inconspicuum*) was observed on a few barren areas within the colonies. The presence of these rare plants makes the protection of this island a top priority for Parks Canada.

The purpose of this study was therefore to determine whether the Herring Gulls on Ile Nue affect the vegetation and soils on their nesting sites over a breeding season. It was predicted that over one season gulls would cause decreases in % cover of plants due to the ripping of leaves and branches during nest building activities and burning of vegetation through faeces deposition. Changes in species composition in the gull-affected sites could occur on a more long term basis due to changes in soil nutrient levels, and would therefore not appear in this short term study. It was also predicted that the high nutrient content of the faeces deposited would cause significant increases in soil nutrients at the gull affected sites.

MATERIALS AND METHODS

Study Area

The Mingan Achipelago National Park Reserve consists of approximately 900 islands and islets, of which 40 are larger than 10 ha, situated in the Gulf of St Lawrence up to 4 km off the coast of the Moyenne Côte Nord (55°10-15'N, 62°50'W - 64°13'W) (Fig 1). One of the unique features of the Mingan Island National Park Reserve is its rich flora. There are more plant species within the archipelago (452 species over 90 km^2) than have been found on the rest of the north shore combined (380 species over 225 000 km^2) (Dryade Ltee. 1986). Of these, 419 plant species are indigenous to the area and approximately 20 are considered to be rare. The increased variety on the islands occur because of a combination of three factors: 1) soil, 2) climate and 3) habitat diversity.

1) Soil: The limestone base of the islands releases nutrients such as calcium and magnesium which are accessible to plant roots. Many of the rare plants in the Archipelago require limestone to grow.

2) Climate: Ninety percent of the archipelago is in the Boreal zone and 10% is hemi-Arctic. Although the archipelago is not in the temperate zone, certain elements of this climatic zone are at their northern limit. There is a strong maritime influence which results in warmer winter temperatures and delays the advent of spring. The small accumulation of snow in the winter favours dwarf trees and bushes, lichens, and Arctic-alpine plants. There is also increased humidity from the ocean (Dryade Ltee. 1986).

3) Habitat Diversity: Six distinct habitats are present on the islands ranging from boreal forest to open cliffs (Table 2).

Ile Nue has been zoned in the highest category for protection due to its highly sensitive flora. Sixty-two percent of the surface of the island is covered with maritime tundra, consisting of low vegetation exposed to strong maritime winds (Dryade Ltée 1986). Two types of tundra occur on Ile Nue: The first is dominated by Arctic-alpine vegetation forming a carpet dominated by *Cladina stellaris* and *Empetrum nigrum*, which is extremely sensitive to physical impact due to its slow recovery rate (Gratton *et al.* 1988), while the second consists of small shrubs and plants (dominated by *Empetrum nigrum* and *Ledum groenlandicum*). Due to the fragility of this habitat (i.e. designated "zone de protection integrale" according to Environment Canada), public access to the area is strictly forbidden. The gulls nest in the second category of tundra, only a small tern colony having been observed in the lichen dominated tundra.

Methods

Prior to nest-building activities by the gulls (mid-May) in 1995, exclosures were established as control sites within the colony using a Randomized Complete Block Design (Sokal and Rohlf 1981.). Three sites in the gull colony (shrub tundra) were chosen for the installation of 3 exclosures each, making a total of 9 control plots. Exclosures measured 5x5 m and were comprised of 1.25 cm mesh netting for the walls and 12.5 cm mesh netting on the top. To minimize the effects of gulls nesting nearby, a 50 cm buffer zone was established along each wall inside the exclosures where no vegetative or soil measurements were taken. For each exclosure, a paired treatment plot of the same size was established. Treatment plots were positioned to ensure that gulls were present. The exact number of nests could not be controlled, however, the plots contained either one or two Herring Gull nests. The treatment plots were approximately 20 m from the exclosures to reduce disturbance of the nesting gulls when sampling within the exclosure (Fig 3). Presence of nesting birds at the sites was determined using aerial photographs and ground census data obtained during the summer of 1994.

Vegetation and soil measurements:

To quantify vegetation, 6 circular quadrats (50 cm^2) were placed inside each exclosure. Plots were subdivided into 6 equal parts and a quadrat was randomly placed within each part to obtain an average sample representative of the whole area within the exclosure (Barbour *et al.* 1987). Vegetation characteristics were noted (species composition, cover and density) within each quadrat. All species in the quadrat were identified and categorized as either native or alien, and annual or perennial (Table 3). Percentage cover was estimated using phytosociological methodology, estimating cover visually to within 5% (Barbour *et al.* 1987). Density was calculated for species where individual plants could be counted (Table 3). This was achieved by counting the number of plants in each quadrat. Seasonal growth was determined for *Ledum groenlandicum* using a standard ruler to measure the length of new shoots (approximately 10 shoots per exclosure) at the end of the breeding season (mid August). These same vegetative measurements were taken at each treatment plot. Small sticks were planted in the centre of the quadrats to mark the areas for the next sampling period. Measurements were repeated on a monthly basis, from the beginning of the nesting period (end of May) until the end of the fledging period (mid-August).

To obtain soil measurements, each exclosure and treatment plot was divided into four equal parts. Soil cores were taken randomly from each of the four using a standard soil sampler with a 5 cm core diameter. The first 5 cm of topsoil was collected for analysis. Each group of four subsamples was then combined for each site within the colony to get one average sample representative of that particular site (ie. gull versus exclosure). Samples were taken monthly during the same period as the vegetation measurements. These samples were dried and later analysed for nitrogen (N) and phosphorous (P) using colorimetric analysis (Bremner and Mulvaney 1982), potassium (K) using a flame photometer (Knudsen *et al.* 1982) as well as calcium (Ca) and magnesium (Mg) using atomic absorption spectrometry (Lanyon and Heald 1982). Additional soil samples were taken from gull roosting areas in mid-June and mid-August. Faeces collected at this time were analysed for nutrient content using the same methodology. Because fresh faeces were collected using plastic sheeting, all the faeces pooled into folds, making it impossible to determine the actual number of deposits present. The faeces data were therefore not analysed statistically along with the soils.

Egg hatching chronology and density for pre and post hatching periods were recorded for the treatment plots throughout the season. The density of gulls present within the plots was determined by observation from blinds set up at two of the three sampling sites.

Statistical Analysis

Vegetation and soil data were analysed by applying Repeated Measures Analysis of variance (ANOVAR) (Crowder and Hand 1990, Tzilkowski and Storm 1993), as an efficient method for monitoring permanent sites over a period of time (Green 1993). This was performed using the statistical package SAS (SAS Institute 1985). Due to the small *p/n* ratio (where *p* is the number of dependent variables and *n* is the sample size), the Univariate analysis was chosen as the strongest test in this case (Moser and Saxton 1990, Potvin *et al.* 1990, Green 1993). Since every exclosure had a nearby corresponding treatment in a similar habitat, paired observation differences (i.e. exclosure-treatment) were used for the analysis (Green 1993). This method was used to compare % cover and density for plants as well as nutrient changes in the soil (pH, N, P, K, Ca, Mg). Data were collected for 13 species of plants, 5 of which appeared too infrequently to analyse (Table 3). Percentage cover of bare soil was also recorded and analysed statistically. The Arcsine Transformation was used for the percentage cover data to prevent the variance from becoming a function of the mean (Sokal and Rohlf 1981).

Growth measurements for *Ledum* were analysed using a paired *t*-test (Sokal and Rohlf 1981). The shoot lengths measured at the end of the season for each exclosure/treatment pair were analysed to establish the significance of the differences between these two plots.

ANOVAR results are discussed using the corrected *F*-test, which applies any necessary corrections to the degrees of freedom (Green 1993). The Huynh-Feldt (H-F) adjustment was chosen over the Greenhouse-Geiser (G-G); for this study, G-G tends to overestimate the power of the test because the number of replicates (9) is small with respect to the number of repeated measures (4)(Greenhouse and Geiser 1959, Huynh and Feldt 1970). Significance was established at the 0.10 level because the small sample size for this study makes it more difficult to detect differences between treatment and exclosures over time.

RESULTS

Four of nine treatment plots contained two nests, however in only two of these were both nests successful (Table 4). Unfortunately, this treatment with two successful nests (P2) contained the most missing quadrats for the last sampling period, therefore the mean was based on fewer quadrats. Two of the single nest treatment plots were abandoned after disappearance of the eggs, but gull faeces and trampled vegetation confirmed gull activity. All treatment plots were treated equally because the overall average of successful nests per area was close to one.

The peak of hatching occurred from the last week of June into the first week of July (Table 4). Because high predation rates involving neighbouring gulls were observed during mid season, visits to the nests to determine hatching chronology were minimized. Adult gulls thus stayed around their nest sites to protect their eggs. This ensured that vegetative and soil measurements were taken where gull activity actually occurred.

Although tall vegetation within the treatment plots made an accurate count of gulls difficult, density data showed that attendance patterns differed markedly between pre and post hatching periods (Figure 4). On average, there was a higher number of gulls within the nest site during the pre hatching period (1.4 gulls per nest; n=29; based on a daily average of 4 observations per half hour) as compared to the post hatching period (1.1 gulls per nest; n=25; based on a daily average of 4 observations per half hour)(Figure 4).

Vegetation

The dominant vegetative association in the treatment plots consisted of *Deschampsia* (44% for treatments, 57% average cover for exclosures) and *Stellaria* (42% treatments, 42% exclosures) in June, switching to *Deschampsia* (66% exclosures, 43% treatments) and *Epilobium* (25% exclosures, 29% treatments) by August (Figure 5). *Ledum* was also present in large patches in both the exclosures and treatment plots. A total of 12 species of plants was found in the exclosures and 13 in the treatment plots. The one species occurring only for the treatment plots was *Maianthemum*, which occurred in 2 quadrats of a possible 63. Moss and bare soil were found in both exclosures and perimeters, however the moss was only present during the first and second sampling periods (June and July).

Percentage cover: No significant site effects were found for the plant species analysed (*F*-test; $P>0.10$), indicating that all sites were homogenous.

Only *Ledum groenlandicum* showed a significant effect over time (*F*-test; $P< 0.10$; Table 5), indicating that the differences between the percentage cover of this species in the exclosures versus the treatment plots increased over the season. For quadrats where *Ledum* was present, the plant showed an average increase in cover of 3% in the exclosures as compared to a 5% decrease in the treatment plots from May until August (Figure 5).

Deschampsia, Urtica and *Stellaria* did not show significant differences in percentage cover (*F*-test; $P>0.10$; Table 6). *Deschampsia* followed a similar trend in both exclosures and perimeters, until August when there was a decrease in the treatment plots as compared to an increase in the exclosures. *Urtica* peaked higher in the exclosures than treatment plots in July however decreased more by August. *Stellaria* followed a similar trend for both exclosures and treatment plots (Figure 5). *Epilobium* and bare soil also did not show significant differences with P values being close to one (Table 6).

Density: Plant species measured for density did not reveal significant differences between exclosures and treatment plots throughout the season. There was a greater increase in individual *Epilobium* plants in the exclosures than the treatment plots, however this increase was not significant (*F*-test; P>0.10; Table 7), and the pattern over the season for exclosures and treatment plots was similar (Figure 6). The *F*-test probabilities of differences for the other plant species analysed are listed in Table 8.

Density differences between exclosures and treatment plots increased for *Cornus* throughout the summer, peaking in August when there was an increase in the average number of individuals in the exclosures and a decrease in the treatment plots (Figure 6), however this was not significant. Differences in density between exclosures and treatment plots were at their highest in June for both *Urtica* and *Trientalis,* however they decreased during July and August.

Growth: Growth measurements for *Ledum* revealed that shoots in the exclosures were 13% longer than shoots in the treatment plots. This result was significant (*t*-test; P=0.056; Table 10).

The means and standard errors per month for all plant species analysed are summarized in Table 9. Some small sticks used to mark the quadrat locations for all the vegetative measurements were removed by immature gulls in mid-August prior to the last sampling date. The closer the quadrats were to the nest, the greater the loss of markers. This activity accounted for a loss of nearly 50% of the markers in the gull treatment plots at the end of the season. This made it impossible to find the initial quadrat locations thereby reducing the number of quadrats used to represent the average for each treatment for the final sampling session.

Soils

Soil analysis yielded no significant site effects for the nutrients measured (*F*-test; P>0.10), therefore this effect was deemed to be negligible.

No significant changes in nitrogen, potassium, calcium or magnesium were found between exclosures and treatment plots. Soil pH in the treatment plots showed a significant increase over the summer (7%) as compared to the exclosures which decreased by 1% (*F*-test; P<0.10; Table 11; Figure 7). There was also a significant difference in soil phosphorous levels between treatment/exclosure pairs, with phosphorous levels in the exclosures increasing slightly (8%) from 0.8 to 0.9mg/g, while increasing by 115% (1.1 to 2.4mg/g) in the treatment plots (*F*-test; P<0.10; Table 12; Figure 7). Differences in calcium were not significant (*F*-test; P>0.10; Table 12) increasing both in the exclosures (from 5.2 to 8.5mg/g) and the treatment plots (7.2 to 11.9mg/g) which resulted in increases of 63% and 64% respectively (Table 13; Figure 7) . Although there were also increases in nitrogen, potassium and magnesium in the treatment plots, these were nt significant (Table 12). Means and standard errors for the differences in soil nutrients between exclosures and treatment plots over the summer are summarized in Table 14.

Although no statistical analysis was conducted, soil nutrient levels on the study sites versus roosting sites and actual faeces content showed that roosting sites had higher concentrations of nutrients than the treatment plots (Figure 8). The pH levels of the roosting sites increased by 36% from June (pH = 4.7) to a pH of 6.4 in August, which is close to the pH of the faeces, 6.5.

DISCUSSION

Vegetation

The same plant species were present in the exclosures and treatment plots throughout the season with the exception of *Maianthemum* for which a total of 19 individuals appeared in two treatment plots in July and disappeared by mid August. It was not expected that changes in species composition would occur over one breeding season since increased soil nutrient levels from faeces only bring about such changes over time once the nutrients have been absorbed by the plant (Gillham 1961, Sobey and Kenworthy 1979, Gillmore *et al.* 1984, Hogg and Morton 1983, Hogg *et al.* 1989). The dominant plants, *Deschampsia*, *Stellaria* and *Ledum* in June, and *Deschampsia*, *Epilobium* and *Ledum* in August, are not the same as those described for the island in 1983 (Dryade 1986) when the dominant plant species in the gull colonies consisted of *Empetrum nigrum*, *Ledum* and *Epilobium*. Although the dominant species were chosen subjectively by visual observation in 1983 (P. Grondin, pers. comm.), our study found no *Empetrum* in any of the exclosures or treatment plots. This species was only observed close to the shore where gull activity is at a minimum. *Empetrum* is sensitive to repeated trampling (Gratton *et al.* 1988). Feeding studies on the island in 1995/1996 showed that the berries of this plant constituted 81% of food pellets collected when the berries became available in August (A. Boyne pers. comm.). These two factors combined with possible increases in soil nutrients since the last study may have contributed to the disappearance of this species within the gull colonies.

Ledum groenlandicum was the only plant to differ significantly in the exclosures versus the treatment plots over the 1995 breeding season. Percentage cover increased in the exclosures and decreased in the treatment plots. There were also significantly larger increases in growth rate according to shoot length in exclosures versus treatment plots.

Ledum is commonly found in organic bog soils across Québec, although it is most abundant in the cooler northern regions of the province (Marie-Victorin 1964). Bog soils are characterized by their high acidity and low nitrogen levels. According to the Canadian Soil Classification System (Commission Canadienne de Pédologie 1987), these organic fibrisols are what characterize the soils of gull nesting sites on Ile Nue (Dryade Ltee. 1980). *Ledum* bushes are not usually trampled by birds, because of their height and "robustness". However, as observed, gulls do perch on this plant, burning the leaves directly with their faeces. As a bog species, *Ledum* is tolerant of low levels of nitrogen, giving it a competitive edge against most other species in nitrogen poor soils. However, when the nutrient level is raised, other plants who were out-competed in the low nitrogen soils are then able to out-compete *Ledum*. This secondary effect of fertilization should occur on a more long-term basis and affect other species as well. For this study, the only immediate effect likely to be shown over one season is the tearing of *Ledum* both by adults during territorial disputes and by the young as they grow. It is likely that this combination of effects on *Ledum* made it the only one to show significant change during the study. While other plant species received faeces and/or were trampled, only *Ledum* was seen to be pulled and torn by the birds.

Gulls are known to have carried seeds of alien annual plants to areas where they nested (Gillham 1961, Hogg and Morton 1983). This was not observed in this study (Table 2). *Stellaria* was the only annual plant species found in the study site quadrats. The lack of annuals in such tundra ecosystems of which perennials dominate may be due to the lack of prolonged heat which enables the seeds of annual species to germinate (Bliss 1971).

On average, the percentage of bare soil increased almost fivefold in the treatment plots and threefold in the exclosures, although this was not significant due to high variability within the data set.

There were no significant effects of the gulls on either the % cover or density of *Epilobium* over one season. This does not support the view that nesting gulls are associated with *Epilobium* (Couillard et Grondin 1983, Dryade 1986). People from the area who have frequented the island for generations state that the plant has always been present, although possibly not in such large quantities (C. Kavanagh pers. comm.). *Epilobium* is a pioneer species and often invades areas which have recently been ravaged by fire, hence the common name fireweed. Its seed, equipped with a coma, or feather-like structure, is dispersed by wind and water (Morton and Hogg 1989). Although gulls do not disperse the seed of this plant directly, they may till and manure the soil creating a suitable area for a pioneer species to grow (Gillham 1961).

Ten of the 20 plant species categorized as rare in the park can be found on Ile Nue (Dryade Ltee. 1986). It should be noted that these species remain confined to cliffs and/or calcareous rock surfaces which tend to be concentrated near the shores. Although *Erysimum inconspicuum* was observed within the colony on patches of exposed rock, these patches are not used for nesting, nor for roosting and therefore are not likely to be damaged by the gulls.

Soils

The pH level of the soil was significantly increased by the presence of the gulls. This contradicts other studies where faeces rendered the soil more acidic (Bernard *et al.* 1971, Gilmore *et al.* 1984). At Ile Nue organic fibrisol soil is already very acidic (pH 4.3-5.1), therefore the addition of faeces (pH 6.3-6.9) has a buffering effect causing the pH to rise. This may be another reason why a plant such as *Ledum*, which is tolerant to acidic soils does not do as well in the presence of the gulls.

A higher increase in phosphorous in the treatment plots versus exclosures (Figure 7) was the only significant nutrient change recorded over the season. Although other studies have shown significant changes in more than one nutrient, the increase in phosphorous levels was usually much greater than the rest (Gilmore *et al.* 1984) because phosphorous remains in the soil for several years after many other nutrients have leached out (Hogg and Morton 1983). High phosphorous levels can be attributed not only to direct input from faeces, but also to the accumulation of dead and decaying animal matter around the nest sites (Hogg and Morton 1983). Although phosphorous was the only nutrient found to be significantly different between exclosures and treatment plots, with the exception of nitrogen there was generally a larger increase in nutrient levels in the treatment plots compared to the exclosures (Table 13). Although the increases in nutrient levels were not statistically significant in our study, we feel that given a longer term experiment these changes would have yielded significant differences. Nitrogen is the only nutrient which showed a greater overall increase in the exclosures as compared to the treatment plots, however the level was still higher in the treatment plots by the last sampling date (Figure 7).

This study focussed specifically on the effects of the gulls on nesting sites. During our observations it was confirmed that adult gulls do not defecate on their territories until the young have hatched. The largest deposition of faeces onto the nesting site therefore occurs during the second half of the breeding season, limiting the input of faeces and therefore the duration of the nutrient input into the soil to a period of approximately two months (Table 4). Adult gulls were seen congregating at roosting sites, which vary in size and are often located on mounds where the ground is slightly elevated from its surroundings. At these sites, both trampling and faeces input effects were concentrated due to the large number of birds occurring in a relatively small area. Unlike the nest sites, birds were seen to defecate at these sites throughout the breeding season. The highest levels of soil nutrients occurred at these roosting sites. For pH, calcium, potassium and magnesium, these levels rose close to those of the faeces themselves (Figure 8). Calcium and magnesium levels in the faeces were high in June, and decreased sevenfold by August. Gulls usually alter their diet to fish once the young have hatched (Pierotti and

Anette 1990). The birds were feeding on foods containing high levels of calcium and magnesium (molluscs, crustaceans) at the beginning of the summer, switching later to a diet consisting of fish (from chick regurgitation data) explaining the large decrease in magnesium and calcium levels as the summer progressed. Landfill sites are a common roosting location for gulls (Belant *et al.* 1993): Ile Nue is located approximately 6 km from the nearest landfill. Although gulls will travel to find food, their roosting areas are usually located near the nesting sites. Herring Gulls will not feed at landfill sites if higher quality food such as fish is available (Belant *et al.* 1993). Observations showed few gulls at the landfill when capelin normally spawn in the Archipelago from July to August (Grégoire 1996), however they were seen feeding at the landfill site prior to this period (A. Boyne pers.comm.). The roosting areas therefore may vary from one colony to another. Vegetation on these mounds was either nonexistent, or dominated by *Stellaria* sp. This may be because *Stellaria* is most often dispersed by gulls through faeces deposition after they digest the seeds. (Morton and Hogg 1989). *Stellaria* tends to dominate other plant species which may have been present on the roosting sites before the arrival of the birds (Sobey and Kenworthy 1979).

All the soil and vegetation of the islands lays on a bed of sedimentary limestone. The soil depth varies from 30 cm to 1.5 m (P. Richard, pers. comm.). The raised mounds used as roosting spots, have a thicker layer of peat soil than the surrounding areas. Because of this, vegetative cover may differ from the surrounding areas. Because there was no control site on the island it is difficult to make conclusions concerning the vegetation present prior to the arrival of the gulls. It is recommended that future studies examine the soil composition at roosting sites by taking soil samples throughout the year to determine nutrient inputs of high quantities of faeces. Placing exclosures over some roosting sites would help to determine what plants would succeed, if any, when these high usage areas are protected from gull activity. Although in the short term, the null hypothesis of no effect by the gulls is accepted for most species of plants studied, biologically, certain changes discussed earlier confirm the need for a follow up study. As previous studies have shown, although fertilization of nutrients can be beneficial in small amounts, extreme disturbance and high faeces input can cause considerable change in vegetation (Table 1). Increases in soil nutrient levels brought about by the gulls, even though not statistically significant are thus still plausible (Figure 7). This is the first study looking at effects of Herring Gulls on Maritime Tundra and therefore the effects on the vegetation and soils may differ from studies discussed earlier (Table 1) as the habitats were markedly different. Since gulls were probably nesting on sites used for exclosures in prior years, it may take time before more significant differences appear, if any, between the exclosures and treatments. The average density of nests around the study sites on Ile Nue was 0.007 nests/m^2, however denser sites have been located on other sites on the island (B. Roberge pers. comm.). This Herring Gull nest spacing on the island is the same as on Barrier Island in the Great Lakes (Hogg and Morton 1983) and lower than on Great Island in Newfoundland at 0.018 nests/m^2 (Pieriotti 1982). However, the density within the treatments were 0.040 nests/m^2 because for every 25 m control plot there was at least one nest. Differences in soil and soil chemistry (high acidity) of the study site may be a key element in changes in vegetation and soil nutrient levels caused by the gulls. The removal of sampling markers by immature gulls in areas with high gull activity accounts for a loss of data points where effects on vegetation may have been most prominent. This combined with the small sample size and high variability within the data could also account for the differences in our results. The exclosuress will remain in place after the 1995 season as a part of a long term Parks Canada study to monitor effects of the gulls on the vegetation.

Since 1988-1993, there appears to have been a sharp decline (-21.33%) (Chapdelaine 1995) in Herring Gull populations in most sanctuaries along the north shore of the Gulf of St Lawrence. According to nest chronology data obtained on Ile Nue for the past two years, we have noted a significant decrease in successful nests, indicating a possible future population decline. Data for the latest gull census on the island in 1996 is not yet available. Knowing whether gull populations in the archipelago are increasing or decreasing will be important in formulating management decisions concerning potential vegetation damage in the area.

Populations of other birds nesting on Ile Nue such as Greater Black-backed Gull (*Larus marinus*), Arctic (*Sterna paradisaea*) and Common Terns (*Sterna Hirundo*) as well as Eider Ducks (*Somateria mollissima*) should also be monitored to verify how they react to this decrease in the Herring Gull population. Muskrats (*Ondatra zibethica*) were abundant on Ile Nue. They did not appear to affect the gulls, although they contribute to the formation of mounds or roosting spots through their excavations and soil displacement. The activities of the muskrats may also affect the vegetation of the islands through this soil displacement. It would also be beneficial to have an estimate of their population density.

Conclusion

One plant species was found to differ significantly between exclosures and treatment plots in a gull colony over the 1995 season, *Ledum groenlandicum.* One soil nutrient, phosphorous, was significantly higher in the treatment plots and soil pH was lowered through faeces input on the treatment plots. Observations of roosting sites suggest that, large concentrations of these birds damage all vegetation, leaving bare soil behind. The soil samples from these sites indicate high nutrient levels, in some cases close to the levels in faeces themselves. This confirms the need to study these roosting sites more closely. Over the short term study, I did not expect to see changes in species composition, however the disappearance of *Empetrum* on the gull sites since the 1983 inventory shows that, over time, species changes have occurred. The reasons for its disappearance remain unknown. It is therefore imperative to keep the exclosures intact and to watch for any long term changes caused by gull activity on Ile Nue.

LITERATURE CITED

Babb, T.A. and L.C. Bliss. 1974. Effects of physical disturbance on Arctic vegetation in the Queen Elizabeth Islands. J. Appl. Ecol. 11:549-562.

Barbour, M.G., J.H. Burk and W.D. Pitts. 1987. Terrestrial Plant Ecology. 2nd edition. The Benjamin/Cummings Publishing Company, Inc. Los Angeles, C.A. 634 pp.

Bazely, D.R. and R.L. Jefferies. 1985. Goose faeces: a source of nitrogen for plant growth in a grazed salt marsh. J. Appl. Ecol. 22:693-703.

Belant, J.L, T.S. Seamans, S.W. Gabrey and S.K. Ickes. 1993. Importance of landfills to nesting Herring Gulls. Condor 95:817-830.

Belland, R.J, W.B. Schofield and T.A. Henderson. 1992. Bryophytes of Mingan Archipelago National Park Reserve, Quebec: a boreal flora with Arctic and alpine components. Can. J. Bot. 70:2207-2222.

Bernard, J.M., D.W. Davidson and R.G. Koch. 1971. Ecology and floristics of Knife Island, a gull rookery on Lake Superior. Ecol. 37:101-103.

Blakemore, L.C. and H.S. Gibbs. 1968. Effects of Gannets on soil at Cape Kidnappers, Hawke's Bay. New Zeal. J. Sci. 11:54-6

Bliss, L.C. 1971. Arctic and alpine plant life cycles. Ann. Rev. Ecol. Syst. 2:405-437.

Blokpoel, H., and G.D. Tessier, 1983. Overhead wires an Monofilament lines exclude Ring-billed Gulls from public places. Ninth Bird Control Seminar. Oct 4-6, 1983. Bowling Green Ohio. pp 15-19.

Blokpoel, H., and G.D. Tessier, 1984. Overhead wires an Monofilament lines exclude Ring-billed Gulls from public places. Wildl. Soc. Bull. 12:55-58.

Bosman, A.L., and P.R. Hockey. 1986. Seabird guano as a determinant of rocky intertidal community structure. Mar. Ecol. Prog. Ser. 32:247-257.

Bouchard, D. et J. Ouzilleau. 1992. Monitoring 1991. Impacts d'utilisation sur les milieux fragiles. Réserve de park national de l'Archipel de Mingan. Rapport présenté par FORAMEC à Environnement Canada, Service de la conservation des ressources naturelles, Service canadien des parks, région du Québec. 35 pp.

Bremner, J.M. & C.S. Mulvaney. 1982. Methods of soil analysis, part 2. Agronomy 9. Amer. Soc. Agron., Madison, Wis. pp 595-624.

Brousseau, P. 1984. Inventaire des oiseaux marins de huit îles du secteur ouest de l'Archipel de Mingan. Service Canadien de la faune. 11 pp.

Bukacinski, D., A. Rutkowska and M. Bukacinska. 1994. The effects of nesting Black-headed Gulls (*Larus ridibundus* L.) on the soil and vegetation of a Vastula River island, Poland. Ann. Bot. Fenn. 31:233-243.

Burger, A.E. H.J. Lindeboom and A.J. Williams. 1978. The mineral and energy contributions of guano of selected species of birds to the Marion Island terrestrial ecosystem. S. Afr. Antart. Res. 8:59-70.

Challinor, J.L. and P.L. Gersper. 1975. Vehicle perturbation effects upon tundra soil-plant system: II Effects on the chemical regime. Soil. Sci. Soc. Amer. Proc. 39:689-695.

Chapdelaine, G. 1995. Fourteenth census of seabird populations in the sanctuaries of the north shore of the Gulf of St Lawrence, 1988-1993. Can. Field-Nat. 109:220-226.

Chapdelaine, G. et A. Bourget. 1981. Distribution, abondance et fluctuations des population d'oiseaux marins de l'Archipel de Mingan (Golfe du Saint-Laurent, Québec). Nat. Can. 108:219-227.

Chapdelaine, G. and P. Brousseau. 1992. Distribution, abundance, and changes of seabird populations of the Gaspé peninsula, Québec, 1979 to 1989. Can. Field Nat. 106:427-434.

Chapin, F.S. and G.R. Shaver. 1981. Changes in soil properties and vegetation following disturbance of Alaskan Arctic Tundra. J. Appl. Ecol. 18:605-617.

Commission Canadienne de Pédologie. 1987. La classification des sols du Canada (deuxième édition). Research Branch, Agriculture Canada Publ. 1646, 164 pp.

Couillard, L. et P. Grondin. 1983. Les îles de Mingan: des siècles à raconter. Gouvernement du Québec, Québec. 241 pp.

Coulson, J.C., N. Duncan and C. Thomas. 1982. Changes in the breeding biology of the Herring Gull (*Larus argentatus*) induced by reduction in the size and density of the colony. J. Anim. Ecol. 51:739-756.

Crowder, M.J and D.J. Hand. 1990. Analysis of repeated measures. Chapman and Hall, New York. 257 pp.

DesGranges, J.L., G. Chapdelaine et P. Dupuis. 1984. Sites de nidification des populations du Cormoran à aigrettes au Québec. Can. J. Zool. 62:1260-1267.

Dryade Ltée. 1980. Etude phyto-ecologique de l'Archipel de Mingan. Document préparé pour l'office de la planification et de developpement du Québec. Tome 1, 77 pp et Tome 2, 148 pp.

Dryade Ltée. 1986. La végétation de l'Archipel de Mingan. Document préparé pour Parcs Canada, région du Québec. Tome 1:108pp et Tome 2:98 pp.

Dusi, J.L. 1977. Impact of Cattle Egrets on an upland colony area. Proceedings of the Colonial Waterbird Group. p 39-40.

Furness, R.W. and P. Monaghan. 1987. Seabird Ecology. Chapman and Hall, New York. 164 pp.

Gaston, A.J. and G. Donaldson. 1995. Peat deposits and Thick-billed Murre colonies in Hudson Strait and Northern Hudson Bay: clues to post-glacial colonization of the area by seabirds. Arctic 487:345-358.

Gauthier, J. et Y. Aubry. 1995. Les Oiseaux Nicheurs du Quebec: Atlas des Oiseaux Nicheurs du Quebec meridional. Association quebecoise des groupes d'ornithologues, Societe quebecoise de protection des oiseaux, Service canadien de la faune, Environnement Canada, region du Quebec, Montreal, xvii + 1295 pp.

Géhu, J.M. et J.Géhu-Franck. 1961. Recherches sur la végétation et le sol de la réserve de l'île des Landes (I. et V.) et de quelques îlots de la côte Nord-Bretagne. Incidences de l'avifaune marine sur la flore. Bulletin du laboratiore maritime de Dinard. 47:19-51.

Gersper, P.L. and J.L. Challinor. 1975. Vehicle perturbation effects upon a tundra soil-plant system: I Effects on morphological and physical environmental properties of soil. Soil. Sci. Soc. Amer. Proc. 39:737-744.

Gillham, M.E. 1956a. Ecology of the Pembrokeshire Islands. IV effects of treading and burrowing by birds and mammals. J. Ecol. 44,1:51-82.

Gillham, M.E. 1956b. Ecology of the Pembrokeshire Islands. V. manuring by the colonial seabirds and mammals with a note on seed distribution by gulls. J. Ecol. 41:84-99.

Gillham, M.E. 1960a. Destruction of indigenous heath vegetation in Victorian sea-bird colonies. Aust. J. Bot. 8:277-294.

Gillham M.E. 1960b. Vegetation of New Zealand Shag colonies. Trans. Roy. Soc. N.Z. 88:362-380.

Gillham, M.E. 1961. Alteration of breeding habitat by sea-birds and seals in western Australia. J. Ecol. 49:289-300.

Gillham, M.E. 1963 Some interactions of plants, rabbits and sea-birds on South African islands. J. Ecol. 51:275-294.

Gillham, M.E. 1977. Vegetation of sea and shore-bird colonies on Aldabra Atoll. Atoll Res. Bul. 200:1-19.

Gillmore, A.R., G.Z. Gertner and G.L.Rolfe. 1984. Soil chemical changes with roosting birds. Soil Science 138:158-163.

Gouvernain, R.C. 1996. Indirect impacts of soil trampling on tree growth and plant succession in the North Cascade Mountains of Washington. Biol. Cons. 75:279-287.

Gratton, L., D. Robert, B. Réjean, et M. Chagnon. 1988. La capacité de support de la pointe nord de l'Ile Nue de Mingan. Rapport final du Goupe SOGEAM présenté au service de la conservation des ressources naturelles, Parks Canada, région du Québec 95 pp.

Green, R.H. 1993. Application of repeated measures design in environmental impact and monitoring studies. Aust. J. Ecol. 18:81-98.

Greenhouse, S.W. and S. Geisser. 1959. On the methods of analysis of profile data. Psychometrika 24:95-112.

Grégoire, F. 1996. Capelin in the St. Lawrence. DFO, Atlantic Fisheries, Stock Status Report 96/25. Available from: Maurice Lamontagne Institute, Mont-Joli, Québec. 6pp.

Grenier, A. et C. Kavanagh. 1993. État des populations de goélands (Larus argentatus, Larus delawarensis et Larus marinus) de la réserve de park national de L'Archipel de Mingan. Environnement Canada, District de Mingan 34 pp.

Grondin, P., R. Chiasson et R. Thériault. 1986. La végétation de l'archipel de Mingan, Tome 2: Présentation des îles. Firme Dryade. 91 pp.

Grondin, P. et M. Melancon. 1980. Etudes Ecologiques: étude phyto-écologique de la Grosse Ile au Marteau et de l'Ile à Samuel, archipel de Mingan, Québec. Laboratoire d'écologie forestiere, Université Laval, Québec. 227 pp.

Hawke, D.J. and H.K.J. Powell. 1995. Soil solution chemistry at a Westland Petrel breeding colony, New Zealand: Palaeoecological implications. Aust. J. Soil Res. 33:915-924.

Headley, A.D. 1996. Heavy metal concentrations in peat profiles from the high Arctic. Sci. of the Tot. Env. 177:105-111.

Hogg, E.H. and J.K. Morton. 1983. The effects of nesting gulls on the vegetation and soil of islands in the Great Lakes. Can. J. Bot. 61:3240-3254.

Hogg, E.H., J.K Morton and J.M. Venn. 1989. Biogeography of island floras in the Great Lakes. I. Species richness and composition in relation to gull nesting activities. Can. J. Bot. 67:961-969.

Howes, L. and W.A. Montevecchi. 1993. Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Can. J. Zool. 71:1516-1520.

Huynh, H and L.S. Feldt. 1970. Conditions under which mean square ratios in repeated measurements designs have exact *F*-distributions. J. Am. Stat. Assoc. 65:1582-1589.

Ishizuka, K. 1966. Ecology of the ornithocoprophilous plant communities on breeding places of the Black-tailed Gull, *Larus crassirostris*, along the coast of Japan. Ecol. Rev. 16:229-244.

Knudsen, D., G.A. Peterson and P.F. Pratt. 1982. Methods of soil analysis, part 2. Agronomy 9. Am. Soc. Agronomy, Madison, Wis. pp 228-238.

Agronomy 9. Am. Soc. Agronomy, Madison, Wis. pp 228-238.

Lanyon, L.E. and W.R. Heald. 1982. Methods of soil analysis, part 2. Agronomy 9. Am. Soc. Agronomy, Madison, Wis. pp 247-262.

Levesque, B., P. Brousseau and P. Simard. 1993. Impact of the Ring-billed Gull (*L. delawarensis*) on the microbiological quality of recreational water. Appl. Env. Microb. 59:1228-1230.

Lewis, H.F. 1929. The natural history of the double-crested cormorant (*Phalacrocorax auritus auritus* (Lesson)). Ph.D Thesis, Cornell University, Ithaca, New York. 94pp.

Lloyd, C., M.L. Tasker and K. Partridge. 1991. The status of seabirds in Britain and Ireland. T & a.D. Poyser, London. p 155-169.

Marie-Victorin, Fr. 1964. Flore Laurentienne. Les Presses de l'Université de Montréal, Québec. 925 pp.

Marie-Victorin, Fr. and Rolland-Germain, Fr. 1969. Flore de l'Anticostie-Minganie. Les Presses de l'Université de Montréal, Montréal, Que.

Mizutani, H, Hasegawa, H. and E. Wada. 1986. High nitrogen isotope ratio for soils of seabird rookeries. Biogeochem. 2:221-247.

Mizutani, H., Y. Kabaya, P.J. Moors, T.W. Speir and G.L. Lyon. 1991. Nitrogen isotope ratios identify deserted seabird colonies. Auk 108:960-965.

Mizutani, H. and E. Wada. 1988. Nitrogen and carbon isotope ratios in seabird rookeries and their ecological implications. Ecology 69(2):340-349.

Monaghan, P. 1983. Gulls: populations and problems. In: Enjoying Ornithology. T. and A.D. Poyser. Carlton, England pp 232-237.

Montevecchi, W.A. and R. Myers 1996. Dietary changes of seabirds indicate shifts in pelagic food webs. Sarsia 80:313-322.

Moors, P.J., T.W. Speir and G.L. Lyon. 1988. Soil analysis and $^{13}C/^{12}C$ ratios identify sites of deserted Rockhopper Penguin colonies. Auk 105:796-799.

Morton, J.K. and E.H. Hogg. 1989. Biography of island floras in the Great Lakes. II. Plant dispersal. Can. J. Bot. 67:1803-1820.

Moser, E.B. and A.M. Saxton. 1990. Repeated measures analysis of variance: application to tree research. Can. J. For. Res. 20:524-535.

Murton, R.K. and E.N. Wright (ed). 1968. The problem of birds as pests. Symposia of the Institute of Biology No.7. Academic Press, London. 254 pp.

Ostergaard, D.E. 1981. Use of monofilament fishing line as a gull control. Prog. Fish-cult. 43:134.

Pieriotti, R. 1982. Habitat selection and its effect on reproductive output in the Herring Gull in Newfoundland. Ecol. 63:854-868.

Pierotti, R., and C.A. Anette. 1990. Diet and reproductive output in seabirds. Bioscience 40:568-574.

Pierrotti, R.J. and T.P. Good. 1994. Herring Gull (*Larus argentatus*). *In* The Birds of North America, No. 124 (A. Poole and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union. 28 pp.

Pounder, E.J. 1985. The effects of footpath development on vegetation at the Okstindan Research in Arctic Norway. Biol. Cons. 34(3):273-288.

Potvin, C., Lechowicz, M.J. and S. Tardif. 1990. The statistical analysis of ecophysiological response curves obtained from experiments involving repeated measures. Ecol. 7(4):1389-1400.

Rickard, W.E. and J. Brown. 1974. Effects of vehicles on Arctic Tundra. Env. Cons. 1:55-62.

Roberge, B. 1996. Program de sensibilisation au dérangement des oiseaux marins coloniaux et éthique de navigation dans l'archipel de Mingan. 1996 working document available from: Parks Canada (Service de la Conservation), Havre St Pierre, Québec.

Robinson, K. 1991. Report on the erection of a gull exclosure on Shag Point Island, Terra Nova National Park. Atlantic Canada Tern Working Group. Newsletter 1991-92.

Russell, R.S. 1940. Physiological and ecological studies on an arctic vegetation. J. Ecol.28: 269-288.

SAS Institute 1985. SAS user's guide:statistics. Version 5 edition. SAS Institute, Cary, North Carolina, USA. 1289 pp.

Shugart, G.W. 1976. Effects of Ring-billed Gull nesting on vegetation. The Jack Pine Warbler 54:50-53.

Smith, V.R. 1978. Animal-plant-soil nutrient relationships on Marion Island (Subantarctis). Oecologia (Berl.) 32:239-253.

Sobey, D.G. 1976. The effect of Herring Gulls on the vegetation of the Isle of May. Trans. Bot. Soc. Edinburgh 42:469-485.

Sobey, D.G. 1977. The defaecating behaviour of Herring Gulls (*Larus argentatus*). Ibis 119:515-520.

Sobey, D.G. and J.B. Kenworthy. 1979. The relationship between Herring Gulls and the vegetation of their breeding colonies. J. Ecol. 67:469-496.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Freeman and Co., San Francisco, US. 857 pp.

Soots R.F. and J.F. Parnell. 1975. Herring and Greater Black-backed Gulls nesting in North Carolina. Auk 92:154-157.

Thomas, G.J. 1972. A review of gull damage and management methods at nature reserves. Biol. Conserv. 4:117-127.

Tinbergen, N. 1967. The Herring gull's world. Anchor Books. Doubleday & Company, inc. Garden City, New York. 297 pp.

Tzilkowski, W.M. and G.L.Storm. 1993. Detecting change using repeated measures analysis: White-tailed Deer abundance at Gettysburg National Military Park. Wildl. Soc. Bull. 21:411-414.

Weseloh, D.V. and R.T. Brown. 1970. Plant distribution within a heron colony. Amer. Midl. Nat. 86:57-64.

Willard, B.E. and J.W. Marr. 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biol. Cons. 3:181-190.

Wright, E.N. 1980. Bird problems in agriculture. Proceedings of a conference "Understanding agricultural bird problems" held at Royal Holloway College, Univ. of London, April 4-5, 1979. BCPC Publications, Croydon. 210 pp.

Zelenskaya, L.A. 1995. Influence of settlements of large gulls on the vegetation of maritime tundra. Russian J. Ecol. 26:395-399.

Table 1. The Effects of marine birds on the vegetation and/or soils of their breeding grounds.

Bird Species	Causative Agent	Impact	Source
Heron *Ardea sp.*	faeces trampling	-decrease in percentage cover and density of vegetation at base of nest. -stunted growth and death of woody shrubs and trees.	Soots and Parnell 1975 Weseloh and Brown 1970
Northern Gannet (*Sula bassanus*) Cape Gannet (*Sula capensis*)	faeces	-acidification and nitrification of the soil. -increase in soil phosphorous and potassium. -depletion in exchangeable calcium and magnesium.	Blakemore and Gibbs 1968 Gillham, 1963.
Westland Petrel (*Procellaria westlandica*)	faeces	-significantly lower concentrations of soil Al and natural organic matter. -significantly higher concentrations in extractable phosphates.	Hawke and Powell 1995
Kittiwake Gull (*Rissa tridactyla*) Glaucous Gull (*Larus hyperboreus*)	faeces	-high concentrations of heavy metals in soil.	Headley 1996
Black-tailed Gull (*Larus crassirostris*)	trampling	-inhibited growth of seedling plants -growth of ornithocoprophilous plant communities such as lichen, bryophyte and algae. -destruction of certain shrub species around nesting sites.	Ishizuka 1966 Gillham 1963

Table 1. (cont'd)

Bird Species	Causative Agent	Impact	Source
Royal Terns (*Sterna maxima*)	faeces	-enrichment of soil with nutrients, rendering soil more suitable for non-native species. -alteration of species composition. -significant increase in soil nitrogen, becoming readily available to plants through the activity of bacteria in soil.	Russell 1940
Dominican Gull (*Larus dominicus*)	faeces	-aid in the establishment of lichens on rocks.	Smith 1978
Thick-billed Murre (*Uria lomvia*)	-faeces -food abandonment	-correlation between breeding colonies and distribution of peat moss deposits.	Gaston and Donaldson 1995
Rockhopper Penguin (*Eudyptes crysocome*)	faeces	-changes in nutrient levels detected for more than 30 years after abandonment of the site.	Moors *et al.* 1988 Mizutani *et al.* 1991.
Adelie Penguin (*Pygoscelis adeliae*)	faeces	-certain plants, animals, and soils found to be dependent on the input of organic nitrogen.	Mizutani and Wada 1988.
The Jackass Penguin (*Spheniscus demersus*)	nest-building	-tearing up of considerable quantities of vegetation.	Gillham 1963.
Gentoo Penguin (*Pygoscelis papua*)	faeces trampling	-damage of vegetation.	Smith 1978.

Table 1. (cont'd)

Bird Species	Causative Agent	Impact	Source
King Penguin (*Aptenodytes patagonicus*)	faeces	-annihilation of plants.	Smith 1978.
White-capped Noddie (*Anous stolidus*)	faeces	-replacement of original vegetation cover to plant species more tolerant to faeces input.	Gillham 1977
Bronze Shag (*Phalacrocorax chalconotus*).	faeces trampling	-elimination of most indigenous plants, leaving bare ground behind.	Gillham 1960b
Stewart Island Shag (*Phalacrocorax stewarti*)	faeces nest-building	-burning of vegetation (absorption of faeces through the roots which weakens tissues, facilitating damage by perching birds). -use of twigs for nest-building contributing to the eventual demise of the tree.	Gillham 1960b Gillham 1977
Wandering Albatross (*Diomedea exulans*) Giant Petrel (*Macronectes giganteus*)	faeces	-increases in organic soil nitrogen and phosphorous resulting in healthier dark green vegetation around nesting areas	Smith 1978

Table 1. (cont'd)

Bird Species	Causative Agent	Impact	Source
Snow Goose (*Anser caerulescens*)	faeces	-significant increase in standing crop and a higher nitrogen level in shoots of forage species in a nitrogen- deficient salt marsh over a growing season. -significant increases in nitrogen isotopes.	Bazely and Jefferies 1985 Mizutani *et al.* 1986.
Double-crested Cormorant (*Phalacrocorax auritus*)	faeces	-burning of vegetation on lower branches and ground vegetation below nest sites due to high phosphoric acid content. -destruction of shelter for other bird species such as Eider Ducks (*Somateria mollissima*) and Black Ducks (*Anas rubripes*) -alteration of shrub community on nesting sites. -accumulation of faeces around nests.	Lewis 1929, Dusi 1977 Grondin *et al.* 1986 DesGranges *et al.* 1984. Gillham 1963.

Table 2. Distribution of vascular plants by habitat within the Mingan Island National Park Reserve.

Habitat	% of total surface area	# of plant taxa
boreal forest	56%	55
bogs & fens	16%	135
littoral	16%	95
maritime tundra	8%	71
lakes	4%	11
cliffs	35 km	50

(modified from Grondin et Melancon 1980)

Table 3. Origin and classification of lifespan for species of plants measured at the study sites on Ile Nue.

species	origin	lifespan	% cover	density
Betula pimula	native	bush	x	
Cornus canadensis	native	perennial	x	x
Deschampsia flexuosa	native	perennial	x	
Epilobium angustifolium	native	perennial	x	x
Ledum groenlandicum	native	bush	x	
Maïanthemum canadense	native	perennial	x	x
Poa pratensis	native	perennial	x	
Ribes hirtellum	native	bush	x	x
Rubus chamaemorus	native	perennial	x	x
Rubus idaeus	native	perennial	x	
Stellaria sp.	native	annual	x	
Trientalis borealis	native	perennial	x	x
Urtica dioica	native	perennial	x	x

Note: The plants marked with an x were measured for analysis. Percentage of bare soil was also used in the analysis.

Table 4. Egg hatching chronology for the experimental treatment plots on Ile Nue in the 1995 breeding season.

treatment	05/30/95	06/01/95	06/06/95	06/15/95	06/22/95	06/29/95	07/16/95
W1	3	3	3	3	3	3ch	0
W2	1	1	2	2	0	0	0
W3	1	1	1	1	1	1ch	0
	0	0	0	0	1	1	1ch
S1	3	3	2	2	2	2	1ch
	0	0	0	3	3	3	0
S2	1	2	3	3	3	3ch	1ch+1de
S3	1	2	0 pred	0	0	0	0
P1	1	1	3	3	3	2ch+1pip	0
	0	0	1	0	0	0	0
P2	2	2	2	2	2	2ch	0
	3	3	3	3	1+2pip	3ch	0
P3	3	3	3	3	3	3	0

Note: The numbers represent eggs found in the nest, ch=chicks found within 1 metre of the nest, pip=pipped eggs, de=dead chick.

Table 5. Univariate analysis of repeated measures for *Ledum groenlandicum* differences in % cover between exclosuress and treatment plots on Ile Nue in 1995.

					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	2	0.09847	11.82	0.0023	0.0115	0.0023
Time * Site	2	0.00760	0.91	0.4932	0.4695	0.4932
Error	10	0.00833				

Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 6. Mean square (MS), F-ratio (F) and probabililities *(P>F)* from the univariate analysis of % cover differences between exclosure and treatment pairs over time (n=9) on Île Nue in 1995.

species	MS	F	*P>F*
Ledum groenlandicum	0.098	11.82	0.002
Deschampsia flexuosa	0.109	1.39	0.293
Urtica dioica	0.003	0.73	0.505
Stellaria sp.	0.020	0.39	0.689
Epilobium angustifolium	0.091	0.19	0.826
bare soil	0.008	0.17	0.843

Table 7. Univariate analysis of repeated measures for *Epilobium angustifolium* differences in density between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P*>*F*	
Source	df	MS	*F*	*P*>*F*	G-G	H-F
Time	2	29.7698	1.95	0.1924	0.2121	0.1924^{ns}
Time * Site	2	27.0334	1.77	0.2109	0.2430	0.2109
Error	10	15.2512				

Note: Adj *P*>*F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 8. Mean square (MS), F-ratio (F) and probabililities *(P>F)* from the univariate analysis of density differences between exclosure and treatment pairs over time (n=9) on Ile Nue in 1995.

species	MS	F	*P>F*
Epilobium angustifolium	29.77	1.95	0.192
Cornus canadensis	9.98	0.63	0.552
Trientalis borealis	9.16	1.88	0.203
Urtica dioica	0.380	0.37	0.702

Table 9. The means ($\bar{x}$) and standard errors (SE) of the differences between exclosures and treatment plots in cover and density from May to August on Ile Nue , 1995.

Species		Cover				Density			
		May	June	July	Aug	May	June	July	Aug
Cornus	$\bar{x}$					-0.194	-0.054	0.533	2.378
	SE					0.315	0.312	2.049	1.342
Deschampsia	$\bar{x}$	0.155	0.140	0.060	0.289				
	SE	0.082	0.075	0.048	0.131				
Epilobium	$\bar{x}$	-0.037	-0.026	0.034	-0.010	-4.493	-3.442	-1.994	-1.649
	SE	0.033	0.056	0.069	0.130	1.358	2.330	2.214	1.836
Ledum	$\bar{x}$	0.137	0.151	0.177	0.296				
	SE	0.067	0.069	0.075	0.062				
Stellaria	$\bar{x}$	-0.011	-0.029	0.008	0.064				
	SE	0.118	0.133	0.106	0.162				
Trientalis	$\bar{x}$					-0.291	-2.380	1.603	0.357
	SE					0.819	1.297	1.015	0.292
Urtica	$\bar{x}$	-0.011	-0.013	0.008	-0.012	-0.049	-0.133	-0.096	0.269
	SE	0.019	0.027	0.042	0.025	0.458	0.957	1.078	0.512$\bar{x}$
bare soil	$\bar{x}$	0.032	-0.055	0.003	-0.030				
	SE	0.082	0.010	0.057	0.099				

Table 10. A *t*-test of the differences of two means for *Ledum groenlandicum* growth shoots in the exclosures versus the treatment plots on Ile Nue in 1995.

variable	df	t_s	$t_{.05(144)}$	P
shoot length	8	2.25	2.31	0.054

Note: t_s is the calculated value, $t_{.0.5(8)}$ is the critical value for t for a 90% confidence limit with degees of freedom (df) equal to 8. P is the significance level of the t_s calculated.

Table 11. Univariate analysis of repeated measures for pH differences between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P*>*F*	
Source	df	MS	*F*	*P*>*F*	G-G	H-F
Time	3	0.62380	4.46	0.0253	0.0931	0.0482*
Time * Site	6	0.08831	0.63	0.7035	0.5904	0.6572
Error	12	0.13990				

Note: Adj *P*>*F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

Table 12. Mean square(MS), F-ratio (F) and probabililities *(P>F)* from the univariate analysis of soil nutrient differences between exclosure and treatment pairs over time (n=9) on Ile Nue in 1995

soil nutrient	MS	F	*P>F*
pH	0.624	4.46	0.048
phosphorous	7.158	5.37	0.027
calcium	16.528	1.02	0.417
nitrogen	98.614	2.12	0.168
potassium	1.002	2.11	0.201
magnesium	0.283	1.34	0.306

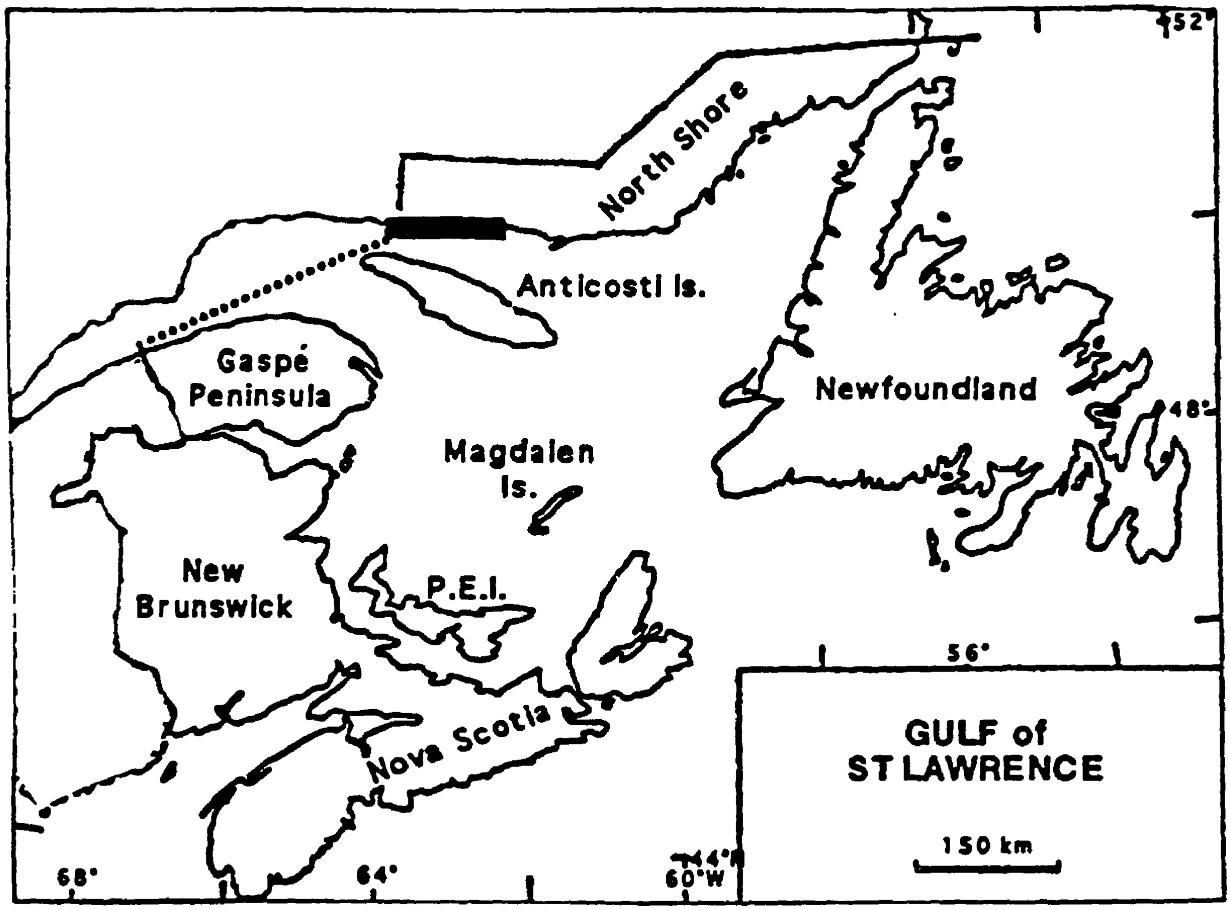
Table 13. Percentage increases/decreases in soil nutrients in exclosures and treatment plots from May to August, 1995, on Ile Nue.

soil nutrient	exclosure	treatment
pH	↓ 1.4%	↑ 6.7%
nitrogen	↑ 216.8%	↑ 119.9%
phosphorous	↑ 8.3%	↑ 114.5%
potassium	↑ 1486.0%	↑ 1919.6%
calcium	↑ 62.9%	↑ 63.7%
magnesium	↑ 11.48%	↑ 8.7%

Table 14. The means ($\bar{x}$) and standard errors (SE) for differences in pH and soil nutrients between exclosures and treatment plots from May to August on Ile Nue, 1995.

soil nutrient		May	June	July	Aug
pH	$\bar{x}$	-0.133	0.225	-0.067	-0.550
	SE	0.102	0.062	0.130	0.262
nitrogen	$\bar{x}$	-4.756	2.700	-1.275	-3.550
	SE	3.843	3.784	1.070	1.398
phosphorou	$\bar{x}$	-0.310	0.253	-0.463	-1.653
s	SE	0.291	0.112	0.443	0.736
potassium	$\bar{x}$	-0.036	0.031	-0.028	-0.801
	SE	0.026	0.054	0.284	0.412
calcium	$\bar{x}$	-3.465	-0.145	-1.929	-4.358
	SE	1.120	1.357	1.901	1.331
magnesium	$\bar{x}$	0.133	0.534	0.169	0.155
	SE	0.115	0.237	0.301	0.264

Figure 1. Location of the Mingan Island National Park Reserve. Designated by the black bar (from Belland *et al.* 1992)



North Shore
Anticosti Is.
Gaspé
Peninsula
Magdalen
Is.
Newfoundland
New
Brunswick
P.E.I.
Nova Scotia
GULF of
ST LAWRENCE
150 km
52°
48°
44°N
56°
68°
64°
60°W

Figure 2. Location of Ile Nue within the Mingan Islands.

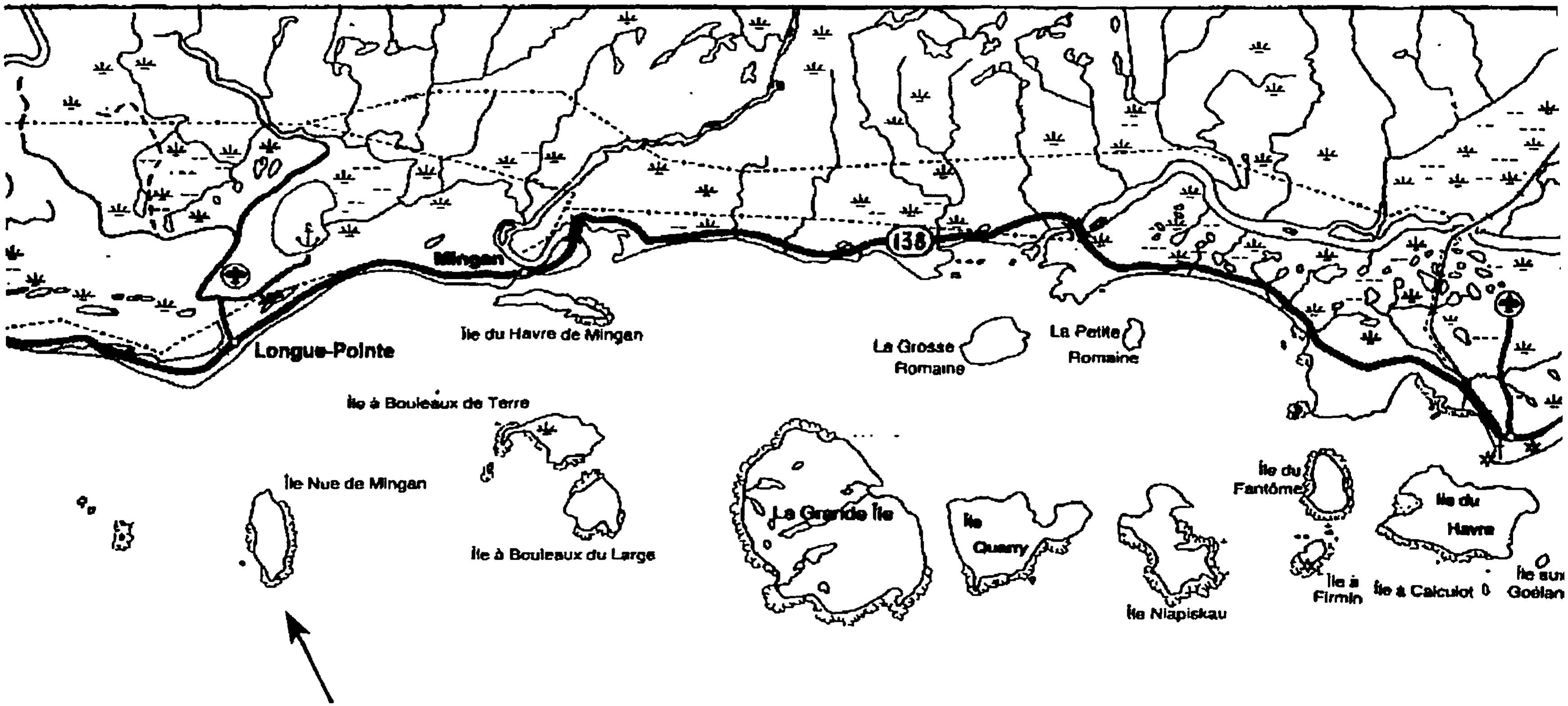

Longue-Pointe
Mingan
138
Île du Havre de Mingan
La Grosse Romaine
La Petite Romaine
Île à Bouleaux de Terre
Île Nue de Mingan
Île à Bouleaux du Large
La Grande Île
Île Quarry
Île Niapiskau
Île du Fantôme
Île du Havre
Île à Firmin
Île à Calculot

Figure 3. Location of study sites and exclosure/treatment pairs on Ile Nue, Mingan Island National Park Reserve

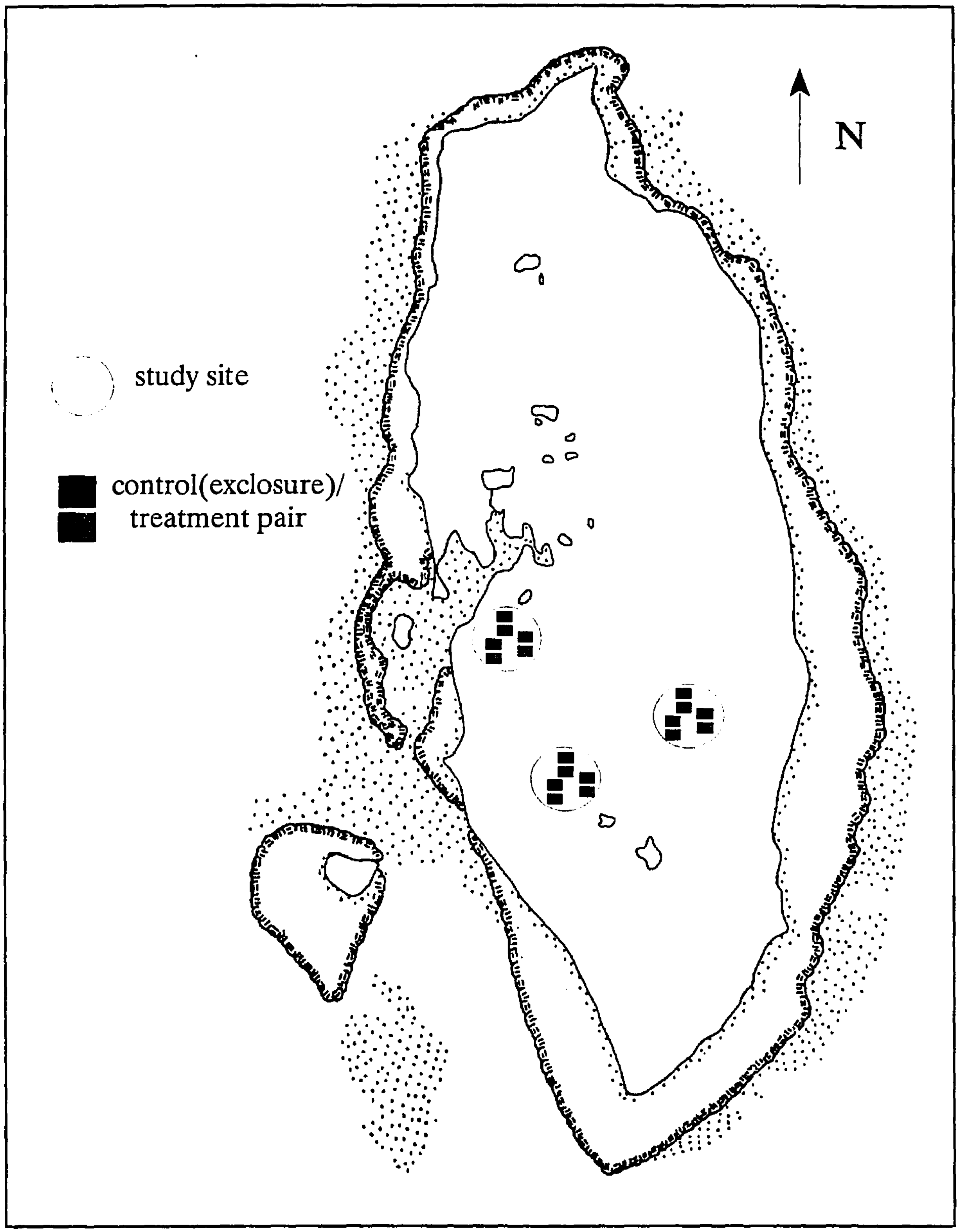
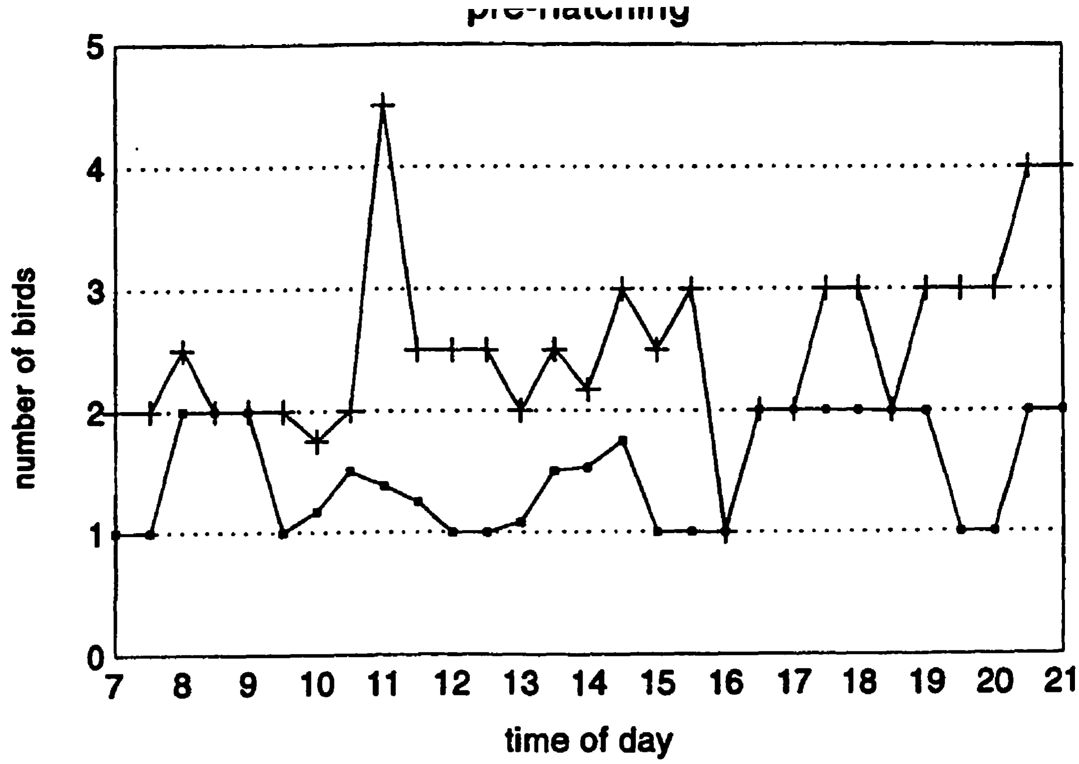

N
study site
control(exclosure)/
treatment pair

Figure 4. Average number of gulls present on the treatment plots during the pre and post-hatching periods on Ile Nue, 1995.


pre-hatching
number of birds
0
1
2
3
4
5
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
time of day

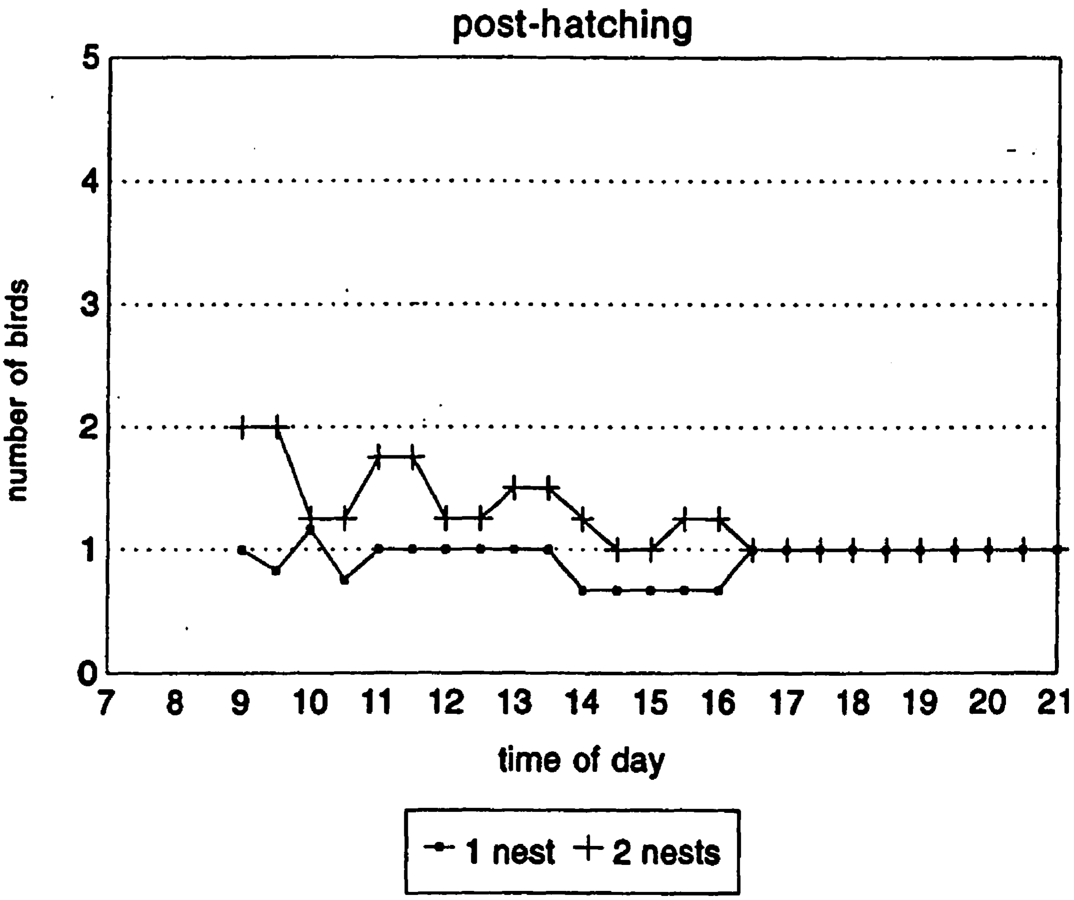
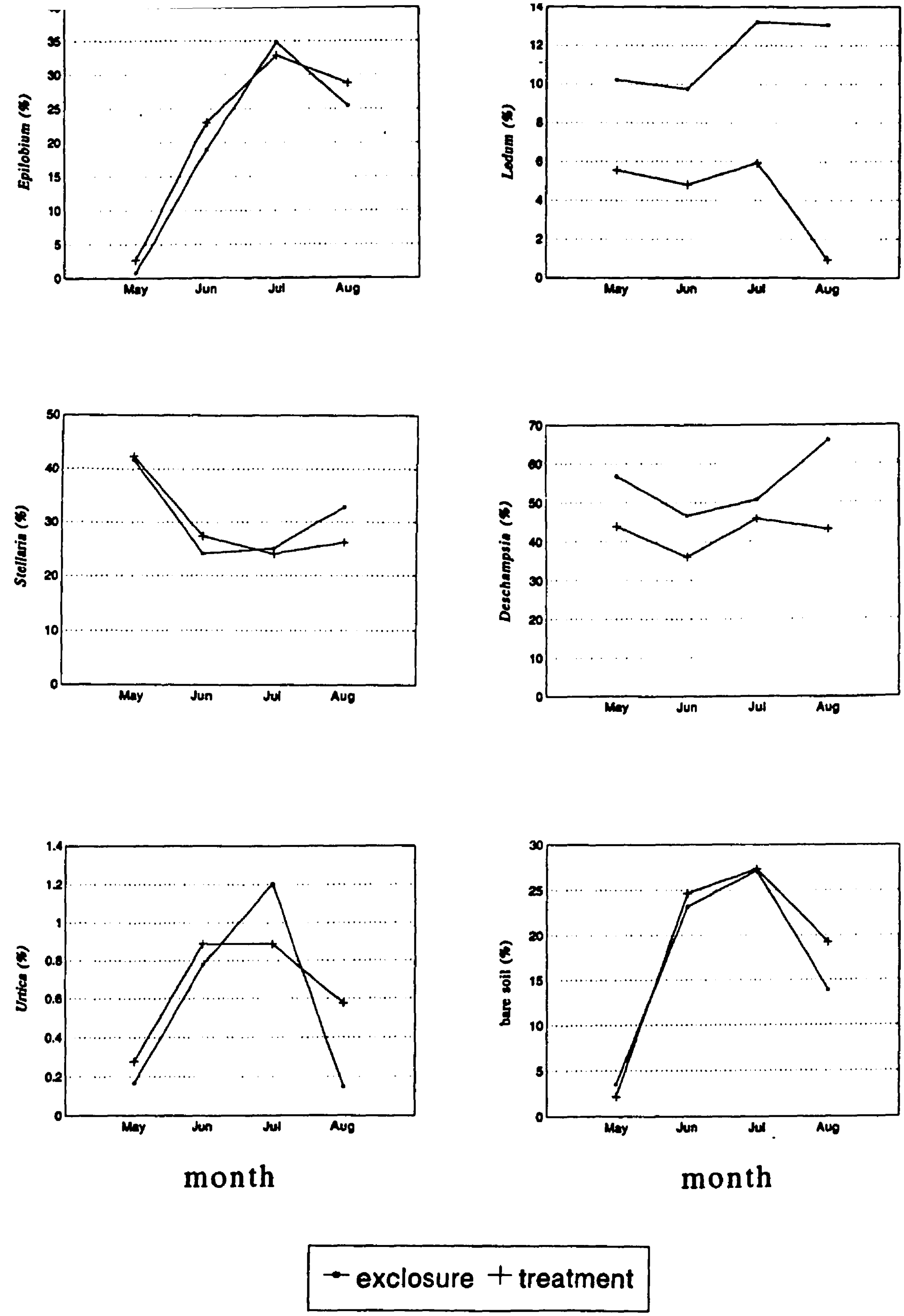

post-hatching
number of birds
0
1
2
3
4
5
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
time of day
1 nest
2 nests

Figure 5. Percentage cover of plant species measured in exclosures and treatment plots during the 1995 breeding season on Ile Nue.



Epilobium (%)
Ledum (%)
Stellaria (%)
Deschampsia (%)
Urtica (%)
bare soil (%)
May
Jun
Jul
Aug
month
month
exclosure
treatment

Figure 6. Density of plant species measured in exclosures and treatment plots during the 1995 breeding season on Ile Nue.

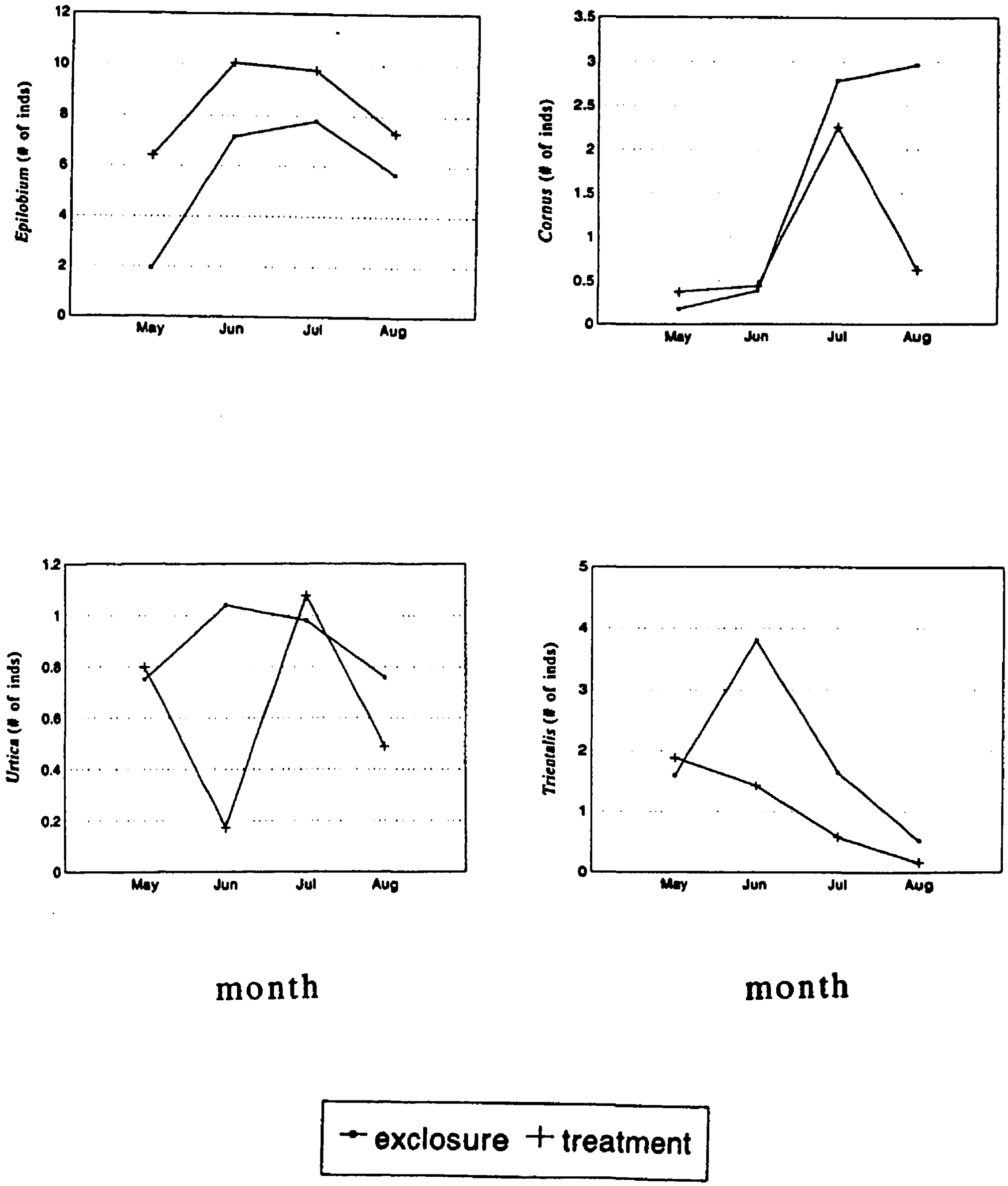
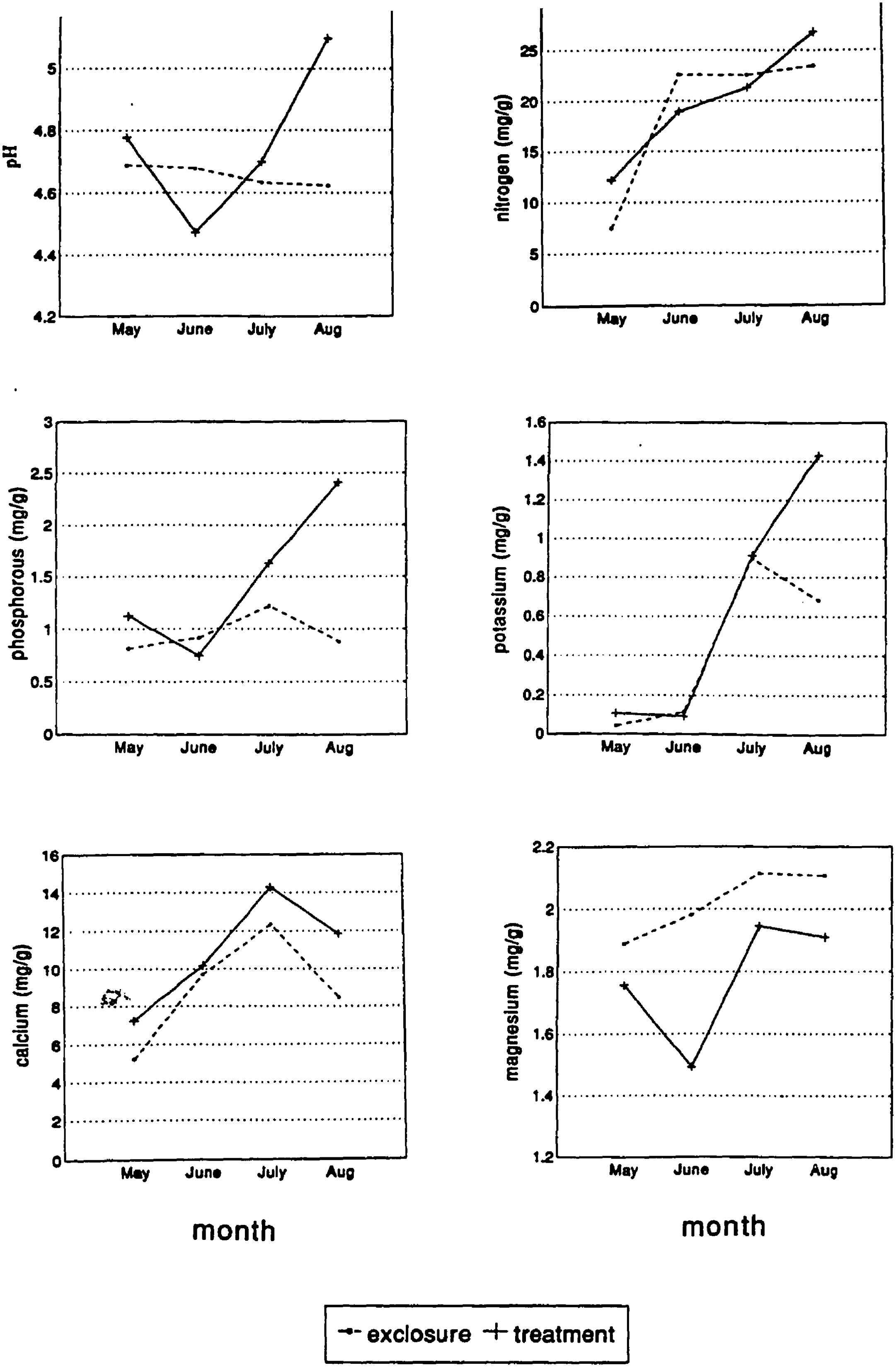
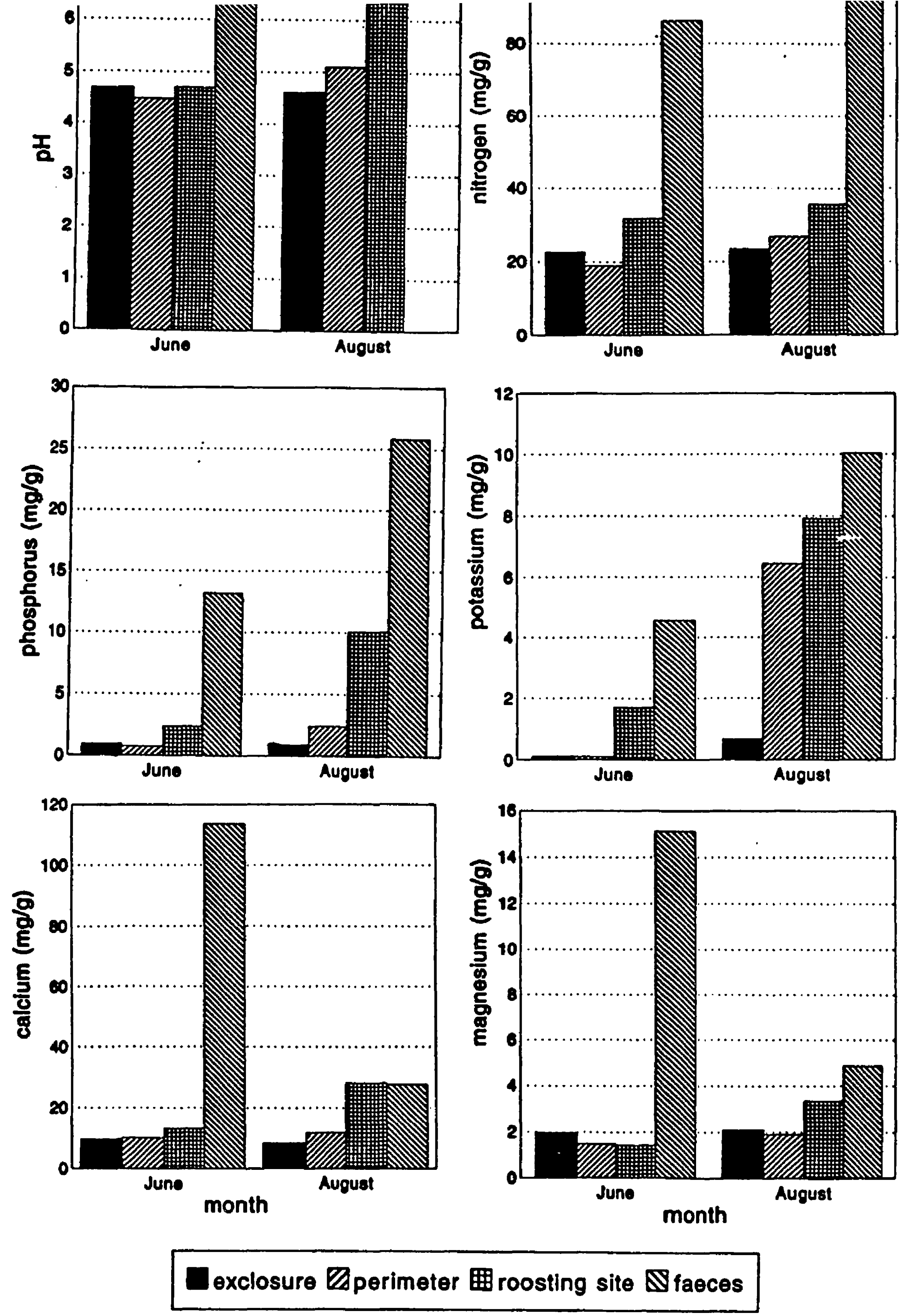

Epilobium (# of inds)
12
10
8
6
4
2
0
May
Jun
Jul
Aug
Cornus (# of inds)
3.5
3
2.5
2
1.5
1
0.5
0
May
Jun
Jul
Aug
Urtica (# of inds)
1.2
1
0.8
0.6
0.4
0.2
0
May
Jun
Jul
Aug
Trientalis (# of inds)
5
4
3
2
1
0
May
Jun
Jul
Aug
month
month
exclosure
treatment

Figure 7. Levels of nutrients in exclosures and treatment plots during the 1995 breeding season on Ile Nue.



pH
4.2
4.4
4.6
4.8
5
nitrogen (mg/g)
0
5
10
15
20
25
phosphorous (mg/g)
0
0.5
1
1.5
2
2.5
3
potassium (mg/g)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
calcium (mg/g)
0
2
4
6
8
10
12
14
16
magnesium (mg/g)
1.2
1.4
1.6
1.8
2
2.2
May
June
July
Aug
month
exclosure
treatment

Figure 8. Levels of nutrients detected in soils and faeces at exclosures, treatment plots and roosting sites on Ile Nue.


pH
nitrogen (mg/g)
phosphorus (mg/g)
potassium (mg/g)
calcium (mg/g)
magnesium (mg/g)
June
August
month
exclosure
perimeter
roosting site
faeces

APPENDIX I:

STATISTICAL TABLES

Table 1.1. Univariate analysis of repeated measures for *Deschampsia flexuosa* differences in % cover between exclosures and treatment plots on Ile Nue in 1995.

					Adj $P>F$	
Source	df	MS	F	$P>F$	G-G	H-F
Time	2	0.10922	1.39	0.2924	0.2917	0.2930
Time * Site	2	0.00622	0.08	0.9869	0.9324	0.9847
Error	10	0.78358				

Note: Adj $P>F$ are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted F-tests. MS, mean square.

Table 1.2. Univariate analysis of repeated measures for *Urtica dioica* differences in % cover between exclosures and treatment plots on Ile Nue in 1995.

					Adj $P>F$	
Source	df	MS	F	$P>F$	G-G	H-F
Time	2	0.00277	0.73	0.5049	0.4839	0.5049
Time * Site	2	0.00116	0.37	0.8231	0.7906	0.8231
Error	10	0.00310				

Note: Adj $P>F$ are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted F-tests. MS, mean square.

Table 1.3. Univariate analysis of repeated measures for *Stellaria sp.* differences in % cover between exclosures and treatment plots on Ile Nue in 1995.

					Adj $P>F$	
Source	df	MS	F	$P>F$	G-G	H-F
Time	2	0.01982	0.39	0.6585	0.5868	0.6885
Time * Site	2	0.03608	0.60	0.6722	0.6021	0.6722
Error	10	0.05115				

Note: Adj $P>F$ are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted F-tests. MS, mean square.

Table 1.4. Univariate analysis of repeated measures for *Epilobium angustifolium* differences in % cover between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	2	0.09127	0.19	0.8263	0.7303	0.8263
Time * Site	2	0.01629	0.35	0.8401	0.7635	0.8401
Error	10	0.04693				

Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 1.5. Univariate analysis of repeated measures for bare soil differences in % cover between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P*>*F*	
Source	df	MS	*F*	*P*>*F*	G-G	H-F
Time	2	0.00845	0.17	0.8433	0.7146	0.8433
Time * Site	2	0.08904	1.83	0.2003	0.2481	0.2003
Error	10	0.04874				

Note: Adj *P*>*F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 1.6. Univariate analysis of repeated measures for *Cornus canadensis* differences in density between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	2	9.98030	0.63	0.5515	0.4885	0.5515
Time * Site	2	4.57914	0.29	0.8779	0.7968	0.8779
Error	10	15.7934				

Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 1.7. Univariate analysis of repeated measures for *Trientalis borealis* differences in density between exclosures and treatment plots on Ile Nue in 1995.

Source	df	MS	*F*	*P*>*F*	Adj *P*>*F*	
					G-G	H-F
Time	2	9.16329	1.88	0.2025	0.2158	0.2025
Time * Site	2	3.31411	0.68	0.6210	0.5909	0.6210
Error	10	4.86925				

Note: Adj *P*>*F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted *F*-tests. MS, mean square.

Table 1.8. Univariate analysis of repeated measures for *Urtica dioica* differences in density between exclosures and treatment plots on Ile Nue in 1995.

					Adj $P>F$	
Source	df	MS	F	$P>F$	G-G	H-F
Time	2	0.37997	0.37	0.7023	0.6238	0.7023
Time * Site	2	0.86529	0.83	0.5336	0.5056	0.5336
Error	10	1.03754				

Note: Adj $P>F$ are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) (1970) adjusted F-tests. MS, mean square.

Table 1.9. Univariate analysis of repeated measures for Phosphorous differences between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	3	7.15834	5.37	0.0141	0.0685	0.0269
Time * Site	6	1.43566	1.08	0.4277	0.4247	0.4284
Error	12	1.33274				

Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser(G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

Table 1.10. Univariate analysis of repeated measures for Calcium differences between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	3	16.5286	1.02	0.4166	0.3999	0.4166
Time * Site	6	8.69153	0.55	0.7579	0.6950	0.7579
Error	12	16.1488				

Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

Table 1.11. Univariate analysis of repeated measures for Nitrogen differences between exclosures and treatment plots on Ile Nue in 1995.

					Adj *P*>*F*	
Source	df	MS	*F*	*P*>*F*	G-G	H-F
Time	3	98.6142	2.12	0.1684	0.2222	0.1684
Time * Site	6	74.9303	1.61	0.2505	0.3107	0.2505
Error	12	46.6164				

Note: Adj *P*>*F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

Table 1.12. Univariate analysis of repeated measures for Potassium differences between exclosures and treatment plots on Ile Nue in 1995.

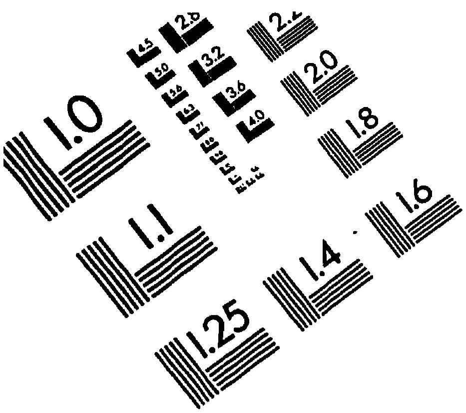
					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	3	1.00226	2.11	0.2008	0.2631	0.2008
Time * Site	6	0.64250	1.21	0.4118	0.4418	0.4118
Error	6	0.47582				

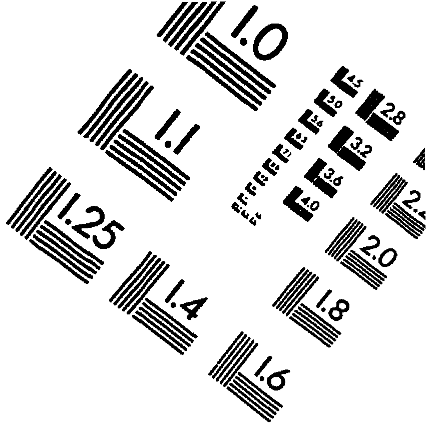
Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

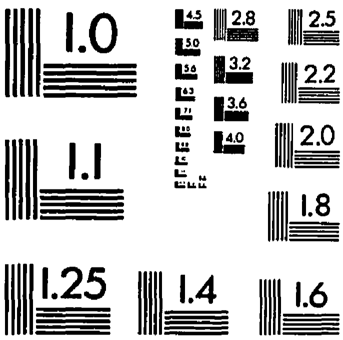
Table 1.13. Univariate analysis of repeated measures for Magnesium differences between exclosures and treatment plots on Ile Nue in 1995.

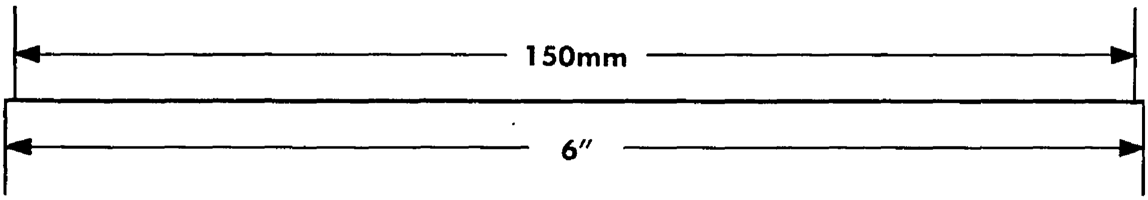
					Adj *P>F*	
Source	df	MS	*F*	*P>F*	G-G	H-F
Time	3	0.28282	1.35	0.3059	0.3114	0.3059
Time * Site	6	0.25927	1.23	0.3552	0.3732	0.3552
Error	12	0.21058				

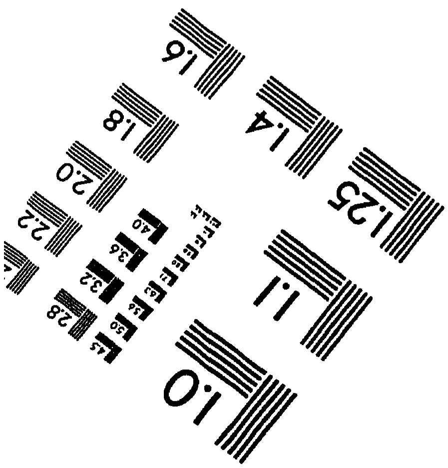
Note: Adj *P>F* are probabilities associated with the Greenhouse Geisser (G-G)(1959) and Huynh-Feldt (H-F) adjusted *F*-tests. MS, mean square.

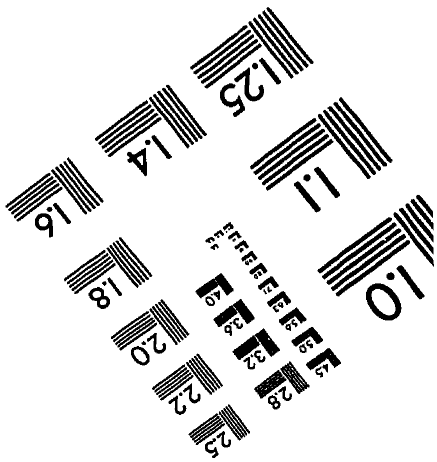












APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989