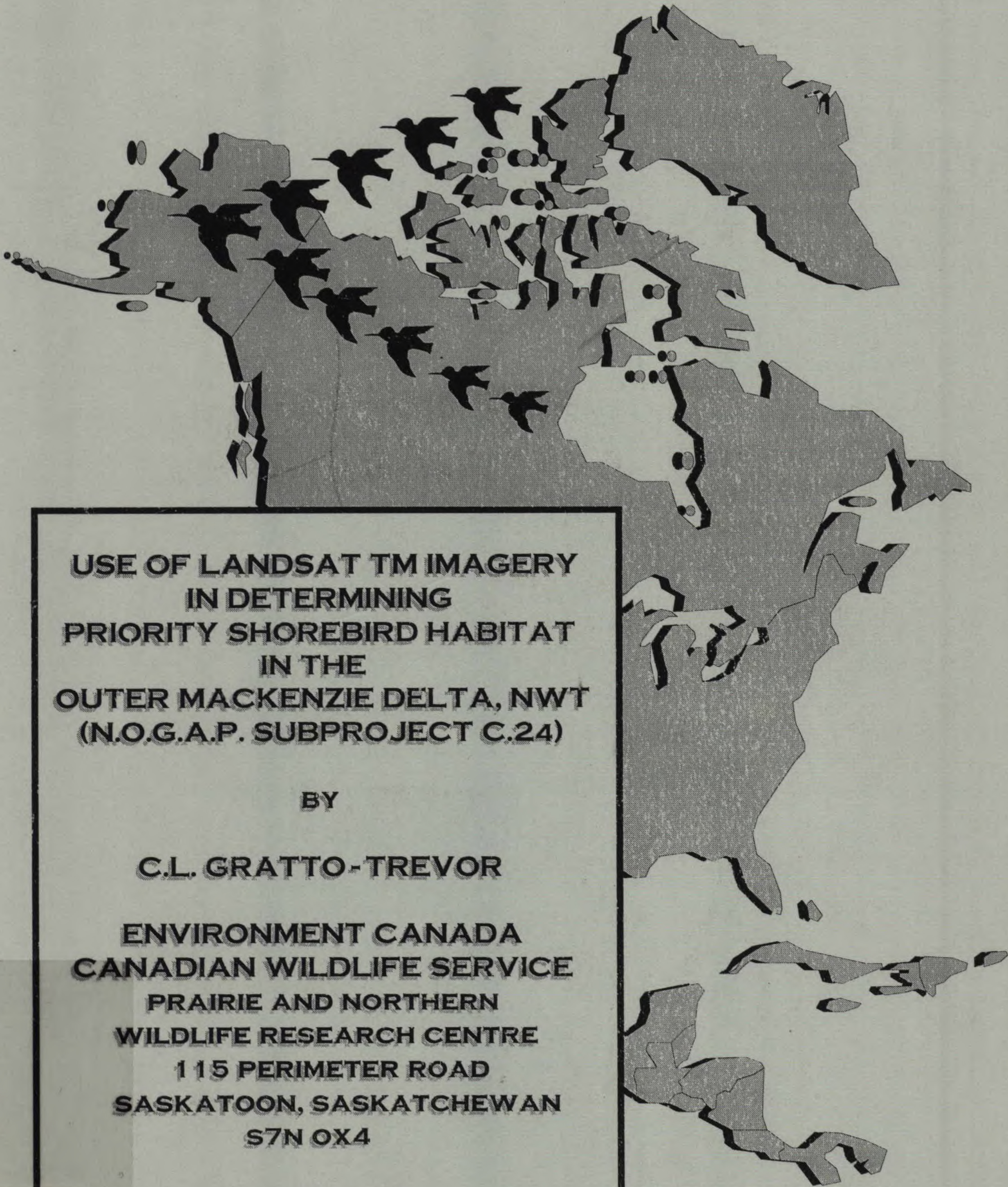

USE OF LANDSAT TM IMAGERY IN DETERMINING PRIORITY SHOREBIRD HABITAT IN THE OUTER MACKENZIE DELTA, NWT (N.O.G.A.P. SUBPROJECT C.24)

BY

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115 PERIMETER ROAD
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S7N 0X4

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ABSTRACT

Since the breeding range of most North American shorebirds (sandpipers, plovers, godwits, snipe, etc.) is restricted to arctic Canada and Alaska, any major impact on habitat there could have severe effects on population levels of entire species. The outer Mackenzie Delta, NWT is the area in Canada first in line for future major oil and gas development. Therefore, this project concentrated on determining important areas for shorebirds in the Mackenzie Delta, for use in mitigating effects of any future development in this area. In addition, I tested the effectiveness of using satellite imagery in identifying priority habitat and numbers of shorebirds, in the hope that this technique could be used elsewhere in the arctic for this purpose.

A previous study (Dickson et al. 1989) determined that analysis of Channel 3, 4, and 5 bands of LANDSAT TM imagery could accurately identify priority shorebird habitat in their small study area in the outer Mackenzie Delta. I tested their technique by extending the research area to include virtually all of the outer delta. In 1991 and 1992, ground plots in different habitats were censused for breeding shorebirds, and aerial surveys were carried out to determine habitat use, flock size, and distribution of fall migrants. Seasonal changes in invertebrate prey of shorebirds, and differences in invertebrate densities among habitats, were examined in 1993.

Most species of shorebirds are present in the area from late May until late August. Nests are initiated in early to late June, and hatch of shorebird young peaks in early to mid July. Egg laying can be delayed due to inclement weather in the spring that results in a decreased availability of invertebrate prey. Invertebrate numbers were highest in the wettest habitat. In the year studied, water levels dropped dramatically by late June, and most areas were dry by mid July. Therefore, aquatic invertebrates were apparently most available to shorebirds in late June, after which insect hatch resulted in an abundance of adult terrestrial invertebrates.

No large concentrations of shorebirds (>500 birds) were found staging in the outer delta during fall migration. Small shorebird species tended to flock in mudflat areas, while larger birds usually remained inland. Rafts of phalaropes, very aquatic shorebirds, may have been missed in these surveys as they likely stage farther from shore.

The most common species of shorebirds breeding in the area were Red-necked Phalaropes (*Phalaropus lobatus*) and Common Snipe (*Capella gallinago*), followed by Semipalmated Sandpipers (*Calidris pusilla*) and Stilt Sandpipers (*Calidris himantopus*), then Pectoral Sandpipers (*Calidris melanotos*), Whimbrel (*Numenius phaeopus*), Hudsonian Godwits (*Limosa haemastica*), Lesser Golden Plovers (*Pluvialis dominica*), and Semipalmated Plovers (*Charadrius semipalmatus*). Long-billed Dowitchers (*Limnodromus scolopaceus*) were rarely seen. Most species of breeding shorebirds were concentrated in areas of low-centre polygons, sedge, and "low" upland tundra (damp and tussocky). Snipe were an exception, being most commonly observed in willow habitat. Semipalmated Plovers were only found breeding on sparsely vegetated gravel pads. Recommendations are made for methods of conducting censuses of breeding shorebirds in the arctic. Total number of shorebirds nesting in the outer delta was estimated at 60,513 pairs.

Although the LANDSAT TM imagery analysis used here correctly identified habitat types near the original, intensively ground-truthed area, it often misidentified habitats at some sites 10 to 30 km away. This was thought to be due primarily to irregular flooding and subtle year to year differences in water levels in the active outer delta, and edge habitats not distinguished by the satellite imagery. However, this technique can be used to roughly identify potential shorebird habitat, and at least eliminate obviously unsuitable areas in large regions of the arctic.

My recommendations for mitigating potential effects of oil and gas development on shorebird populations in the outer Mackenzie Delta include avoiding disturbance of priority shorebird habitat (low-centre polygons, "pure" sedge, and "low" upland tundra), and wetland habitat in general, especially from mid May to early August.

ACKNOWLEDGEMENTS

I would like to acknowledge the enormous assistance of Richard Cotter, Mark Kornder, Stephen Pepper, and Paul Sawatsky, for data collection and analysis. Judith Kennedy also assisted in some of the field work. Denis Jaques (Ecosat Geobotanical Surveys Inc.) produced the LANDSAT TM Imagery maps and a report, much of which is included in Chapter 2. A number of the figures were produced by John Trevor, K. A. Gratto, and Richard Cotter. Aid in preparation of the manuscript was gratefully received from L. Tomkewich, and in checking the manuscript from C. Olson.

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Logistical support was provided by a number of people and organizations. The Inuvik Research Centre (Govt. N.W.T.) provided considerable help, including accommodation while in Inuvik, loan of equipment, and transportation to and from Inuvik Airport. The Polar Continental Shelf Project in Tuktoyaktuk (Dept. Energy, Mines and Resources) supplied some equipment, provided daily radio contact while in the field, accommodation for the aerial surveyor, allowed me to buy helicopter time as needed, and even sent us baked goods at times in the field! I also appreciated the advice and support of a number of people in the Canadian Wildlife Service (C.W.S. Prairie and Northern Region), particularly H.L. Dickson and A.L. Smith who had worked in the Fish Island area previously, my supervisor, Dr. A.W. Diamond, and also K. McCormick who was in charge of the N.O.G.A.P. program for the Canadian Wildlife Service, and also helped in obtaining permits. I also appreciated the normally prompt receipt of all permits necessary for Arctic work, from all organizations involved, but particularly from R. Forsyth, C.W.S. Yellowknife.

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1. Background

The breeding range of most North American shorebirds (Order Charadriiformes, suborder Charadrii) is restricted to arctic Canada and Alaska. Any major impact on habitat in these areas could have severe effects on population levels of entire species. In addition, shorebirds are an important component of arctic ecosystems: in some areas they compose a major portion of the vertebrate biomass in tundra communities during the summer (Norton 1973).

The Mackenzie Delta - Beaufort Sea Land Use Planning Commission has identified present and planned petroleum-related activity in that region (Land-use Requirements For Anticipated Hydrocarbon Development in the Mackenzie Delta - Beaufort Sea Land Use Planning Region 1989). Much of the proposed development is centred around Richards Island. In the first phase of gas development, three processing plants are planned: Niglintgak and Taglu on Richards Island, and Parson's Lake on the mainland. These three plants would be connected by pipelines, and a separate pipeline for hydrocarbon liquids is likely. In the second phase, offshore pipelines would be linked to Taglu, crossing lowland areas. At Taglu, a permanent on-site staff of 30 to 50 persons is expected for a period of 20 years or more. It is therefore important to determine population densities and distributions, and habitat requirements of wildlife in the area, to ensure knowledgeable decisions relating to protection of the migratory bird species and sustainable developments in the area.

Very little information is available on nesting and staging habitat requirements, and population densities, of shorebirds in the Canadian Arctic. However, previous NOGAP subproject C-7-3 (1985-1987) involved an intensive study of shorebird habitat and phenology in a small study area on Fish Island, in the outer Mackenzie Delta, NWT (Dickson et al. 1989). Information on shorebird nesting densities was related to habitat types as identified by digital LANDSAT imagery analyses. Several habitat types were found to be important for nesting and staging shorebirds. Subsequently, these important habitat types were identified in the outer delta and Richards Island by visual inspection of LANDSAT imagery. The current project refines, expands, and tests the results of the previous study. In addition to providing information useful for consideration in land use planning and mitigation of potential development impacts, this project will provide a preliminary database for subsequent studies involving effects of climate change and monitoring the health of arctic shorebird populations. As well, the project tests whether shorebird densities and distributions can be determined throughout the arctic, by examining the effectiveness of LANDSAT TM imagery in identifying important shorebird habitat. This information will also provide information on shorebird distribution and densities for use in adjusting boundaries of the Kendall Island Bird Sanctuary (NOGAP subproject 7.1).

1.2. General Objectives and Report Outline

Major objectives are as follows:

1. Verify the existence of Dickson et al.'s (1989) priority shorebird breeding habitat type by use of ground survey plots throughout the outer delta.

2. Examine the accuracy of the LANDSAT TM analysis technique in identifying habitat types throughout the outer delta, via ground plots.

3. Estimate total breeding populations of shorebirds in the outer delta, and identify important areas for breeding birds, using LANDSAT TM analysis.

4. Determine size and distribution of flocks of fall staging shorebirds via aerial surveys.

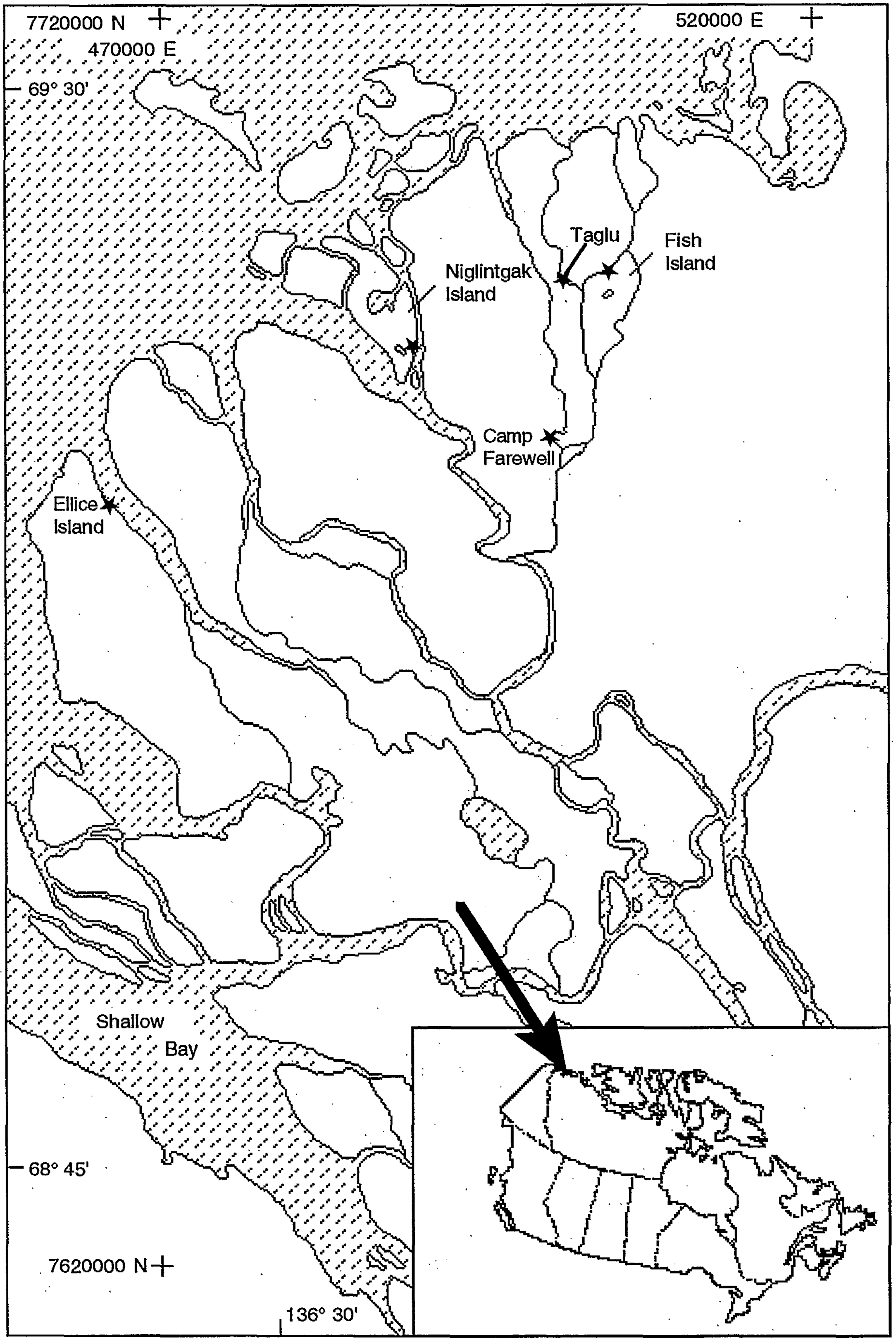
5. Examine invertebrate prey densities throughout the breeding season in areas of good and poor shorebird breeding habitat.

Chapter 1 (Introduction) describes the purpose of the study, the study area and the study species. In Chapter 2 (LANDSAT Imagery Analysis), methodology of the LANDSAT analysis is discussed. This analysis is used to examine habitat preferences of shorebirds in Chapter 3 (Aerial Surveys: Fall Staging Shorebirds) and Chapter 4 (Ground Plots: Breeding Shorebirds). Chapter 3 also describes fall flock sizes and distributions. Accuracy of the LANDSAT analysis in assigning habitat types is explored in Chapter 4, as well as accuracy of ground surveys methods, existence of "priority shorebird habitat", and densities of shorebirds in different habitats. Total number of shorebirds breeding in the outer delta is estimated. Differences in invertebrate numbers among habitat types and during the season are discussed in Chapter 5 (Invertebrate Sampling). The remaining chapters are very short. Nest hatch dates and measurements of breeding adults are described in Chapter 6 (Shorebird Measurements and Nests), and differences between years in summer weather conditions in Chapter 7 (Weather). Chapter 8 (General Conclusions) briefly discusses the primary findings of this study, and makes suggestions for future management of outer delta shorebird populations.

1.3. Study Area

The study area encompassed approximately 765,000 ha in the outer Mackenzie Delta, NWT, above the treeline (Fig. 1.1). The Mackenzie Delta is a subdivision of the Arctic Coastal Plain, and consists of alluvium sediments and Pleistocene glacial drift underlain by Cretaceous and Cenozoic rocks (Bostock 1976). Winters are long and cold, and precipitation low. Mean annual precipitation along the coast is 13 cm, and average monthly temperatures peak in July: 10° C in Tuktoyaktuk. Mean annual temperature in Inuvik is -6° C and in Tuktoyaktuk, -11° C (Burns 1973).

Figure 1.1. Study area in the outer Mackenzie Delta, NWT. *Camp sites in 1991 to 1993 are marked by small stars.*


7720000 N
470000 E
520000 E
69° 30'
Taglu
Fish
Island
Niglintgak
Island
Camp
Farewell
Ellice
Island
Shallow
Bay
68° 45'
7620000 N
136° 30'

Channel freeze up begins in late September, and peak discharge into the delta follows breakup in late May or early June. Occasionally discharge is very high after heavy precipitation in late summer (Hirst et al. 1987). Temperature regimes and the amount of ice cover on delta channels determines the extent of spring flooding. Thermal breakups, in warm springs, occur in four of five years. Flooding of the delta is minimal. Mechanical breakups, about one year of five, occur in cool springs. Up to 90 percent of the outer delta may be flooded (Bigras 1990). High or low centred polygons are common in areas that are poorly drained, with fine-grained materials, in continuous or discontinuous permafrost (Ritchie 1984). Formation of polygons requires ice-rich, frozen terrain and a mean annual temperature of -6° C or cooler (Mackay 1972).

Flooding frequency, duration, rate of sediment deposition and erosion rates are important in determining vegetation type present. *Equisetum*, *Carex* and *Salix* exist in areas where these conditions are most severe, with poplars and spruce in more favourable sites. Herbaceous dominated areas are flooded annually, willow/alder vegetated areas about two to five years out of ten, and areas with spruce and alder one to two years out of ten (Hirst et al. 1987). Substrate factors such as soil texture, moisture, and drainage are also important in determining vegetation type present. Sedge, *Arctophila*, and *Equisetum* can survive inundation of more than 50 days per year, and willow dominated areas up to a month. Spruce and poplar are usually only flooded for two or three days per year. Silt deposition can be heavy in low areas (*Equisetum* areas averaged 9.2 cm per year), but is much lighter at higher elevations (Hirst et al. 1987). The Beaufort Sea coastline is submerging at the rate of one to two metres per year, with some areas up to 10-20 m/yr. Storm surges that result from strong onshore winds are most common in late summer, and can affect water levels as far south as Inuvik (Bigras 1990). Plant communities in the delta area have been described in detail by Corns (1974), Dickson et al. (1989) and Jaques (1991).

1.4. Study species

Shorebirds (Order Charadriiformes, suborder Charadrii) are a diverse group of birds, including sandpipers, plovers, phalaropes, snipe, godwits and curlews. All species of shorebirds are protected by international agreements between Canada, the United States, and other countries. Only the Common Snipe (*Capella gallinago)*, of all shorebirds breeding in the outer Mackenzie Delta, can be legally hunted in Canada or the United States. Shorebirds are most often seen in southern Canada during migration. Some species gather in immense flocks at staging areas, often in coastal habitats. There they feed primarily on benthic invertebrates in intertidal zones. Most shorebirds breeding in arctic Canada winter in the southern United States, Central America, or South America.

In May, the birds migrate north to breed. Most North American shorebirds, particularly the sandpipers, breed in arctic Canada and Alaska. The birds arrive in the Mackenzie Delta about the time the river ice breaks in the spring, and start egg laying by mid June. Females use energy reserves left over from migration, but must also acquire additional resources after arrival from the south, in order to produce eggs. Together the four eggs of the clutch weigh almost as much as the female, and contain more than twice her body calcium.

Shorebirds do not appear to store calcium as do some other birds such as geese, but must obtain it from their own bodies, their invertebrate prey, and in at least some areas, by eating the bones of small mammals found on the tundra (MacLean 1974). In years when the weather stays cold into mid-June, the birds find it difficult to find enough insects and other invertebrate prey to produce eggs. Particularly in the high arctic, the birds may not be able to produce eggs in some years. Even in areas farther south than the outer Mackenzie Delta, a large proportion of females may not breed in severe years (Gratto-Trevor 1991).

Nest failure is usually due to predators of shorebirds and their eggs. Foxes, weasels, hawks, owls, and jaegers are common predators of shorebird eggs, young, and sometimes adults (Norton 1973, Gratto-Trevor 1994). Nests are occasionally deserted by the incubating parent(s), most commonly on late nests not due to hatch until near the end of July, but also in biparental incubating species when one parent is killed (Gratto-Trevor 1991). After about three weeks of incubation, shorebird eggs hatch. Hatch of shorebirds in an area is fairly synchronous: timed for peak insect emergence, particularly of diptera such as midges and mosquitoes (Holmes and Pitelka 1968). Young shorebirds are extremely precocial, able to walk and feed themselves from hatch. They need only be brooded and guarded for several weeks by their parent(s). Young fledge in two to three weeks, by which time most adults have migrated south. Juveniles follow several weeks after the adults, in late July and August (MacNeil and Cadieux 1972, Askenazie and Safriel 1979, Morrison 1984).

Large numbers of shorebirds breed in the outer Mackenzie Delta above the treeline. Some of the most common species are as follows. Letter codes of these species used in this report are listed in Table 1.1. Much of the information on species below is from Cramp and Simmons (1983). Estimates of Canadian populations are from Morrison et al. (1994).

Red-necked Phalaropes (*Phalaropus lobatus*), are the most common shorebirds breeding in the area. These small aquatic birds have a polyandrous mating system, where females desert their mates after laying a clutch of eggs, and attempt to obtain new mates. Males carry out all incubation and brood care. This species breeds throughout most of the subarctic regions of the palaearctic and nearctic, and nearctic populations winter off the coast of South America. Many migrate through prairie Canada. Females are slightly larger than males, and are brighter in plumage. There are estimated to be over two million Red-necked Phalaropes breeding in Canada.

Common Snipe (*Capella gallinago*) are also abundant. This species is polygynous, with only female incubation and brood care. Sexes are similar in plumage. This species breeds throughout much of the world. North American breeders winter from the central United States to northern South America. Males are particularly obvious when "winnowing" during flight displays.

Semipalmated Sandpipers (*Calidris pusilla*) are small, common, monogamous shorebirds, with both parents sharing equally in incubation. Males provide most brood care, while females migrate slightly earlier than their mates. Semipalmated Sandpipers breed throughout subarctic Alaska and Canada, with most wintering along the northern coast of South America. Migration routes vary with different populations: western breeders appear to migrate north

Table 1.1. Breeding shorebirds observed in this study and their letter codes.

Species	Scientific name	Letter code
Common Snipe	*Capella gallinago*	COSN
Hudsonian Godwit	*Limosa haemastica*	HUGO
Lesser Golden Plover	*Pluvialis dominica*	LEGP
Long-billed Dowitcher	*Limnodromus scolopaceus*	LBDO
Pectoral Sandpiper	*Calidris melanotos*	PESA
Red-necked Phalarope	*Phalaropus lobatus*	RNPH
Semipalmated Sandpiper	*Calidris pusilla*	SESA
Semipalmated Plover	*Charadrius semipalmatus*	SEPL
Stilt Sandpiper	*Calidris himantopus*	STSA
Whimbrel	*Numenius phaeopus*	WHIM

and south through the interior of North America, central breeders north through the prairies and south along the east coast of Canada and the United States, and eastern breeders north through eastern United States, south primarily from the eastern coast of Canada. Western breeders are smaller than eastern birds, particularly with respect to bill length. Sexes are similar in plumage, although males are slightly smaller than females, especially in bill length Gratto-Trevor 1992, Gratto-Trevor and Dickson 1994). An estimated two to five million Semipalmated Sandpipers breed in the world.

Pectoral Sandpipers (*Calidris melanotos*) are common breeders in some areas in some years. They have little fidelity to breeding sites and tend to nest in groups. The birds are polygynous, with uniparental female incubation and brood care. Females are smaller than males in this species. Pectoral Sandpipers breed in the subarctic of Canada and Alaska, as well as in Siberia. Nearctic populations winter primarily in northern third of South America. They migrate primarily through central North America in the spring and fall. The Canadian population is estimated to be approximately 25,000.

Stilt Sandpipers (*Calidris himantopus*) are medium-sized monogamous shorebirds, primarily found in western Canada. Males normally incubate during the day; females by night (Jehl 1973). Females are slightly larger than males, particularly in bill length. Stilt Sandpipers breed throughout subarctic Canada and Alaska, and winter primarily in central South America. Migration is almost entirely through the prairies in spring and fall. Approximately 50,000 Stilt Sandpipers are thought to breed in Canada.

Long-billed Dowitchers (*Limnodromus scolopaceus*) breed uncommonly in the study area. This species breeds primarily in Alaska, the Mackenzie Delta in Canada, and northeast Siberia. They winter from the southern United States south to Guatemala. During migration, it is very difficult to separate from the Short-billed Dowitcher (*L. griseus*). Migration is concentrated in the interior of North America in both spring and fall. The Canadian population is thought to approximate 50,000 birds.

Semipalmated Plovers (*Charadrius semipalmatus*) are small plovers found nesting on gravel pads or beaches in the outer delta. They are monogamous and biparental incubators. This species breeds throughout subarctic Canada and Alaska, with isolated populations breeding as far south as the New England States (Godfrey 1986). They winter in the southern United States to northern South America, and migrate through much of southern Canada. Sexes differ slightly in plumage, with males being brighter than their mates. Approximately 50,000 birds are thought to breed in Canada.

Lesser Golden Plovers (*Pluvialis dominica*) are large, monogamous, biparental-incubating plovers. The North American birds have been recently split into two species (Conners et al. 1993), the American Golden Plover (*P. dominica*) and the Pacific Golden Plover (*P. fulva*). The American Golden Plover is the species breeding in the Mackenzie Delta, and throughout subarctic Canada and parts of Alaska. These populations winter in the interior of South America. The birds migrate north through the interior of North America and south primarily along the east coast. Males are also brighter in plumage than females. The Canadian population is thought to be less than 50,000 birds.

Hudsonian Godwits (*Limosa haemastica*) are very large, monogamous shorebirds. Breeding areas appear disjunct, as the species breeds only along the Hudson Bay coast and in the area of the outer Mackenzie Delta in Canada, as well as in parts of Alaska (Godfrey 1986). Major staging areas in Canada are southern James Bay (presumably Hudson Bay population) and Quill Lakes, Saskatchewan (probably Mackenzie Delta breeders). Birds are thought to fly directly from these sites to South America, where they winter at the souther tip of South America and Tierra del Fuego (Morrison and Ross 1989). Males in this species are brighter in plumage than females, although females are slightly larger in size. About 50,000 birds are thought to exist (Morrison et al. 1994).

Whimbrel (*Numenius phaeopus*) are also large, monogamous shorebirds. They breed in subarctic areas of the palaearctic and nearctic. Nearctic breeders winter from the southern United States to Chile and Brazil. Most migration is overland, but the birds are sometimes common in the fall in the Maritime provinces. The Canadian population is estimated at 25,000 birds.

Eskimo Curlews (*Numenius borealis*) are similar, but smaller, than Whimbrel. The species is nearly extinct. The Mackenzie Delta may be one of the last areas in the world where Eskimo Curlew still exist, as several have been sighted recently in the area, although none as known breeders (Dickson et al. 1989). No Eskimo Curlews were observed during this study.

CHAPTER 2

LANDSAT TM ANALYSIS

2. LANDSAT TM ANALYSIS

2.1. Introduction and Objectives

Recently, satellite imagery has been used to identify and map habitat types, including wetlands, and areas suitable for wildlife (e.g. Tomlins and Boyd 1988, Avery and Haines-Young 1990, Ferguson 1991). In the outer Mackenzie Delta, a previous study determined that LANDSAT Thematic Mapper (TM) imagery could be used to identify and map vegetation types of the area (Jaques 1987, Dickson et al. 1989). Habitat types were ground-truthed in a small area of the outer delta (Fish Island and vicinity), and related to several types of satellite imagery, including LANDSAT Multi-spectral Scanner (MSS) and LANDSAT TM. It was determined that LANDSAT TM imagery was superior in identifying potential nesting and staging habitat of migratory shorebirds.

The purpose of the present project was to test the results of the Dickson study by extending the research area to include the entire outer delta, instead of just the area around Fish Island. Therefore, methodology for the LANDSAT TM analysis was identical to that used by Dickson et al. (1989), including use of the same imagery (23 July 1986). However, with the exception of "priority shorebird habitat" (LANDSAT Classification Unit 9), habitat types in this study are not identical (although in most cases similar) to those of Dickson. Here they were selected for ease of ground recognition by non-botanists, since the results were intended to provide simple habitat categories for use by ornithologists. For the same reason, as well as for ease of statistical analysis, I clumped the 25 LANDSAT Classification Units (LCUs) produced by the LANDSAT analysis into 7 general habitat types, of varying importance to breeding shorebirds.

D. Jaques (Ecosat Geobotanical Surveys Inc.) was again contracted to provide the LANDSAT TM analysis, and most of the following sections from this chapter are taken from his report (Jaques 1991). Ground-truthing of vegetation type and shorebird densities undertaken in this project were not used to help produce his results, but were used to test them afterwards (see Chapter 4).

2.2. Methods (Jaques 1991)

Four quadrants of LANDSAT TM imagery were obtained for 23 July 1986. The visible red (Channel 3), reflective infrared (Channel 4) and mid-infrared (Channel 5) bands were analyzed for each image using unsupervised classification algorithm of Maximum Likelihood Rule (Van Trees 1968). Prior to each quadrant classification, quantitative radiometric calibration was conducted on the raw data following the procedure described by Murphy et al. (1983). Then the radiometrically corrected data were ratioed to eliminate between-scene radiometric variance as much as possible. The ratio followed the forms: 3/(3+4+5), 4/(3+4+5), and 5/(3+4+5). Following the initial classification, all four images were mosaicked together into one master full image. This master full image was then geometrically corrected to 1:50,000 National Topographic System topographic map sheets. Forty-eight ground control points were acquired throughout the full geographic range of the study area to produce the transformation equation. A third-order polynomial relationship was derived from this data and resampling conducted to 30 m pixels. A Root Mean Squared-error factor for both pixel (height) and sample (width) dimensions was 6.3 m and 8.1 m, respectively, so that the U.T.M. correction produced a mosiac with these average accuracies in both dimensions.

Once the initial classification was conducted, these results were analyzed using ground truth data from several sources, especially colour aerial photography flown across the delta in 1981 by B.C. Hydro from southwest to northeast midway within the outer delta, with detailed ground-truthing (Pearce and Cordes 1985). Vegetation mapping of Garry Island was also used (Kerfoot 1969), as well as vegetation mapping and descriptions of Reid and Calder (1977). These sets of data were used to identify the vegetation characteristics of the LCUs and served to control revision of the initial mapping results.

Once final map units were identified, they were generalized into two different results. The first involved combining all LCUs into a smaller number of derivative LCUs which still accurately reflect the major vegetation types found in the delta. The second involved mapping potential shorebird staging and breeding habitat, using the same methods as Dickson et al. (1989). LCUs recognized by Dickson et al. as characterizing potential shorebird staging habitat were mapped. For potential nesting habitat, 21 June 1986 LANDSAT TM imagery was used in conjunction with the 23 July 1986 LANDSAT TM image and vegetation classification. Those vegetation types represented by appropriate LCUs were processed into a single file and class. The 21 June 1986 image data were geometrically co-registered to the U.T.M.-corrected 23 July 1986 image data and pixels with more than 90% water cover were logically subtracted from the potential nesting habitat. This leaves potentially useful nesting vegetation not inundated by water on 21 June 1986 as a distinct third derivative map unit.

Each of the mapping processes were mapped onto colour Applicon maps at both 1:100,000 and 1:50,000 scales. The final 16 LANDSAT LCUs were mapped onto one map series. Potential staging and nesting habitat units were mapped on a second map series. Area computations were conducted using automated pixel count software.

2.3. Results (Jaques 1991)

2.3.1. <u>LANDSAT classification</u>

The initial maximum likelihood classification produced 64 signatures of distinct classes (merge factor 1.39). These were merged into 25 classes based on multispectral covariance matrix similarity and a decimation factor of 2.0. The 25 classes were then grouped into 16 major LANDSAT Classification Units (LCUs) based on geographic distribution, spectral signature similarities and correlation with the ground truth data and maps (Fig. 2.1). Multispectral band digital values of each class are shown in Table 2.1, as well as grouping into the 16 LCUs.

Figure 2.1. ***LANDSAT TM imagery colour Applicon map, 1:100,000 scale, of entire study area.*** *See Table 2.3 and text for description of LANDSAT Classification Units (LCUs).*

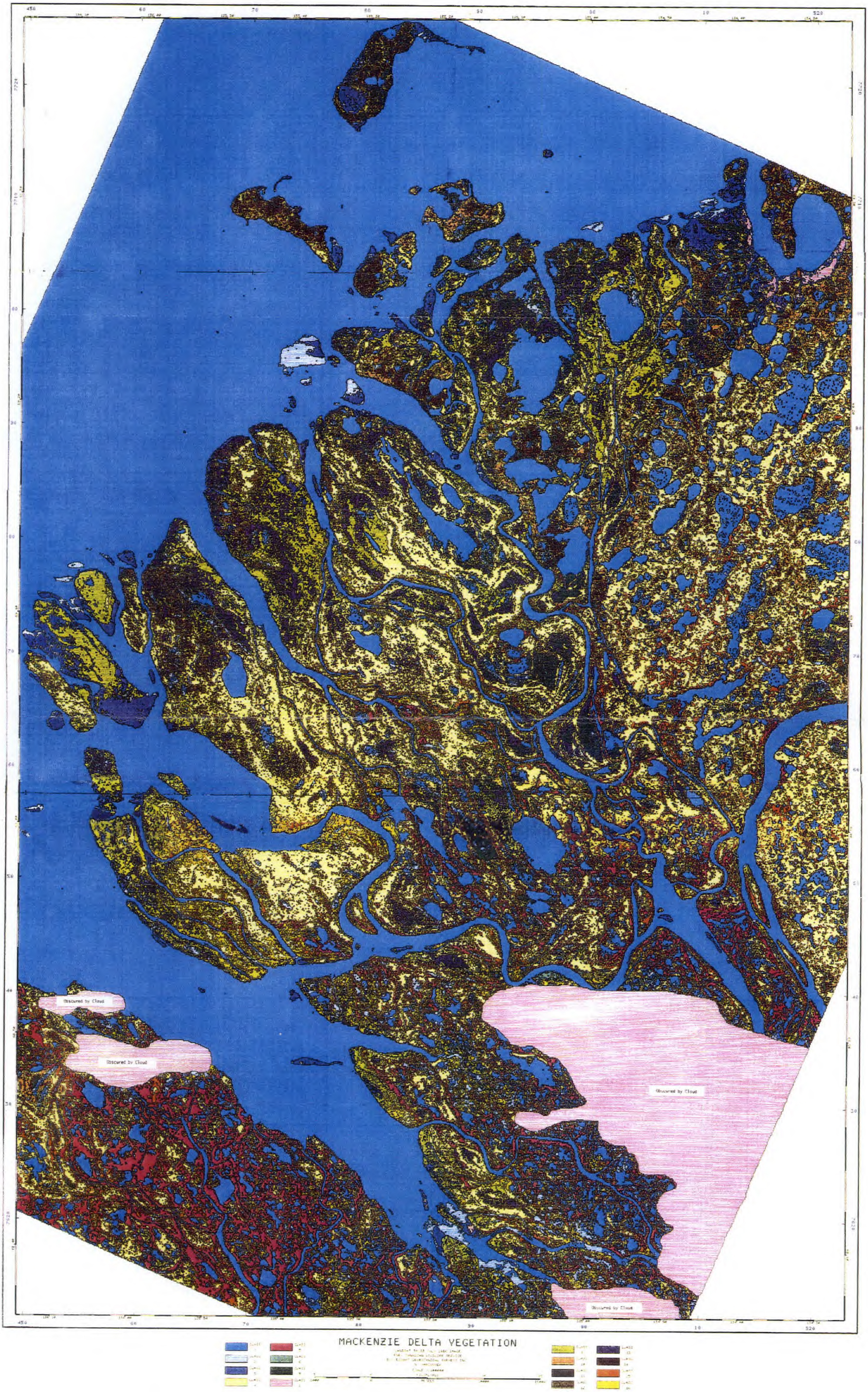

MACKENZIE DELTA VEGETATION
Obscured by Cloud
Obscured by Cloud
Obscured by Cloud
Obscured by Cloud

Table 2.1. Radiometric Digital Number (DN) Values of 23 July 1986 LANDSAT TM Classification for the outer Mackenzie Delta, NWT (Jaques 1991)

LCU	Original LANDSAT Classification	Band 3 DN (SD)	Band 4 DN (SD)	Band 5 DN (SD)
1	1	207.7 (9.5)	152.5 (31.6)	0.02 (0.3)
1	2	197.3 (7.0)	134.4 (33.9)	6.3 (6.9)
1	3	217.3 (21.0)	78.9 (26.5)	12.1 (16.1)
4	4	105.9 (5.7)	180.1 (20.4)	104.0 (11.0)
5	5	93.2 (3.7)	251.3 (6.1)	82.8 (6.7)
2	6	170.7 (14.7)	126.3 (19.9)	42.1 (17.0)
3	7	135.3 (5.2)	111.7 (16.8)	96.5 (10.9)
2	8	170.6 (7.7)	162.0 (12.8)	25.7 (8.1)
6	9	127.7 (9.1)	227.5 (19.0)	51.5 (12.9)
7	10	113.2 (5.8)	116.3 (7.9)	124.2 (6.8)
2	11	166.1 (5.8)	203.3 (22.6)	12.6 (9.4)
3	12	153.2 (6.6)	98.6 (16.2)	78.5 (8.9)
8	13	129.2 (5.6)	63.3 (12.7)	127.1 (9.0)
8	14	142.0 (7.9)	62.5 (13.5)	110.6 (7.0)
9	15	120.6 (3.3)	155.6 (15.0)	95.9 (7.9)
10	16	102.5 (2.0)	155.8 (6.0)	119.9 (2.9)
11	17	131.4 (3.4)	161.0 (14.8)	78.6 (7.5)
11	18	136.7 (2.8)	184.0 (6.7)	61.0 (4.1)
8	19	114.2 (5.0)	86.8 (6.7)	136.7 (5.0)
12	20	111.0 (2.2)	140.2 (6.8)	116.0 (4.0)
13	21	116.0 (2.6)	132.8 (5.2)	112.7 (2.8)
14	22	104.9 (1.9)	137.7 (5.4)	125.3 (3.0)
15	23	99.4 (4.0)	216.5 (8.1)	95.7 (6.2)
16	24	114.5 (3.9)	201.4 (7.6)	82.7 (5.0)
16	25	105.4 (4.4)	230.7 (8.0)	81.2 (3.9)

These LCUs were initially described as follows:

LCU 1 represents open water bodies, rivers, channels and near-shore shallows completely submerged by water. DN values in Band 5 are very low for this LCU.

LCUs 2 and 3 represent areas affected by storm surging in summer. These shoreline sites are very wet, and LCU 2 has extensive areas with open water. Dark silts and sandy silts make up the parent materials. Vegetation cover is scant to low and dominated by seedlings of *Equisetum arvense, Carex aquatilis, C. subspathacea, Arctagrostis latifolia, Arctophila fulva* and others. Cover is up to 20%, but usually much lower.

LCU 8 represents a shoreline storm surge-affected LCU possessing lighter sandy parent materials. Plant cover is always very low. This LCU occurs only sporadically throughout the study area except in the extreme northwest portion at about 134°30'W, 69°27'N. Band 5 reflectance DN values are very high for this LCU while Band 4 DN values are very low. These unique spectral properties make this LCU highly distinctive and readily identifiable from any other LCU.

LCU 4 is one of the most extensive classes, representing moderately dense, medium height shrub cover dominated by willows (*Salix lanata/Carex aquatilis and Salix alaxensis/ Equisetum arvense*).

LCUs 10 and 14 represent areas of coarser old Pleistocene parent materials. LCU 10 represents areas with somewhat higher plant cover density and standing crop, and a significantly higher willow component. However, low heath species (i.e.. *Betula nana, Vaccinum vitis-idaea, Ledum palustre, Chaemaedaphne calyculata, Andromeda polifolia*) are abundant and co-dominate on these sites. LCU 14 represents somewhat drier sites than LCU 10, with high cover of *Eriophorum vaginatum, Dryas integrifolia, Carex bigelowii, Betula nana, Ledum palustre* and others.

LCU 5 represents dense, tall willow and alder (*Salix alaxensis, Alnus crispa*) stands. In the southern portion of the study area, willow and alder are augmented by poplar (*Populus balsamifera*). The very high Band 4 reflectance and very low Band 3 reflectance indicates the very high leaf area and biomass of these sites.

LCUs 15 and 16 are characterized by dense, medium to tall height willow cover (*Salix alaxensis, S. interior, S. lanata*), predominately on levees and backslopes of levees. LCU 15 has a lower density and biomass of shrubs than LCU 5 but higher than LCU 16.

LCUs 6 and 11 represent very wet sites where open water is a predominant component. LCU 6 is significantly wetter than LCU 11. Both are commonly found near areas of low centre polygonal ground in the outer delta. *Carex aquatilis* and other species characteristic of wetter environments predominate the plant cover.

LCU 9 is somewhat drier than LCUs 6 and 11. LCU 9 possesses a dense cover primarily of *Carex aquatilis*, and biomass is much greater in LCU 9 than in either LCU 6 or 11. LCU 9 is also characteristic of low centre polygonal ground.

LCUs 13 and 12 are generally drier than LCU 9, are found upslope from 9, and possess lower cover and biomass of *Carex*. Low to medium shrub cover, predominately *Salix lanata*, is found in LCUs 13 and 12: 15-35% of total cover in 13, and 35-65% in 12.

LCU 7 is commonly adjacent to LCUs 13 and 12, but somewhat drier, with a lower biomass and cover than either 13 or 12.

2.3.2. Land area of LCUs

Areas occupied by each LCU defined and mapped in the study were calculated (Table 2.2). Over 40% of the study area is occupied by water. The distribution of lakes within the outer delta is not homogenous: Richards Island is about 20% lake surface, the delta area south of Middle Channel about 30-35% except for the outer island portion adjacent to Shallow Bay, the area south of Shallow Bay about 25%, and the outer islands west of Richards Island about 10-15%.

Mudflats and sparsely vegetated sandflats occupy about 22% of the total study area (LCUs 2, 3, and 8). LCUs dominated by tall or medium willows, alder and poplar make up 47%. The dense willow-alder-poplar LCU 5 occurs especially abundantly south of Shallow Bay, south of Middle Channel, and north of Middle Channel inland 20-30 km from the ocean. This apparently reflects the lack of flooding found throughout these regions: this cover type may represent the climax vegetation of the delta in the absence of flooding by spring flows of the Mackenzie River and storm surging from the Beaufort Sea.

LCUs with low shrub heath-*Eriophorum-Dryas* in the older delta Pleistocene deposit areas occupy about 6% of the study area (LCUs 10 and 14), compared to 9% in areas dominated by low willow (especially *Salix lanata, S. pulchra*: LCUs 12 and 13).

LCUs with herbaceous vegetation dominant make up about 16% (LCUs 6, 7, 9, and 11) of the total area. They are much more abundant north of Shallow Bay, extending 20-30 km inland from the Beaufort Sea coast on the outer islands of the delta.

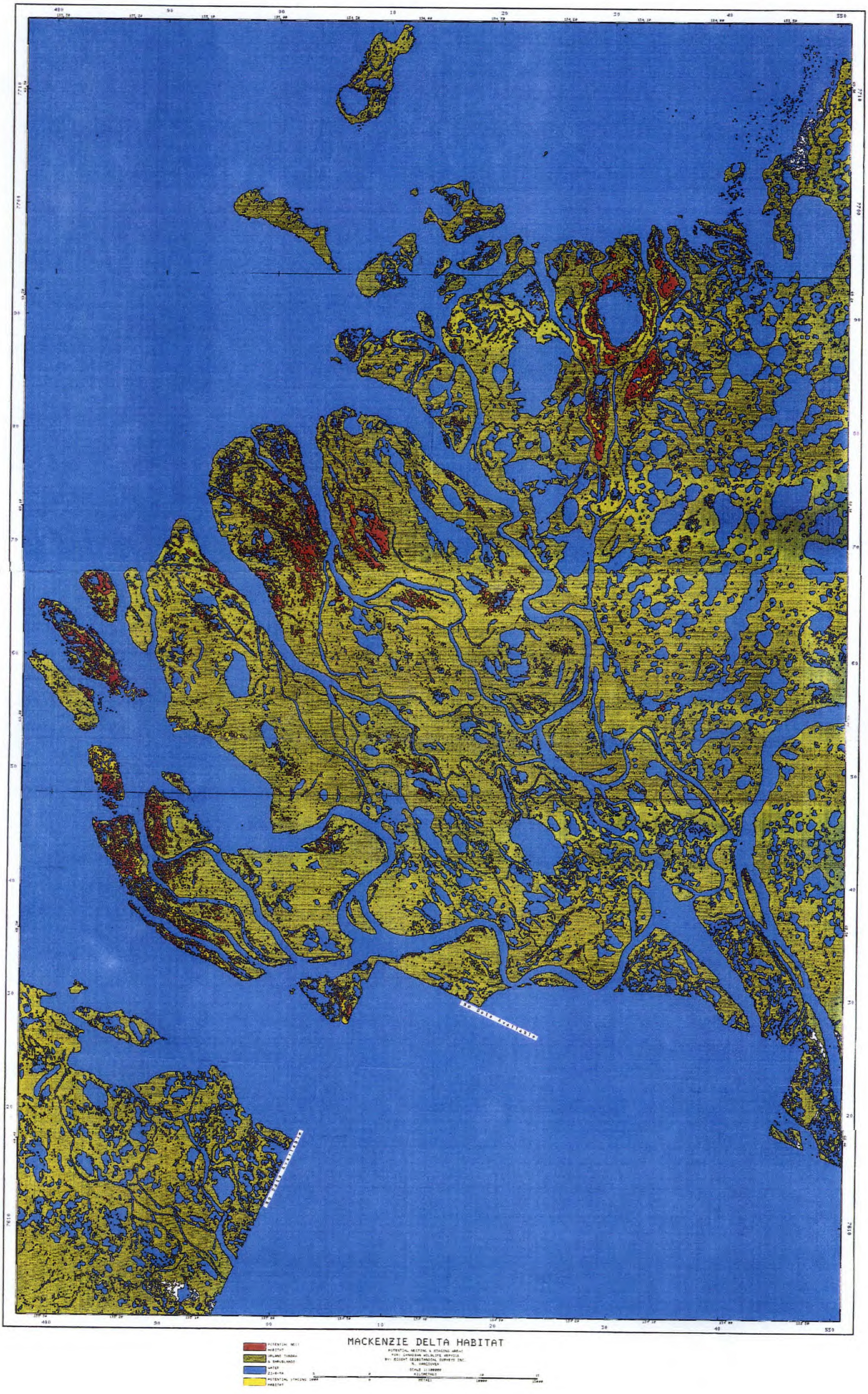
2.3.3. Potential shorebird staging and nesting habitat

The areas mapped as Potential Shorebird Nesting Habitat (Fig. 2.2) occupy 177,217 pixels of the LANDSAT map area (15,949 ha), and Potential Shorebird Staging Habitat 36,599 pixels (3,294 ha). Potential Nesting Habitat is mapped most abundantly near Fish Island-Big Lake, adjacent to Shallow Bay on the north shore, and on the outer portions of the two islands just north of Ellice Island. Scattered areas also exist throughout the rest of the study area. Potential Staging Habitat is most commonly mapped near Potential Nesting Habitat, except for areas north of Ellice Island. Since the Potential Nesting Habitat was

Table 2.2. Areas of LCUs for the outer Mackenzie Delta, NWT from 23 July 1986 LANDSAT Thematic Mapper (Jaques 1991)

LCU	# Pixels	Area (ha)	% (incl. water)	% (excl. water)
1	3,504,752	315,428	41.2	-
2	352,034	31,683	4.2	7.0
3	209,209	18,829	2.5	4.2
4	1,319,994	118,799	15.5	26.4
5	430,226	38,720	5.1	8.6
6	112,998	10,170	1.3	2.3
7	127,918	11,515	1.5	2.6
8	526,593	47,393	6.2	10.6
9	433,960	39,056	5.1	8.7
10	196,093	17,648	2.3	3.9
11	106,791	9,611	1.3	2.1
12	204,434	18,399	2.4	4.1
13	232,263	20,904	2.7	4.7
14	122,331	11,010	1.4	2.4
15	323,049	29,074	3.8	6.5
16	294,333	26,490	3.5	5.9
TOTAL	8,496,978	764,728	100.0	
Total (excl. water)	4,992,226			100.0

Figure 2.2. ***LANDSAT TM imagery colour Applicon map, 1:100,000 scale, of potential shorebird nesting and staging areas in entire outer delta.*** *See text for methodology in determining potential nesting and staging areas.*


MACKENZIE DELTA HABITAT
POTENTIAL NESTING & STAGING AREAS
FOR: CANADIAN WILDLIFE SERVICE
BY: ECOSAT GEOBOTANICAL SURVEYS INC.
N. VANCOUVER
SCALE 1:100000
KILOMETRES
METRES
POTENTIAL NEST HABITAT
UPLAND TUNDRA & SHRUBLANDS
WATER
POTENTIAL STAGING HABITAT

determined by flooding on 21 June 1986 only, this may not represent the norm, and may vary between years.

2.4. Discussion

Accuracy of the LANDSAT TM habitat classification and Potential Shorebird Staging and Nesting Habitat map is discussed in detail in Chapter 4, when ground-truth data from the present study are presented. Description of the 25 LCU types seemed reasonably accurate, with the exception of LCU 10 and 14. Both were indeed "upland tundra" habitats, but LCU 14 appeared more damp than 10, especially early in the season, rather than drier, as defined in the LANDSAT analysis report (Jaques 1991). LCU 14, which I called "low" uplands, was usually found in upland "valleys", generally contained more small creeks than 10 ("high" uplands), and was characterized by grass/sedge "tussocks".

For ease of recognition and statistical analysis, I clumped the 16 LCUs into 7 general Habitat Types, based on similarity of vegetation type when observed, and their relative importance as shorebird habitat (Table 2.3). These Habitat Types are used throughout the reminder of this report, and calculated areas of each are listed in Table 2.4.

2.5. Conclusions

A LANDSAT TM analysis was carried out by Jaques (1991) for the entire outer Mackenzie Delta, using the same methodology and imagery (23 July 1986) as a previous study on shorebirds in part of this area. Sixteen LANDSAT Classification Units were identified and mapped, and described based on results of previous ground-truth studies. Potential Shorebird Nesting and Staging Habitat was also mapped in the study area, again using the methodology suggested by a previous study (Dickson et al. 1989).

Table 2.3. LANDSAT Classification Units (LCUs) and Habitat Types, excluding open water

Habitat Type	LCU	Description
I (mudflats)	2	very wet bare mudflats with little or no vegetation cover; very shallow standing water
	3	moderately wet to dry mud/silt flats with *Equisetum* cover low to medium; gravel pads
II (emergents)	6	very wet emergents
	7	wet emergents (drier than LCU 6 and LCU 13)
	8	emergents/water complex/; shoreline sites with low plant cover
III (wet sedge/willow)	11	willow, sedge, *Equisetum*/water complex, very wet
	12	short to medium willow (*Salix lanata*)/sedge (*Eriophorum*); higher plant cover than LCU 13
	13	short to medium willow/sedge (*Eriophorum*)-wetter and lower plant cover than LCU 12
	15	moderately wet, medium to tall willow (*Salix richardsonii*)/sedge shrubland
	16	wet, moderately dense medium to tall willow (*Salix richardsonii*)/sedge shrubland
IV (dense willow)	4	high plant cover; willow/sedge uplands and alluvial flats; backslope shrub type
	5	alder and tall willow (*Salix alaskensis, S. lanata*) dense cover
V (upland tundra)	10	Pleistocene uplands dry tundra; dwarf shrub; higher
	14	Pleistocene uplands tundra; dwarf shrub; lower; tussocks
VI (sedge/low-centred polygons)	9	moderately wet, sedge/patterned ground

Table 2.4. Areas of Habitat Types for the outer Mackenzie Delta, NWT from 23 July 1986 LANDSAT Thematic Mapper

Habitat Type*	Area (ha)	% (excl. water)
I (mudflats)	50,512	11.2
II (emergents)	69,076	15.4
III (wet sedge/willow)	104,478	23.2
IV (dense willow)	157,519	35.1
V (uplands)	28,658	6.4
VI (polygons/sedge)	39,056	8.7
TOTAL	449,299	100.0

*Clumping of LCUs (see Table 2.3).

CHAPTER 3

AERIAL SURVEYS:

FALL STAGING SHOREBIRDS

3. AERIAL SURVEYS: FALL STAGING SHOREBIRDS

3.1. Introduction and Objectives

Previous to this study, no systematic surveys for staging shorebirds had been carried out in the most of the outer Mackenzie Delta, so although no large concentrations of the birds had been reported, it was not known if significant staging sites had been overlooked. Alexander (1986), during aerial surveys of the Beaufort Sea coast from Komakuk Beach, Yukon to Baillie Islands, NWT, observed less than 100 shorebirds during late July and late August. Aerial surveys of Mckinley Bay and Hutchison Bay of the Tuktoyaktuk Peninsula resulted in few shorebirds as well, averaging 54 to 82 shorebirds per bay (Cornish and Dickson 1986), and no large concentrations of staging shorebirds were seen along the Yukon coastal plain (Hawkings 1987). Interest in identifying the importance and locations of shorebird staging sites in the outer Mackenzie Delta was due to two factors. First, potential future oil and gas development in the area meant coastal staging birds would be at risk in case of oil spills there. Second, boundaries of the Kendall Island Migratory Bird Sanctuary were being reconsidered, so any important sites for shorebirds could be included in the sanctuary if located nearby. Therefore, the primary objective of the aerial surveys was to determine if significant numbers of shorebirds staged in specific areas in the outer Mackenzie Delta during fall migration. In addition, by using LANDSAT TM imagery to identify habitat types used by these birds, it was possible to identify any priority staging habitat, and determine where this habitat existed in the area. In this way, important staging sites could be identified, and potentially negative land use activities mitigated.

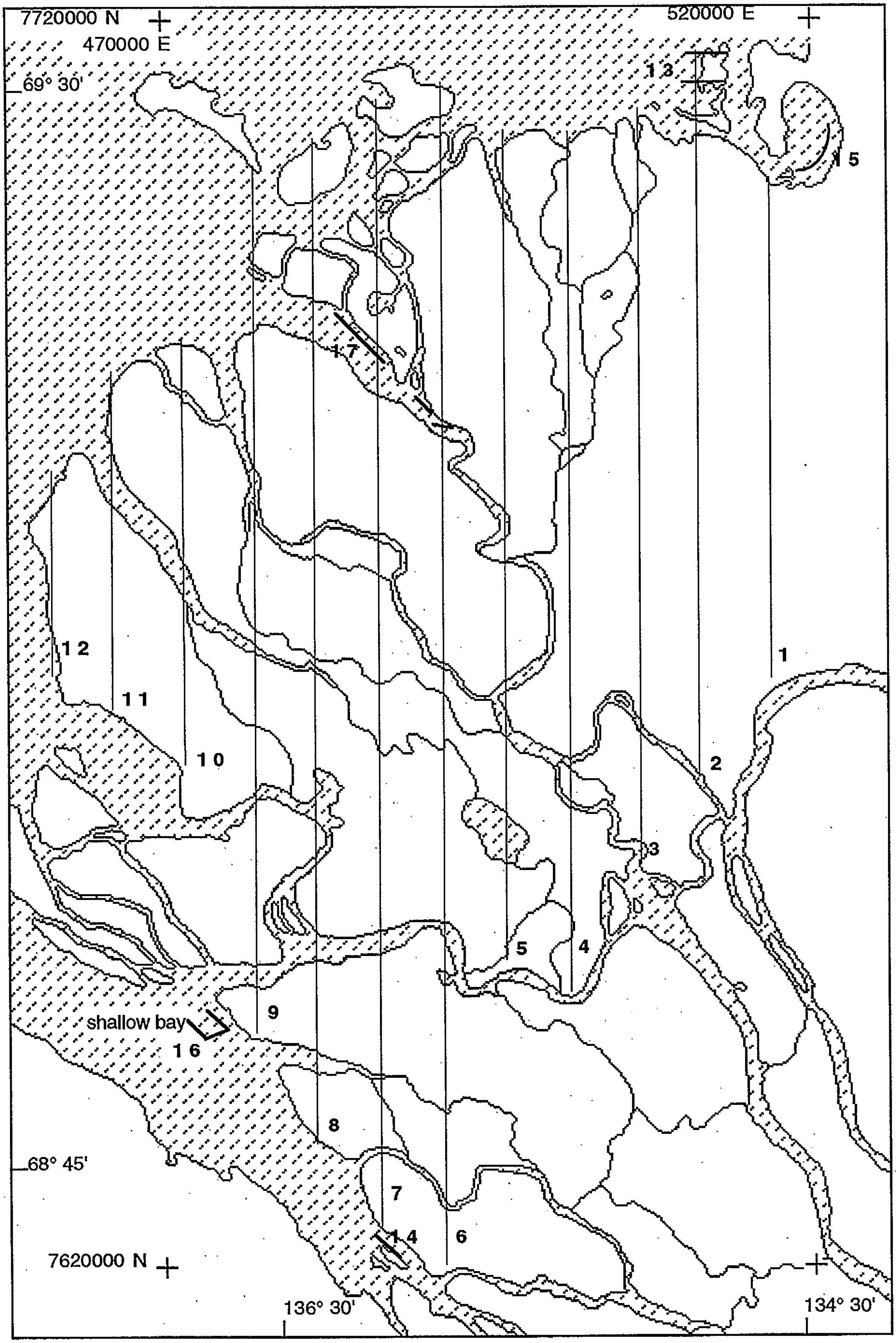
3.2. Methods

3.2.1. <u>Data Collection</u>

In 1991 and 1992, aerial helicopter surveys for shorebirds were carried out. Twelve transects were aligned north to south, 10 km apart, originating at the confluence of the delta with Mackenzie Bay, and extending as far south as Reindeer Channel or Shallow Bay (Fig. 3.1). The remaining transects were located over estuarine mudflats. Transects 13 and 14 extended east to west: #13 in Mackenzie Bay and #14 in Shallow Bay. Transects 15 to 17 were flown over mudflats in Mallik Bay, Shallow Bay, and Middle Channel.

Each transect was subdivided into segments 2 km long. Each segment was labelled, with ascending numbers north to south for transects 1 to 12. The boundary between segments was marked on the transect lines on a 1:250,000 scale topographic map. Transects 1 to 14 were flown in 1991, and 1 to 17 in 1992. Each survey was flown in a Bell 206B helicopter operating out of the Polar Continental Shelf Project (Dept. E.M.R.) in Tuktoyaktuk. Surveys were flown at a height of approximately 30 m at an airspeed of 80 km/hr (1991) or 90 km/hr (1992), with one observer and the pilot. In 1991 the observer was R. Cotter, and in 1992, M. Kornder. The pilot navigated using the marked 1:125,000 scale topographic map, and announced the start and the end of a transect line, as well as the segment number as it was

Figure 3.1. Aerial survey transects for fall staging shorebirds. *Transects 1 to 14 were censused in 1991, and 1 to 17 in 1992.*



7720000 N
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520000 E
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shallow bay
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7620000 N
136° 30'
134° 30'

entered. In 1992, a GPS (Global Positioning System) was used to more accurately determine start and end of the transect and each segment.

Using a tape recorder, the observer recorded the time at the start and end of each transect, the time at the beginning of each segment, and the time and location of each observation of a shorebird or shorebird group in a 100 m swath along the transect line. Size of the shorebird (large, medium, small) and number of birds in the group was also recorded. Potential species of shorebirds in each size class are listed in Table 3.1.

Approximately two days (14 hrs) were required for each survey of all transects. Three surveys were flown in each year: the first (19-20 July) to coincide with flocking of failed and nonbreeders (brood-rearing period for successful birds); the second (31 July-1 August 1991, 4-5 August 1992) during staging of adults and juveniles; and the third (17-18 August 1991, 18-20 August 1992) was expected to observe flocking juveniles only, as most adults would have migrated south by that time.

3.2.2. Data Analysis

Habitat availability was determined by overlaying aerial transects on the LANDSAT TM map, 1:100,000 scale (Fig. 2.2). Each pixel on the map represented 80 m X 80 m, and was classified to one of 16 different Land Classification Units (LCUs: Table 2.3). Along the length of each transect, the habitat type of each pixel flown over was identified. Pixels of open water (LCU 1) and undefined habitat (obscured by cloud) were excluded. The remaining 15 LCUs were combined into six Habitat Types (Table 2.3) for analysis. The percent frequency of each Habitat Type was calculated (number of pixels of each Habitat Type per total number of pixels).

To determine habitat use, each observation of a shorebird or group was overlayed on the same 1:100,000 scale LANDSAT map. The Habitat Type of each pixel where shorebird(s) were observed was noted. Groups of shorebirds were clumped as follows: <5 individuals; 5-15; and >15 birds.

Chi-square tests of independence were conducted to determine significance ($p<0.05$) in habitat use between surveys and size-group classes. A chi-square goodness-of-fit test was used to determine whether a significant difference ($p<0.05$) existed between the "expected" utilization of Habitat Types (based on availability), and the observed frequency of their usage. To investigate which Habitat Types were selected for, avoided, or used in equal proportion to their availability, Bonferroni 95% confidence intervals were calculated (Neu et al. 1974, Byers et al. 1984, White and Garrot 1990). Where the expected proportion of usage does not lie within the confidence intervals it can be concluded that the expected and actual utilization were significantly different. In these instances, if the expected proportion of usage was lower than the (observed) confidence intervals, than that Habitat Type was "preferred", and if the reverse was true then that Habitat Type was "avoided" (Byers et al. 1984, White and Garrot 1990).

Table 3.1. Shorebird species included in each shorebird size category during aerial surveys

Size	Species
SMALL	Red-necked Phalarope Semipalmated Sandpiper Semipalmated Plover
MEDIUM	Stilt Sandpiper Long-billed Dowitcher Pectoral Sandpiper Common Snipe Black-bellied Plover Lesser Golden Plover
LARGE	Whimbrel Hudsonian Godwit

3.2. Results

3.2.1. Differences between years and among surveys

Most groups of shorebirds observed during aerial surveys in 1991 and 1992 were very small, with a median of five or less birds per group (Table 3.2). The maximum flock size seen on the transects was 200 birds in 1991, although a flock of more than 500 shorebirds was observed off the transect at an extensive tidal flat along North Point, in the extreme northeast of the delta (M. Kornder, pers. comm.). No larger groups were seen. Median flock size did not vary greatly among surveys, but the largest groups were usually found during the second survey in a year, commonly at the coast (Figs. 3.2 to 3.7).

Transects 1 to 14 were censused in the same manner in both 1991 and 1992. A total of 197 shorebird groups were observed in 1991 (1 to 200 birds), and only 114 groups (1 to 30 birds) in 1992. The number of groups observed was similar in 1991 and 1992 during survey 1, but fewer groups were seen in the last two surveys in 1992 compared to 1991 (Table 3.3). Only 4% of all groups seen in 1992 were composed of 15 or more birds, compared to 12% in 1991. The three new transects run in 1992 were all coastal. Ten groups (1 to 50 birds) were observed in these transects, all during survey 1.

Availability of the seven Habitat Types (obtained from clumping 16 LCUs) along the aerial survey transects is shown in Table 3.4. Percentages of each Habitat Type are very similar to those of the entire study area (Table 2.3) when open water is excluded, with the exception of Type II (emergents), which is under-represented. Most of the habitat defined by the LANDSAT TM analysis as "open water" was observed as "mudflat" during the surveys. However, I used the LANDSAT TM designations for all habitats, so excluded from the analyses all "open water" habitat and the birds seen there. "Undefined" habitat (areas of cloud cover) was also excluded, but made up less than 1% of the available area. "Dense willow" (Habitat Type IV) was the most common of the remaining Habitat Types, followed by "wet sedge/willow" (Type III). "Mudflat" (Type I), "low centre polygons and sedge" (Type VI), "upland tundra" (Type V) and "emergents" (Type II) each made up less than 10% of the survey area.

I used a chi-quare test of independence to determine if differences existed between years in the distribution of shorebird group observations among Habitat Types (Sokal and Rohlf 1981), all surveys in a year combined (Table 3.5). The tests were not significant (including "open water" category, df=6, chi-square=7.60, p=0.27; excluding "open water", df=5, chi-square=2.99, p=0.70). I also tested whether there were differences among surveys in a year in distribution of sightings among Habitat Types. In order to obtain sufficient expected values per cell, I combined similar Habitat Types. In 1991, I combined Habitat Types II and III, and found no significant differences among surveys (df=8, chi-square=12.22, p=0.14). Results were similar in 1992, when Habitat Types II and III were combined, and Types IV and V (df=6, chi-square=4.19, p=0.65).

Densities of shorebirds along the transect lines are shown in Table 3.6. These ranged from 0.08 to 1.53 shorebirds per km of transect in different surveys and years, and 0.8 to 15.3 shorebirds per km^2.

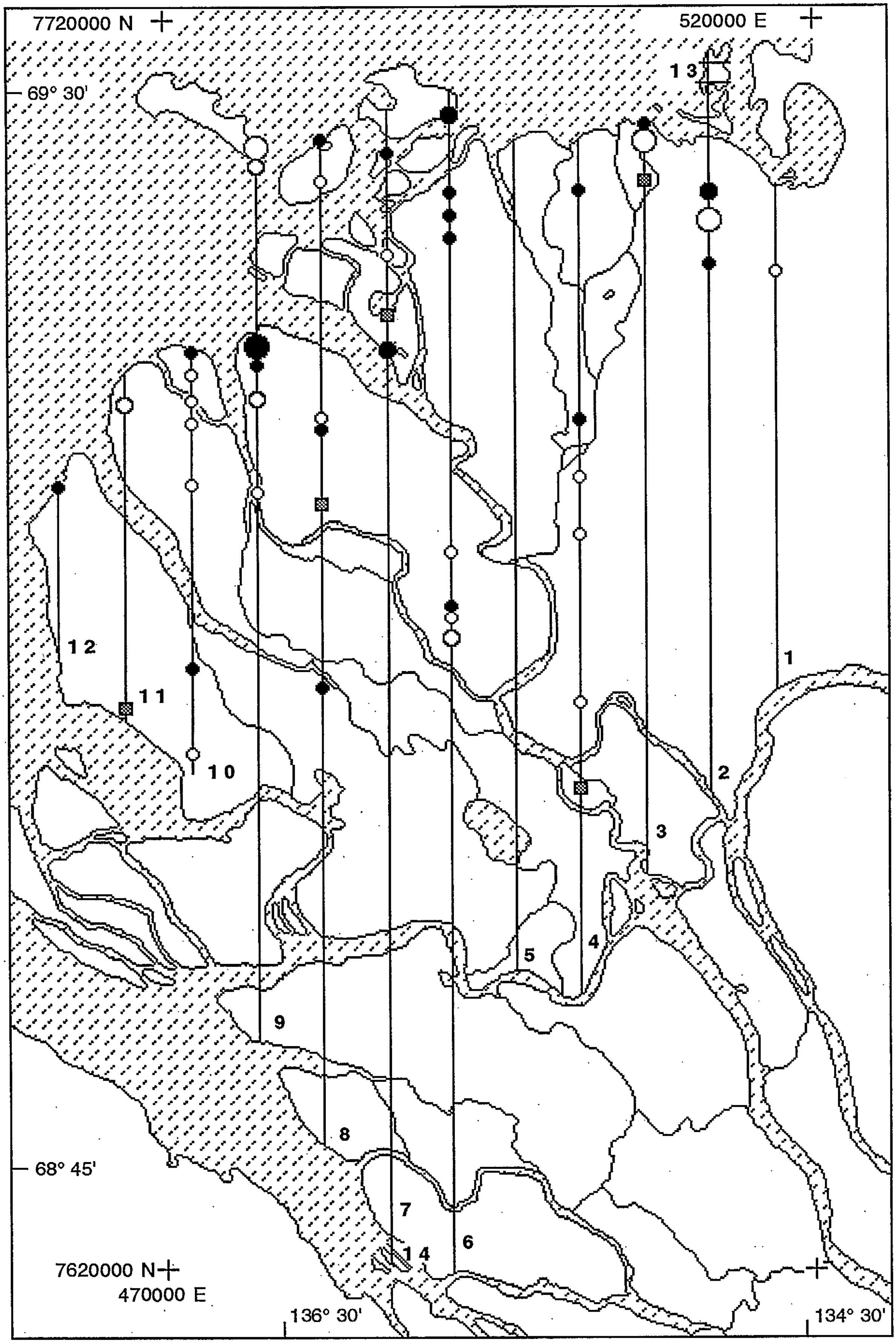
Table 3.2. Numbers of shorebird groups observed during aerial surveys, 1991 and 1992, for transects 1 to 14.

1991						
Survey	n	Mean	SE	Median	Minimum	Maximum
1	47	4.0	0.79	2	1	25
2	92	11.7	2.73	5	1	200
3	58	7.4	1.40	4	1	60
Total	197					
1992						
Survey	n	Mean	SE	Median	Minimum	Maximum
1	46	4.6	0.69	2	1	16
2	44	4.7	0.93	2	1	30
3	24	2.4	0.55	1	1	10
Total	114					

Figure 3.2. Results of first aerial survey in 1991 (19-20 July). *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND

	GROUP SIZE		
SHOREBIRD SIZE	<5	5-14	>14
Small	○	●	■
Medium	○	●	■
Large	○	●	■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7620000 N
470000 E
136° 30'
134° 30'

Figure 3.3. ***Results of second aerial survey in 1991 (31 July, 1 August).*** *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND

	GROUP SIZE		
SHOREBIRD SIZE	<5	5-14	>14
Small	○	●	■
Medium	○	●	■
Large	○	●	■

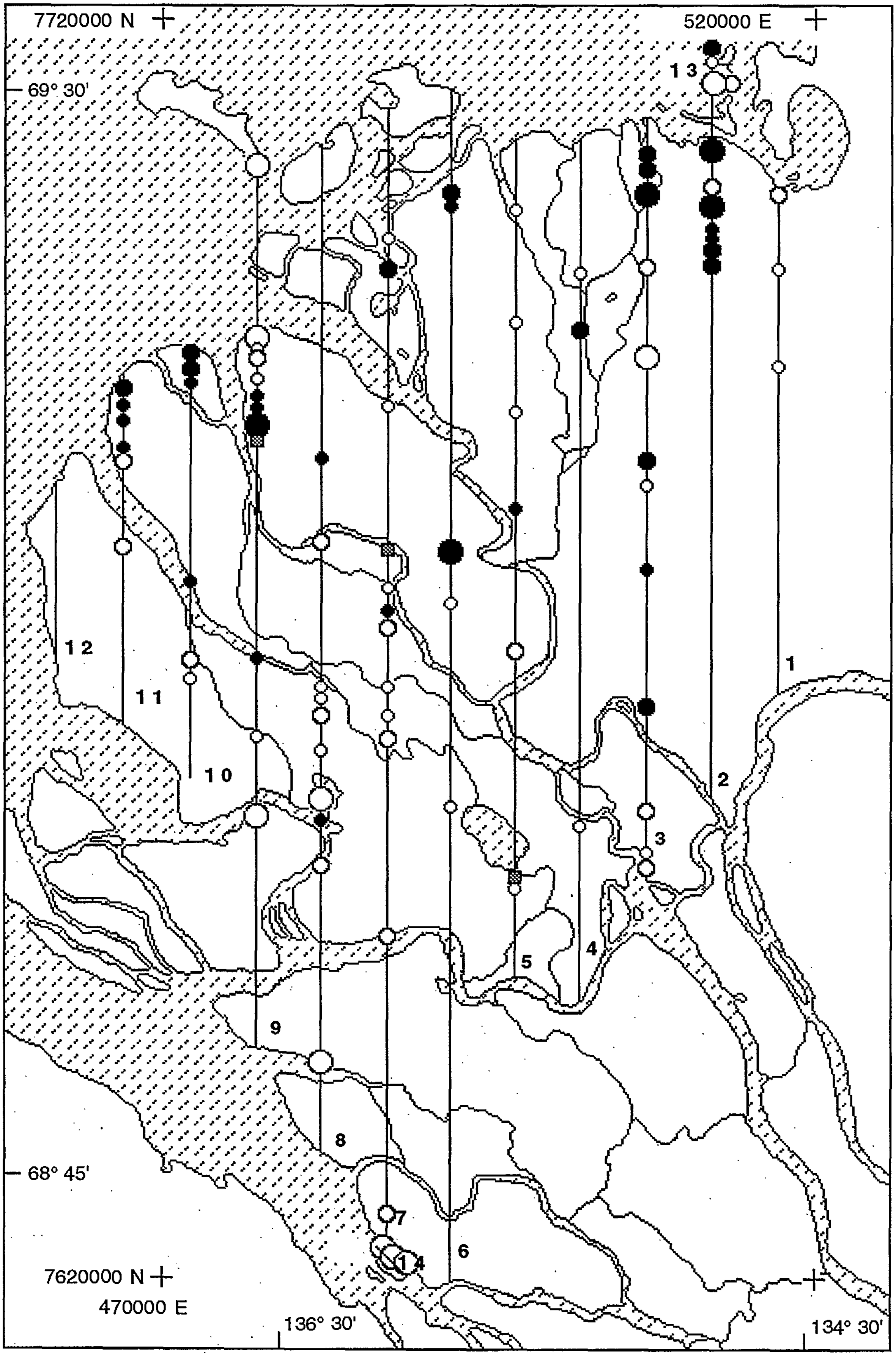
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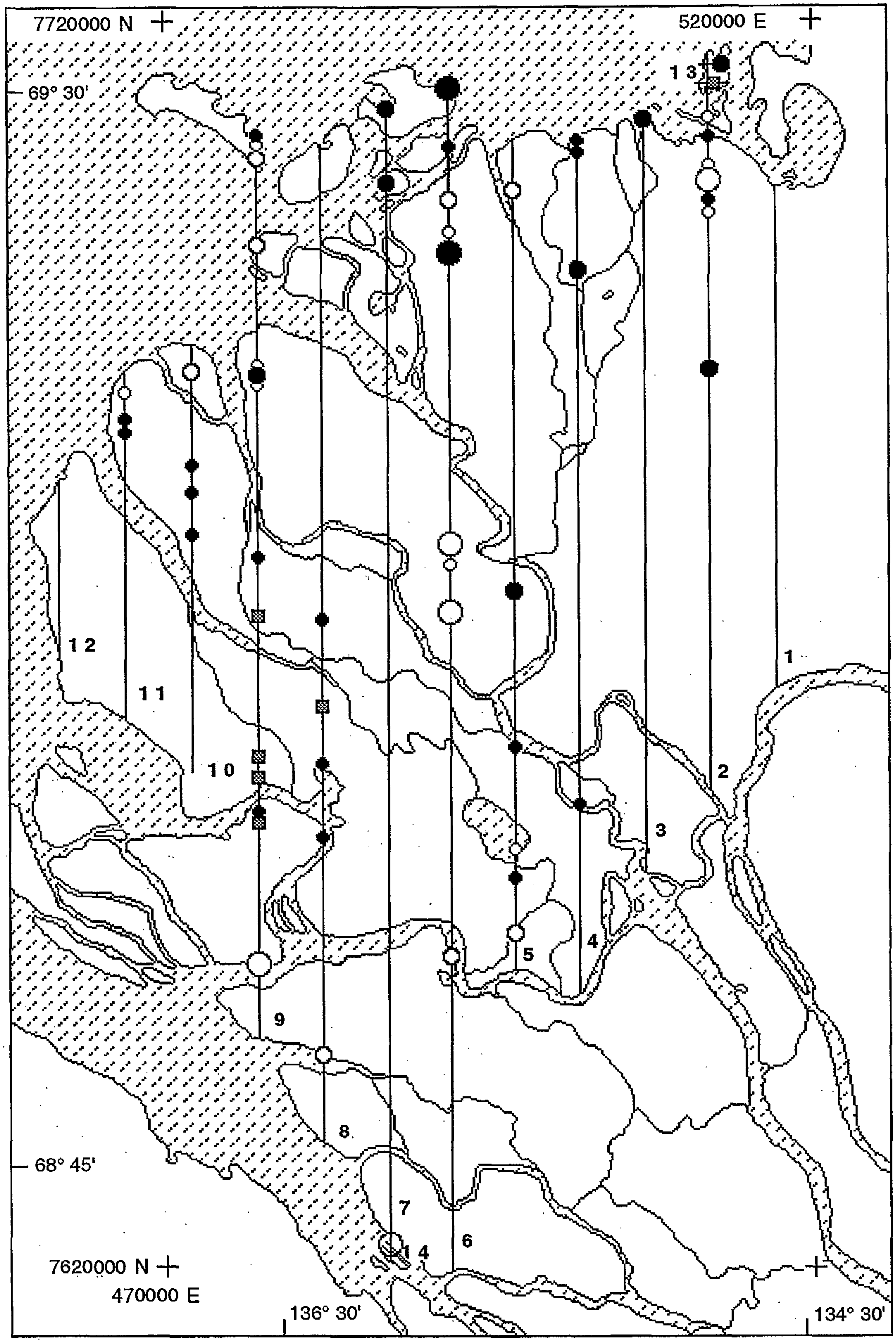
Figure 3.4. Results of third aerial survey in 1991 (17-18 August). *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND

SHOREBIRD SIZE	GROUP SIZE <5	5-14	>14
Small	○	●	■
Medium	○	●	■
Large	○	●	■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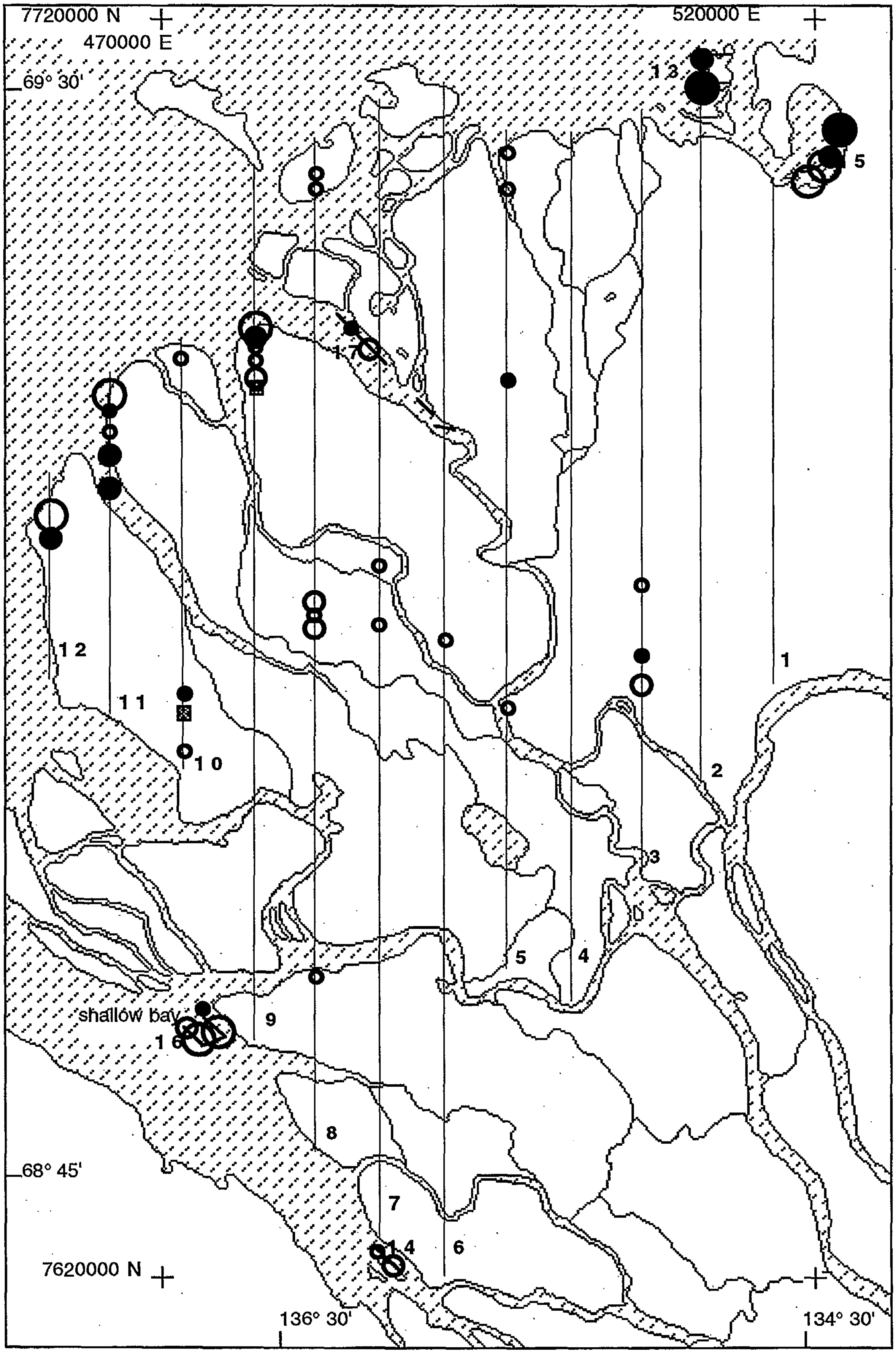
68° 45'
7620000 N
470000 E
136° 30'
134° 30'

Figure 3.5. ***Results of first aerial survey in 1992 (19-20 July).*** *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND

SHOREBIRD SIZE	GROUP SIZE <5	GROUP SIZE 5-14	GROUP SIZE >14
Small	○	●	■
Medium	○	●	■
Large	○	●	■



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1 4
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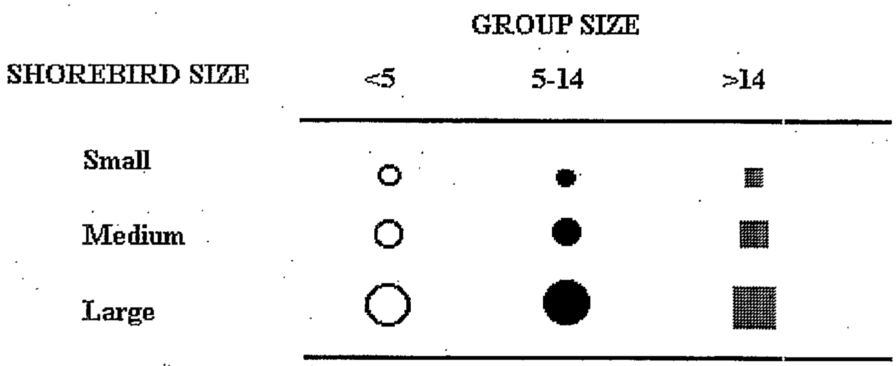
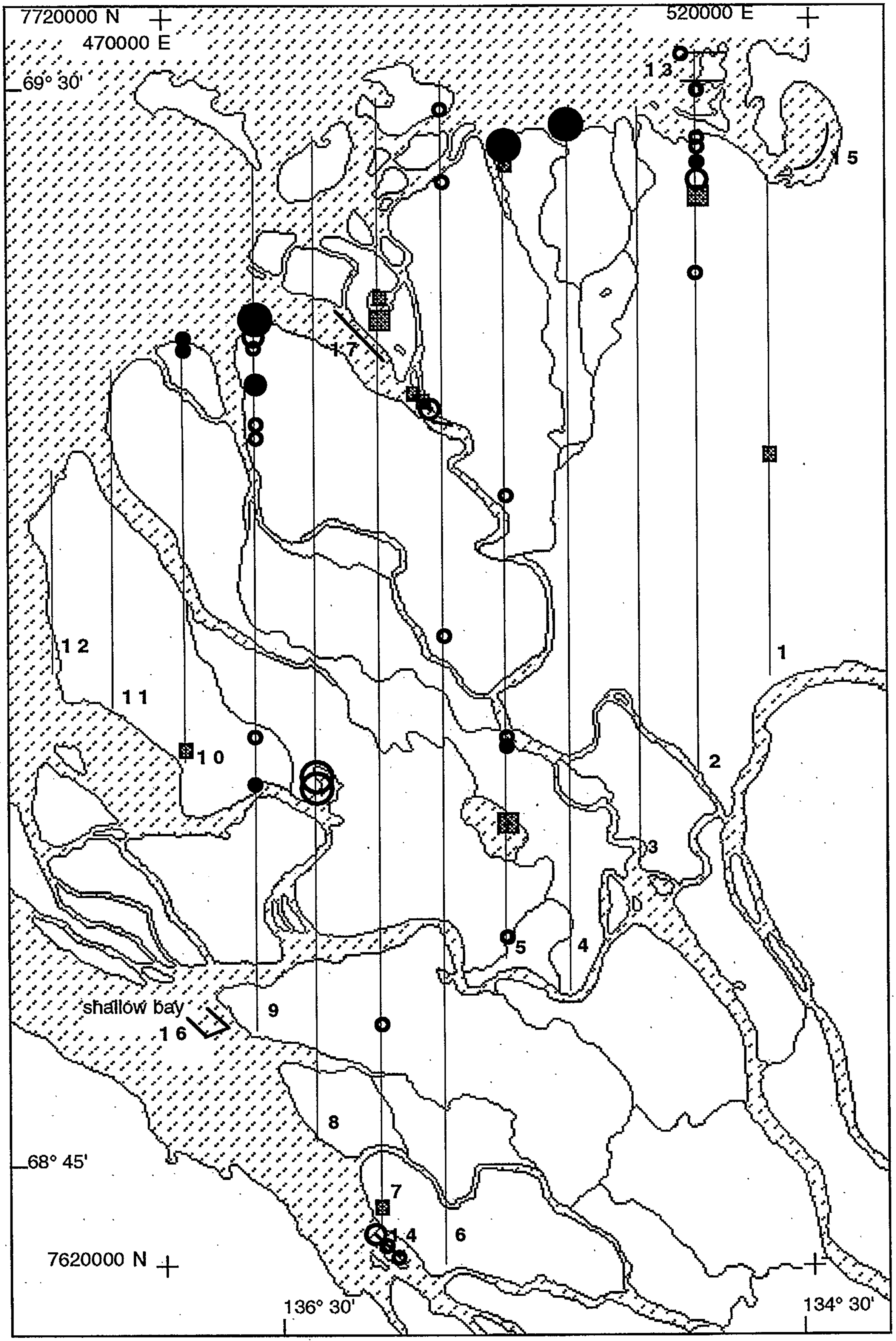
1 6
1 7

Figure 3.6. ***Results of second aerial survey in 1992 (4-5 August).*** *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND





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134° 30'

Figure 3.7. Results of third aerial survey in 1992 (18-20 August). *Symbols mark locations of flocks of shorebirds. Potential shorebird species of each size class are listed in Table 3.1.*

LEGEND

	GROUP SIZE		
SHOREBIRD SIZE	<5	5-14	>14
Small	○	●	■
Medium	○	●	■
Large	○	●	■

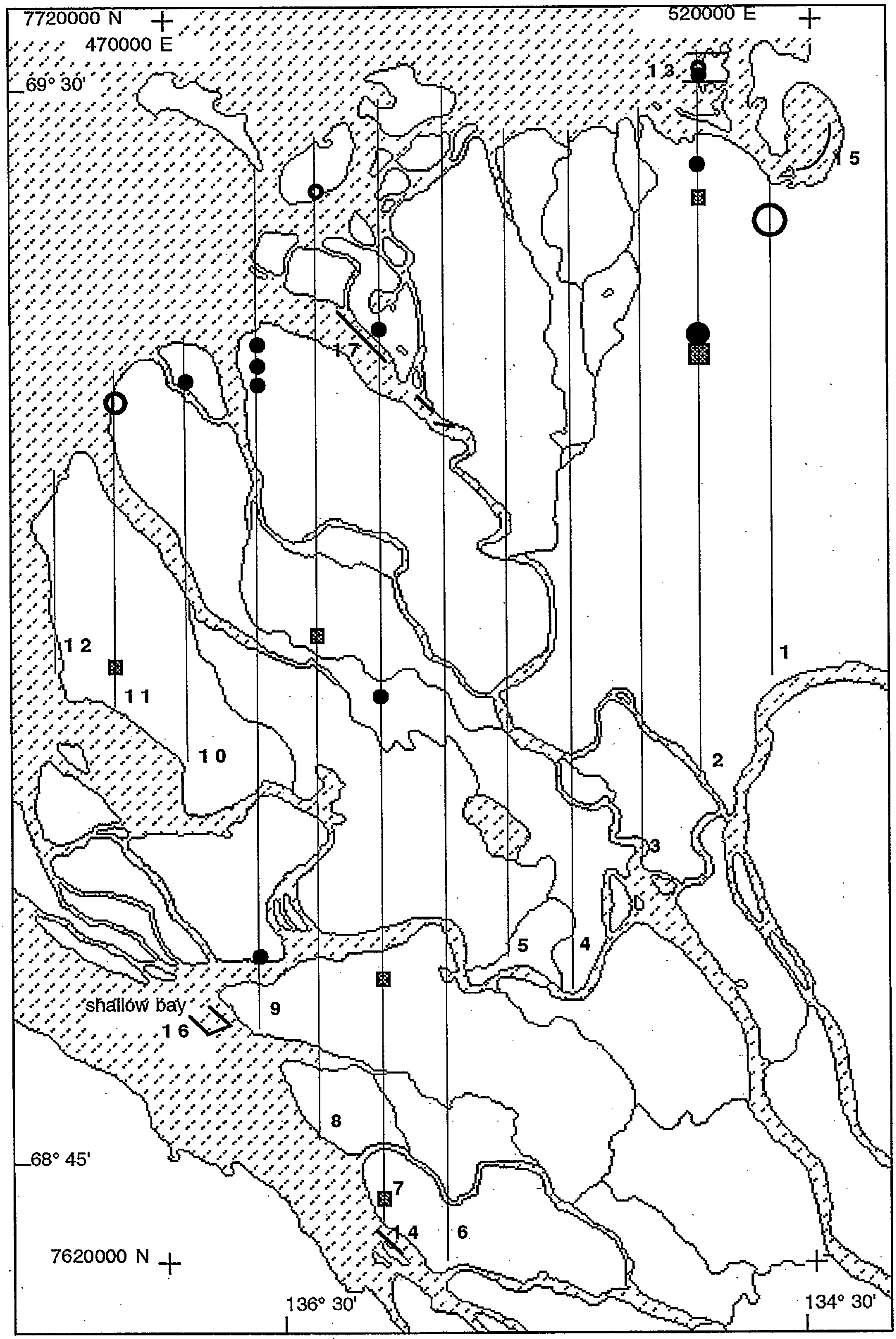

7720000 N
470000 E
520000 E
69° 30'
13
15
17
1
12
11
10
2
3
5
4
shallow bay
16
9
8
68° 45'
7
14
6
7620000 N
136° 30'
134° 30'

Table 3.3. Aerial surveys 1991 and 1992: Number of groups of shorebirds observed in each survey, for transects 1 to 14. See Table 3.1 for potential species in each shorebird size category.

		1991				1992			
		Group Size (# birds)				Group size (# birds)			
Survey	Shorebird Size	≤4	5-14	≥15	All	≤4	5-14	≥15	All
1	small	15	5	2	22	22	12	0	34
	medium	16	3	1	20	4	5	0	9
	large	5	0	0	5	2	0	0	2
	total	36	8	3	47	28	17	0	45
2	small	25	18	10	53	18	5	2	25
	medium	17	16	3	36	4	5	1	10
	large	3	0	0	3	7	1	2	10
	total	45	34	13	92	29	11	5	45
3	small	10	8	5	23	2	3	0	5
	medium	19	8	2	29	12	0	0	12
	large	6	0	0	6	6	1	0	7
	total	35	16	7	58	20	4	0	24
All	TOTAL	116	58	23	197	77	32	5	114

Table 3.4. Aerial surveys, 1991 and 1992: Habitat available along all transects, identified by LANDSAT TM analysis. Habitat types are defined in Table 2.3.

	1991			1992		
Habitat type	# pixels	%	% excluding open water & undefined	# pixels	%	% excluding open water & undefined
Open Water	2088	23.9	-	2132	23.8	-
I mudflats	782	8.9	11.8	871	9.8	12.9
II emergents	415	4.8	6.3	453	5.1	6.7
III sedge/willow	1856	21.2	28.0	1863	20.9	27.5
IV dense willow	2361	27.0	35.6	2362	26.4	34.9
V upland tundra	509	5.8	7.7	511	5.7	7.5
VI polygons, sedge	705	8.1	10.6	710	7.9	10.5
Undefined (clouds)	39	0.4	-	39	0.4	-
Total	8747			8932		

Table 3.5. Aerial Surveys, 1991 and 1992: Numbers of shorebird groups observed in different LANDSAT TM analysis habitat types, by survey. Habitat types are described in Table 2.3; "W"=open water.

1991 (Transects 1-14)		Habitat Type							
	Survey	I	II	III	IV	V	VI	W	Total
All groups	1	8	4	15	10	1	4	5	47
	2	13	6	27	17	4	9	16	92
	3	12	1	11	10	1	14	9	58
	Total	33	11	53	37	6	27	30	197
Groups ≥5 Birds	1	4	0	4	2	0	0	1	11
	2	11	3	9	7	2	7	8	47
	3	6	0	4	5	1	4	3	23
	Total	21	3	17	14	3	11	12	81

1992 (All Transects)		Habitat Type							
	Survey	I	II	III	IV	V	VI	W	Total
All Groups	1	11	7	13	9	3	6	6	55
	2	11	2	9	12	4	4	3	45
	3	7	2	5	6	0	4	0	24
	Total	29	11	27	27	7	14	9	124
Groups ≥5 Birds	1	9	4	5	0	2	2	3	25
	2	6	0	5	3	0	1	1	16
	3	0	1	1	2	0	0	0	4
	Total	15	5	11	5	2	3	4	45
1992 (Transects 1-14)									
All groups		23	8	27	27	7	14	8	114
Groups ≥5 birds		11	2	11	5	2	3	3	37

Table 3.6. Density of shorebirds during fall migration 1991 and 1992, along aerial transects. Transects were 100 m wide.

Year	Survey	No. birds	Birds/km of transect	Birds/km^2
1991	1	187	0.27	2.67
1991	2	1073	1.53	15.33
1991	3	430	0.61	6.14
1992	1	390	0.54	5.46
1992	2	207	0.29	2.90
1992	3	58	0.08	0.81

3.2.2. Differences among habitats: overall

Chi-square goodness-of-fit tests were used to determine whether shorebird groups were distributed among Habitat Types in accordance with availability of habitat, or whether they occurred more or less frequently then expected in certain Habitat Types. Bonferroni 95% confidence intervals were used to determine which specific Habitat Types were used significantly more or less than expected (Neu et al. 1974, Byers et al. 1984, White and Garrot 1990). As noted above, if confidence intervals do not include the "expected" value, the difference is significant: if the "expected" value is higher, then that Habitat Type was used less frequently than expected ("avoided"); if lower, then it was used more frequently ("preferred"). Distribution of shorebird observations are listed in Tables 3.7 and 3.8. In all tests involving confidence intervals noted below, results were identical using uncombined Habitat Types. Combined data were used when cell sizes of expected values were less than 5 flocks.

Overall in 1991, shorebirds were observed significantly less frequently than expected in dense willow and upland tundra habitats (Appendix 3.1). When "family groups" ($\leq$ 4 birds) were excluded from the analyses, shorebird flocks were found significantly more than expected in mudflat areas, and less in dense willow (Appendix 3.2). Results were similar in 1992: overall, birds "preferred" mudflats and "avoided" dense willow habitat (Appendix 3.3). When Habitat Types II, III, and VI were combined, and IV and V, groups of 5 or more shorebirds were observed significantly more often than expected on mudflats, and less than expected in dense willow (Appendix 3.4).

3.2.3. Differences among habitats: shorebird size

To determine whether size was a factor in shorebird group distribution, small shorebirds were tested separately from medium and large species. In 1991, small shorebirds overall "selected" mudflats and "avoided" dense willow (Appendix 3.5). The same result was obtained after excluding small groups ($\leq$ 4 birds), and combining Habitat Types II, III, and IV; and IV and V (Appendix 3.6). In 1992, overall no habitats were used significantly more or less than expected by small shorebirds (combining II and III; IV and V, Appendix 3.7). However, when small groups were excluded, small shorebird species "preferred" mudflats and "avoided" dense willow/upland tundra habitat (Appendix 3.8). In 1991, overall, medium and large shorebirds were observed less commonly than expected in upland tundra (Appendix 3.9), but when small groups were excluded, no differences were significant (combining II, III, and VI; IV and V, Appendix 3.10). Again no differences were significant overall with medium and large shorebirds in 1992 (combining II and III, Appendix 3.11). Sample sizes for medium and large birds in 1992 were too small for analysis when small groups were excluded, but no differences were evident.

Table 3.7. Aerial Surveys 1991: Numbers of shorebird groups observed in the different LANDSAT TM habitat types, all surveys combined. Habitat types are described in Table 2.3; "W" = open water. See Table 3.1 for potential species in each shorebird size category.

Group Size	Shorebird Size	Habitat Type I	II	III	IV	V	VI	W	Total
≤ 4 birds	small	5	4	16	8	2	3	12	50
	medium	6	3	18	9	1	10	5	52
	large	1	1	2	6	0	3	1	14
	total	12	8	36	23	3	16	18	116
5-14 birds	small	7	2	5	6	2	5	4	31
	medium	3	0	9	5	0	5	5	27
	large	0	0	0	0	0	0	0	0
	total	10	2	14	11	2	10	9	58
≥15 birds	small	8	1	2	1	1	1	3	17
	medium	3	0	1	2	0	0	0	6
	large	0	0	0	0	0	0	0	0
	total	11	1	3	3	1	1	3	23
TOTAL		33	11	53	37	6	27	30	197

Table 3.8. Aerial surveys 1992: Numbers of shorebird groups observed in the different LANDSAT TM habitat types, all surveys and transects combined. Habitat types are described in Table 2.3; "W" = open water. See Table 3.1 for potential species in each shorebird size category.

Group Size	Shorebird Size	Habitat Type I	II	III	IV	V	VI	W	Total
≤ 4 birds	small	7	4	7	12	3	4	5	42
	medium	6	1	5	6	0	4	0	22
	large	1	1	4	4	2	3	0	15
	total	14	6	16	22	5	11	5	79
5-14 birds	small	5	2	6	2	2	3	2	22
	medium	3	2	3	2	0	0	1	11
	large	0	0	1	1	0	0	0	2
	total	8	4	10	5	2	3	3	35
≥15 birds	small	5	0	0	0	0	0	1	6
	medium	0	1	1	0	0	0	0	2
	large	2	0	0	0	0	0	0	2
	total	7	1	1	0	0	0	1	10
TOTAL		29	10	26	27	7	14	9	124

3.3. Discussion

Concentrations of post-breeding shorebirds in the delta were at most hundreds, rather than thousands, of birds. Densities were similar to those observed by Cornish and Dickson (1986) in the terrestrial portion of their aerial transects of Mckinley and Hutchison Bays, Tuktoyaktuk Peninsula, NWT. Most of the largest flocks observed during the present study were small species of shorebirds, primarily concentrated along the coast. Numbers of birds appeared much lower in 1992 than in 1991, particularly during the later surveys. This might have been due to early departure from the area of non or failed breeders, if failure rates were higher in 1992.

The distribution of shorebird groups among habitat types was similar between years and among surveys. Dense willow and upland tundra were generally used significantly less frequently than expected, and mudflats more so. This was particularly true for flocks of more than four birds, in small shorebird species. Larger shorebird species showed little difference between habitat availability and usage, but large flocks of large species were very uncommon. Unlike small species, larger shorebirds may not form large groups on the coast of the delta before starting migration south. However, since large species are generally much less common than small species in general, large flocks of large species would more likely be missed by our surveys.

3.4. Conclusions

Although no really large concentrations of shorebirds were observed in this study, any oil spills along areas of extensive mudflat (e.g. North Point, Shallow Bay, Mallik Bay) in July or August could have severe effects on local populations, especially on small and medium shorebird species such as Semipalmated Sandpipers, Red-necked Phalaropes, or Pectoral Sandpipers. It is also possible that large rafts of phalaropes could stage off-shore, and have been missed in these land-based surveys.

CHAPTER 4

GROUND PLOTS:

BREEDING SHOREBIRDS

4. GROUND PLOTS: BREEDING SHOREBIRDS

4.1. Introduction and Objectives

In order to effectively monitor and protect populations of shorebirds in the Canadian Arctic, we need to know breeding densities and distribution of each species. Currently we have very scattered information for very few species, usually from many years ago, and seldom for more than one season. It is obviously logistically impossible to search the entire Canadian Arctic in order to determine densities and distributions of breeding shorebirds. Use of satellite imagery in mapping habitat types important to nesting shorebirds offers potential for extrapolation from small-scale ground surveys. Although this method has been used successfully to map and monitor wetlands (Tomlins and Boyd 1988), classify muskox habitat (Ferguson 1991), and even estimate populations of Dunlin (*Calidris alpina*) breeding in Scotland (Avery and Haines-Young 1990), very few studies have involved breeding shorebirds. Dickson et al. (1989) conducted a study in the Fish Island area, Mackenzie Delta, NWT, to determine if important shorebird habitat could be identified using LANDSAT Multi-spectral Scanner (MSS) or Thematic Mapper (TM) imagery. Using information from their small study area, they found that LANDSAT TM imagery analysis was able to accurately map their major habitat types, including priority shorebird nesting habitat. In the present study, shorebirds were censused in plots of different habitat types throughout the outer delta, to determine if the results of Dickson's study could be extrapolated beyond the area of Fish Island.

Specifically, the objectives of the ground surveys were as follows: first, to test whether the priority shorebird breeding habitat identified by Dickson's study was indeed the most important habitat for breeding shorebirds throughout the entire outer delta; second, to examine the accuracy of the LANDSAT TM analysis habitat classifications in the entire outer delta; third, to determine overall densities of breeding shorebird pairs in each major habitat type in the area, and each species of shorebird; fourth, to calculate overall numbers of breeders in the outer Mackenzie Delta; and fifth, to determine the accuracy of the census technique used here.

4.2. Methods

4.2.1. <u>1991</u>

In 1991, breeding surveys were carried out in two areas of the outer Mackenzie Delta: from 17 to 26 June on Fish Island, and from 2 to 12 July on Niglintgak Island (Fig. 1.1). One of the primary objectives of the 1991 surveys was to test census techniques so that more plots could be accurately and efficiently censused for breeding shorebirds in 1992. Since plots were set up in several different habitats, the 1991 data also allowed an initial test of the accuracy of the LANDSAT TM habitat classifications, as well as shorebird use of different habitat types. Two plots on Fish Island, which had been censused in previous years (Dickson et al. 1989), were re-censused in 1991 and 1992, allowing some inter-year comparison of breeding densities.

Plot size was 200 m X 200 m, with one to four plots together at a site. Each plot was divided into a 50 m X 50 m grid, with a 1 m high stake with flagging tape placed every 50 m. Plot sites were labelled with ascending letters west to east, and ascending numbers north to south. The westernmost and easternmost stakes were marked with blue and yellow flagging, with lines within alternating between orange and blue flagging. This system allowed the observer to accurately locate observations of shorebirds and nests within the plot area.

Each plot was censused three times: Fish Island plots by two observers, and Niglintgak plots by three persons. In all cases. observers walked 50 m apart. The first and third censuses of a plot involved observers walking along grid lines. During the second survey, observers walked halfway between grid lines. In this way observers could have walked no farther than 12.5 m from a nest if it existed during any two censuses. Surveys of a plot were carried out anywhere from one to six days apart, most commonly (85%) three to five days, depending upon weather conditions. In both 1991 and 1992, surveys were only carried out if weather conditions were suitable (not raining or snowing, not extremely windy, not extremely cold). Time from first to third survey varied from four to nine days, averaging eight days (n=26 plots at 9 sites, SD=1.4 days). All flagging (except for one corner marker in some cases) was removed during the third survey.

During each survey, locations of shorebirds in the grid were recorded. Habitat type was noted during the first census of a plot. In addition to the nine grid plots of 1991, two gravel pads (Fish Island and Niglintgak) were searched for breeding shorebirds ("plots" 10 and 11). Locations of plots are shown in Figures 4.1 and 4.2.

4.2.2. <u>1992</u>

In 1992, a total of 61 plots were surveyed in the areas surrounding camp A (near Camp Farewell: 15-25 June), camp B (northern Ellice Island: 28 June to 2 July), and camp C (Taglu: 6 to 14 July). Locations of camps are shown in Figure 1.1, and plots in Figures 4.1, 4.3, and 4.4. Plot locations were chosen to be representative of the major habitat types identified by LANDSAT TM analysis of the study area. Surveyed plots were 200 m X 200 m. Each plot was censused only once by three observers walking 25 m apart. Therefore observers approached within at least 12.5 m of any bird in the plot. Plot locations were marked on detailed aerial photographs. Plots were not marked with flagging tape, but paced off in specific compass directions.

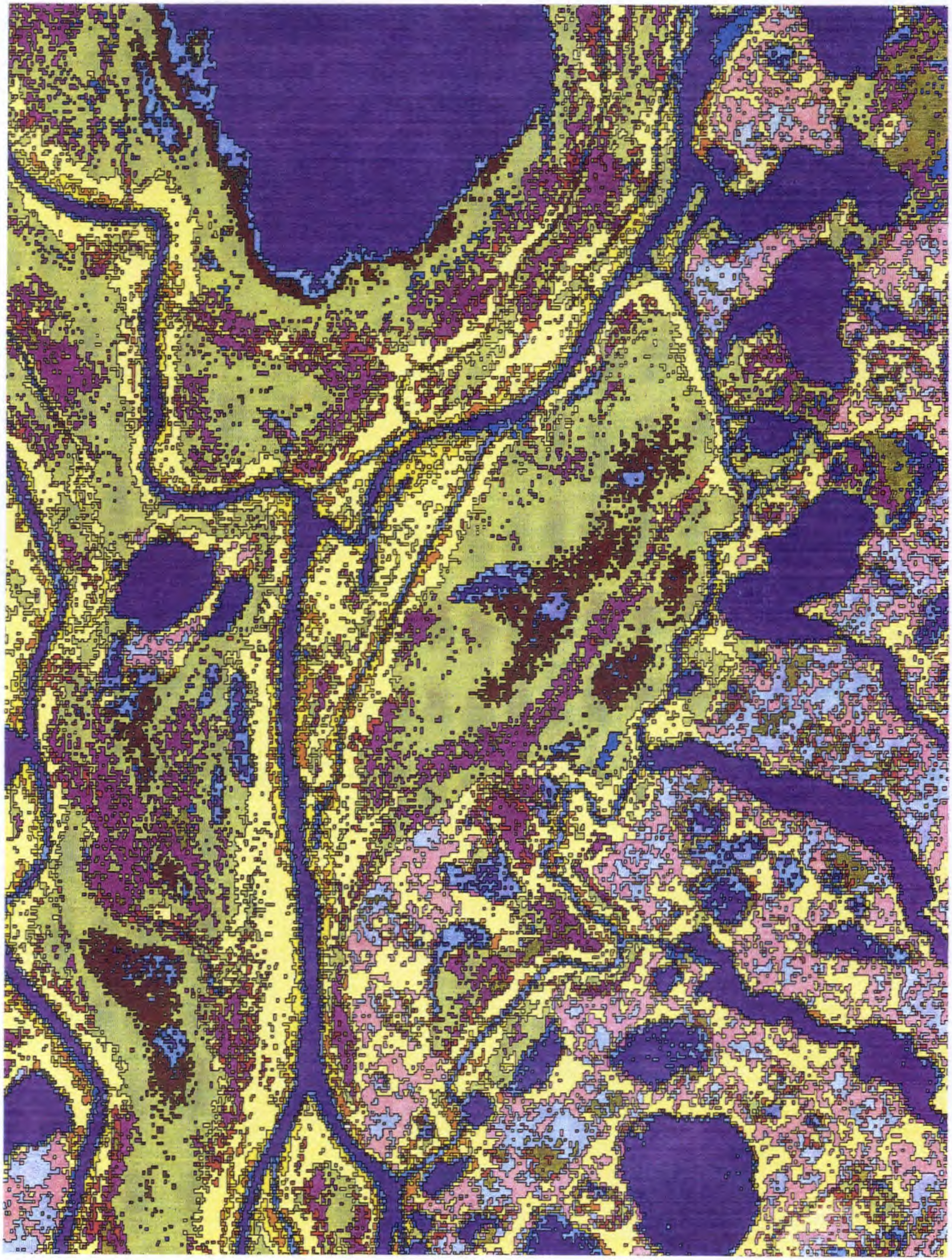
4.2.3. <u>Determination of breeding pairs</u>

The overall totals of shorebird pairs in a plot was determined by location and behaviour of shorebirds seen during the three censuses. Only birds flushed from, or landing in the plot were counted. Since only male phalaropes care for eggs or young, female phalaropes were not considered when calculating breeding "pairs". In many cases, and most

Figure 4.1. LANDSAT TM imagery colour Applicon map, 1:50,000 scale: Fish Island and Taglu area. *Overlays: 1991 First Camp with all ground plots labelled; 1992 Camp C with all ground plots marked. LCU=LANDSAT Classification Unit. For more detail on habitat types, see Chapter 2.*

LEGEND

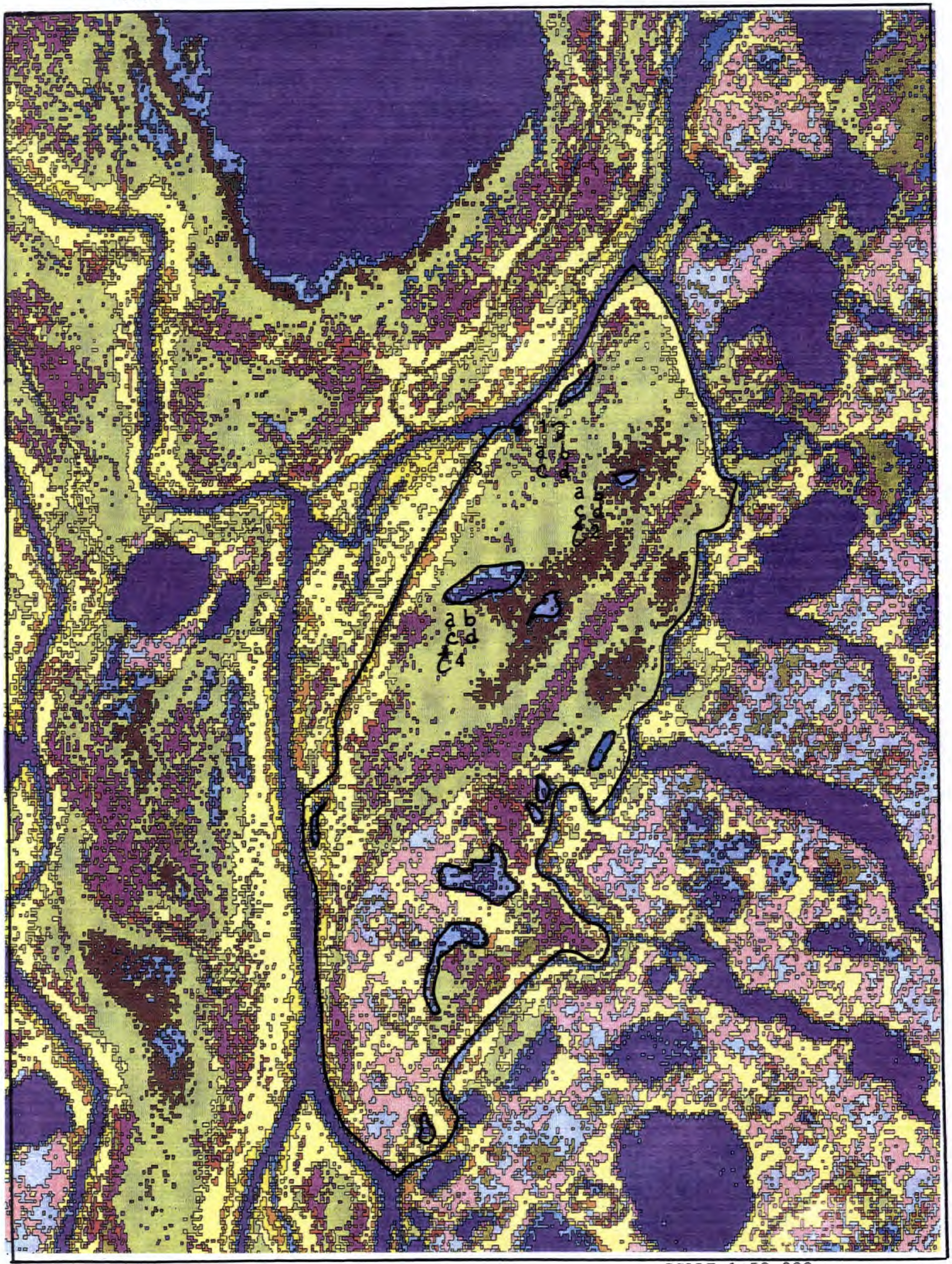
Colour		***Description***
0A8	LCU 1	*open water*
004	LCU 2	*very wet bare mudflats with little or no vegetation cover; very shallow standing water*
02G	LCU 3	*moderately wet to dry mud/silt flats with Equisetum cover low to medium; gravel pads*
400	LCU 4	*high plant cover; willow/sedge uplands and alluvial flats; backslope shrub type*
0G0	LCU 5	*alder and tall willow (Salix alaskensis, S. lanata) dense cover*
G46	LCU 6	*very wet emergents*
G22	LCU 7	*wet emergents (drier than LCU 6 and LCU 13)*
040	LCU 8	*emergents/water complex/; shoreline sites with low plant cover*
G02	LCU 9	*moderately wet, sedge/patterned ground (low-centre polygons)*
220	LCU 10	*Peistocene uplands dry tundra; dwarf shrub; higher*
G82	LCU 11	*willow, sedge, Equisetum/water complex, very wet*
G60	LCU 12	*short to medium willow (Salix lanata)/sedge (Eriophorum); higher plant cover than LCU 13*
0G2	LCU 13	*short to medium willow/sedge (Eriophorum)-wetter and lower plant cover than LCU 12*
202	LCU 14	*Pleistocene uplands tundra; dwarf shrub; lower; tussocks*
G20	LCU 15	*moderately wet, medium to tall willow (Salix richardsonii)/sedge shrubland*
G00	LCU 16	*wet, moderately dense medium to tall willow (Salix Richardsonii)/sedge shrubland*



0 SCALE 1:50,000 2

KILOMETRES

1991



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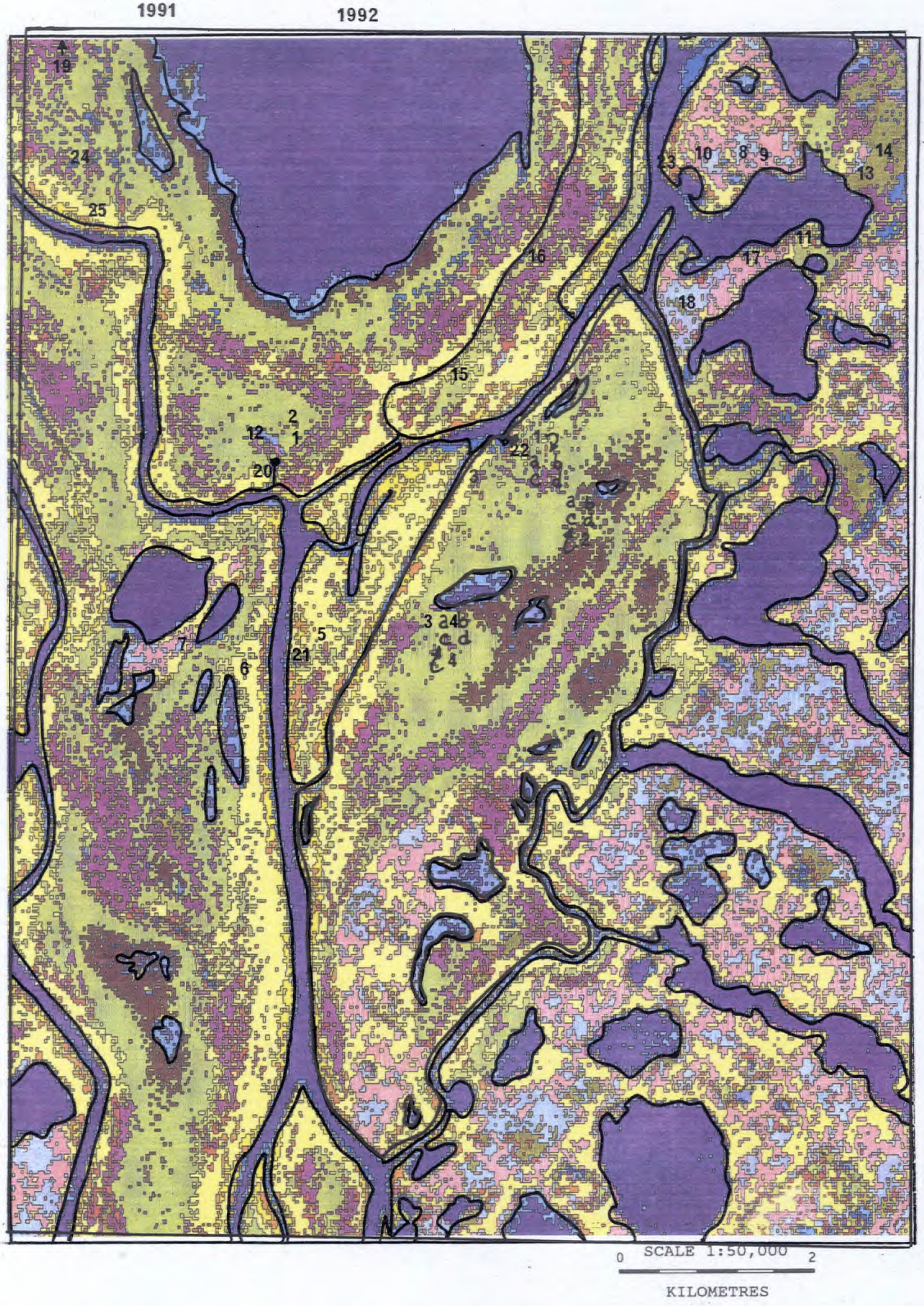
1991
1992
19
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21
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6
SCALE 1:50,000
0
2
KILOMETRES

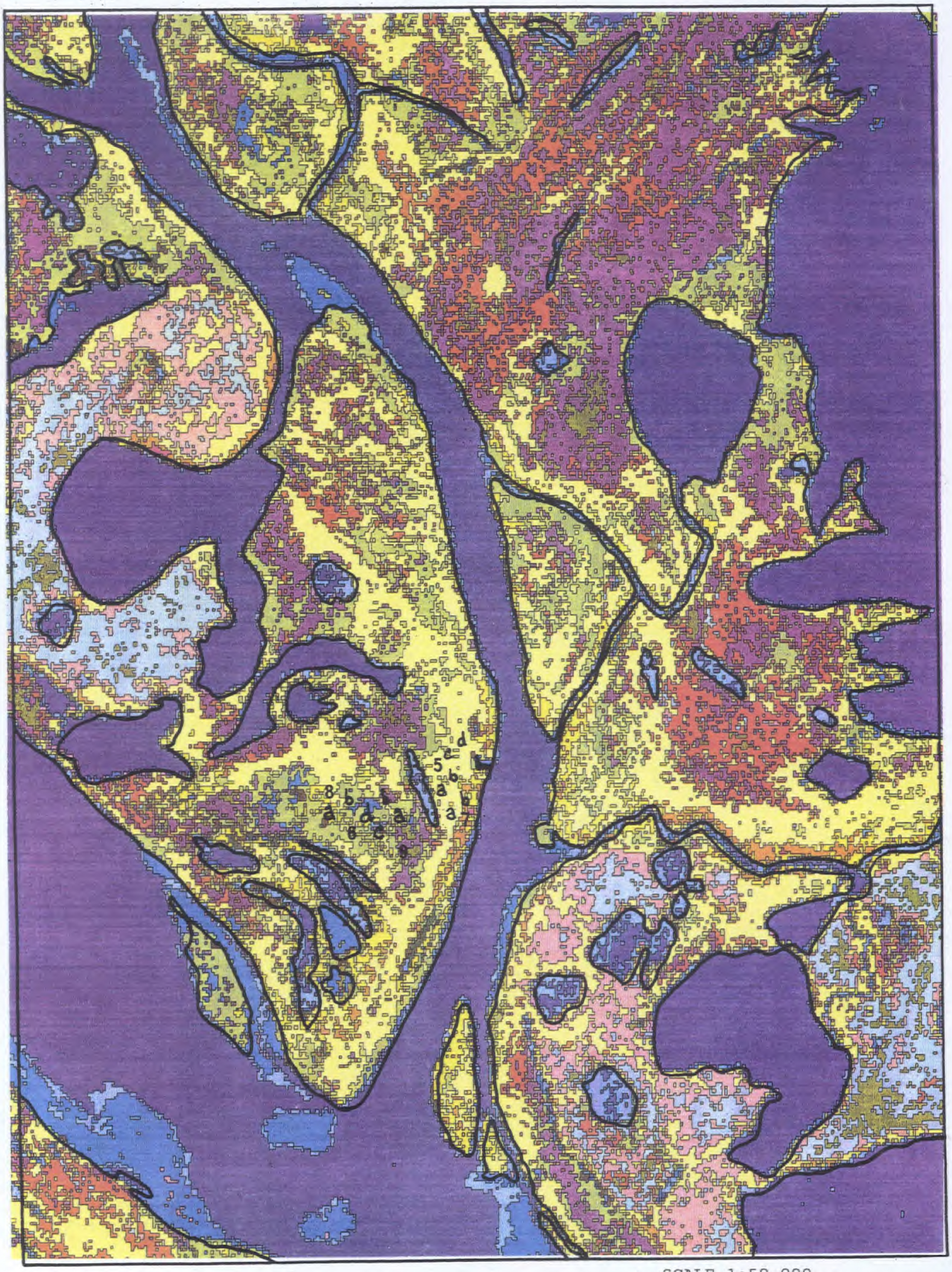
Figure 4.2. LANDSAT TM imagery colour Applicon map, 1:50,000 scale: Niglintgak Island area. *Overlay: 1991 Second Camp with all ground plots labelled. LCU=LANDSAT Classification Unit. For more detail on habitat types, see Chapter 2.*

LEGEND

Colour		***Description***
0A8	LCU 1	*open water*
004	LCU 2	*very wet bare mudflats with little or no vegetation cover; very shallow standing water*
02G	LCU 3	*moderately wet to dry mud/silt flats with Equisetum cover low to medium; gravel pads*
400	LCU 4	*high plant cover; willow/sedge uplands and alluvial flats; backslope shrub type*
0G0	LCU 5	*alder and tall willow (Salix alaskensis, S. lanata) dense cover*
G46	LCU 6	*very wet emergents*
G22	LCU 7	*wet emergents (drier than LCU 6 and LCU 13)*
040	LCU 8	*emergents/water complex/; shoreline sites with low plant cover*
G02	LCU 9	*moderately wet, sedge/patterned ground (low-centre polygons)*
220	LCU 10	*Peistocene uplands dry tundra; dwarf shrub; higher*
G82	LCU 11	*willow, sedge, Equisetum/water complex, very wet*
G60	LCU 12	*short to medium willow (Salix lanata)/sedge (Eriophorum); higher plant cover than LCU 13*
0G2	LCU 13	*short to medium willow/sedge (Eriophorum)-wetter and lower plant cover than LCU 12*
202	LCU 14	*Pleistocene uplands tundra; dwarf shrub; lower; tussocks*
G20	LCU 15	*moderately wet, medium to tall willow (Salix richardsonii)/sedge shrubland*
G00	LCU 16	*wet, moderately dense medium to tall willow (Salix Richardsonii)/sedge shrubland*


0 SCALE 1:50,000 2
KILOMETRES

1991



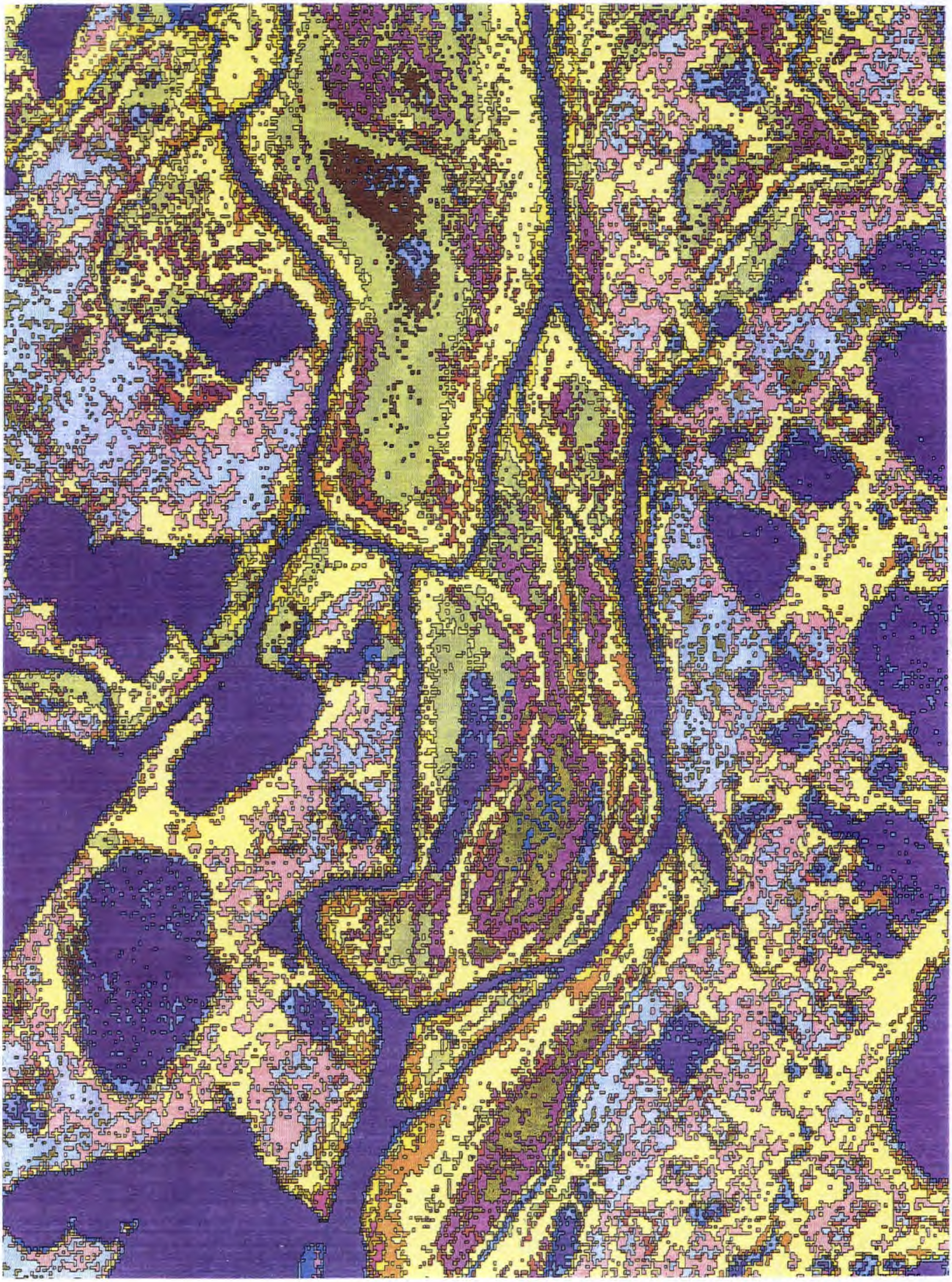
0 SCALE 1:50,000 2

KILOMETRES

Figure 4.3. LANDSAT TM imagery colour Applicon map, 1:50,000 scale: Camp Farewell area. *Overlay: 1992 Camp A with all ground plots labelled. LCU=LANDSAT Classification Unit. For more detail on habitat types, see Chapter 2.*

LEGEND

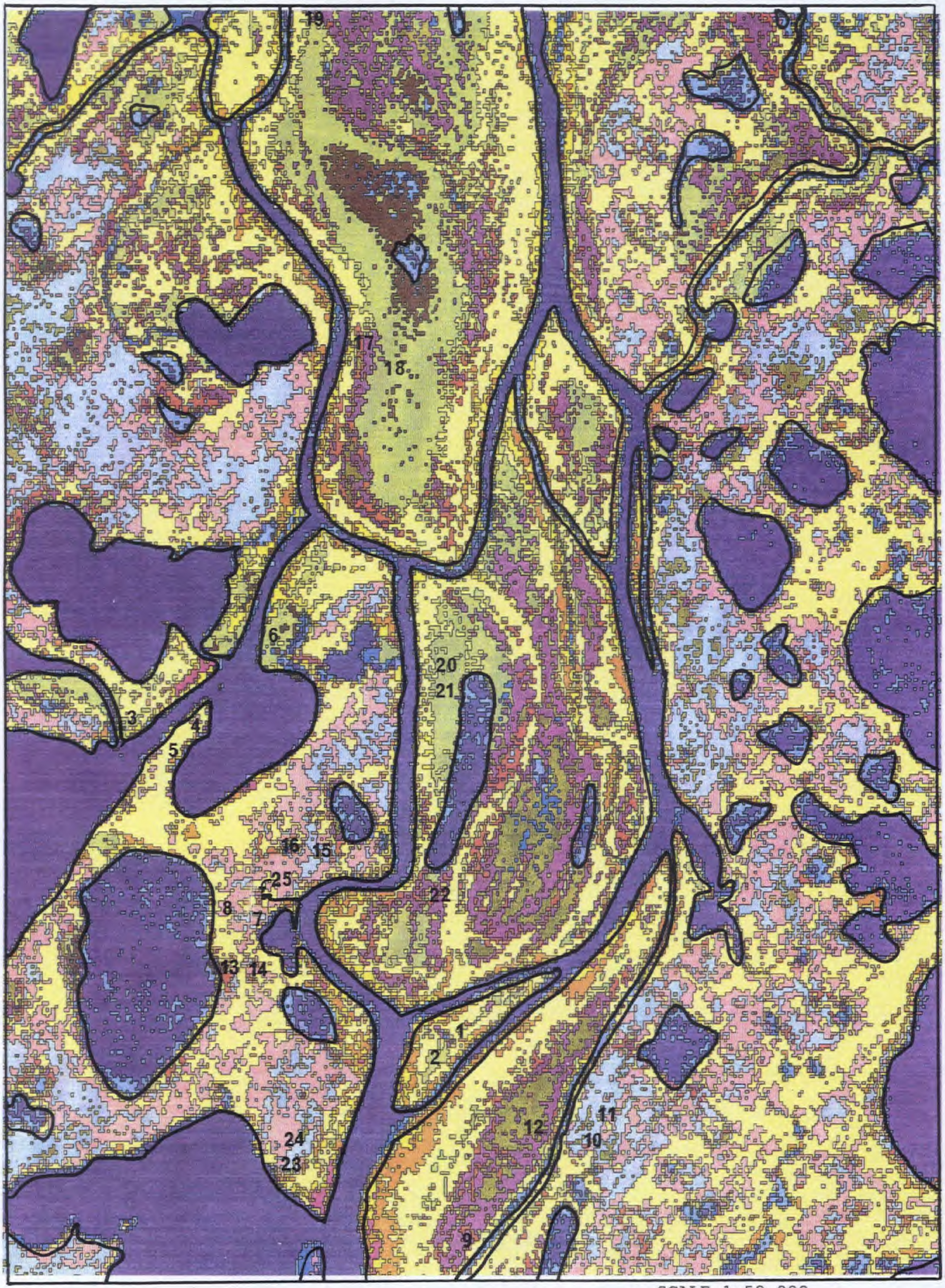
Colour		***Description***
0A8	LCU 1	*open water*
004	LCU 2	*very wet bare mudflats with little or no vegetation cover; very shallow standing water*
02G	LCU 3	*moderately wet to dry mud/silt flats with Equisetum cover low to medium; gravel pads*
400	LCU 4	*high plant cover; willow/sedge uplands and alluvial flats; backslope shrub type*
0G0	LCU 5	*alder and tall willow (Salix alaskensis, S. lanata) dense cover*
[illegible]	LCU 6	*very wet emergents*
G22	LCU 7	*wet emergents (drier than LCU 6 and LCU 13)*
040	LCU 8	*emergents/water complex/; shoreline sites with low plant cover*
G02	LCU 9	*moderately wet, sedge/patterned ground (low-centre polygons)*
220	LCU 10	*Peistocene uplands dry tundra; dwarf shrub; higher*
G82	LCU 11	*willow, sedge, Equisetum/water complex, very wet*
G60	LCU 12	*short to medium willow (Salix lanata)/sedge (Eriophorum); higher plant cover than LCU 13*
0G2	LCU 13	*short to medium willow/sedge (Eriophorum)-wetter and lower plant cover than LCU 12*
202	LCU 14	*Pleistocene uplands tundra; dwarf shrub; lower; tussocks*
G20	LCU 15	*moderately wet, medium to tall willow (Salix richardsonii)/sedge shrubland*
G00	LCU 16	*wet, moderately dense medium to tall willow (Salix Richardsonii)/sedge shrubland*



0 SCALE 1:50,000 2

KILOMETRES

1992



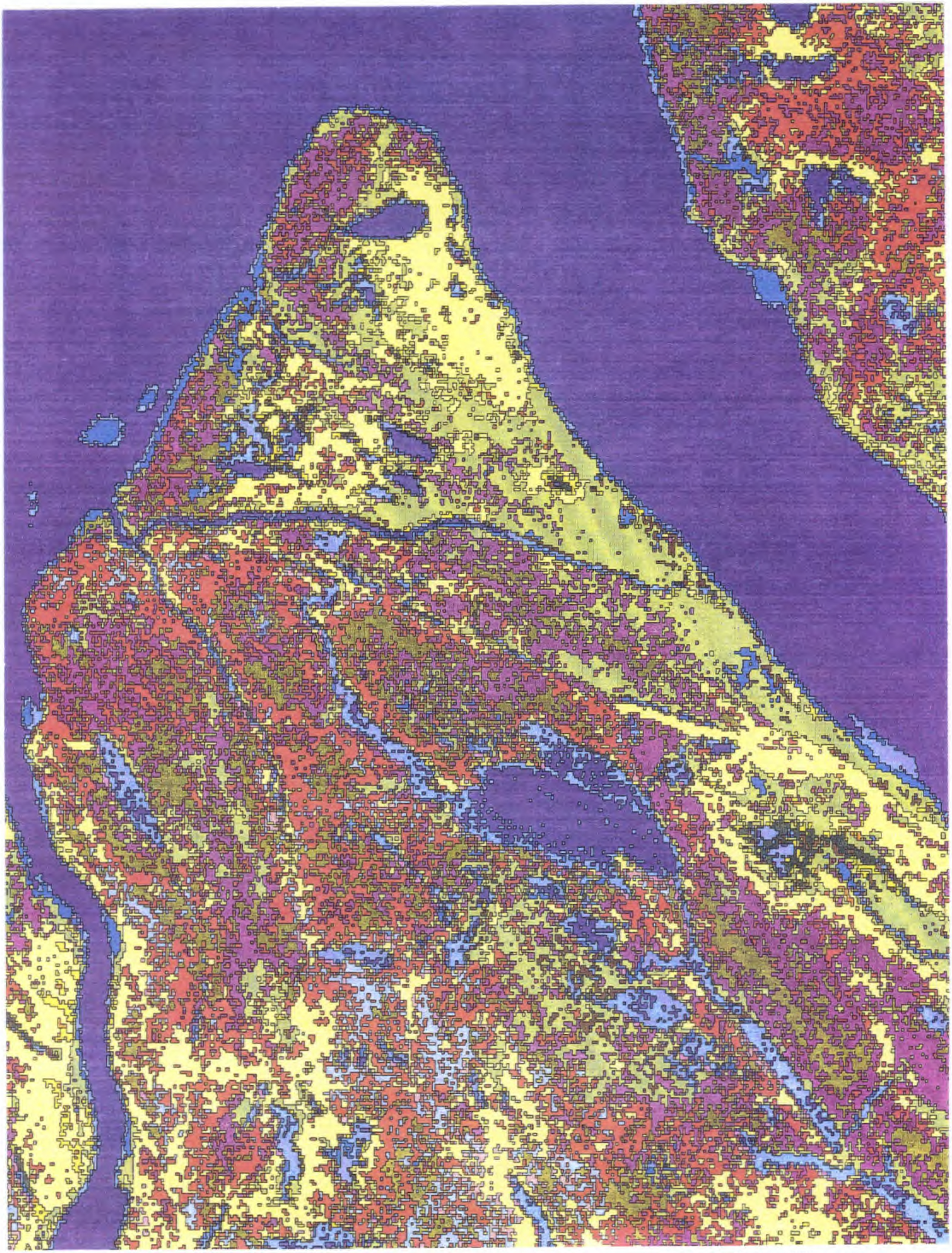
0 SCALE 1:50,000 2

KILOMETRES

Figure 4.4. LANDSAT TM imagery colour Applicon map, 1:50,000 scale: Ellice Island area. *Overlay: 1992 Camp C with all ground plots labelled. LCU=LANDSAT Classification Unit. For more detail on habitat types, see Chapter 2.*

LEGEND

Colour		***Description***
0A8	LCU 1	*open water*
004	LCU 2	*very wet bare mudflats with little or no vegetation cover; very shallow standing water*
02G	LCU 3	*moderately wet to dry mud/silt flats with Equisetum cover low to medium; gravel pads*
400	LCU 4	*high plant cover; willow/sedge uplands and alluvial flats; backslope shrub type*
0G0	LCU 5	*alder and tall willow (Salix alaskensis, S. lanata) dense cover*
G46	LCU 6	*very wet emergents*
G22	LCU 7	*wet emergents (drier than LCU 6 and LCU 13)*
040	LCU 8	*emergents/water complex/; shoreline sites with low plant cover*
G02	LCU 9	*moderately wet, sedge/patterned ground (low-centre polygons)*
220	LCU 10	*Peistocene uplands dry tundra; dwarf shrub; higher*
G82	LCU 11	*willow, sedge, Equisetum/water complex, very wet*
G60	LCU 12	*short to medium willow (Salix lanata)/sedge (Eriophorum); higher plant cover than LCU 13*
0G2	LCU 13	*short to medium willow/sedge (Eriophorum)-wetter and lower plant cover than LCU 12*
202	LCU 14	*Pleistocene uplands tundra; dwarf shrub; lower; tussocks*
G20	LCU 15	*moderately wet, medium to tall willow (Salix richardsonii)/sedge shrubland*
G00	LCU 16	*wet, moderately dense medium to tall willow (Salix Richardsonii)/sedge shrubland*



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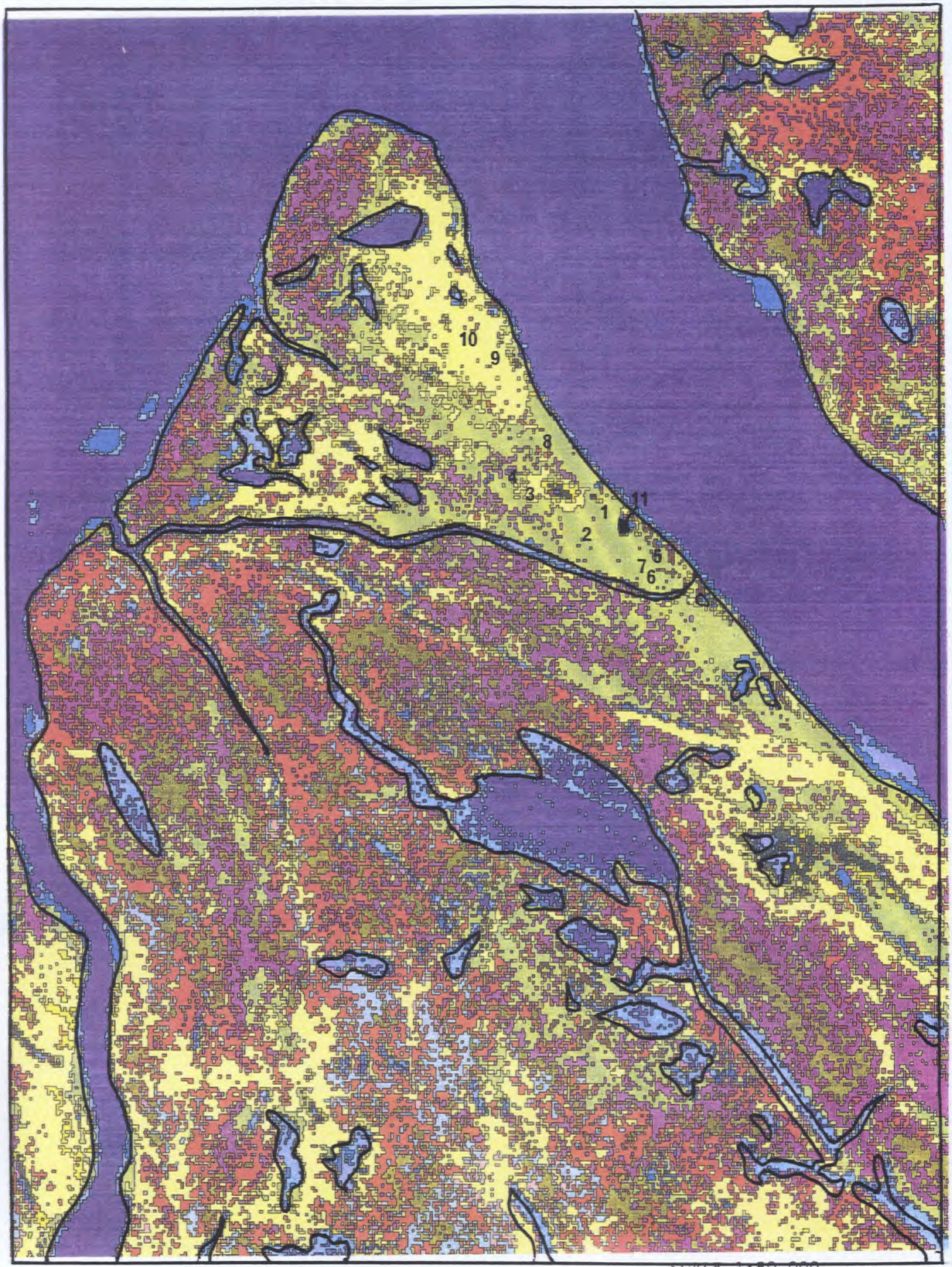
KILOMETRES

1992



0 SCALE 1:50,000 2

KILOMETRES

species, "pairs" were represented by single birds flushed from the plot. Breeding pairs per km^2 was calculated for different (observed) habitat types by multiplying plot means by 25.

4.3. Results

4.3.1. Accuracy of ground surveys

4.3.1.1. ***Within-year variation.*** As noted above, each plot was censused three times in 1991 (Table 4.1, Appendix 4.1). Numbers of shorebirds observed often varied among surveys. However, in over two-thirds of the plots, number of pairs varied by at most one pair across all three surveys of the plot (Table 4.2). Fifteen percent of the plots varied by a maximum of two pairs, and another 15% by more than two pairs. Variation among censuses was greatest in areas of high shorebird density, but plots with a maximum of more than two pairs always contained at least one bird (Table 4.3). Plots with a maximum of one to two pairs always had at least one census with no birds. Overall, about half of the plots showed no difference between surveys, approximately one quarter indicated increases, and a quarter decreases (Table 4.4).

In the most used habitat type, breeding pairs per km^2 varied by 10 to 30% between surveys, and during each census, 50 to 70% of the overall total were seen. The pattern of (observed) habitat use was, however, consistent. Habitat Type VI (low centre polygons and sedge) contained the most birds in all censuses, and Type IV (dense willow) the least, when Common Snipe were excluded (Table 4.5). Densities in Type III habitat (wet sedge/willow) were inconsistent, but only four plots of this type were surveyed in 1991.

4.3.1.2. ***Between-year variation.*** Only two plots were censused in more than one year. Plot 4a (1991), 3C (1992), 1 (1993) contained, overall, one Pectoral Sandpiper (nest), two Stilt Sandpiper and two Hudsonian Godwit pairs in 1991; never less than three pairs of shorebirds per survey (20-28 June 1991). In 1992 (7 July), no shorebirds were seen, and in 1993 (8 July), one Whimbrel was observed in the plot, and one Pectoral Sandpiper just outside it. Plot 4b (1991), 4C (1992), 2 (1993) had one Whimbrel pair (and nest) plus one Red-necked Phalarope male during each census in 1991 (20-28 June), two Red-necked Phalarope males in 1992 (7 July), and a pair of Hudsonian Godwits in 1993 (8 July).

4.3.2. Accuracy of LANDSAT TM habitat type identification

The 13 plots censused in 1991 on Fish Island were at four sites (Fig. 4.1), compared to five sites for 13 plots at Niglintgak Island (Fig. 4.2). LANDSAT Classification Units (LCUs) determined by LANDSAT TM analysis were noted for all 26 plots and clumped into three Habitat Types (Table 4.1, Appendix 4.2): III (west sedge/willow), IV (dense willow), and VI (low centre polygons or "pure" sedge). After the initial census, I also gave each plot an observed LCU and Habitat Type, based on descriptions provided by the LANDSAT analyst, D. Jaques (Table 2.3). The Fish Island and Niglintgak areas were both low and

Table 4.1 Numbers of breeding shorebirds observed in plots, 1991. Habitat types determined by LANDSAT TM analysis, observed habitat types, and numbers of shorebirds seen in plots during each survey. Overall total of shorebirds per plot is the best estimate of number of breeding shorebirds per plot, and includes incidental information not collected during official surveys. Habitat types are described in Table 2.3. Dates of surveys and species observed are listed in Appendix 4.1. Plots are 200 m x 200 m.

			Shorebird "pairs"			
Plot	LANDSAT Habitat Type	Observed Habitat Type	Survey 1	Survey 2	Survey 3	Overall Total
1a	VI	VI	0	0	0	0
b	III	III	1	0	0	1
c	VI	VI	0	0	0	0
d	III	III	0	0	0	0
2a	VI	VI	1	0	1	1
b	III	III	1	1	0	1
c	VI	VI	1	0	0	1
d	III	III	0	0	1	1
3a	IV	IV	0	1	0	1
4a	VI	VI	3	5	3	5
b	VI	VI	2	2	2	2
c	VI	VI	1	1	0	1
d	VI	VI	2	2	3	3
5a	IV	IV	0	0	0	0
b	IV	IV	0	2	1	2
c	IV	IV	0	0	0	0
d	IV	IV	0	0	0	0
6a	VI	VI	3	1	2	3
b	III	VI	1	7	3	8
c	VI	VI	6	1	7	7
d	VI	VI	1	9	8	9
7a	IV	IV	0	0	0	0
b	IV	IV	0	0	0	0
8a	VI	VI	0	2	0	2
b	VI	VI	3	4	1	4
9a	III	IV	0	0	0	0

Table 4.2. Variation in numbers of shorebirds observed per plot across surveys, 1991. Change in number per plot refers to maximum variation in number of pairs observed across all three surveys of a plot.

	Change in number of shorebird "pairs" per plot		
	≤ 1 "pair"	2 "pairs"	> 2 "pairs"*
No. of plots	18	4	4
% of plots	69%	15%	15%

*Ranged from a difference of 3 to 8 birds per plot. All of these plots were in an area where Red-necked Phalaropes were very common.

Table 4.3. Variation among surveys in a plot, 1991: consistency of presence or absence of breeding shorebirds.

Shorebird(s) seen per plot	No. birds	Number of plots Maximum 1-2 "pairs"	Number of plots Minimum > 2 "pairs"
Never (0/3 censuses)	9	-	-
Sometimes (1-2 censuses)	-	9	0
Always (3/3 censuses)	-	0	8

Table 4.4. Variation among ground censuses, 1991: differences between surveys within a plot.

	Total plots	Difference between censuses (% of plots)		
		No change	Decrease	Increase
Census 1-2	26	14 (54%)	5 (19%)	7 (27%)
Census 1-3	26	14 (54%)	6 (23%)	6 (23%)
Census 2-3	26	12 (46%)	9 (35%)	5 (19%)

Table 4.5. Total numbers of breeding shorebird pairs per km^2 (plot mean x 25) in different (observed) habitat types, 1991. Habitat types are defined in Table 2.3.

ALL SHOREBIRDS	Total/km^2			
Habitat type	Survey 1	Survey 2	Survey 3	"Overall Total"
VI (polygons or sedge)	43	60	54	84
IV (dense willow)	0	10	3	10
III (wet sedge/willow)	12	6	6	19

EXCLUDING COMMON SNIPE	Total/km^2			
Habitat type	Survey 1	Survey 2	Survey 3	"Overall Total"
VI (polygons or sedge)	43	57	52	77
IV (dense willow)	0	0	0	0
III (wet sedge/willow)	12	6	0	12

primarily damp to wet. They included no upland sites.

Habitat Types of all 13 plots in the Fish Island area were correctly identified by the LANDSAT analysis (Table 4.6). Two of the 13 plots on Niglintgak Island were misidentified: one plot observed as Type VI (sedge) and another seen as Type IV (dense willow) were both defined by LANDSAT analysis as Type III (wet sedge/willow).

In 1992, the 61 plots were well scattered around the three camp sites (Figs. 4.1, 4.3, 4.4): Taglu area (25 plots), Camp Farewell area (25 plots), and northern Ellice Island (11 plots). Nine plots consisted of gravel pads and were identified correctly by the LANDSAT analysis. These are excluded from further analyses as eight of the nine were artificial manmade habitats, and contained only one species of shorebird, Semipalmated Plovers, which were never seen on any other plot habitat types. The remaining plots included Habitat Types II, IV and VI mentioned above, as well as II (emergent vegetation) and V (upland tundra) (Appendices 4.3, 4.4).

In the Taglu area, which was very near the Fish Island site, only three of 18 plots were misidentified (Table 4.7). Many plots were low-lying habitats, but uplands were also surveyed here. One plot identified as Type I (mudflats or gravel pads), and one identified as Type II (emergents) were observed as Type VI (polygons or sedge). One plot observed as Type VI was identified by LANDSAT as type III (wet sedge/willow).

The Camp Farewell area was the farthest inland, and this region contained the greatest proportion of upland tundra of any area examined. Here 11 of 24 plots were misidentified by the LANDSAT analysis. Three plots observed as Type V (upland tundra), one plot seen as Type III (wet sedge/willow), and one Type VI (polygons or sedge) were all identified by LANDSAT as IV (dense willow). Two plots observed as Type III were identified as VI, and two of Type VI, around pond margins, were described by LANDSAT analysis as Type V. Two other plots of Type VI were misidentified: one as Type II and the other as Type III.

Northern Ellice Island was the most coastal of all areas censused, and consisted entirely of low-lying sites, with no upland tundra. Eight of 10 plots were misidentified as to observed habitat type. Three plots of Type III and two of Type II were described by LANDSAT at Type VI. Two plots observed as Type III and one as Type II were defined as Type IV.

A chi-square goodness-of-fit test was used to determine whether significant differences in accuracy of LANDSAT-defined habitat types existed among the five sampling areas. Although the overall chi-square was not significant (chi-square=7.03, df=4, p>0.10), calculation of Bonferroni 95% confidence intervals indicated that fewer plots than expected were correctly identified to Habitat Type for the Ellice Island area (Appendix 4.5). Significance of Bonferroni confidence intervals is not dependent upon significance of the overall chi-square (Neu et al. 1974, Byers et al. 1984, White and Garrot 1990).

4.3.3. <u>Importance of habitat type to breeding shorebirds</u>

4.3.3.1. Presence/absence data. In 1991, the percentage of plots with shorebird(s) was significantly higher in LANDSAT-identified or observed Habitat Type VI (low centre polygons or "pure" sedge) than Types IV and III combined (dense willow, wet sedge/willow)

Table 4.6. Percent accuracy of habitat types defined by LANDSAT TM analysis versus observed habitat types, 1991. Habitat types are defined in Table 2.3. Locations of camps and plots are shown in Figures 1.1, 4.1 and 4.2.

Location	No. Plots	% Correctly Identified by LANDSAT (N)	Dist. from Fish Island area (km)
Fish Island	13	100 (13)	0
Niglintgak Island	13	85 (11)*	15

*LANDSAT described two plots as Habitat type III (wet sedge/ willow): one was observed as type VI (sedge) and the other as type IV (dense willow).

Table 4.7. Percent accuracy of habitat types defined by LANDSAT TM analysis versus observed habitat types, excluding gravel pads, 1992. Habitat types are defined in Table 2.3. Locations of camps and plots are shown in Figures 1.1, 4.1, 4.3, and 4.4.

Location	Camp	No. Plots	% Correctly Identified by LANDSAT (N)	Distance from Fish Island area (km)
Taglu area	C	18	83% (15)[1]	0
Camp Farewell area	A	24	54% (13)[2]	10
North Ellice Island	B	10	20% (2)[3]	30

[1] Habitat types misidentified: 1 gravel pad/disturbed ground (I) observed as sedge (VI); 1 emergents (II) observed as polygons/sedge (VI); 1 polygons/sedge (VI) observed as wet sedge/willow (III).

[2] Habitat types misidentified: 5 plots dense willow (IV) observed as: upland tundra (V: 3 plots), wet sedge/willow (III: 1 plot) and sedge (VI: 1 plot); 2 plots upland tundra (around pond margins) observed as sedge (VI); 2 plots polygons/sedge (VI) observed as wet sedge/willow (III); 1 plot emergents (II) observed as sedge (VI); and 1 plot wet sedge/willow (III) observed as sedge (VI).

[3] Habitat types misidentified: 5 plots polygons/sedge (VI) observed as: wet sedge/willow (III: 3 plots) and emergents (II: 2 plots); 3 plots dense willow (IV) observed as: wet sedge/willow (III: 2 plots) and emergents (II: 1 plot).

in survey 1, but not in survey 2, survey 3, or overall (Tables 4.8, 4.9, Fig. 4.5). When Common Snipe were excluded from the analysis, Habitat Type VI had a significantly higher percentage of plots with shorebird(s) than Type IV&III in all but survey 2 using LANDSAT-identified Habitat Types (Table 4.10), and in all surveys and overall, with observed Habitat Types (Table 4.11, Fig. 4.6).

In 1992, with many plots misidentified to Habitat Type by the LANDSAT analysis, there was no significant relationship between percentage of plots with shorebirds, and Habitat Type (combining Types I, II, III and IV), including or excluding snipe (Table 4.12). However, when observed Habitat Type was used, Type VI had the highest percentage of plots with shorebird(s), and the relationship with Habitat Type (Types II, III, and IV combined) was significant, including or excluding Common Snipe (Table 4.13, Fig. 4.7).

4.3.3.2. ***Number of breeding pairs***. Mean shorebird pairs per plot was greatest in Habitat Type VI (polygons or sedge) in 1991, significantly so in surveys 1 and overall (LANDSAT-identified and observed Habitat Types, ANOVA with GT2 family error test for differences between Habitat Types, Tables 4.8, 4.9, Fig. 4.8). When Common Snipe were excluded, Type VI (LANDSAT or observed) again had the greatest number of shorebirds per plot, significant in survey 1 and overall (ANOVA significant in all comparisons in observed; Tables 4.10, 4.11, Fig. 4.9).

Using LANDSAT-identified Habitat Types in 1992, there was a significant relationship between number of shorebird pairs per plot and habitat, but the result was opposite to that expected, with more breeding shorebirds in Habitat Type I&II (bare ground, emergents), than Type VI (polygons and sedge) (Table 4.12). When snipe were excluded, the significance was lost.

Number of breeding shorebirds was again, in agreement with the 1991 results, highest in observed Habitat Type VI in 1992, including or excluding snipe (Table 4.13, Fig. 4.10). Type VI plots had significantly more shorebirds per plot that Type V (upland tundra) or Type III (west sedge/willow). The number of plots for Types IV (dense willow) and II (emergents) was considerably less, so it is not surprising that differences from Type VI were not significant.

Although number of breeding pairs was low for Habitat Type V (upland tundra), this result is somewhat misleading. There were two type of uplands defined by LANDSAT: LCU 10 and LCU 14. The LANDSAT TM analyst (see Chap 2) described LCU 14 as drier than LCU 10, with a high cover of cottongrass, *Dryas* and *Carex*. In my observations, LCU 10 was higher and drier than 14, with a dense shrubby cover of birch and aspen. Any water present was in small, deep depressions. LCU 14, on the other hand, was most often an upland "valley"; lower and wetter than LCU 10, with hummocky grassy clumps of vegetation, and often small creeks.

No shorebirds were found breeding in LCU 10: none were present in any of the 10 plots. However shorebird(s) were observed in three of the six LCU 14 plots, with a total of five pairs present (Mean=0.83 pairs per plot, SD=1.17). Three of these pairs were Semipalmated Sandpipers (three different plots, 2 nests, plus one with chick), one Lesser Golden Plover (nest), and one Stilt Sandpiper (nest).

Table 4.8. Number of breeding shorebird pairs seen per plot in different habitat types, as identified by LANDSAT, 1991. Habitat types are defined in Table 2.3. Plots were 200 m x 200 m.

		Survey 1		Survey 2		Survey 3		Overall Total	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	13	10 (77%)	1.77 (1.69)	9 (69%)	2.08 (2.60)	8 (62%)	2.08 (2.66)	11 (85%)	2.92 (2.72)
IV (dense willow)	7	0 (0%)	0.00 (0.00)	2 (29%)	0.43 (0.79)	1 (14%)	0.14 (0.38)	2 (29%)	0.43 (0.79)
III (wet sedge/ willow)	6	3 (50%)	0.50 (0.55)	2 (33%)	1.33 (2.80)	2 (33%)	0.67 (1.21)	4 (67%)	1.83 (3.06)

[1]G-tests with William's correction; combining habitat types IV and III; df=1; Survey 1 ($G = 3.91$, $p < 0.05$), Survey 2 ($G = 1.94$, $p > 0.10$), Survey 3 ($G = 2.31$, $p > 0.10$), overall total ($G = 1.46$, $p > 0.10$).

[2]Anova, GT2 family error test, $p < 0.05$; Survey 1 ($p = 0.01$, GT2 VI > IV); Survey 2 ($p = 0.33$), Survey 3 ($p = 0.11$), overall total ($p = 0.12$).

Table 4.9. Number of breeding shorebird pairs seen per plot in different (observed) habitat types, 1991. Habitat types are defined in Table 2.3. Plots were 200 m x 200 m.

		Survey 1		Survey 2		Survey 3		Overall Total	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	14	11 (79%)	1.71 (1.64)	10 (71%)	2.43 (2.82)	9 (64%)	2.14 (2.57)	12 (86%)	3.29 (2.95)
IV (dense willow)	8	0 (0%)	0.00 (0.00)	2 (25%)	0.38 (0.74)	1 (12%)	0.12 (0.35)	2 (25%)	0.38 (0.74)
III (wet sedge/ willow)	4	2 (50%)	0.50 (0.58)	1 (25%)	0.25 (0.50)	1 (25%)	0.25 (0.50)	3 (75%)	0.75 (0.50)

[1]G-tests with William's correction, combining habitat types IV and III, df=1; Survey 1 ($G = 5.44$, $p < 0.025$); Survey 2 ($G = 2.92$, $p < 0.10$); Survey 3 ($G = 3.74$, $p < 0.10$), Overall total ($G = 1.96$, $p < 0.10$).

[2]Anova, GT2 family error test $p < 0.05$; Survey 1 ($p = 0.01$, GT2 VI > IV); Survey 2 ($p = 0.07$); Survey 3 ($p = 0.05$); Overall total ($p = 0.02$, GT2, VI > IV).

Figure 4.5. Percentage of plots with breeding shorebird(s) in different observed habitat types, 1991. *See text for explanation of "overall" category and for more detail on habitat types. Numbers above bars represent number of plots with shorebird(s).*

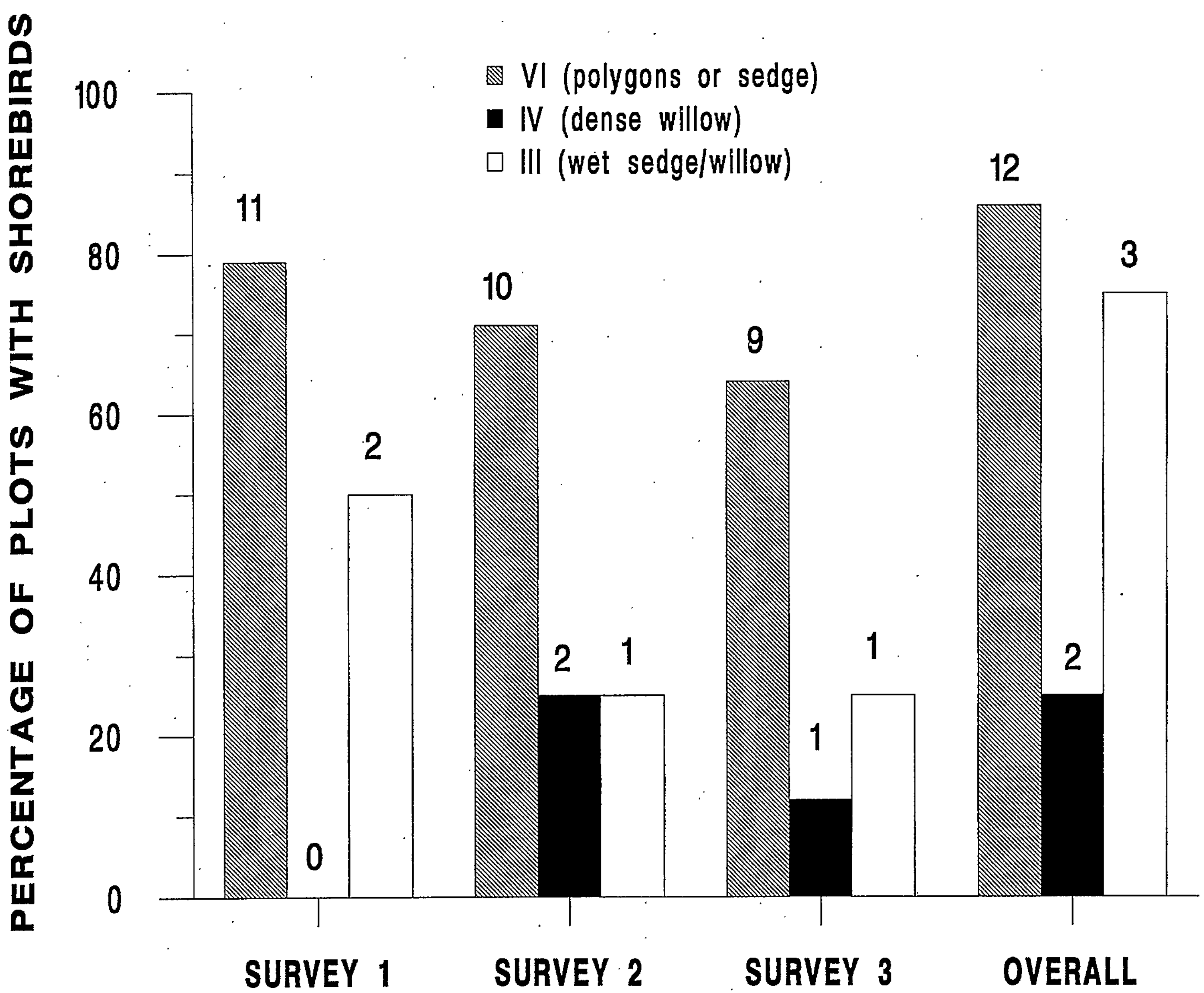

PERCENTAGE OF PLOTS WITH SHOREBIRDS
100
80
60
40
20
0
VI (polygons or sedge)
IV (dense willow)
III (wet sedge/willow)
11
0
2
10
2
1
9
1
1
12
2
3
SURVEY 1
SURVEY 2
SURVEY 3
OVERALL

Table 4.10. Number of breeding shorebird pairs (excluding Common Snipe) seen in different habitat types identified by LANDSAT, 1991. Habitat types are defined in Table 2.3. Plots were 200 m x 200 m.

		Survey 1		Survey 2		Survey 3		Overall Total	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	13	10 (77%)	1.77 (1.69)	8 (62%)	2.43 (1.92)	8 (62%)	2.08 (2.66)	11 (85%)	2.77 (2.55)
IV (dense willow)	7	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)
III (wet sedge/ willow)	6	3 (50%)	0.50 (0.55)	2 (33%)	1.33 (2.80)	1 (17%)	0.33 (0.82)	3 (50%)	1.50 (2.74)

[1]G-tests with William's correction, combining habitat types IV and III, df=1; Survey 1 ($G = 3.91$, $p < 0.05$), Survey 2 ($G = 3.78$, $p < 0.10$); Survey 3 ($G = 6.08$, $p < 0.025$); overall total ($G = 4.77$, $p < 0.05$).

[2]Anova, GT2 family error test $p < 0.05$; Survey 1 ($p = 0.01$, GT2 VI > IV); Survey 2 ($p = 0.20$); Survey 3 ($p = 0.06$), overall total ($p = 0.05$, GT2 VI > IV).

Table 4.11. Number of breeding shorebird pairs seen per plot (excluding Common Snipe) in different (observed) habitat types, 1991. Habitat types are defined in Table 2.3. Plots were 200 m x 200 m.

		Survey 1		Survey 2		Survey 3		Overall Total	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	14	11 (79%)	1.71 (1.64)	9 (64%)	2.29 (2.70)	9 (64%)	2.07 (2.56)	12 (86%)	3.07 (2.70)
IV (dense willow)	8	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)	0 (0%)	0.00 (0.00)
III (wet sedge/ willow)	4	2 (50%)	0.50 (0.58)	1 (25%)	0.25 (0.50)	0 (0%)	0.00 (0.00)	2 (50%)	0.50 (0.58)

[1]G-tests with William's correction, combining habitat types IV and III, df=1; Survey 1 ($G = 5.44$, $p < 0.025$); Survey 2 ($G = 6.08$ $p < 0.025$); Survey 3 ($G = 8.42$, $p < 0.005$), overall total ($G = 6.34$, $p < 0.025$).

[2]Anova GT2 family error test $p < 0.05$; Survey 1 ($p = 0.02$, GT2 VI > IV); Survey 2 ($p = 0.04$); Survey 3 ($p = 0.04$); overall total ($p = 0.005$, GT2 VI > IV).

Figure 4.6. Percentage of plots with breeding shorebird(s) (excluding Common Snipe) in different observed habitat types, 1991. *See text for explanation of "overall" category and for more detail on habitat types. Numbers above bars represent number of plots with shorebird(s).*

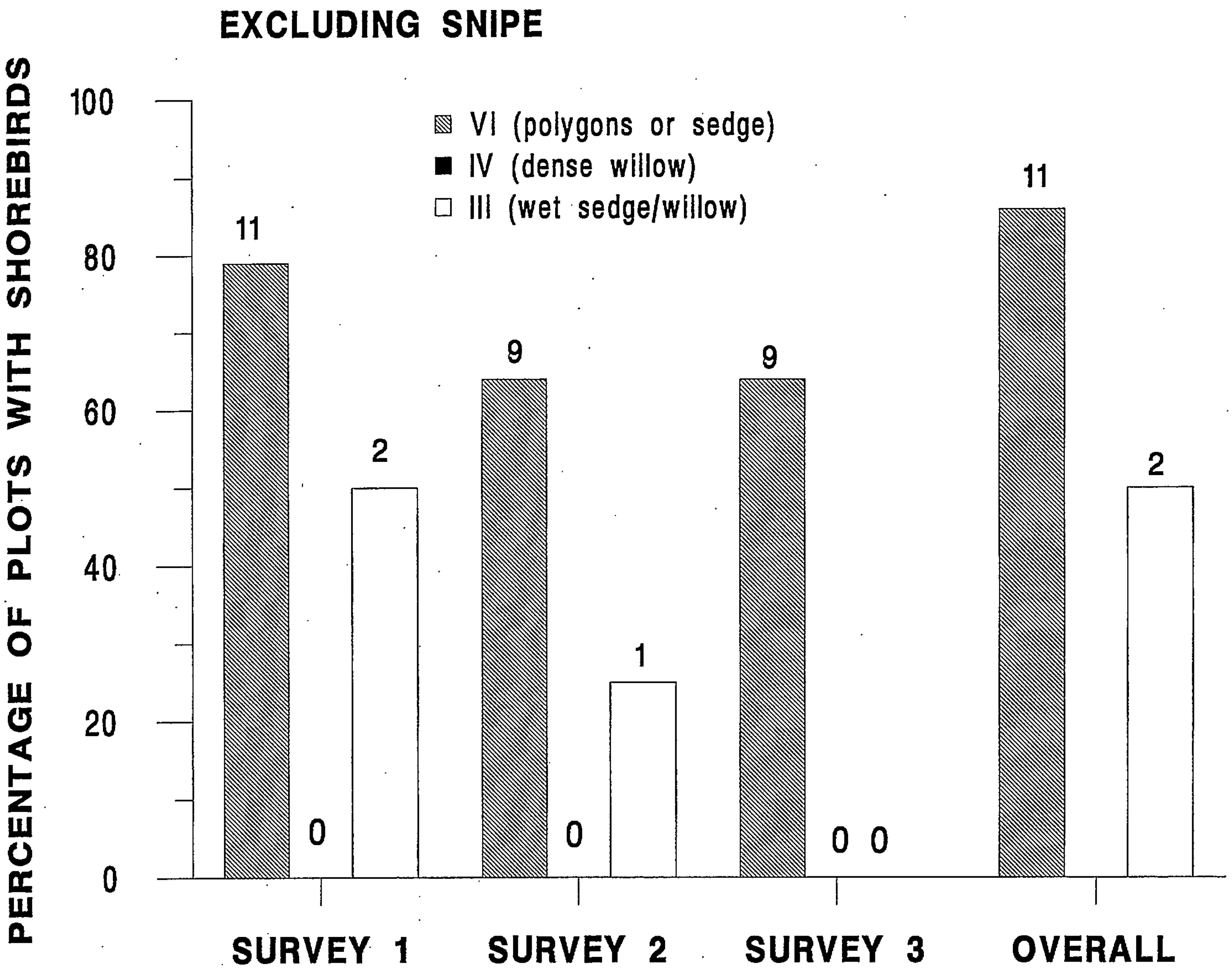

EXCLUDING SNIPE
PERCENTAGE OF PLOTS WITH SHOREBIRDS
100
80
60
40
20
0
VI (polygons or sedge)
IV (dense willow)
III (wet sedge/willow)
11
0
2
9
0
1
9
0 0
11
2
SURVEY 1
SURVEY 2
SURVEY 3
OVERALL

Table 4.12. Number of breeding shorebird pairs seen per plot in different habitat types identified by LANDSAT, 1992. Habitat types are defined in Table 2.3. Plots were 200 m x 200 m.

		All Shorebirds		Excluding Common Snipe	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	17	4 (24%)	0.41 (0.80)	4 (24%)	0.35 (0.70)
V (upland tundra)	14	5 (36%)	1.00 (1.96)	5 (36%)	1.00 (1.96)
IV (dense willow)	10	3 (30%)	0.05 (0.97)	3 (30%)	0.50 (0.97)
III (wet sedge/ willow)	7	2 (29%)	0.86 (1.86)	1 (29%)	0.50 (0.71)
I&II (emergents, gravel)	4	4 (100%)	2.75 (1.26)	4 (100%)	2.25 (1.50)

[1]G-tests with William's correction, combining habitat types I, II, III and IV, df=2; all shorebirds ($G = 1.05$, $p > 0.50$), excluding snipe ($G = 0.69$, $p >$ 0.50.

[2]Anova, GT2 family error test $p < 0.05$, all shorebirds ($p = 0.053$, GT2 II&I > VI), excluding snipe ($p = 0.18$).

Table 4.13. Number of breeding shorebird pairs seen per plot in different (observed) habitat types, 1992. Habitat types are defined in Table 2.3.

		All Shorebirds		Excluding Common Snipe	
Habitat type	# plots	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)	[1]# Plots with bird(s) (%)	[2]Mean pairs per plot (S.D.)
VI (polygons or sedge)	16	11 (69%)	1.94 (1.98)	11 (69%)	1.75 (1.98)
V (upland tundra)	15	3 (20%)	0.33 (0.82)	3 (20%)	0.33 (0.82)
IV (dense willow)	2	1 (50%)	0.50 (0.71)	1 (50%)	0.50 (0.71)
III (wet sedge/ willow)	15	2 (13%)	0.13 (0.35)	1 (7%)	0.07 (0.26)
II (emergents)	4	1 (25%)	1.00 (2.00)	1 (25%)	1.00 (2.00)

[1]G-tests with William's correction, combining habitat types II, III and IV, df=2; all shorebirds ($G = 6.93$, $p < 0.05$), excluding snipe ($G = 8.33$, $p < 0.025$).

[2]Anova GT2 family error test $p < 0.05$, all shorebirds ($p = 0.004$, GT2 VI > V, VI > III), excluding snipe ($p = 0.01$, GT2 VI > V, VI > III).

Figure 4.7. ***Percentage of plots with breeding shorebird(s) in different observed habitat types, 1992.*** *See text for more detail on habitat types. Numbers above bars represent number of plots with shorebird(s).*

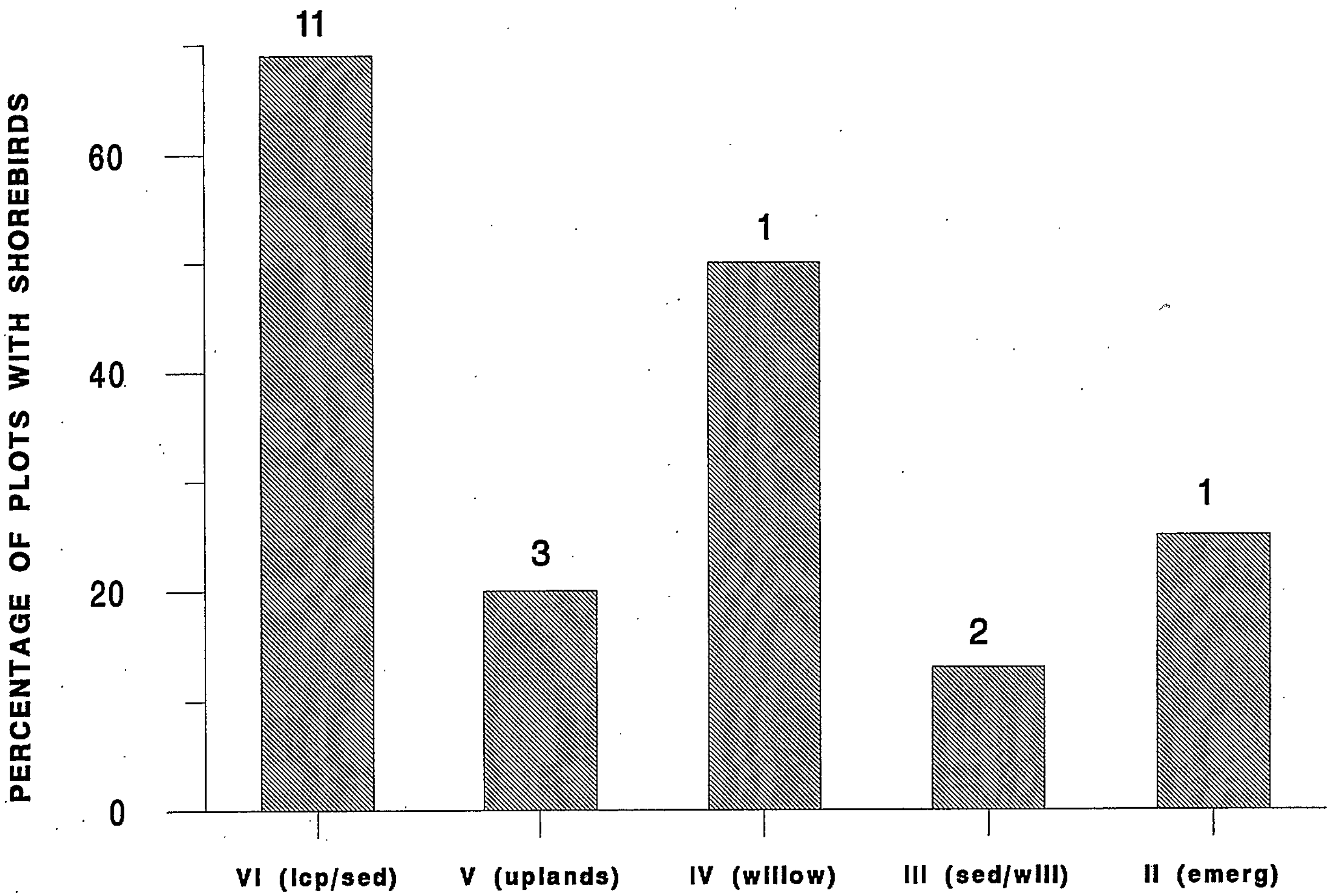
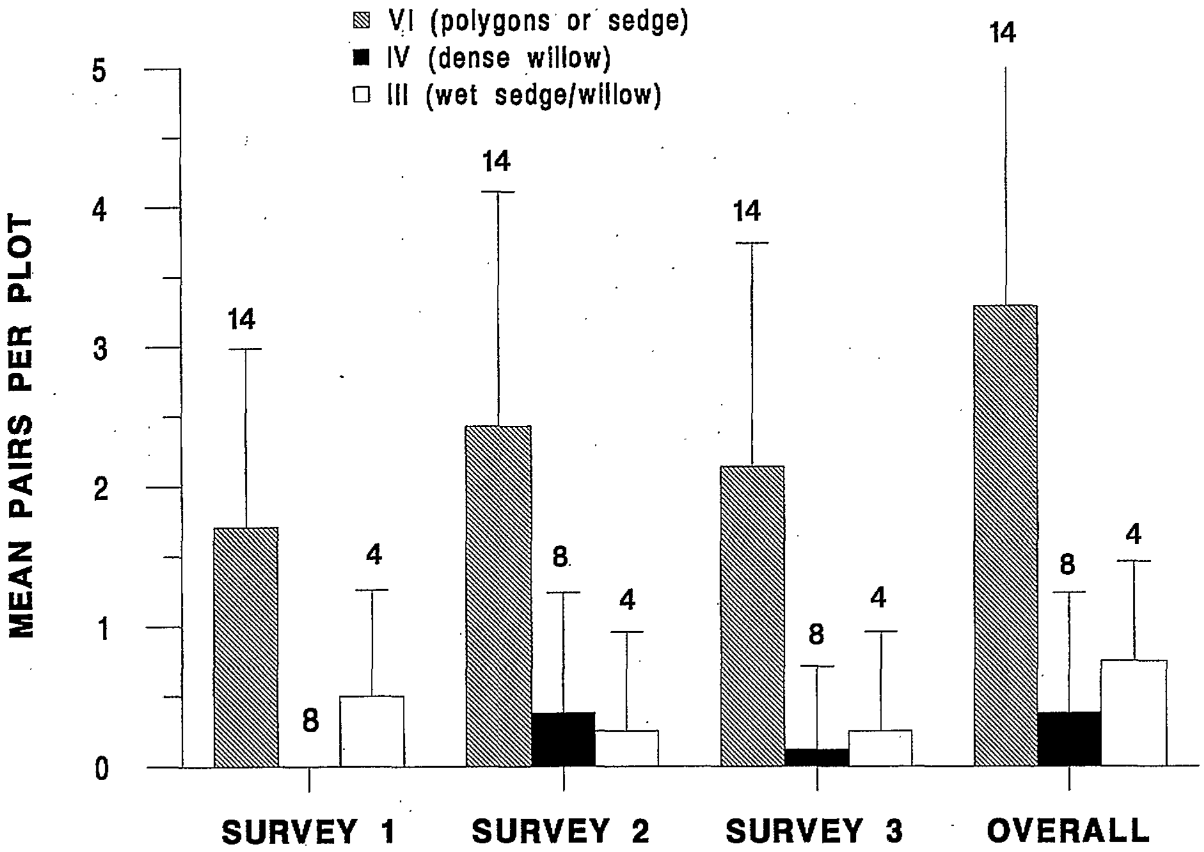

PERCENTAGE OF PLOTS WITH SHOREBIRDS
60
40
20
0
11
3
1
2
1
VI (lcp/sed)
V (uplands)
IV (willow)
III (sed/will)
II (emerg)

Figure 4.8. Mean pairs of breeding shorebirds per plot in different observed habitat types, 1991. *See text for explanation of "overall" category, more detail on habitat types, and definition of "pairs". Numbers above bars represent number of plots surveyed.*



VI (polygons or sedge)
IV (dense willow)
III (wet sedge/willow)
MEAN PAIRS PER PLOT
0
1
2
3
4
5
14
8
4
14
8
4
14
8
4
14
8
4
SURVEY 1
SURVEY 2
SURVEY 3
OVERALL

Figure 4.9. Mean pairs of breeding shorebirds (excluding Common Snipe) per plot in different observed habitat types, 1991. *See text for explanation of "overall" category, more detail on habitat types, and definition of "pairs". Numbers above bars represent number of plots surveyed.*

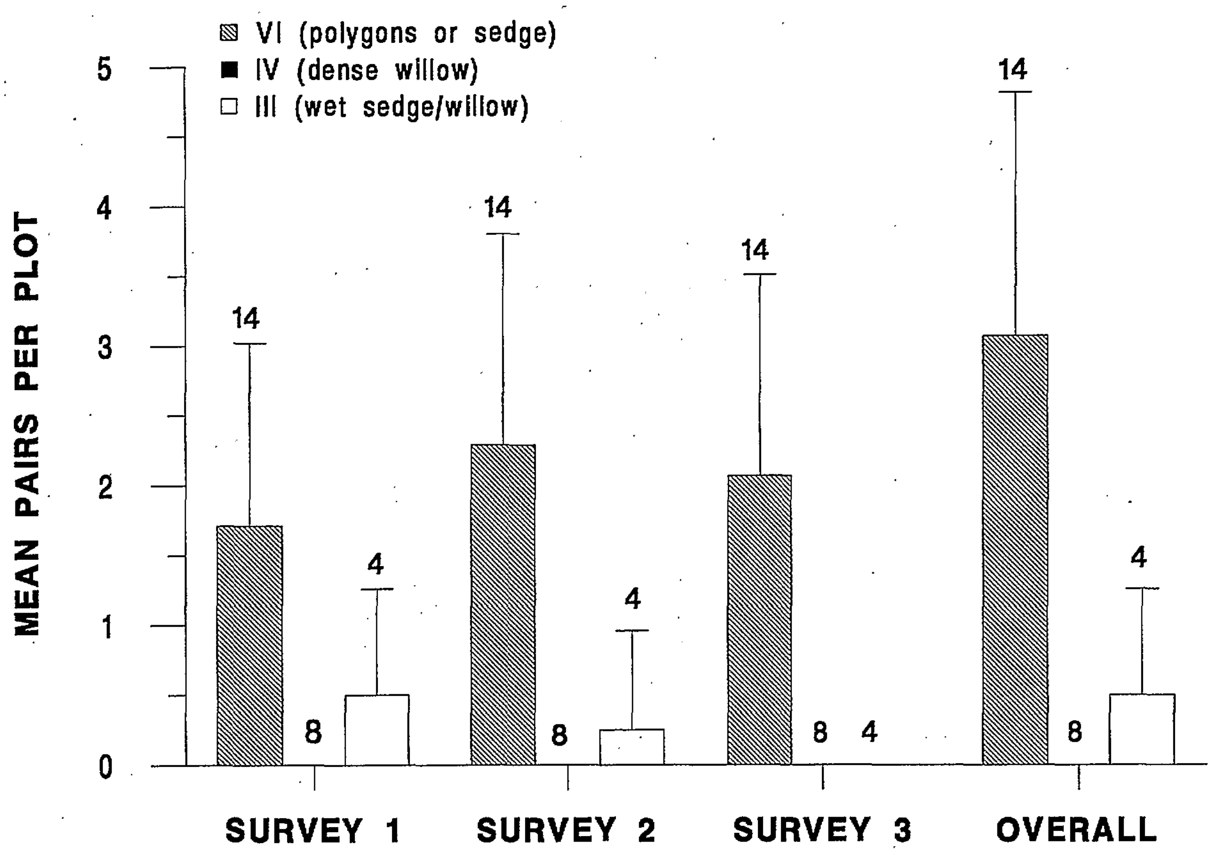
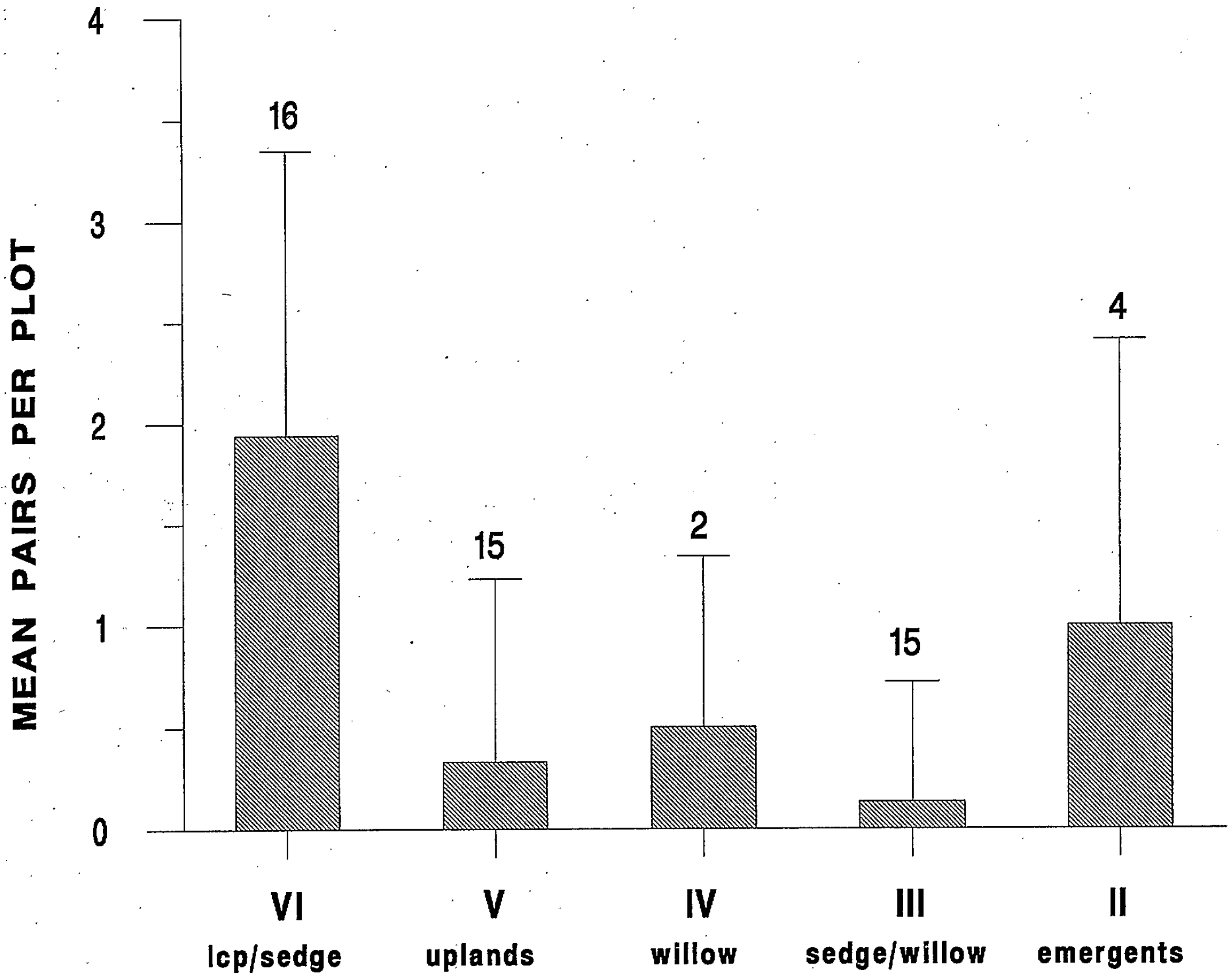

VI (polygons or sedge)
IV (dense willow)
III (wet sedge/willow)
MEAN PAIRS PER PLOT
0
1
2
3
4
5
14
8
4
14
8
4
14
8
4
14
8
4
SURVEY 1
SURVEY 2
SURVEY 3
OVERALL

Figure 4.10. ***Mean pairs of breeding shorebirds per plot in different observed habitat types, 1992.*** *See text for more detail on habitat types and definition of "pairs". Numbers above bars represent number of plots surveyed.*



MEAN PAIRS PER PLOT
4
3
2
1
0
16
15
2
15
4
VI
lcp/sedge
V
uplands
IV
willow
III
sedge/willow
II
emergents

4.3.4. Species densities in different habitats

Densities of each shorebird species observed during censuses were calculated for each Habitat Type. Densities were calculated as pairs per km^2 (plot means X 25), to obtain whole numbers. Results for 1991 and 1992 were very similar (Tables 4.14, 4.15). In Habitat Type VI (low centre polygons or sedge), Red-necked Phalaropes were the most common shorebirds, followed by Stilt Sandpipers and then Common Snipe. Whimbrel and Semipalmated Sandpipers were sometimes present, occasionally Hudsonian Godwits, Lesser Golden Plovers and Pectoral Sandpipers, and rarely, Long-billed Dowitchers. This concurs with incidental observations in non-plot sites.

Most Type IV (dense willow) plots were censused in 1991, when only Common Snipe were observed in these plots. In 1992, one Red-necked Phalarope male and day-old chicks were found in a small patch of "pure" sedge in one of the two observed Type IV plots. Aside from such small patches of other habitat, no shorebirds other than snipe were ever found in dense willow, even during much incidental travel through it to other habitat types. In fact, even snipe were not common in the plots, although males were often seen and heard winnowing overhead.

All Type V (upland tundra) plots were censused in 1992. As noted in the previous section, "high" bushy uplands held no breeding shorebirds during the surveys. However, "low" wetter uplands held Semipalmated Sandpipers and Lesser Golden Plovers as often as did Type VI habitat. A Stilt Sandpiper nest was also found in these low uplands.

Shorebirds were not common in Type III (wet sedge/willow) or Type II (emergents) plots, except in small patches of habitat with a reasonable understorey (not too wet or too bare), where Red-necked Phalaropes were sometimes found. One snipe was also flushed from this habitat.

The only shorebirds ever found breeding on gravel pads were Semipalmated Plovers, with up to two pairs per pad. Of the 10 gravel pads or beaches examined, four held at least one pair of Semipalmated Plovers.

Combining the data from 1991 and 1992 plots, species densities in Type VI plots (low centre polygons or "pure" sedge) ranged from Red-necked Phalaropes at 40.0 pairs/km^2, to Lesser Golden Plovers and Long-billed Dowitchers at 0.8 pairs/km^2 (Table 4.16). The most common species in the uplands (Type V) was Semipalmated Sandpiper at 5.0 pairs/km^2, and in dense willow (Type IV), Common Snipe at 7.5 pairs/km^2. Red-necked Phalaropes were again the most common species in Habitat Types II&III (emergents, wet sedge/willow), at 6.5 pairs/km^2.

As noted in Section 4.2 above, LANDSAT TM analysis often misidentified Habitat Types. Therefore, calculations of amount of total area covered by each habitat in the study area (Table 2.4) are undoubtably incorrect. If misclassification followed a consistent pattern (eg. in X% of plots, Type VI was always called Type III), one could correct area per Habitat Type. However, there is no such simple pattern (eg. some Type VI were observed as III, but some III as VI). Therefore, I used the original LANDSAT TM analysis determination of km^2/Habitat Type to roughly calculate numbers of each shorebird species breeding in the outer Mackenzie Delta (Table 4.17). Values ranged from a high of 61,862 adult Red-necked Phalaropes (30,841 pairs), to a low of 624 Long-billed Dowitchers (312 pairs). Total adult

Table 4.14. Estimated densities of shorebird species in different (observed) habitat types, 1991. Habitat types are described in Table 2.3. Numbers in parentheses are overall total number of breeding pairs/total plots (200 m x 200 m) censused. Species are listed in Table 1.1.

	Habitat type (pairs/km^2)		
Species	VI (polygons or sedge)	IV (willow)	III (wet willow/sedge)
COSN	5 (3/14)	9 (3/8)	6 (1/4)
HUGO	4 (2/14)	0 (0/8)	6 (1/4)
LBDO	2 (1/14)	0 (0/8)	0 (0/4)
PESA	2 (1/14)	0 (0/8)	0 (0/4)
RNPH	52 (29/14)	0 (0/8)	6 (1/4)
SESA	4 (2/14)	0 (0/8)	0 (0/4)
STSA	9 (5/14)	0 (0/8)	0 (0/4)
WHIM	5 (3/14)	0 (0/8)	0 (0/4)

Table 4.15. Estimated densities of shorebird species in different (observed) habitat types, 1992. Habitat types are described in Table 2.3. Numbers in parentheses are number of breeding pairs per total plots (200 m X 200 m) censused. Species are listed in Table 1.1.

	Habitat type (pairs/km^2)				
Species	VI (polygons or sedge)	V (uplands)	IV (willow)	III&II (wet sedge/willow/ emergents)	I (gravel)
COSN	5 (3/16)	0 (0/15)	0 (0/2)	1 (1/19)	0 (0/9)
HUGO	1 (1/32)[1]	0 (0/15)	0 (0/2)	0 (0/19)	0 (0/9)
LBDO	0 (0/16)	0 (0/15)	0 (0/2)	0 (0/19)	0 (0/9)
LEGP	2 (1/16)	2 (1/15)	0 (0/2)	0 (0/19)	0 (0/9)
PESA	2 (1/16)	0 (0/15)	0 (0/2)	0 (0/19)	0 (0/9)
RNPH	30 (19/16)	0 (0/15)	12 (1/2)[2]	7 (5/19)	0 (0/9)
SEPL	0 (0/16)	0 (0/15)	0 (0/2)	0 (0/19)	14 (5/9)
SESA	5 (3/16)	5 (3/15)	0 (0/2)	0 (0/19)	0 (0/9)
STSA	6 (4/16)	2 (1/15)	0 (0/2)	0 (0/19)	0 (0/9)
WHIM	2 (1/16)[3]	0 (0/15)	0 (0/2)	0 (0/19)	0 (0/9)

[1]One HUGO seen just outside plot; 2 others few over and called at two other plots.

[2]One RNPH nest in small patch of wet sedge in dense willow plot.

[3]Two other pairs of WHIM flushed within 250 m of outside of plots: again yielding estimate of 2 prs/km^2 (3/32).

Table 4.16. Combining all plots (excluding gravel pads) of 1991 and 1992: Estimated densities of shorebird species in different (observed) habitat types. Habitat types are described in Table 2.3. Numbers in parentheses are number of breeding pairs/total plots (200 m x 200 m) censused. Species are listed in Table 1.1.

	Habitat type (pairs/km²)			
Species	VI (polygons or sedge)	V (uplands)	IV (willow	II & III (wet sedge/ emergents)
COSN	5.0 (6/30)	0 (0/15)	7.5 (3/10)	2.2 (2/23)
HUGO	1.6 (3/46)	0 (0/15)	0 (0/10)	1.1 (1/23)
LBDO	0.8 (1/30)	0 (0/15)	0 (0/10)	0 (0/23)
LEGP	0.8 (1/30)	1.7 (1/15)	0 (0/10)	0 (0/23)
PESA	1.7 (2/30)	0 (0/15)	0 (0/10)	0 (0/23)
RNPH	40.0 (48/30)	0 (0/15)	2.5 (1/10)	6.5 (6/23)
SESA	4.2 (5/30)	5.0 (3/15)	0 (0/10)	0 (0/23)
STSA	7.5 (9/30)	1.7 (1/15)	0 (0/10)	0 (0/23)
WHIM	3.3 (4/30)	0 (0/15)	0 (0/10)	0 (0/23)
Total	64.9	8.4	10.0	9.8

Table 4.17. Estimates of total shorebird pairs breeding in the outer Mackenzie Delta, NWT (excluding Semipalmated Plovers). Estimates are based on pairs/km^2 (Table 3.16) and extent of each habitat type, determined by LANDSAT TM analysis (Table 2.4). Habitat types are described in Table 2.3 and shorebird species in Table 1.1).

	Shorebird pairs				
Species	VI (polygons or sedge: 391 km^2)	V (upland tundra: 287 km^2)	IV (dense willow: 1575 km^2)	II & III (emergents & wet sedge/willow: 1735 km^2	Total pairs
COSN	1,953		11,814	3,818	17,585
HUGO	625			1,909	2,534
LBDO	312				312
LEGP	312	487			799
PESA	664				664
RNPH	15,622		3,938	11,281	30,841
SESA	1,640	1,433			3,073
STSA	2,929	487			3,416
WHIM	1,289				1,289
Total Pairs	25,346	2,407	15,752	17,008	60,513
Total Pairs (excl. COSN)	23,393	2,407	3,938	13,190	42,928

breeders was estimated at 121,026; or 85,856 excluding Common Snipe.

4.4. Discussion

4.4.1. Accuracy of ground surveys: within and between years

The 1991 plot surveys demonstrated that while differences among habitat types in relative densities of shorebirds remained consistent, actual numbers of shorebirds seen in a single plot could vary greatly between censuses (about half showed no differences between censuses). In some cases this could be explained by loss of a nest, or later in the season, by movement (or loss) of chicks after hatch. Weather can also influence visibility of shorebirds during incubation: in many biparental species the incubating parent sits more tightly in cold weather, while in uniparental incubators such as phalaropes, the nest may be deserted for extensive period of time under poor weather conditions as the parent attempts to obtain enough food to survive. Many species flush closer and closer to the nest as incubation progresses, making them less likely to be flushed during a survey (Gratto-Trevor 1994). We attempted to decrease the variation observed in 1991 censuses by walking only 25 m apart in 1992, compared to 50 m in 1991. In addition, although we tried to avoid inclement weather during surveys, conditions were generally much colder and more overcast in 1991 than 1992 (see Chapter 7), so accuracy of individual surveys should have been higher in 1992 than in 1991.

Our plots were small. Therefore, especially for the larger species such as Whimbrel and Hudsonian Godwits, even though we only counted birds actually flushed from or landing in the plots, we may have overestimated numbers by counting birds nesting outside the plot. This is unlikely to have been a problem for smaller species, except for counting phalaropes feeding on small ponds. The nests of most Whimbrel seen in 1991 were found inside the plots, and some were surprising close together. However, since no Hudsonian Godwit nests were found, birds may have come from outside the plots. We undoubtably missed some birds inside the plots as well, but it is difficult to know how many. It is reassuring that, even though we changed methods slightly between years (three surveys per plot, 50 m apart in 1991; 1 census per plot, 25 m apart in 1992), densities of each species in different habitat types were very similar in 1991 and 1992, except where numbers of plots of a particular habitat type were extremely small. The inconsistency of numbers between years in the only two plots examined in more than one year may be due to the timing of the censuses: early to mid-incubation in 1991, after hatch in 1992 and 1993. Arctic shorebirds often desert the area if nests are depredated, since only nests lost very early in the season can be replaced (Gratto-Trevor 1992, 1994). Dickson et al. (1989) reported nests of Whimbrel, Hudsonian Godwits, Stilt Sandpipers and Long-billed Dowitchers found in a grid plot on Fish Island that was searched periodically throughout the summers of 1986 and 1987. They found that densities of shorebirds varied from 43 to 91 birds/km^2 in different years. Many species of shorebirds return to breed in areas where they have previously nested (Oring and Lank 1984, Gratto et al. 1985, Colwell et al. 1988), although for some species such as Pectoral Sandpipers, large year-to-year variation in numbers may exist (Pitelka 1959, Norton 1973).

4.4.2. Accuracy of LANDSAT TM habitat type identification

The LANDSAT TM imagery analysis accurately identified habitat types in the vicinity of Dickson's original study area, Fish Island. Even some distance away, at Niglintgak Island, priority shorebird habitat was correctly mapped, even though it was observed as "pure" sedge, rather than the low-centre polygon habitat that Dickson et al. (1989) appeared to solely consider important shorebird nesting habitat (he did not study phalaropes). However, farther inland, in areas with a higher proportion of upland habitat, LANDSAT identification of habitat type was considerably less accurate, and at an exposed coastal location, very few plots were correctly mapped as to habitat type.

Some of the misidentifications can be explained by differences in water levels between years. The imagery used was from 1986, while fieldwork of the present study was carried out in 1991 and 1992. Since flooding regimes can differ greatly from year to year (see Study Area in Chapter 1 and also Chapter 7), areas suitable for shorebird nesting in one year may not be useful in other years. This would be particularly significant in regions most prone to flooding, such as low-lying sites closest to the coast. It seems unlikely that large portions of northern Ellice Island would have changed from sedge to bare ground/*Equisetum* in six years, although the coast is submerging and coastal erosion can be significant (Bigras 1990). Results of this study would tend to suggest that areas on the coast defined as priority shorebird nesting habitat (Fig. 2.2), namely northern Ellice Island and the islands near the mouth of Shallow Bay, are very unlikely to provide sufficient cover for shorebird nesting.

Reasons for misidentification of habitat types in the inland area (Camp Farewell) are less clear. Sedge habitat along the margins of ponds within tundra uplands was often identified as uplands, presumably being too narrow a habitat to be picked up by the imagery. Upland sites were not common in Dickson's original study, so may have been less readily separated out by the analysis. Both upland tundra and dense willow involve rather dense vegetation, and not all dense willow was in wet areas, so this may have led to signature overlap.

The LANDSAT TM analysis used here, while correctly identifying priority shorebird habitat in areas intensively ground-truthed, may not always be readily extrapolated to surrounding areas, particularly in those subject to rapid habitat change (e.g. irregular flooding of the delta). This limits the use of the technique in estimating shorebird breeding densities in large regions of the arctic, although it may be useful in roughly identifying potential shorebird habitat, and at least eliminating obviously unsuitable areas,

4.4.3. Importance of habitat type to breeding shorebirds

The priority habitat type of Dickson et al. (1989), which here included both low-centre polygonal ground and "pure" sedge areas, contained by far the highest densities of breeding shorebird pairs (65/km^2), compared to dense willow (10/km^2), emergents and wet sedge/willow (10/km^2), and upland tundra (8/km^2). Most of these were Red-necked Phalaropes. Excluding phalaropes, the "priority" habitat still contained the highest densities of birds (25/km^2), with lower densities in upland tundra (8/km^2), dense willow (7/km^2), and emergents and wet sedge/willow (3/km^2). Excluding snipe, the next most common species, densities were still highest in polygon/sedge (20/km^2) and upland tundra (8/km^2), and lowest in dense willow (0/km^2) and emergents and wet sedge/willow (1/km^2). In fact, if only low upland tundra is considered, densities are similar (21/km^2) to those in priority habitat, when phalaropes and snipe are excluded. No birds were observed in high upland tundra plots.

The densities of birds in priority habitat appears comparable to results of Dickson et al. (1989) in primarily priority habitat on Fish Island, although they calculated birds per area rather than pairs. They observed 43 to 91 birds/km^2. Since "pairs" does not necessarily mean that two birds were seen, it is not possible to directly compare numbers. In wet sedge/patterned ground and wet sedge habitats at Stokes Point and Phillips Bay, Yukon, a far greater density of shorebirds were seen (176-177 birds/km^2).

4.4.4. Species densities in different habitats

Here, Red-necked Phalaropes were the most common breeding shorebird, followed by Common Snipe. Stilt Sandpipers and Semipalmated Sandpipers were also abundant. Hudsonian Godwits and Whimbrel were less common, and Lesser Golden Plovers, Pectoral Sandpipers, and Long-billed Dowitchers even less so. Other visitors to the area concur with these rankings in most cases, but disagree in several respects. Martell et al. (1984) list Common Snipe as uncommon to rare above the treeline. This statement is presumably from Porsild's (1943) report, who also lists only two Stilt Sandpipers. Hudsonian Godwits are not listed at all, but Barry and Spencer (1976) note that Porsild missed some species as he did not spend much time in the outer delta.. Common Snipe were most obvious winnowing, but were flushed from plots on numerous occasions, particularly in 1991 when more willow sites were censused. Höhn (1959) notes changes in the bird composition of the Anderson River Delta in 1955 compared to a previous study there in the 1860's. He related this to a northward movement of the treeline, and loss of high-arctic shorebird species in the area. Perhaps snipe have moved north as well, even above the treeline.

In the western portion of the Mackenzie Delta, on the arctic coastal plain, Semipalmated Sandpipers, Pectoral Sandpipers, Red-necked Phalaropes and Lesser Golden Plovers were considered abundant in the early to mid-seventies, with Common Snipe and Baird's Sandpiper (*Calidris bairdii*) fairly common, and Red Phalaropes (*Phalaropus fulicarius*), Buff-breasted Sandpipers (*Tryngites subruficollis*), Long-billed Dowitchers, Whimbrel and Stilt Sandpipers uncommon (Salter et al. 1980). Also in the western part of the delta (Yukon), Hawkings (1986) listed Red-necked Phalaropes and Semipalmated Sandpipers as common, and Pectoral Sandpiper and Common Snipe as uncommon breeders. The remaining species observed in the present study were considered uncommon summer visitants. The western delta is apparently much drier than the central delta studied here.

Densities of different species in Dickson's main study area on Fish Island ranged from a high of 46 birds/km^2 for Red-necked Phalaropes, to a low of 1 Lesser Golden Plover/km^2. Densities of different species in that study (Dickson et al. 1989) agree reasonably well with those of the present study. Those working primarily on the Yukon coast have tended to have higher densities of most species overall, although results vary widely. Densities of Lesser

Golden Plovers, Semipalmated Sandpipers, Pectoral Sandpipers and Long-billed Dowitchers in particular seem higher in the west (*in* Hawkings 1987).

4.4.5. Overall numbers of shorebirds in the outer Mackenzie Delta

Overall numbers of breeding shorebird pairs were calculated for the entire study area using habitat areas calculated from the LANDSAT TM imagery analysis, even though the analysis is known to commonly misidentify habitat types in some areas. The numbers are therefore suspect. In particular, numbers of Hudsonian Godwits appear high, due primarily to a bird seen in a wet sedge/willow plot, and the large amount of that habitat type in the study area. Numbers of Pectoral Sandpipers seem low, but in the years of this study they were not common in any area visited. Except for Hudsonian Godwits, then, numbers of shorebirds appear plausible, although it is not possible to determine their accuracy.

Slaney and Co. (1974a) used information from aerial surveys and a number of point censuses in different habitats to calculate total numbers of shorebirds breeding in a 990 square mile area of the Mackenzie Delta. This is about a third of the size of the present study. They estimated 19,000 Common Snipe, 750 Whimbrel, 19,000 Pectoral Sandpipers, 19,000 Semipalmated Sandpipers, and 25,000 Red-necked Phalaropes. The ranking of species is similar to the present study, except for the high numbers of Pectoral Sandpipers. This is not necessarily surprising considering the inconsistency in breeding densities of Pectoral Sandpipers from year to year. In terms of absolute numbers, if one considers that Slaney and Co.'s study area is a third smaller, and that they are considering total birds, not pairs, then estimates of Whimbrel and Red-necked Phalaropes compare very well, while numbers of snipe are half again mine. Numbers of Semipalmated Sandpipers and Pectoral Sandpipers are very much higher in their study. It is somewhat suspicious that their estimates for snipe, Pectoral Sandpipers and Semipalmated Sandpipers are identical, and that Hudsonian Godwits, Long-billed Dowitchers, Lesser Golden Plovers and Stilt Sandpipers are totally missing. Since much of their information is apparently derived from counts at "stations" (how?), it is very unlikely to be as accurate as the plot surveys of the present study.

4.5. Conclusions

The ground census technique used here obviously missed some breeding shorebirds, and undoubtably counted at least a few birds that bred outside the plots. Recommendations for ground censuses of breeding shorebirds in subsequent studies are described in Chapter 8.

The priority shorebird nesting habitat identified by Dickson et al. (1989) certainly contained the highest densities of breeding shorebirds. However, here it included sedge meadows, in addition to the well-developed low-centre polygonal ground described by Dickson et al. This habitat was particularly important for Red-necked Phalaropes, Whimbrel, Hudsonian Godwits, and Pectoral Sandpipers. Stilt Sandpipers and Semipalmated Sandpipers also used "low" upland tundra, as did Lesser Golden Plovers. Common Snipe appeared most prevalent in willow habitat, while Semipalmated Plovers were only found in areas of gravel with little vegetation. Densities of shorebirds in different habitat types are thought to be reasonably accurate for the areas surveyed, especially when data from both years were combined.

The accuracy of the LANDSAT TM imagery analysis in determining vegetation type was very high near the original, intensively ground-truthed study site, but in several areas 10 to 30 km away, many plots were misidentified as to habitat type. This was thought to have resulted primarily from year to year differences in water depth in the outer delta, variation in flooding regimes and coastal storm surges, and inability of the satellite imagery to distinguish narrow margins of important habitat around ponds and small lakes. Therefore, accuracy of the calculated overall numbers of breeding shorebirds is questionable. However, numbers of most species seem reasonable, except for that of the Hudsonian Godwit, which is biased by a bird seen in wet sedge/willow. Since this habitat is quite prevalent and the species uncommon, it greatly inflated the overall species number.

CHAPTER 5

INVERTEBRATE SAMPLING

5. INVERTEBRATE SAMPLING

5.1. Introduction and Objectives

One important aspect of shorebird habitat that had not been examined in the Mackenzie Delta was availability of their invertebrate prey. Food habits of shorebirds have been studied at several breeding areas in North America (e.g. Churchill, Manitoba, Baker 1977; Barrow, Alaska, Holmes and Pitelka 1968), and consist primarily of Chironomid larvae and other Dipteran insect larvae and adults, small snails, spiders, and beetles. In addition, arctic nesting shorebirds have been found to feed on other invertebrates such as copepods, ostracods, small bivalves, polychaetes, amphipods, and nematodes in other areas (Hicklin and Smith 1979, Boates 1980, Lewis 1983, Gratto et al. 1984, Morrison 1984, Peer et al. 1986). So, although potential prey types of breeding shorebirds are reasonably well known, availability of these invertebrates in different habitats is less well studied. The objective of invertebrate sampling carried out in 1993 in the outer Mackenzie Delta was, then, twofold: first, to measure differences in potential invertebrate prey of shorebirds among different habitat types, to determine whether maximum numbers occurred in priority shorebird habitat; and second, to examine changes in invertebrate availability throughout the breeding season.

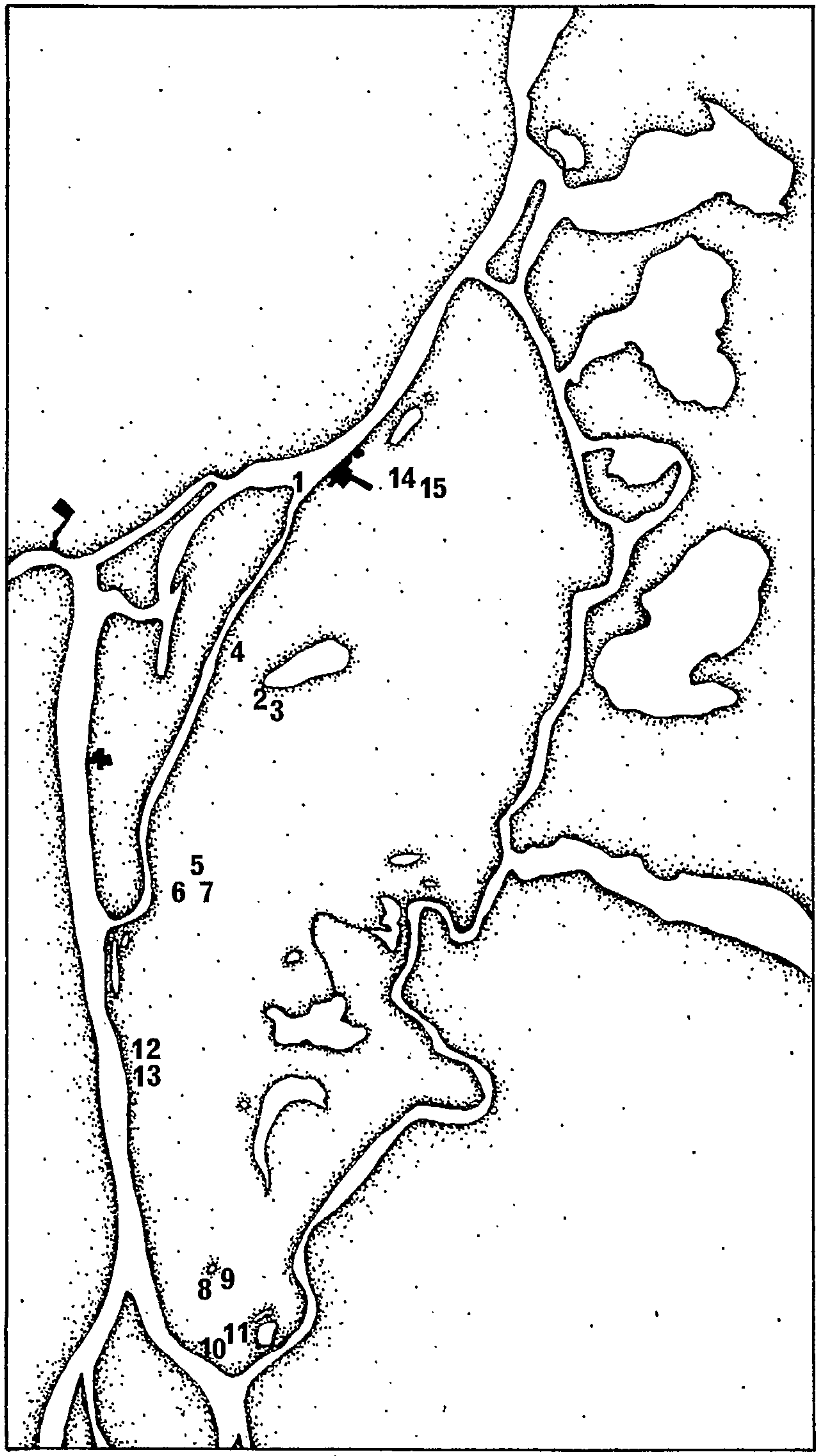
5.2. Methods

Invertebrate samples were collected only in 1993, from areas of putatively good and poor shorebird nesting habitat. Most samples were collected by sweep-net (for surface invertebrates, primarily adult insects), and by "stovepipe" sampler (for water column and upper substrate invertebrates, primarily insect larvae, crustaceans, and coleopterans). A total of 15 sites were sampled to represent different vegetation types present in the area (Appendix 5.1). Four sample sites in areas of low-centre polygons (sites 2, 3, 14, and 15) and two in "pure" sedge (4, 5) were considered good shorebird nesting habitat. Other habitats sampled were: one mudflat (site 1), two wet sedge/willow (6, 7), two "high" upland tundra (8, 9), two "low" upland tundra (10, 11), and two dense willow (12, 13). All sites were located on Fish Island (Fig. 5.1). Samples were taken from all sites three times during the shorebird breeding season: Trial A, 19-22 June; Trial B, 29 June; and Trial C, 8 July. Therefore samples at a site were taken seven to ten days apart. Samples were sorted within a week of collection, identified primarily to class (Diptera to family), and measured under a dissecting microscope to the nearest mm. A list of classification categories is found in Appendix 5.2.

5.2.1. <u>Sweep-net Sampling</u>

A canvas sweep-net on a wooden handle was used to brush terrestrial vegetation for aerial invertebrates. Walking at a slow pace, the researcher swept the vegetation in front of him in a methodical back and forth motion for a distance of 50 paces. The sample was then placed in a whirl-pac plastic bag.

Figure 5.1. Invertebrate sampling sites on Fish Island, 1993. *See text for habitat type of each site.*



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5.2.2. Core Sampling

Plastic tubes 30.5 cm long, with a diameter of 6.5 cm, were used to extract core samples. Three tubes were pushed into the substrate to a depth of approximately 26 cm, then topped with plastic caps. As the tubes were pulled out of the substrate the suction created allowed a sample core to be extracted in the tube. A wooden stake was then inserted into the bottom end of the tube and the cap removed. By pushing the tube onto the stake the substrate core was extruded out of the top of the tube. A 15 cm length of substrate was cut from the core sample with a putty knife and placed in a 425 µm sieve. Samples were sieved immediately and placed into whirl-pac plastic bags in 85% ethanol. Cores were taken only from mudflat habitat.

5.2.3. Stovepipe Sampling

This method was used only where standing water was present. A 26.4 cm diameter plastic pail with the bottom removed was inserted into the substrate to a depth of several centimetres. A flat-bottomed probe was used to disturb the upper substrate and mix it into the water. During the first set of sampling (Trial A), sites contained considerably more water than in later sampling periods (Fig. 5.2, Appendix 5.3). Therefore, in Trial A, 30 samples were collected with a 150 ml beaker and poured into a 425 µm sieve. In Trials B and C, the two later sampling periods, virtually all water in the bottomless pail was removed with a beaker and put through the sieve. All samples were immediately sieved and stored in whirl-pac plastic bags in 85% ethanol.

5.3. Results

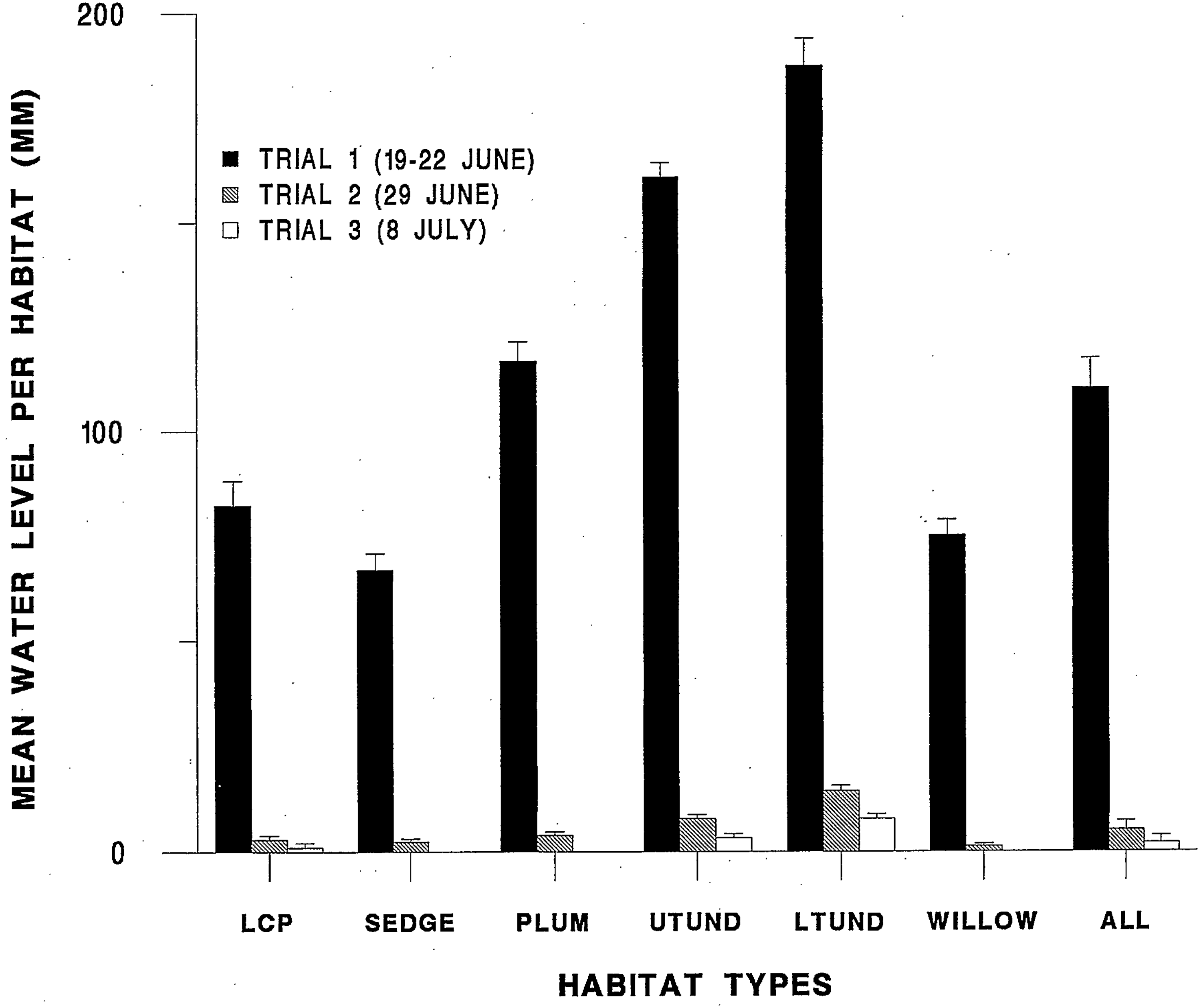
5.3.1. Core Samples

Core samples were taken only in the mudflat habitat. No invertebrates were found in the first and third sampling periods (Trial A and C), and only one nematode in the second set of samples (Trial B).

5.3.2. Sweep-net Samples

5.3.2.1. ***Differences among habitats.*** Nothing was obtained in sweep-net samples taken in the mudflat habitat. Elsewhere, sweep-net samples were dominated by adult dipteran insects, with 12 families represented (Appendix 5.4). Culicidae adults (mosquitoes) were by far the most abundant invertebrates found in the samples (present in 26/42 samples, and all habitats). Dolichopopidae adults were common (9/42 samples), as were Ichneumonidae adults (in 5/42 samples, 4/6 habitats), and Tabanidae (5/42 samples, 3/6 habitats). Other Dipterans included Empididae, Tipulidae, Ceratopogonidae, and Syrphidae (each found in 2/42 samples),

Figure 5.2. Seasonal change in water levels at invertebrate sampling sites, 1993. *N=12 for lcp, 6 for each other habitat type, and 42 for "all". LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; ALL=all sites. Trial=sampling period.*


MEAN WATER LEVEL PER HABITAT (MM)
200
100
0
TRIAL 1 (19-22 JUNE)
TRIAL 2 (29 JUNE)
TRIAL 3 (8 JULY)
LCP
SEDGE
PLUM
UTUND
LTUND
WILLOW
ALL
HABITAT TYPES

as well as Chironomidae, Simulidae, Stratiomyidae, and Muscidae (each in only 1/42 samples). Classes Odonata (2/42 samples), Arachnida (Aranae, 1/42), and Hemiptera (Pleidae, 1/42) were also represented. Taxonomic classification of these groups is described in Appendix 5.2.

No invertebrates were found in the first sampling period (Trial A: 19-22 June). The first major insect hatch was on 23 June 1993, 25 June 1992, and 20 June 1991.

In the second sampling period (Trial B: 29 June), there was no significant difference among habitats (low-centre polygons, sedge, wet sedge/willow, dense willow, "low" uplands, "high" uplands), either in numbers of adult mosquitoes (ANOVA: n=14 sites, p=0.73, Fig. 5.3), or all invertebrates (ANOVA: n=14 sites, p=0.86, Fig. 5.4). Results were similar when habitat types were combined into "priority shorebird habitat" (polygons and sedge), upland ("low" and "high"), and willow-type (wet sedge/willow, dense willow) habitats (Culicidae: ANOVA p=0.21; All: ANOVA p=0.33).

There were also no significant differences among habitats in the third sampling period (Trial C: 8 July), with Culicidae (ANOVA: n=14 sites, p=0.73, Fig. 5.3), or all invertebrates (ANOVA: n=14 sites, p=0.73, Fig. 5.4), even when habitats were combined (Culicidae: ANOVA p=0.33; All: ANOVA p=0.39).

5.3.2.2. ***Changes during the season.*** As noted above, no invertebrates were obtained during the first sampling period. This led to significant differences between number of invertebrates captured in Trial A versus Trial B or C (n=42 samples; Culicidae adults: ANOVA p=0.005, GT2 family error test for differences between groups; All invertebrates: ANOVA p=0.008, GT2). There was no significant difference between numbers of invertebrates taken in the second and third sampling periods (GT2 not significant). In fact, numbers of Culicidae increased between the second and third sampling periods (Trial B to C) in seven, stayed the same in one, and decreased in six of the 14 sampling sites. For total invertebrates, numbers increased in seven and decreased in seven sites. This was in contrast to the difference between the first and second sampling periods, where Culicidae numbers increased in 12 of 14 sites, remaining the same in two; and increased in all 14 sites in numbers of total invertebrates.

5.3.3. Stovepipe Samples

5.3.3.1. ***Differences among habitats in numbers of invertebrates.*** Stovepipe samples (water column and upper substrate) from the mudflat contained only Chironomid larvae (Diptera), nematodes, and decapods (Crustaceans). Decapods were found only at the mudflat site, and nematodes in all seven habitats (Appendix 5.4). Both insects and crustaceans were very common in the other six habitats (low centre polygons, "pure" sedge, wet sedge/willow, dense willow, "high" and "low" upland tundra). Dipteran insects were the most abundant, including Chironomid larvae (all seven habitats), Culicid larvae and pupae (six habitats), Ephydrids (only polygon and sedge sites), and Ceratopogonid larvae (only low-centre polygons). Other insects identified were in orders Coleoptera (low numbers in all but sedge and mudflat sites), Trichoptera (5/7 habitats), Collembola (in one sample in sedge only), and

Figure 5.3. Sweep-net samples 1993: Total number of Culicidae adults (mosquitoes) collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

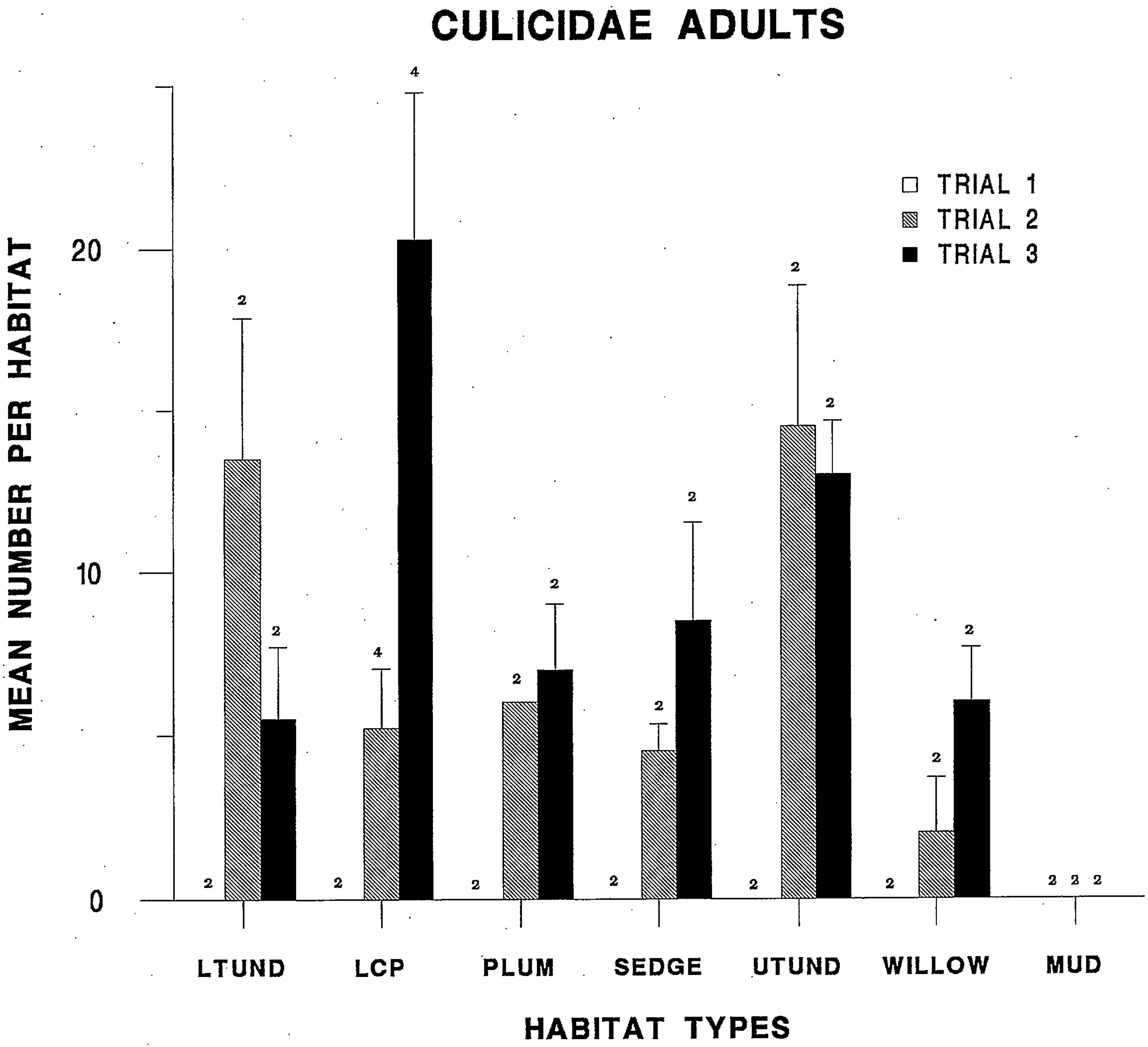
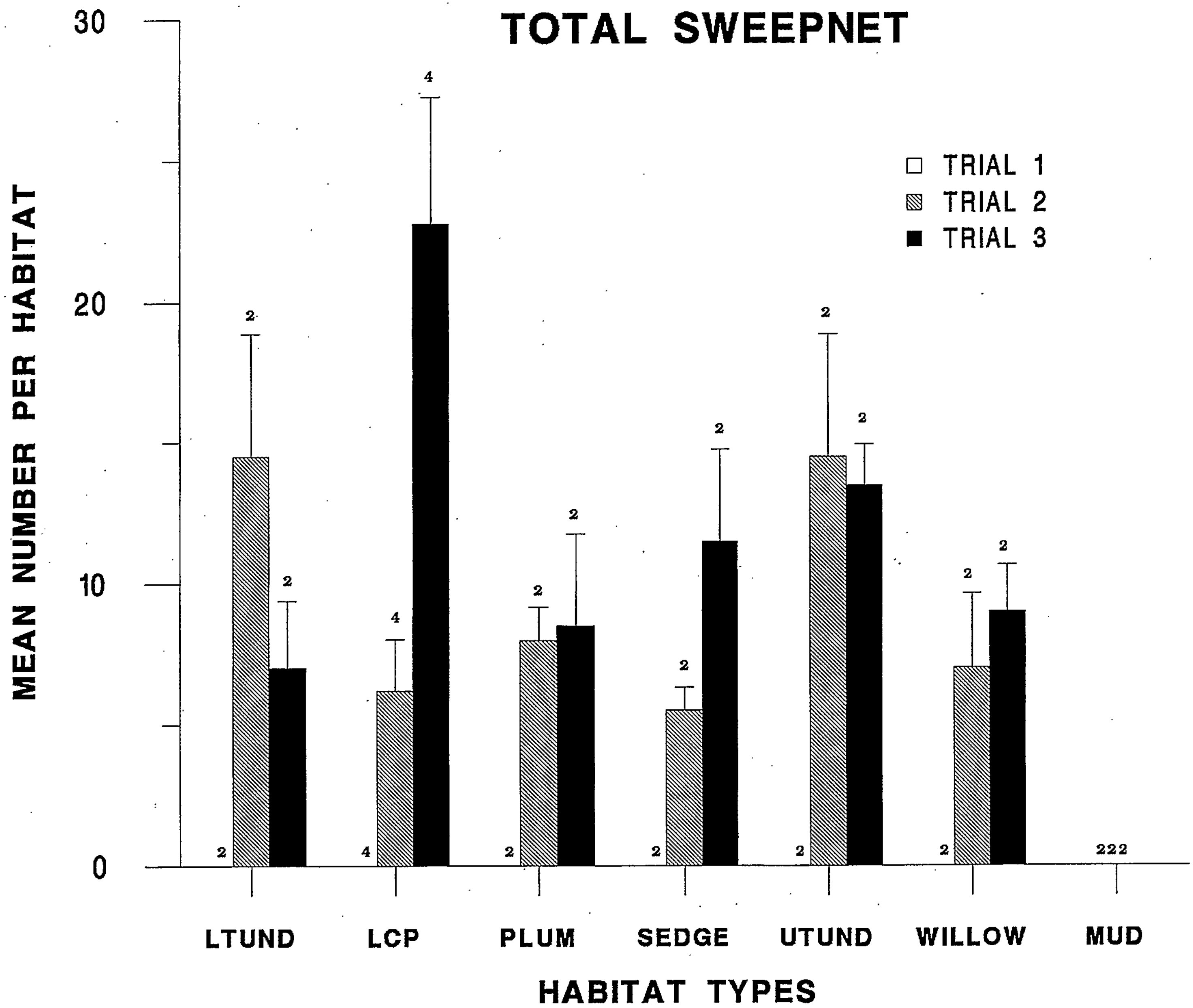

CULICIDAE ADULTS
TRIAL 1
TRIAL 2
TRIAL 3
MEAN NUMBER PER HABITAT
HABITAT TYPES
LTUND
LCP
PLUM
SEDGE
UTUND
WILLOW
MUD
0
10
20

Figure 5.4. Sweep-net samples 1993: Total number of invertebrates collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*



TOTAL SWEEPNET
MEAN NUMBER PER HABITAT
30
20
10
0
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
PLUM
SEDGE
UTUND
WILLOW
MUD
HABITAT TYPES

Hemiptera (in one sample in polygons only).

Crustaceans included Orders Copepoda (all but mudflat habitats), Cladocera (5/7 habitats), Amphipoda (4/6 habitats, in low numbers), and Ostracoda (only in one sample at a low-centre polygon site). Representatives of Arachnids (spiders: uncommon in 3/7 habitats) and Gastropods (snails: low numbers in 6/7 habitats) were also present. Taxonomic classification of all groups is described in Appendix 5.2.

Diptera. Numbers of the most common invertebrates were compared in different habitats (Table 5.1). For Chironomid larvae (Fig. 5.5, Table 5.1), numbers in wet sedge/willow were significantly greater than in any other habitat in both the first and second sampling periods. Many sites held no water by the third sampling period, so few stovepipe samples could be taken (none from sedge/willow), and differences between habitats were not significant.

Results for Culicid larvae (Fig. 5.6, Table 5.1) were similar to those for Chironomid larvae in the first set of samples. Numbers in wet sedge/willow were significantly greater than in any other habitat. However, in the second sample set, "high" upland tundra had significantly more mosquito larvae than any other habitat, and wet sedge/willow more than low-centre polygon sites. Again, due to drying up at sites by 8 July, there were no significant differences among habitats in the third set of samples.

Interestingly, only low-centre polygons held any Culicid pupae during first sampling (Fig. 5.7, Table 5.1), but wet sedge/willow had significantly more pupae than dense willow, "low" uplands, sedge and mudflats in the second samples. No differences were significant in the few samples of the last set.

Overall, due primarily to the presence of large numbers of Chironomid larvae, total numbers of dipterans (Fig. 5.8, Table 5.1) were significantly greater in wet sedge/willow than in any other habitat in both the first and second sets of samples.

Crustaceans. There were no differences among habitats in numbers of copepods (Fig. 5.9). Numbers of Cladocera (Fig. 5.10, Table 5.1) were significantly greater in wet sedge/willow than in any other habitat during the first sampling period. There were no significant differences among habitats in the second and third set of samples. Overall, due to high numbers of cladocerans, total numbers of crustaceans (Fig. 5.11, Table 5.1) was significantly greater in wet sedge/willow than in mudflat, "high" upland, low-centre polygon, and dense willow habitats during the first sampling period. There were no significant differences among habitats in sampling periods two or three.

Others. There were significantly more coleopterans (Fig. 5.12, Table 5.1) during the second sampling set in dense willow than in low uplands, high uplands or sedge, but no significant differences in other periods.

Numbers of gastropods (Fig. 5.13, Table 5.1) were significantly greater in wet sedge/willow than in low uplands, high uplands, sedge, low-centre polygons or dense willow in the first set of samples. Numbers in wet sedge/willow were significantly greater than in low uplands in the second samples, while there were no significant differences among habitats in the third set.

Table 5.1. Differences among habitats in numbers of invertebrates collected by stovepipe sampling, 1991: results of ANOVAs and GT2 family error tests for differences between habitats (Sokal & Rolf 1981). Habitat Types are as follows: I = mudflat, III = wet sedge/willow, IV = dense willow, V(L) = "low" upland tundra, V(H) = "high" upland tundra, VI(P) = low-centre polygons, VI(S) = "pure" sedge.

Invertebrate group	Trial (sampling period)	ANOVA # sites	ANOVA P	Significant GT2 tests ($p < 0.05$)
Diptera				
Chironomid larvae	A	15	0.0001	III>I, III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	B	15	0.0004	As above.
	C	6	0.79	-
Culicid larvae	A	15	0.0003	III>I, III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	B	15	0.0003	V(H)>I, V(H)>III, V(H)>IV, V(H)>V(L), V(H)>VI(P), V(H)>(S), III>VI(P)
	C	6	0.58	-
Culicid pupae	B	15	0.006	III>I, III>IV, III>V(L), III>VI(S)
	C	6	0.07	-
All Diptera	A	15	0.0001	III>I, III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	B	15	0.0001	As above.
	C	6	0.42	-
Crustacea				
Copepods	A	15	0.25	-
	B	15	0.10	-
	C	6	0.41	-
Cladocerans	A	15	0.0009	III>I, III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	B	15	0.08	-
	C	6	0.53	-
All Crustaceans	A	15	0.005	III>I, III>IV, III>V(H), III>VI(P)
	B	15	0.11	-
	C	6	0.62	-

Table 5.1 Continued.

Invertebrate group	Trial (sampling period)	ANOVA # sites	ANOVA P	Significant GT2 tests (p < 0.05)
Others				
Coleopterans	A	15	0.92	-
	B	15	0.02	IV>V(L), IV>V(H), IV>VI(S)
	C	6	0.18	-
Gastropods	A	15	0.01	III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	B	15	0.01	III>V(L)
	C	6	0.46	-
Nematodes	A	15	0.0001	VI(S)>I, VI(S)>III, VI(S)>IV, VI(S)>V(L), VI(S)>V(H), VI(S)>VI(P)
	B	15	0.44	
	C	6	0.79	
All invertebrates	A	15	0.0001	III>I, III>IV, III>V(L), III>V(H), III>VI(P), VI(S)>I, VI(S)>IV, VI(S)>V(L), VI(S)>V(H), VI(S)>VI(P)
	B	15	0.007	III>I, III>IV, III>V(L), III>V(H), III>VI(P), III>VI(S)
	C	6	0.81	-

***Figure 5.5.* Stovepipe samples 1993: Total number of Chironomidae (midge) larvae collected in different habitat types.** *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

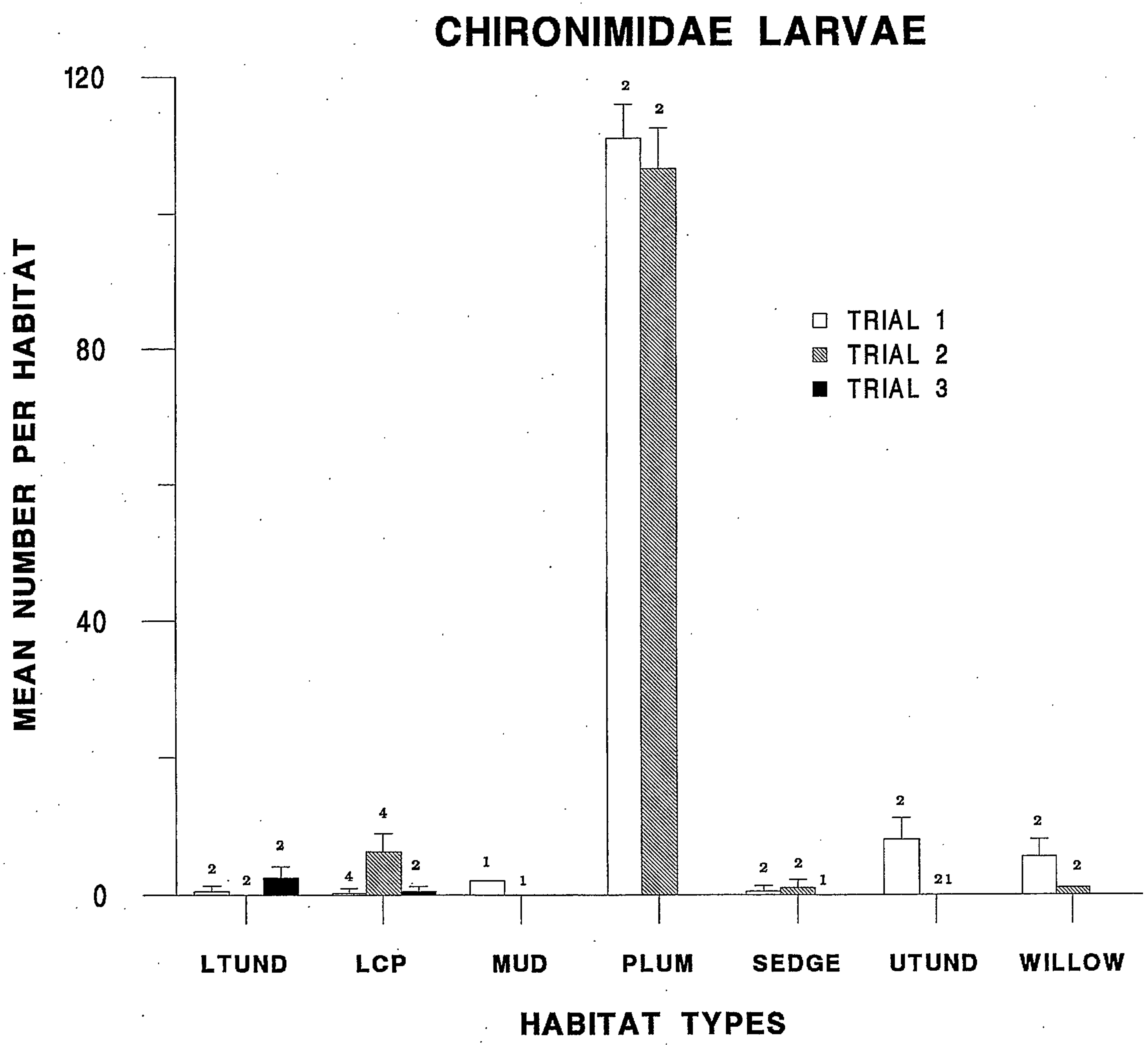

CHIRONIMIDAE LARVAE
120
80
40
0
MEAN NUMBER PER HABITAT
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.6. Stovepipe samples 1993: Total number of Culicidae (mosquito) larvae collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

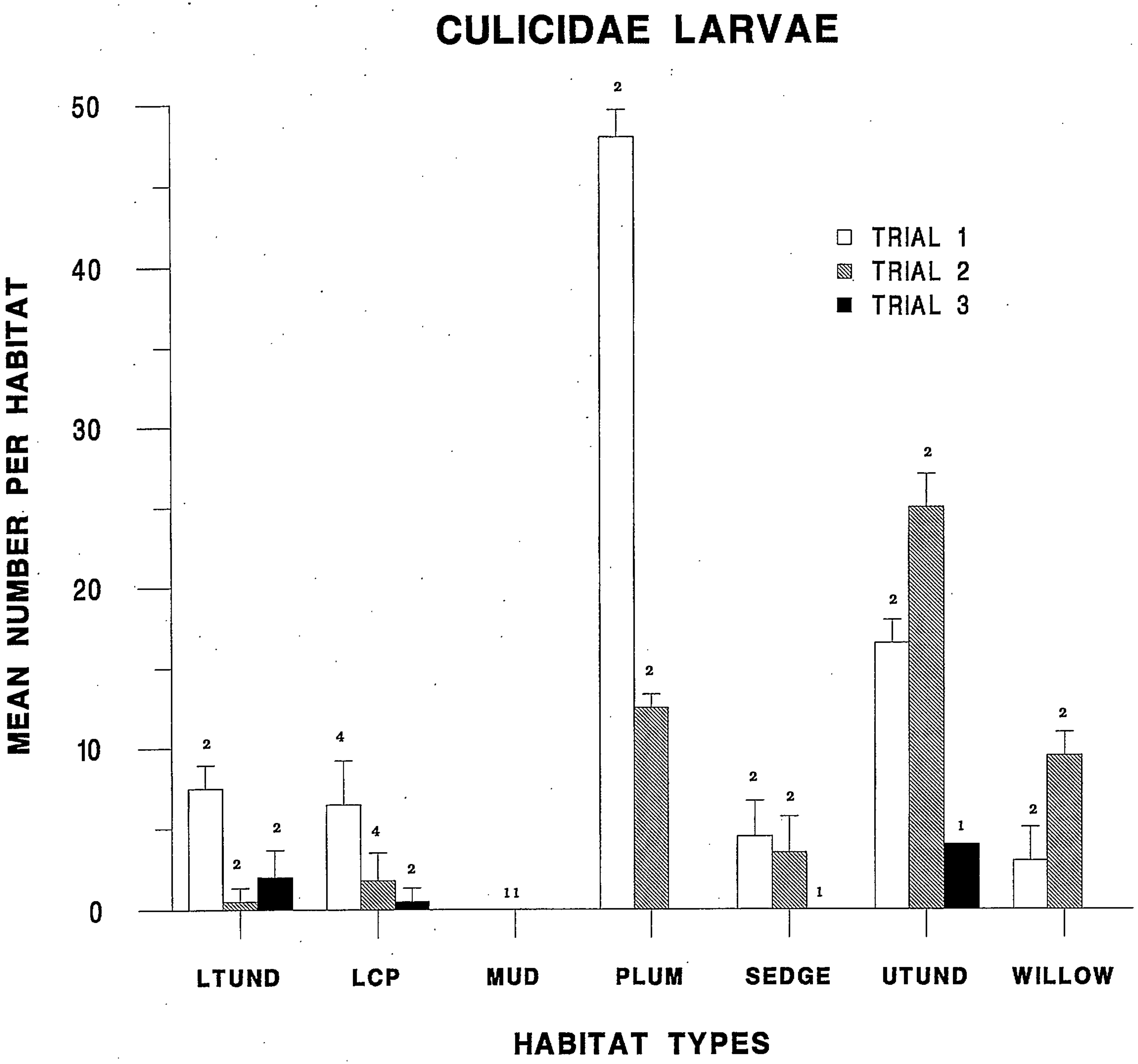
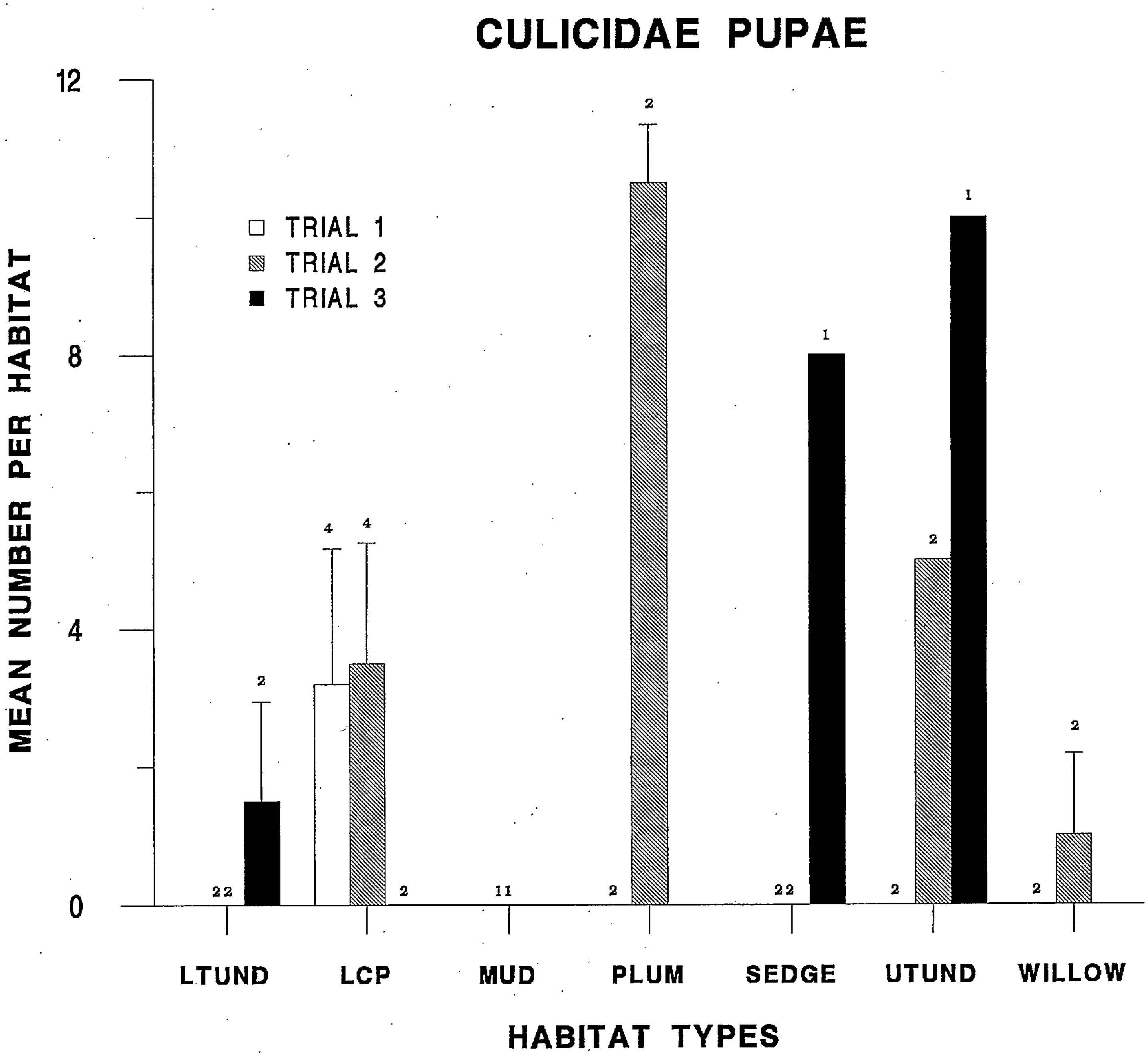
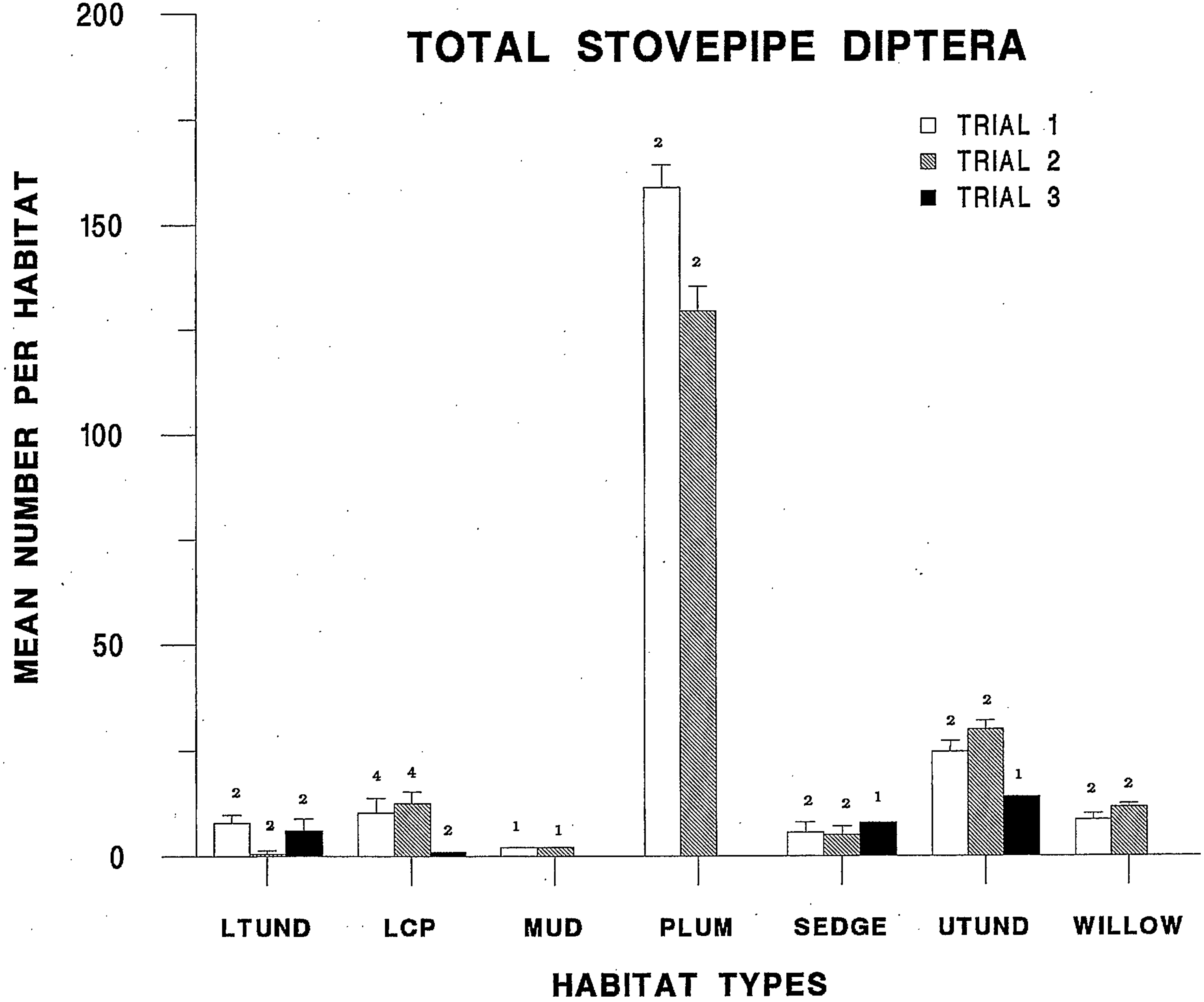

CULICIDAE LARVAE
MEAN NUMBER PER HABITAT
HABITAT TYPES
0
10
20
30
40
50
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW

Figure 5.7. Stovepipe samples 1993: Total number of Culicidae (mosquito) pupae collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*



CULICIDAE PUPAE
12
8
4
0
MEAN NUMBER PER HABITAT
TRIAL 1
TRIAL 2
TRIAL 3
2 2 2
4 4 2
1 1
2 2
1 2 2
2 2 1
2 2
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.8. Stovepipe samples 1993: Total number of Dipteran insects collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*



TOTAL STOVEPIPE DIPTERA
TRIAL 1
TRIAL 2
TRIAL 3
MEAN NUMBER PER HABITAT
200
150
100
50
0
2
2
2
2
4
4
2
1
1
2
2
2
2
1
2
2
1
2
2
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.9. Stovepipe samples 1993: Total number of Copepods (Crustacea) collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

COPEPODS

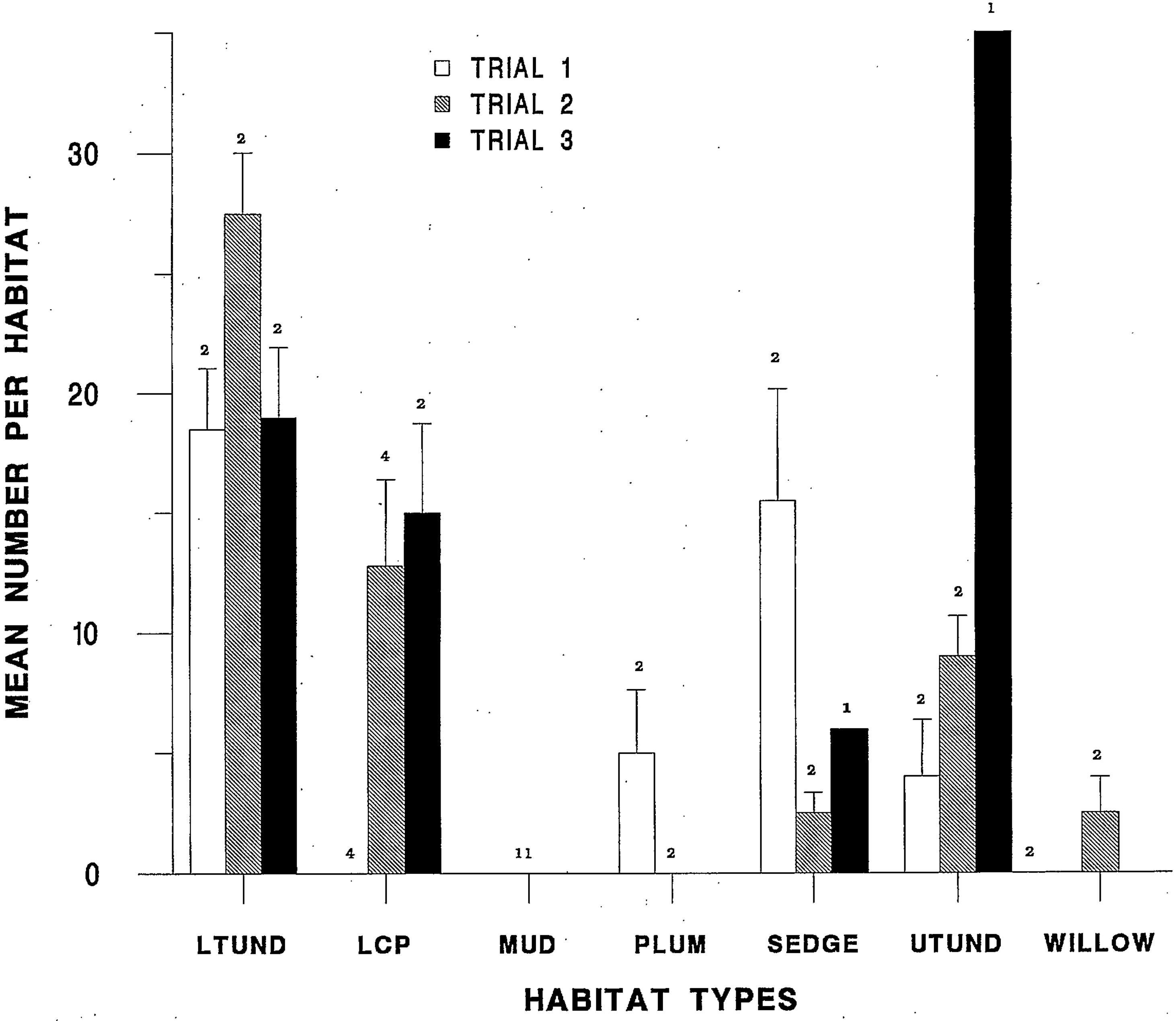

TRIAL 1
TRIAL 2
TRIAL 3
MEAN NUMBER PER HABITAT
0
10
20
30
2
2
2
4
2
4
11
2
2
2
2
1
2
2
1
2
2
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.10. Stovepipe samples 1993: Total number of Cladocera (Daphnia and allies: Crustacea) collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

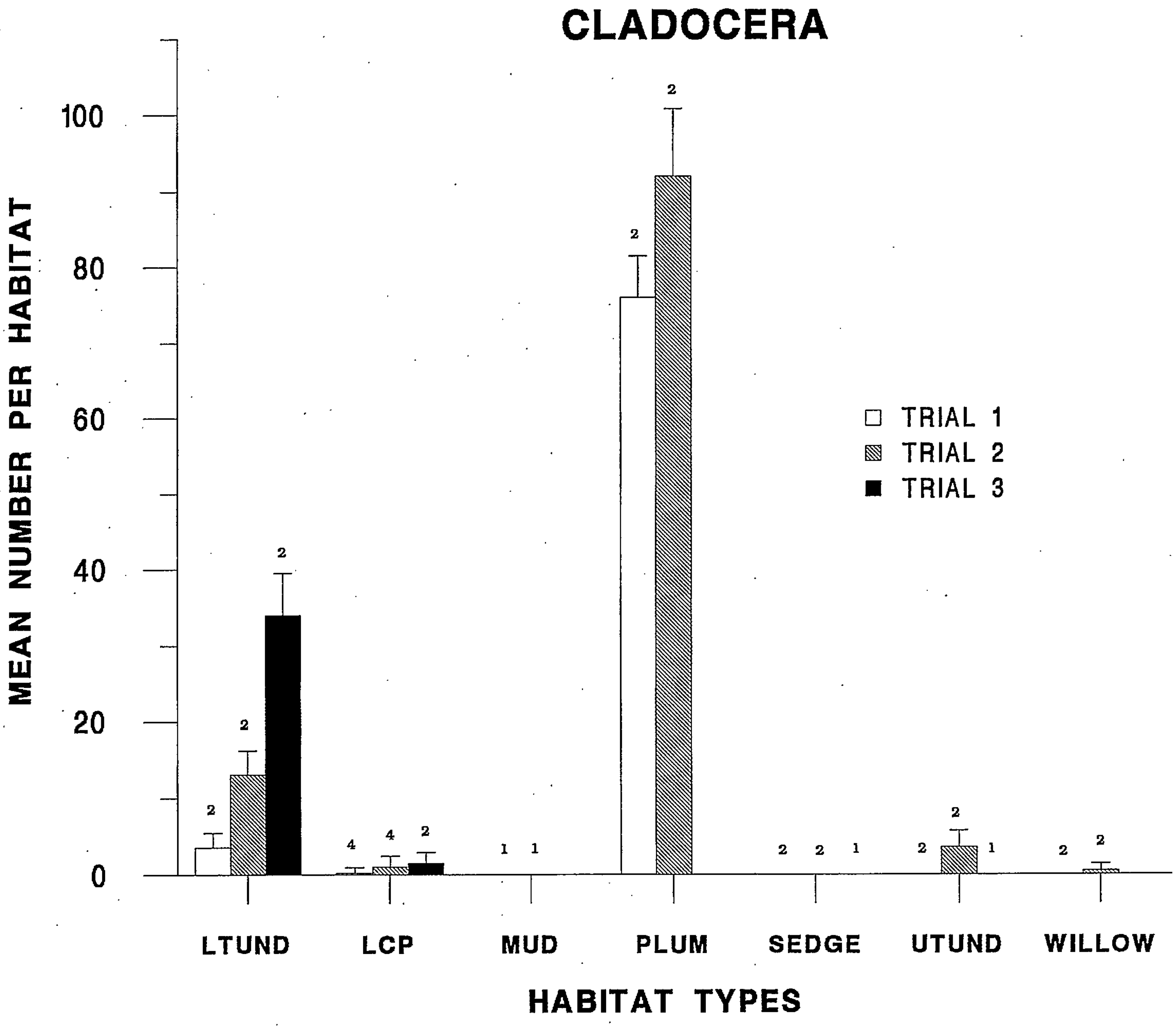

CLADOCERA
MEAN NUMBER PER HABITAT
100
80
60
40
20
0
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.11. Stovepipe samples 1993: Total number of Crustaceans collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

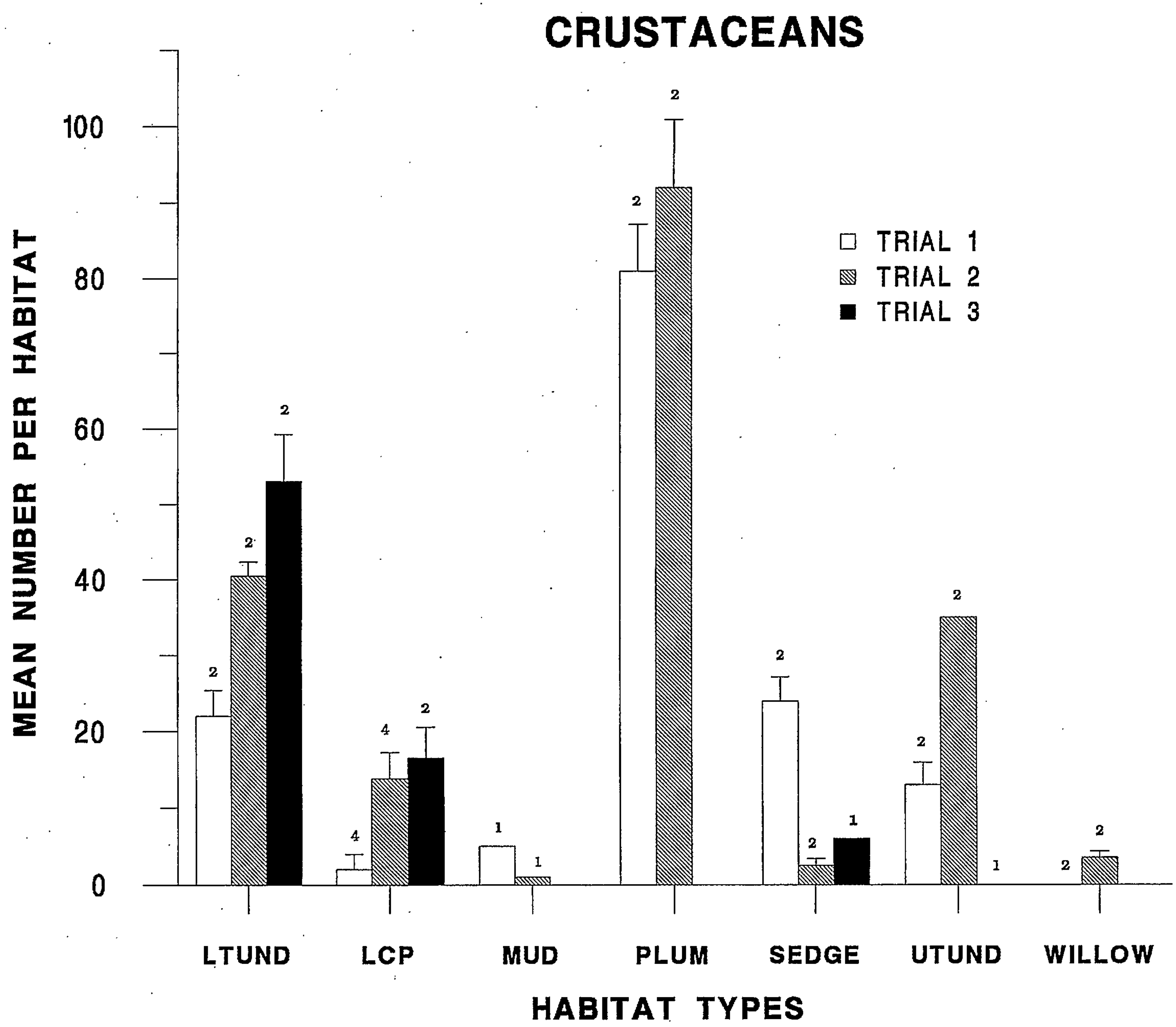

CRUSTACEANS
MEAN NUMBER PER HABITAT
0
20
40
60
80
100
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.12. Stovepipe samples 1993: Total number of Coleoptera (beetles) collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

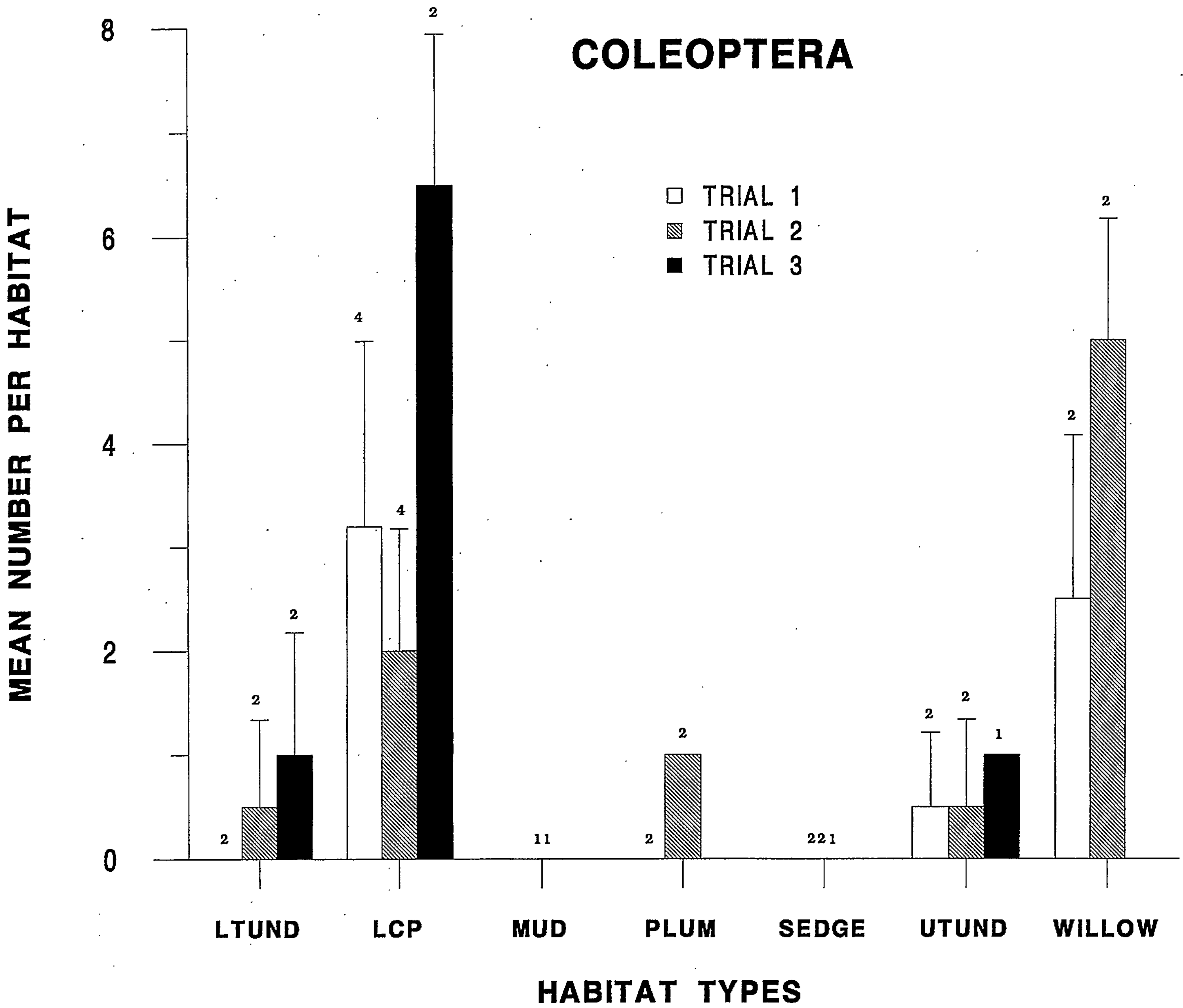
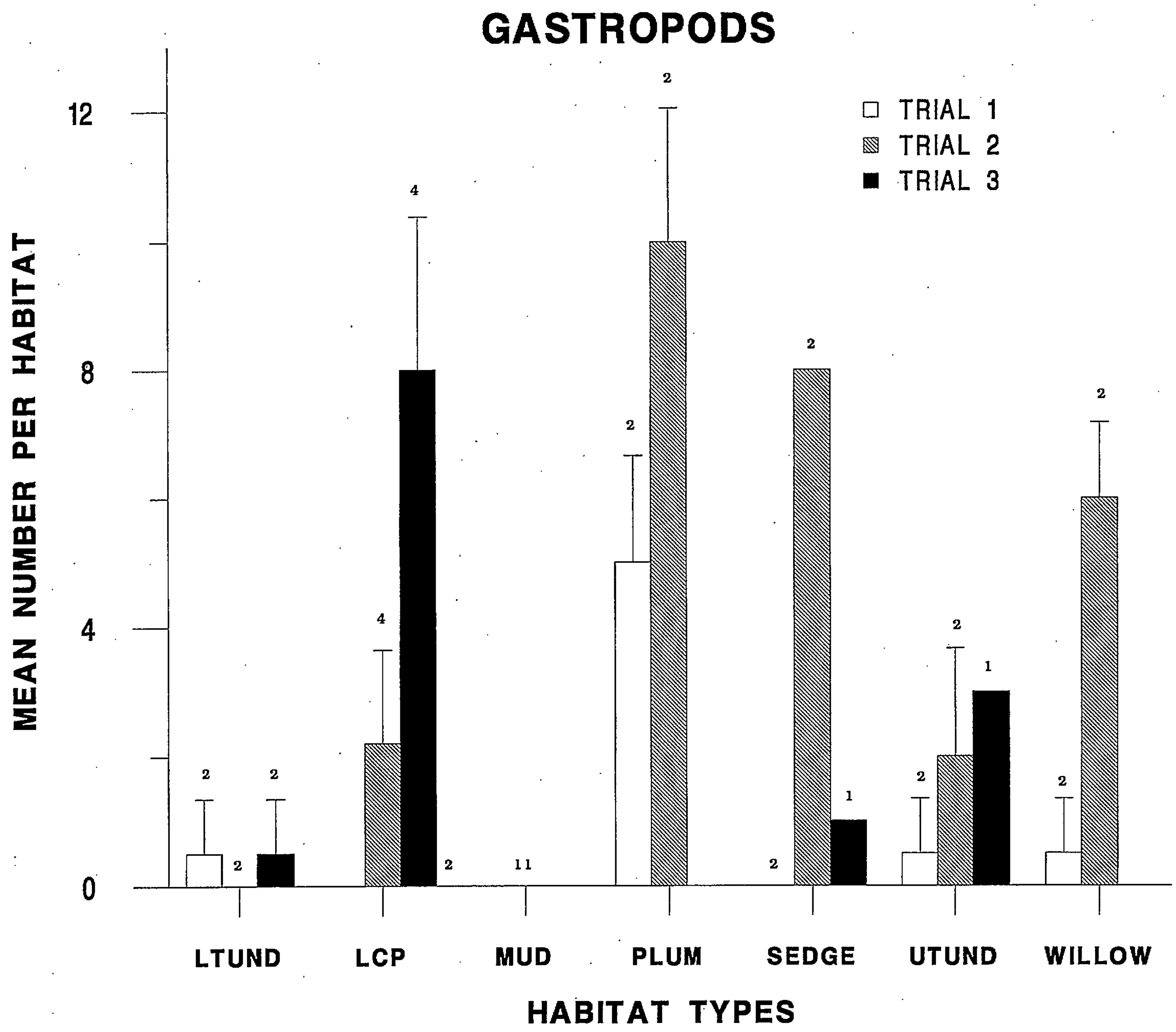

COLEOPTERA
TRIAL 1
TRIAL 2
TRIAL 3
MEAN NUMBER PER HABITAT
0
2
4
6
8
2
2
2
4
4
2
11
2
2
221
2
2
1
2
2
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.13. Stovepipe samples 1993: Total number of Gastropods (snails) collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*



GASTROPODS
MEAN NUMBER PER HABITAT
12
8
4
0
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Numbers of nematodes (Fig. 5.14, Table 5.1) were significantly greater in sedge than in any other habitat during the first sampling period, but there were no significant differences in sampling periods two or three.

Numbers of all invertebrates found in the stovepipe samples were significantly greater in wet sedge/willow or "pure" sedge, compared to any other habitat, in the first sampling period (Fig. 5.15, Table 5.1). During the second sampling period, numbers in wet sedge/willow were significantly greater than in any other habitat. All sedge/willow sites were dry during the third sampling period, and there were no significant differences among habitat types.

When Habitat Types were combined ("priority shorebird habitat"=polygons and sedge; uplands=high and low tundra; willow-types=wet sedge/willow and dense willow; mudflats), virtually all significant differences noted above were lost (Table 5.2).

5.3.3.2. ***Invertebrate measurements.*** Average measurements of invertebrates collected in the stovepipe samples are shown in Table 5.3. The four most common invertebrate groups were analyzed for differences in size (length) among sampling periods (Fig. 5.16). Chironomid larvae were significantly smaller in the first sampling period than in the second or third set of samples (ANOVA: n=507, p=0.0001, GT2). There were no significant differences in size of mosquito larvae over the season (ANOVA: n=310, p=0.13). Cladocerans were significantly longer in the second set of samples, compared to the first (ANOVA: n=386, p=0.0001, GT2), and copepods in the first samples were significantly smaller than those in the second and third sets (ANOVA: n=322, p=0.0001, GT2).

5.4. Discussion

5.4.1. Invertebrate prey of adult shorebirds

The most common invertebrates present in the aquatic samples (Dipteran insects: Chironomidae larvae, Culicidae larvae and pupae; small Crustaceans: Cladocera, Copepoda; and nematodes), are known to be shorebird prey (Holmes 1966, Hicklin and Smith 1979, Boates 1980, Lewis 1983, Gratto et al. 1984, Morrison 1984, Peer et al. 1986). Beetles, spiders and snails are also taken, and spiders in particular may be most significant to shorebirds early in the breeding season (Danks 1971). Of these invertebrates, nematodes are probably the least important, since they are not mentioned in any food habit studies of these shorebird species on the breeding grounds (e.g. Holmes and Pitelka 1968, Baker 1977).

Small crustaceans in arctic ponds, especially Cladocerans and Copepods greater than 1 mm in length, are most commonly eaten by breeding phalaropes (Dodson and Egger 1980). Diptera are the most common prey of all other breeding shorebirds studied here, with average prey size ranging from 3 to 10 mm (Holmes 1966, Holmes and Pitelka 1968, Baker 1977). Here, sizes of Chironomid larvae, Cladocerans and Copepods increased during the season, with Chironomid larvae averaging 4.7 mm (ranging from 2 to 13 mm), Culicid larvae 6.9 mm (2 to 10), Cladocera 2.0 mm (1 to 7), and Copepods 1.9 mm (1 to 3). Therefore, most

Figure 5.14. Stovepipe samples 1993: Total number of Nematode worms collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

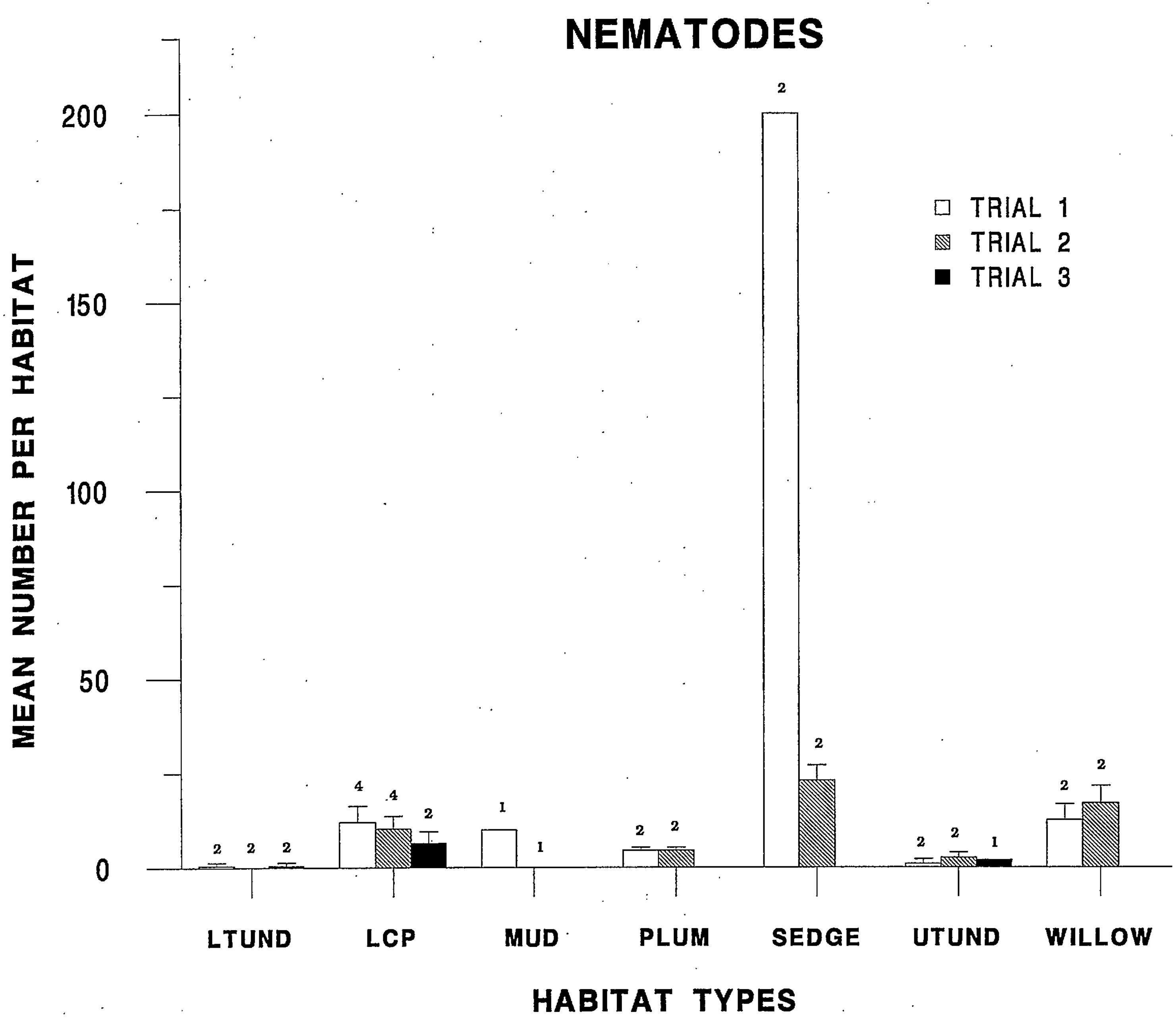

NEMATODES
MEAN NUMBER PER HABITAT
0
50
100
150
200
TRIAL 1
TRIAL 2
TRIAL 3
2
2
2
4
4
2
1
1
2
2
2
2
2
2
1
2
2
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Figure 5.15. Stovepipe samples 1993: Total number of invertebrates collected in different habitat types. *LCP=low centre polygon habitat; SEDGE="pure" sedge; PLUM=wet sedge/willow; UTUND=high upland tundra; LTUND=low upland tundra; WILLOW=dense willow; MUD=mudflat.. Trial=sampling period. Small numbers above bars represent number of sites sampled.*

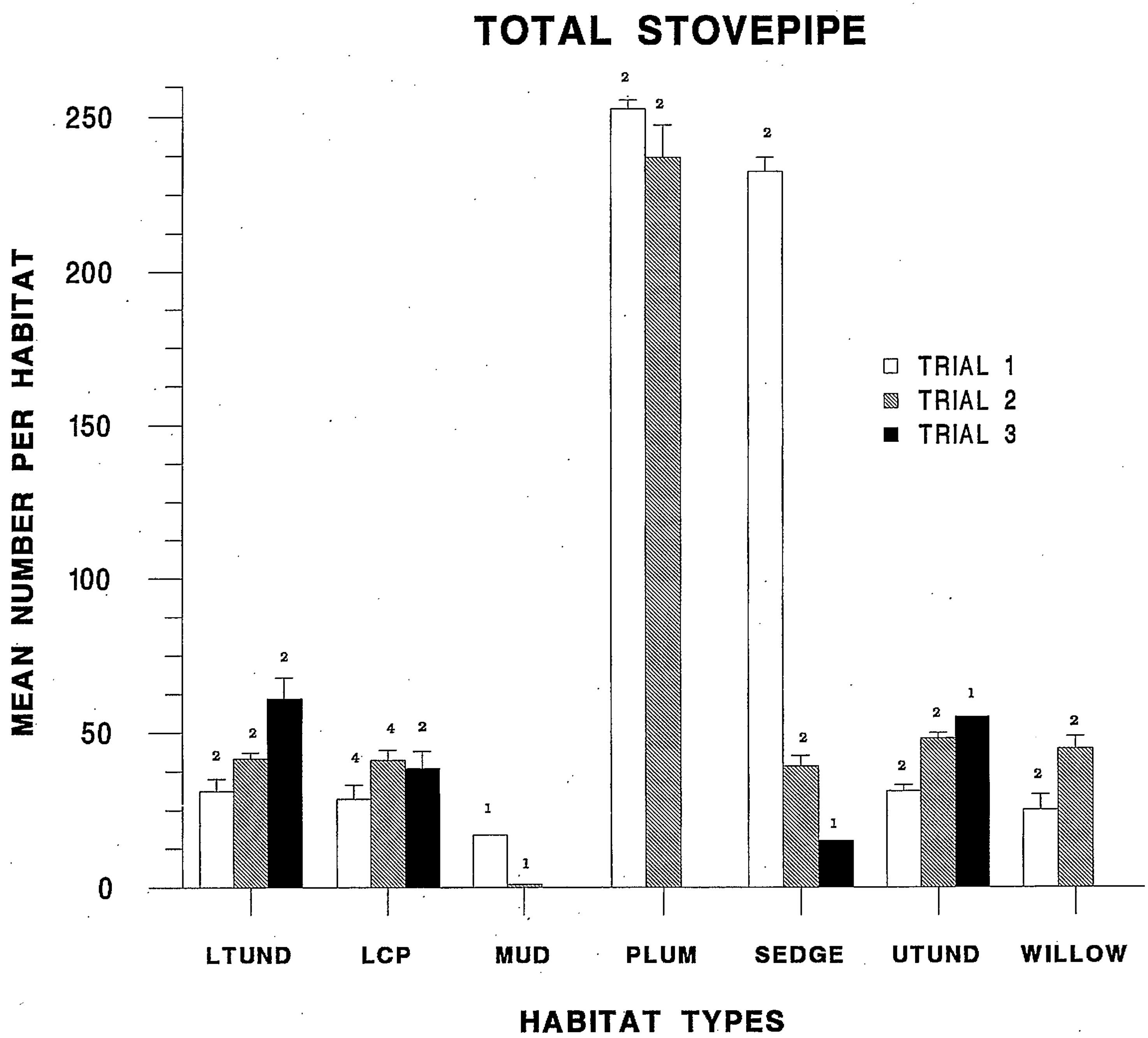

TOTAL STOVEPIPE
MEAN NUMBER PER HABITAT
250
200
150
100
50
0
TRIAL 1
TRIAL 2
TRIAL 3
LTUND
LCP
MUD
PLUM
SEDGE
UTUND
WILLOW
HABITAT TYPES

Table 5.2. Comparisons between habitat types of numbers of invertebrates in stovepipe samples. Habitats used were: low-centre polygon + sedge sites combined (6 sites), high + low uplands combined (4 sites), wet sedge/willow + dense willow combined (4 sites); mudflat (1 site). Results were virtually identical with the mudflat site included or excluded. Tests were ANOVAs with GT2 family error test for specific differences if ANOVA was significant ($P < 0.05$).

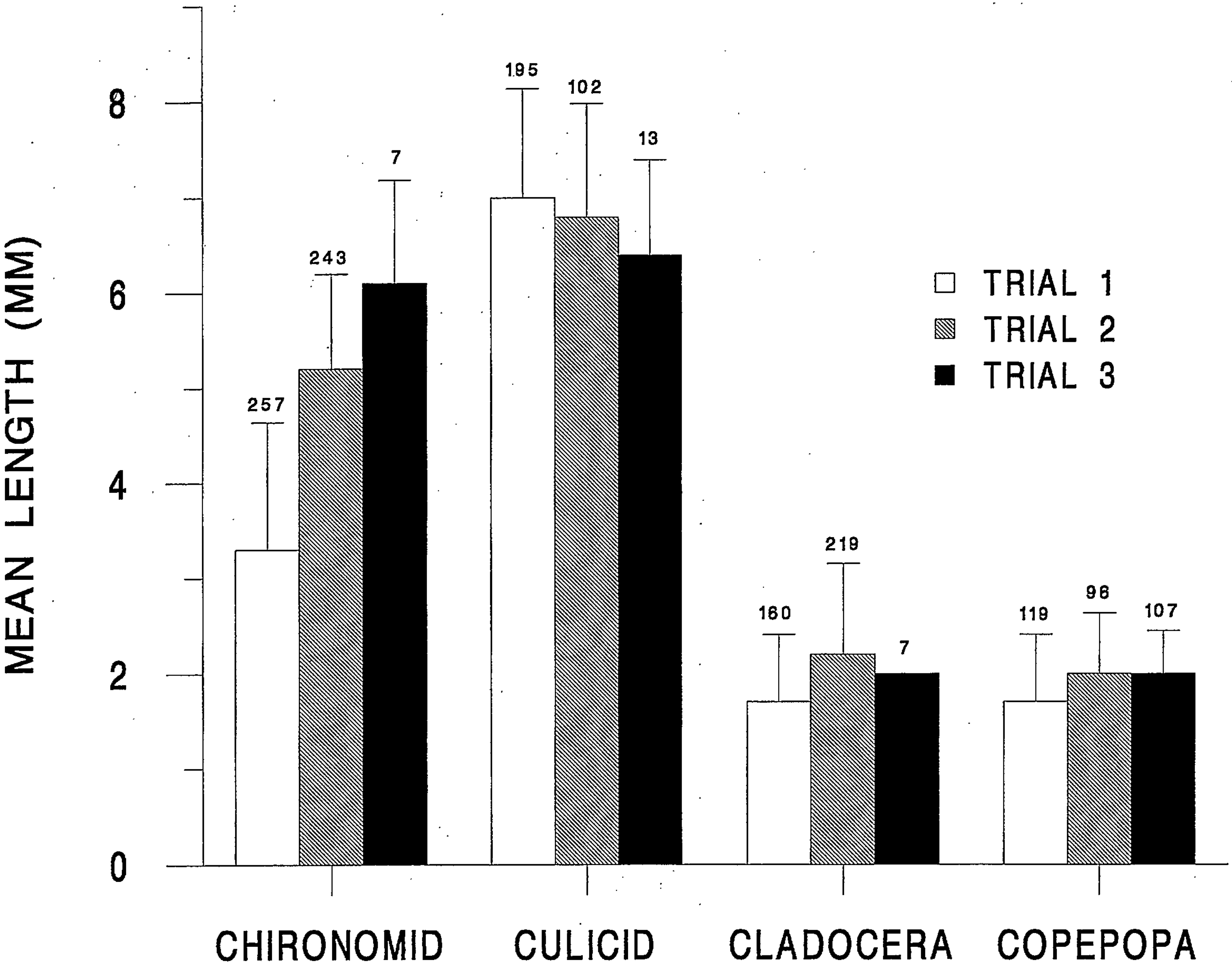
Invertebrates	Trial A (19-22 June, n=15 sites) ANOVA P	Trial B (29 June, n=15 sites) ANOVA P	Trial C (8 July, n=6 sites) ANOVA P
Chironomid larvae	0.08	0.14	0.48
Culid larvae	0.22	0.17	0.16
Culid pupae	0.42	0.45	0.70
Diptera total	0.12	0.12	0.34
Copepods	0.61	0.13	0.25
Cladocerans	0.14	0.30	0.27
Crustacea total	0.40	0.45	0.14
Coleopterans	0.86	0.19	0.24
Gastropods	0.12	0.04*	0.27
All invertebrates	0.45	0.13	0.31

*GT2: Wet sedge/willow + dense willow > uplands.

Table 5.3. Measurements of invertebrates collected in stovepipe samples, 1993. See Appendix 5.2 for classification of invertebrates.

Invertebrate	N	Mean (mm)	STD	MIN (mm)	MAX (mm)
Chironomidae larvae	507	4.7	1.8	2	13
Culicidae larvae	310	6.9	1.3	2	10
Culicidae pupae	55	4.7	0.8	2	6
Ephydridae	2	14.0	14.1	4	24
Coleoptera	50	5.3	2.1	3	12
Dytiscidae	10	8.4	3.8	5	17
Trichoptera	7	12.4	7.0	5	22
Collembola	1	2.0	-	2	2
Hemiptera	1	12.0	-	12	12
Copepoda	322	1.9	0.4	1	3
Cladocera	386	2.0	0.8	1	7
Hyalellidae	4	2.0	0.0	2	2
Ostracoda	3	1.3	0.6	1	2
Decapoda	5	9.4	2.9	5	13
Eubranchiopod	24	6.5	1.1	5	8
Aranae	1	1.0	-	1	1
Hydracarina	5	1.6	0.9	1	3
Gastropoda	69	6.3	2.3	1	12

Figure 5.16. Mean length of invertebrates collected in stovepipe samples 1993. *CHIRONOMID=Chironomidae (midge) larvae; CULICID=Culicidae (mosquito) larvae; CLADOCERA=Cladocera (crustacean); COPEPODA=Copepoda (crustacean). Trial= Sampling period.*


MEAN LENGTH (MM)
0
2
4
6
8
257
243
7
195
102
13
160
219
7
119
96
107
TRIAL 1
TRIAL 2
TRIAL 3
CHIRONOMID
CULICID
CLADOCERA
COPEPOPA

organisms sampled were potential shorebird prey. At Barrow, Alaska, mosquitoes were considered unimportant compared to Chironomids (Holmes and Pitelka 1968). In the outer Mackenzie Delta samples, Culicid larvae were abundant. Although numbers of mosquito larvae were considerably lower than Chironomids in the habitat with most invertebrates (wet sedge/willow), they were higher in all other habitats.

5.4.2. Variation between habitats in numbers of aquatic prey

Overall, Dipteran larvae were most abundant in samples from wet sedge/willow, rather than priority shorebird habitat, in the first two sampling periods. Crustaceans (mostly Cladocera) were also most abundant in wet sedge/willow during mid June. Priority shorebird nesting habitat is probably a compromise between availability of invertebrate food, and presence of suitable nest sites (dry areas with suitable cover). Good nest sites are usually not available in wet sedge/willow, but wet sedge/willow habitat is normally located in close proximity to low centre polygon, sedge, and low upland habitats, which do contain suitable nesting cover. Therefore birds nesting in these habitats have the option of foraging in nearby wet sedge/willow as well. It is interesting that virtually nothing was found in the mudflat samples, perhaps due to the high silt content of water in river channels.

5.4.3. Seasonal availability of aquatic prey

Availability to shorebirds of aquatic prey is usually dependent on water level. Thus, when water levels were high in mid June, most small shorebirds could only forage along wetland margins, in shallow water. Water levels decreased dramatically by the second sampling period, and more invertebrates were available to the birds, particularly those species of invertebrates burrowing in pond sediments. Therefore, the sampling methodology used here (sampling only some of the upper substrate mixture during first sampling, and all of the mix in the second and third sets) probably mimicked to a large extent the availability of aquatic invertebrates to shorebirds. In 1993, many ponds in all habitats had dried up, resulting in decreased availability at that time. However, availability of aquatic invertebrates can temporarily decline at any time during the summer in periods of intense rainfall, when pond water levels increase (Holmes 1966).

5.4.4. Prey of nestlings

Newly hatched shorebirds forage almost entirely on adult insects and spiders (Holmes 1966). Shorebird hatch in the arctic is therefore timed for peak insect emergence. Emergence of mosquitoes and midges in the arctic usually begins in late June and peaks in early to mid July (McClure 1943, Holmes 1966, MacLean and Pitelka 1971, Danks and Oliver 1972, Corbet and Danks 1973). Initial emergence of mosquitoes in the outer Mackenzie Delta varied from 20 June in 1991 to 25 June in 1992, and nothing was obtained in the first set of sweepnet samples in 1992 (19-22 June), when first emergence was noted on 23 June. By the second sampling period at the end of June, insect emergence was well under way, and continued through the third set of sampling in early July. Shorebird hatch also peaked in early July (see Chapter 6). No difference was found among habitat types, or between the second and third set of samples, in number of adult insects captured.

Insect emergence is primarily dependent on temperature: temperatures of less than 7° C may act to delay emergence of Chironomids. Emergence dates are often synchronous within a pond, but vary from pond to pond depending on pond depth. For shallow and temporary ponds (350 to 930 mm in depth) on Ellesmere Island, most Chironomids emerged between 30 June and 10 July. In deeper ponds (>2000 mm), most emerged between 15 and 27 July (Danks and Oliver 1972). Since insect emergence is temperature dependent, and shorebird nestling need adult insects for food, temperatures in June can have marked effects on shorebird reproductive success (Myers and Pitelka 1979). Even later in the season, periods of low temperatures or extremely strong winds decrease availability of adult flying insects, with some being directly killed by weather and others having reduced activity. However, once conditions improve, more insects quickly emerge (Holmes 1966). In Alaska, peak insect emergence occurred before the summer temperature maximum, and usually abruptly declined just as the temperature reached its seasonal peak. This synchronous emergence has been viewed as a predator-swamping technique (MacLean and Pitelka 1971). However, others have suggested that the timing of insect emergence in he arctic reflects a balance between maximum temperature in July, and increased temperature uncertainty from late July on (Myers and Pitelka 1979).

5.5. <u>Conclusions</u>

In June, aquatic invertebrate prey of adult shorebirds (dipteran insects, small crustaceans) was highest in wet sedge/willow habitat, rather than priority shorebird nesting habitat. Priority shorebird habitat presumably reflects a balance between prey availability and availability of suitable nest sites. Due to lower water levels in late June, availability of aquatic invertebrates probably peaked at that time, decreasing in early July as ponds dried up. Adult insects emerged in late June and early July, about the time most shorebird nests hatched. Shorebird nestlings are dependent on adult insects for food.

CHAPTER 6

SHOREBIRD MEASUREMENTS AND NESTS

6. SHOREBIRD MEASUREMENTS AND NESTS

6.1. Introduction and Objectives

Nests were monitored as much as possible, to determine nesting chronology of shorebirds, mostly by back-dating of hatch dates and young chicks. Since camp sites were moved during the summers of both 1991 and 1992, in no instance could a nest be followed from laying to hatch. Therefore, breeding success rates could not be obtained. Where possible, breeding adults were captured to obtain measurement data, blood samples for future DNA analysis, and marked for recognition elsewhere, all in an attempt to determine migration routes, staging sites, and wintering areas of Mackenzie Delta breeders.

6.2. Methods

6.2.1. Shorebirds.

Breeding shorebirds were captured either in a chicken-wire walk-in nest trap (if incubating), or a monofilament mist net (if with brood). Adults were banded with a single white plastic leg flag, a stainless steel (aluminum for large species) C.W.S. band, a two-tone light/dark green colour band, and two other colour bands (red, orange, yellow, blue, light green, or dark green), in individual colour combinations.

Birds were measured: maximum wing length (flattened and straightened, to nearest mm with wing rule), bill length (culmen: feathering to tip, to nearest 0.1 mm with digital calipers), tarsus (to nearest 0.1 mm with digital calipers), and mass (to nearest 0.5 g with Pesola balances). Where possible, sex was determined by plumage, bill measurements, or behaviour (depending on the species).

Any chicks found were marked with a stainless steel C.W.S. band.

6.2.2. Nests.

Nests were marked in an obscure fashion with flagging tape, when found during censuses or otherwise. Number, condition, and size of eggs were recorded (maximum length and maximum width, with digital calipers to nearest 0.1 mm). Nests were sometime revisited, usually to capture an incubating adult. However, since in 1991 and 1992 camp sites were changed two to three times in a season, in no instance was a nest followed from initiation to hatch. In fact, no nests were found during the laying period. Hatch dates were known for some nests, and calculated for others by estimating age of young chicks captured.

6.3. Results

6.3.1. Breeding Adults.

A total of 46 adult shorebirds were captured on nest or with broods from 1991 to 1993. The Common Snipe and Pectoral Sandpipers were females, and the Red-necked Phalaropes males, since these species have uniparental incubation, as noted in Section 1.4. The remaining species are biparental incubators, but Lesser Golden Plovers and Semipalmated Plovers can be sexed by plumage differences in the breeding season, particularly when both parents are present (Prater et al. 1977). Semipalmated Sandpiper and Stilt Sandpiper females average longer bills than males. Sexes can be determined with a high degree of confidence when both members of a pair have been measured (Gratto-Trevor 1991, 1992). Measurements of adults are shown in Table 6.1, with male and female Semipalmated Plovers, Semipalmated Sandpipers, and Stilt Sandpipers in Table 6.2. One of the 11 Semipalmated Sandpiper adults captured showed Partial Postjuvenile Moult, so was a yearling (Gratto and Morrison 1981). It was captured on nest, and appeared to be a male by bill length.

One male Semipalmated Plover (band number 811-05858), which was captured on nest just east of Fish Island in 1992 (Plot 21C: see Fig. 4.1), had been previously banded. The bird was one of 10 adult Semipalmated Plovers marked during fall migration 1991 at Little Quill Lake, Saskatchewan. No other previously banded birds were found, except for a pair of Semipalmated Plovers marked during 1992 at Taglu gravel pad (Plot 20C: see Fig. 4.1), that were found back in the same area in 1993. None of the three Whimbrel, three Semipalmated Plovers, two Pectoral Sandpipers or one Red-necked Phalarope adults banded on Fish Island in 1991 were seen there in 1992 or 1993. Since sites varied between years, there was little other opportunity to search areas where birds had been banded in previous years.

6.3.2. Chicks.

Chicks banded from 1991 to 1993 included one Pectoral Sandpiper, 12 Red-necked Phalaropes, seven Semipalmated Plovers, five Semipalmated Sandpipers, and four Stilt Sandpipers, for a total of 29.

6.3.3. Nests.

A total of 50 eggs of five species were measured from 1991 to 1993 (Table 6.3). Of the 28 shorebird nests examined during incubation, 5 held three eggs, 22 four eggs, and 1 five eggs (Common Snipe: 1 four egg; Lesser Golden Plover: 1 four egg; Pectoral Sandpiper: 2 four egg; Red-necked Phalarope: 1 three egg, 6 four egg; Semipalmated Plover: 1 three egg, 4 four egg; Semipalmated Sandpiper: 5 four egg; Stilt Sandpiper 1 five egg; Whimbrel: 3 three egg, 3 four egg). No nests were found during initiation.

Table 6.1. Measurements of breeding adult shorebirds captured in the outer Mackenzie Delta from 1991 to 1993. Species codes are explained in Table 1.1. SEX: F=females, M=males, B=both sexes.

SPECIES	SEX	WING (mm)			BILL (mm)			TARSUS (mm)			MASS (g)		
		N	Mean (range)	SE	N	Mean (range)	SE	N	Mean (range)	SE	N	Mean (range)	SE
COSN	F	1	137.0 -	-	1	65.5 -	-	1	35.6 -	-	1	107.0 -	-
LEGP	F	1	190.0 -	-	1	23.8 -	-	1	45.9 -	-	1	148.0 -	-
PESA	F	3	134.3 (130-138)	2.33	3	30.0 (28.9-31.3)	0.70	3	29.3 (29.2-29.5)	0.10	3	62.7 (55.0-70.0)	4.33
RNPH	M	11	112.4 (110-118)	0.68	11	22.4 (20.8-24.2)	0.35	11	21.8 (20.5-22.8)	0.21	11	31.9 (28.5-35.5)	0.59
SEPL	B	11	124.8 (120-129)	0.83	11	12.6 (10.9-16.7)	0.45	11	24.6 (22.5-26.3)	0.35	11	46.4 (43.5-49.5)	0.50
SESA	B	11	98.8 (94-101)	0.67	11	18.6 (16.7-20.5)	0.35	11	22.6 (21.4-23.6)	0.26	11	25.9 (21.5-29.5)	0.84
STSA	B	5	133.0 (131-138)	1.30	5	40.0 (38.7-42.5)	0.68	5	40.9 (33.4-45.4)	2.01	4	55.8 (50.5-67.0)	3.82
WHIM	B	3	255.7 (253-258)	1.45	4	92.0 (84.8-97.5)	2.71	4	62.6 (59.3-65.6)	1.39	4	397.0 (354.0-442.0)	22.71

Table 6.2. Measurements of breeding adult shorebirds identified to sex. SEPL (Semipalmated Plovers) were sexed by plumage (blacker= male); SESA (Semipalmated Sandpipers) were sexed by bill length in known pairs (shorter= male); and by single parent with brood (male); STSA (Stilt Sandpipers) were sexed by bill length in known pairs (shorter= male).

		WING (mm)			BILL (mm)			TARSUS (mm)			MASS (g)		
SPECIES	SEX	N	Mean (range)	SE	N	Mean (range)	SE	N	Mean (range)	SE	N	Mean (range)	SE
SEPL	F	4	126.2 (123-129)	1.38	4	12.5 (12.0-13.2)	0.27	4	25.3 (24.4-26.3)	0.39	4	47.9 (46.0-49.5)	0.83
	M	5	124.8 (121-127)	1.02	5	13.2 (11.6-16.7)	0.90	5	24.8 (24.2-25.5)	0.22	5	45.6 (43.5-46.5)	0.53
SESA	F	3	100.7 (100-101)	0.33	3	19.9 (18.9-20.5)	0.52	3	23.5 (23.3-23.6)	0.09	3	28.8 (28.0-29.5)	0.44
	M	6	97.3 (94-100)	0.80	6	17.9 (16.7-18.5)	0.28	6	22.3 (21.6-23.6)	0.32	6	23.8 (21.5-26.5)	0.76
STSA	F	2	135.5 (133-138)	2.50	2	41.2 (39.8-42.5)	1.35	2	43.4 (41.3-45.4)	2.05	2	58.8 (50.5-67.0)	8.23
	M	2	131.5 (131-132)	0.50	2	38.8 (38.7-38.9)	0.10	2	42.3 (42.3-42.3)	0.00	1	54.0 -	-

Table 6.3. Egg measurements of shorebirds nesting in the outer Mackenzie Delta, 1991 to 1993. Species codes are explained in Table 1.1.

			Length (mm)			Width (mm)		
Species	# Eggs	# Nests	Mean	SE	(Range)	Mean	SE	(Range)
LEGP	4	1	47.2	0.48	(46.1-48.2)	33.1	0.13	(32.8-33.4)
SEPL	12	3	32.8	0.26	(30.8-34.0)	23.7	0.26	(22.2-25.2)
SESA	12	3	30.3	0.15	(29.2-31.0)	21.3	0.09	(20.8-21.9)
STSA	5	1	37.3	0.26	(36.8-38.2)	25.9	0.11	(25.5-26.1)
WHIM	17	5	59.2	0.47	(55.9-63.2)	41.0	0.24	(38.4-42.5)

Pipped eggs and young chicks suggested the following hatch dates:

1991 Red-necked Phalaropes: 1, 3, 6, 9, 10 July (a few nests not pipped by 12 July)
Semipalmated Plovers: 30 June
Semipalmated Sandpipers: 2, 4, 6, 7 July
Stilt Sandpipers: 8 July

1992 Pectoral Sandpipers: 7 July
Red-necked Phalaropes: 6, 6 July
Semipalmated Plovers: 10, 11 July
Semipalmated Sandpipers: 4, 7 July
Stilt Sandpipers: 6 July

1993 Whimbrel: 6 July.

Therefore, in 1991, first known hatch date was 30 June, with virtually all nests hatched by 10 July, averaging 5 July (n=11, median 6 July). In 1992, first known hatch was 4 July, all known nests hatched by 11 July, averaging 7 July (n=8, median 6.5 July).

6.4. Discussion

Hatch dates of shorebirds (early to mid July) in 1991 and 1992 agree with those obtained in this area earlier (Campbell 1973, Dickson et al. 1989). In fact, these dates are similar to those in other parts of the low to mid-arctic (e.g. Barrow, Alaska: Holmes 1966, Ashkenazie and Safriel 1979; Melville Peninsula: Montgomerie et al. 1983, Churchill, Manitoba: Jehl 1973, Gratto-Trevor 1992), although shorebirds in certain parts of Alaska, such as Prudhoe Bay (pers. obs.) and Nome (Sandercock, pers. comm.), may initiate nests earlier, at least in some years. As noted in Chapter 5, hatch of arctic shorebirds is normally timed for peak insect emergence, as adult insects provide the primary food for nestlings.

6.5. Conclusions

Shorebird nests in the outer Mackenzie Delta hatched in early to mid July, so most nests were initiated in the second and third weeks of June.

CHAPTER 7

WEATHER

7. WEATHER

7.1. Introduction and Objectives

Weather data was collected in the study area to obtain additional information on inter-year variation, and to determine how the summers of 1991 and 1992 compared with the norm, so that shorebird breeding densities could be better put in perspective. Dickson et al. (1989) collected weather information at Fish Island from 1985 to 1987, and Slaney and Co. (1974b) at nearby Taglu in 1972 and 1973.

7.2. Methods

Daily weather information was collected in 1991 and 1992. Between 0800 and 1000, present, minimum and maximum temperatures (to 0.1 °C) were recorded from a digital min/max thermometer. At that time, wind strength (measured by anemometer) and direction, % cloud cover, and presence or absence of precipitation or fog were noted.

7.3. Results

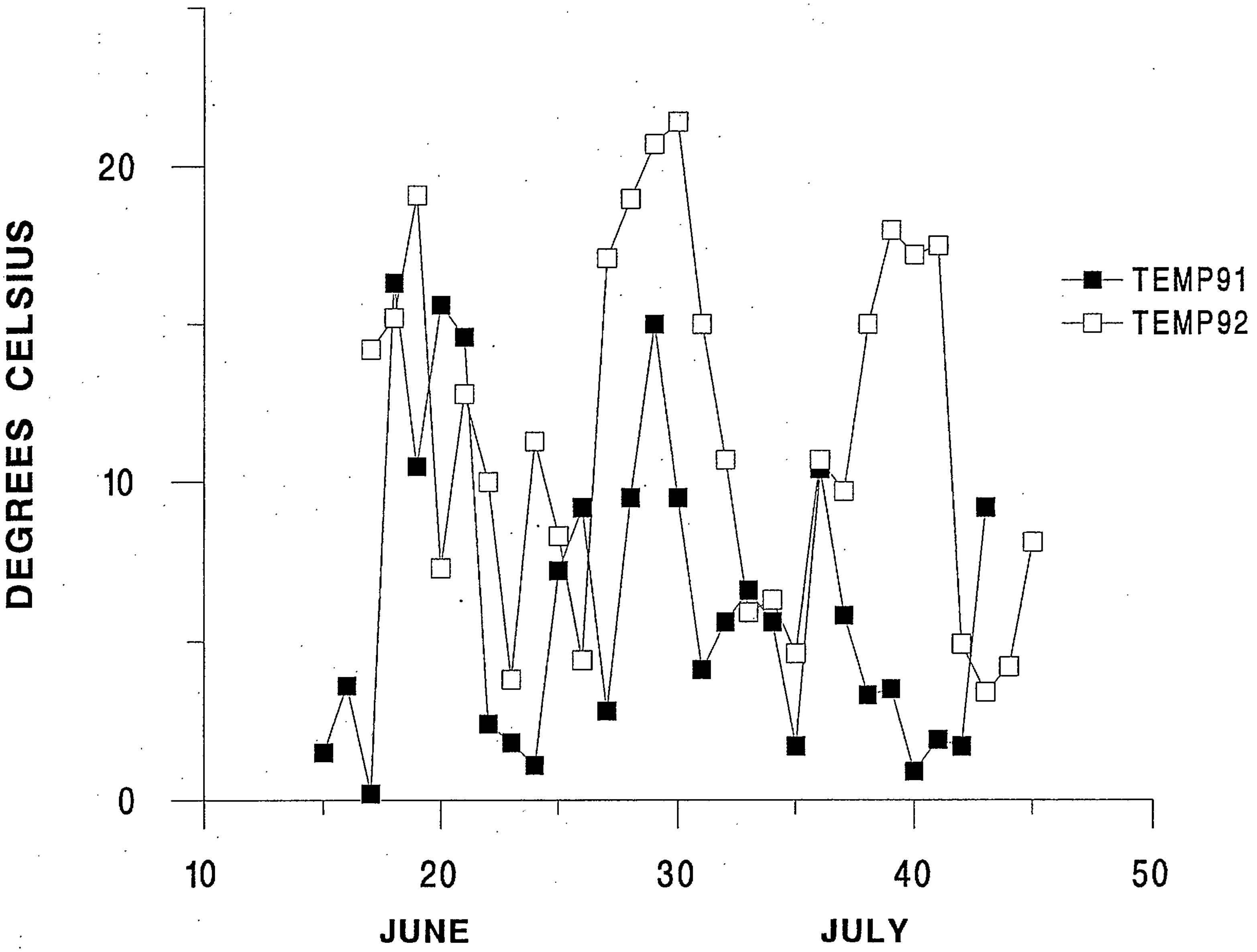
7.3.1. Temperature

Daily temperatures, minimums, and maximums for 1991 and 1992 are shown in Figures 7.1 and 7.2. Differences between years, and between the first and second halves of each season (last two weeks in June; first two weeks in July) were compared (Table 7.1). Morning temperatures averaged significantly warmer in the first half of 1992 than in either the first or second half of 1991, and the second half of 1992 was also significantly warmer than the second half of 1991. For daily minimum temperatures, both the first and second halves of 1992 were significantly warmer than the second half of 1991. Average maximum temperatures in the second half of 1992 were significantly warmer than in the second half of 1991. Overall, temperatures in 1992 were warmer than those in 1991, especially the second half of 1991. However, there were no significant differences between seasons within a year, in the mid-June to mid-July period. The number of days with precipitation was similar in 1991 and 1992, but there were twice as many heavily overcast days in 1991 as 1992 (Table 7.1).

7.3.2. Timing of Spring Break-up

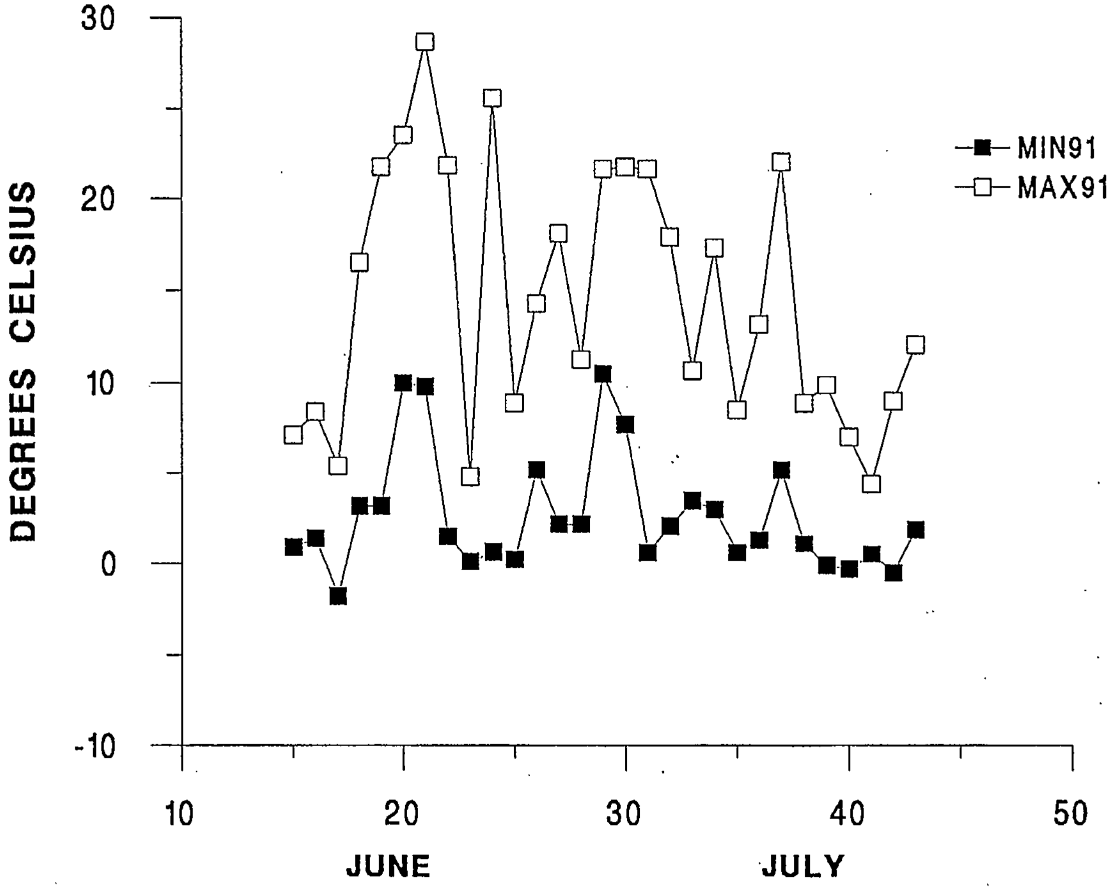
The timing of spring break-up of ice in the Mackenzie River was very different between years. Initiation of ferry transport at Inuvik is dependent on ice breakup. Ferry initiation dates from 1981 to 1993 (N.W.T. Dept. Transportation, Inuvik, pers. comm.) varied from 26 May (1991) to 11 June (1992), averaging 4-5 June (S.D. 4.0). Ice breakup was the earliest in 1991 and the latest in 1992, in at least 13 years. Flooding in the outer delta was

Figure 7.1. ***Morning temperatures, mid June to mid July, 1991 and 1992, outer Mackenzie Delta, NWT.*** *Black boxes= 1991; White boxes= 1992. 1=1 June, 31=1 July.*

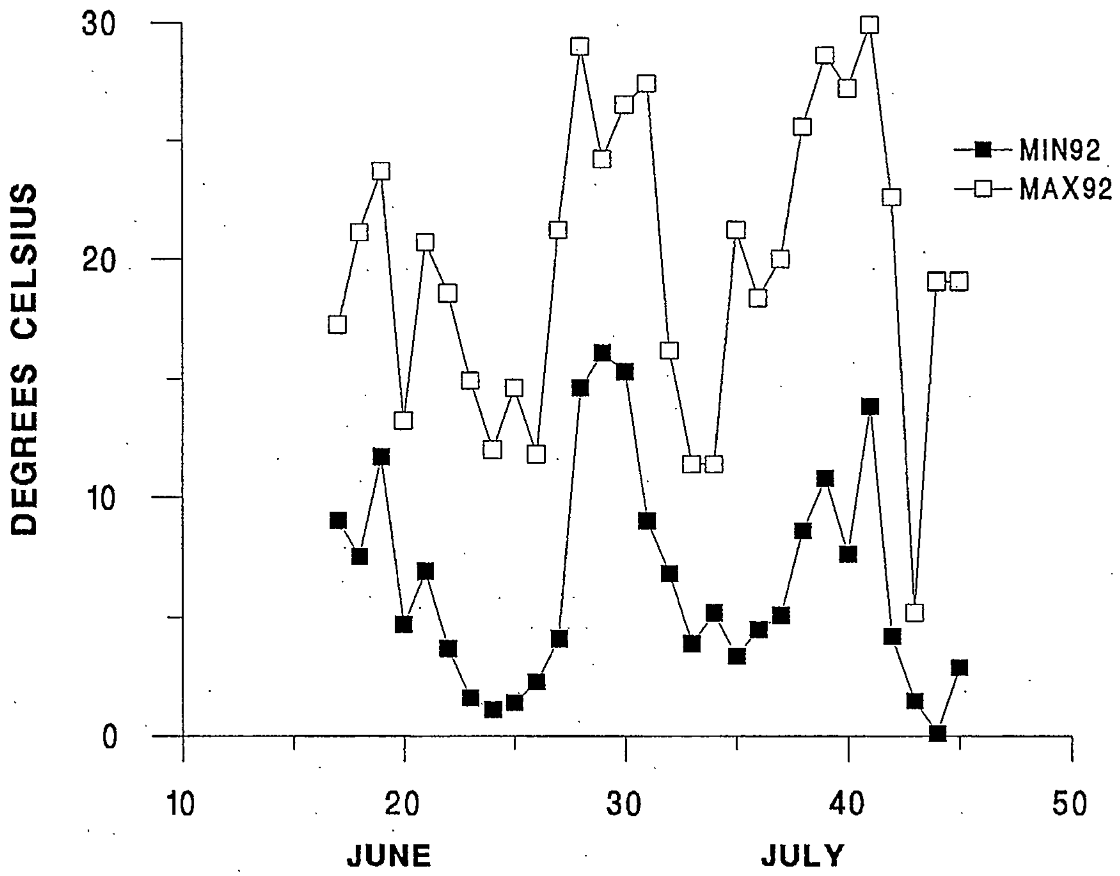


DEGREES CELSIUS
20
10
0
10
20
30
40
50
JUNE
JULY
TEMP91
TEMP92

Figure 7.2. Daily minimum and maximum temperatures, mid June to mid July, 1991 (upper graph) and 1992 (lower graph). *Black boxes= daily minimums; White boxes, daily maximums. 1=1June, 31=1 July.*



30
20
10
0
-10
DEGREES CELSIUS
MIN91
MAX91
10
20
30
40
50
JUNE
JULY



30
20
10
0
DEGREES CELSIUS
MIN92
MAX92
10
20
30
40
50
JUNE
JULY

Table 7.1. Weather conditions from mid-June to mid-July, 1991 and 1992, in the outer Mackenzie Delta, NWT. Period 1 = last two weeks of June; Period 2 = first two weeks of July. "Present" Temperature = temperature taken between 0800 and 1000 each day.

			Mean Temperature °C (SE)				Cloud Cover (# days)			
Period	Year	# Days	Present[1] (Range)	MIN[2] (Range)	MAX[3] (Range)	# Days with Precip.	0-15%	20-80%	90-100%	Fog
1	1991	16	7.6 (1.4) (0.2 to 16.3)	3.6 (1.0) (-1.8 to 10.5)	16.2 (1.9) (4.8 to 28.7)	4	7	2	7	0
2	1991	13	4.6 (0.8) (0.9 to 10.4)	1.4 (0.5) (-0.5 to 5.2)	12.6 (1.6) (4.4 to 22.0)	1	3	3	7	0
1	1992	14	13.2 (1.6) (3.8 to 21.4)	7.1 (1.4) (1.1 to 16.1)	18.5 (1.5) (11.8 to 29.0)	1	9	1	1	3
2	1992	15	10.1 (1.4) (3.4 to 18.0)	5.8 (0.9) (0.1 to 13.8)	20.2 (1.8) (5.2 to 29.9)	5	6	2	6	1

[1]Present temperatures, differences among periods and years: ANOVA P = 0.0006, n = 58, GT2: Period 1, 1992 > Period 1, 1991; Period 1, 1992 > Period 2, 1991; Period 2, 1992 > Period 2, 1991.

[2]Minimum temperatures, differences among periods and years: ANOVA P = 0.002, n = 58, GT2: Period 1, 1992 > Period 2, 1991; Period 2, 1992 > Period 2, 1991.

[3]Maximum temperatures, differences among periods and years: ANOVA P = 0.02, n = 58, GT2: Period 2, 1992 > Period 2, 1991.

extensive in 1992; on 11 June, only the gravel pads were above water in the northern Fish Island and northern Ellice Island areas. Flooding was not nearly as extreme in 1991. Ferry service was initiated on 4 June 1993, an average year.

7.4. Discussion

Although spring break-up was considerably later in 1992 than 1991, temperatures were much warmer in 1992, especially during the first half of July, when nests were hatching. Therefore, although early break-up in 1991 may have allowed some birds to nest earlier than normal (although this is not supported by back-dating hatch dates), survival of young may have been higher in 1992. Weather conditions during shorebird hatch in 1991 were generally very cold, wet, and windy, so invertebrate prey may have been unavailable for the young birds.

Dickson et al. (1989) averaged temperatures taken at 0800 and 1700 hrs to determine weekly means. Averages of their weekly mean temperatures in 1985, 1986, and 1987 were 9.8, 11.0, and 10.4°C respectively, in the last two weeks of June, and 10.0, 9.9, and 13.2°C in the first two weeks of July. In the present study, "present" temperatures were taken only in the morning, so cannot be directly compared to those of Dickson, although mean temperature in June 1992 is higher than in any other year, while the mean in July 1991 is lower than any other. Minimums and maximums were taken in a similar fashion in both studies, and minimums in 1985, 1986, and 1987 averaged 2.5, 2.0 and 3.5°C respectively in the last half of June, and 6.0, 1.0, and 4.5°C in the first half of July. Maximums averaged 16.0, 20.4, and 21.5°C in the last two weeks of June, and 17.5, 20.1 and 23.8°C in the first two weeks of July. Again, compared to Dickson et al. (1989), average minimum in June 1992 was considerably warmer, and average maximum in July 1991 considerably cooler. Therefore, not only were weather conditions in 1991 and 1992 very different, they were extreme compared to 1985, 1986, and 1987. However, conditions in 1991 and 1992 probably did not greatly affect numbers of shorebirds that nested, since temperatures during June 1991 were apparently no harsher than during Dickson's study. However, climate might have influenced survival of young in 1991, since temperatures were very cold in the first half of July.

7.5. Conclusions

Weather conditions were considerably warmer in 1992, compared to the 1991 breeding season, although ice break-up in the Mackenzie River at Inuvik was several weeks earlier in 1991 than 1992. Most shorebirds present probably bred in both years.

CHAPTER 8

GENERAL CONCLUSIONS

8. GENERAL CONCLUSIONS

8.1. Phenology

Shorebirds arrive in the outer Mackenzie Delta primarily in late May, about the time the river ice breaks up. Since timing of breakup varies from year to year, as does extent of flooding of the outer delta, initiation of shorebird nests can vary by several weeks between seasons. Egg laying also depends on the availability of invertebrate prey, as most female shorebirds must supplement stored energy with food obtained on the breeding grounds in order to produce eggs. Nests are initiated in early to late June, and hatch of shorebird young is timed for peak insect hatch in early to mid July. Therefore disturbance of the birds would have the greatest impact between late May and late July.

8.2. Fall migration

Shorebirds staged in the outer delta in small groups (up to several hundred birds) primarily from mid July to late August, both inland and on the coast. Small species tended to gather in larger flocks on the coast, compared to larger species in smaller groups inland. In Alaska, movement from the tundra to littoral zones in preparation for fall migration was noted for some species, including Semipalmated Plovers and Red-necked Phalaropes, while others, notably Hudsonian Godwits, Lesser Golden Plovers, Whimbrel, Long-billed Dowitchers and Pectoral Sandpipers, remained inland (Conners et al. 1979, Gill and Handel 1981). Dickson et al. (1989) noted flocks on Long-billed Dowitchers at inland areas during fall migration.

No really extensive flocks of shorebirds were seen in coastal areas of the Mackenzie Delta, so mostly local populations of shorebirds would be at risk in case of an oil spill: with the exception of the aquatic phalaropes, which probably stage farther out into the sea than our transects covered.

8.3. Shorebird ground censuses: monitoring vs. habitat studies

Based on the results of this study, and my experience in other arctic shorebird breeding areas, I would recommend census lines within a plot no more than 25 m apart, (unless using rope drags, which are not suitable in all habitat types), and larger plots of 400 m X 400 m or more, depending on the species of interest and density of breeders. It is certainly much more accurate to census plots several times a season, rather than once, but this must be balanced against obtaining enough plots of different habitat types in order to compare densities.

If the primary purpose of the study is to monitor changes in shorebird numbers from year to year, then multiple censuses within a season should be carried out. Variation in numbers could be due merely to within and between year differences in weather conditions, nest depredation rates, or time of season (Gratto-Trevor 1994). Monitoring is most accurate when all birds are marked, but this is exceedingly time-consuming. Multiple censusing of a few large plots per season is a reasonable alternative.

Conversely, if determination of shorebird densities in different habitat types is the primary objective of the study, then one must suffer some loss of accuracy in determining population numbers by having only one census per plot per season while increasing numbers of plots examined. Number of habitat types should be kept to a minimum, and be easily recognizable in the field, as long as habitat characteristics important to nesting shorebirds are still considered. Transects are a way to gather large amounts of data quickly, but I consider the gain in sample area to be far outweighed by the likelihood of missing small species and those that flush close to their nest (e.g. phalaropes, Hudsonian Godwits), and counting birds that are not nesting within the width of the transect (e.g. Whimbrel). Unmarked, paced plots seem a reasonable compromise in habitat studies.

8.4. Densities and distribution of breeding shorebirds in the outer delta

Densities of shorebirds breeding in the outer delta were not extremely high, except for some dense patches of Red-necked Phalaropes. Areas of low-centre polygons, easily identified from aerial photographs, were very important for breeding shorebirds, and contained many species, including the uncommon Hudsonian Godwit, as well as Red-necked Phalaropes (thought to be decreasing in numbers: Morrison et al. 1994), Whimbrel, Pectoral Sandpipers and Stilt Sandpipers. Areas of damp sedge were used by large numbers of Red-necked Phalaropes, as well as many of the species listed above. Semipalmated Sandpipers were sometimes found in patches of sparse willow in these areas, and often at low hummocky upland tundra sites, which also contained Lesser Golden Plovers. Semipalmated Plovers were only found on gravel pads in the study area.

Therefore, areas of low-centre polygons, sedge meadow, and upland tundra "valleys" should be left as undisturbed as possible. Most of these major areas are identified in Figures 2.1 and 2.2. However, areas purporting to be priority shorebird nesting habitat that are directly on the Beaufort Sea coast, including northern Ellice Island and many of the islands near the mouth of Shallow Bay, are unlikely to be useful to nesting shorebirds due to extensive and prolonged flooding that has resulted in a lack of ground cover vegetation. Whether this reflects misidentification by the LANDSAT analysis, or actual changes in vegetation since the satellite imagery was taken in 1986, is unknown. We did not ground-truth these areas until 1992. Therefore, while densities of shorebirds in observed habitat types are probably reasonably accurate, overall totals, using percentages of each habitat type as identified by LANDSAT, are suspect. Nevertheless, only the number of Hudsonian Godwits seems particularly dubious, since it is biased by the unusual occurrence of a bird in a common but little used habitat type.

In terms of recommendations to include important shorebird areas within the boundaries of the Kendall Island Migratory Bird Sanctuary, I would suggest that Fish Island and vicinity, including the area just east of Big Horn Point, are among the most significant breeding areas for shorebirds in the delta.

8.5. Use of LANDSAT TM imagery in determining shorebird habitat

Other studies have found LANDSAT TM imagery useful for identification of habitat types: why does this study appear to be different? Perhaps it is because the difference between good and poor shorebird habitat often depends on subtle differences in water levels and "understorey" vegetation: and in much of the active outer delta, these factors are liable to considerable change from year to year. Irregular flooding, subtle year-to-year differences in water depth, and edge habitats not distinguished by LANDSAT imagery led to misidentification of habitat types in several areas 10 to 30 km from the original, intensively ground-truthed study area. Most shorebirds are small, and not colonial breeders, so can nest in very small patches of appropriate habitat. I conclude that this technique can, however, be used to roughly identify potential shorebird habitat, and at least eliminate obviously unsuitable areas, in large regions of the arctic that have no recent aerial photography.

8.6. Mitigation of the potential effects of oil and gas activity on shorebirds

Shorebirds were primarily found breeding in low-centre polygon habitat, sedge meadows, and low tussocky upland tundra. This areas should be disturbed as little as possible, especially between mid May and early August. Most of the major areas of these habitats should by identifed in Figures 2.1 and 2.2, excluding "priority nesting habitat" in northern Ellice Island and the islands near the mouth of Shallow Bay that are primarily *Equisetum*. If these outer delta sites were accurately identified as priority shorebird habitat by 1986 LANDSAT TM imagery, then the coastal erosion observed throughout the Beaufort Sea, in conjunction with increased storm surges, has had a major effect on vegetation in a very short period of time. Since global warming is expected to greatly increase coastal erosion and extent and frequency of storm surges in this area (Bigras 1990), it is particularly significant to note the comments of Blasco (1991). He suggested that depletion of oil and gas resevoirs may result in settling similar to that of the North Sea under similar circumstances, and so further compound the problem of sea level rise and coastal erosion.

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APPENDICES

APPENDIX 3.1

Confidence Intervals, aerial surveys 1991, all surveys and all group sizes: Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	782	0.12	33	0.20	19.7	8.93	0.12	0.12	0.28
II (emergents)	407	0.06	11	0.06	10.3	0.05	0.02	0.06	0.12
III (sedge/willow)	1856	0.28	53	0.32	46.8	0.82	0.22	0.28	0.41
IV (willow)	2361	0.35	37	0.22	59.6	8.55	0.14	0.36[1]	0.31
V (upland tundra)	509	0.08	6	0.04	12.8	3.64	-0.00	0.08[2]	0.07
VI (sedge & polygons)	705	0.11	27	0.16	17.8	4.77	0.09	0.11	0.24
TOTAL	6620	1.00	167	1.00	167.0	26.76 (df=5)			

[1]Dense willow habitat used significantly less than expected.

[2]Upland tundra habitat used significantly less than expected.

APPENDIX 3.2

Confidence Intervals, aerial surveys, 1991, all surveys, but family groups (flocks ≤ 4 shorebirds) excluded: Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s).
Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	782	0.12	21	0.31	8.2	20.26	0.16	0.12[1]	0.45
II (emergents)	407	0.06	3	0.04	4.2	0.36	-0.02	0.06	0.11
III (sedge/willow)	1856	0.2	17	0.25	19.4	0.28	0.11	0.28	0.38
IV (willow)	2361	0.35	14	0.20	24.6	4.57	0.08	0.36[2]	0.33
V (upland tundra)	509	0.0	3	0.04	5.3	1.00	-0.02	0.08	0.11
VI (sedge & polygons)	705	0.11	11	0.16	7.3	1.82	0.04	0.11	0.28
TOTAL	6620	1.00	69	1.00	69.0	28.29 (df=5)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow used significantly less than expected.

APPENDIX 3.3

Confidence Intervals, aerial surveys 1992, all surveys and all group sizes: Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	29	0.25	14.8	13.64	0.14	0.13[1]	0.36
II (emergents)	453	0.07	11	0.10	7.7	1.42	0.02	0.07	0.17
III (sedge/willow)	1863	0.27	27	0.24	31.6	0.68	0.13	0.28	0.34
IV (willow)	2362	0.35	27	0.23	40.1	4.29	0.13	0.35[2]	0.34
V (upland tundra)	511	0.08	7	0.06	8.7	0.33	0.00	0.07	0.12
VI (sedge & polygons)	710	0.10	14	0.12	12.1	0.31	0.04	0.10	0.20
TOTAL	6770	1.00	115	1.00	115.0	20.67 (df=5)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow habitat used significantly less than expected.

APPENDIX 3.4

Confidence Intervals, aerial surveys 1992, all surveys, but family groups (flocks ≤ 4 shorebirds) excluded: Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	15	0.37	5.3	17.93	0.17	0.13[1]	0.56
II & III & VI (emergents, sedge/ willow, polygons)	3026	0.45	19	0.46	18.3	0.02	0.26	0.45	0.67
IV (willow, uplands)	2873	0.42	7	0.17	17.4	6.22	0.02	0.42[2]	0.33
TOTAL	6770	1.00	41	1.00	41.0	24.17 (df=2)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow and upland tundra habitats used significantly less than expected.

APPENDIX 3.5

Confidence Intervals, aerial surveys 1991, small shorebird species (all surveys, all group sizes): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s).
Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	20	0.25	9.3	12.19	0.12	0.13[1]	0.38
II (emergents)	453	0.07	7	0.09	4.9	0.95	0.00	0.06	0.17
III (sedge/willow)	1873	0.27	23	0.29	22.1	0.03	0.16	0.28	0.43
IV (willow)	2362	0.35	15	0.19	28.2	6.16	0.07	0.36[2]	0.31
V (upland tundra)	511	0.08	5	0.06	6.1	0.19	-0.01	0.08	0.14
VI (sedge & polygons)	710	0.10	9	0.12	8.4	0.04	0.02	0.11	0.21
TOTAL	6620	1.00	79	1.00	79.0	19.56 (df=5)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow habitat used significantly less than expected.

APPENDIX 3.6

Confidence Intervals, aerial surveys 1991, small shorebird species (all surveys, but excluding small family groups): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	782	0.12	15	0.37	4.8	21.30	0.17	0.12[1]	0.56
II & III & VI (emergents, sedge/ willow, polygons)	2968	0.45	16	0.39	18.4	0.31	0.19	0.45	0.59
IV & V (willow, uplands)	2870	0.43	10	0.24	17.8	3.40	0.07	0.43[2]	0.42
TOTAL	6620	1.00	41	1.00	41.0	25.01 (df=2)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow and upland tundra habitats used significantly less than expected.

APPENDIX 3.7

Confidence Intervals, aerial surveys 1992, small shorebird species (all surveys, all group sizes): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s).
Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	17	0.27	8.0	10.21	0.12	0.13	0.42
II & III (emergents, sedge/willows)	2316	0.34	19	0.31	21.2	0.23	0.15	0.34	0.46
IV & V (willow, uplands)	2873	0.42	19	0.31	26.3	2.03	0.15	0.42	0.46
VI (sedge & polygons)	710	0.11	7	0.11	6.5	0.04	0.01	0.10	0.22
TOTAL	6670	1.00	62	1.00	62.0	12.51 (df=3)			

APPENDIX 3.8

Confidence Intervals, aerial surveys 1992, small shorebird species (all surveys, excluding small family groups): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	10	0.40	3.2	14.31	0.14	0.13[1]	0.66
II & III & IV (emergents, sedge/ willow, polygons)	3026	0.45	11	0.44	11.2	0.00	0.18	0.45	0.70
IV & V (willow, uplands)	2873	0.42	4	0.16	10.6	4.12	-0.03	0.42[2]	0.35
TOTAL	6670	1.00	25	1.00	25.0	18.43 (df=2)			

[1]Mudflat habitat used significantly more than expected.

[2]Dense willow and upland tundra habitat used significantly less than expected.

APPENDIX 3.9

Confidence Intervals, aerial surveys 1991, medium and large shorebird species (all surveys, all group sizes): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	782	0.12	13	0.15	10.4	0.65	0.05	0.12	0.25
II (emergents)	407	0.06	4	0.04	5.4	0.37	-0.01	0.06	0.10
III (sedge/willow)	1856	0.28	30	0.34	24.6	1.15	0.21	0.28	0.47
IV (willow)	2361	0.35	22	0.25	31.4	2.81	0.13	0.36	0.37
V (upland tundra)	509	0.08	1	0.01	6.8	4.91	-0.02	0.08*	0.04
VI (sedge & polygons)	705	0.11	18	0.21	9.4	7.94	0.09	0.11	0.32
TOTAL	6620	1.00	88	1.00	88.0	17.83 (df=5)			

*Upland tundra used significantly less than expected.

APPENDIX 3.10

Confidence Intervals, aerial surveys 1991, medium and large shorebird species (all surveys, but excluding small family groups): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	782	0.12	6	0.21	3.2	2.31	0.01	0.12	0.42
II & III & VI (emergents, sedge/ willow, polygons)	2968	0.44	15	0.54	12.4	0.56	0.29	0.44	0.78
IV & V (willow, uplands)	2970	0.44	7	0.25	12.4	2.33	0.03	0.44	0.47
TOTAL	6720	1.00	28	1.00	28.0	5.20 (df=2)			

APPENDIX 3.11

Confidence Intervals, aerial surveys 1992, medium and large shorebird species (all surveys, all group sizes): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	12	0.23	6.8	3.94	0.07	0.13	0.38
II & III (emergents, sedge/willow)	2316	0.34	19	0.36	18.1	0.04	0.18	0.34	0.53
IV (dense willow)	2362	0.35	13	0.24	18.5	1.63	0.09	0.35	0.40
V (upland tundra)	511	0.08	2	0.04	4.0	1.00	-0.03	0.08	0.11
VI (sedge & polygons)	710	0.10	7	0.13	5.6	0.37	0.01	0.10	0.25
TOTAL	6770	1.00	53	1.00	53.0	6.98 (df=4)			

APPENDIX 3.12

Confidence Intervals, aerial surveys 1992, medium and large shorebird species (all surveys, but excluding small family groups): Habitat usage versus availability. Habitat available = total pixels in survey transects. Habitat used (observed) = total pixels with shorebird(s). Avail. = Available; Obs. = Observed; Exp. = Expected.

Habitat Type	Habitat Avail. (pixels)	% Avail.	Habitat Used (Obs.)	% Used (Obs.)	Habitat Used (Exp.)	Chi-square	Lower C.I. (Obs.)	% Habitat Used (Exp.)	Higher C.I. (Obs.)
I (mudflats)	871	0.13	5	0.31	2.1	4.20	0.01	0.13	0.62
II & III & VI (emergents, sedge/ willow, polygons)	3026	0.45	8	0.50	7.1	0.10	0.17	0.45	0.83
IV & V (willow, uplands)	2873	0.42	3	0.19	6.8	2.12	-0.07	0.42	0.44
TOTAL	6770	1.00	16	1.00	16.0	6.42 (df=2)			

APPENDIX 4.1

Plot surveys, 1991: Breeding shorebirds observed. Species are defined in Table 1.1. Numbers refer to breeding attempts (pairs).

Plot	Survey	Date	Shorebirds Observed
1a	1	17 June	0
	2	21 June	0
	3	26 June	0
	Overall		0
1b	1	17 June	1 HUGO
	2	21 June	0
	3	26 June	0
	Overall		1 HUGO
1c	1	17 June	0
	2	21 June	0
	3	26 June	0
	Overall		0
1d	1	17 June	0
	2	21 June	0
	3	26 June	0
	Overall		0
2a	1	18 June	1 RNPH pair
	2	21 June	0
	3	26 June	1 medium shorebird
	Overall		1 RNPH pair
2b	1	18 June	1 RNPH male
	2	21 June	1 RNPH male
	3	26 June	0
	Overall		1 RNPH male
2c	1	18 June	1 STSA
	2	21 June	0
	3	26 June	0
	Overall		1 STSA
2d	1	18 June	0
	2	21 June	0
	3	26 June	1 COSN
	Overall		1 COSN
3a	1	19 June	0
	2	20 June	1 COSN
	3	24 June	0
	Overall		1 COSN (nest)
4a	1	20 June	1 PESA, 1 STSA, 1 HUGO
	2	23 June	2 HUGO pairs, 2 STSA, 1 PESA
	3	28 June	2 HUGO pairs, 1 STSA
	Overall		1 PESA (nest), 2 STSA, 2 HUGO pairs
4b	1	20 June	1 WHIM pair, 1 RNPH male
	2	23 June	1 WHIM pair, 1 RNPH
	3	28 June	1 WHIM pair, 1 RNPH
	Overall		1 WHIM pair (nest), 1 RNPH male

Appendix 4.1. Continued.

Plot	Survey	Date	Shorebirds Observed
4c	1	20 June	1 RNPH male
	2	23 June	1 RNPH
	3	28 June	0
	Overall		1 RNPH (nest)
4d	1	20 June	2 WHIM pairs
	2	23 June	1 WHIM pair, 1 STSA
	3	28 June	2 WHIM pairs, 1 STSA
	Overall		2 WHIM pairs (2 nests), 1 STSA
5a	1	2 July	0
	2	7 July	0
	3	10 July	0
	Overall		0
5b	1	2 July	0
	2	7 July	2 COSN
	3	10 July	1 COSN
	Overall		2 COSN
5c	1	2 July	0
	2	7 July	0
	3	10 July	0
	Overall		0
5d	1	2 July	0
	2	7 July	0
	3	10 July	0
	Overall		0
6a	1	3 July	3 RNPH
	2	9 July	1 COSN
	3	12 July	2 RNPH males
	Overall		2 RNPH males, 1 COSN
6b	1	3 July	1 SESA (nest)
	2	9 July	1 SESA, 6 RNPH males
	3	12 July	1 SESA, 1 RNPH male, 1 COSN
	Overall		1 SESA (nest), 6 RNPH males, 1 COSN
6c	1	3 July	6 RNPH males
	2	9 July	1 RNPH male
	3	12 July	6 RNPH males, 1 STSA pair (with chicks)
	Overall		6 RNPH males, 1 STSA pair (with chicks)
6d	1	3 July	1 RNPH male
	2	9 July	8 RNPH males, 1 COSN
	3	12 July	8 RNPH males
	Overall		8 RNPH males, 1 COSN
7a	1	4 July	0
	2	7 July	0
	3	9 July	0
	Overall		0

Appendix 4.1 Continued.

Plot	Survey	Date	Shorebirds Observed
7b	1	4 July	0
	2	7 July	0
	3	9 July	0
	Overall		0
8a	1	5 July	0
	2	9 July	1 RNPH male, 1 LBDO
	3	12 July	0
	Overall		1 RNPH male, 1 LBDO
8b	1	5 July	2 RNPH males, 1 SESA
	2	9 July	3 RNPH males, 1 SESA
	3	12 July	1 SESA
	Overall		3 RNPH males, 1 SESA (nest)
9a	1	5 July	0
	2	6 July	0
	3	9 July	0
	Overall		0

APPENDIX 4.2

LCUs (LANDSAT Classification Units) identified by LANDSAT TM, and observed in ground plots, 1991. LCU types are defined in Table 2.3.

Plot	LANDSAT LCU	Observed LCU
1a	60% 9, 40% 13	9
b	70%, 13, 30% 9	13
c	60% 9, 40% 13	9
d	60% 13, 40% 9	13
2a	90% 9, 10% 11	9
b	70% 11, 30% 9	11
c	70% 9, 30% 11	9
d	70% 11, 30% 9	11
3a	80% 4, 20% 9	4
4a	90% 9, 10% 13	9
b	100% 9	9
c	80% 9, 20% 13	9
d	70% 9, 30% 13	9
5a	100% 4	4
b	80% 4, 20% 9	4
c	80% 4, 20% 9	4
d	100% 4	4
6a	70% 9, 30% 4	9
b	70% 13, 30% 4	9
c	70% 9, 30% 3	9
d	60% 9, 20% 4, 20% 13	9
7a	70% 4, 30% 15	4
b	70% 4, 30% 15	4
8a	45% 9, 40% 4, 25% 16	9
b	80% 9, 20% 4	9
9a	40% 13, 20% 7, 20% 4, 20% 9	4

APPENDIX 4.3

LCUs (LANDSAT Classification Units) identified by LANDSAT TM, and observed in ground plots, 1992. LCU types are defined in Table 2.3. All plots are 200 m x 200 m

Plot	LANDSAT LCU	Observed LCU
1A	50% 4, 30% 9, 20% 7	9 wet sedge
2A	70% 9, 15% 13, 15% 4	15 low wet willow
3A	80% 4, 20% 9	11 low willow/sedge/*Equisetum*
4A	80% 4, 15% 10	10 dry upland, some wet holes
5A	90% 4, 5% 10, 5% 15	10 dry upland, some wet holes
6A	80% 9, 10% 4, 5% 11, 5% 7	11 low wet willow/*Equisetum*
7A	80% 10, 20% 14	14 low uplands (grass, hummocks, creeks)
8A	70% 4, 30% 10	10 dry uplands
9A	85% 13, 10% 15, 5% 7	13 flooded low sedge/willow
10A	50% 14, 5% 10, 40% 7, 5% 4	14 low uplands (grass, hummocks, creeks)
11A	70% 14, 10% 10, 10% 5, 10% 7	14 low uplands, bunchgrass, creeks
12A	100% 7	9 sedge
13A	30% 12, 30% 11, 10% 9,7,4, 5% 1,2	9 swampy; ridges of sedge by lake
14A	40% 10, 20% 14, 10% 5, 30% 4	9 sedge margin around pond
15A	60% 14, 40% 10	14 low uplands (damp, grass hummocks)
16A	50% 10, 5% 14, 10% 5, 15%4, 10%3, 5%7	9 sedge ridges around pond
17A	80% 13, 10% 12, 10% 9	13 low wet sedge/willow
18A	85% 9, 15% 11	9 wet sedge, poor high centre polygons
19A	60% 9, 40% 13	9 damp sedge/moss/sparse willow
20A	95% 9, 5% 4	9 wet sedge
21A	100% 9	9 wet sedge
22A	100% 13	13 low wet sedge/willow
23A	100% 10	10 shrubby dry uplands (birch, aspen)
24A	70% 10, 30% 14	10 shrubby dry uplands (birch, aspen)
25A	100% 3	3 gravel pad, sparse vegetation
1B	100% 9	7 wet *Equisetum*/sedge
2B	100% 9	7 wet *Equisetum*/sedge
3B	70% 4, 30% 9	7 wet hummocky sedge
4B	100% 6	6 wet *Hipparus*/sedge around pond
5B	55% 11, 35% 9, 5% 4, 5% 2	11 *Equisetum*/sedge/bare ground
6B	100% 9	11 *Equisetum*/bare ground/willow
7B	100% 9	11 *Equisetum*/bare ground/willow
8B	70% 9, 30% 13	11 *Equisetum*/sedge/sparse willow
9B	100% 4	11 wet low grass & sedge/tiny willow
10B	100% 4	11 wet low grass & sedge/tiny willow
11B	100% 3	3 grave pad, sparse vegetation
1C	90% 9, 10% 11	9 poor polygons/sedge/short willow
2C	100% 9	9 poor polygons/sedge/short willow
3C	100% 9	9 l.c. polygons/sedge/short willow/moss
4C	95% 9, 5% 11	9 l.c. polygons/sedge/short willow/moss
5C	85% 4, 10% 9, 5% 12	4 high thick wet willow/sedge patches
6C	70% 4, 25% 9, 5% 12	4 medium willow & tall sedge
7C	40% 10, 40% 14, 20% 4	10 dry uplands (alder/willow/sedge)
8C	50% 10, 50% 14	10 dry uplands-high
9C	80% 10, 20% 14	10 dry uplands-high
10C	70% 10, 30% 14	14 hummocky low uplands, creeks
11C	75% 9, 25% 4	9 mostly pure sedge, some willow/*Equisetum*
12C	50% 2, 40% 9, 5% 11, 5% 13	9 sedge, short willow, pond margin

Appendix 4.3 Continued.

Plot	LANDSAT LCU	Observed LCU
13C	60% 13, 40% 7	13 dryish, medium sparse willow/*Equisetum*
14C	90% 7, 10% 13	9 poor polygons (sedge/low willow)
15C	85% 9, 15% 4	15 dense low hummocky willow/sedge
16C	70% 13, 10% 4, 10% 9, 10% 12	13 dense low hummocky willow/sedge
17C	90% 10, 5% 14, 5% 4	10 dry high bushy uplands (birch)
18C	50% 14, 40% 7, 5% 1	14 low uplands (hummocky grass clumps)
19C	100% 3	3 gravel pad, sparse vegetation
20C	100% 3	3 gravel pad, sparse vegetation
21C	100% 3	3 gravel pad, sparse vegetation
22C	100% 3	3 gravel pad, sparse vegetation
23C	100% 3	3 gravel (natural beach), sparse vegetation
24C	100% 3	3 gravel pad, sparse vegetation
25C	100% 3	3 gravel pad, sparse vegetation

APPENDIX 4.4

Habitat types and numbers of breeding shorebirds observed in ground plots, 1992. Habitat types are described in Table 2.3. Species abbreviations are listed in Table 1.1.

Plot	Date	LANDSAT Habitat Type	Observed Habitat Type	No. of breeding pairs of Shorebirds*	Species
1A	17 June	IV	VI	3	3 pr. RNPH
2A	17 June	VI	III	0	0
3A	18 June	IV	III	0	0
4A	18 June	IV	V	0	0
5A	18 June	IV	V	0	0
6A	18 June	VI	III	0	0
7A	19 June	V	V	1	1 SESA (nest)
8A	19 June	IV	V	0	0
9A	20 June	III	III	1	1 COSN
10A	20 June	V	V	0	0
11A	20 June	V	V	0	0
12A	20 June	II	VI	3	1 pr. RNPH, 2 COSN
13A	21 June	III	VI	5	2 STSA, 1 pr. LEGP, 1 RNPH pr., 1 pr. WHIM
14A	21 June	V	VI	2	2 RNPH
15A	22 June	V	V	3	1 SESA (nest), 1 LEGP, 1 STSA (nest)
16A	22 June	V	VI	7	2 SESA (1 nest), 1 STSA, 4 RNPH males
17A	23 June	III	III	0	0
18A	23 June	VI	VI	2	1 COSN, 1 RNPH
19A	23 June	VI	VI	2	2 RNPH males
20A	24 June	VI	VI	1	1 RNPH male
21A	24 June	VI	VI	0	0
22A	24 June	III	III	0	0
23A	25 June	V	V	0	0
24A	25 June	V	V	0	0
25A	15 June	I	I	0	0
1B	29 June	VI	II	0	0
2B	29 June	VI	II	0	0
3B	29 June	IV	II	0	0
4B	29 June	II	II	4	4 RNPH males
5B	30 June	III	III	0	0
6B	30 June	VI	III	0	0
7B	30 June	VI	III	0	0
8B	2 July	VI	III	0	0
9B	2 July	IV	III	1	1 RNPH (nest)
10B	2 July	IV	III	0	0
11B	28 June	I	I	0	0
1C	6 July	VI	VI	0	0
2C	6 July	VI	VI	0	0
3C	7 July	VI	VI	0	0
4C	7 July	VI	VI	2	2 RNPH
5C	8 July	IV	IV	1	1 RNPH male (with chicks)
6C	8 July	IV	IV	0	0
7C	8 July	V	V	0	0

Appendix 4.4 Continued.

Plot	Date	LANDSAT Habitat Type	Observed Habitat Type	No. of breeding pairs of Shorebirds*	Species
8C	9 July	V	V	0	0
9C	9 July	V	V	0	0
10C	9 July	V	V	1	1 SESA (with chicks)
11C	9 July	VI	VI	0	0
12C	6 July	I	VI	2	1 RNPH, 1 STSA
13C	10 July	III	III	0	0
14C	10 July	II	VI	3	1 SESA (with chicks), 1 RNPH male, 1 PESA (with chicks)
15C	11 July	VI	III	0	0
16C	11 July	III	III	0	0
17C	14 July	V	V	0	0
18C	14 July	V	V	0	0
19C	14 July	I	I	2	2 pr. SEPL (1 with chicks)
20C	6 July	I	I	1	1 pr. SEPL (nest)
21C	7 July	I	I	2	2 pr. SEPL (nest)
22C	7 July	I	I	0	0
23C	9 July	I	I	0	0
24C	12 July	I	I	0	0
25C	12 July	I	I	0	0

*Counted only male RNPH.

APPENDIX 4.5

Confidence Intervals: Accuracy of LANDSAT-identified habitat types.

Distance from Fish Is. (km)	Area	# Plots	% Plots	# Correct (Obs.)	% Correct (Obs.)	# Correct (Exp.)	Chi-sq.	Lower C.I. (Obs.)	% Correct (Exp.)	Higher C.I. (Obs.)
0	Fish Island	13	0.17	13	0.24	9.0	1.78	0.09	0.17	0.39
0	Taglu Area	18	0.23	15	0.28	12.5	0.52	0.12	0.23	0.44
10	Farewell Area	24	0.31	13	0.24	16.6	0.79	0.09	0.31	0.39
15	Niglintgak Island	13	0.16	11	0.20	9.0	0.44	0.06	0.19	0.35
30	Ellice Island	10	0.13	2	0.04	6.9	3.50	-0.03	0.13*	0.10
Total		78	1.00	54	1.00	54.0	7.03 (df=4)			

*Percent correct significantly less than expected at Ellice Island area.

APPENDIX 5.1

Invertebrate sampling on Fish Island, 1993: Times and weather conditions.

Site	Habitat Type	Trial	Date	Time	Air Temp. (°C)	Water Temp. (°C)	Wind (km/hr)
1	mudflats	A	19 June	1247	14.9	13.4	NW 12-15
		B	29 June	1245	23.1	16.2	E 11-16
		C	8 July	1503	22.0	17.9	E 12-15
2	polygons	A	19 June	1425	20.8	13.4	NW 12-15
		B	29 June	1215	24.4	15.7	E 7-9
		C	8 July	1335	26.6	17.3	E 12-13
3	polygons	A	19 June	1445	20.4	13.2	NW 12-14
		B	29 June	1200	24.5	14.7	E 8-11
		C	8 July	1342	25.3	15.4	E 12-15
4	sedge	A	19 June	1520	16.9	8.8	NW 12-15
		B	29 June	1235	24.2	15.6	E 7-9
		C	8 July	1438	25.4	dry	E 12-15
5	sedge	A	19 June	1557	22.0	4.2	NW 14-18
		B	29 June	1135	23.0	8.3	E 8-10
		C	8 July	1229	20.1	dry	NE 16-18
6	wet sedge/willow	A	19 June	1625	22.2	10.8	NW 12-16
		B	29 June	1140	21.1	14.8	E 7-10
		C	8 July	1234	21.5	dry	NE 15-18
7	wet sedge/willow	A	19 June	1639	20.2	9.7	NW 14-16
		B	29 June	1150	20.3	14.8	E 6-8
		C	8 July	1240	23.5	dry	NE 16-20
8	high uplands	A	20 June	1446	12.4	5.4	NW 10-12
		B	29 June	1025	19.8	9.1	E 7-9
		C	8 July	1239	21.4	9.0	E 10-14
9	high uplands	A	20 June	1500	12.6	7.9	NW 10-12
		B	29 June	1035	19.0	9.2	E 10-12
		C	8 July	1226	22.7	10.1	E 10-12
10	low uplands	A	20 June	1603	15.0	8.4	NW 11
		B	29 June	1050	23.1	8.1	E 9-11
		C	8 July	1220	22.9	12.0	E 10-14
11	low uplands	A	20 June	1611	13.4	9.0	NW 11
		B	29 June	1056	21.3	8.5	E 8-12
		C	8 July	1215	24.1	8.2	E 9-14
12	dense willow	A	20 June	1631	16.1	6.5	NW 8-10
		B	29 June	1300	19.1	8.1	E 7-11
		C	8 July	1201	18.4	dry	E 9-13
13	dense willow	A	20 June	1642	14.1	8.9	NW 8-10
		B	29 June	1315	22.5	11.8	E 7-11
		C	8 July	1208	18.4	dry	E 9-13
14	polygons	A	22 June	1357	13.9	9.7	NE 8-11
		B	29 June	1325	23.0	12.4	E 12-15
		C	8 July	1524	24.7	dry	E 15
15	polygons	A	22 June	1407	17.8	8.6	NE 8-11
		B	29 June	1340	23.0	11.5	E 12-15
		C	8 July	1530	24.7	dry	E 12-15

APPENDIX 5.2

Classification of invertebrates collected, 1993. Invertebrates collected were identified to italicized terms. Compiled from Little (1972), Barnes (1974), and Thorp and Covich (1991). Abbreviations used in Appendix 5.4 are in capital letters.

Phylum Arthropoda
- **Subphylum Mandibulata**
  - **Class Insecta**
    - Order Hymenoptera (wasps)
      - Family *Ichneumonidae* (adults: ICHNEV)
    - Order *Coleoptera* (beetles: COLEOP)
      - Family *Dytiscidae* (predacious diving beetles, adults: DYTISC)
    - Order *Trichoptera* (Caddisflies, TRICHO)
    - Order *Hemiptera* (true bugs, HEMIPT)
      - Family *Pleidae* (pygmy backswimmers, PLEIDA)
    - Order *Collembola* (springtails, COLLEM)
    - Order *Odonata* (dragonflies, damselflies, adults: ODONAT)
    - Order Diptera
      - Suborder Nematocera
        - Family *Chironomidae* (midges, larvae: CHIRLA , adults: CHIRAD)
        - Family *Ceratopogonidae* (biting midges, larvae: CERALA, adults: CERAAD)
        - Family *Culicidae* (mosquitoes, larvae: CULILA, pupae: CULIPU, adults: CULIAD)
        - Family *Simuliidae* (blackflies, adults: SIMULI)
        - Family *Tipulidae* (crane flies, adults: TIPULI)
      - Suborder Brachycera
        - Family *Dolichopopidae* (long-legged flies, adults: DOLIAD)
        - Family *Empididae* (dance flies, adults: EMPIDI)
        - Family *Ephydridae* (shore flies, EPHYDR)
        - Family *Muscidae* (aquatic muscids, adults: MUSCID)
        - Family *Stratiomyidae* (soldier flies, adults: STRATI)
        - Family *Syrphidae* (rat-tailed maggots, adults: SYRPHI)
        - Family *Tabanidae* (deer or horseflies, adults: TABANI)
  - **Class Crustacea**
    - **Subclass Brachiopoda**
      - Order Diplostraca
        - Suborder *Cladocera* (water fleas, CLADOC)
    - **Subclass *Copepoda*** (copepods, COPEPO)
    - **Subclass Malacostraca**
      - Order *Decapoda* (shrimp, DECAPO)
      - Order Amphipoda (amphipods)
        - Family *Hyalellidae* (HYALEL)
    - **Subclass *Ostracoda*** (ostracods, OSTRAC)
- **Subphylum Chelicerata**
  - **Class Arachnida**
    - Order *Aranae* (aquatic spiders, ARANAE)
    - Order Acarina (mites and ticks), Group *Hydracarina* (water mites, HYDRAC)

Phylum *Nematoda* (round worms, NEMATO)

Phylum Mollusca
- **Class *Gastropoda*** (snails, GASTRO)

APPENDIX 5.3

Water levels at sites of "stovepipe" samples, Fish Island, 1993.

		Water levels (mm)		
Site	Habitat	Trial A (19-22 June)	Trial B (29 June)	Trial C (8 July)
2	l.c. polygons	70,78,90	3,4,4	1,2,2
3	l.c. polygons	98,110,120	3,4,4	2,3,2
4	"pure" sedge	65,77,88	2,2,2	0,0,0
5	"pure" sedge	40,60,70	3,2,3	0,0,0
6	wet sedge/willow	95,95,145	3,3,4	0,0,0
7	wet sedge/willow	105,120,140	4,4,5	0,0,0
8	"high" uplands	155,160,165	7,8,8	3,4,4
9	"high" uplands	140,172,174	7,8,9	2,3,3
10	"low" uplands	200,210,220	14,15,12	8,8,8
11	"low" uplands	225,145,125	12,15,17	6,8,9
12	dense willow	65,70,80	1,1,1	0,0,0
13	dense willow	65,70,100	1,1,2	0,0,0
14	l.c. polygons	48,50,65	2,2,2	0,0,0
15	l.c. polygons	48,50,160	1,2,3	0,0,0
Total	Mean	110.2	5.0	1.9
	S.D. (N)	51.2 (42)	4.4 (42)	2.8 (42)
Excluding dry Sites:				
	Mean	110.2	5.0	4.3
	S.D. (N)	51.2 (42)	4.4 (42)	2.7 (18)

APPENDIX 5.4

Invertebrates collected on Fish Island,
in the outer Mackenzie Delta, NWT, in 1993.
Abbreviations of invertebrates are defined in Appendix 5.2.

METHOD=SWEEPNET HABITAT=LOW-CENTRE POLYGONS

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
2	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	B	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.
2	C	.	.	42	1	.	.	.	.	1	.	.	.	.	.	.
3	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	B	.	.	8	.	.	.	.	.	.	.	.	.	.	.	2
3	C	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.
14	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14	B	.	.	1	.	.	.	.	1	.	.	.	.	1	.	.
14	C	.	.	33	1	.	.	.	.	2	.	.	.	.	.	.
15	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15	B	.	.	8	.	.	.	.	.	.	.	.	.	.	.	.
15	C	.	.	4	.	.	.	.	.	2	.	.	.	.	.	.

METHOD=SWEEPNET HABITAT=LOW UPLAND TUNDRA

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
10	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	B	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
10	C	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.
11	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
11	B	.	.	27	.	1	.	.	.	.	.	.	.	.	.	.
11	C	.	.	9	2	.	.	.	.	.	.	.	.	.	.	.

Appendix 5.4 continued.

METHOD=SWEEPNET HABITAT=WET SEDGE/WILLOW

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
6	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	B	.	.	6	3	.	.	.	.	.	.	.	.	.	.	.
6	C	.	.	13	.	.	.	.	.	.	2	1	.	.	.	.
7	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	B	.	.	6	.	1	.	.	.	.	.	.	.	.	.	.
7	C	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.

METHOD=SWEEPNET HABITAT=SEDGE

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
4	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	B	.	.	5	.	1	.	.	.	.	.	.	.	.	.	.
4	C	.	.	15	2	.	.	.	.	1	.	.	.	.	1	.
5	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	B	.	1	4	.	.	.	.	.	.	.	.	.	.	.	.
5	C	.	.	2	1	.	.	.	.	.	.	.	.	.	1	.

Appendix 5.4 continued.

METHOD=SWEEPNET HABITAT=HIGH UPLAND TUNDRA

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
8	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	B	.	.	28	.	.	.	.	.	.	.	.	.	.	.	.
8	C	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.
9	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	B	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
9	C	.	.	11	.	.	.	.	.	.	.	.	1	.	.	.

METHOD=SWEEPNET HABITAT=DENSE WILLOW

SITE	TRIAL	CHIRAD	CERAAD	CULIAD	DOLIAD	ICHNEV	EMPIDI	TIPULI	SIMULI	TABANI	SYRPHI	STRATI	MUSCID	PLEIDA	ODONAT	ARANAE
12	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12	B	2	.	4	.	2	4	.	.	.	.	.	.	.	.	.
12	C	.	.	4	1	1	.	.	.	.	1	.	.	.	.	.
13	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13	B	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.
13	C	.	.	8	1	.	1	.	.	1	.	.	.	.	.	.

Appendix 5.4 continued.

METHOD=STOVEPIPE HABITAT=LOW-CENTRE POLYGONS

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
2	A	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	B	14	1	.	6	.	1	1	.	.	.	.	.	4	.	.	.	.	.	.	20
2	C	.	.	.	1	.	5	.	.	.	.	.	.	3	.	25	.	.	.	12	13
3	A	.	.	.	.	.	.	.	.	1	.	.	.	1	3	.	.	4	.	.	40
3	B	11	3	.	.	2	.	1	.	.	.	.	.	.	.	9	.	.	.	2	19
3	C	1	.	.	.	.	8	.	.	.	.	.	.	.	.	5	.	.	.	4	.
14	A	.	.	1	12	5	13	.	2	.	.	1	.	.	.	.	.	.	.	.	3
14	B	.	.	.	.	5	4	.	1	.	.	.	.	.	.	31	.	.	.	5	.
15	A	.	.	.	14	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
15	B	.	.	.	1	7	1	.	.	.	.	.	.	.	.	11	.	.	.	2	2

METHOD=STOVEPIPE HABITAT=LOW UPLAND TUNDRA

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
10	A	1	.	.	9	.	.	.	.	.	.	.	.	7	.	23	.	.	.	1	1
10	B	.	.	.	.	.	.	1	.	.	.	.	.	20	.	23	.	.	.	.	.
10	C	5	.	.	4	3	.	.	.	.	.	.	.	56	.	25	.	.	.	1	1
11	A	.	.	.	6	.	.	.	.	.	.	.	.	.	.	14	.	.	.	.	.
11	B	.	.	.	1	.	.	.	.	.	.	.	.	6	.	32	.	.	.	.	.
11	C	.	.	.	.	.	2	.	.	.	.	.	.	12	.	13	.	.	.	.	.

Appendix 5.4 continued.

METHOD=STOVEPIPE HABITAT=MUDFLAT

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
1	A	2															5				10
1	B																1				

METHOD=STOVEPIPE HABITAT=WET SEDGE/WILLOW

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
6	A	129			50								2	54					7		4
6	B	81			13	11		1						36					9	4	5
7	A	93			46				3				1	98		10			3		5
7	B	132			12	10	1							148					4	3	4

METHOD=STOVEPIPE HABITAT=SEDGE

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
4	A				1													17			200
4	B	2							1							2				8	35
4	C					8										6				1	
5	A	1		1	8					5	1					31					200
5	B			1	7											3				8	11

Appendix 5.4 continued.

METHOD=STOVEPIPE HABITAT=HIGH UPLAND TUNDRA

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
8	A	15	.	.	15	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	2
8	B	.	.	.	28	5	.	1	.	.	.	.	.	.	.	7	.	.	.	4	1
9	A	1	.	.	18	.	.	1	.	.	.	.	.	.	.	8	.	.	.	.	.
9	B	.	.	.	22	5	.	.	.	.	.	.	.	7	.	11	.	1	.	.	4
9	C	.	.	.	4	10	1	.	.	.	.	.	.	.	.	35	.	.	.	3	2

METHOD=STOVEPIPE HABITAT=DENSE WILLOW

SITE	TRIAL	CHIRLA	CERALA	EPHYDR	CULILA	CULIPU	COLEOP	DYTISC	TRICHO	HEMIPT	COLLEM	ARANEA	HYDRAC	CLADOC	OSTRAC	COPEPO	DECAPO	HYALEL	EUBRAN	GASTRO	NEMATO
12	A	1	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12	B	1	.	.	8	2	3	1	1	.	.	.	1	1	.	1	.	1	.	5	32
13	A	10	.	.	.	.	5	.	2	.	.	.	.	.	.	.	.	.	.	1	25
13	B	1	.	.	11	.	5	1	1	.	.	.	.	.	.	4	.	.	.	7	2

QL 685.6 .N6 G72 1994 c.1
Use of LANDSAT TM imagery in determining priority shorebird habitat in the outer Mackenzie Delta, NWT (N.O.G.A.P.