Identification of Nesting and Staging Shorebird Areas in the Mackenzie River Delta and Richards Island Area, Northwest Territories Using Landsat Thematic Mapper Imagery 1985-1987. NOGAP Project C7.3

by H. Loney Dickson
Dennis Jaques
Sam Barry
E.S. Telfer
Alan R. Smith

Environment Canada Environnement Canada
Canadian Wildlife Service Service canadien de la faune

Canada

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NOGAP PROJECT C7.3

by

H. Loney Dickson
Canadian Wildlife Service
Edmonton, Alberta

Dennis Jaques
Ecosat Geobotanical Surveys Inc.
Vancouver, British Columbia

Sam Barry
Canadian Wildlife Service
Edmonton, Alberta

E.S. Telfer
Canadian Wildlife Service
Edmonton, Alberta

Alan R. Smith
Canadian Wildlife Service
Saskatoon, Saskatchewan

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RÉSUMÉ

Le 29 juin 1984, la compagnie Polar Gas Limited demandait à l'Office national de l'énergie l'autorisation de construire un gazoduc le long de la vallée du Mackenzie, du champ gazier de Taglu situé dans l'île Richards, dans les Territories du Nord-Ouest, jusqu'aux environs de Edson en Alberta au sud. Le présent project a été mis sur pied pour répondre à cette proposition ainsi qu'à l'appel du Programme d'initiatives pétrolières et gazières dans le Nord, un programme fédéral visant à "améliorer l'état de préparation du gouvernement en matière de mise en valeur des hydrocarbures dans le Nord, en favorisant la coordination des activités de recherche en matière de politique, de planification et de réglementation...

Des données relatives à l'habitat, à la phylopatrie, à la fidélité au site, à la phénologie et à la distribution des oiseaux de rivage ont été recueillies sur le terrain de 1985 à 1987 dans le secteur proposé pour le gazoduc de Taglu. La barge hudsonienne, le courlis corlieu, le bécasseau à échasses, le bécasseau à long bec et le pluvier semipalmé sont les principales espèces concernées, mais des données ont aussi été recueillies sur toutes les espèces d'oiseaux. En 1986, un programme a été mis sur pied pour permettre de définir les types d'habitat dans l'île Fish, Territoires du Nord-Ouest, et de cartographier l'habitat de nidification de ces espèces d'oiseaux de rivage dans un secteur de 20 300 hectares autour de l'île, à l'aide de l'imagerie LANDSAT. L'imagerie LANDSAT a également été utilisée pour la cartographie des aires de repos potentielles du bécasseau à long bec dans cette région. Nous avons évalué

les imageries du scanneur multibande (SMB) et de l'appareil de cartogaphe thématique (TM) afin de déterminer si elles convenaient à ce genre de travail : le SMB s'est révélé moins efficace que le capteur TM pour déterminer les habitats potentiels de nidification et de repos des oiseaux de rivage. En effet, sa faible résolution spatiale et spectrale ainsi que l'absence de bandes visibles dans la gamme de l'infrarouge moyen et du bleu en limitaient l'utilisation en cartographie compte tenu du degré de détail nécessaire. L'analyse numérique et visuelle de l'imagerie TM, parallèlement à celle des données recueillies sur le terrain en 1985, a servi à définir le type d'habitat ainsi que les aires de nidification et de repos dans l'île Fish. L'analyse visuelle seule a servi à extrapoler les résultats au reste de la région à l'étude. Au total, 22 zones ont été définies comme aires principales de nidification dans la région à l'étude. Les résultats et les méthodes de ce premier programme ont également été appliqués à tout l'extérieur du delta du Mackenzie et de l'île Richards. Plus de 350 sites ont été déterminés comme aires potentielles de nidification et de repos. Les données recueillies sur le terrain en 1986 et 1987 ont été utilisées pour permettre de vérifier l'hypothèse et les résultats des données LANDSAT et de mieux définir les besoins en habitat de chaque espèce. Des données sur divers aspects de la densité, de la taille des populations, de la phénologie, de la phylopatrie et de la fidélité au site des diverses espèces d'oiseaux de rivage sont également présentées. Les cartes qui figurent dans le présent rapport définissent les aires potentielles de nidification et de repos et aideront les gestionnaires à évaluer les futures demandes de mise en valeur, les planificateurs à organiser l'utilisation des terres et serviront à tous les autres chercheurs intéressés par les corrélations habitat/faune.

ABSTRACT

On 29 June 1984, Polar Gas Limited applied to the National Energy Board to construct a gas pipeline from the Taglu Gas Field on Richards Island, Northwest Territories (NWT), south along the Mackenzie River valley to terminate near Edson, Alberta. Our project was initiated in response to this proposal and in response to the call for the Northern Oil and Gas Action Program, a federal government program aimed at "...advanc(ing) the state of government preparedness for hydrocarbon development on the north by accelerating policy, planning and regulating research activities ... in a coordinated fashion".

Field data, relating to habitat requirements, philopatry, fidelity, phenology and distribution of shorebirds, were collected in 1985 through 1987 in the area of the proposed Taglu gas gathering system. Hudsonian godwit, whimbrel, stilt sandpiper, long-billed dowitcher and semiplamated plover were the main species of concern, although data on all bird species was collected. In 1986, we initiated a program to define habitat types on Fish Island, Northwest Territories, and to map nesting habitat of these shorebird species in a 20 300 hectare area around Fish Island, Northwest Territories using LANDSAT imagery. LANDSAT imagery was also used to map potential staging areas of long-billed dowitchers in this region. We examined both Multi-spectral Scanner (MSS) and Thematic Mapper (TM) imagery for their suitability in conducting this work and found that MSS was inferior to TM imagery for identifying potential shorebird nesting and staging habitat: because the low spatial and spectral resolution and lack

of mid-infrared and blue visible bands on MSS imagery limited the use of MSS data in mapping at the level of detail required. Digital and visual analysis of TM imagery, in conjunction with 1985 field data, was used to define habitat type and nesting and staging areas on Fish Island. Visual analysis alone was used to expand the findings to the remainder of the main study area. A total of 22 areas were defined as prime nesting sites in the main study area. We also applied the findings and methods of this first program to the whole outer Mackenzie River delta and Richards Island. Over 350 sites were identified as potential nesting or staging habitat. Field data in 1986 and 1987 were utilized to test the assumption and results of the LANDSAT findings and to further define the habitat requirement of each species. Data on the various aspects of the densities, population sizes, phenology, philopatry and site fidelity of various shorebird species is also presented. The maps presented in this report define potential nesting and staging sites and will help management of future development proposals, land use planners, and other researchers interested in habitat/wildlife correlations in the future.

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1.0 INTRODUCTION

In the late 1960s oil and gas was discovered in the Mackenzie River delta region. On 29 June 1984, Polar Gas Limited applied to the National Energy Board to construct a gas pipeline from the Taglu Gas Field on Richards Island, Northwest Territories (NWT), south along the Mackenzie River valley to terminate near Edson, Alberta. Our project was initiated in response to this proposal and in response to the call for the Northern Oil and Gas Action Program, a federal government program aimed at "...advanc(ing) the state of government preparedness for hydrocarbon development on the north by accelerating policy, planning and regulating research activities ... in a coordinated fashion".

Exploration, drill site operations, transportation and collection systems activity pose potential conflicts with nesting and staging shore-bird species. Conflicts between shorebirds and hydrocarbon development will only be mitigated if a better understanding of the distribution, abundance, habitat requirements and phenology of the shorebird species involved is gained.

This project directs particular attention to the hudsonian godwit, whimbrel, stilt sandpiper, long-billed dowitcher and the semipalmated plover.

The field studies of 1985 through 1987 concentrated on a small study region (henceforth referred to as the "main study area") (Fig. 1 in report section "2.0 STUDY AREA") of the Mackenzie River delta between 10 June and July 20. We conducted LANDSAT imagery analyses in 1986 and 1987 to define potential nesting and staging habitats of shorebirds in the Mackenzie River Delta. The first year of this study concentrated on the smaller main study area and in the second we expanded the coverage of the first years results to the remaining outer delta and Richards Island (Fig. 1 in "2.0 STUDY AREA" section). The results of the LANDSAT analysis are presented separately in Appendices 1 and 2. Information on past LANDSAT programs which are relevant to this project are also presented in Appendix 1, pp 13 to 15).

The results of this study will help us advise industry on siting of hydrocarbon infrastructure, to recommend mitigation techniques to minimize the effects of industrial developments, and to provide a predevelopment data base for future monitoring of shorebird population levels and the habitats which support them.

2.0 STUDY AREA

The main study area (Fig. 1) of some 20 300 hectares is located in the Mackenzie River delta on the Beaufort Sea coast. In this area we conducted ground surveys and detailed habitat mapping and evaluations. The 1986 LANDSAT work concentrated on this area with particular attention given to Fish Island (Fig. 1). LANDSAT work in 1987 expanded the identification of important nesting and staging sites to the remainder of Richards Island and the outer Mackenzie River delta (Fig. 1).

2.1 Climate

The study area is located entirely within the Marine Tundra Climatic Zone (Burns 1973). The general boundary of this climatic zone parallels the arctic coast extending offshore about 80 km, and from the Alaska-Yukon boundary to Sachs Harbor on Banks Island. Detailed information on adjacent

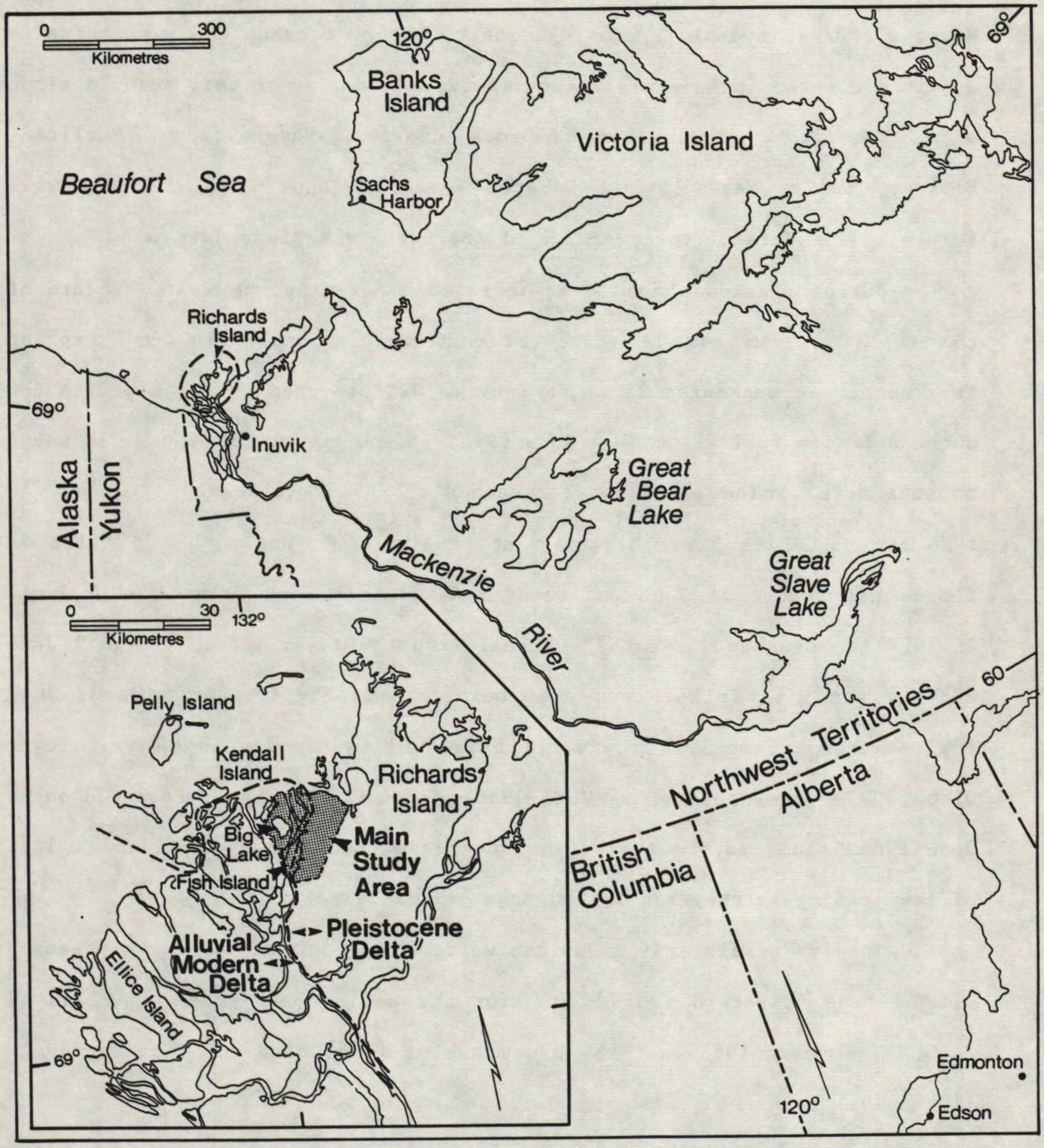


Figure 1. Study area location of the 1985 to 1987 shorebird project on the outer Mackenzie River delta, Northwest Territories.

climate zones, growing season, general annual temperature information and Mackenzie River hydrology, in relation to spring breakup and winter freeze up, is presented in Appendix 1 (pp. 16-19). A review of this section along with Appendix 1 sections on Bedrock Ecology, Physiography, Surficial Ecology, Soils, Vegetation and Water Features (App. 1, pp. 19-26) will inform the readers of the dynamics of the Mackenzie River delta.

Spring breakup played a major role in defining the start up date of the field program and in shorebird nest initiations. In 1985, spring breakup of the Mackenzie River at Inuvik, NWT occurred on 2 June, with the outer delta in full flood on 4 June (Fish Island was completely under water on this date). The flood water receeded from Fish Island on 12 June. In 1986 the Mackenzie River broke up at Inuvik on 8 June with the delta in flood just before 14 June and water receeding on Fish Island on 16 June. In 1987 the breakup was rather unusual with the river going out on 9 June without the Fish Island area ever being completely flooded. On 12 June 1987, although Fish Island was still flooded, water levels were at least 0.3to 0.6 m lower than on 14 June 1986 and similar to those recorded on 16 June 1986. This may be a result of decreased run off upstream and a lack of ice jamming in the Fish Island area of the delta.

The 1987 field season was the warmest year of the three field season with a mean temperature of 11.4°C for the period between 14 June and 12 July. The years 1986 and 1985 saw means of 10.6°C and 7.9°C respectively (Table 1).

The 1987 field season was also the windiest but sunniest of the three years with 9 020 400 m of wind. The 1985 and 1986 field seasons had 7 717 600 and 1 129 000 m of wind respectively. Wind direction generally

Table 1. Temperature conditions (°C)[a] recorded on Fish Island, Northwest Territories in 1985, 1986, and 1987 between approximately 14 June and 12 July.

		Temperature*				
		Weekly average	Weekly maximum		Weekly minimum	
Period	Year	*	°C	Date	°C	Date
8-14 June	1985	1.7	4.5	8/06	-0.5	12/06
14-21 June	1985	5.84	12.5	20/06	-1	16/06
	1986	9.28	21.7	19/06	0	18/06
	1987	12.46	21.5	18/06	7	14/06
21-28 June	1985	13.66	19.5	23/06	6	22/06
	1986	12.58	19.2	23/06	4	25/06
	1987	8.31	21.5	27/06	0	26/06
28/ June 5/ July	1985[b]	13.1	21.0	3/07	9	4/07
	1986	10.27	23.5	4/07	1	3/07
	1987	12.28	19.5	28/06	8	4/07
5-12/ July	1985	6.86	14.0	10/07	3	6/07
	1986	9.52	16.7	6/07	1	11/07
	1987	13.21	28.0	9/07	1	5/07

[a] Time: weather was recorded at approximately 0800 hrs and 1900 hrs each day.

[b] The following dates for this period in 1985 are lacking data: 29/06, 1, 2 and 3/07.

*Monthly average temperatures in June for each year (1985-1987) were 8.0, 11.0 and 11.0 respectively.
Monthly average temperatures in July for each year (1985-1987) were 8.4, 9.9 and 12.0 respectively.
The average temperatures for each field season between 1985 and 1987 was 7.9, 10.6 and 11.4 respectively.

tended to be from the northeast. In 1985, 15 of 24 days we recorded data had greater than 50% cloud cover. In 1986 and 1987, we recorded weather data on 28 days each year. There was >90% cloud cover on 19 and 13 days in 1986 and 1987 respectively.

2.2 Physiography

The landforms and topography of the Mackenzie River delta region have been considered in detail by Mackay (1963a) and Bostock (1970, 1976). Bostock (1970) defined the broad physiographic subdivisions of the Mackenzie Delta Division of the Arctic Coastal Plain Region. The Mackenzie Delta Division is divided into two major subdivisions: Modern Delta and Pleistocene Delta (Fig. 1).

The Modern Mackenzie Delta is a maze of lakes, channels, islands and alluvial interchannel land areas covering about 12 178 km^2, making it the largest delta in North America (Peterson et al. 1981). The importance of the channel and lake types for vegetation and possibly shorebird habitat lies in the fact that annual flooding controls the nutrient status and therefore type and quantity of vegetation development. In addition, the amount and duration of flooding determine, to a very large degree, the availability and suitability of wetland areas for nesting and staging habitat for shorebirds (Hogg et al. 1986).

The delta can be subdivided into three Sections: Alluvial Islands, Main Delta and Rocky Islands. The majority of the main study area is within the Alluvial Islands Section of the Modern Mackenzie Delta Subdivision.

The Pleistocene Mackenzie Delta Subdivision runs from Richards Island to Cape Dalhousie (Fig. 1). This Subdivision has been split into

12 Sections (Mackay 1963[a]). Portions of the study area are included within the Tununuk Low Hills Section. Altitudes of this Section range from 15-60 m in elevation. Lakes and pingos are numerous.

2.3 Vegetation

The vegetation of the study area is entirely within the Arctic Tundra region (Rowe 1972). Numerous studies have been completed describing the vegetation of the Mackenzie River delta (Anon. 1974; Babb 1974; Bliss 1974; Bliss & Wein 1972; Brown 1956; Cody 1965; Cordes & McLennan 1984; Cordes et al. 1984; Corns 1974; Crampton 1973, 1977; Gill 1971; Hernandez 1973, 1974; Hirvonen et al. 1975; Hogg et al. 1986; Janz 1974; Jeffries 1977; Johansen 1924; Lambert 1972; Oswald & Senyk 1977; Pearce & Cordes 1985; Porsild 1938, 1951; Porsild & Cody 1980; Reid & Calder 1977; Ritchie 1984; Sherrington 1978; Strang 1973; Tarnocai & Kristof 1976; Wallace et al. 1974; Wein & Bliss 1973; Wiken et al. 1980, 1981; Younkin 1974; Zoltai & Tarnocai 1974).

The main study area is completely outside the distribution limits of tree species. However, tall shrubs, medium shrubs, dwarf shrubs, herbaceous plant species (including grasses and sedges), mosses and lichens are abundant in various combinations of dominance and presence, particularly in the lowlands. On the delta uplands, extensive areas contain plant community types with herbs and dwarf shrubs combining in dominance.

3.0 METHODS

The field program ran from 10 June to 20 July in 1985, 1986 and 1987.

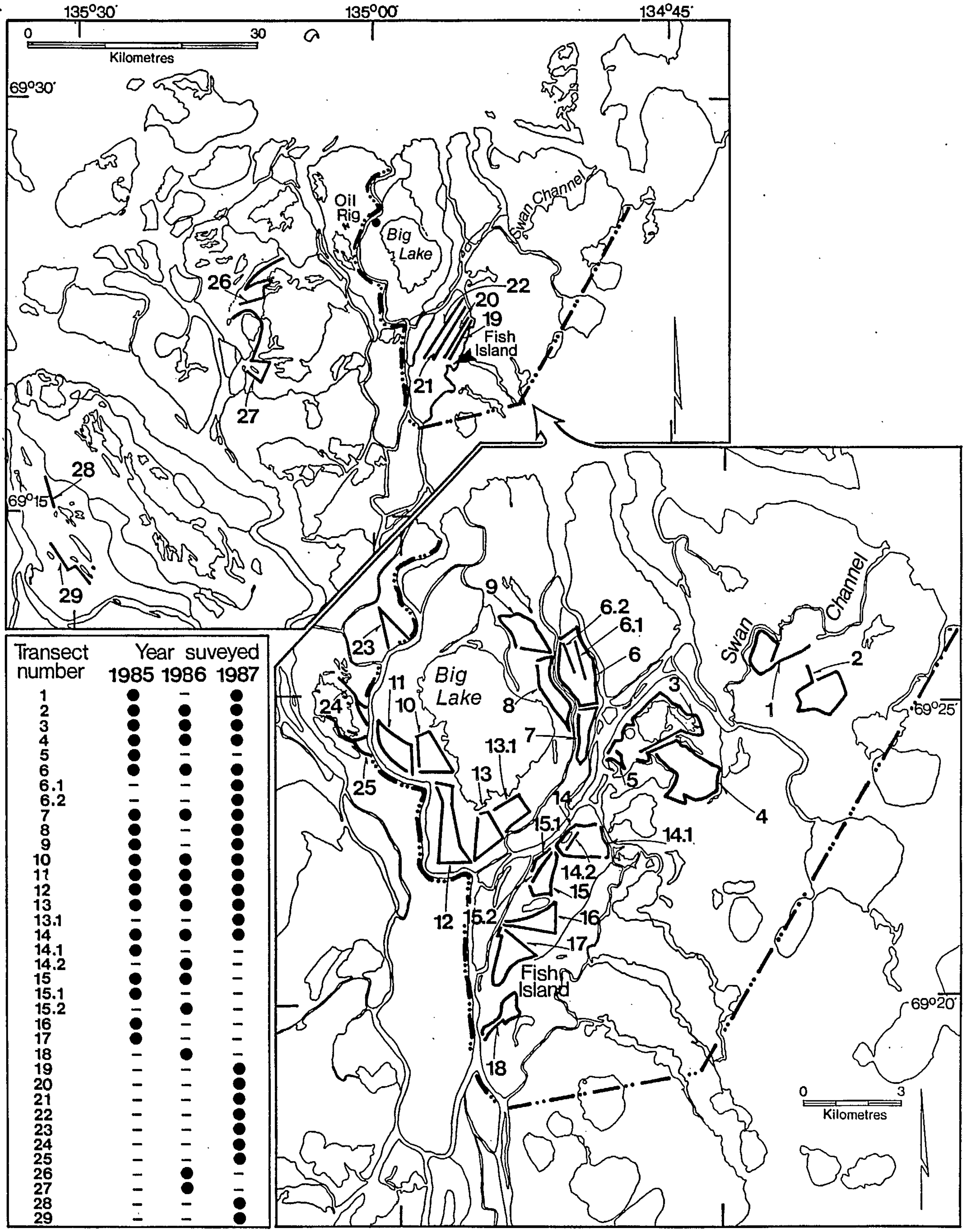
During those periods, field staff collected weather data including the temperature, wind speed and direction, cloud cover and types and precipitation twice daily (0800 hours and 1900 hours).

We collected bird data and related habitat data along transects throughout the main study areas (Fig. 2) each year and on a grid system (plot surveys) on Fish Island proper in 1986 and 1987 (Fig. 3). In 1986 using field data from 1985, LANDSAT Multispectral Scanner (MSS) and Thematic Mapper (TM) imagery, we defined habitat types on Fish Island and produced maps showing: 1) the nesting habitat of whimbrel, hudsonian godwit, long-billed dowitchers and stilt sandpipers; and 2) the potential staging sites of long-billed dowitchers within the main study area. These results also defined the usefulness of MSS & TM imagery for the project. The resulting methodologies were then applied to the whole of the outer Mackenzie River delta following the 1987 field season.

The methods used for each of these related aspects of the study follow.

3.1 Transect Surveys

The ground surveys in 1985, 1986 and 1987 employed the Fixed Transect Method described by Emlen (1971). This method enables collection of bird data over an extensive area in a relatively efficient manner. The limitations of the method are discussed by Emlen (1971) and Berthold (1976). In 1985 we used air photo interpretation and descriptions provided in various reports (Hogg et al. 1986, Barry 1976) along with results of aerial and boat reconnaissance trips upon our arrival in early June 1985, for selecting sites for transect locations. We selected transect sites to ensure that we covered as broad a spectrum of habitats as possible.



Transect number	Year suveyed 1985	1986	1987
1	●	–	●
2	●	●	●
3	●	●	●
4	●	●	●
5	●	–	–
6	●	●	●
6.1	–	–	●
6.2	–	–	●
7	●	●	●
8	●	–	●
9	●	–	●
10	●	●	●
11	●	●	●
12	●	●	●
13	●	●	●
13.1	–	–	●
14	●	●	●
14.1	●	–	–
14.2	–	●	–
15	●	●	–
15.1	●	–	–
15.2	–	●	–
16	●	–	–
17	●	–	–
18	–	●	–
19	–	–	●
20	–	–	●
21	–	–	●
22	–	–	●
23	–	–	●
24	–	–	●
25	–	–	●
26	–	●	–
27	–	●	–
28	–	–	●
29	–	–	●

Figure 2. Transect locations and year(s) each transect was surveyed in the Mackenzie River delta study area, 1985 to 1987.

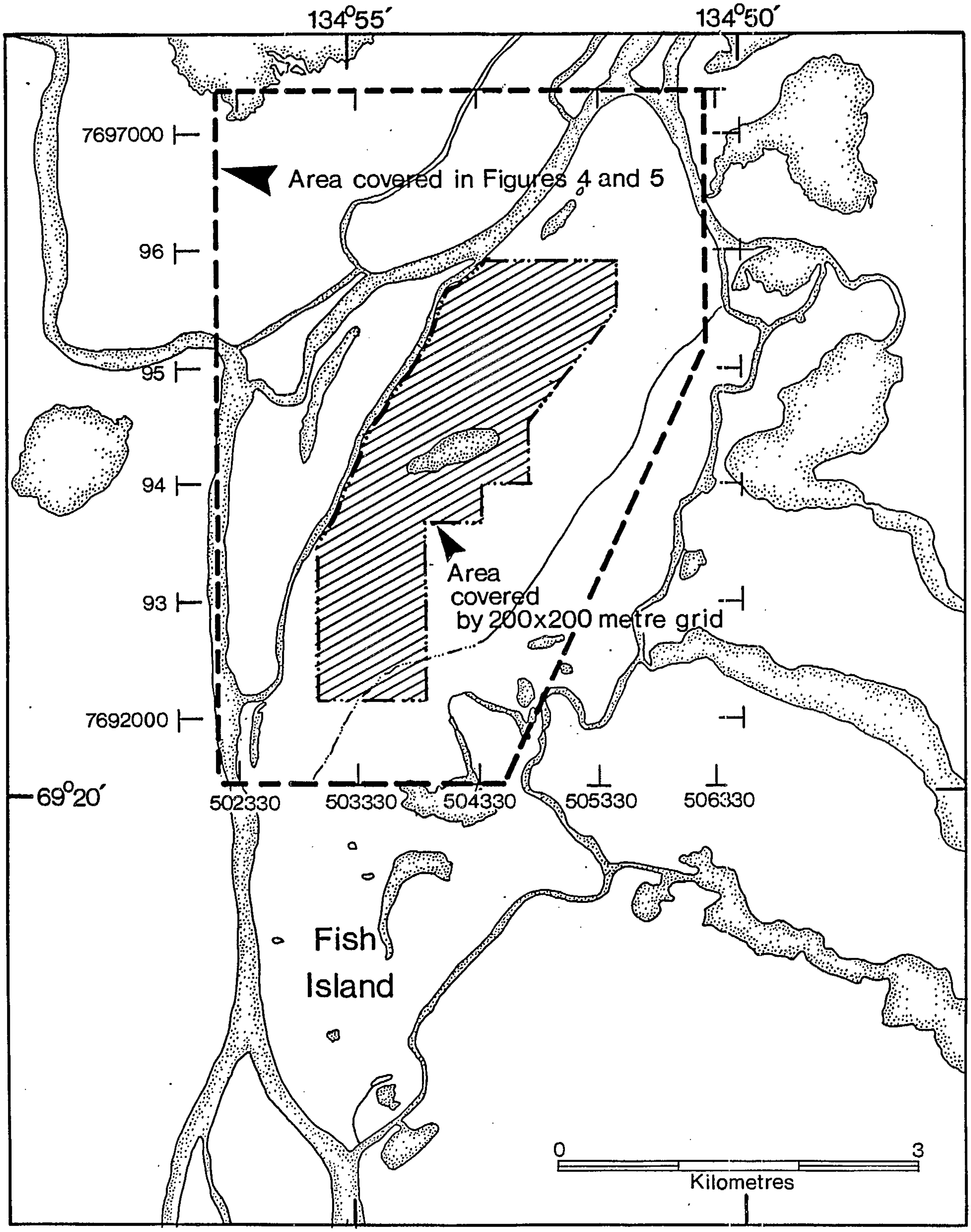


Figure 3. Area of Fish Island, Northwest Territories covered by 200 by 200 metre grid surveys in 1986 and 1987.

We plotted transect locations onto 1:50,000 topographic maps, airphotos or airphoto mosaics of the study area for use in the field. Before the start of each survey, we recorded the start time, location, transect number and weather conditions. Field staff conducted surveys along the transects and recorded all birds sighted, or heard, within 50 m of the transect line as "on transect". Each bird noted in locations beyond 50 m of the transect line we recorded as "off transect". We also recorded flying birds, and by defining if the bird was using the transect area (50 m to each side) or not, we would then record the bird as "on transect" or "off transect". For each observation, we recorded the species, number, age, sex and behaviour.

We related our bird data to the habitat changes observed along the transects. When a habitat changed, we assigned a new "section number" to the transect and we assigned the same "section number" to all bird observations made within that habitat. We defined a habitat change when the values of any of the major habitat parameters(listed below) changed. Thus each transect comprises a series of "habitat segments" or "sections" based on habitat type within which we recorded our bird observations.

We described the habitat of each section using the following parameters:

Aspect - Upland or lowland

- Flat, gently sloping or steeply sloping

Micro Relief - Each type of micro relief (listed below) was rated as to its abundance/prominence: sparse, moderate, abundant and the height of each type recorded in inches

- High centred polygons - height refers to height of centre above the surrounding troughs

- Low centred polygons - height refers to height of the ridges surrounding the polygon
- Hummocks
- Tussocks
- Mounds

Soil moisture - Dry, moist, saturated or wet (to touch)

Open water - Percent of habitat area with open water types listed below

Open water type - Lake, lagoon, creek, river, pond

Standing water - Percent of land area (excluding OPEN water areas) in habitat having standing water (not lakes etc. but flooded vegetation). The depth of standing water was also recorded.

Total Cover - Percent of land (excluding "Open Water") with vegetation

Vegetation dominance The percent of the vegetated land possessing the following types of vegetation.

- Graminoid: Grasses & sedges
- Dwarf Shrub: Shrubs under 0.5 m
- Tall Shrub: Shrubs over 0.5 m
- Heath: Plants from the family Ericaceae and the genus *Dryas*
- Herbs: All other flowering plants not included in other groups
- Moss & Lichens: All mosses and lichens
- Equisetum: Horsetails (mainly *Equisetum variegatum*)

We conducted transect surveys in 1985, 1986 and 1987. Whenever possible, we duplicated transects of the previous year and new areas were also surveyed (Fig. 2).

For each nest found, the observer recorded the date found, species, habitat, number of eggs, nest lining and cover. The nest location was also plotted onto maps. For priority shorebird species (whimbrel, hudsonian godwit, long-billed dowitcher and stilt sandpiper) we physically numbered each egg with pencil and recorded the length, width and weight using callipers and pisola scales. We revisited priority species nests as often as possible to reweigh the eggs and to determine the fledging date.

3.2 Plot Surveys

Following the 1985 field season, data analysis of the various transects conducted in that year indicated that Fish Island had the highest densities of shorebirds in the study area. To acquire detailed information on the nesting density, territory size, habitat requirements and the aspect of the breeding biology of the priority shorebird species, we set up a plot survey system in 1986. We surveyed these plots were surveyed in both 1986 and 1987.

The field crew set up a grid system comprised of 200 x 200 m squares using a theodolite on the western section of Fish Island (Fig. 3). Each corner was marked with a 0.6 m wooden stake. The plot system was labeled by ascending letters going west to east and ascending numbers going north to south. We used three different colours of flagging (red, orange and blue) to enhance visability of the stakes in the field. Each north-south plot line was given one colour hence plot line colours went from red to orange to blue to red to orange etcetra from west to east. This plot system enabled the observer to know where they were on the ground and more importantly to know where nests and birds were when they flew or landed.

In 1986 and 1987 observers walked plot lines throughout the field season. We recorded bird observations in the same manner as the transect surveys except the observer also plotted the priority shorebird species location, and movements on plot maps and noted their behavior. Thus the exact location of whimbrels, stilt sandpipers, hudsonian godwits and long-billed dowitchers were recorded together with where they flew and landed.

In 1986 vegetation data was also collected along the grid lines following the methods employed on the transects. We used these data to initially guide the LANDSAT vegetation mapping.

Nest data was collected in a similar manner to that described in the Transect Method section. We located many shorebird nests on Fish Island by examining the plotted movements of the shorebirds. Areas with heavy concentration of movement would often reflect a nesting territory.

3.3 Landsat

In 1986 we initiated a LANDSAT analysis and mapping program of the main study area and in 1987 expanded these developed methods to the whole outer Mackenzie River delta. Additional specific details on the methods of processing and analyses, to those provided below, can be found in Appendix 1 (pp. 5 to 12) and in Appendix 2 (pp. 3 to 7).

3.3.1 Landsat 1986

The specific objectives of the 1986 LANDSAT satellite study were to identify and map shorebird nesting and staging habitat in the main study area and to identify and map vegetation units on Fish island (Fig. 1). All vegetation and shorebird habitat data used for the LANDSAT classification systems were from the 1985 and 1986 ground-based field studies. Since the 1986 survey provided the best habitat data for the study area, we selected the 21 June 1986 and 23 July 1986 LANDSAT TM images for the LANDSAT study. We also acquired a LANDSAT Multispectral Scanner scene (scene #50842-20040) dated 21 June 1986.

For the MSS data we produced a Vericolour III colour negative image following a Band 7, 5, 4 enhanced colour composite. This was followed by a multiple linear contrast stretch enhancement of each band (Moik 1980). This enhancement enabled differentiation of the land features of interest in the Main Study Area, with each pixel representing an 80 x 80 m area on the ground. Visual interpretation of this MSS photographic product was conducted on prints at a scale of 1:150,000.

We conducted the analysis of the LANDSAT TM imagery in several steps: 1) The radiometric and geometric correction of the raw digital data. 2) We determined the radiometric characteristics of the two LANDSAT images (21 June 1986 and 23 July 1986). 3) For the two TM images, we used 6 of the possible 7 bands found on TM imagery to produce a three band false colour combination for every possible band combination (total of 20) from one date. We selected the band combinations which best interpreted the major land surface features on Fish Island. Contrast enhancements were applied to both dates of TM imagery as well as the one date (21 June 1986) of MSS imagery to produce optimum photographic products for visual interpretation of vegetation on Fish Island and shorebird nesting and staging habitat on Fish Island and the main study area (Fig. 1). 4) We conducted computer habitat mapping of Fish Island using an unsupervised classification algorithm. This classification satisfied the project requirements for vegetation cover mapping. Each vegetation class was assigned a solid colour and produced onto a multi-colour image map of the study area. 5) We evaluated these results with the available ground truth information to define the optimum method for identifying potentially significant shorebird nesting and staging habitat units.

We visually interpretated LANDSAT vegetation cover types using ground control data collected during 1985 and 1986. Water regimes at the time of the field surveys also provided valuable data for visual interpretation. Photographs obtained from helicopter over flights at the same time as the ground field surveys (i.e. late June-early July 1986) served as additional "ground truth".

After completion of the LANDSAT analysis we performed a series of chi-square (Conover 1980) and binomial tests to further evaluate the adequacy of the methods used to define nesting habitat using LANDSAT TM imagery. These analyses also explored the importance of the LANDSAT Classification Units (LCU) as a tool for defining habitat use of the priority shorebirds along with semipalmated sandpipers, pectoral sandpipers, red-necked phalaropes, and red phalaropes.

3.3.2 Landsat 1987

We used the methodologies similar to those developed in the first LANDSAT program to define the nesting and staging sites for whimbrels, hudsonian godwits, long-billed dowitchers and stilt sandpipers in virtually all of the outer Mackenzie River delta region, including Richards Island on the east and extending to the eastern edge of Shoalwater Bay in the Yukon Territory (Fig. 1). We acquired LANDSAT TM imagery for the entire study area outlined on Figure 1 for the dates of 21 June 1986 and 12 July 1986. The initial study (LANDSAT 1986) used automated computer mapping of statistically significant classification units (termed "LANDSAT Classification Units" (LCUs)) in combination with visual interpretation of enhanced colour photographic products to identify potential nesting and staging habitat sites. This expanded study only used visual interpretation of enhanced colour photographic products. Although this produced more generalized results, it is believed that the majority of important potential nesting and staging habitat sites have been identified.

We identified potential nesting habitat sites using the following image types: Bands 5-4-3 composite of 21 June 1986; Bands 3-2-1 composite of 23 July 1986; and Bands 4-3-2 composite of 23 July 1986. We analyzed three of the four colour composite photographic images to identify image characteristics correlated with important biophysical features as identified from the first LANDSAT study. The Bands 5-4-3 composite from 21 June 1986 identified critical standing water categories which are the following:

sites with 0-10% standing water on 25-27 June 1986;

sites with 15-40% standing water on 25-27 June 1986; and

sites with greater than 50% standing water on 25-27 June 1986.

Bands 3-2-1 composite of 23 July 1986 imagery identified tall and low shrub vegetation categories, while bands 4-3-2 false colour infrared 23

July 1986 LANDSAT TM image product identified the shrub categories mentioned above and the sedge and sedge-grass dominated vegetation types within the entire study area. This image also differentiated most clearly the areas occupied by sedge-grass vegetation and open water categories.

We mapped sites of high potential for shorebird nesting habitat using each of the colour image enhancements together. We identified as potential nesting sites those areas having 15-40% standing water on 21 June 1986, less than 35% low shrub canopy cover and possessing greater than 30% sedge and sedge-grass vegetation composition as identified on the natural colour and colour infrared enhancements.

Potential staging habitat sites for long-billed dowitchers were also identified using these LANDSAT TM enhanced photographic products. The identification of potential staging habitat is limited by few verified staging habitat locations obtained from ground field surveys being defined. However, using the best data available from the field surveys, potential staging habitats were identified and mapped.

Potential staging habitat sites are those which possess large proportions of open water in a mosaic with 30-35% sedge or sedge-grass vegetation cover. The complexes made up of these mosaic components are also located adjacent to substantial bodies of open water. The middle infrared colour composite (Bands 4-5-3) from 23 July 1986, colour infrared composite (Bands 4-3-2) and natural colour composite (Bands 3-2-1) images were used to identify these habitat features.

The reader is referred to Appendix 2 (pages 3 to 8) for additional details of the LANDSAT analysis.

4.0 RESULTS AND DISCUSSION

In 1985 and more specifically in 1986, we conducted interim analysis of the field transect and plot data to provide baseline data for the LANDSAT portion of the program. An analysis of bird use by habitat type was required to direct the LANDSAT program. These preliminary findings are presented first within the following LANDSAT results. Comparative analyses of the 1985, 1986 and 1987 data is presented later as are many results and discussions relative to specific species.

4.1 Landsat 1986

Preliminary analysis of 1985 and 1986 vegetation field data provided vegetation ground data necessary to calibrate and evaluate the LANDSAT TM and MSS imagery for mapping vegetation types of the Main study area (Fig. 1). Only 1985 and 1986 bird transect data and 1986 bird plot data were used in the LANDSAT portion of this project. We used the 1987 bird transect data and the 1987 bird plot data to test the results of the LANDSAT analysis. The results of analysis of transect data, presented below, is followed by the analysis of the plot data that was utilized in the LANDSAT analysis.

4.1.1 Transect Field Data

In 1985, we surveyed a total of 83.5 km of shorebird habitats in 17 transects and in 1986, 80.4 km in 15 transects (Fig. 2, App. 3). Twelve transects were surveyed in both years, while five were only covered in 1985 and three in 1986 only.

Although we collected detailed macro- and micro-topography data for each transect the analysis at this stage of the program classified the various habitat types on a very broad basis. We defined a total of seven major habitats for the LANDSAT analysis as follows:

Lowlands with well-developed low-centered polygons (grasses, sedges, horsetail, dwarf shrub);

Lowlands with poorly-developed low-centered polygons (grasses, sedge;

Levees (shrubs, grasses, horsetail);

Uplands with or without high-centered polygons (dwarf shrub, heath, grasses);

Tall shrub;

Barren (man made gravel pads, log (wood) drift lines, mudflats).

The habitat types and the amounts (km) represented on each transect are presented in Table 2 (1985) and Table 3 (1986). We used those data to calculate the density of each shorebird species in each habitat (Tables 4 and 5). We determined habitat preferences using a chi-square analysis (Zar 1984).

Total shorebird densities declined considerably from 0.91 to 0.43 birds/ha from 1985 to 1986. The preference for well-developed low-centred polygons remained strong however (1985: chi-square = 12 493.24; df = 4; p <0.01; 1986: chi-squared = 11 175.82; df = 4; p <0.01).

The priority species, as a group, showed a strong preference for well-developed low-centred polygons in both years (1985: chi-square = 4550.52; df = 4; p <0.01: 1986: chi-square = 524.31; df = 4; p <0.01). Densities declined by over half from 0.17 birds/ha in 1985 to 0.08 birds/ha in 1986. Most of this change is a result of a decline in the number of stilt sandpipers (from 0.08 to 0.02 birds/ha), and long-billed dowitchers

Table 2. Ground coverage (km) of major habitats defined by transect in the main study area in 1985.

	Amount of habitat surveyed per transect (km).					
	Lowlands					
Transect	LCPs[a] well-dev.	LCPs[b] poor-dev.	Levees	Uplands	Other[c]	Total
1		4.1	0.6		0.7-ts	5.4
2	1.1	0.4		1.8	1.4-ts	4.7
3		3.2		3.1		6.3
4		5.2		2.0	0.3-dw	7.5
5				1.6	t-ts	1.6
6		1.7	4.7			6.4
7		1.3	3.9			5.2
8		5.2				5.2
9		4.6	t			4.6
10		4.3			t-mm	4.3
11		4.0			t-mm	4.0
12	2.8	3.5			0.1-mm	6.4
13	1.5	2.7			t-mm	4.2
14	2.8		2.1			4.9
15	2.5		1.0		0.5-mm	4.0
16	3.6		t			3.6
17	5.2		t			5.2
Total km	19.5	40.2	12.3	8.5	3.0	83.5

[a]LCPs well-dev. = well-developed low-centred polygons.
[b]LCPs poor-dev. = poorly-developed low-centred polygons.
[c]Other: dw = driftwood; mm = man-made; ts = tall shrub.
t = trace, <0.1/km.

(from 0.02 to 0.00 birds/ha). The transect containing the highest densities of these two species (Transect 16) was not surveyed on 1986. If Transect 16 is excluded, then the 1985 density of the stilt sandpiper would be 0.3 birds/ha and the long-billed dowitcher less than 0.01 birds/ha.

0,03?

Table 3. Ground coverage (km) of major habitats defined by transect in the main study area in 1986.

	Amount of habitat surveyed per transect (km).					
	Lowlands					
Transect	LCPs[a] well-dev.	LCPs[b] poor-dev.	Levees	Uplands	Other[c]	Total
1		4.1	0.6		0.7-ts	5.4
2	1.1	0.4		1.8	1.4-ts	4.7
3		3.2		3.1		6.3
4		5.2		2.0	0.3-dw	7.5
6		1.7	4.7			6.4
7		1.3	3.9			5.2
10		4.3			t-mm	4.3
11		4.0			t-mm	4.0
12	2.8	3.5				6.3
13	1.5	2.7			t-mm	4.2
14	1.5		0.2			1.7
15	2.5		1.0		0.5-mm	4.0
18	0.5	0.2		2.3	t-ts	3.0
26	2.5	6.2				8.7
27	1.0	7.7				8.7
Total km	13.4	44.5	10.4	9.2	2.9	80.4

[a]LCPs well-dev. = well-developed low-centred polygons.
[b]LCPs poor-dev. = poorly-developed low-centred polygons.
[c]Other: dw = driftwood; mm = man-made; ts = tall shrub.
t = trace, <0.1/km.

Transect 16 is characterized by the presence of well-developed low-centred polygons. These are distinguished by deep water (over 0.5 m) and the presence of prominent margins and central mounds. Twenty-two of the 43 stilt sandpiper and 12 of the 15 long-billed dowitchers recorded in 1985 were from this particular habitat.

Table 4. Habitat use by shorebirds in the main study area in 1985.

Species	Number and density of birds per habitat type[f]						
	Lowlands						
	LCPs[a] well-dev.	LCPs[b] poor-dev.	Levees	Uplands	Other	Total	
Semipalmated Plover					3	3	
					0.10	t	
Whimbrel	24*	3				27	
	0.12	0.01				0.03	3/km²
Hudsonian Godwit	8	19	3			30	
	0.04	0.05	0.02			0.04	4/km²
Stilt Sandpiper	43*	18	1	4		66	
	0.22	0.04	0.01	0.05		0.08	8/km²
Buff-breasted Sandpiper	1					1	
	0.01					0.01	
Long-billed Dowitcher	15*					15	
	0.08					0.02	2/km²
Lesser Golden Plover	2	7	1			10	
	0.01	0.02	0.01			0.01	1/km²
Lesser Yellowlegs	2					2	
	0.01					t	
Semipalmated Sandpiper	3	26	49*	6	4 [d,e]	88	
	0.02	0.06	0.40	0.07	0.13	0.11	11/km²
Pectoral Sandpiper	33*	33	5			71	
	0.17	0.08	0.04			0.09	9/km²
Common Snipe	12	43	4	2	1 [d]	62	
	0.06	0.11	0.03	0.02	0.03	0.08	8/km²
Red-necked Phalarope	128*	215	35	6		384	
	0.66	0.53	0.28	0.07		0.46	46/km²
Total all shorebirds	271*	364	98	18	8	759	'85 91/km²
coverage (ha)	195.00	402.00	123.00	85.00	30.00	835.00	
density (birds/ha)	1.39	0.91	0.80	0.21	0.27	0.91	'86 43/km²
	= 139/km²	91/km²	80/km²	21/km²	27/km²	91/km²	

[a]LCPs well-dev. = well-developed low-centred polygons.
[b]LCPs poor-dev. = poorly-developed low-centred polygons.
[c]on drill pad
[d]in driftwood
[e]in tall shrub
[f]Upper figure refers to number of birds recorded, lower to density (birds/ha).
*preferred vegtation community, see text
t=Trace (<0.1/ha).

Table 5. Habitat use by shorebirds in the study area in 1986.

	Number and density of birds per habitat type[f]					
	Lowlands					
Species	LCPs[a] well-dev.	LCPs[b] poor-dev.	Levees	Uplands	Other	Total
Semipalmated Plover			2			2
			0.02			t
Whimbrel	16*	11	1			28
	0.12	0.02	0.01			0.03
Hudsonian Godwit	8*	14				22
	0.06	0.03				0.03
Stilt Sandpiper	5	2	3	4		14
	0.04	t	0.03	0.04		0.02
Lesser Golden Plover			1			1
			0.01			t
Semipalmated Sandpiper	15*	11	1	4	3[c,d]	34
	0.11	0.02	0.01	0.04		0.04
Pectoral Sandpiper	21*	21	3			45
	0.16	0.05	0.03			0.06
Common Snipe	5	22	15*	2		45
	0.03	0.05	0.14	0.02		0.06
Red-necked Phalarope	54*	58	8			120
	0.40	0.13	0.08			0.15
Red Phalarope	24	7	1			32
	0.18	0.02	t			0.04
TOTAL ALL SHOREBIRDS	148*	146	35	10	3	342
coverage (ha)	134.00	445.00	104.00	92.00	29.00	804.00
density (birds/ha)	1.10	0.33	0.34	0.11	0.10	0.43

[a]LCPs well-dev. = well-developed low-centred polygons.
[b]LCPs poor-dev. = poorly-developed low-centred polygons.
[c]on drill pad
[d]in driftwood
[e]in tall shrub.
[f]Upper figure refers to number of birds recorded, lower to density (birds/ha).
t = trace, <0.1/ha.
*preferred vegetation community.

Preference for well-developed low-centred polygons in general was statistically significant for:

1) whimbrel in both years (1985: chi-square = 69.69; df = 2; $p < 0.01$;

2) hudsonian godwit in 1986 (chi-square = 24.84; df = 2; $p < 0.01$); and

3) stilt sandpiper in 1985 (chi-square = 69.39; df = 3; $p < 0.01$).

Long-billed dowitchers were only observed in well-developed low-centered polygon habitat as was the only buff-breasted sandpiper recorded (12 June 1985).

Other shorebird species showing strong preference for well-developed low polygons are the pectoral sandpiper in both years (1985: chi-square = 27.09; df = 3; $p < 0.01$; 1986: chi-square = 205.49; df = 3; $p < 0.01$), the red-necked phalarope in both years (1985: chi-square = 71.44; df = 4; $p < 0.01$; 1986: chi-square = 1471.78; df = 3; $p < 0.01$) and the semipalmated sandpiper in 1986 (chi-square = 171.70; df = 4; $p < 0.01$). In the only year that it was present (1986) the red phalarope favoured well-developed low-centred polygons (chi-square = 4734.26; df = 2; $p < 0.05$). The only species favouring other habitats are the common snipe (levees in 1986; chi-square = 108.86; df = 3; $p < 0.01$) and the semipalmated sandpiper (levees in 1985; chi-square = 136.43; df = 3; $p < 0.01$).

Our analysis of the results of the ground surveys indicates that shorebirds have a strong preference for lowland areas. Within the lowlands, shorebirds as a group prefer well-developed low-centred polygons. Although sample sizes are small, the best developed low-centred polygons (those with a prominent central mound) may be the optimum shorebird habitat both in terms of species richness and numbers. These trends are even stronger when only the special study species are considered.

These preferences are probably a function of the proximity of various habitat requirements such as dry areas for nesting and shallow water for foraging. The better developed the polygons, the smaller the areas within which these requirements can be met. Thus territories could be smaller and higher breeding densities could be achieved. These areas also offer a greater diversity of habitats, thus a greater species diversity is expected to occur.

The inter-year differences in transect results are two fold. Firstly, there was an overall decline in the number of individuals of most shorebird species. Secondly, there were shifts and intensification of habitat preferences (some of these are evidenced by marked changes in chi-square values).

It is possible that differences in water-levels may be responsible for shifts in habitat preferences and that climatic conditions could be a factor in changing the densities of some shorebird species. More individuals of low-arctic nesting species, such as the semipalmated sandpiper and red-necked phalarope, may have nested to the south of the study area because of the cooler conditions that prevailed in 1986. Similarly these conditions may have caused the red phalarope to nest south of its normal mid- to high-arctic nesting area.

4.1.2 Plot Field Data

Our plot surveys of Fish Island collected bird data in relation to various habitat parameters. Only data from the 1986 plot surveys were used in the LANDSAT analysis. Rough maps showing the distribution of the percent cover of each habitat parameter, based on data collected while doing plot surveys, were prepared along with the distribution of the amount of standing water. The subjectivity of the evaluation of percent cover of many of the parameters proved to be a major problem. Different observers reported widely differing assessments of the percent cover of many parameters at a given point on the plots. Due to this problem we only used the assessment of shrub cover, grass and sedge (graminoid) cover and standing water cover over Fish Island for the LANDSAT program. We used rough field data maps of each of these parameters in the following categories:

Grasses and Sedges:	5-10%; 15-20%; 20-35%; 35-55% and 55%+;
Shrubs:	5-10%; 15-20%; 20-35%; 35-55% and 55%+;
Standing water:	0-10% and 0-7cm deep; 15-40% and 2.5-15 cm deep; 50-70% and 2.5-7.5 cm deep; 75-80% and 7.5-20 cm deep; 80% and variable depths.

For standing water, we used data presented on maps for three time periods: Data collected on 23 June; 25-27 June and 2-7 July. As the island is completely flooded in the spring it was felt that water changes throughout the season, particularly early in the year, would play a major role in defining shorebird nesting areas.

We defined the location of the various plots on the UTM-corrected LANDSAT TM imagery of the Fish Island study area thereby correlating the habitat field data results with the LANDSAT imagery.

4.1.3. Nesting/Habitat

We identified nesting sites of the priority shorebird species located on Fish Island in 1985 on maps for the LANDSAT analysis. Details of those data and analysis in relation to habitat can be found in later portions of the report. However, a brief summary of the results used for the LANDSAT analysis are presented below.

Within the lowlands, the priority shorebirds as a group, as well as most other shorebird species, prefer well-developed low-centered polygons. The data also suggests that shorebird breeding activities are controlled by the annual spring flood of the Mackenzie River delta. The result is that nest initiation is delayed such that all nesting in lowland areas is remarkably synchronous.

In this regard we point out that the older the terrain, less frequent the flooding and shorter duration the flooding, the better developed are low-centered polygons in this Low Arctic environment (Mackay 1963). Further details on the growth and aging of the Mackenzie River delta are provided in Appendix 1 (pages 29 to 30).

4.1.4 Imagery Analysis

The technical details on the results of the LANDSAT imagery analysis can be found in Appendix 1 (pages 31 to 45). This includes details on preprocessing of LANDSAT digital data and preparation and selection of photographic image enhancement combinations used to differentiate the vegetation cover types. Only a brief outline on which images were used and why they were selected is presented here.

Evaluation of each of the major image enhancement combinations showed that numerous vegetation cover types can be differentiated. No single TM colour composite could be used to map all possible vegetation types. Three of the colour combinations were required to maximize vegetation type differentiation for the study area. These are the natural color (bands 1-2-3), false color infrared (2-3-4) and color-mid infrared (3-4-5) images. Detailed image interpretation for vegetation mapping was only conducted using the July 23 TM imagery.

Visual interpretation of any remote sensing image is dictated largely by spatial resolution characteristics of the imagery. Although the instantaneous field-of-view (IFOV) for LANDSAT TM imagery is nominally 30 m, adjacent ground features of high contrast can be differentiated when the physical dimensions of the features are about 1/3 IFOV (10 m in diameter). Thus low-centred polygon ridges, troughs, central depressions and other important features found in the study area could not be resolved adequately by LANDSAT TM images for recognition and mapping of polygon fields. Likewise individual tall, medium and dwarf shrubs cannot be resolved. The following discussion identifies the spectral differentiation which was found in the analysis of the three LANDSAT TM photographic enhancements (i.e. bands 1-2-3, 2-3-4 and 3-4-5).

The false color-infrared (bands 2-3-4) and color mid-infrared (bands 3-4-5) photographs clearly differentiate the upland ecosystems on Pleistocene surficial materials from the lowland ecosystems on Recent alluvium. The natural colour (bands 1-2-3) photograph does not allow clear differentiation between the two major ecosystem types.

Within the lowland ecosystems, all three photographic products clearly show the dense, tall shrub cover along the highest parts of the levees. Dense stands of medium to short shrubs are most clearly differentiated on the natural colour enhancement but the other two colour products allow this vegetation cover type to be differentiated as well. A wide range of colour variations are seen within this vegetation cover type on the false colour infrared and colour mid-infrared photographic products, while this vegetation type appears more homogeneous in colour on the natural colour photographic product. Presumably the colour variability in the two infrared products are produced by species composition, biomass and/or soil/leaf moisture variability.

Extensive sedge/grass vegetation cover exists over much of the main study area. All three photographic products allow visual interpretation of this vegetation cover type. However, the false colour infrared and colour mid-infrared products show marked variability in colour patterns within this type while little internal colour variability is seen in the natural colour photographic product. Differences in moisture status and proportion of pixels covered by open water likely produce the large variability in colour patterns on the two infrared photographic products. Five distinct colour patterns are seen on the colour mid-infrared product; four on the colour infrared product; and two on the natural colour product.

Water bodies are shown on the photographic products. Natural colour photographic products show the greatest variability within water bodies. The colour variability within water bodies is largely due to the great variability in reflectance due to suspended sediment concentration differences. In many cases the contrast between water and land is so low that small, shallow ponds cannot be distinguished from land areas on the natural colour products. The colour infrared and colour mid-infrared photographic products provide clear separation between water bodies and land surfaces. However, small ponds less than 50 m in diameter cannot be clearly separated from saturated ground in the two infrared photographic products. Once pond size increases beyond 50 m in diameter they are clearly identifiable as continuous water bodies.

Disturbed sites show clearly on all photographic products. Where the coarse textured parent materials of levees have been disturbed small areas of 20-25 m in diameter can be defined. Any features greater than about 0.5 ha can be identified as to type of feature.

The 21 June 1986 LANDSAT TM imagery was also enhanced to produce photographic products. All enhancements appeared similar in colour variability. The flooding which had occurred two to three weeks prior to the acquisition of the imagery rendered most lowland areas very dark in appearance on the images. Levees and outer delta areas where flood waters had receeded, appear much lighter and appear in various similar hues due to the more advanced phenological stage of the vegetation cover on these drier areas. The Pleistocene uplands were similarly much more advanced in vegetation growth at the date of this imagery and possessed fairly saturated hues of red, yellow and green on different enhancements.

The TM band 3-4-5 color enhancement was used to interpret water level conditions on Fish Island. Sites with 0-10% standing water, as determined from the field survey of the Canadian Wildlife Service on 25-27 June 1986, appeared quite distinct on this enhancement. Colour values vary substantially on these sites. This large variability is likely due to small differences in plant composition and phenological development at this early date in the growing season.

Sites with 15-40% standing water are also distinctly differentiated on this enhancement. These sites appear much darker than the previous one. The predominant colour is dark brown (6.5 YR 2.5/1.0) but significant mottles of lighter reddish brown (2.5 YR 3.5/2.5) are abundant throughout these areas. Water depths are 2.5-15 cm on these sites but the significant areas without standing water are also identifiable.

Where standing water was covering greater than 50% of the surface area, darker colours appear on the enhanced TM image. Complete water coverage resulted in very dark brown colours on this enhancement. Almost equal amounts of the lighter brown appear to indicate specific sites where water covered only 15-40% of the surface.

Therefore?

4.1.5 Computer Mapping of LANDSAT TM Imagery

4.1.5a Habitat Mapping

The unsupervised Maximum Likelihood Classifier analysis of the 23 July 1986 LANDSAT TM image of the Fish Island study area was used to generate a vegetation cover map of the study area at a scale of approximately 4 miles to the inch (i.e. 1:15,840). The resulting map had 21 LANDSAT Classification Units (LCUs)(Figs. 4 and 5). Of these 21, 14 represent extensive or ecologically important LCUs. Table 6 defines each of the colours (LCU's) found on Figures 5 and 6. 4 + 5?

LCUs 15 - #21 were undefined at the time of the LANDSAT analysis. However subsequent field work enabled broad definitions to be made for each of these LCUs (Table 6).

4.1.5b Shorebird Habitat Analysis

Figure 6 shows the location of known nesting sites for whimbrel, stilt sandpiper and long-billed dowitcher and the known staging site for Long-billed dowitchers within the study area. The reader should note that only 1985 data, and to a lesser extent 1986 data, were used for the LANDSAT analysis. However, the extensive field surveys that led to the identification of these specific sites serve as a preliminary set of data to evaluate the usefulness of LANDSAT TM and MSS imagery for identification and mapping of the important potential nesting and staging habitat for these species of shorebirds.

4.1.5b.1 Nesting Habitat

Field data indicate that stilt sandpipers prefer low-centered polygon habitats. Based on the 1985 data, the nests had a vegetation cover of grass/sedge (30-50% cover) with some dwarf shrub less than 30 cm tall. The nests were located in the low areas of the polygons.

In 1985 and 1986 we found all whimbrel and stilt sandpiper nests in well-developed low-centered polygon areas (Fig. 6). All whimbrel nests found on Fish Island in 1985 and 1986 occurred on mounds or on the ridges of the low-centered polygons. They were, therefore, quite exposed although some had grasses and dwarf shrubs sheltering the nests. At the time we located three of these nests (26 June 1985 and 3 July 1985), standing water occupied 20-90% of the polygon area and was 5-20 cm deep. Whimbrel tended to nest in slightly wetter locations than stilt sandpipers but both species can nest very close to each other.

The long-billed dowitcher nest was also located in well-developed low-centered polygons. When we found the nest (22 June 1986) there was 30% standing water, at a 10 cm depth. The actual nest was located on a small ridge of the polygon which had a 30% cover of grass/sedge and 50% dwarf shrub cover, less than 30 cm tall, rooted in a dense moss base (Fig. 6).

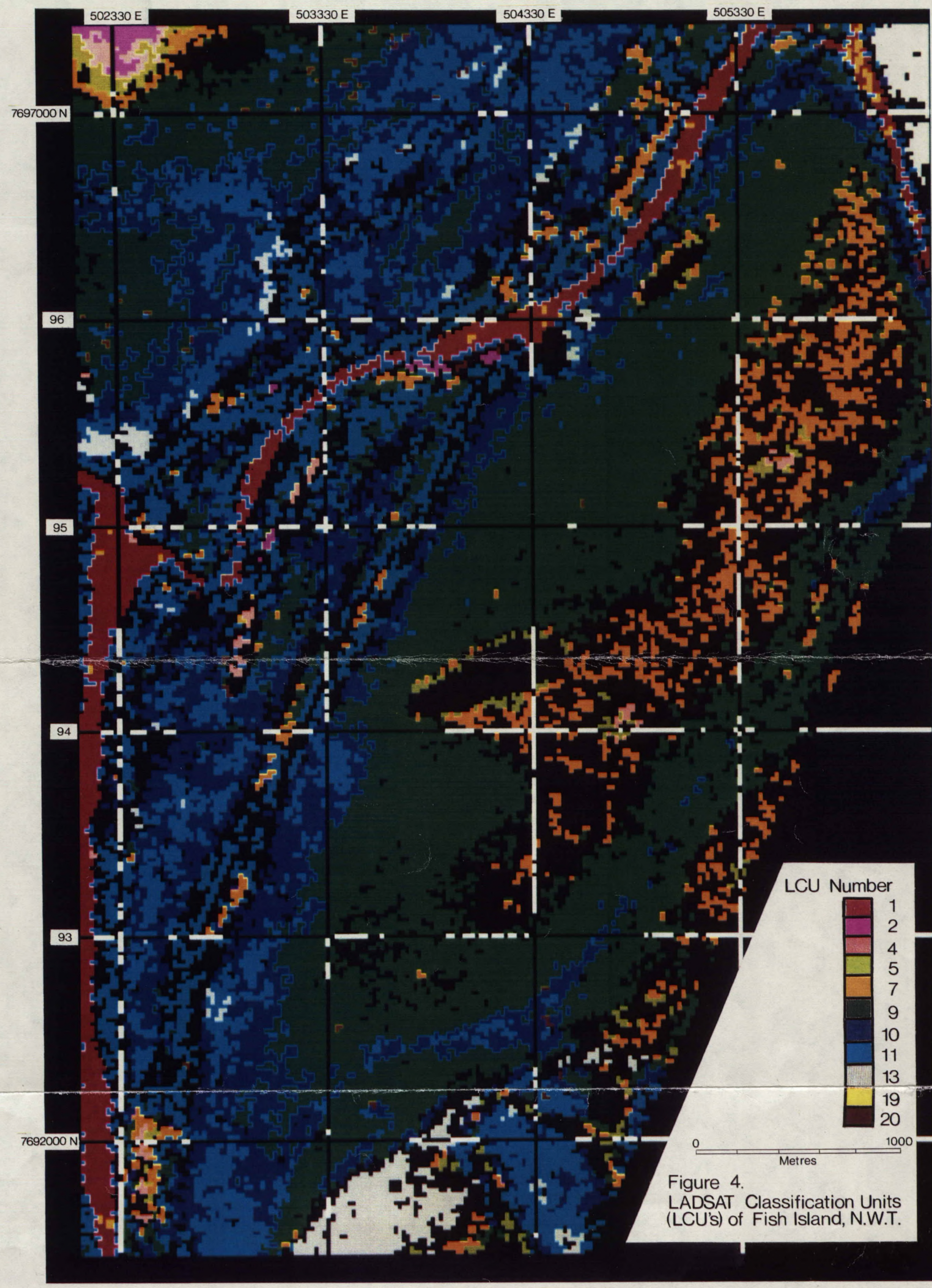


Figure 4.
LADSAT Classification Units (LCU's) of Fish Island, N.W.T.

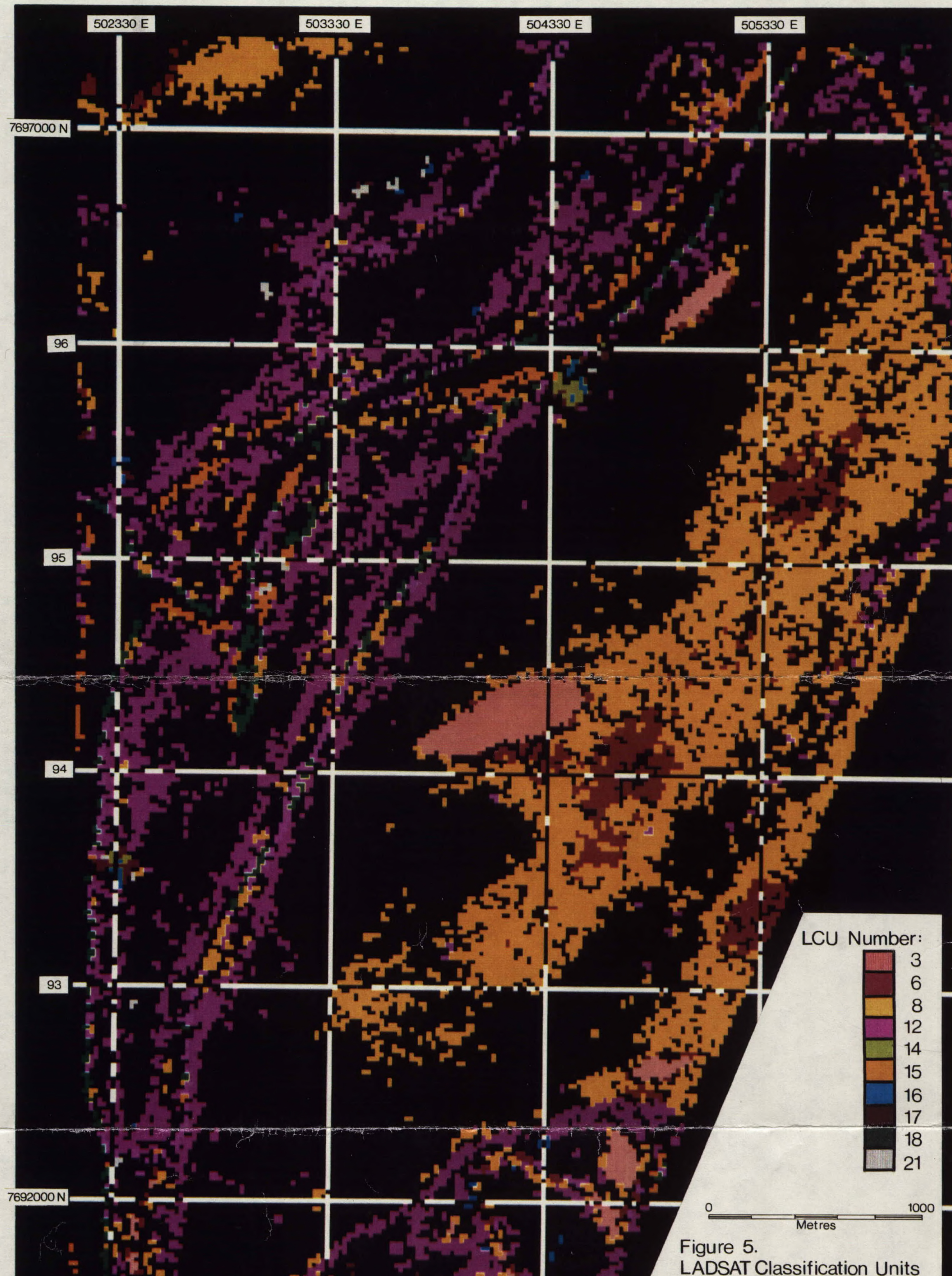


Figure 5.
LADSAT Classification Units (LCU's) of Fish Island, N.W.T.

Table 6. Definition of each habitat type represented by pixel colours (LCU types) identified on Figures 4 and 5 for Fish Island, Northwest Territories.

LCU #	Colour	Figure	Habitat representation
1	red	4	water with heavy sediment concentration
2	purple	4	water with moderate sediment concentration
3	tan	5	water with little suspended sediment
4	tan	4	shallow tundra ponds with little emergent vegetation
5	lime green	4	largely covered by deep water with 10-15% vegetation cover in July
6	redish brown	5	about equal proportion of deep water and vegetation cover in late July
7	orange	4	wet sites covered by emergent vegetation: up to 15% deep water cover
8	yellow	5	>55% grass/sedge cover: 25-27 June with >75% standing water
9	dark green	4	mixed dwarf shrub and grass/sedge: grass sedge >15%, dwarf shrub <35%
10	dark blue	4	>35% dwarf shrub represent gradient in dwarf shrub density and height from lowest to highest from LCU #10 to 12 respectively
11	light blue	4	>35% dwarf shrub represent gradient in dwarf shrub density and height from lowest to highest from LCU #10 to 12 respectively
12	purple	5	>35% dwarf shrub represent gradient in dwarf shrub density and height from lowest to highest from LCU #10 to 12 respectively
13	gray	4	dwarf shrub dominated pleistocene upland
14	lime green	5	barren gravel with vegetation removed by human activity
15	orange	5	unvegetated mudflats
16	light blue	5	disturbed sites with some grasses and herbs
17	brown	5	disturbed sites: gravel with tall shrubs or: exposed peat
18	dark green	5	shallow silt laiden water over mudflats ± emergent vegetation
19	yellow	4	undefined: water in river channels
20	red brown	4	disturbed tundra (possible grouping of LCU #14 and #19)
21	gray	5	unknown: disturbed tundra ?

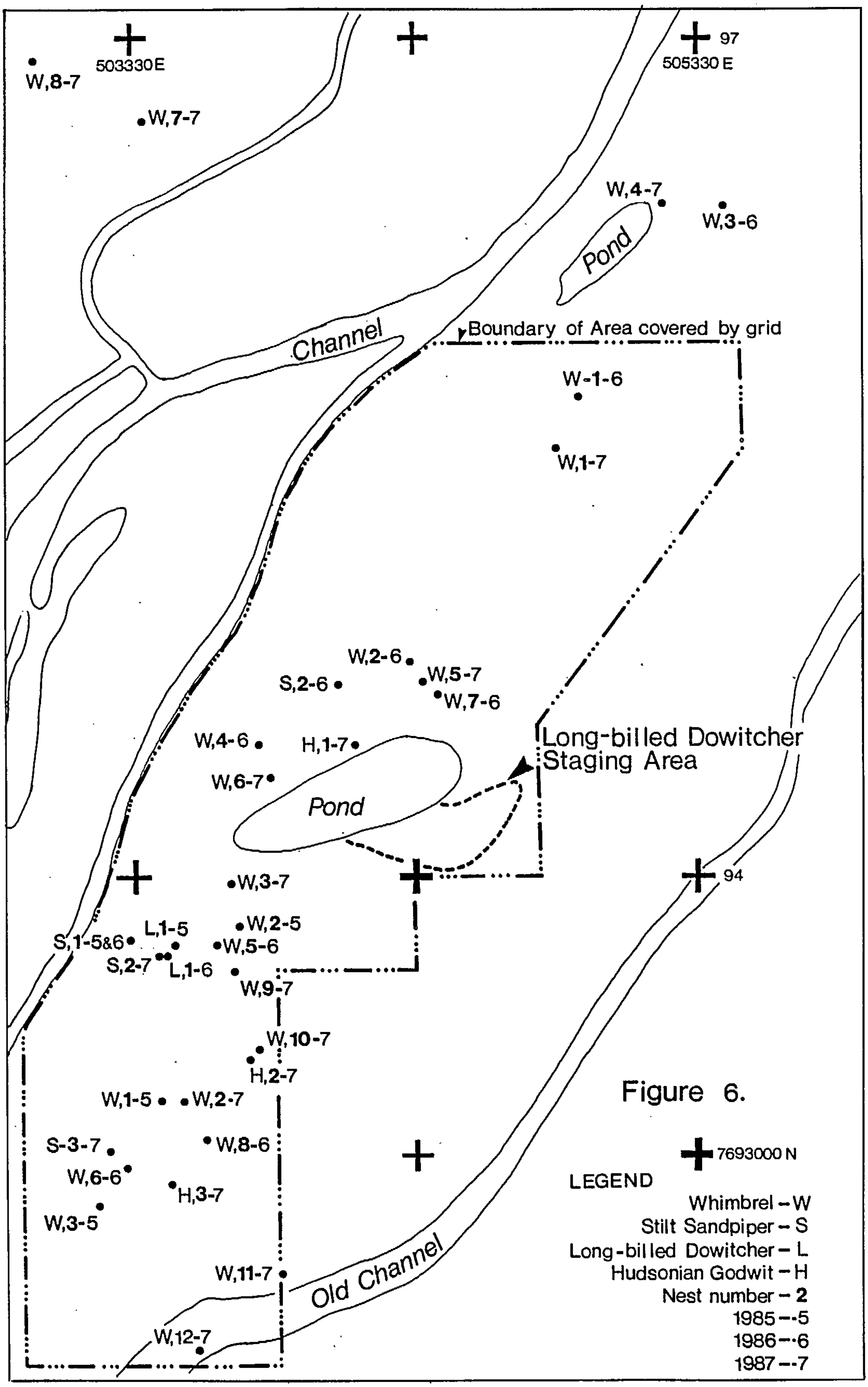


Figure 6. Nesting and staging sites of whimbrel, stilt sandpiper, long-billed dowitchers and hudsonian godwits on Fish Island and adjacent areas, Northwest Territories in 1985, 1986 and 1987. Readers can also use overlay labeled Figure 6 from back pocket and place it over Figure 4 and/or 5 on page(s) 34 and 35.

The centre of the polygon contained horsetail and grass/sedge cover of 50% with a 15% dwarf shrub cover only 15 cm tall.

All three species appear to favor nesting in areas of well-developed low-centered polygons on Fish Island and nearby areas. As these sites are subject to annual flooding at spring breakup, the nesting activity must occur after the ridges or mounds of the polygons become exposed as water levels receed. With stilt sandpipers, major portions of the center of the polygons may have to become exposed before nesting is initiated.

The nesting requirements for whimbrel and stilt sandpipers are found on Fish Island almost entirely within the LANDSAT Classification Unit (LCU) #9 ("dark green" on Fig. 4). Unfortunately the 1985 nest data was inaccurately plotted and this led to a conclusion that whimbrel and stilt sandpiper and long-billed dowitcher nests were found totally within LCU #9. In 1986, after the LANDSAT analysis was completed, the stilt sandpipers nest was relocated and mapped accurately using the LANDSAT map. This stilt sandpiper nest site was the same as in 1985 (Nest 1, 1985, 1986, Fig. 6) and in 1987 a nest was again found in a nearby location (Nest 2, 1987). We assumed that the nests were laid by the same parents year after year (Fig. 6). This placed the nest within different LCU zones. However, these nests are very closely associated with areas dominated by LCU #9 as can be seen in Figure 6 and in Appendix 1 (pp 42).

The potential nesting habitat for whimbrel and stilt sandpipers was thus identified using LCU #9 in combination with visual interpretation of the three July image enhancements. Visual interpretation allowed separation of much drier areas in well-developed low-centered polygons without dense shrub cover (i.e. less than 55%) in LCU #9 on the basis of colour. Figure 7 shows the locations of these prime potential nesting areas on Fish Island.

Table 7 presents the pixel composition of an area of 44 100 square metres centered over a nest site (7x7 pixels) and also the actual pixel type a nest was located on. This information is presented for the nests of the four priority species. Although our area classification was made only with data from 1985, the nests of stilt sandpipers, long-billed dowitchers and particularly whimbrel were within LCU #9 a significant portion of the time in 1986 and 1987: whimbrel 21 of 23 nests, stilt sandpiper 2 of 3 nests (1 pair renested three times in the same location dominated by LCU #10 but very close to a LCU #9 dominated area) and the long-billed dowitchers nested in the same area adjacent to a LCU #9 habitat. Unfortunately we did not discover any hudsonian godwit nests in 1985 or 1986, but found three in 1987, two of which were dominated by LCU #9 and one dominated by LCU #8 but adjacent to a LCU #9 area (Table 7).

The one long-billed dowitcher nest site was similar to those selected by stilt sandpipers and whimbrels. A long-billed dowitcher's nest was also discovered in the same area in 1986 in LCU #11 (Table 7, Fig. 6). The 1985 nest site was located within close proximity to dense dwarf shrub LCUs(i.e. LCUs #10 and #11, "light blue" and "dark blue" on Fig. 4).

The 21 June LANDSAT TM band 3-4-5 enhanced photograph illustrates clearly the water cover conditions as they existed on Fish Island at that date. Areas with 15-40% standing water on this date appear to define the areas used for nesting by stilt sandpipers, long-billed dowitchers and whimbrel. The areas identified on Fish Island within that category (using the June LANDSAT imagery) have also been mapped on Figure 7. Boundaries of

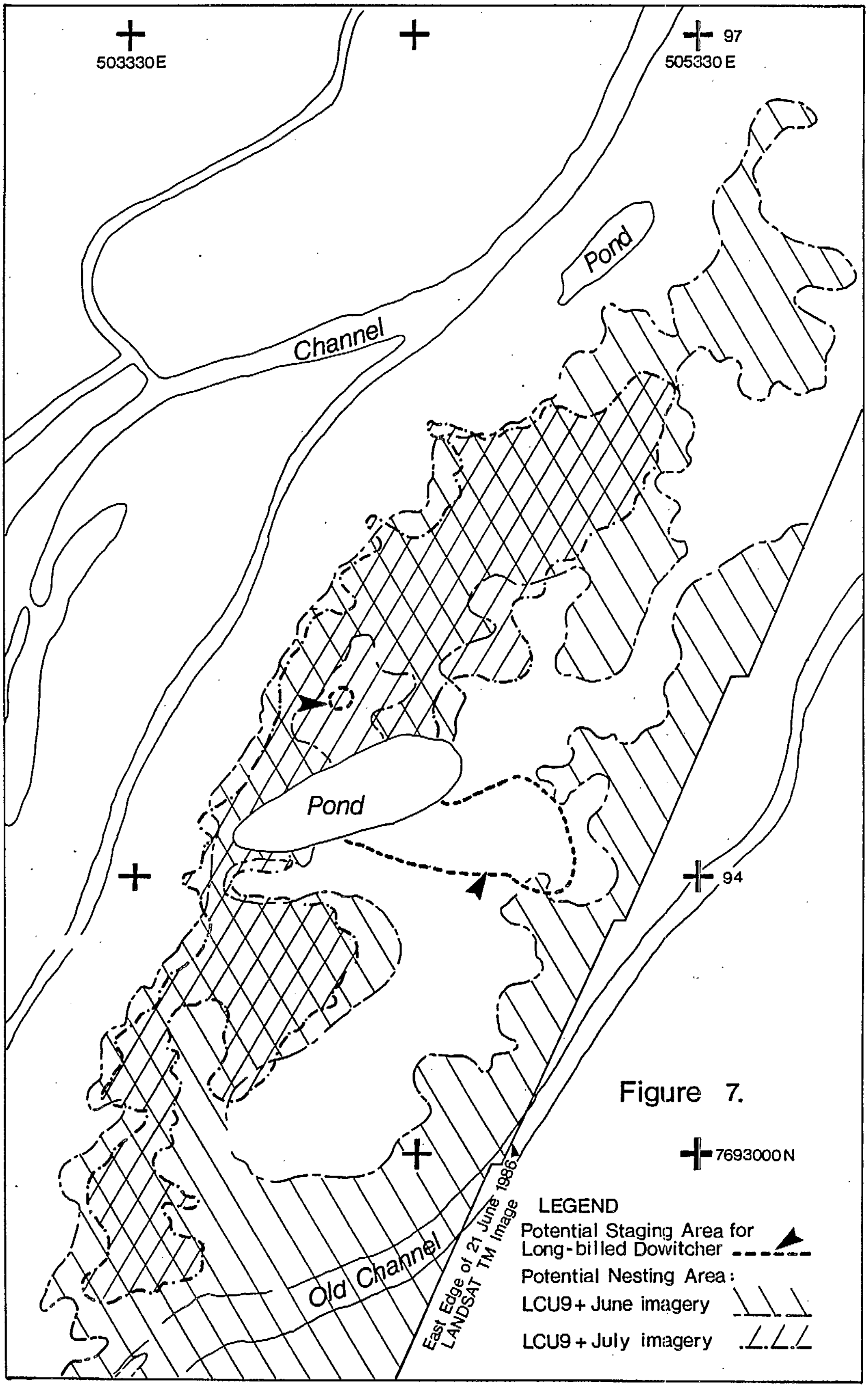


Figure 7. Potential nesting sites for whimbrel, stilt sandpipers, hudsonian godwit and long-billed dowitcher on Fish Island, Northwest Territories.
Readers can also use overlay labeled Figure 7 from back pocket and place it over Figure 4 and/or 5 on page(s) 34 and 35.

Table 7. LCU representation within 105 m of the nest sites found on Fish Island, Northwest Territories, in 1985, 1986 and 1987.

			# of pixels per LCU within 105 m of nest										Nest area		
Year	Species[c]	Nest number	3	5	8	9	10	11	12	17	21	LCU at Nest	July image*	June image[a]	LCU within[b] 60 m of nest
1987	HUGO	1	6	4	9	30						9	1	0	
1987	HUGO	2			3	46						9	1	1	
1987	HUGO	3			41	7						8	1	1	
1985	LBDO	1				8	21	20				11	0	2	9
1986	LBDO	1				8	16	25				11	0	2	9
1985	SLSA	1					34	15				11	0	2	
1986	SLSA	1					34	15				11	0	2	9
1986	SLSA	2				49						9	1	2	
1987	SLSA	2				8	16	25				11	0	2	9
1987	SLSA	3				42	7					9	2	1	
1985	WHIM	1				49						9	1	1	
1985	WHIM	2				49						9	1	1	
1985	WHIM	3				49						9	1	1	
1986	WHIM	1				49						9	0	1	
1986	WHIM	2			2	47						9	1	1	
1986	WHIM	3				49						9	0	1	
1986	WHIM	4				45	2	2				9	2	1	
1986	WHIM	5			3	46						9	1	1	
1986	WHIM	6			2	45	2					9	1	1	
1986	WHIM	7			5	44						9	1	1	
1986	WHIM	8			14		35					8	2	1	
1987	WHIM	1				49						9	1	1	
1987	WHIM	2			4	45						9	2	1	
1987	WHIM	3				49						9	2	1	
1987	WHIM	4			6	41						9	0	0	
1987	WHIM	5				49						9	1	1	
1987	WHIM	6				49						9	1	1	
1987	WHIM	7				1	28	12	4	1	3	11			
1987	WHIM	8				49						9			
1987	WHIM	9				49						9	1	1	
1987	WHIM	10			1	48						9	1	1	
1987	WHIM	11				41	5	3				9	0	1	
1987	WHIM	12				47		2				9	0	1	

*Area defined for potential nesting using the July LANDSAT TM imagery (0=nest outside defined zone, 1 = nest is in defined zone and 2 = nest is within 60 m of zone but outside defined zone).

[a]Area defined for potential nesting using the June LANDSAT TM imagery (0=nest outside defined zone, 1 = nest is in defined zone and 2 = nest is within 60 m of zone but outside defined zone).

[b]Indicates that nest is extremely close (60 m) from an area dominated by the indicated LCU type.

[c]Species nesting HUGO-Hudsonian Godwit, LBDO-Long-billed Dowitcher, SLSA-Stilt Sandpiper and WHIM-Whimbrel

areas on Figure 7 are somewhat different from those identified by the computer classified and multiple image visual interpretation described earlier (using the July LANDSAT image). We believed, at the time of analysis, that the July imagery better defined the proper potential nesting habitat but that the June imagery may be sufficient for preliminary analysis purposes. These imagery analyses will henceforth be referred to as the "July Image Method" and the "June Image Method". However examinations of the 1985, 1986 and 1987 nest data suggests a different result.

For each nest site, we plotted the location of the nest within the July Image Method nesting area (solid line, Fig. 7) or within the June Image Method nesting area (dashed line Fig. 7), (Table 7).

For the three hudsonian godwit nests the July Image Method was the most effective in defining potential nesting area: 100% of the nests (3) were found within the designated nesting area defined using the July Image Method.

The long-billed dowitchers nest site fell outside both methods of analysis (June Image and July Image Methods). However, it was within 60 m of the area identified using the June Image Method interpretation.

Stilt sandpiper nests were outside the nesting area identified using the July Image Method, four out of five times; although one nest (nest 3, 1987) was within 60 m of being inside. The June Image Method interpretation included only one nest site; however, all remaining five nests were within 60 m of being included.

Whimbrel nest sites were within the nesting area defined using the July Image Method 12 of 16 times, with four nest sites being within 60 m of inclusion. The June image included all but one of 16 nests. However this one nest (nest 4, 1987) was in an extremely small (4x4 pixels) area (120 m x 120 m) which was missed in the visual interpretation.

Thus it appears that the June Image Method selected a larger percentage of the nest sites, but the July Image Method may still be selecting the preferred nesting sites for the priority species.

Using a chi-square analysis we tested whether the distribution of LCUs within 90 m of each grid line were the same, in grid segments where birds of a given species were seen as compared with those where no observations were made.

is this valid? I believe first must test distributions of LCU in each segment

The results of these tests (Table 8) indicate that all priority species along with semipalmated and pectoral sandpipers and red-necked and red phalaropes significantly differentiate ($p < 0.05$) the habitat (LCUs) which they use. There is however, an overlap in the habitats (LCUs) being used by each species observed on Fish Island (see Table 8: "all segments"). ? The sample (number of observations on grid segments) were small for red phalaropes and semipalmated sandpipers and to some extent for long-billed dowitchers (Table 9). The lack of data points suggests that semipalmated sandpipers do not use low-centered polygon habitat for nesting. It also suggests that although long-billed dowitchers do nest in low-centered polygon habitat they may in fact prefer drier areas outside the study area. Information from other biologists suggests that long-billed dowitchers are more common in other areas along the Beaufort Sea including the Tuktoyaktuk Peninsula (Dickson, D.L., pers. comm.) and the Yukon North Slope (Dickson D.L., pers.comm. and Dickson D.L., 1988).

Table 8. Chi-squared analysis (DF = 6) of shorebird use on Fish Island, Northwest Territories, within the two methods of LANDSAT analysis (June Image and July Image Methods) for LCUs #6, 7, 8, 9, 10, 11 and 12 as a group.

	All segments		June image method[a]		July image method[b]		In both methods[ab]	
Species*	X^2	$p < 0.05$	X^2	$p < 0.05$	X^2	$p < 0.05$	X^2	$p < 0.05$
WHIM	1427.7	<0.05	545.5	<0.05	68.3	<0.05	554.3	<0.05
SLSA	468.1	<0.05	237.7	<0.05	28.8	<0.05	240.0	<0.05
HUGO	534.0	<0.05	130.8	<0.05	87.9	<0.05	147.6	<0.05
LBDO	220.7	<0.05	143.2	<0.05	10.4	>0.05	112.4	<0.05
SESA	86.8	<0.05	170.6	<0.05	252.5	<0.05	367.9	<0.05
PESA	898.2	<0.05	314.0	<0.05	58.1	<0.05	324.7	<0.05
RDNP	344.3	<0.05	125.2	<0.05	116.8	<0.05	130.3	<0.05
REPH	181.3	<0.05	54.9	<0.05	22.5	<0.05	53.9	<0.05

*WHIM-Whimbrel, SLSA-stilt sandpiper, HUGO-Hudsonian godwit, LBDO-Long-billed dowitcher, SESA-Semipalmated sandpiper, PESA-Pectoral sandpiper, RDNP-Red-necked phalarope, REPH-Red phalarope.
[a]analysis based on June 1986 Landsat imagery.
[b]analysis based on July 1986 Landsat imagery.

Although there are very few records for red phalarope, we note that this species is more often found nesting on the high arctic islands and was only found in the study area in 1986. This was apparently due to the harsh weather conditions in the arctic islands during the spring of 1986 (T. Barry, pers. comm.). In fact the sighting of a white-rumped sandpiper on the gravel pad in 1986 (mid June for 3 days) also indicates delayed migration. 1987 was also a bad spring

We also observed significant differentation in the use of habitat when we plotted only those observation data which fell within the potential nesting area defined for the priority shorebird species using the June imagery (Fig. 8, Table 8: Nesting

Table 9. The number of records of sightings of each species per grid segment utilized in the chi-squared and binomial analysis for records falling within nesting habitat as delineated by the two LANDSAT analysis methods (June Image and July Image Methods).

	Number of records of segments included as bird sightings					
	June Image [a]		July Image [b]		In Either Method[ab]	
Species*	Out	In	Out	In	Out	In
WHIM	26	107	42	91	21	112
HUGO	16	68	29	55	12	72
LBDO	4	3	5	2	3	4
SLSA	9	39	14	34	8	40
PESA	10	46	18	38	8	48
SESA	0	4	2	2	0	4
RDNP	11	12	17	6	11	12
REPH	2	3	2	3	2	3

*SESA-Semipalmated sandpiper, PESA-Pectoral sandpiper, RDNP-Red-necked phalarope, REPH-Red phalarope, WHIM-Whimbrel, SLSA-Stilt sandpiper, HUGO-Hudsonian godwit, LBDO-Long-billed dowitcher.
[a]analysis based on June 1986 Landsat imagery (June Image Method)
[b]analysis based on July 1986 Landsat imagery (July Image Method)

area: June). When only observation data falling within the potential nesting area defined using the July imagery was used (Fig. 7), all species except long-billed dowitchers showed a significant differentiation ($p < 0.05$) of the habitats they use. This suggests that the July imagery alone (assuming that shorebird species were sighted in the preferred nesting areas) is unsuitable for defining potential nest sites of long-billed dowitchers on the Mackenzie River delta.

We used a normal approximation to the binomial distribution (Mendenhall, 1979) to test whether the proportions of each LCU type was the same where each species was seen compared to where it was absent. For these tests we pooled the LCU data on all segments where a species was observed (Appendix 4) and conducted four different tests: 1) including data from all segments surveyed on Fish Island; 2) including data from only those segments falling within the area identified as nesting habitat defined using the June 1986 imagery; 3) including data from only those segments falling within the area identified as nesting habitat defined using the July 1986 imagery; and 4) including data from the area falling only within the overlap nesting area of the June and July imagery interpretation (Fig. 7). Table 10 presents the results of these binomial tests. Appendix 5 presents the test statistics. Tests were only conducted for LCUs #6 through #12; all other LCUs were represented by less than 100 pixels, scattered through-out the area and were therefore ignored as inconsequential.

Whimbrel, hudsonian godwit and pectoral sandpipers and to some extent, stilt sandpipers, are similar in their habitat preference (Table 10). All species are selecting for LCU #9. Stilt sandpipers show some difference in their habitat preference in that there is no significant selection or avoidance of LCU #10. By examining the results of the 4 methods of analysis, defined in Table 10, we found that the June LANDSAT imagery better defines the shorebird nesting habitat than does the July image. Assuming that the distributions of the priority shorebird species on Fish Island reflects nesting territories or their preference to habitat suitable for nesting, we compared the results of the four methods (Table 10). We found that the results for "method 0", which uses all available data, is almost identical to the results of "method 1", which uses only the data falling within the nesting zone identified using the June 1986 LANDSAT imagery.

Table 10. Binomial test results of shorebird use of LCU #6, 7, 8, 9, 10, 11 and 12 on Fish Island, Northwest Territories.

	Binomial test results of each LCU for 4 data sets						
	6**	7	8	9	10	11	12
Species	0 1 2 3*	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3
WHIM	- - N -	- - - -	- - + -	+ + + +	- - - -	- N - -	- N N N
HUGO	- N N N	- - - -	- N + N	+ + N +	- - - -	- N N N	- N N N
SLSA	- N N N	- - ! -	- - - -	+ + N +	N N + +	- N N N	! ! N !
PESA	- ! N !	- - + -	- - N -	+ + + +	- - - -	- - - -	! ! N !
LBDO	+ + N +	N N N N	- N N N	N N + N	- ! ! !	N N - N	! N - N
SESA	! N N N	! ! N !	- N + N	- - - -	- + + +	- + + +	! N N N
RDNP	+ + N +	N N N N	+ + + +	- - - -	- ! ! !	! ! N !	- N + N
REPH	+ N N N	N ! N !	N ! ! !	N + + +	! ! ! !	! N N N	! N N N

*Methods of analysis: (DSB)

0 binomial test of all pixel data from all segments surveyed on Fish Island.

1 binomial test of data from segments which fell within the nesting area defined using the June 1986 LANDSAT data imagery, Figure 8.

2 binomial test of data from segments which fell within the nesting area defined using July 1986 LANDSAT imagery.

3 binomial test of data from segments which fell within the nesting area defined using both the June and July LANDSAT (i.e; area within both, not total area of both).

**Results in this column are either "-", "N", "+" or !.

- = binomial test defined that the given species significantly avoided this LCU type ($p < 0.05$).

! = binomial test defined that the given species significantly avoided this LCU type ($p < 0.05$) however no birds of the species were seen in this LCU.

+ = binomial test defined that this species significantly selected this LCU type ($p < 0.05$).

N = binomial test was not significant.

To test whether the results of the LANDSAT analysis, which showed that the percentage of dwarf shrub, graminoid and standing water were the most important habitat variables for the priority shorebird species, we conducted a Three Means Clustering procedure on the transect data collected throughout the study area (Wilkinson, 1987). The LANDSAT analysis identified that the priority shorebird species preferred LCU #9 for nesting. LCU #9 represents a low-centered polygon habitat with greater than 15% graminoid and less than 35% dwarf shrub. The study also indicated that the priority species nested in areas with 15-40% standing water cover.

The Three Means Cluster analysis used all the available Transect habitat data. Standing water, graminoid and dwarf shrub were the best discriminating variables, in this order of priority, for defining the three clusters (Appendix 6). Thus the assumptions made in preparation for the LANDSAT analysis, that these were the three most important variables, was substantiated.

In order to provide a preliminary assessment of potential nesting habitat throughout the main study area (Fig. 1), the 21 June 1986 LANDSAT TM image was produced for this area and interpreted for potential prime nesting habitat areas. We also conducted visual interpretation of the natural colour, false colour infrared and colour mid-infrared images for this larger area, to exclude areas of dense shrub cover and areas which did not dry sufficiently by July to serve as important nesting habitat.

Initial analysis and mapping of the 21 June 1986 LANDSAT TM enhanced image located 22 areas within the main study area which appear to be similar to the prime nesting habitat located on Fish Island. Subsequent refinement of that first stage of mapping with the three enhanced July TM images showed that only portions of those areas and, in fact, not all of them meet the other requirements as areas with potential nest sites (Fig. 8).

4.1.5b.2 Staging Habitat

Although only one area was located where staging was evident for long-billed dowitchers, this information served as a data base for preliminary analysis of the LANDSAT TM and MSS imagery for identification and mapping of potential long-billed dowitcher staging habitat areas.

Figure 6 shows the one location where these birds were observed staging. Analysis of the LANDSAT vegetation maps shows that this site is made up of a mosaic of LCUs #4, 5, and 7 on Figure 4 as well as LCUs #3, and 6 on Figure 5. This combination includes areas with large proportions open water but possessing 30-35% vegetation cover in a complex mosaic pattern adjacent to a substantial body of open water (i.e. large sediment-free lake). Similar areas found throughout Fish Island can be recognized and are mapped on Figure 7. These sites may be other staging areas for long-billed dowitchers. Potential staging areas throughout the larger study area cannot be accurately identified since vegetation cover was not mapped throughout that larger study area. Thus the important LCUs cannot be located. Visual interpretation only allowed for broad potential staging areas to be located (Fig. 8) in the main study area.

4.2 Multispectral Scanner Imagery Analysis

We conducted the analysis of LANDSAT MSS, 21 June 1986, Imagery in parallel with analysis of the TM imagery from the same date. The MSS

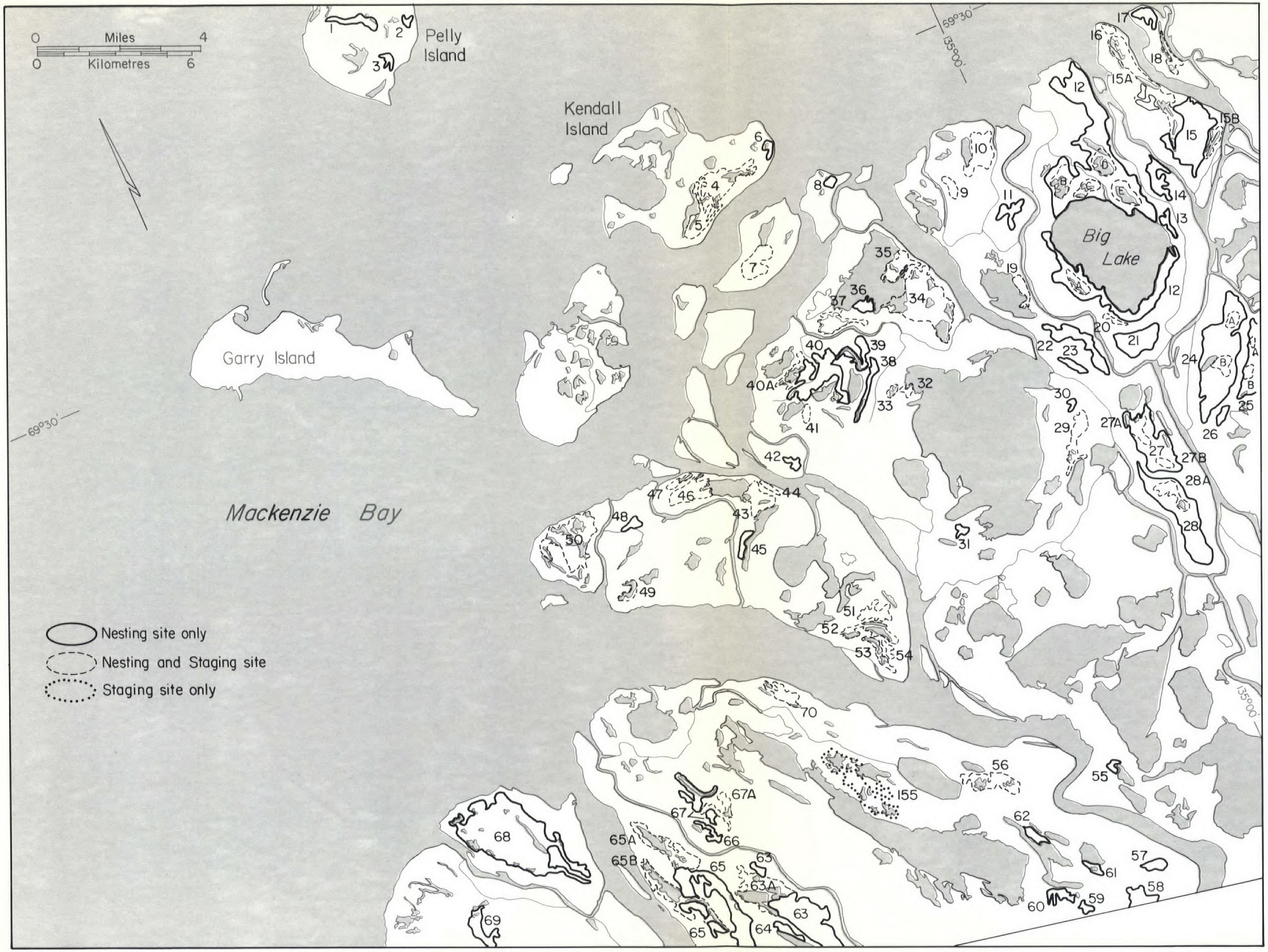


Figure 8. Potential nesting and staging sites defined using LANDSAT TM imagery in the main study area and the Kendell Island subarea, Mackenzie River delta, Northwest Territories.

imagery has much lower spatial resolution data (80 X 80 m pixels) than TM data (30 X 30 m pixels). Visual interpretation of MSS imagery can only be conducted down to scales of 1:150,000 or about 1 inch = 2 miles while the TM photographic products can be interpreted down to scales of about 1:31,680. In addition, the MSS imagery only possesses bands in visible green and red spectral areas as well as two near infrared bands (Bands 6 and 7). LANDSAT TM imagery possesses three visible bands allowing production of important natural color photographic enhancements which cannot be done with MSS imagery. In addition, TM data possesses two mid-infrared bands (Bands 5 and 7) important in mapping water and vegetation which are unavailable with LANDSAT MSS imagery. Another draw-back with MSS imagery is that the data is obtained in a 6-bit digital format as opposed to 8-bit format with TM imagery. This means that MSS imagery can only detect 64 distinct radiometric levels throughout the entire spectral sensitivity range of its sensors. TM imagery is able to differentiate 256 levels and is therefore able to detect much smaller differences in spectral reflectance quantities than MSS. This allows TM imagery to be used for more refined classification of vegetation, soil moisture and water conditions than MSS imagery. As a result of these limitations, we found the LANDSAT MSS imagery to be unsuitable for the detailed visual interpretation required to identify potential nesting and staging habitats of priority shorebirds.

4.3 Landsat 1987

For purposes of analysis and photographic LANDSAT TM image production, we broke up the entire outer Mackenzie River delta study area into five subareas (Fig. 9), as listed below:

Kendall Island = 187 387.2 ha (462 846.4 acres);

Ellice Island = 187 129.8 ha (462 210.6 acres);

Shallow Bay = 80 580.0 ha (199 032.6 acres);

N. Richards Island = 195 453.7 ha (482 770.7 acres); and

S. Richards Island = 220 304.0 ha (494 750.9 acres).

Technical details regarding the processing and analysis of the two sets of imagery (21 June 1988 and 23 July 1988) can be found in Appendix 2 (pages 8 to 13).

The multiple linear contrast enhancements applied to each band followed the same methodology applied in the previous analyses (Moik 1980). Visual analysis of the 1:50,000 scale LANDSAT TM photographic products enabled us to produce maps showing the distribution of potential nesting and staging habitat sites throughout the study area. Figures 8, 10, 11, 12 inclusive, show the distribution of these sites. Numerous sites which may serve as important shorebird nesting habitat are located on these figures. The most extensive sites which exhibit image characteristics very similar to those found for known shorebird nesting habitat on Fish Island include the following sites: #12, 15, 19, 21-25, 27, 28, 31, 43, 51, 56, 58, 59, 60, 63, 65, 66, 67, 69, 70-76, 82, 83, 99-102, 104, 110, 111, 113-123, 135, 148, 151-154, 324, 327, 351 and 357. Numerous sites which may serve as important staging sites are also located on these Figures.

A portion of the outer Mackenzie River delta south of Shallow Bay could not be mapped because the 23 July 1986 LANDSAT image was not available. We identified and mapped areas flooded on 21 June 1986 (Figure 13) but those areas cannot be interpreted as potential nesting or staging habitat sites.

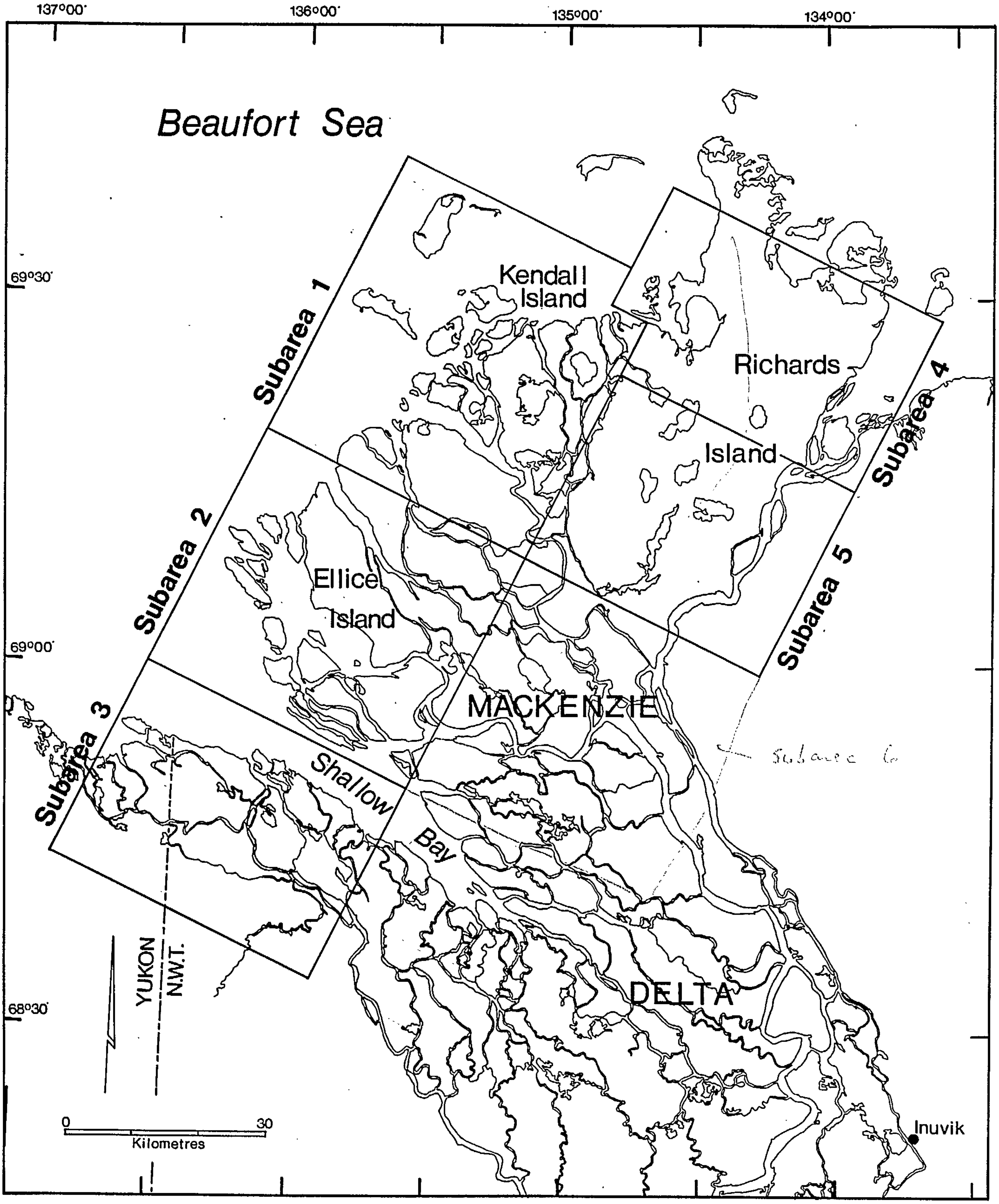


Figure 9. Location of subareas in the outer Mackenzie River delta, Northwest Territories Study Area.

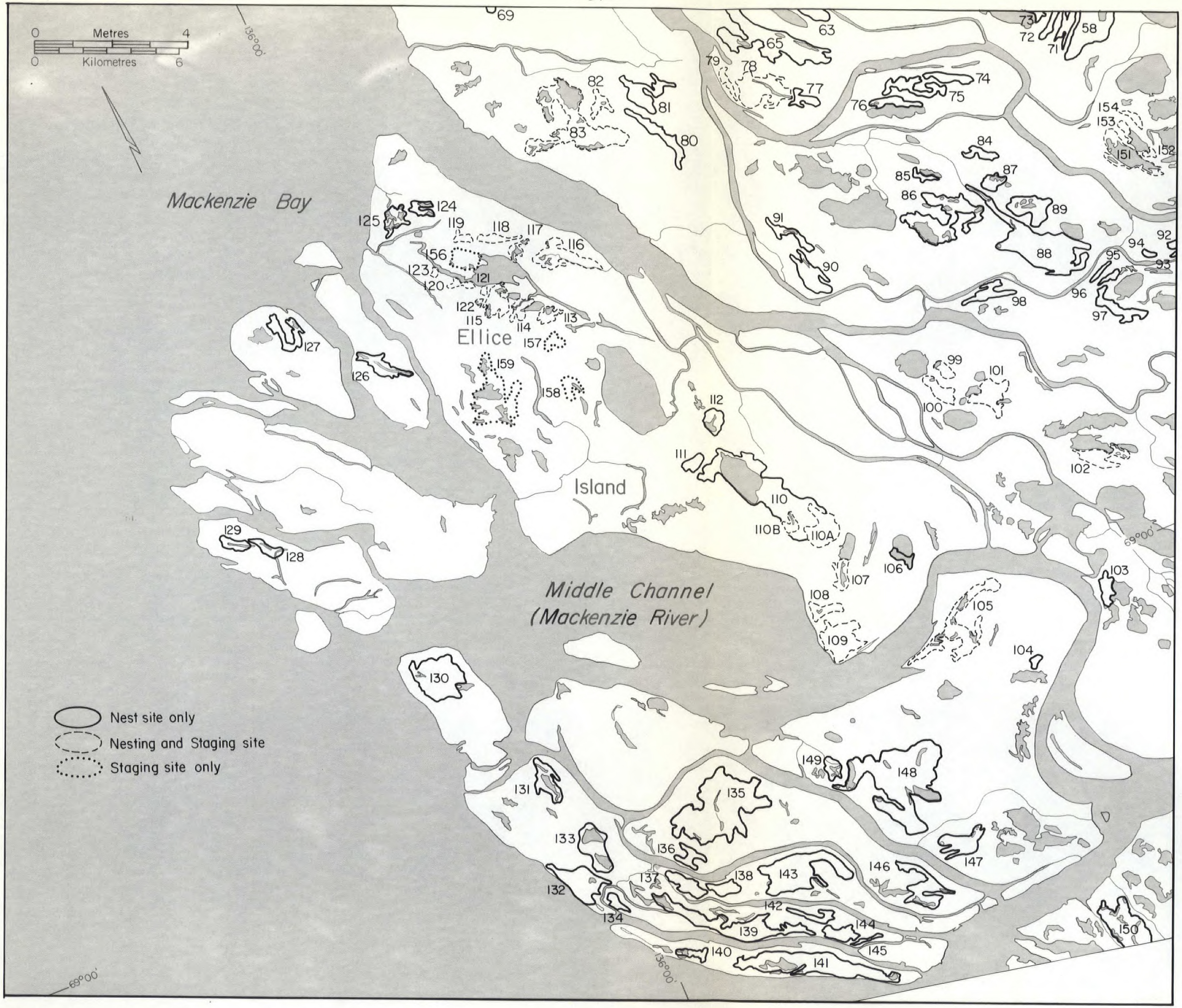


Figure 10. Potential nesting and staging sites defined using LANDSAT TM imagery, Ellice Island Subarea, Mackenzie River delta, Northwest Territories.

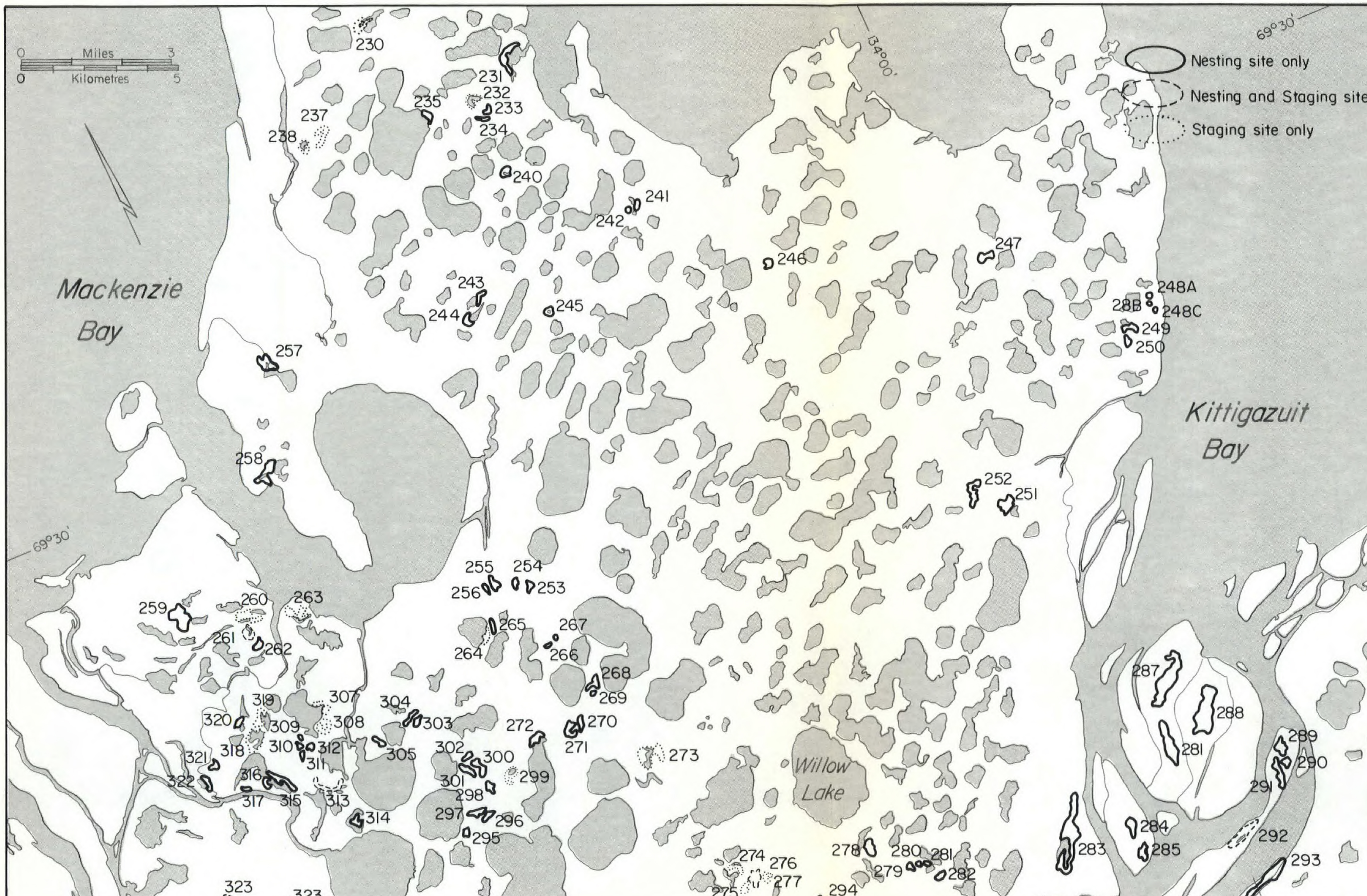


Figure 11. Potential nesting and staging sites defined using LANDSAT TM imagery in the North Richards Island Subarea, Northwest Territories.

Figure 12. Potential nesting and staging sites defined using LANDSAT TM imagery in the South Richards Island Subarea, Northwest Territories.

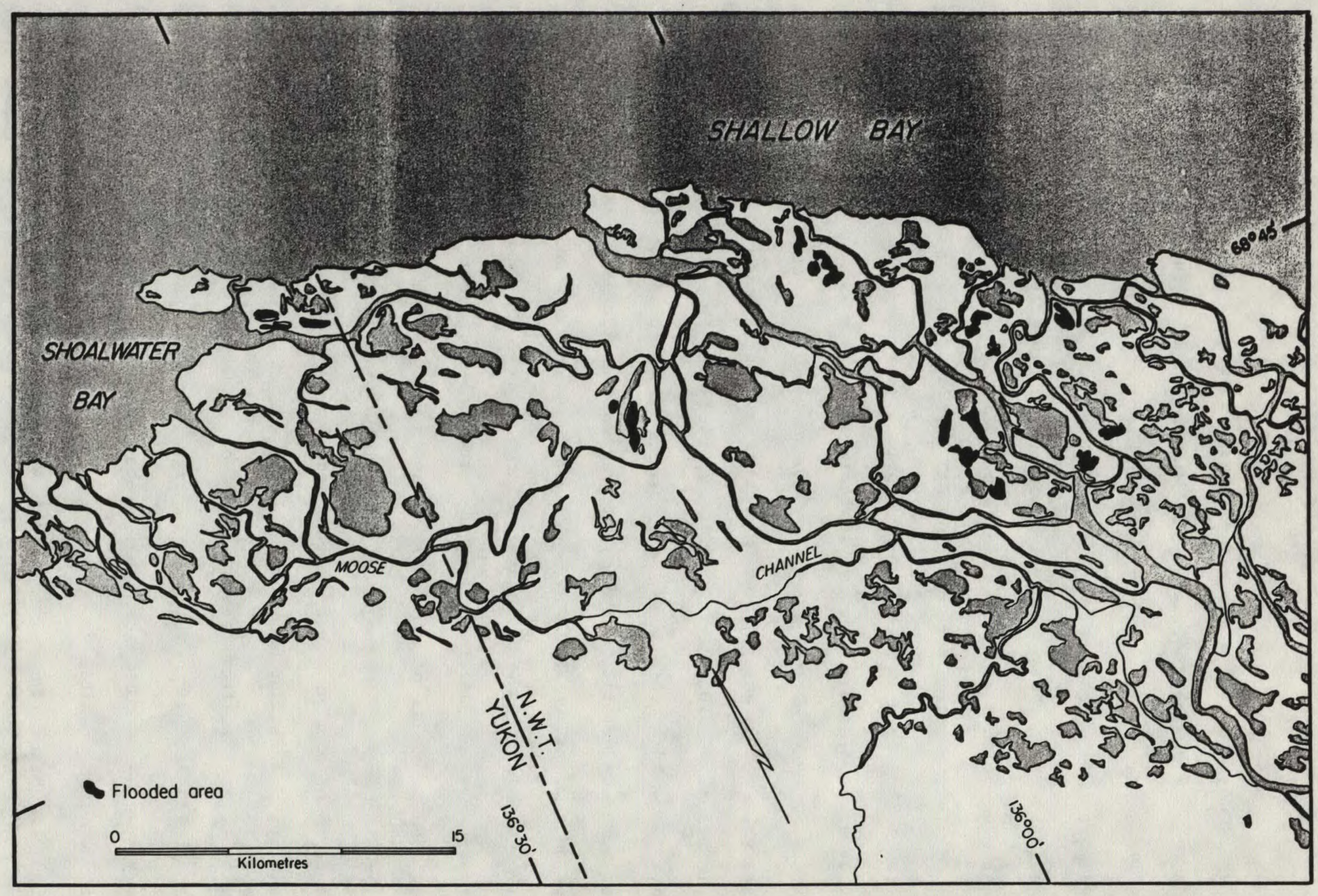


Figure 13. Location of flooded areas south of Shallow Bay, Northwest Territories determined from 21 June 1986 LANDSAT Thematic Mapper Imagery. (#A-H and J-R) Scale 1:250,000.

The potential nesting and staging habitat sites that we were able to identify are mapped on Figures 8, 10, 11 and 12. The major concentration of these sites are north of Shallow Bay within an area of recent sedimentation (the active portion of the Mackenzie River delta). Many of the smaller sites may serve as important staging habitat but it is unlikely that many of them serve as important nesting areas.

To determine if our LANDSAT analysis was accurate in defining potential nesting habitat for the priority species, we examined the field transect data from all years (Appendix 3).

Of the 36 transects surveyed, 24 intersected sites identified through LANDSAT analysis as potential nesting areas (transects 1, 2, 6, 6.1, 6.2, 8, 9, 10, 12, 13, 13.1, 14, 14.2, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25 and 27). Of these 24 transects, Transects 6.1, 6.2, 8 and 19 did not have any priority species observed on them (Table 11 and Fig. 14-17 and Appendix 3 and 4). We only surveyed transects 6.1 and 6.2 in 1987 (Table 11) because of the relatively large number of whimbrel we saw "Off Transect" on Transect 6 (5 birds) the previous year. In 1986 extremely high water levels occurred on Transects 6, 6.1 and 6.2 with 60-80% cover (15-20 cm deep) as compared with almost no standing water the previous year. These high water levels undoubtedly account for the absence of priority species on transects 6.1 and 6.2 and for decreases in numbers of priority species from previous years on Transect 6 (Table 11).

Transect 19 had extremely high standing water levels in 1987, the only year we visited it. This probably accounts for the few birds seen. It is quite possible that in 1986, the year that the LANDSAT imagery we used was taken, the water levels were much lower in this area than in

Table 11. Birds observed per kilometre and number of whimbrel, stilt sandpiper, hudsonian godwit and long-billed dowitcher observed "on transect" on each transect in 1985, 1986 and 1987, Mackenzie River delta, Northwest Territories.

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off)		
		1985	1986	1987
1	WHIM	0	-	0
	SLSA	.89 (10)*	-	1.25 (7)
	HUGO	.53 (3)	-	0
	LBDO	0	-	0
2	WHIM	0	0	0
	SLSA	.84 (4)	.42 (2)	2.11 (13)
	HUGO	0	0	0
	LBDO	0	0	0
3	WHIM	0	0	0
	SLSA	.53 (8)	.13 (3)	.53 (4)
	HUGO	.13 (1)	0	0
	LBDO	0	0	.13 (1)
4	WHIM	0	0	0 (12)
	SLSA	0	0	.73 (6)
	HUGO	.61 (6)	.12 (1)	0
	LBDO	0	0	0
5	WHIM	0	-	-
	SLSA	0	-	-
	HUGO	0	-	-
	LBDO	0	-	-
6	WHIM	0	0 (5)	.20 (1)
	SLSA	0	.40 (3)	.20 (2)
	HUGO	.40 (2)	0	0
	LBDO	0	0	0
6.1	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	0
	LBDO	-	-	0

Table 11. Continued.

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off) 1985	1986	1987
6.2	WHIM	–	–	0
	SLSA	–	–	0
	HUGO	–	–	0
	LBDO	–	–	0
7	WHIM	0	0	0
	SLSA	.17 (1)	0	0
	HUGO	.87 (7)	0	0
	LBDO	0	0	0
8	WHIM	0	–	0
	SLSA	0	–	0
	HUGO	0	–	0
	LBDO	0	–	0
9	WHIM	0	–	0
	SLSA	.85 (5)	–	0
	HUGO	.85 (12)	–	.42 (3)
	LBDO	0	–	0
10	WHIM	0	0	0
	SLSA	.24 (4)	0	0
	HUGO	.47 (6)	1.19 (5)	.24 (1)
	LBDO	0	0	.24 (1)
11	WHIM	0	0	0
	SLSA	0 (1)	0	0 (1)
	HUGO	0 (2)	0 (2)	.51 (2)
	LBDO	0	0	0
12	WHIM	1.60 (10)	2.08 (13)	1.44 (9)
	SLSA	.96 (6)	.16 (1)	0 (1)
	HUGO	.32 (2)	.64 (9)	.64 (4)
	LBDO	.16 (1)	0 (1)	.16 (1)

Table 11. Continued.

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off) 1985	1986	1987
13	WHIM	.89 (13)	0 (1)	0 (1)
	SLSA	1.04 (12)	.15 (1)	.15 (1)
	HUGO	0 (1)	.45 (5)	.45 (4)
	LBDO	0	0	0
13.1	WHIM	-	-	.55 (12)
	SLSA	-	-	.14 (1)
	HUGO	-	-	.14 (8)
	LBDO	-	-	0
14	WHIM	0 (1)	.30 (2)	0
	SLSA	0	0	0
	HUGO	.91 (4)	0 (1)	0
	LBDO	0	0	0
14.1	WHIM	0	-	-
	SLSA	0	-	-
	HUGO	0	-	-
	LBDO	0	-	-
14.2	WHIM	-	0	-
	SLSA	-	0	-
	HUGO	-	.79 (1)	-
	LBDO	-	0	-
15	WHIM	0 (1)	3.56 (9)	-
	SLSA	1.19 (3)	.40 (1)	-
	HUGO	.79 (2)	1.58 (4)	-
	LBDO	.40 (1)	0	-

Table 11. Continued.

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off) 1985	1986	1987
15.1	WHIM	1.79 (4)	-	-
	SLSA	0	-	-
	HUGO	0	-	-
	LBDO	0	-	-
15.2	WHIM	-	0	-
	SLSA	-	0	-
	HUGO	-	0	-
	LBDO	-	0	-
16	WHIM	.81 (9)	-	-
	SLSA	6.78 (30)	-	-
	HUGO	.81 (7)	-	-
	LBDO	2.44 (9)	-	-
17	WHIM	1.16 (15)	-	-
	SLSA	0 (1)	-	-
	HUGO	.58 (7)	-	-
	LBDO	.39 (2)	-	-
18	WHIM	-	0	-
	SLSA	-	.71 (5)	-
	HUGO	-	.24 (1)	-
	LBDO	-	0	-
19	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	0
	LBDO	-	-	0
20	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	.93 (3)
	LBDO	-	-	0

Table 11. Continued..

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off) 1985	1986	1987
21	WHIM	-	-	.53 (2)
	SLSA	-	-	.26 (1)
	HUGO	-	-	.53 (5)
	LBDO	-	-	.53 (2)
22	WHIM	-	-	0 (1)
	SLSA	-	-	0 (1)
	HUGO	-	-	0 (6)
	LBDO	-	-	.42 (2)
23	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	.41 (1)
	LBDO	-	-	0
24	WHIM	-	-	0
	SLSA	-	-	.56 (2)
	HUGO	-	-	.28 (1)
	LBDO	-	-	0
25	WHIM	-	-	.45 (1)
	SLSA	-	-	.89 (2)
	HUGO	-	-	1.78 (9)
	LBDO	-	-	2.23 (5)
26	WHIM	-	0	-
	SLSA	-	0	-
	HUGO	-	0	-
	LBDO	-	0	-

Table 11. Continued.

Transect	Species[a]	Birds/km by year for on transect data only (no. on and off) 1985	1986	1987
27	WHIM	-	.52 (7)	-
	SLSA	-	.10 (2)	-
	HUGO	-	0	-
	LBDO	-	0	-
28	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	0
	LBDO	-	-	0
29	WHIM	-	-	0
	SLSA	-	-	0
	HUGO	-	-	.27 (1)
	LBDO	-	-	0

*Number of birds observed on and off transect.
[a]For definition of species acconyms see Appendix 7.

subsequent years. We have no explanation for the few birds seen on Transect 8.

Of the 12 transects which did not intersect a potential nesting area (Transects 3, 4, 5, 7, 11, 14.1, 15.1, 15.2, 18, 26, 28, 29), seven had priority species (Table 11). Of these seven (Transects 3, 4, 7, 11, 15.1, 18 and 29), Transect 3 had 15 of the 19 priority species sightings which were made during the 3 years of surveys. These 15 sightings were all within upland habitat. Since the LANDSAT analysis, that defined priority species nesting areas, was based on data analysis and digital analysis from Fish Island (a lowland area), it is not surprising that potential nesting areas in upland habitats were missed on Richards Island (upland habitat).

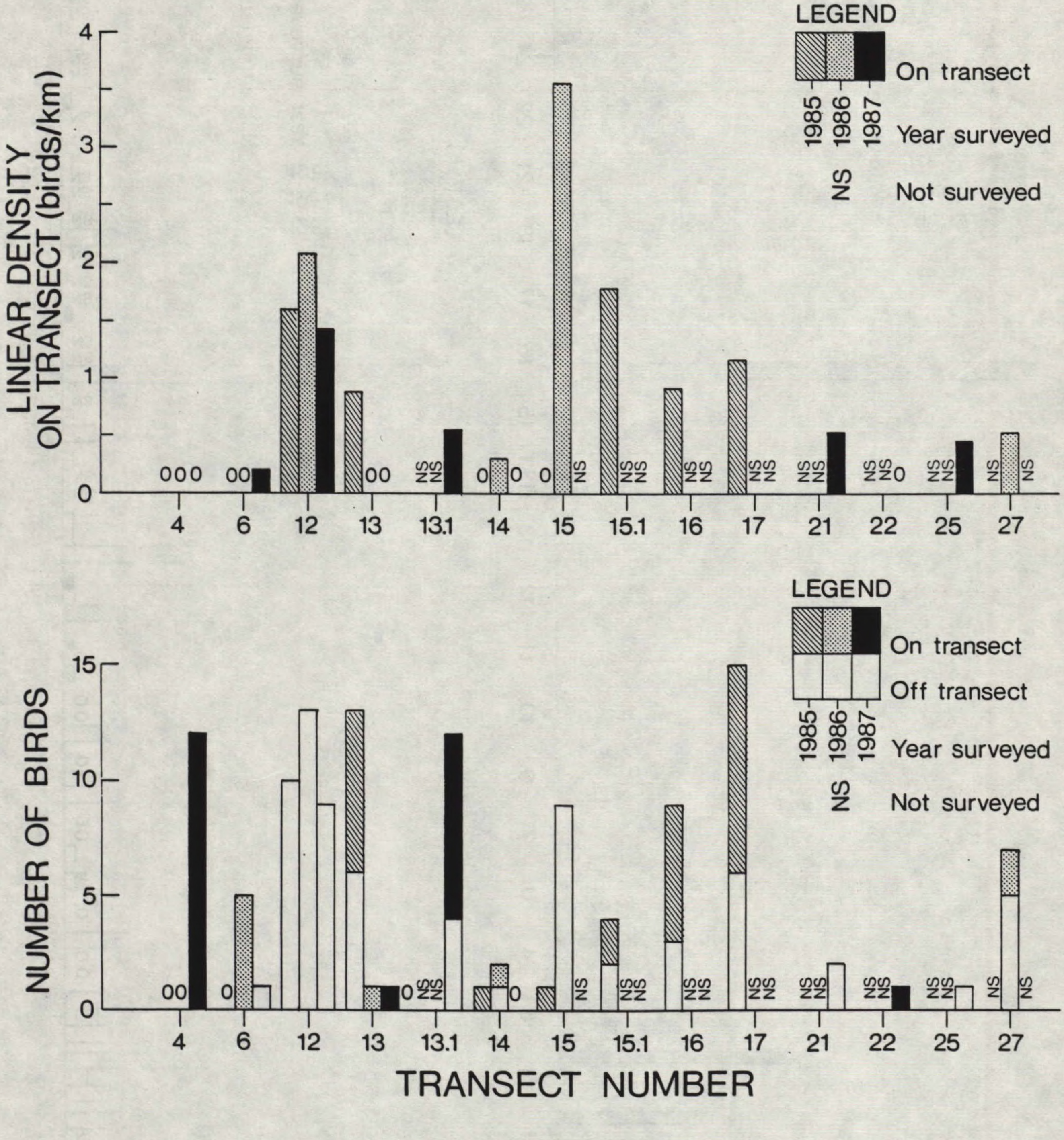


Figure 14. Whimbrel abundance data collected for all transects in each of 1985, 1986 and 1987 in the Mackenzie River delta study area.

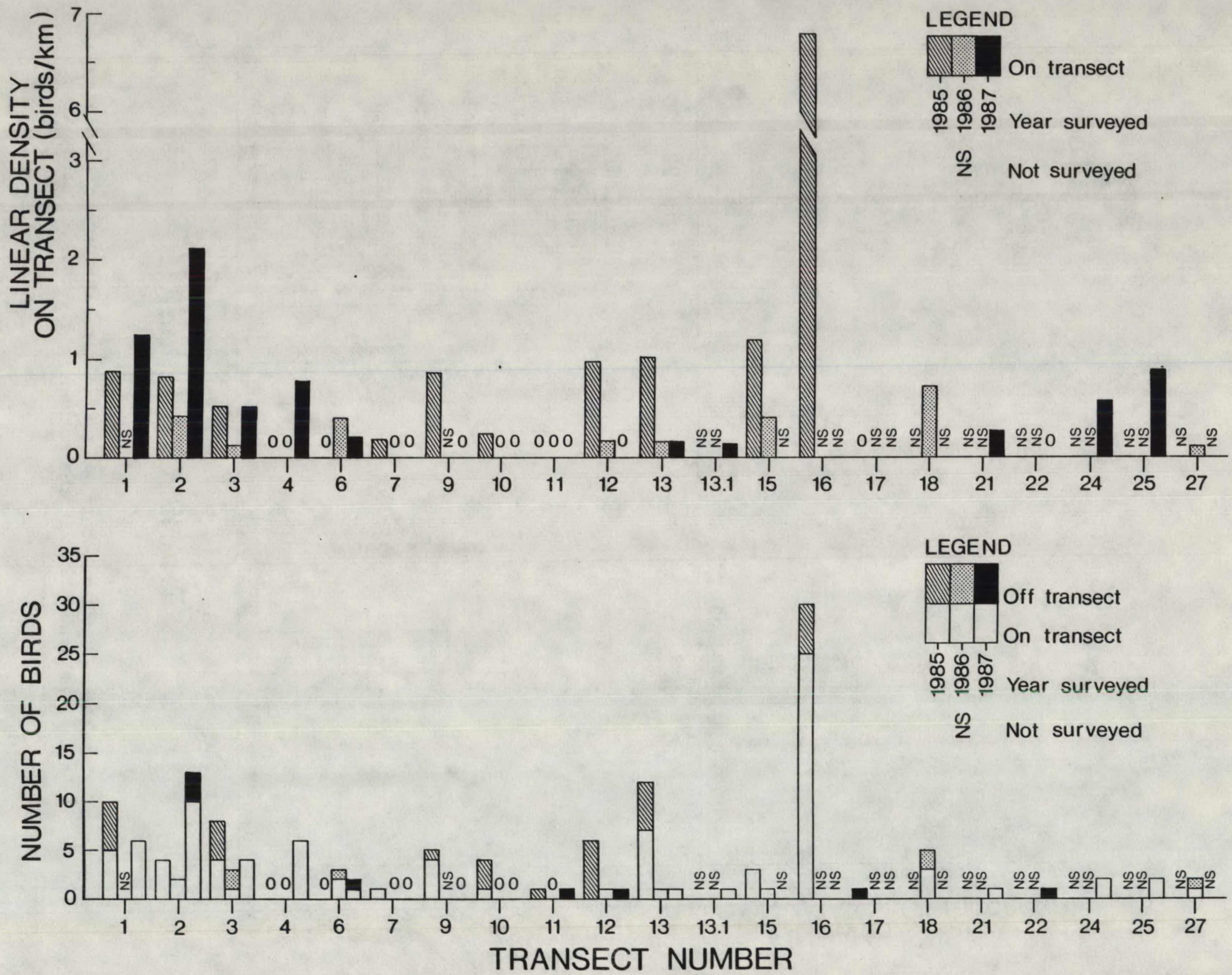


Figure 15. Stilt sandpiper abundance data collected for all transects in each of 1985, 1986 and 1987 in the Mackenzie River delta study area.

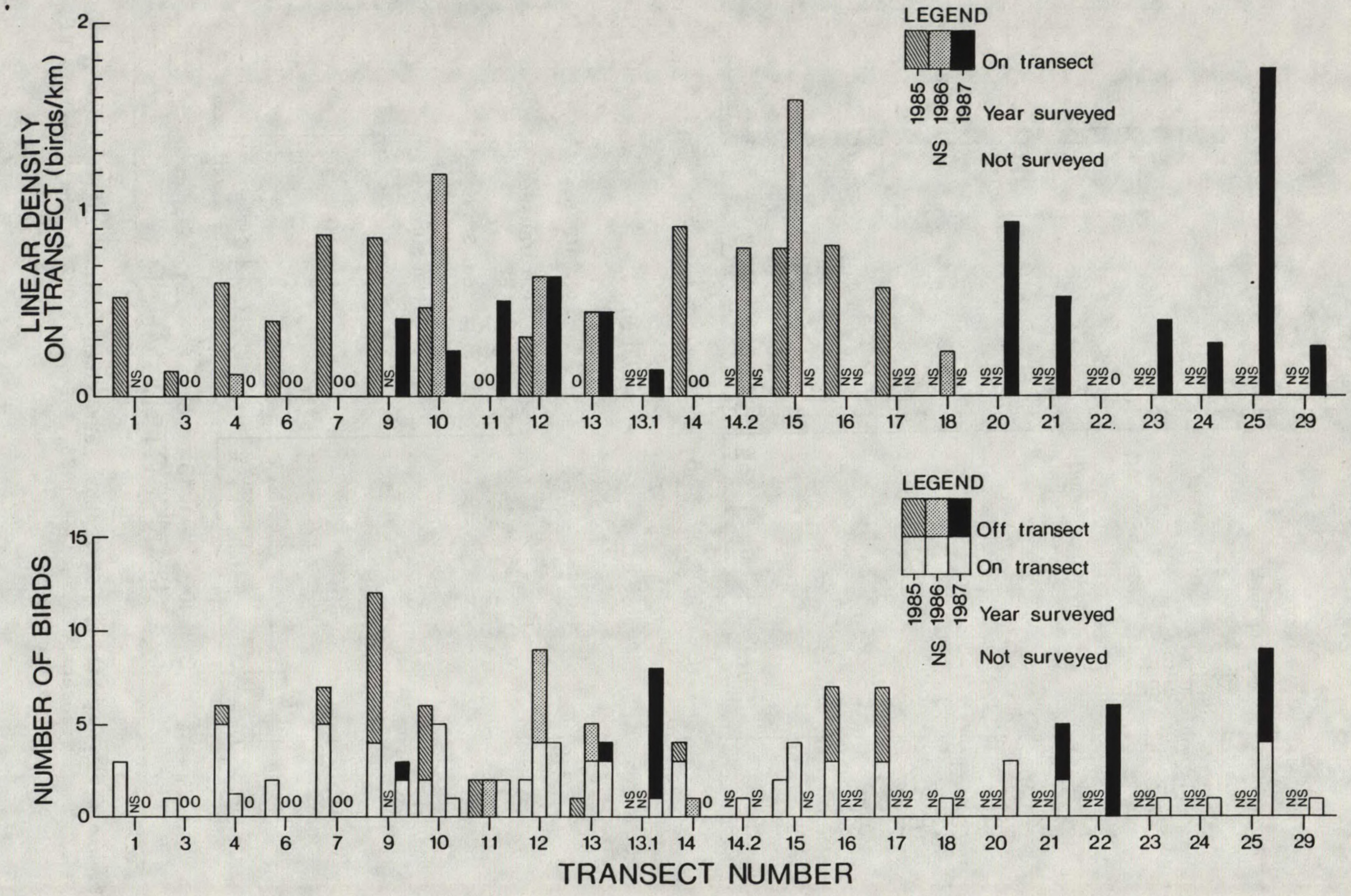


Figure 16. Hudsonian godwit abundance data collected for all transects in each of 1985, 1986 and 1987 in the Mackenzie River delta study area.

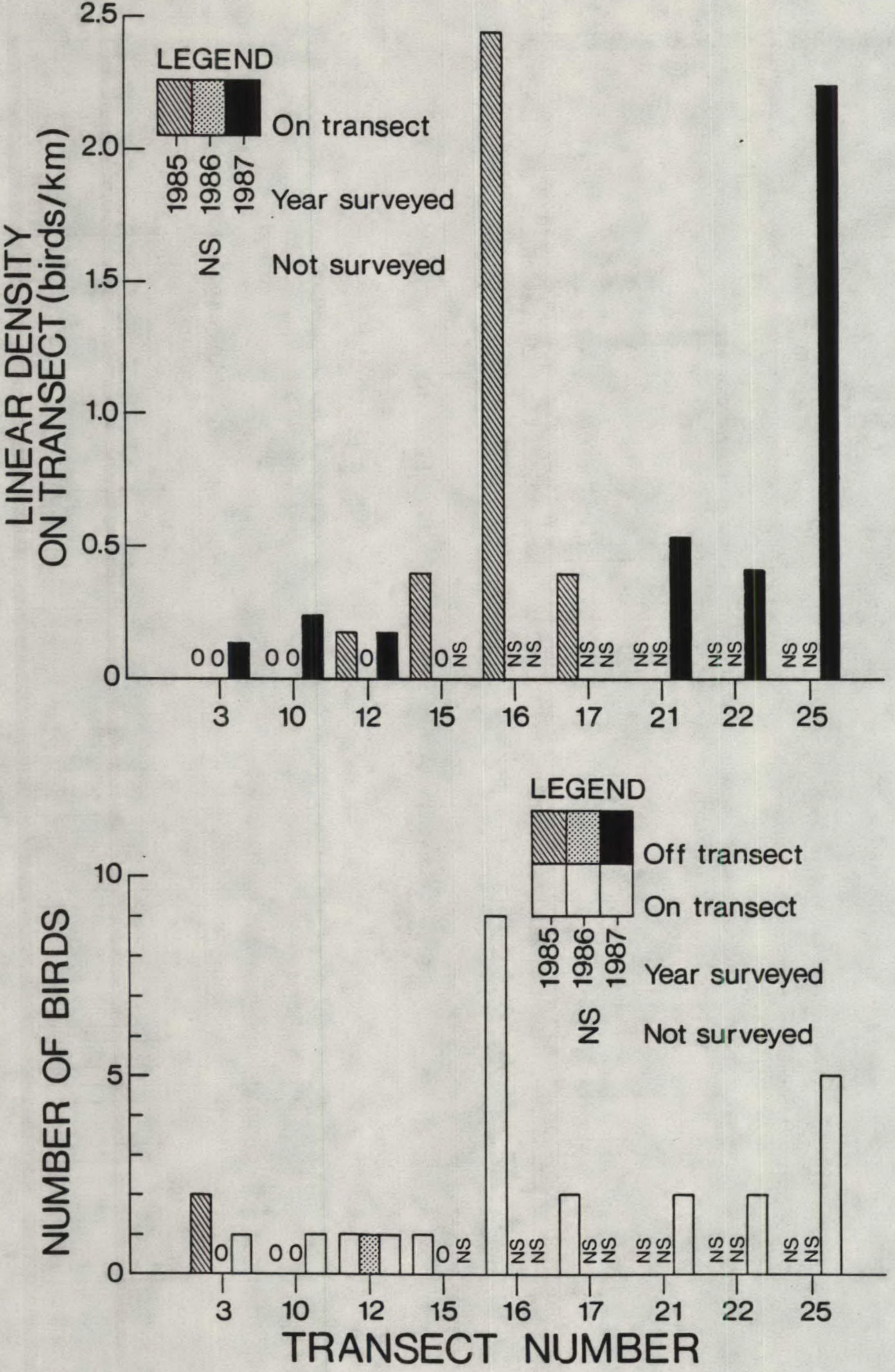


Figure 17. Long-billed dowitcher abundance data collected for all transects in each of 1985, 1986 and 1987 in the Mackenzie River delta study area.

Of the four remaining priority shorebird species, stilt sandpipers were in Transect 3, Section 9 which is a very narrow band of lowland habitat surrounded by uplands and adjacent to a lake. It is quite probable that the visual interpretation of LANDSAT did not pick up this narrow band of nesting habitat. In fact in 1987 a stilt sandpiper was found nesting in this area. All bird observations on transect 11 were recorded as off transect, or were spending the majority of their time in the area covered by Transect 10. Thus all priority species records from Transect 11 were observed in the area covered by Transect 10.

In Transect 15.1, two whimbrel were seen on and two were seen off transect. Both these birds were undoubtedly nesting pairs from just east of this sighting location within Transect area 15.

Transect 7 observations were made in sites very close to shorebird nesting area 14 (Fig. 8). It should be noted that the areas identified on Figures 8, 10, 11 and 12 were nesting areas and these data are merely observations. The areas defined in these figures were also referred using July imagery which may have eliminated some areas useful to nesting (see previous discussion on plot data results).

Their seemed to be no reason for the presence of the birds observed on Transects 4, 18 and 29. The species seen on these transects were hudsonian godwit and stilt sandpipers. No nest data existed for the hudsonian godwit at the time of the LANDSAT analysis but a nest was actually found near the beginning of Transect 4. Stilt sandpipers have demonstrated their broad habitat capabilities and the observations made on these transects merely illustrate that refinement of the LANDSAT results are required to fully address the use areas for this species.

In summary, with the exceptions discussed above, it appears that the sites defined by the LANDSAT analysis as nesting areas are reliable. The results also illustrate the need for conducting digital analysis throughout the study area as part of the process to define nesting sites. Visual interpretation does have definite limitations.

4.4 Species Discussion

General information on the presence, absence or breeding status of each species observed during the study is presented in Appendix 7 along with information reported by Barry and Spencer (1976). A total of 79 species have been recorded in the main study ardea in one or more of the 4 years (1976, 1985, 1986, 1987) of which 41 have been recorded as breeding. Twenty-one shorebirds were recorded in the main study area of which 10 were breeding.

Specific species discussions, presented below, are limited to the priority shorebird species studied in this program.

4.4.1 Semipalmated Plover (Charadrius semipalmatus)

Semipalmated plovers showed a distinct preference for nesting on the man made gravel pads in the area. All successful nests were found only in these locations. Only one nest, consisting only of a scrape, was found off the pads. This scrape was discovered on 28 June 1987 when two unbanded plovers were found displaying in an area at Big Horn Point. Given the late date this scrape was initiated, we assumed that these were young birds or failed breeders from a site outside the study area. See Figure 19 for nest site locations.

To examine philopatry and mate fidelity, we captured adult birds at the nest sites in 1986 and 1987 and banded them with unique colour band combinations. Young of the year were also banded but only with a U.S. Fish and Wildlife metal band and two white flag bands (indicating their western arctic origin) following the methods described by Myers et al. (1985) and Myers (pers. comm.).

Table 12 presents the nest sites and colour band combinations for each of the adult birds for each year and site. Figure 18 illustrates the exact location of each nest by nest site.

As illustrated in Table 12, time did not permit all adult birds to be banded in either 1986 or 1987. The results however do indicate that semipalmated plovers have strong nest site fidelity. Of the six nests discovered in 1986, five of these nest sites had at least one or both adults return to the same location in 1987. Evidence of pair change between years was only observed in one pair between 1986 and 1987. In 1987, at nest site 76, both adults "RB" and "OW" were seen at the nest location (Fig. 19, Site 3) when it was first discovered. The adult "RB" left the area and flew to the nest location 66 (Fig. 18, Site 3) and then flew off to the east. This bird was never seen again in 1987 and adult "OW" was joined by an unbanded adult in all subsequent visits. Thus it appears that this species is philopatric although not enough pairs were banded to truly confirm this fact.

There were no cases of birds moving their nest location to a different gravel pad between years (Fig. 18). Birds were observed at nestsites other than their own. In 1986 adult "GO" from nest 64, Site 1 (Fig. 18) was observed near nest 61 on Site 2. Movements of birds within a

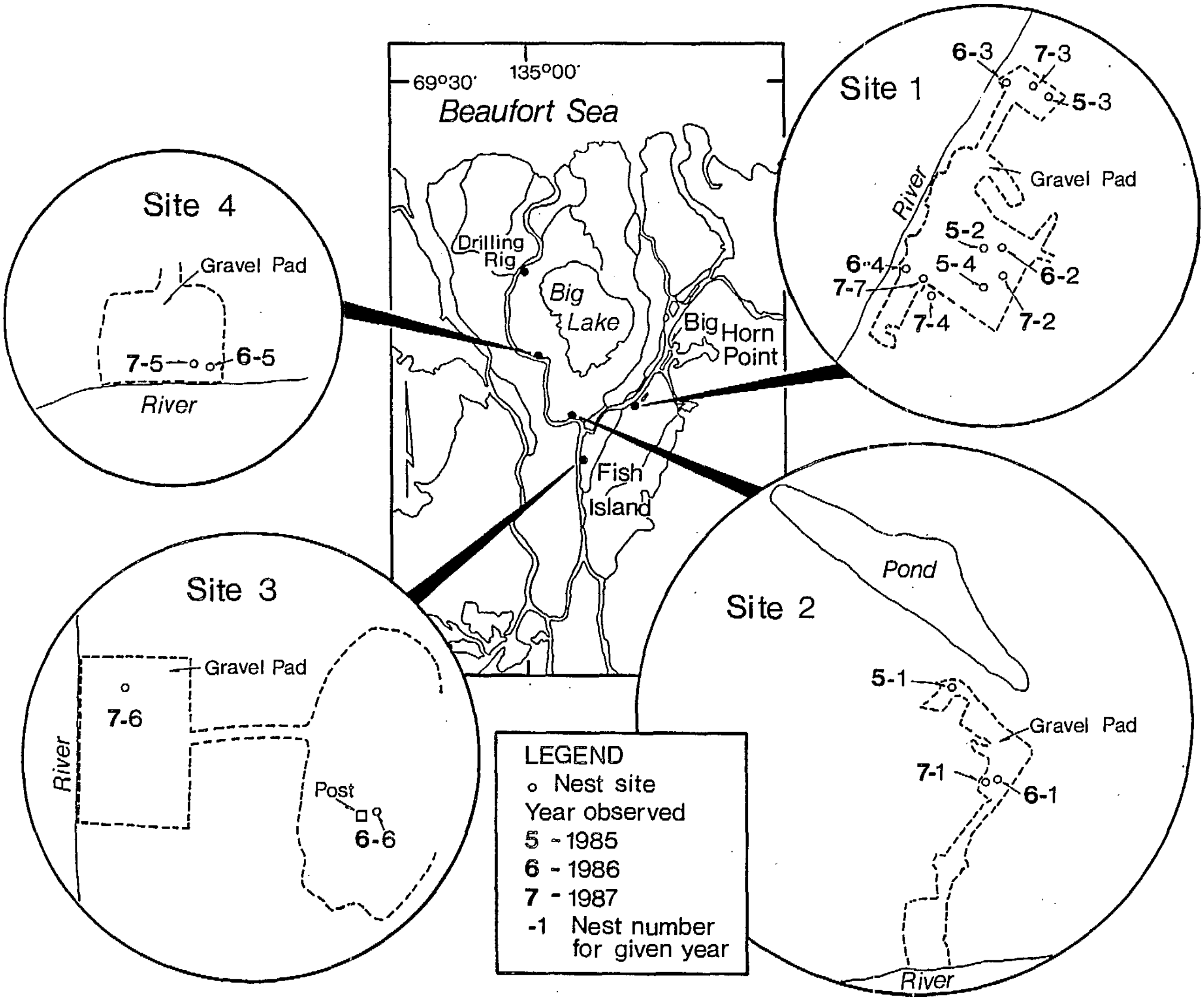


Figure 18. Site location and location of each semipalmated sandpiper nest by site in 1985, 1986 and 1987, Mackenzie River delta, Northwest Territories.

Table 12 Semipalmated ~~sandpiper~~ plover nest site data collected in 1985, 1986 and 1987 in the main study area, Mackenzie River delta, Northwest Territories.

Band combinations for each nest for each year and number of young banded

1985[a] Nest No. @	1986 Nest No. @	1986 band combination of adults (M,FwGO:.-,_)*	1986 No. of young banded (not banded)	1987 Nest No. @	1987 band combination of adults (M,FwGO,-,_)	1987 No. of young banded (not banded)
51	61	OG		71	OG	
		1 adult unbanded			1 unbanded bird	
52	62	GW	3	72	GW	1
		OR	(0)		M,FwGR;-,FwBG	
53	63	GR	4	73	2 unbanded adults	1
		1 adult unbanded	(0)			
54	64	RO	3	74	RO	
		GO	(0)		GO	
	65	OB		75	OB	
		1 adult unbanded				
	66	RB		76	OW**	
		OW			1 unbanded bird	
				77	BO	4
					BR	
				78	nest only a scrape, 2 unbanded adults present	

*Combination on table are only last 2 colour bands added to complete combination.
[a]No birds banded in 1985.
@The first number of the nest refers to the year it was discovered e.g. 1985 nests are 51, 52 etc. 1986 and 61 etc.
**Bird with combinations RB was at nest when first discovered but OW definately paired with unbanded bird after this.

site to adjacent territories was common on Site 1. Any individual adult could be found within 10 m of another pair's nest.

Except on Site 1, there was only one nesting pair per gravel pad. Even on Site 1, nest locations were at least 40 m apart with the exception of the bird banded as "RO" in 1986. In 1987 "RO" was found beside an unbanded bird on nest 77. This unbanded bird was captured and banded "BO". Two days later it was observed standing beside an unbanded bird on nest 77, thus indicating that "RO" was not part of this pair. "RO" was later found nesting less than 10 m away with its partner from 1976 "GO".

Of particular interest was the observation of no breeding pairs at sites 5 or 6. Both of those sites lacked vegetation. All other factors, (e.g. adjacent water and gravel) seemed to be the same. The nest data collected from 1985 through 1987 indicates that all nests were within 0.5 m of some form of vegetation, most often grasses. Thus vegetation appears to be a major factor in the nesting requirements of this species. If this is correct, semipalmated plovers could expand their use of the delta considerably as vegetation comes in on the drill pads. Industry could therefore enhance these sterile communities upon abandonment by seeding in scattered areas on the pads with grass.

Of the 10 young banded in 1986, none were observed in the study area in 1987 which suggests either extremely high mortality rates or that young move into other areas for nesting.

4.4.2 Eskimo Curlew (*Numenius borealis*)

Eskimo Curlews were not recorded in the study area. A possible observation was made on nearby Kendall Island on 10 July 1985 when a flock of six birds was seen by Michael Whittman and Tupper Blake of Inverness, California. This record, however, has since been questioned as to its validity. Recent site records by D. Lynne Dickson (CWS Edmonton) include single birds from the Tuktoyaktuk Peninsula at Hutchison Bay in 1981 and Atkinson Point on 15 August 1982. There are a number of other records by several observers from the Anderson River region: 3-13 August 1955; 18 July 1961; 4 June 1962, 18, 28 May, 12 June, 6 July 1964; 8 August 1976; and 8 June 1980 (Gollop _et al_ 1986). Unfortunately none of these records were verified by a photograph and none of them strongly suggest breeding. Since some of these records fall within the nesting period of 8 June to 12 July (as determined from MacFarlane 1891) and all of them fall within possible former breeding range as outlined in Gollop and Sheir (1978), these records could involve local breeding attempts.

4.4.3 Whimbrel (_Numenius phaeopus_)

Although enjoying a fairly large Canadian breeding range, the whimbrel is a relatively uncommon shorebird. Breeding habitat is quite variable and includes, for example, the dry subalpine tundra of the Yukon and poorly-drained subarctic tundras of northwestern district of Mackenzie and the Hudson Bay lowlands (Godfrey 1966).

On Fish Island we found whimbrel nesting in areas dominated by LCU #9 (Table 7), indicating a preference for low-centered polygon habitat with more than 15% graminoid cover, less than 35% dwarf shrub cover and with 15-40% standing water at the time of, or shortly after, nest initiation. All of our whimbrel sightings made on transects occurred in this habitat. Attempts to define nest site fidelity and mate fidelity through banding of individual birds was unsuccessful: too much time was required to capture individual birds. By mapping the nest sites discovered each year on Fish Island we found that adult birds do, to some extent, return to the same nesting area year after year (Fig. 6). Skeel (1983) reported a 26% return rates from one year to the next (variance = 7%) in sedge meadow-heath tundra habitats and 99% (variance = 30%) in hummock-bog habitats. A total of 90.9% of the birds in this latter habitat re-nested within 400 m of their previous year's nest site.

By examining the nest site data on Fish Island for 1986 and 1987 and assuming that nests situated within 400 m of the previous years' nest were of the same pair, we found that six of 10 pairs (60%) of the birds demonstrated nest site fidelity, three were not near 1987 nests and one was not found.

The potential nesting territory, on Fish Island, as defined by the LANDSAT results, (excluding high water sites) is approximately 200 ha. We discovered 3 whimbrel nests on Fish Island (0.015 nests/ha) in 1985, 3 nests (0.04 nests/ha) in 1986 and 10 nests (0.05 nests/ha) in 1987. These densities are similar to those reported by Skeel (1983) for whimbrel pairs found in sedge meadow habitat near Churchill, Manitoba. Her results indicated a mean density of 0.39 nests/ha in 1973 and 1974 (1973, 0.049 nests/ha: 1974 0.029 nests/ha).

In terms of nesting chronology, from observations made prior to our study, the five earliest arrival dates are 21, 24, 24, 26 and 30 May (Porsild 1943, P.S. Taylor unpubl., Salter et al.1980, Gollop et al. 1974a). Nests with eggs were discovered in the Babbage River area, Yukon Territory, from 8 June to 6 July (P.S. Taylor unpubl., Gollop et al. 1974a). By back-dating about 23 days for incubation (Godfrey 1966) from our 1985 hatching dates of 7 and 8 July we estimate clutches were initiated about 15 June 1985.

In 1986, nests with eggs were first located for whimbrel on 20 June. One nest had an egg as late as 7 July 1986 before being predated. Assuming this egg was near hatching, the laying date in 1986 for whimbrel would be no earlier than 15 June, similar to 1985. Given the late spring drawdown of water levels on Fish Island, these results indicate that this species, as in the semipalmated plover, spent little time in setting up territories in 1986. No fledging occurred in 1986 as a result of predation.

In 1987, visits were made less frequently due to concern that the high predation rate in 1986 (100%) might have been attributed to observer presence (no actual signs of this existed).

Hatching dates for at least three nests was after 16 July in 1987. As a result of the late hatching date and fewer visits we could only use three nests for determining nesting chronology. One nest definitely hatched on 7 July 1987 while the other two nests hatched between 14 and 16 July 1987, thus a nest initiation date of 22 or 23 June. Departure dates from the Yukon North Slope extend from 20 to 30 August (Grunberg 1977, Gollop and Davis 1974). No data on departure dates were collected during this project.

Territory size and proximity of nearest neighbour yielded a mean distance of a nest to the nearest neighbour of 483 m (8 nests; minimum 147 m, maximum 836 m) in 1986 and 480 m (12 nests; minimum 278 m, maximum 950 m in 1987, not significantly different (t-test, $p < 0.05$). Only our

1987 results differ significantly (t-test $p < 0.05$) from that found by Skeel (1983) in 1974 for this mean is considerably larger for whimbrel nesting in sedge meadow habitat near Churchill, Manitoba (max. 374 m in 1973 and 242 m in 1974).

One particular note of interest was one pair of whimbrel with two nests. Whimbrel nest Site 5 was found on 21 June 1987 with two nest sites with two eggs each within one foot of each other. At the time of discovery, we judged that one of the nests was not being incubated. However, egg weights taken on 22 June (Table 13) indicate that both nests were being incubated, although one egg from the assumed incubated nest may have been added (nest 2, egg 2, Table 13).

We rechecked these nests on 2 July 1987 and all the eggs were gone: we assumed that the nests had been predated. No references were found in the literature describing similar types of whimbrel nesting situations.

By plotting the movements of adults around the nest sites, we determined the territory sizes were at most 24 ha and is similar to that found by Skeel (1983) in sedge meadow habitat at Churchill, Manitoba. This includes both the feeding area and the nesting territory defended against aerial and ground predators. Whimbrel feed in the area surrounding the nest.

Table 13. Egg data related to two nests for whimbrel nest Site 5 on Fish Island, Northwest Territories recorded on 22 June 1987.

Nest	Status	Egg	Length (mm)	Width (mm)	Weight (g)
1	Nest	1	60.5	40.0	48
1	Incubated	2	59.0	39.5	46
2	Assumed	1	59.7	40.2	47
2	Unincubated	2	57.2	39.5	42

4.4.4 Hudsonian Godwit (*Limosa haemestica*)

The Hudsonian godwit is an uncommon bird with a local breeding distribution. Breeding localities include: Cook Inlet and probably Kotzebue and Norton Sounds, Alaska; the Mackenzie River and Anderson River deltas and probably Akimiski Island, Northwest Territories; the Churchill Region, Manitoba; and Sutton River, Ontario (Kessel and Gibson 1978, Godfrey 1966). The nesting habitat (based on observations from the Churchill area) is generally described as moist tundra at or near tree line (Hagar 1966, Jehl and Smith 1970). Observations in this study area showed that breeding extends 50 km beyond the tree line.

Hudsonian godwits were found in a wide variety of lowland habitats, showing, however, no strong preference for any particular lowland type (chi-square = 5.06; df = 1; $p > 0.01$) in 1985. The only nest found in 1985 was an area of poorly-developed polygons with about 5 cm of standing water and approximately equal proportions of dwarf shrub (willow), *Equisetum*, sedge and moss (Fig. 6). We found no nests in 1986, but found three on Fish Island in 1987 (Fig. 6). Two of these nests fell within an area dominated by LCU #9 while the third was in an area dominated by LCU #8 but adjacent to an LCU #9 area (Table 11). Two broods found in 1985 were also within the LCU #9 habitat type.

All nests were sheltered, overgrown by grass and dwarf shrubs. This, along with the birds' behaviour of not flushing from the nest until the searcher was within 3 feet (or less) of the nest, may account for the extremely low numbers of godwit nests being found.

On numerous occasions we observed hudsonian godwits feeding or sitting in one area, frequently at the same location, for over an hour and then fly off out of sight. We noted no parental behaviour that assisted in leading us to a nest site.

When we found a nest however, we were mobbed by up to 10 hudsonian godwits, many of which flew in from over 2 km away. Massive searches around a discovered nest site resulted in no additional nests being found, thus eliminating the idea of colonial nesting. However, there is definitely cooperative nest defence by this species.

Data on regional phenology are meagre. Grunberg (1982, 1983b) reports first arrival dates of 28 May 1982 and 29 May 1983 at Inuvik. Godwits were present on the study area upon arrival on 7 June 1985 and by 16 June 1986 (high water levels limited their accessing the area in 1986). In 1987, godwits were already on site upon our arrival on 13 June.

Although no nests with eggs were found in 1985, the discovery of three newly-hatched broods on 6 and 7 July 1985 suggest that incubation is synchronous; and that, on the basis of a 22-25 incubation period (Johnsgard 1981), it extended from about 11 June to 5 July. These dates correspond reasonably well with those reported in Bent (1962): 9 June 1862 at Ft. Anderson, and 30 June 1897 and 29 June 1899 at Mackenzie Bay. In 1987 we discovered nests on 21 June, 23 June and 24 June. Data on hatching was only available for the nest discovered on 23 June. This nest had pipped eggs on 12 July 1987. Giving 2 days for hatching (14 July) this nest would have been laid between 20 and 23 June 1987. The latest departure date, from the Beaufort Sea region, is 10 August 1972 at Nunaluk Spit, Yukon Territory (Gollop and Davis 1974). No data is available from this study on departure dates.

4.4.5 Buff-breasted Sandpiper (Tryngites subrificollis)

The buff-breasted sandpiper has an extremely local breeding range, found only in western low arctic Canada and northern Alaska (Johnsgard 1981). The known breeding localities nearest the study area are the Firth River in the Yukon and the Horton River in the Northwest Territories (Gollop et al. 1974b, Godfrey 1966). The nesting habitat is described as being well-drained grassy tundra; territories can, however, include marshy tundra (Johnsgard, 1981). We saw our only observations of this species in marshy tundra. On 12 June 1985 we saw a displaying male in an area of well-developed low-centred polygons on Fish Island which is represented by LCU #9 (Transect 15, Fig. 2). In 1987 we observed another bird in early July in the same area. The nearest suitable nesting habitat was about 2 km to the east. No buff-breasted sandpipers were recorded in 1986.

The regional phenology is as follows: first spring records are for 26 May 1972 at Babbage River, Yukon, and 26-29 May at Inuvik, the first nest was found on 10 June 1972 at the Firth River, and the latest fall record was 22 August 1972 at Nunaluk Spit (Gollop et al. 1974b, Grunberg 1983a, Gollop and Davis 1974).

4.4.6 Long-billed Dowitcher (Limnodromus scolopaceus)

The breeding range of this species extends from the northeast of Siberia to northeastern Canada (Johnsgard 1981). Prior to this study Canadian breeding records were restricted to the Anderson River area (MacFarlane 1981, Pitelka 1950, T. Barry pers. comm.). The nests found in June 1986 added the Mackenzie River delta to the known Canadian breeding range. Photographs, bill measurements and tail markings confirm that the nest found in 1986 is that of a long-billed dowitcher and not short-billed dowitcher.

LANDSAT analysis and ground data defined that long-billed dowitchers nested in areas with 15-40% standing water and in areas immediately adjacent to LCU's #11 (dense dwarf shrub) on the Mackenzie River delta. This analysis however, is based on the findings of only 2 nests, both of which were extremely close (<50 meters) to each other. Only 1 nest was found each year (1985/86) thus suggesting that the 1986 nest may have been the same breeding pair as that of 1985. Records from the Tuktoyaktuk Peninsula indicate that long-billed dowitchers also nest in drier tundra habitat (Dickson, D.L. pers comm.).

In 1986 we discovered a dowitchers nest (Fig. 6) on 22 June with four eggs, three of which were pipped on 8 August. All of the young were gone on 10 August. Given a 20-21 day incubation period, the laying of the complete clutch would have occurred between 21 and 22 June 1986. This species is similar to the hudsonian godwit in its secretive nature around the nest, although it does flush at around 4 metres. However, the bird we observed walked approximately 5-10 metres and stood motionless and silent, thus making it very difficult to find their nest.

We observed staging of long-billed dowitchers at Swan Channel and on Fish Island (Figs. 6 and 8). Both sites have large proportions of open water with 30-35% vegetation cover (ponded tundra).

The previous early arrival date is 28 May at Firth River (Gollop _et al_. 1974b). The latest known departure date is 15 September at Nunluk Spit, Yukon (Gollop and Davis 1974).

4.4.7 Stilt Sandpiper (Micropalama himantopus)

The Stilt Sandpiper is perhaps the most abundant and widespread shorebird species included in this study. Its breeding range extends across the low arctic of the continent from extreme northern Alaska to the Hudson Bay lowlands. The habitat selected by this species is in general low, well-vegetated tundra (Godfrey 1966). In the study area, the preference for well-developed polygons is marked, based on 1985 data (chi-square = 69.39; df = 3; $p < 0.01$).

Nesting of stilt sandpipers occurred within LCU #9 on Fish Island, during the life of the project (Table 7). Analysis of the LANDSAT imagery and habitat data indicates that stilt sandpipers nest in areas with 15-40% standing water (21 June imagery) and relatively little dwarf shrub (20%), in well developed low central polygon habitat.

Early arrival dates from Inuvik, NWT, are 16 May 1984 and 26 May 1982 and from Komakuk Beach, Yukon Territory, on May (Grunberg 1982, 1984; Salter et al. 1980). Nests with eggs have been found as early as 15 June at Clarence Lagoon, Yukon, and young as early as 8 July at Blow River, Yukon Territory, (Salter et al. 1980). Late departure dates from the North Slope include 4 and 7 August (Salter et al. 1980).

We found one nest in 1985 on 26 June and the young were assumed fledged on 3 July. In 1986 we found two Stilt Sandpiper nests, one on 20 June with four eggs which hatched on 8 July and the other nest on 2 June with one egg. This latter nest had four eggs on 25 June but was destroyed by a predator on 30 June 1986. In 1987, we found nests on 15, 16 and 24 June respectively, no fledging data were recorded for these nests in 1987 although the second nest had no eggs on 2 July 1987. Given a 21 day incubation period the first nest would have been laid on or around 18 June 1986. The 1985 clutch would have been initiated around 13 June 1985. The 1987 nest may have been laid on the 10-12 June 1987.

5.0 ENVIRONMENTAL IMPACT MITIGATION

The results of this project have identified approximately 22 areas within the main study area (Fig. 1) as important nesting areas for shorebirds (Fig. 8). Over 350 areas were identified as potentially important shorebird nesting or staging territories (Figs. 8, 10, 11 & 12) in the whole outer Mackenzie River delta (Fig. 9). Insufficient funds for conducting digital LANDSAT analysis resulted in a less refined definition of sites outside the Main study area. This however, should not present undue difficulties for any industry, government or other lands use organizations or individuals in utilizing the results of this study.

Any development taking place in the outer Mackenzie River delta that could alter habitat or disturb (e.g. noise) shorebirds between May and September should be avoided. Potential negative affects could be mitigated by staying clear of those sites identified in Figures 8, 10, 11 & 12.

Given that the majority of the sites are only potentially important areas, field studies to examine site specific development areas should be conducted prior to development. The results might well indicate no impact potential exists.

In future years monitoring should be done of some forms of developments (e.g. pipelines, pumping stations) to clearly determine impacts on shorebirds. The results might indicate that some forms of development would be less harmful if facilities were constructed in the winter and were in place by the breeding season. In addition the less affects there are on surrounding terrain from a given development site the less chance there is that development will negatively affect shorebirds.

This study only addresses one species group of wildlife and only relates to the Mackenzie River delta and large lowlands areas on Richards Island, NWT. Development proposals would of course be required to examine other wildlife concerns prior to development. The Northern Oil and Gas Activities Program report by Alexander et al. 1988 will provide agencies with additional information on critical wildlife areas along the outer edge of the Mackenzie River delta and in fact the whole Beaufort Sea coast.

6.0 CONCLUSIONS

Through the collection of 3 years of field data on shorebirds in a small area on Mackenzie River delta, an evaluation of important potential shorebird nesting habitat and long-billed dowitcher staging sites was possible. These results coupled with LANDSAT Thematic Mapper Imagery enabled the definitions of over 350 potential nesting or staging shorebird sites throughout the Mackenzie River delta.

A comparative evaluation of LANDSAT MSS imagery was also conducted. The LANDSAT MSS imagery was found to be far inferior to the LANDSAT TM imagery for identification of potential shorebird nesting and staging habitat. The low spatial and spectral resolution and lack of mid-infrared and blue visible bands on MSS imagery severely limits the utility of MSS for vegetation and habitat mapping in the level of detail required for this study.

TM imagery from late July 1986 was enhanced to produce all possible band combinations for use in visual interpretation of vegetation of the outer Mackenzie Delta study area located on Fish Island. Five types of visual photographic enhancements were observed given the vegetation-soil-parent material-topography relationships found in the study area. Of the five general types, three have proven significant for analysis of vegetation and shorebird nesting and staging habitat. (TM bands 1-23, TM bands 2-3-4, and TM bands 3-4-5). All other TM enhancements produce far less habitat information than these three enhancement types for this particular study using the late July image date.

Unsupervised classification of the July 1986 TM digital data provided twenty-eight recognizable LANDSAT Classification Units (LCU's) which were reduced to twenty-one of major importance. Fourteen of these LCU's were found in significant abundance on the Fish Island Study Area. This automated classification produced LCU's representing three shrub-dominated vegetation types, three grass/sedge vegetation types, two grass/sedge and water complex types, four water and/or emergent vegetation complex types and two barren LCU types.

A late June 1986 LANDSAT TM photographic enhancement of bands 3-4-5 proved useful and highly accurate for identification and mapping of water level conditions at the time of shorebird nesting. Visual interpretation of this image on Fish Island showed that refined subdivisions could be recognized and mapped within the computer-classified LCU representing well-developed low-centered polygon terrain with mixed dwarf shrub/grass-sedge vegetation cover. This subdivision of LCU #9 represents areas which are known to be preferred nesting habitat for whimbrel, stilt sandpipers and long-billed dowitchers on Fish Island. Visual interpretation of four LANDSAT TM images (i.e. June Bands 3-4-5, July Natural Color, July False color infrared and July Color mid-infrared) were used to produce a map of potential nesting habitat throughout the main study area encompassing Fish Island and Big Lake to the outer mouth of the Harry Channel in the Mackenzie River delta. Evaluation of these results led to the extension of these LANDSAT techniques to the remainder of the outer Mackenzie River delta.

Staging areas of long-billed dowitchers were evaluated using the LANDSAT TM imagery. It was found that computer classification very accurately identified the wetland/water complexes apparently preferred for staging by this species on Fish Island. Visual interpretation of enhanced TM imagery was used for a general analysis of potential staging habitat. Additional ground data on the location of long-billed dowitchers staging sites is needed to more clearly define and verify the findings of the LANDSAT analysis.

This project shows that both visual and computer-aided methods of analysis of LANDSAT TM imagery can be used separately and together for identification of potential nesting and staging shorebird habitat. In addition, moderately detailed vegetation types can be identified both visually and digitally on mid-July TM imagery of this Low Arctic wetland environment.

Further field surveys need to be conducted to determine the accuracy of LANDSAT TM mapping of potential long-billed dowitcher staging areas in the Mackenzie River delta.

Similarly, prime potential nesting habitat areas located by visual interpretation of the four LANDSAT TM enhanced images should be visited during the 1987 field season to survey for nesting activity. LCU #9 should be mapped throughout the entire large study area of the Mackenzie River delta and combined with this visual interpretation method to refine the location of prime potential nesting sites.

Further research should be conducted on computer analysis of the June 1986 imagery to determine whether or not automated computer classification can be used to produce similar mapping of water regimes as has been demonstrated using visual interpretation techniques. Further detailed automated classification of vegetation cover types should be conducted on the shrub to grass/sedge to emergent to water gradient within the lowland ecosystems of the study area. Further refined computer classification may be able to produce automatic mapping of the refined subdivisions of LCU #9 which covers extensive areas of the Mackenzie River delta and possesses large but subtle internal variations in vegetation, soils, moisture and water cover conditions.

Biophysical inventory of the larger study area or entire Mackenzie River delta region should be conducted to the Ecosection level using visual and computer-aided analysis of LANDSAT TM imagery. This would allow a framework for statistical tests of preference by individual shorebird species for specific habitat units in the larger study area. This analysis would also eliminate, to a large degree, the misclassification error produced if automated computer classification results are applied to a larger area than the Fish Island Study Area thereby refining the results presented in the report.

The results of data collected and analysis conducted on the specific study species (hudsonian godwit, whimbrel, stilt sandpiper, long billed dowitcher and semipalmated plover) identified that whimbrel, hudsonian godwit and to a lesser extent, stilt sandpipers and long-billed dowitchers all selected similar habitat for nesting: 15-40% standing water, <25% dwarf shrub with 30-50% graminoids in well developed low-centred polygon habitat. Semipalmated plovers were found nesting only on man-made environments: gravel pads from oil and gas exploration. Data indicates that this species has adventitiously entered the area as a result of development. The data also indicates that revegetation programs on newly completed and abandoned gravel pads would dramatically decrease the time these sites would be unavailable for nesting by semipalmated plover.

Further studies and analyses are required to enable the definition of habitats in drier sites or better drained sites (e.g. Tuktoyaktuk Pennsula, Yukon coastal plains) or in upland areas (Richards Island, Tuktoyaktuk peninsula). Time and finances limited the analysis and the study to the lowland communities of the Mackenzie River delta above treeline to a great extent.

Additional data on shorebirds and other birds, observed during the study, is available upon request from the author.

The results of this study will enable the Department of Environment to evaluate development proposals and advise industry, land use planners and other government agencies and individuals on ways to mitigate potential environmental effects on the shorebird populations of the Mackenzie River delta. It will also provide a data base for planners and developers to evaluate various alternative sites for development prior to any proposal for development. It is hoped that this work, coupled with the results of Alexander _et al_. (1988), will go a long way in ensuring the longevity of the wildlife resources of the Mackenzie River delta region and of Canada.

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Appendix 1. LANDSAT Thematic Mapper Imagery for analysis of shorebird habitat and vegetation in the Outer Mackenzie Delta area, Northwest Territories by Dennis Jaques, Ecosat Geobotanical Surveys Inc. 1987.

INTRODUCTION

This study was initiated by the Canadian Wildlife Service, Edmonton, Alberta to determine whether LANDSAT Multispectral Scanner (MSS) and Thematic Mapper (TM) imagery could be used to identify and map the nesting and staging habitat of whimbrels, Hudsonian godwits, long-billed dowitchers and stilt sandpipers. The study area occurs in the outer Mackenzie Delta of northwestern Northwest Territories. Field studies conducted by Canadian Wildlife Service personnel provide ground data used in this present LANDSAT study. Field surveys have been conducted in 1985 and 1986 in the intensive study area of Fish Island; the more general study area covering the west side of Richards Island and portions of the Kendall Island Bird Sanctuary were also surveyed in 1981 and 1982 (Hogg et al. 1986).

These four shorebird species are part of a larger group of shorebird species receiving international co-operative study to define their habitat requirements during nesting, migration and wintering (Myers et al. 1987). Shorebirds generally possess low reproductive rates and therefore nesting success is of vital importance to their survival. Nesting and staging sites in the Canadian and Alaskan arctic need to be defined, located and protected from disturbance or destruction.

In the late 1960's oil and gas was discovered in the Mackenzie Delta region. Over 150 wells were drilled with a nominal success of about 2 1/2 out of 10. Exploration, drill site operations and transportation/collection systems activity pose potential conflict with nesting and staging shorebird species. Therefore, studies by the Canadian Wildlife Service have been conducted to assist in this effort. This present study is a small part of that overall effort to aid in our understanding of the location of and habitat requirements for shorebirds within this area of past and potential future industrial activity.

The specific objectives of this LANDSAT satellite study involve two phases as defined by the terms-of-reference for the study. The first is to identify and map shorebird nesting and staging habitat of the Kendall Island Bird Sanctuary study area and the second is to identify and map vegetation units of the smaller Fish Island study area. Two dates of LANDSAT imagery were to be analyzed in this study using both visual and computer-assisted analysis techniques. It is important to note that all vegetation and shorebird habitat data and classification systems were provided by the Canadian Wildlife Service from their past ground-based field studies in the study areas.

Copies of this report will be presented upon request to the author:

H. Loney Dickson
Wildlife Biologist
Canadian Wildlife Service
4999 - 98 Avenue
Edmonton, Alberta
T6B 2X3

Appendix 2. Identification of Potential Shorebird Nesting and Staging Habitat Sites using LANDSAT Thematic Mapper Imagery in the Outer Mackenzie Delta, Northwest Territories, Canada by Dennis Jaques, Ecosat Geobotanical Surveys Inc. 1987.

ABSTRACT

Two dates of LANDSAT Thematic Mapper imagery were required to identify potential nesting and staging habitat for shorebirds in the Outer Mackenzie Delta of Northwest Territories. Late June and late July 1986 images were required to identify these sites. Radiometrically and geometrically corrected raw computer data were processed to produce special photograhic enhancements of both dates. A mid-infrared, near infrared and visible red waveband combination (Bands 5, 4 and 3 respectively) were used for the June image. Three enhanced images were used from the July imagery. These include a natural colour (bands 3-2-1), false colour infrared (bands 4-3-2) and mid-infrared (bands 4-5-3) colour composites. Visual interpretation of these images together produced maps at 1:50,000 scale showing the locations of over 350 sites which may serve as nesting or staging habitat for shorebirds.

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H. Loney Dickson
Wildlife Biologist
Canadian Wildlife Service
4999 - 98 Avenue
Edmonton, Alberta
T6B 2X3

Appendix 3. Bird observations made along transects surveyed from 1985 to 1987 on the Mackenzie River delta, Northwest Territories.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
AMWI	8	1987	1	2	5180	0.193
ARLO	1	1985	0	3	5621	0
ARLO	1	1987	1	1	5621	0.178
ARLO	2	1985	6	6	4740	1.266
ARLO	2	1986	0	2	4740	0
ARLO	3	1985	4	8	7541	0.53
ARLO	3	1986	1	1	7541	0.133
ARLO	3	1986	0	3	7541	0
ARLO	3	1987	0	1	7541	0
ARLO	4	1985	2	2	8225	0.243
ARLO	6	1986	0	2	5057	0
ARLO	8	1985	0	2	5180	0
ARLO	9	1985	3	5	4720	0.636
ARLO	10	1986	5	5	4215	1.186
ARLO	10	1987	0	3	4215	0
ARLO	11	1986	0	1	3918	0
ARLO	12	1985	2	2	6241	0.32
ARLO	12	1987	2	2	6241	0.32
ARLO	13	1985	0	2	6730	0
ARLO	13	1986	1	1	6730	0.149
ARLO	14	1985	0	3	3285	0
ARLO	14	1987	0	1	3285	0
ARLO	15	1985	0	1	2529	0
ARLO	16	1985	0	2	3687	0
ARLO	18	1986	0	3	4245	0
ARLO	24	1987	0	2	3590	0
ARLO	27	1986	1	4	9718	0.103
ARLO	29	1987	2	2	3763	0.531
ARTE	1	1985	0	7	5621	0
ARTE	1	1987	3	3	5621	0.534
ARTE	2	1985	2	3	4740	0.422
ARTE	2	1986	5	5	4740	1.055
ARTE	2	1987	11	16	4740	2.321
ARTE	3	1986	0	6	7541	0
ARTE	3	1987	2	2	7541	0.265
ARTE	3	1987	2	2	7541	0.265
ARTE	4	1985	2	2	8225	0.243
ARTE	7	1985	0	2	5739	0
ARTE	7	1986	1	1	5739	0.174
ARTE	8	1985	1	1	5180	0.193
ARTE	9	1985	0	8	4720	0
ARTE	9	1987	2	2	4720	0.424
ARTE	10	1985	1	3	4215	0.237
ARTE	10	1986	0	4	4215	0
ARTE	10	1987	1	1	4215	0.237

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length) (m)	Birds/km[b]
ARTE	11	1985	0	2	3918	0
ARTE	12	1985	5	5	6241	0.801
ARTE	12	1986	4	6	6241	0.641
ARTE	12	1987	1	1	6241	0.16
ARTE	13	1986	1	1	6730	0.149
ARTE	13	1987	1	1	6730	0.149
ARTE	14	1985	0	1	3285	0
ARTE	14	1986	0	1	3285	0
ARTE	14.1	1985	2	2	1740	1.149
ARTE	15	1985	9	10	2529	3.559
ARTE	15	1986	0	6	2529	0
ARTE	16	1985	2	4	3687	0.542
ARTE	18	1986	2	4	4245	0.471
ARTE	20	1987	2	2	3236	0.618
ARTE	22	1987	0	4	4740	0
ARTE	24	1987	1	1	3590	0.279
ARTE	25	1987	7	10	2245	3.118
ARTE	27	1986	2	2	9718	0.206
ATSP	1	1985	2	2	5621	0.356
ATSP	1	1987	1	2	5621	0.178
ATSP	2	1985	5	6	4740	1.055
ATSP	2	1986	5	5	4740	1.055
ATSP	2	1987	10	10	4740	2.11
ATSP	3	1985	22	24	7541	2.917
ATSP	3	1986	12	17	7541	1.591
ATSP	3	1986	9	9	7541	1.193
ATSP	3	1987	11	13	7541	1.459
ATSP	4	1985	5	5	8225	0.608
ATSP	4	1987	0	1	8225	0
ATSP	5	1985	4	5	1546	2.587
ATSP	6	1985	6	6	5057	1.186
ATSP	6	1986	0	1	5057	0
ATSP	6	1987	6	7	5057	1.186
ATSP	7	1986	0	1	5739	0
ATSP	8	1987	7	7	5180	1.351
ATSP	11	1986	0	1	3918	0
ATSP	11	1987	1	1	3918	0.255
ATSP	12	1986	1	3	6241	0.16
ATSP	12	1987	5	5	6241	0.801
ATSP	13	1985	0	1	6730	0
ATSP	13	1986	1	2	6730	0.149
ATSP	13.1	1987	1	1	7336	0.136
ATSP	14	1987	2	2	3285	0.609
ATSP	15.1	1985	2	2	1118	1.789
ATSP	15.2	1986	5	5	1273	3.928
ATSP	18	1986	7	7	4245	1.649

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
ATSP	27	1986	0	1	9718	0
ATSP	28	1987	1	1	2001	0.5
BAEA	3	1987	0	1	7541	0
BAEA	4	1985	0	1	8225	0
BBPL	1	1987	1	1	5621	0.178
BBSA	15	1985	1	1	2529	0.395
BKSW	3	1986	0	2	7541	0
BKSW	3	1986	0	2	7541	0
BKSW	3	1987	0	1	7541	0
BKSW	27	1986	1	1	9718	0.103
BRAN	1	1985	6	6	5621	1.067
BRAN	2	1985	0	6	4740	0
BRAN	2	1986	1	3	4740	0.211
BRAN	2	1987	0	1	4740	0
BRAN	9	1985	0	3	4720	0
CAGO	3	1986	0	2	7541	0
CAGO	6	1985	4	4	5057	0.791
CAGO	7	1985	2	2	5739	0.348
CAGO	8	1987	0	2	5180	0
CAGO	9	1985	2	9	4720	0.424
CAGO	9	1987	2	2	4720	0.424
CAGO	10	1985	0	3	4215	0
CAGO	11	1987	0	2	3918	0
CAGO	12	1985	7	7	6241	1.122
CAGO	13	1985	0	5	6730	0
CAGO	14	1985	0	4	3285	0
CAGO	14	1986	1	1	3285	0.304
CAGO	14	1987	4	4	3285	1.218
CAGO	15	1985	10	11	2529	3.954
CAGO	15	1986	2	6	2529	0.791
CAGO	15.1	1985	2	2	1118	1.789
CAGO	16	1985	2	2	3687	0.542
CAGO	17	1985	0	2	5172	0
CAGO	18	1986	0	2	4245	0
CAGO	19	1987	5	8	2940	1.701
CAGO	20	1987	9	9	3236	2.781
CAGO	21	1987	10	10	3803	2.63
CAGO	22	1987	1	3	4740	0.211
CAGO	22	1987	0	1	4740	0
CANV	1	1985	0	11	5621	0
CANV	4	1985	1	1	8225	0.122
COLO	13	1986	0	1	6730	0
CORA	3	1987	0	2	7541	0
CORA	9	1987	1	1	4720	0.212
CORA	11	1985	2	4	3918	0.51
CORA	13	1985	0	1	6730	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
CORA	13.1	1987	1	1	7336	0.136
CORA	14	1985	0	1	3285	0
CORA	14	1986	0	1	3285	0
CORA	15	1985	2	2	2529	0.791
CORA	15.1	1985	0	3	1118	0
CORA	27	1986	0	1	9718	0
CORE	1	1985	7	7	5621	1.245
CORE	1	1987	3	3	5621	0.534
CORE	3	1985	2	2	7541	0.265
CORE	3	1986	2	3	7541	0.265
CORE	3	1986	2	2	7541	0.265
CORE	6	1987	8	8	5057	1.582
CORE	6.2	1987	1	1	1273	0.786
CORE	7	1985	2	2	5739	0.348
CORE	8	1987	9	9	5180	1.737
CORE	9	1985	4	4	4720	0.847
CORE	11	1986	1	1	3918	0.255
CORE	12	1987	6	8	6241	0.961
CORE	15.2	1986	1	1	1273	0.786
CORE	28	1987	7	9	2001	3.498
COSN	1	1985	0	1	5621	0
COSN	1	1987	0	1	5621	0
COSN	2	1985	1	1	4740	0.211
COSN	2	1986	0	1	4740	0
COSN	3	1985	8	9	7541	1.061
COSN	3	1986	1	3	7541	0.133
COSN	3	1987	0	1	7541	0
COSN	4	1985	5	9	8225	0.608
COSN	4	1986	1	2	8225	0.122
COSN	6	1985	5	5	5057	0.989
COSN	6	1986	12	21	5057	2.373
COSN	6	1987	2	3	5057	0.395
COSN	7	1985	8	15	5739	1.394
COSN	7	1986	0	6	5739	0
COSN	7	1987	1	2	5739	0.174
COSN	8	1985	8	8	5180	1.544
COSN	8	1987	5	7	5180	0.965
COSN	9	1985	4	6	4720	0.847
COSN	10	1985	1	4	4215	0.237
COSN	10	1986	2	2	4215	0.474
COSN	11	1985	6	8	3918	1.531
COSN	11	1986	6	8	3918	1.531
COSN	11	1987	6	8	3918	1.531
COSN	12	1985	1	1	6241	0.16
COSN	12	1987	1	1	6241	0.16
COSN	13	1985	2	3	6730	0.297

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
COSN	14	1985	3	11	3285	0.913
COSN	14	1986	3	4	3285	0.913
COSN	14	1987	1	1	3285	0.304
COSN	14.1	1985	1	1	1740	0.575
COSN	14.2	1986	0	2	1273	0
COSN	15.1	1985	2	2	1118	1.789
COSN	15.2	1986	4	4	1273	3.142
COSN	16	1985	5	5	3687	1.356
COSN	17	1985	2	4	5172	0.387
COSN	18	1986	1	2	4245	0.236
COSN	19	1987	0	1	2940	0
COSN	20	1987	4	4	3236	1.236
COSN	21	1987	3	3	3803	0.789
COSN	22	1987	3	6	4740	0.633
COSN	26	1986	3	4	10630	0.282
COSN	27	1986	7	11	9718	0.72
COSN	28	1987	3	3	2001	1.499
COSN	29	1987	0	1	3763	0
DUCK	1	1987	0	40	5621	0
DUCK	2	1987	1	1	4740	0.211
FOSP	1	1985	2	3	5621	0.356
FOSP	2	1985	2	2	4740	0.422
FOSP	2	1986	1	1	4740	0.211
FOSP	3	1985	5	7	7541	0.663
FOSP	3	1986	0	1	7541	0
FOSP	14.1	1985	1	1	1740	0.575
GEES	3	1987	0	2	7541	0
GLGU	1	1985	0	1	5621	0
GLGU	1	1987	8	10	5621	1.423
GLGU	2	1985	2	6	4740	0.422
GLGU	2	1986	5	7	4740	1.055
GLGU	2	1987	23	25	4740	4.852
GLGU	3	1985	1	1	7541	0.133
GLGU	3	1986	3	4	7541	0.398
GLGU	3	1986	2	3	7541	0.265
GLGU	3	1987	1	1	7541	0.133
GLGU	3	1987	1	2	7541	0.133
GLGU	4	1985	1	1	8225	0.122
GLGU	4	1986	1	1	8225	0.122
GLGU	4	1987	1	1	8225	0.122
GLGU	6	1985	2	4	5057	0.395
GLGU	6	1986	0	2	5057	0
GLGU	6	1987	0	1	5057	0
GLGU	6	1987	1	1	5057	0.198
GLGU	6.2	1987	0	1	1273	0
GLGU	7	1985	4	4	5739	0.697

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
GLGU	7	1986	0	9	5739	0
GLGU	7	1987	0	7	5739	0
GLGU	8	1985	2	5	5180	0.386
GLGU	8	1987	5	5	5180	0.965
GLGU	9	1985	2	4	4720	0.424
GLGU	9	1987	2	2	4720	0.424
GLGU	10	1985	0	7	4215	0
GLGU	10	1986	2	4	4215	0.474
GLGU	10	1987	3	10	4215	0.712
GLGU	11	1986	1	1	3918	0.255
GLGU	11	1987	1	8	3918	0.255
GLGU	12	1985	0	2	6241	0
GLGU	12	1986	1	2	6241	0.16
GLGU	12	1987	2	2	6241	0.32
GLGU	13	1985	0	2	6730	0
GLGU	13	1987	1	2	6730	0.149
GLGU	14	1985	0	2	3285	0
GLGU	14	1986	0	5	3285	0
GLGU	14.2	1986	0	1	1273	0
GLGU	15	1985	0	1	2529	0
GLGU	15.1	1985	0	1	1118	0
GLGU	17	1985	0	1	5172	0
GLGU	18	1986	1	3	4245	0.236
GLGU	19	1987	2	2	2940	0.68
GLGU	20	1987	7	7	3236	2.163
GLGU	21	1987	5	8	3803	1.315
GLGU	22	1987	0	3	4740	0
GLGU	25	1987	0	1	2245	0
GLGU	28	1987	0	1	2001	0
GRSC	14	1987	0	2	3285	0
GWFG	1	1985	15	36	5621	2.669
GWFG	1	1987	0	7	5621	0
GWFG	2	1985	0	28	4740	0
GWFG	2	1986	3	7	4740	0.633
GWFG	2	1987	5	5	4740	1.055
GWFG	3	1986	6	7	7541	0.796
GWFG	3	1987	4	4	7541	0.53
GWFG	3	1987	6	6	7541	0.796
GWFG	4	1985	2	18	8225	0.243
GWFG	4	1986	1	1	8225	0.122
GWFG	6	1985	9	10	5057	1.78
GWFG	6	1986	1	4	5057	0.198
GWFG	6	1987	0	19	5057	0
GWFG	7	1985	13	25	5739	2.265
GWFG	7	1986	1	20	5739	0.174
GWFG	7	1987	23	82	5739	4.008

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
GWFG	8	1985	2	13	5180	0.386
GWFG	8	1987	0	19	5180	0
GWFG	9	1985	12	21	4720	2.542
GWFG	9	1987	7	8	4720	1.483
GWFG	9	1987	2	2	4720	0.424
GWFG	10	1985	1	10	4215	0.237
GWFG	10	1986	0	8	4215	0
GWFG	10	1987	4	6	4215	0.949
GWFG	11	1985	0	22	3918	0
GWFG	11	1986	17	24	3918	4.339
GWFG	11	1987	9	23	3918	2.297
GWFG	12	1985	31	51	6241	4.967
GWFG	12	1986	3	39	6241	0.481
GWFG	12	1987	6	7	6241	0.961
GWFG	13	1985	10	18	6730	1.486
GWFG	13	1986	0	2	6730	0
GWFG	13	1987	1	1	6730	0.149
GWFG	13.1	1987	10	20	7336	1.363
GWFG	14	1985	23	26	3285	7.002
GWFG	14	1986	0	12	3285	0
GWFG	14	1987	2	6	3285	0.609
GWFG	15	1985	2	19	2529	0.791
GWFG	15.1	1985	8	8	1118	7.156
GWFG	16	1985	3	11	3687	0.814
GWFG	17	1985	0	2	5172	0
GWFG	18	1986	1	6	4245	0.236
GWFG	19	1987	3	33	2940	1.02
GWFG	20	1987	0	28	3236	0
GWFG	21	1987	0	11	3803	0
GWFG	22	1987	3	7	4740	0.633
GWFG	25	1987	2	2	2245	0.891
GWFG	29	1987	2	2	3763	0.531
GWTE	1	1985	1	4	5621	0.178
GWTE	3	1986	2	2	7541	0.265
GWTE	6	1985	1	2	5057	0.198
GWTE	6	1986	1	1	5057	0.198
GWTE	7	1985	2	2	5739	0.348
GWTE	14.1	1985	4	4	1740	2.299
HORE	1	1985	8	8	5621	1.423
HORE	3	1985	10	10	7541	1.326
HORE	3	1986	6	6	7541	0.796
HORE	3	1986	3	3	7541	0.398
HORE	3	1987	1	1	7541	0.133
HORE	6.2	1987	1	1	1273	0.786
HORE	11	1986	4	4	3918	1.021
HUGO	1	1985	3	3	5621	0.534

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
HUGO	3	1985	1	1	7541	0.133
HUGO	4	1985	5	6	8225	0.608
HUGO	4	1986	1	1	8225	0.122
HUGO	6	1985	2	2	5057	0.395
HUGO	7	1985	5	7	5739	0.871
HUGO	9	1985	4	12	4720	0.847
HUGO	9	1987	2	3	4720	0.424
HUGO	10	1985	2	6	4215	0.474
HUGO	10	1986	5	5	4215	1.186
HUGO	10	1987	1	1	4215	0.237
HUGO	11	1985	0	2	3918	0
HUGO	11	1986	0	2	3918	0
HUGO	11	1987	2	2	3918	0.51
HUGO	12	1985	2	2	6241	0.32
HUGO	12	1986	4	9	6241	0.641
HUGO	12	1987	4	4	6241	0.641
HUGO	13	1985	0	1	6730	0
HUGO	13	1986	3	5	6730	0.446
HUGO	13	1987	3	4	6730	0.446
HUGO	13.1	1987	1	8	7336	0.136
HUGO	14	1985	3	4	3285	0.913
HUGO	14	1986	0	1	3285	0
HUGO	14.2	1986	1	1	1273	0.786
HUGO	15	1985	2	2	2529	0.791
HUGO	15	1986	4	4	2529	1.582
HUGO	16	1985	3	7	3687	0.814
HUGO	17	1985	3	7	5172	0.58
HUGO	18	1986	1	1	4245	0.236
HUGO	20	1987	3	3	3236	0.927
HUGO	21	1987	2	5	3803	0.526
HUGO	22	1987	0	6	4740	0
HUGO	23	1987	1	1	2414	0.414
HUGO	24	1987	1	1	3590	0.279
HUGO	25	1987	4	9	2245	1.782
HUGO	29	1987	1	1	3763	0.266
JAEG	2	1985	0	1	4740	0
JAEG	4	1985	0	1	8225	0
JAEG	15	1985	0	1	2529	0
JAEG	26	1986	1	1	10630	0.094
LALO	1	1985	19	26	5621	3.38
LALO	1	1987	3	3	5621	0.534
LALO	2	1985	33	35	4740	6.962
LALO	2	1986	26	26	4740	5.485
LALO	2	1987	35	35	4740	7.384
LALO	2	1987	3	3	4740	0.633
LALO	3	1985	43	48	7541	5.702

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
LALO	3	1986	31	38	7541	4.111
LALO	3	1986	75	75	7541	9.946
LALO	3	1987	38	41	7541	5.039
LALO	3	1987	32	32	7541	4.243
LALO	4	1985	18	18	8225	2.188
LALO	4	1986	17	18	8225	2.067
LALO	4	1987	10	10	8225	1.216
LALO	5	1985	7	7	1546	4.528
LALO	6	1985	6	6	5057	1.186
LALO	6	1986	8	9	5057	1.582
LALO	6	1987	15	16	5057	2.966
LALO	6.1	1987	2	3	1733	1.154
LALO	6.2	1987	4	4	1273	3.142
LALO	7	1985	18	22	5739	3.136
LALO	7	1986	7	7	5739	1.22
LALO	7	1987	38	40	5739	6.621
LALO	8	1985	9	9	5180	1.737
LALO	8	1987	7	7	5180	1.351
LALO	9	1985	9	11	4720	1.907
LALO	9	1987	28	31	4720	5.932
LALO	10	1985	1	1	4215	0.237
LALO	10	1986	2	2	4215	0.474
LALO	11	1985	7	10	3918	1.787
LALO	11	1986	8	8	3918	2.042
LALO	11	1987	6	12	3918	1.531
LALO	12	1985	8	8	6241	1.282
LALO	12	1986	12	14	6241	1.923
LALO	12	1987	6	6	6241	0.961
LALO	13	1985	9	12	6730	1.337
LALO	13	1986	4	5	6730	0.594
LALO	13	1987	2	2	6730	0.297
LALO	14	1985	0	3	3285	0
LALO	14	1986	3	4	3285	0.913
LALO	14.1	1985	1	2	1740	0.575
LALO	14.2	1986	1	1	1273	0.786
LALO	15	1985	10	10	2529	3.954
LALO	15	1986	4	4	2529	1.582
LALO	16	1985	3	8	3687	0.814
LALO	17	1985	1	4	5172	0.193
LALO	18	1986	9	9	4245	2.12
LALO	20	1987	1	1	3236	0.309
LALO	21	1987	1	1	3803	0.263
LALO	23	1987	9	9	2414	3.728
LALO	24	1987	2	2	3590	0.557
LALO	25	1987	2	2	2245	0.891
LALO	26	1986	15	15	10630	1.411

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
LALO	27	1986	19	19	9718	1.955
LALO	28	1987	2	2	2001	1.0
LALO	29	1987	1	1	3763	0.266
LBDO	3	1985	0	2	7541	0
LBDO	3	1987	1	1	7541	0.133
LBDO	10	1987	1	1	4215	0.237
LBDO	12	1985	1	1	6241	0.16
LBDO	12	1986	0	1	6241	0
LBDO	12	1987	1	1	6241	0.16
LBDO	15	1985	1	1	2529	0.395
LBDO	16	1985	9	9	3687	2.441
LBDO	17	1985	2	2	5172	0.387
LBDO	21	1987	2	2	3803	0.526
LBDO	22	1987	2	2	4740	0.422
LBDO	25	1987	5	5	2245	2.227
LESC	4	1985	2	2	8225	0.243
LESC	6	1985	2	2	5057	0.395
LESC	13	1985	2	2	6730	0.297
LEYE	3	1985	0	1	7541	0
LEYE	5	1985	0	1	1546	0
LEYE	12	1987	1	1	6241	0.16
LEYE	14.1	1985	0	1	1740	0
LEYE	16	1985	2	2	3687	0.542
LGPL	1	1985	1	1	5621	0.178
LGPL	7	1985	3	3	5739	0.523
LGPL	8	1985	0	1	5180	0
LGPL	9	1985	1	1	4720	0.212
LGPL	12	1985	3	3	6241	0.481
LGPL	13	1985	2	2	6730	0.297
LGPL	15.2	1986	1	1	1273	0.786
LGPL	19	1987	0	2	2940	0
LOON	13.1	1987	1	1	7336	0.136
LOON	18	1986	0	1	4245	0
LTJA	3	1987	2	2	7541	0.265
LTJA	3	1987	1	1	7541	0.133
LTJA	7	1985	2	2	5739	0.348
LTJA	9	1985	4	4	4720	0.847
LTJA	12	1987	2	2	6241	0.32
LTJA	13	1985	1	1	6730	0.149
LTJA	15	1986	3	3	2529	1.186
LTJA	16	1985	0	2	3687	0
MALL	6	1985	1	1	5057	0.198
MEGU	19	1987	0	1	2940	0
NOHA	1	1985	0	1	5621	0
NOHA	3	1985	2	3	7541	0.265
NOHA	4	1985	0	1	8225	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
NOHA	6	1986	1	1	5057	0.198
NOHA	7	1985	1	1	5739	0.174
NOHA	9	1985	1	2	4720	0.212
NOHA	11	1985	0	1	3918	0
NOHA	13	1985	1	2	6730	0.149
NOHA	14	1986	1	1	3285	0.304
NOHA	17	1985	0	1	5172	0
NOPI	1	1985	72	91	5621	12.809
NOPI	1	1987	0	2	5621	0
NOPI	2	1985	2	6	4740	0.422
NOPI	3	1985	7	9	7541	0.928
NOPI	3	1986	3	15	7541	0.398
NOPI	3	1986	5	5	7541	0.663
NOPI	3	1987	4	8	7541	0.53
NOPI	3	1987	1	1	7541	0.133
NOPI	4	1985	7	9	8225	0.851
NOPI	4	1986	4	4	8225	0.486
NOPI	4	1987	1	1	8225	0.122
NOPI	6	1985	12	12	5057	2.373
NOPI	6	1986	6	11	5057	1.186
NOPI	6	1987	69	73	5057	13.644
NOPI	6.2	1987	15	15	1273	11.783
NOPI	7	1985	35	41	5739	6.099
NOPI	7	1986	7	12	5739	1.22
NOPI	7	1987	17	64	5739	2.962
NOPI	8	1985	8	10	5180	1.544
NOPI	8	1987	0	7	5180	0
NOPI	9	1985	5	45	4720	1.059
NOPI	9	1987	15	18	4720	3.178
NOPI	10	1985	6	9	4215	1.423
NOPI	10	1986	1	5	4215	0.237
NOPI	10	1987	6	9	4215	1.423
NOPI	11	1985	2	7	3918	0.51
NOPI	11	1987	5	5	3918	1.276
NOPI	12	1985	17	17	6241	2.724
NOPI	12	1986	6	15	6241	0.961
NOPI	12	1987	4	4	6241	0.641
NOPI	13	1985	6	10	6730	0.892
NOPI	13	1986	0	1	6730	0
NOPI	13	1987	2	2	6730	0.297
NOPI	13.1	1987	2	4	7336	0.273
NOPI	14	1985	4	4	3285	1.218
NOPI	14	1986	1	7	3285	0.304
NOPI	14	1987	8	11	3285	2.435
NOPI	14.1	1985	0	2	1740	0
NOPI	14.2	1986	0	1	1273	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
NOPI	15	1985	1	2	2529	0.395
NOPI	15	1986	0	8	2529	0
NOPI	15.1	1985	0	1	1118	0
NOPI	15.2	1986	0	1	1273	0
NOPI	16	1985	17	21	3687	4.611
NOPI	17	1985	1	1	5172	0.193
NOPI	18	1986	1	1	4245	0.236
NOPI	19	1987	3	4	2940	1.02
NOPI	20	1987	22	22	3236	6.799
NOPI	21	1987	5	18	3803	1.315
NOPI	22	1987	12	22	4740	2.532
NOPI	29	1987	0	8	3763	0
NOSV	2	1985	1	1	4740	0.211
NOSV	6	1985	4	7	5057	0.791
NOSV	7	1985	10	13	5739	1.742
NOSV	8	1985	0	1	5180	0
NOSV	9	1987	3	3	4720	0.636
NOSV	11	1987	0	2	3918	0
NOSV	12	1985	3	3	6241	0.481
NOSV	12	1986	1	1	6241	0.16
NOSV	14	1987	0	2	3285	0
NOSV	14.1	1985	0	2	1740	0
NOSV	15.1	1985	2	2	1118	1.789
NOWA	8	1987	1	1	5180	0.193
NOWA	13	1985	0	1	6730	0
OLDS	1	1985	8	20	5621	1.423
OLDS	1	1987	3	9	5621	0.534
OLDS	2	1985	7	8	4740	1.477
OLDS	2	1986	9	9	4740	1.899
OLDS	2	1987	2	2	4740	0.422
OLDS	3	1985	7	13	7541	0.928
OLDS	3	1986	1	1	7541	0.133
OLDS	3	1987	2	2	7541	0.265
OLDS	4	1985	8	8	8225	0.973
OLDS	9	1985	1	6	4720	0.212
OLDS	9	1987	2	2	4720	0.424
OLDS	12	1985	2	4	6241	0.32
OLDS	12	1986	0	5	6241	0
OLDS	12	1987	2	2	6241	0.32
OLDS	13	1986	1	1	6730	0.149
OLDS	14.1	1985	5	5	1740	2.874
OLDS	15	1985	2	2	2529	0.791
OLDS	25	1987	1	1	2245	0.445
PAJA	1	1987	2	3	5621	0.356
PAJA	2	1986	1	1	4740	0.211
PAJA	3	1986	1	2	7541	0.133

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
PAJA	3	1986	0	1	7541	0
PAJA	3	1987	4	4	7541	0.53
PAJA	3	1987	1	1	7541	0.133
PAJA	4	1986	5	5	8225	0.608
PAJA	6	1985	0	2	5057	0
PAJA	6	1987	1	1	5057	0.198
PAJA	6.1	1987	2	2	1733	1.154
PAJA	7	1985	2	2	5739	0.348
PAJA	7	1987	0	2	5739	0
PAJA	8	1985	0	1	5180	0
PAJA	10	1985	0	3	4215	0
PAJA	10	1986	1	1	4215	0.237
PAJA	11	1986	0	3	3918	0
PAJA	12	1985	0	1	6241	0
PAJA	12	1986	1	2	6241	0.16
PAJA	12	1987	2	4	6241	0.32
PAJA	13	1985	1	1	6730	0.149
PAJA	13.1	1987	3	3	7336	0.409
PAJA	14	1986	1	1	3285	0.304
PAJA	15	1985	2	2	2529	0.791
PAJA	15	1986	3	3	2529	1.186
PAJA	16	1985	2	2	3687	0.542
PAJA	17	1985	0	1	5172	0
PAJA	18	1986	3	3	4245	0.707
PAJA	20	1987	2	2	3236	0.618
PAJA	21	1987	4	4	3803	1.052
PAJA	22	1987	2	2	4740	0.422
PAJA	27	1986	2	5	9718	0.206
PAJA	28	1987	0	1	2001	0
PASS	3	1987	0	2	7541	0
PESA	1	1985	8	12	5621	1.423
PESA	2	1985	1	2	4740	0.211
PESA	2	1986	5	5	4740	1.055
PESA	2	1987	1	1	4740	0.211
PESA	3	1985	0	1	7541	0
PESA	3	1986	6	8	7541	0.796
PESA	3	1986	0	1	7541	0
PESA	3	1987	4	5	7541	0.53
PESA	3	1987	1	1	7541	0.133
PESA	4	1985	5	6	8225	0.608
PESA	6	1985	1	1	5057	0.198
PESA	6	1986	2	2	5057	0.395
PESA	6	1987	4	4	5057	0.791
PESA	6.1	1987	1	3	1733	0.577
PESA	6.2	1987	1	1	1273	0.786
PESA	7	1985	4	4	5739	0.697

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
PESA	7	1986	0	1	5739	0
PESA	7	1987	7	10	5739	1.22
PESA	8	1985	1	1	5180	0.193
PESA	8	1987	1	2	5180	0.193
PESA	9	1985	11	14	4720	2.331
PESA	9	1987	2	2	4720	0.424
PESA	10	1985	3	14	4215	0.712
PESA	10	1986	7	8	4215	1.661
PESA	10	1987	2	2	4215	0.474
PESA	11	1985	2	3	3918	0.51
PESA	11	1987	1	1	3918	0.255
PESA	12	1985	1	4	6241	0.16
PESA	12	1986	10	10	6241	1.602
PESA	12	1987	4	4	6241	0.641
PESA	13	1985	3	5	6730	0.446
PESA	13	1986	2	5	6730	0.297
PESA	13.1	1987	2	7	7336	0.273
PESA	14	1985	8	9	3285	2.435
PESA	14	1986	3	3	3285	0.913
PESA	14	1987	0	2	3285	0
PESA	14.2	1986	1	1	1273	0.786
PESA	15	1985	10	11	2529	3.954
PESA	15	1986	6	11	2529	2.372
PESA	16	1985	10	13	3687	2.712
PESA	17	1985	1	5	5172	0.193
PESA	18	1986	3	3	4245	0.707
PESA	21	1987	2	2	3803	0.526
PESA	22	1987	2	3	4740	0.422
PESA	23	1987	1	1	2414	0.414
PESA	24	1987	2	2	3590	0.557
PESA	25	1987	0	1	2245	0
PESA	27	1986	2	2	9718	0.206
POJA	3	1986	0	1	7541	0
POJA	5	1985	2	2	1546	1.294
POJA	11	1985	0	1	3918	0
POJA	12	1986	0	1	6241	0
POJA	14	1985	0	1	3285	0
POJA	15	1986	1	1	2529	0.395
RBME	4	1985	2	2	8225	0.243
RBME	10	1985	2	2	4215	0.474
RBME	21	1987	0	2	3803	0
RDNP	1	1985	89	93	5621	15.833
RDNP	1	1987	9	10	5621	1.601
RDNP	2	1985	3	3	4740	0.633
RDNP	2	1986	25	25	4740	5.274
RDNP	2	1987	13	13	4740	2.743
RDNP	2	1987	0	1	4740	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
RDNP	3	1985	27	28	7541	3.58
RDNP	3	1986	1	2	7541	0.133
RDNP	3	1987	1	1	7541	0.133
RDNP	3	1987	4	4	7541	0.53
RDNP	4	1985	11	13	8225	1.337
RDNP	4	1986	3	3	8225	0.365
RDNP	4	1987	3	3	8225	0.365
RDNP	6	1985	2	7	5057	0.395
RDNP	6	1986	13	16	5057	2.571
RDNP	6	1987	2	2	5057	0.395
RDNP	6.1	1987	3	5	1733	1.731
RDNP	6.2	1987	5	7	1273	3.928
RDNP	7	1985	52	52	5739	9.061
RDNP	7	1986	2	3	5739	0.348
RDNP	7	1987	18	23	5739	3.136
RDNP	8	1985	6	8	5180	1.158
RDNP	9	1985	36	55	4720	7.627
RDNP	9	1987	19	19	4720	4.025
RDNP	10	1985	22	31	4215	5.219
RDNP	10	1986	31	31	4215	7.355
RDNP	10	1987	1	1	4215	0.237
RDNP	11	1985	2	2	3918	0.51
RDNP	11	1987	3	3	3918	0.766
RDNP	12	1985	7	9	6241	1.122
RDNP	12	1986	14	14	6241	2.243
RDNP	13	1985	6	9	6730	0.892
RDNP	13	1986	1	1	6730	0.149
RDNP	13.1	1987	3	3	7336	0.409
RDNP	14	1985	34	34	3285	10.35
RDNP	14	1986	12	12	3285	3.653
RDNP	14	1987	3	5	3285	0.913
RDNP	14.1	1985	1	1	1740	0.575
RDNP	15.2	1986	1	1	1273	0.786
RDNP	16	1985	78	85	3687	21.155
RDNP	17	1985	0	1	5172	0
RDNP	18	1986	6	6	4245	1.413
RDNP	19	1987	5	5	2940	1.701
RDNP	20	1987	4	4	3236	1.236
RDNP	21	1987	7	7	3803	1.841
RDNP	22	1987	15	15	4740	3.165
RDNP	24	1987	2	2	3590	0.557
RDNP	25	1987	5	6	2245	2.227
RDNP	25	1987	2	2	2245	0.891
RDNP	26	1986	3	3	10630	0.282
RDNP	27	1986	5	6	9718	0.515
RDNP	29	1987	5	5	3763	1.329
REDP	1	1987	0	1	5621	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
REDP	2	1985	5	5	4740	1.055
REDP	2	1986	3	3	4740	0.633
REDP	2	1987	21	22	4740	4.43
REDP	3	1985	4	8	7541	0.53
REDP	3	1986	1	15	7541	0.133
REDP	3	1986	15	26	7541	1.989
REDP	3	1987	10	16	7541	1.326
REDP	3	1987	8	8	7541	1.061
REDP	4	1985	5	9	8225	0.608
REDP	4	1986	4	5	8225	0.486
REDP	4	1987	4	5	8225	0.486
REDP	6	1986	3	3	5057	0.593
REDP	6	1987	18	20	5057	3.559
REDP	6.1	1987	3	3	1733	1.731
REDP	6.2	1987	8	9	1273	6.284
REDP	7	1987	12	14	5739	2.091
REDP	8	1985	0	4	5180	0
REDP	9	1987	1	1	4720	0.212
REDP	10	1985	0	1	4215	0
REDP	10	1986	0	1	4215	0
REDP	10	1987	5	6	4215	1.186
REDP	11	1985	0	1	3918	0
REDP	11	1986	4	9	3918	1.021
REDP	11	1987	29	43	3918	7.402
REDP	12	1985	2	2	6241	0.32
REDP	13	1985	4	6	6730	0.594
REDP	13	1987	3	4	6730	0.446
REDP	13.1	1987	19	23	7336	2.59
REDP	13.1	1987	1	1	7336	0.136
REDP	14	1986	0	2	3285	0
REDP	14.2	1986	0	2	1273	0
REDP	15	1985	3	3	2529	1.186
REDP	18	1986	6	6	4245	1.413
REDP	20	1987	1	1	3236	0.309
REDP	21	1987	0	1	3803	0
REDP	22	1987	0	1	4740	0
REDP	24	1987	2	2	3590	0.557
REDP	26	1986	2	4	10630	0.188
REDP	27	1986	8	8	9718	0.823
REDP	29	1987	8	10	3763	2.126
REPH	2	1986	9	9	4740	1.899
REPH	6	1986	1	1	5057	0.198
REPH	7	1986	1	1	5739	0.174
REPH	10	1986	4	4	4215	0.949
REPH	12	1986	11	11	6241	1.763
REPH	12	1987	1	1	6241	0.16

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
REPH	13	1986	2	2	6730	0.297
REPH	14	1986	13	16	3285	3.957
REPH	14.2	1986	0	2	1273	0
REPH	16	1985	1	1	3687	0.271
RLHA	4	1987	1	1	8225	0.122
RLHA	6	1985	0	3	5057	0
RLHA	7	1985	1	1	5739	0.174
RLHA	7	1987	1	3	5739	0.174
RLHA	8	1985	0	1	5180	0
RLHA	9	1985	1	2	4720	0.212
RLHA	10	1987	0	1	4215	0
RLHA	11	1985	1	1	3918	0.255
RLHA	11	1987	2	2	3918	0.51
RLHA	12	1985	2	2	6241	0.32
RLHA	13	1985	0	1	6730	0
RLHA	13	1986	2	2	6730	0.297
RLHA	13.1	1987	1	1	7336	0.136
RLHA	16	1985	1	1	3687	0.271
RLHA	23	1987	1	1	2414	0.414
RLHA	29	1987	1	1	3763	0.266
RTLO	1	1985	2	5	5621	0.356
RTLO	1	1987	0	0	5621	0
RTLO	2	1986	0	1	4740	0
RTLO	4	1985	3	5	8225	0.365
RTLO	4	1986	1	1	8225	0.122
RTLO	5	1985	2	2	1546	1.294
RTLO	7	1985	0	1	5739	0
RTLO	8	1985	1	2	5180	0.193
RTLO	10	1985	3	7	4215	0.712
RTLO	10	1986	6	6	4215	1.423
RTLO	11	1985	0	2	3918	0
RTLO	12	1986	0	2	6241	0
RTLO	12	1987	1	1	6241	0.16
RTLO	14	1986	0	2	3285	0
RTLO	19	1987	0	0	2940	0
RTLO	20	1987	2	2	3236	0.618
RTLO	21	1987	1	1	3803	0.263
RTLO	22	1987	2	5	4740	0.422
SACR	1	1985	6	10	5621	1.067
SACR	1	1987	1	3	5621	0.178
SACR	2	1985	11	11	4740	2.321
SACR	2	1987	3	3	4740	0.633
SACR	3	1986	0	4	7541	0
SACR	3	1987	4	4	7541	0.53
SACR	4	1985	9	12	8225	1.094
SACR	4	1986	2	2	8225	0.243

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
SACR	4	1987	3	3	8225	0.365
SACR	6	1985	6	8	5057	1.186
SACR	6	1986	4	65	5057	0.791
SACR	6	1987	7	8	5057	1.384
SACR	6.2	1987	3	3	1273	2.357
SACR	7	1985	7	23	5739	1.22
SACR	7	1986	6	48	5739	1.045
SACR	7	1987	2	11	5739	0.348
SACR	8	1985	2	3	5180	0.386
SACR	8	1987	1	3	5180	0.193
SACR	9	1985	10	29	4720	2.119
SACR	9	1987	6	8	4720	1.271
SACR	10	1985	2	7	4215	0.474
SACR	10	1986	0	2	4215	0
SACR	10	1987	1	2	4215	0.237
SACR	11	1985	1	11	3918	0.255
SACR	11	1986	7	17	3918	1.787
SACR	11	1987	2	10	3918	0.51
SACR	12	1985	11	11	6241	1.763
SACR	12	1986	3	20	6241	0.481
SACR	12	1987	0	5	6241	0
SACR	13	1985	1	8	6730	0.149
SACR	13	1986	2	14	6730	0.297
SACR	13	1987	4	6	6730	0.594
SACR	13	1987	0	2	6730	0
SACR	13.1	1987	3	12	7336	0.409
SACR	13.1	1987	0	2	7336	0
SACR	14	1985	2	4	3285	0.609
SACR	14	1986	2	4	3285	0.609
SACR	14	1987	1	1	3285	0.304
SACR	14.1	1985	1	2	1740	0.575
SACR	14.2	1986	0	2	1273	0
SACR	15.1	1985	5	5	1118	4.472
SACR	16	1985	0	4	3687	0
SACR	17	1985	1	8	5172	0.193
SACR	18	1986	1	3	4245	0.236
SACR	19	1987	2	4	2940	0.68
SACR	20	1987	2	2	3236	0.618
SACR	21	1987	8	15	3803	2.104
SACR	22	1987	1	4	4740	0.211
SACR	23	1987	0	2	2414	0
SACR	25	1987	1	2	2245	0.445
SACR	26	1986	4	7	10630	0.376
SACR	27	1986	8	18	9718	0.823
SACR	28	1987	3	3	2001	1.499
SAGU	1	1985	0	2	5621	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
SAGU	2	1985	1	1	4740	0.211
SAGU	2	1986	3	3	4740	0.633
SAGU	2	1987	2	3	4740	0.422
SAGU	11	1985	0	20	3918	0
SAGU	12	1986	2	3	6241	0.32
SAGU	13	1986	0	1	6730	0
SAGU	15	1986	0	1	2529	0
SAND	6	1987	1	1	5057	0.198
SASP	1	1985	10	10	5621	1.779
SASP	1	1987	3	4	5621	0.534
SASP	2	1985	16	16	4740	3.376
SASP	2	1986	12	12	4740	2.532
SASP	2	1987	22	23	4740	4.641
SASP	3	1985	49	54	7541	6.498
SASP	3	1986	15	18	7541	1.989
SASP	3	1986	18	19	7541	2.387
SASP	3	1987	17	17	7541	2.254
SASP	3	1987	45	45	7541	5.967
SASP	4	1985	21	21	8225	2.553
SASP	4	1986	11	12	8225	1.337
SASP	4	1987	20	20	8225	2.432
SASP	5	1985	1	1	1546	0.647
SASP	6	1985	16	16	5057	3.164
SASP	6	1986	28	28	5057	5.537
SASP	6	1987	16	16	5057	3.164
SASP	6.1	1987	3	3	1733	1.731
SASP	6.2	1987	7	7	1273	5.499
SASP	7	1985	16	18	5739	2.788
SASP	7	1986	8	15	5739	1.394
SASP	7	1987	27	30	5739	4.705
SASP	8	1985	24	24	5180	4.633
SASP	8	1987	4	4	5180	0.772
SASP	9	1985	43	48	4720	9.11
SASP	9	1987	19	20	4720	4.025
SASP	10	1985	11	16	4215	2.61
SASP	10	1986	7	7	4215	1.661
SASP	10	1987	21	21	4215	4.982
SASP	11	1985	45	48	3918	11.485
SASP	11	1986	16	18	3918	4.084
SASP	11	1987	28	33	3918	7.147
SASP	12	1985	10	11	6241	1.602
SASP	12	1986	6	8	6241	0.961
SASP	12	1987	5	6	6241	0.801
SASP	13	1985	21	31	6730	3.12
SASP	13	1986	2	3	6730	0.297

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
SASP	13	1987	7	7	6730	1.04
SASP	13	1987	3	3	6730	0.446
SASP	13.1	1987	11	14	7336	1.499
SASP	13.1	1987	7	7	7336	0.954
SASP	14	1985	24	24	3285	7.306
SASP	14	1986	12	13	3285	3.653
SASP	14	1987	7	7	3285	2.131
SASP	14.1	1985	4	4	1740	2.299
SASP	14.2	1986	1	1	1273	0.786
SASP	15	1985	2	3	2529	0.791
SASP	15.1	1985	1	1	1118	0.894
SASP	15.2	1986	3	3	1273	2.357
SASP	16	1985	13	15	3687	3.526
SASP	17	1985	2	4	5172	0.387
SASP	18	1986	8	8	4245	1.885
SASP	19	1987	2	2	2940	0.68
SASP	20	1987	6	6	3236	1.854
SASP	21	1987	13	13	3803	3.418
SASP	22	1987	2	6	4740	0.422
SASP	23	1987	23	23	2414	9.528
SASP	24	1987	11	11	3590	3.064
SASP	25	1987	5	5	2245	2.227
SASP	26	1986	18	18	10630	1.693
SASP	27	1986	25	25	9718	2.573
SASP	28	1987	6	6	2001	2.999
SASP	29	1987	7	7	3763	1.86
SCAU	1	1985	8	15	5621	1.423
SCAU	2	1987	0	1	4740	0
SCAU	3	1985	4	4	7541	0.53
SCAU	4	1985	8	8	8225	0.973
SCAU	6	1986	4	4	5057	0.791
SCAU	7	1985	2	2	5739	0.348
SCAU	9	1985	2	2	4720	0.424
SCAU	10	1985	0	4	4215	0
SCAU	12	1985	4	4	6241	0.641
SCAU	15	1985	9	17	2529	3.559
SCAU	18	1986	0	5	4245	0
SEOW	3	1986	1	1	7541	0.133
SEOW	6	1985	0	2	5057	0
SEOW	7	1985	2	2	5739	0.348
SEOW	8	1985	2	2	5180	0.386
SEOW	9	1985	1	1	4720	0.212
SEOW	11	1985	1	1	3918	0.255
SEOW	12	1985	1	2	6241	0.16
SEOW	13	1985	1	1	6730	0.149
SEOW	14	1985	0	1	3285	0

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
SEOW	15	1985	1	1	2529	0.395
SEPL	6	1986	1	1	5057	0.198
SEPL	8	1987	1	2	5180	0.193
SEPL	12	1985	3	3	6241	0.481
SEPL	13	1986	2	2	6730	0.297
SEPL	13.1	1987	2	2	7336	0.273
SEPL	14	1987	1	1	3285	0.304
SEPL	15	1985	0	2	2529	0
SEPL	15.2	1986	1	1	1273	0.786
SEPL	28	1987	1	1	2001	0.5
SESA	1	1985	17	23	5621	3.024
SESA	1	1987	7	7	5621	1.245
SESA	2	1985	5	5	4740	1.055
SESA	2	1986	12	12	4740	2.532
SESA	2	1987	3	3	4740	0.633
SESA	3	1985	12	15	7541	1.591
SESA	3	1986	6	9	7541	0.796
SESA	3	1986	3	4	7541	0.398
SESA	3	1987	14	15	7541	1.857
SESA	3	1987	1	1	7541	0.133
SESA	4	1985	3	3	8225	0.365
SESA	4	1986	1	1	8225	0.122
SESA	4	1987	2	2	8225	0.243
SESA	6	1985	2	6	5057	0.395
SESA	6	1987	1	1	5057	0.198
SESA	7	1985	48	49	5739	8.364
SESA	7	1986	1	2	5739	0.174
SESA	7	1987	1	6	5739	0.174
SESA	8	1987	2	2	5180	0.386
SESA	11	1985	2	2	3918	0.51
SESA	11	1987	2	5	3918	0.51
SESA	12	1987	1	1	6241	0.16
SESA	13	1986	0	2	6730	0
SESA	14	1985	1	1	3285	0.304
SESA	14.1	1985	1	1	1740	0.575
SESA	15.2	1986	0	1	1273	0
SESA	16	1985	0	1	3687	0
SESA	22	1987	0	1	4740	0
SESA	27	1986	7	8	9718	0.72
SHOR	2	1987	3	3	4740	0.633
SHOR	9	1987	1	1	4720	0.212
SHOR	13	1987	0	1	6730	0
SHOR	13.1	1987	0	1	7336	0
SLSA	1	1985	5	10	5621	0.89
SLSA	1	1987	7	7	5621	1.245

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
SLSA	2	1985	4	4	4740	0.844
SLSA	2	1986	2	2	4740	0.422
SLSA	2	1987	10	13	4740	2.11
SLSA	3	1985	4	8	7541	0.53
SLSA	3	1986	0	2	7541	0
SLSA	3	1986	1	1	7541	0.133
SLSA	3	1987	2	2	7541	0.265
SLSA	3	1987	2	2	7541	0.265
SLSA	4	1987	6	6	8225	0.729
SLSA	6	1986	2	3	5057	0.395
SLSA	6	1987	1	2	5057	0.198
SLSA	7	1985	1	1	5739	0.174
SLSA	9	1985	4	5	4720	0.847
SLSA	10	1985	1	4	4215	0.237
SLSA	11	1985	0	1	3918	0
SLSA	11	1987	0	1	3918	0
SLSA	12	1985	6	6	6241	0.961
SLSA	12	1986	1	1	6241	0.16
SLSA	12	1987	0	1	6241	0
SLSA	13	1985	7	12	6730	1.04
SLSA	13	1986	1	1	6730	0.149
SLSA	13	1987	1	1	6730	0.149
SLSA	13.1	1987	1	1	7336	0.136
SLSA	15	1985	3	3	2529	1.186
SLSA	15	1986	1	1	2529	0.395
SLSA	16	1985	25	30	3687	6.781
SLSA	17	1985	0	1	5172	0
SLSA	18	1986	3	5	4245	0.707
SLSA	21	1987	1	1	3803	0.263
SLSA	22	1987	0	1	4740	0
SLSA	24	1987	2	2	3590	0.557
SLSA	25	1987	2	2	2245	0.891
SLSA	27	1986	1	2	9718	0.103
SPAR	2	1987	4	4	4740	0.844
TUSW	1	1985	6	18	5621	1.067
TUSW	1	1987	6	10	5621	1.067
TUSW	2	1985	3	9	4740	0.633
TUSW	2	1986	2	2	4740	0.422
TUSW	2	1987	3	4	4740	0.633
TUSW	3	1985	5	5	7541	0.663
TUSW	3	1987	5	7	7541	0.663
TUSW	4	1985	1	4	8225	0.122
TUSW	4	1986	7	7	8225	0.851
TUSW	4	1987	0	2	8225	0
TUSW	6	1985	2	4	5057	0.395

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
TUSW	6	1986	0	2	5057	0
TUSW	6	1986	2	2	5057	0.395
TUSW	6	1987	1	6	5057	0.198
TUSW	7	1986	4	5	5739	0.697
TUSW	7	1987	1	3	5739	0.174
TUSW	9	1985	0	2	4720	0
TUSW	10	1986	0	3	4215	0
TUSW	11	1985	0	5	3918	0
TUSW	11	1986	0	2	3918	0
TUSW	12	1985	2	4	6241	0.32
TUSW	12	1986	0	4	6241	0
TUSW	12	1987	1	2	6241	0.16
TUSW	13	1985	0	2	6730	0
TUSW	13	1987	8	8	6730	1.189
TUSW	13	1987	1	1	6730	0.149
TUSW	14	1985	0	4	3285	0
TUSW	15	1986	0	2	2529	0
TUSW	21	1987	0	2	3803	0
TUSW	23	1987	0	1	2414	0
TUSW	25	1987	0	2	2245	0
WCSP	1	1985	1	1	5621	0.178
WCSP	1	1987	1	1	5621	0.178
WCSP	2	1986	1	1	4740	0.211
WCSP	3	1986	6	6	7541	0.796
WCSP	3	1986	1	2	7541	0.133
WCSP	3	1987	0	2	7541	0
WCSP	4	1985	0	1	8225	0
WCSP	4	1987	4	4	8225	0.486
WCSP	18	1986	2	2	4245	0.471
WHIM	4	1987	0	12	8225	0
WHIM	6	1986	0	5	5057	0
WHIM	6	1987	1	1	5057	0.198
WHIM	12	1985	10	10	6241	1.602
WHIM	12	1986	13	13	6241	2.083
WHIM	12	1987	9	9	6241	1.442
WHIM	13	1985	6	13	6730	0.892
WHIM	13	1986	0	1	6730	0
WHIM	13	1987	0	1	6730	0
WHIM	13.1	1987	4	12	7336	0.545
WHIM	14	1985	0	1	3285	0
WHIM	14	1986	1	2	3285	0.304
WHIM	15	1985	0	1	2529	0
WHIM	15	1986	9	9	2529	3.559
WHIM	15.1	1985	2	4	1118	1.789
WHIM	16	1985	3	9	3687	0.814
WHIM	17	1985	6	15	5172	1.16

Appendix 3. Continued.

Species[a]	Transect	Year	On transect	On & off transect	Transect length (m)	Birds/km[b]
WHIM	21	1987	2	2	3803	0.526
WHIM	22	1987	0	1	4740	0
WHIM	25	1987	1	1	2245	0.445
WHIM	27	1986	5	7	9718	0.515
WIPT	1	1985	2	2	5621	0.356
WIPT	2	1985	3	3	4740	0.633
WIPT	2	1986	6	6	4740	1.266
WIPT	2	1987	1	1	4740	0.211
WIPT	3	1985	4	4	7541	0.53
WIPT	3	1986	1	2	7541	0.133
WIPT	3	1986	2	2	7541	0.265
WIPT	3	1987	5	6	7541	0.663
WIPT	3	1987	5	5	7541	0.663
WIPT	4	1985	3	3	8225	0.365
WIPT	4	1986	2	2	8225	0.243
WIPT	4	1987	1	1	8225	0.122
WIPT	5	1985	3	3	1546	1.94
WIPT	15	1986	1	1	2529	0.395
WIPT	15.1	1985	2	2	1118	1.789
WIPT	16	1985	2	2	3687	0.542
WIPT	17	1985	1	1	5172	0.193
WIPT	18	1986	13	13	4245	3.062
WWSC	2	1987	0	17	4740	0
WWSC	3	1985	3	3	7541	0.398
WWSC	3	1987	0	2	7541	0
WWSC	4	1985	0	2	8225	0
WWSC	15	1985	2	2	2529	0.791
WWSC	15	1986	7	7	2529	2.768
WWSC	26	1986	0	2	10630	0
YEWB	1	1985	3	3	5621	0.534
YEWB	2	1985	7	7	4740	1.477
YEWB	2	1986	5	5	4740	1.055
YEWB	3	1985	1	3	7541	0.133
YEWB	3	1986	3	3	7541	0.398
YEWB	4	1985	3	3	8225	0.365
YEWB	12	1985	0	1	6241	0

[a]See Appendix 7 for Species Acronym definitions.
[b]Based on "on transect" observations only.

Appendix 4. Sample sizes used for the binomial test results presented in Appendix 5 and Table 10.

Species*	lcu	xl	x2	nl	#segn	n2	#segs	dsb.
WHIM	6	551	22	15408	395	5092	133	0
WHIM	7	1209	42	15408	395	5092	133	0
WHIM	8	3484	690	15408	395	5092	133	0
WHIM	9	7216	3891	15408	395	5092	133	0
WHIM	10	1570	318	15408	395	5092	133	0
WHIM	11	690	90	15408	395	5092	133	0
WHIM	12	371	18	15408	395	5092	133	0
SLSA	6	559	14	18616	478	1808	48	0
SLSA	7	1222	29	18616	478	1808	48	0
SLSA	8	4003	171	18616	478	1808	48	0
SLSA	9	9651	1401	18616	478	1808	48	0
SLSA	10	1724	146	18616	478	1808	48	0
SLSA	11	743	34	18616	478	1808	48	0
SLSA	12	389	0	18616	478	1808	48	0
HUGO	6	521	52	17212	441	3184	84	0
HUGO	7	1191	60	17212	441	3184	84	0
HUGO	8	3620	554	17212	441	3184	84	0
HUGO	9	8742	2285	17212	441	3184	84	0
HUGO	10	1728	139	17212	441	3184	84	0
HUGO	11	735	42	17212	441	3184	84	0
HUGO	12	358	31	17212	441	3184	84	0
LBDO	6	529	44	20132	518	264	7	0
LBDO	7	1240	11	20132	518	264	7	0
LBDO	8	4150	24	20132	518	264	7	0
LBDO	9	10880	147	20132	518	264	7	0
LBDO	10	1855	12	20132	518	264	7	0
LBDO	11	762	15	20132	518	264	7	0
LBDO	12	389	0	20132	518	264	7	0
SESA	6	573	0	20236	521	1104	4	0
SESA	7	1251	0	20236	521	1104	4	0
SESA	8	4144	30	20236	521	1104	4	0
SESA	9	10952	75	20236	521	1104	4	0
SESA	10	1821	46	20236	521	1104	4	0
SESA	11	768	9	20236	521	1104	4	0
SESA	12	389	0	20236	521	1104	4	0
PESA	6	570	3	18184	469	2212	56	0
PESA	7	1218	33	18184	469	2212	56	0
PESA	8	3942	232	18184	469	2212	56	0
PESA	9	9162	1865	18184	469	2212	56	0
PESA	10	1805	62	18184	469	2212	56	0
PESA	11	762	15	18184	469	2212	56	0
PESA	12	389	0	18184	469	2212	56	0
RDNP	6	496	77	19452	502	944	23	0
RDNP	7	1194	57	19452	502	944	23	0
RDNP	8	3832	342	19452	502	944	23	0
RDNP	9	10574	453	19452	502	944	23	0

Appendix 4. Continued.

Species*	lcu	x1	x2	n1	#segn	n2	#segs	dsb.
RDNP	10	1856	11	19452	502	944	23	0
RDNP	11	777	0	19452	502	944	23	0
RDNP	12	387	2	19452	502	944	23	0
REPH	6	539	34	20201	520	192	5	0
REPH	7	1237	14	20201	520	192	5	0
REPH	8	4142	32	20201	520	192	5	0
REPH	9	10915	112	20201	520	192	5	0
REPH	10	1867	0	20201	520	192	5	0
REPH	11	777	0	20201	520	192	5	0
REPH	12	389	0	20201	520	192	5	0
WHIM	6	110	16	9264	237	4104	107	1
WHIM	7	654	23	9264	237	4104	107	1
WHIM	8	1955	497	9264	237	4104	107	1
WHIM	9	5698	3286	9264	237	4104	107	1
WHIM	10	635	208	9264	237	4104	107	1
WHIM	11	156	51	9264	237	4104	107	1
WHIM	12	38	16	9264	237	4104	107	1
SLSA	6	113	13	11828	303	1464	39	1
SLSA	7	672	5	11828	303	1464	39	1
SLSA	8	2337	115	11828	303	1464	39	1
SLSA	9	7726	1203	11828	303	1464	39	1
SLSA	10	728	97	11828	303	1464	39	1
SLSA	11	186	18	11828	303	1464	39	1
SLSA	12	54	0	11828	303	1464	39	1
HUGO	6	108	18	10684	273	2580	68	1
HUGO	7	644	33	10684	273	2580	68	1
HUGO	8	2004	448	10684	273	2580	68	1
HUGO	9	7010	1894	10684	273	2580	68	1
HUGO	10	703	119	10684	273	2580	68	1
HUGO	11	166	38	10684	273	2580	68	1
HUGO	12	39	15	10684	273	2580	68	1
LBDO	6	113	13	13140	338	124	3	1
LBDO	7	672	5	13140	338	124	3	1
LBDO	8	2434	18	13140	338	124	3	1
LBDO	9	8827	77	13140	338	124	3	1
LBDO	10	822	0	13140	338	124	3	1
LBDO	11	204	0	13140	338	124	3	1
LBDO	12	54	0	13140	338	124	3	1
RDNP	6	116	10	12768	329	496	12	1
RDNP	7	653	24	12768	329	496	12	1
RDNP	8	2280	172	12768	329	496	12	1
RDNP	9	8616	288	12768	329	496	12	1
RDNP	10	822	0	12768	329	496	12	1
RDNP	11	204	0	12768	329	496	12	1
RDNP	12	52	2	12768	329	496	12	1
REPH	6	126	0	13152	338	112	3	1
REPH	7	677	0	13152	338	112	3	1

Appendix 4. Continued.

Species*	lcu	x1	x2	n1	#segn	n2	#segs	dsb.
REPH	8	2452	0	13152	338	112	3	1
REPH	9	8792	112	13152	338	112	3	1
REPH	10	822	0	13152	338	112	3	1
REPH	11	204	0	13152	338	112	3	1
REPH	12	54	0	13152	338	112	3	1
PESA	6	126	0	11456	295	1808	46	1
PESA	7	652	25	11456	295	1808	46	1
PESA	8	2280	172	11456	295	1808	46	1
PESA	9	7367	1537	11456	295	1808	46	1
PESA	10	765	57	11456	295	1808	46	1
PESA	11	189	15	11456	295	1808	46	1
PESA	12	54	0	11456	295	1808	46	1
SESA	6	126	0	13104	337	160	4	1
SESA	7	677	0	13104	337	160	4	1
SESA	8	2422	30	13104	337	160	4	1
SESA	9	8829	75	13104	337	160	4	1
SESA	10	776	46	13104	337	160	4	1
SESA	11	195	9	13104	337	160	4	1
SESA	12	54	0	13104	337	160	4	1
WHIM	6	0	2	5440	141	3452	91	2
WHIM	7	82	10	5440	141	3452	91	2
WHIM	8	382	284	5440	141	3452	91	2
WHIM	9	4462	2937	5440	141	3452	91	2
WHIM	10	421	180	5440	141	3452	91	2
WHIM	11	78	26	5440	141	3452	91	2
WHIM	12	8	6	5440	141	3452	91	2
SLSA	6	2	0	7544	196	1272	34	2
SLSA	7	92	0	7544	196	1272	34	2
SLSA	8	590	76	7544	196	1272	34	2
SLSA	9	6269	1075	7544	196	1272	34	2
SLSA	10	479	104	7544	196	1272	34	2
SLSA	11	86	15	7544	196	1272	34	2
SLSA	12	14	0	7544	196	1272	34	2
HUGO	6	1	1	6736	174	2052	55	2
HUGO	7	86	6	6736	174	2052	55	2
HUGO	8	431	235	6736	174	2052	55	2
HUGO	9	5635	1684	6736	174	2052	55	2
HUGO	10	485	95	6736	174	2052	55	2
HUGO	11	80	21	6736	174	2052	55	2
HUGO	12	8	6	6736	174	2052	55	2
LBDO	6	2	0	8708	227	80	2	2
LBDO	7	92	0	8708	227	80	2	2
LBDO	8	663	3	8708	227	80	2	2
LBDO	9	7242	77	8708	227	80	2	2
LBDO	10	580	0	8708	227	80	2	2
LBDO	11	101	0	8708	227	80	2	2
LBDO	12	14	0	8708	227	80	2	2

Appendix 4. Continued.

Species*	lcu	x1	x2	n1	#segn	n2	#segs	dsb.
RDNP	6	2	0	8536	223	252	6	2
RDNP	7	92	0	8536	223	252	6	2
RDNP	8	607	59	8536	223	252	6	2
RDNP	9	7128	191	8536	223	252	6	2
RDNP	10	580	0	8536	223	252	6	2
RDNP	11	101	0	8536	223	252	6	2
RDNP	12	12	2	8536	223	252	6	2
REPH	6	2	0	8676	226	112	3	2
REPH	7	92	0	8676	226	112	3	2
REPH	8	666	0	8676	226	112	3	2
REPH	9	7207	112	8676	226	112	3	2
REPH	10	580	0	8676	226	112	3	2
REPH	11	101	0	8676	226	112	3	2
REPH	12	14	0	8676	226	112	3	2
PESA	6	2	0	7324	191	1464	38	2
PESA	7	67	25	7324	191	1464	38	2
PESA	8	537	129	7324	191	1464	38	2
PESA	9	6061	1258	7324	191	1464	38	2
PESA	10	538	42	7324	191	1464	38	2
PESA	11	93	8	7324	191	1464	38	2
PESA	12	14	0	7324	191	1464	38	2
SESA	6	2	0	8712	227	76	2	2
SESA	7	92	0	8712	227	76	2	2
SESA	8	648	18	8712	227	76	2	2
SESA	9	7300	19	8712	227	76	2	2
SESA	10	549	31	8712	227	76	2	2
SESA	11	93	8	8712	227	76	2	2
SESA	12	14	0	8712	227	76	2	2
WHIM	6	110	16	9464	242	4304	112	3
WHIM	7	654	23	9464	242	4304	112	3
WHIM	8	1971	515	9464	242	4304	112	3
WHIM	9	5862	3448	9464	242	4304	112	3
WHIM	10	655	228	9464	242	4304	112	3
WHIM	11	156	51	9464	242	4304	112	3
WHIM	12	38	16	9464	242	4304	112	3
SLSA	6	113	13	12180	312	1512	40	3
SLSA	7	672	5	12180	312	1512	40	3
SLSA	8	2371	115	12180	312	1512	40	3
SLSA	9	8024	1231	12180	312	1512	40	3
SLSA	10	748	117	12180	312	1512	40	3
SLSA	11	186	18	12180	312	1512	40	3
SLSA	12	54	0	12180	312	1512	40	3
HUGO	6	108	18	10932	279	2732	72	3
HUGO	7	644	33	10932	279	2732	72	3
HUGO	8	2020	466	10932	279	2732	72	3
HUGO	9	7202	2028	10932	279	2732	72	3
HUGO	10	743	119	10932	279	2732	72	3

Appendix 4. Continued.

Species*	lcu	x1	x2	n1	#segn	n2	#segs	dsb.
HUGO	11	166	38	10932	279	2732	72	3
HUGO	12	39	15	10932	279	2732	72	3
LBDO	6	113	13	13500	347	164	4	3
LBDO	7	672	5	13500	347	164	4	3
LBDO	8	2465	21	13500	347	164	4	3
LBDO	9	9116	114	13500	347	164	4	3
LBDO	10	862	0	13500	347	164	4	3
LBDO	11	204	0	13500	347	164	4	3
LBDO	12	54	0	13500	347	164	4	3
RDNP	6	116	10	13168	339	496	12	3
RDNP	7	653	24	13168	339	496	12	3
RDNP	8	2314	172	13168	339	496	12	3
RDNP	9	8942	288	13168	339	496	12	3
RDNP	10	862	0	13168	339	496	12	3
RDNP	11	204	0	13168	339	496	12	3
RDNP	12	52	2	13168	339	496	12	3
REPH	6	126	0	13552	348	112	3	3
REPH	7	677	0	13552	348	112	3	3
REPH	8	2486	0	13552	348	112	3	3
REPH	9	9118	112	13552	348	112	3	3
REPH	10	862	0	13552	348	112	3	3
REPH	11	204	0	13552	348	112	3	3
REPH	12	54	0	13552	348	112	3	3
PESA	6	126	0	11784	303	1880	48	3
PESA	7	652	25	11784	303	1880	48	3
PESA	8	2309	177	11784	303	1880	48	3
PESA	9	7626	1604	11784	303	1880	48	3
PESA	10	805	57	11784	303	1880	48	3
PESA	11	189	15	11784	303	1880	48	3
PESA	12	54	0	11784	303	1880	48	3
SESA	6	126	0	13504	347	160	4	3
SESA	7	677	0	13504	347	160	4	3
SESA	8	2456	30	13504	347	160	4	3
SESA	9	9155	75	13504	347	160	4	3
SESA	10	816	46	13504	347	160	4	3
SESA	11	195	9	13504	347	160	4	3
SESA	12	54	0	13504	347	160	4	3

*See Appendix 7 for species acronyms.

Appendix 5. Binomial of shorebird utilization of individual LCUs 6 to 12 inclusive, within the four methods of LANDSAT analysis for defining nesting habitat.

		Species[a]															
		WHIMBREL		SLSA		HUGO		LBDO		SESA		PESA		RDNP		REPH	
LCU	DSB**	Z1*	P	Z1*	P	Z1*	P	Z1*	P	Z1*	P	Z1*	P	Z1*	P	Z1*	P
6	0	11.8	<0.05	5.5	<0.05	4.4	<0.05	13.7	<0.05	5.7	<0.05	8.1	<0.05	10.2	<0.05	12.6	<0.05
6	1	4.4	<0.05	0.25	>0.05	1.47	>0.05	11.0	<0.05	1.25	>0.05	4.5	<0.05	2.5	<0.05	1.04	>0.05
6	2	1.78	>0.05	0.58	>0.05	0.89	>0.05	0.14	>0.05	0.13	>0.05	0.63	>0.05	0.24	>0.05	0.16	>0.05
6	3	4.5	<0.05	0.26	>0.05	1.61	>0.05	9.4	<0.05	1.23	>0.05	4.5	<0.05	2.6	<0.05	1.02	>0.05
7	0	18.2	<0.05	8.4	<0.05	10.9	<0.05	1.3	>0.05	8.5	<0.05	9.6	<0.05	0.12	>0.05	0.67	>0.05
7	1	15.8	<0.05	8.8	<0.05	9.8	<0.05	0.54	>0.05	3.0	<0.05	7.7	<0.05	0.27	>0.05	2.5	>0.05
7	2	5.5	<0.05	4.0	<0.05	3.8	<0.05	0.92	>0.05	0.90	>0.05	2.7	<0.05	1.66	>0.05	1.09	>0.05
7	3	16.0	<0.05	8.8	<0.05	10.1	<0.05	1.13	>0.05	2.9	<0.05	7.8	<0.05	0.12	>0.05	2.4	<0.05
8	0	13.9	<0.05	12.1	<0.05	4.7	<0.05	4.6	<0.05	14.5	<0.05	12.3	<0.05	12.3	<0.05	1.31	>0.05
8	1	12.4	<0.05	11.1	<0.05	1.64	>0.05	1.14	>0.05	0.09	>0.05	10.6	<0.05	9.5	<0.05	5.1	<0.05
8	2	2.1	<0.05	2.3	<0.05	7.6	<0.05	1.30	>0.05	5.3	<0.05	1.95	>0.05	9.6	<0.05	3.1	<0.05
8	3	12.5	<0.05	11.3	<0.05	1.72	>0.05	1.80	>0.05	0.18	>0.05	10.6	<0.05	9.7	<0.05	5.0	<0.05
9	0	36.7	<0.05	20.9	<0.05	21.9	<0.05	0.5	>0.05	30.6	<0.05	30.2	<0.05	3.8	<0.05	1.19	>0.05
9	1	21.1	<0.05	13.0	<0.05	7.5	<0.05	1.20	>0.05	5.5	<0.05	17.4	<0.05	4.4	<0.05	7.4	<0.05
9	2	3.8	<0.05	1.25	>0.05	1.69	>0.05	3.1	<0.05	13.7	<0.05	3.0	<0.05	3.2	<0.05	4.8	<0.05
9	3	21.1	<0.05	12.1	<0.05	8.3	<0.05	0.54	>0.05	5.6	<0.05	17.7	<0.05	4.6	<0.05	7.4	<0.05
10	0	8.4	<0.05	1.7	>0.05	10.2	<0.05	2.6	<0.05	5.5	<0.05	11.0	<0.05	8.7	<0.05	4.4	<0.05
10	1	3.9	<0.05	0.70	>0.05	3.7	<0.05	2.9	<0.05	11.9	<0.05	5.8	<0.05	5.8	<0.05	2.7	<0.05
10	2	4.6	<0.05	2.4	<0.05	4.1	<0.05	2.4	<0.05	12.0	<0.05	6.3	<0.05	4.3	<0.05	2.8	<0.05
10	3	3.6	<0.05	2.4	<0.05	4.7	<0.05	3.3	<0.05	11.7	<0.05	6.3	<0.05	5.9	<0.05	2.8	<0.05
11	0	8.8	<0.05	4.5	<0.05	8.0	<0.05	1.6	<0.05	5.1	<0.05	8.1	<0.05	6.3	<0.05	2.8	<0.05
11	1	1.90	>0.05	1.01	>0.05	0.30	>0.05	1.40	>0.05	4.2	<0.05	2.6	<0.05	2.8	<0.05	1.33	>0.05
11	2	2.9	<0.05	0.12	>0.05	0.61	>0.05	0.97	>0.05	7.7	<0.05	2.4	<0.05	1.74	>0.05	1.15	>0.05
11	3	2.1	<0.05	1.02	>0.05	0.49	>0.05	1.59	>0.05	4.3	<0.05	2.7	<0.05	2.8	<0.05	1.31	>0.05
12	0	9.3	<0.05	6.2	<0.05	4.2	<0.05	2.3	<0.05	4.6	<0.05	6.9	<0.05	3.9	<0.05	1.94	>0.05
12	1	0.17	>0.05	2.6	<0.05	1.55	>0.05	0.72	>0.05	0.81	>0.05	2.9	<0.05	0.01	>0.05	0.68	>0.05
12	2	0.31	>0.05	1.54	>0.05	1.73	>0.05	0.36	>0.05	0.35	>0.05	1.67	>0.05	2.6	<0.05	0.42	>0.05
12	3	0.26	>0.05	2.6	<0.05	1.43	>0.05	0.81	>0.05	0.80	>0.05	2.9	<0.05	0.03	>0.05	0.67	>0.05

aSee Appendix 7 for species acronyms

*Z1 If $Z1_{calc} > 1.96$ then there is a significant difference at $p < 0.05$.

**DSB - See Table 10 (pp. 47) for definitions.

Appendix 6. Summary statistics of three means clustering analysis* of habitat variables and data from transects conducted in the study area, Mackenzie River delta, Northwest Territories.

Variable**	Between SS	DF	Within SS	DF	F-Ratio	Prob
HCP	1.178	2	71.893	290	2.377	0.095
LCP	65.150	2	313.669	290	30.117	0.000
HUM	20.497	2	197.688	290	15.034	0.000
TUS	2.407	2	146.405	290	2.384	0.094
MND	39.096	2	174.576	290	32.473	0.000
OPEN	1683.987	2	41372.505	290	5.902	0.003
STANDW	188545.853	2	44911.847	290	608.729	0.000
STANDD	728.078	2	5134.454	290	20.561	0.000
GRAM	109358.711	2	72354.525	290	219.157	0.000
DS	27142.549	2	58476.393	290	67.304	0.000
TS	294.888	2	10162.280	290	4.208	0.016
HEATH	7021.405	2	52597.025	290	19.357	0.000
HERB	149.469	2	7609.405	290	2.848	0.060
MOSS	214.646	2	61021.934	290	0.510	0.601
EQUIS	5209.163	2	58602.079	290	12.889	0.000
ASPECT	10.647	2	88.766	290	17.391	0.000

*Method of Wilkinson L. (1987).
**HCP = high-centred polygon; LCP = low centred polygon
HUM = hummock
TUS = tussock
MND = mound
OPEN = % open water
STANDW = % standing water
STANDD = % standing water depth
GRAM = graminoids (gramineal, cyperaceal)
DS = dwarf shurb
TS = tall shrub
HERB = herbaceous flowering plants
MOSS = moss and lichens
EQUIS = *Equisetum*

Appendix 7. Species observed and status in the main study area of the Mackenzie River delta, Northwest Territories from 1985 to 1987 including species acronym definition.

Species acronym	Species name	Barry & Spencer 1976	1985	1986	1987
AMRO	American Robin	X	X	X	X*
AMWI	American Wigeon	X		X	B*
ARLO	Pacific Loon	X	B	B	X
ARTE	Arctic Tern	X	B	X	B
ATSP	American Tree Sparrow	B	X	B	X
BAEA	Bald Eagle	-	X	X	X
BASA	Baird's Sandpiper			X	
BBPL	Black-bellied Plover	X			
BBSA	Buff-breasted Sandpiper		X		X
BKSW	Bank Swallow	X	B	B	B
BLSC	Black Scoter				X
BRAN	Brant	X	X	X	B
CAGO	Canada Goose	X	B	B	B
CANV	Canvasback	-	X	-	B
COEI	Common Elder				X
COLO	Common Loon	X	X	X	
CORA	Common Raven	X	B	B	B
CORE	Common Redpoll	B	B	X	B
COSN	Common Snipe	B	X	X	B
DUCK	Unidentified Duck				
FOSP	Fox Sparrow	B	X	B	X
GEES	Unidentified Geese				
GLGU	Glaucous Gull	X	X	B	B
GOEA	Golden Eagle	X			X
GRSC	Greater Scaup				X
GWFG	Greater White-fronted Goose	B	B	B	B
GWTE	Green-winged Teal	B	X	X	
GYRF	Gyrfalcon	X			
HASP	Harris' Sparrow			X	
HORE	Hoary Redpoll	B		X	X
HUGO	Hudsonian Godwit	X	B	X	B
JAEG	Unidentified Jaeger				
KIEI	King Eider			X	
KILL	Killdeer				X
LALO	Lapland Longspur	B	B	B	B
LBDO	Long-billed Dowitcher		B	B	X
LESA	Least Sandpiper		X		X
LESC	Lesser Scaup		X		X
LEYE	Lesser Yellowlegs	X	X	X	X
LISP	Lincoln Sparrow				X
LGPL	Lesser Golden Plover		X	X	X
LOON	Unidentified Loon				
LTJA	Long-tailed Jaeger	X	X	X	X

Appendix 7. Continued.

Species Acronym	Species Name	Barry & Spencer 1976	1985	1986	1987
MALL	Mallard	B	B		
MEGU	Mew Gull				X
NOHA	Northern Harrier	X	X	X	X
NOPI	Northern Pintail	B	B	B	B
NOSV	Northern Shoveler	B	X	X	B
NOWA	Northern Waterthrush		X	X	X
OLDS	Oldsquaw	X	X	X	B
PAJA	Parasitic Jaeger	X	B	B	B
PASS	Unidentified Passerine				
PEFA	Peregrine Falcon			X	
PESA	Pectoral Sandpiper	B	X	B	B
POJA	Pomarine Jaeger		X	X	X
RBME	Red-breasted Merganser		X	X	
RDNP	Red-Necked Phalarope	B	B	B	B
REDP	Unidentified Redpoll				
REPH	Red Phalarope			B	
RLHA	Rough-legged Hawk	X	B	X	B
RTLO	Red-throated Loon	X	B	X	B
RUBL	Rusty Blackbird	X			
RUTU	Ruddy Turnstone			X	
RWBB	Red-winged Blackbird				X
SACR	Sandhill Crane	B	B	B	B
SAGU	Sabine's Gull	X	B	X	B
SAND	Sanderling			X	
SASP	Savannah Sparrow	B	B	B	B
SCAU	Unidentified Scaup	X		X	X
SDSA	Spotted Sandpiper			X	
SEOW	Short-eared Owl	X	X	X	X
SEPL	Semipalmated Plover		B	B	B
SESA	Semipalmated Sandpiper	B	B	B	B
SHOR	Unidentified Shorebird				
SLSA	Stilt Sandpiper	B	B	B	B
SNBU	Snow Bunting	B		X	
SPAR	Unidentified Sparrow				
SUSC	Surf Scoter			X	
TESW	Tree Swallow			X	
TUSW	Tundra Swan	B	B	B	B
WCSP	White-crowned Sparrow	B	X	X	X
WHIM	Whimbrel	B	B	B	B
WIPT	Willow Ptarmigan	B	B	B	B
WRSA	White-rumped Sandpiper			X	
WWSC	White-winged Scoter	X	X	X	X
YEWT	Yellow Wagtail			X	
YEWB	Yellow Warbler	B	X	X	X

* B = breeding confirmed
X = presence only confirmed

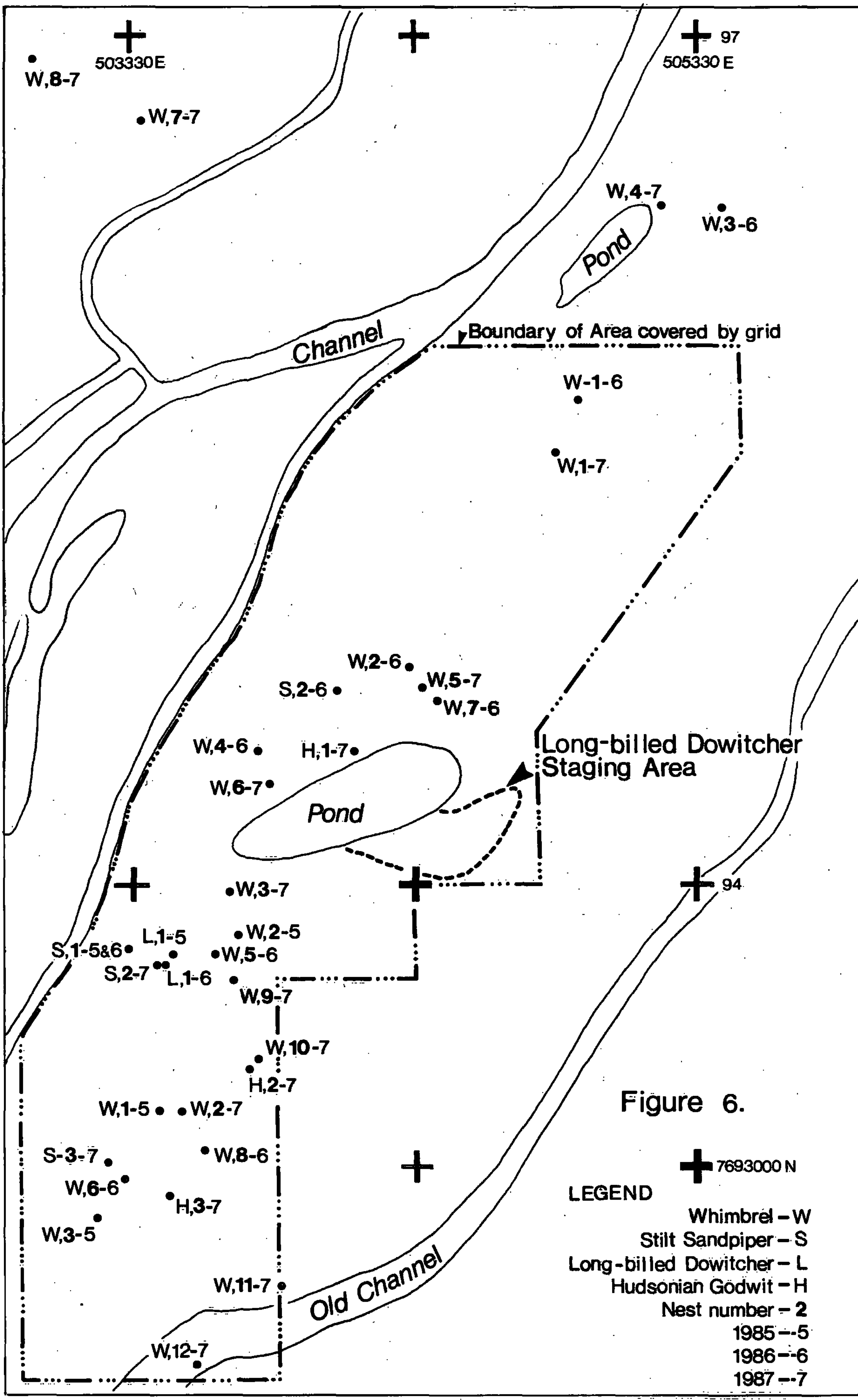
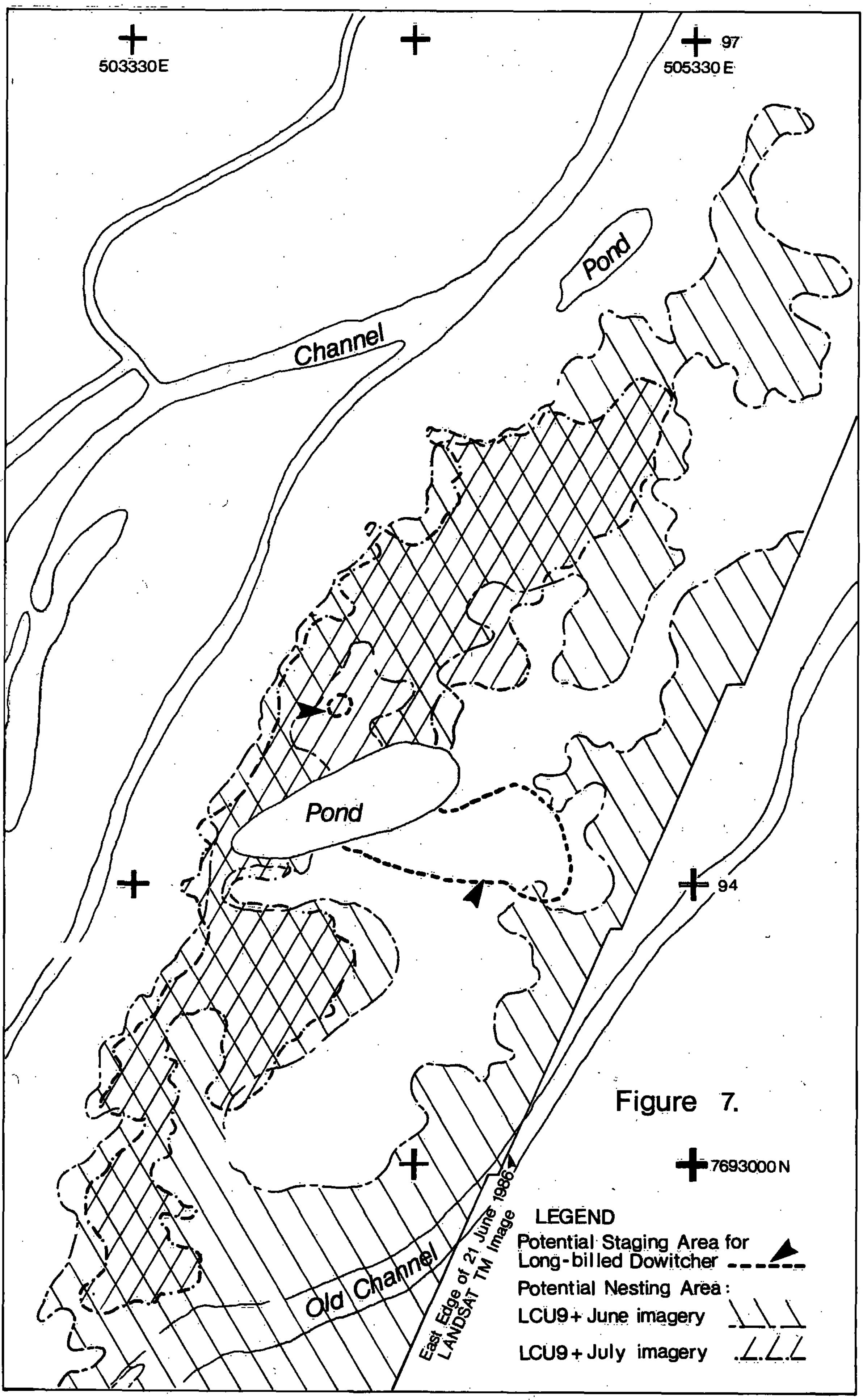

503330E
505330 E
97
94
7693000 N
W,8-7
W,7-7
W,4-7
W,3-6
Pond
Channel
Boundary of Area covered by grid
W-1-6
W,1-7
W,2-6
W,5-7
S,2-6
W,7-6
W,4-6
H,1-7
W,6-7
Pond
Long-billed Dowitcher
Staging Area
W,3-7
W,2-5
L,1-5
S,1-5&6
W,5-6
S,2-7
L,1-6
W,9-7
W,10-7
H,2-7
W,1-5
W,2-7
S-3-7
W,8-6
W,6-6
H,3-7
W,3-5
W,11-7
Old Channel
W,12-7
LEGEND
Whimbrel - W
Stilt Sandpiper - S
Long-billed Dowitcher - L
Hudsonian Godwit - H
Nest number - 2
1985 - 5
1986 - 6
1987 - 7

Figure 6.



503330E
97
505330E
Pond
Channel
Pond
94
Figure 7.
7693000N
East Edge of 21 June 1986
LANDSAT TM Image
Old Channel
LEGEND
Potential Staging Area for Long-billed Dowitcher
Potential Nesting Area:
LCU9 + June imagery
LCU9 + July imagery

QL 685.5 .N6 I42 1989
Identification of nesting and staging shorebird areas in the Mackenzie River Delta and Richards Island area, Northwest