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by

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Abstract

During a 5-year study of the bird populations at Storkersen Point on the Alaska Coastal Plain, 25 of the 72 species observed were recorded as breeding. There are few resident species in an avifauna dominated by swimming and wading birds. To provide insight into habitat use and to devise systems for protecting key habitats, wetlands were classified on the basis of size, depth, vegetation, and water chemistry. The resulting eight classes then were related to bird use.

To determine factors influencing differential use of classes of wetlands, and to provide a basis for understanding the food relationships and problems of pollution of wetlands, invertebrate populations were examined in major freshwater wetlands. There is a strong relationship between the presence of emergent *Arctophila* and *Carex* and high invertebrate populations. Peak populations coincide with peak hatching of shorebirds and ducks. It is concluded from limited sampling of bird food habits that invertebrates constitute the major food source for many bird species on the Coastal Plain.

Retention of large breeding populations of tundra birds is uncertain with the disturbance and change that comes with oil development. Foremost problems will be pollution of these wetlands with oil and wetland modification by impoundment or drainage due to road and pipeline systems.

Based on the characteristics of the birds and their wetland resources, it is recommended that preservation of tundra wetlands is vital to most breeding birds of the moist tundra. Preservation should include: (1) large tracts where no oil development occurs, (2) small and well-distributed units of about 42 km² which should be left undisturbed but which should not prevent oil removal, and (3) protection of key production units from pollutants even in areas of intensive development for oil.

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Introduction and Objectives

Discovery and proposed removal of large oil and gas reserves on Alaska's Arctic Coastal Plain have prompted national concern over potential environmental damage (Bartonek et al. 1971). Current industrial development is limited primarily to the vicinity of Prudhoe Bay, but activities are expanding rapidly as construction of the pipeline for transporting oil nears completion. Moreover, development of potential resources of National Petroleum Reserve No. 4 to the west of Prudhoe Bay was approved by Congress in 1975.

The effects of petroleum exploitation on arctic faunas or habitats could be severe in this relatively simple ecosystem. Serious damage to tundra vegetation results from mechanical disturbance of the surface layer which is subject to seasonal freezing and thawing. Although direct killing of wildlife may be controlled in the area, the indirect and direct effect of human activity may be harmful to animal populations (Bartonek et al. 1971). The tundra ecosystem characteristically has few species but their populations oscillate widely. As a result, this system seems to be one that can exist only in large units (Dunbar 1973).

The most conspicuous habitat feature of the moist coastal tundra is the presence of extensive wetlands that cover 50 to 75% of the coastal plain (Black and Barksdale 1949). Although the ice-free season is short, these wetlands provide the principal attraction for many water-related birds such as sea ducks, geese, swans, loons, and shorebirds. Small lakes and ponds probably are the most vulnerable part of the landscape because they represent discrete units that may collect pollutants, and both fauna and flora may be eliminated without conspicuous signs.

The influence of oil spills on the invertebrate fauna and the flora of such areas could be extremely serious. Aquatic invertebrates seem to be a major food resource for breeding waterfowl (except geese), but information on either invertebrates or water-bird food habits from tundra areas is limited. Evidence from other habitats suggests that invertebrates provide a significant portion of the diet of young waterfowl of various species (Chura 1961; Bartonek and Hickey 1969; Sugden 1969; Bartonek 1972), as well as an essential nutrient source for laying female ducks (Krull 1968; Bengtson 1971*a*; Krapu 1974). Aquatic invertebrates are also a major source of food for shorebirds (Holmes and Pitelka 1968).

The present study was established to assess populations of water birds in relation to their aquatic habitats in the Prudhoe Bay oil fields (Fig. 1). Specific objectives were to: (1) determine the importance of this region to water birds, (2) derive a wetland

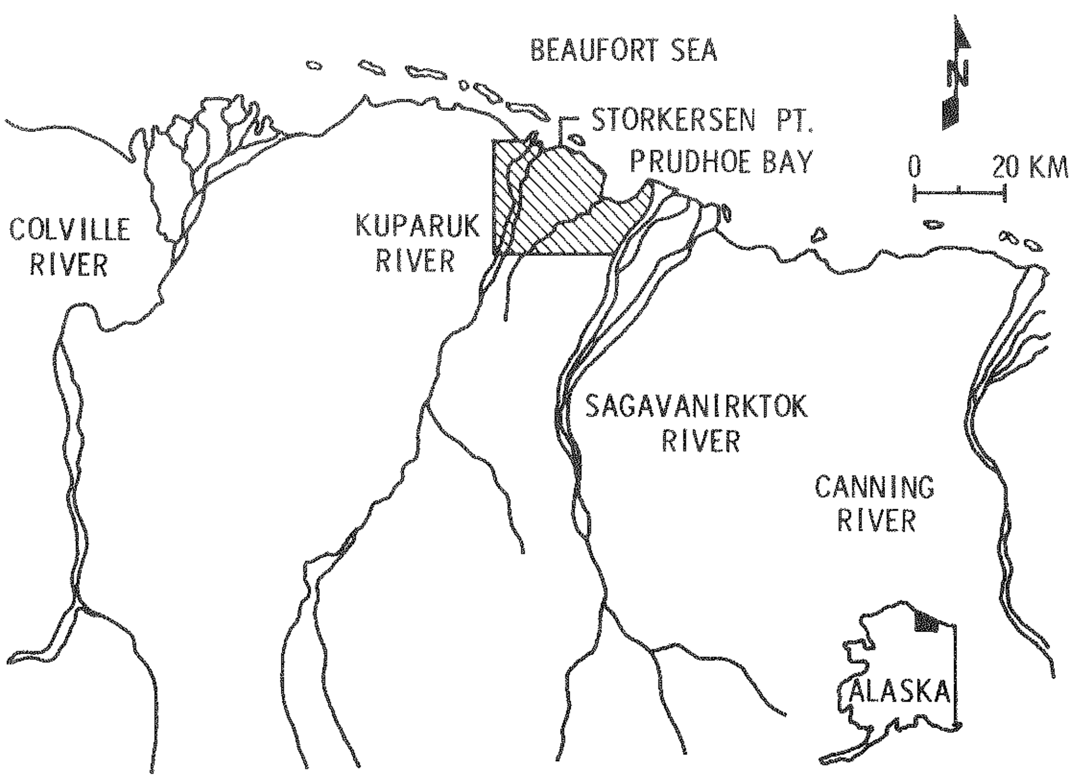

Fig. 1. Location of Storkersen Point study area (black insert) and zone of current intensive oil development (shaded).

classification system that identifies important relationships between birds and wetlands, (3) relate the seasonal abundance and availability of aquatic macroinvertebrates to use by water birds, and (4) provide recommendations for minimizing negative effects of petroleum development on water birds.

This project was part of the Trans-Alaska Pipeline Investigations conducted by River Basins Studies (now Ecological Services) of the U.S. Fish and Wildlife Service. Field seasons extended from about 1 June to mid-August each year except 1975 when field work ended in late July. Bergman was on the site from 1971-1973 and part of 1974, Howard during 1972 and 1973, and Abraham during 1974 and 1975. Assistants included R. F. Bartels (1971 and 1972), D. Janke (1974), and D. V. Derksen (1975). This manuscript constitutes major parts of a Ph.D. dissertation by Bergman (1974), and M.S. theses by Howard (1974) and Abraham (1975) at Iowa State University. Weller supervised this work from 1971 to 1974 while employed at Iowa State University and during 1975 while at the University of Minnesota.

Key individuals involved in the initiation and facilitation of the program were: L. W. Sowl, C. D. Evans, M. A. Monson, J. L. Haddock, and J. C. Bartonek. Many other persons aided the program and their help is sincerely appreciated.

We are indebted to numerous individuals who took time from busy schedules to comment on an earlier draft of this manuscript: J. C. Bartonek, D. V. Derksen, T. Dwyer, C. D. Evans, R. T. Holmes, K. Hussey, B. Kessel, C. Lensink, P. Meyers, H. Nelson, F. Pitelka, and L. W. Sowl. However, we assume total responsibility for the final statements.

Robert D. Bergman, Larry Haddock, and Leonard Boughton of the U.S. Fish and Wildlife Service and their pilot, Robert Johnson, were lost when their plane went down during aerial surveys in south-central Alaska in the fall of 1974. It is sincerely hoped that the results and recommendations presented here will help reduce the potential damage that concerned these dedicated men.

Study Area

The study site is near Storkersen Point (Lat. 70°24'N, Long. 148°43'W) on the Arctic Coastal Plain adjacent to the Beaufort Sea (Fig. 1). Field quarters and landing strip were afforded by an abandoned DEW-line site at the eastern edge of the study area known as Point McIntyre. The climatic regime of the summer months is reflected in data on snow cover and physical characteristics (Table 1).

Efforts were confined mainly to an 18-km^2 area bordering the Beaufort Sea coast on the north and extending inland 7 km. A capped well is present at Storkersen Point, but, as of 1975, major oil operations were 20 km southeast near Prudhoe Bay. The Kuparuk and Sagavanirktok Rivers form large deltas about 8 km west-northwest and 25 km east-southeast, respectively, of Storkersen Point (Fig. 1). The region is part of what Pitelka (1974) termed the Central River Sector of the North Slope. Elevations in the study area range from sea level at coastal lagoons to 10 m on surface residuals a few kilometers inland. The Return Islands form a barrier that affords some protection to the shoreline from wind and sea ice.

The coastal plain is an unglaciated, emergent region of the continental shelf and has low relief and poor drainage. Total area exceeds 65,000 km^2, and the east-west length is about 800 km. Typical relief features are numerous lake basins, polygonal ground, ice-cored mounds (pingos), and relief characteristics of streams and gentle slopes (Hussey and Michelson 1966). Surficial materials on the study area and most of the coastal plain are marine silts, sands, and gravels of the Pleistocene Gubik Formation (Payne et al. 1951).

The Arctic Slope is underlain with permafrost to depths of 508 m (Wahrhaftig 1965; Brooks et al. 1971), portions of which may be products of earlier climates (Pewe 1967). North of the Brooks Range, precipitation is as low as 10.2 cm annually, but arid surface conditions are prevented by low evaporation and transpiration rates and by the lack of subterranean drainage because of permafrost (Johnson and Hartman 1969). The Arctic Slope is further characterized by poor soils (Everett 1975) and tundra vegetation of low growth form (Spetzman 1959; Wiggins and Thomas 1962; Nieland and Hok 1975; Webber and Walker 1975). In spring, water from rapidly melting snow flows over frozen surfaces and fills the numerous shallow thaw lakes and ponds, streams, and rivers (Irving 1972). As summer progresses, the active layer thaws to a depth ranging from 15 cm to 3.66 m, depending on soil type, exposure, drainage, and climate. Standing water disappears from some depressions late in July, but the percentage of the surface area covered by wetlands remains high.

Thaw basins on the Arctic Coastal Plain may form wherever water accumulates on the surface due to restricted drainage (Carson and Hussey 1962). Basins originate in low-center polygons and at junctions of ice wedges. Water impounded in these depressions is heated by insolation in summer and thaws the ground ice below. Alternating processes of freezing, thawing, and water movement enlarge and deepen the basins. As the basins enlarge, breaching

Table 1. *Weather data and phenological events at the Storkersen Point study area from about 1 June to 15 August each year except 1975 when field work ended in late July.*

	1971	1972	1973	1974	1975
Mean temperature (C) (1 June–14 Aug.)					
Daily average	5.0	2.8	3.3	2.8	—
Daily minimum	1.1	0.6	0.6	0.6	-1.1
Daily maximum	7.8	5.0	5.6	5.6	4.4
Extreme temperature (C)					
High	23.3	15.6	24.4	26.1	21.1
Low	-3.3	-4.4	-2.8	-8.3	-6.7
Wind					
Prevailing direction	ENE	ENE	NE	NE	NE
Mean velocity (km/h)	17.7	19.3	16.1	—	—
Highest steady velocity (km/h)	56.3	64.4	56.3	—	—
Sky condition (Percent)					
Clear-partly cloudy	50	40	40	47	—
Overcast	35	35	45	37	—
Fog	15	25	15	17	—
Snow cover (Date)					
50 percent	3 June	10 June	3 June	10 June	10 June
Small wetland ice-free	8 June	15 June	10 June	18 June	11 June
Largest lake (60 ha)					
Ice-free	22 June	2 July	1 July	8 July	2 July

of shorelines by thawing results in fusion or in drainage. Much of the coastal plain land surface is marked by numerous such drained basins in which second generation wetlands have formed in the bottom of the drained lake (Livingstone et al. 1958).

Based on size and shape differences of thaw lakes, Carson and Hussey (1962) divided the coastal plain into eastern and western sections, separated by a boundary paralleling the Colville River at approximately longitude 152°W. In the eastern section, which included the study area, wetlands generally range from about 3 m to rarely more than 1.6 km in length. In the western section, wetlands frequently exceed 1.6 km and several are more than 13 km long.

Thaw lakes commonly are elongate with the long axis oriented 10 to 15 degrees west of true north. According to Carson and Hussey (1962), regularity in basin orientation is caused by a system of circulating currents set up in the lakes by prevailing northeasterly winds.

Part I—Bird Populations

Procedures

Numbers of waterfowl (Anatidae), loons (Gaviidae), phalaropes (Phalaropodidae), sandpipers (Scolopacidae), plovers (Charadriidae), and jaegers (Stercorariidae) were appraised by weekly or biweekly censuses conducted by two or three men. Birds were counted on two 2.6-km^2 plots in 1971, and a third plot was added during the period 1972 to 1975. The three areas were sections 13, 24, and 25 of R 13 E, T 12 N, Umiat meridian, as shown on the 1970 U.S. Geological Survey maps 2561 1 NW and 2561 SW (Fig. 2). Because home ranges of whistling swans *(Olor columbianus)* were larger than the census plots, swan densities were estimated from observations on an 18-km^2 area frequently traversed by the investigators. Other birds were counted on a strip 8 km long and 100 m wide in 1971 and on nine widely spaced

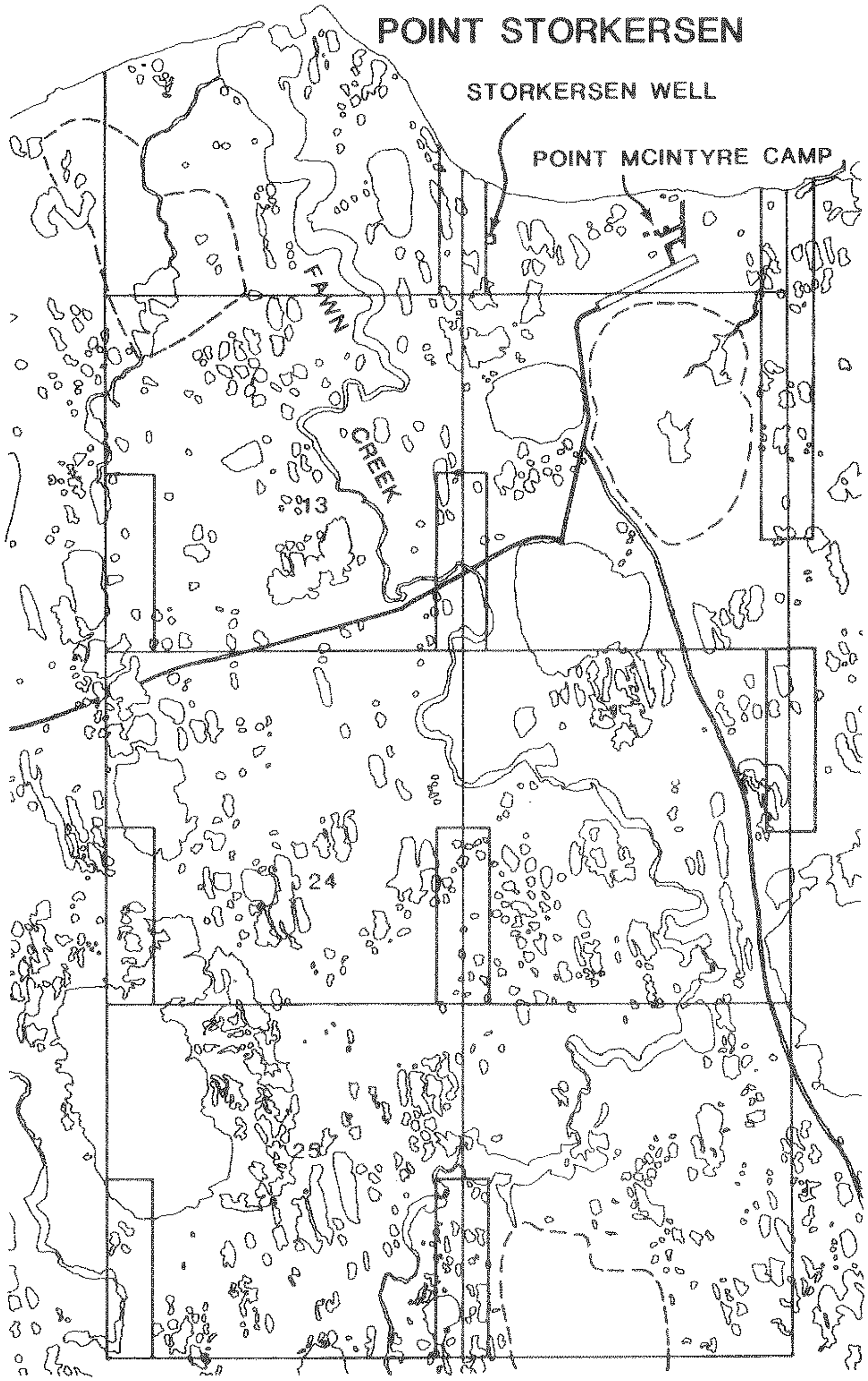

Fig. 2. Map of the Storkersen Point study area showing the Pt. McIntyre Distant Early Warning (DEW-line) site, Storkersen Well, the sections (1.6 km intervals) used for large-bird surveys, and the strips (0.2 km wide) used for small-bird surveys.

quadrats of the same length but 200 m wide totaling 1.6 km^2 in 1972 through 1975 (Fig. 2).

Although no attempt was made to find all nests, those found in the study area were marked with a garden wand and the location was recorded on a map. During 1971–73, nests were rechecked approximately weekly to determine clutch size and nest success. Any nest in which one egg or more hatched was considered successful.

Nesting Species

Water-related birds dominated the bird fauna near Storkersen Point. Of the 25 species that nested in the study area, 11 were swimming birds (waterfowl, loons, and phalaropes), and 4 were wading birds (sandpipers). In addition, black-bellied plovers *(Pluvialis squatarola)*, jaegers *(Stercorarius)*, and glaucous gulls *(Larus hyperboreus)* occasionally used water areas. Lapland longspurs *(Calcarius lapponicus)* and snow buntings *(Plectrophenax nivalis)* were the only breeding passerines, primarily because brush and shrub habitats used by other species on the Arctic Slope (Kessel and Cade 1958; Pitelka 1974) do not exist on this portion of the coastal plain.

Eighteen of the 25 species of nesting birds arrived when snow covered more than 75% of the tundra (Table 2). Water used by black brant *(Branta nigricans)*, ducks, and red phalaropes *(Phalaropus fulicarius)* at this time was in tundra depressions or partially thawed ponds. Terrestrial or grazing birds occupied snow-free patches of tundra. The arctic loon *(Gavia arctica)* and red-throated loon *(Gavia stellata)* were among the last birds to arrive.

Before the ice had melted at Storkersen Point, water birds gathered in nearby staging areas where water was available. Each year, arctic loons, red-throated loons, and king eiders *(Somateria spectabilis)* concentrated in deltas of the Sagavanirktok and Kuparuk Rivers and adjacent zones of the Beaufort Sea where rivers carried melt water to the coast from the phenologically advanced Arctic Foothills and interior coastal plain. An extensive zone partially free of snow and ice also surrounded oil facilities a few

Table 2. *First sighting of 25 species of breeding birds in relation to spring thaw, based on observations from 30 or 31 May each year, 1971–75, at Storkersen Point.*

Species	Range of arrival dates	Maximum snow cover (Percent)
Whistling swan *(Olor columbianus)*	a	> 90
Glaucous gull *(Larus hyperboreus)*	a to 1 June	> 90
Lapland longspur *(Calcarius lapponicus)*	a to 1 June	> 90
White-fronted goose *(Anser albifrons)*	a to 3 June	> 90
Dunlin *(Calidris alpina)*	a to 3 June	> 90
Baird's sandpiper *(C. bairdii)*	a to 3 June	> 90
Semipalmated sandpiper *(C. pusilla)*	a to 4 June	> 90
Ruddy turnstone *(Arenaria interpres)*	a to 4 June	> 90
Snow bunting *(Plectrophenax nivalis)*	a	> 90
American golden plover *(Pluvialis dominica)*	a to 5 June	> 75
Oldsquaw *(Clangula hyemalis)*	a to 5 June	> 75
Pectoral sandpiper *(Calidris melanotos)*	a to 5 June	> 75
Pintail *(Anas acuta)*	a to 7 June	> 75
Black-bellied plover *(Pluvialis squatarola)*	a to 7 June	> 75
Parasitic jaeger *(Stercorarius parasiticus)*	a to 3 June	> 75
King eider *(Somateria spectabilis)*	1 to 5 June	> 75
Red phalarope *(Phalaropus fulicarius)*	1 to 8 June	> 75
Black brant *(Branta nigricans)*	2 to 3 June	> 75
Long-tailed jaeger *(Stercorarius longicaudus)*	2 to 11 June	> 75
Northern phalarope *(Lobipes lobatus)*	2 to 11 June	50–75
Red-throated loon *(Gavia stellata)*	5 to 11 June	25–50
Arctic loon *(Gavia arctica)*	7 to 12 June	25–50
Spectacled eider *(Somateria fischeri)*	7 to 16 June	25–50
Buff-breasted sandpiper *(Tryngites subruficollis)*	7 to 16 June	0–25
Long-billed dowitcher *(Limnodromus scolopaceus)*	16 to 29 June	0–10

[a] Birds on study area when investigators arrived on 30 or 31 May.

kilometers south at Prudhoe Bay, but this early melting was probably caused by road dust covering the snow (Benson et al. 1975).

Of the total number of birds in the study area each spring (Table 3), shorebirds (plovers, sandpipers, and phalaropes) made up 60 to 70%, and waterfowl represented about 15%. Red phalaropes were most abundant, ranging from 15 to 37 birds per km^2 in June. Among waterfowl, densities of pintails *(Anas acuta)*, oldsquaws *(Clangula hyemalis)*, and king eiders were highest, but about 80% of the pintails were males, suggesting that most were nonbreeders. Only two pintail nests were found, both in 1973 when the Prairie Pothole Region was dry, and no broods were seen. Pitelka (personal communication) indicates that breeding of pintails is more regular in the Point Barrow area. Nonbreeders formed approximately 50 to 75% of the black brant and white-fronted goose *(Anser albifrons)* populations in June. Lapland longspurs varied from 10 to 49 birds per km^2 and constituted the dominant upland bird.

Nest initiation by summer residents closely followed their arrival (Table 4). Whistling swans, semipalmated sandpipers *(Calidris pusilla)*, and Lapland longspurs began nesting first, and loons and buff-breasted sandpipers *(Tryngites subruficollis)* started last. Laying was late in 1972 (Table 3), especially for early nesters, due to a delay of approximately 1 week in thawing of snow and ice in nesting habitats. Nesting occurred mainly during periods shown in Fig. 3. Because no attempt was made to find all nests in the study area, numbers shown in Table 4 give only a relative index of nest densities for the majority of species. Red phalaropes and semipalmated sandpipers nested in the highest densities. Pectoral sandpipers *(Calidris melanotos)* and dunlins *(Calidris alpina)* undoubtedly nested in larger numbers than indicated in Table 3, but females usually flushed so far from investigators that they could not locate the nest. All nests of loons and whistling swans and most nests of eiders and white-fronted geese probably were found during the study,

Table 3. *Range of densities of 24 species of breeding birds as shown by lowest and highest values recorded in June, July, and August 1971-75.*

Species	No. per km^2					
	June		July		1-15 August	
	Low	High	Low	High	Low	High
Arctic loon	0.0	1.6	1.0	2.9	1.6	2.2
Red-throated loon	0.0	1.6	0.1	1.6	0.1	1.6
Whistling swan	0.0	0.1	0.0	0.5	0.0	0.4
Black brant[a]	0.0	5.1	0.0	2.0	0.0	0.0
White-fronted goose[a]	0.3	1.6	0.0	2.0	0.4	8.6
Pintail[b]	0.3	7.8	0.0	6.6	8.6	21.1
King eider	0.3	8.9	0.1	3.5	0.4	1.2
Spectacled eider	0.0	1.8	0.0	0.4	0.0	0.6
Oldsquaw	0.3	5.1	1.2	4.3	0.1	9.0
American golden plover	0.1	3.8	0.0	3.5	0.0	5.9
Black-bellied plover	0.0	0.6	0.1	1.6	0.4	2.3
Ruddy turnstone	0.0	3.2	0.0	0.4	0.0	0.4
Buff-breasted sandpiper	0.0	10.0	0.0	3.0	0.0	3.2
Pectoral sandpiper	3.8	22.0	2.5	19.0	8.0	40.4
Dunlin	9.0	21.2	0.0	20.0	5.0	16.0
Baird's sandpiper	0.0	4.0	0.0	6.0	0.4	5.0
Semipalmated sandpiper	11.0	20.0	8.0	47.0	2.0	17.3
Red phalarope	15.6	37.0	3.2	32.0	8.0	83.9
Northern phalarope	0.0	5.0	0.0	3.0	0.0	53.2
Parasitic jaeger	0.4	0.5	0.1	1.2	0.0	0.8
Long-tailed jaeger	0.0	0.4	0.0	0.4	0.0	0.4
Glaucous gull	0.1	0.2	0.3	0.3	0.3	0.3
Lapland longspur	10.0	48.8	6.0	10.0	2.0	5.1
Snow bunting	0.0	3.0	0.0	4.0	0.0	5.0

[a] Nonbreeders made up 50 to 75% of the population in June.

[b] Nonbreeders made up more than 90% of the population in June.

Table 4. *Estimated date of first egg laying and clutch size of birds at Storkersen Point, 1971-73.*

Species	No. of nests	Est. date first egg laid in June 1971	1972	1973	Clutch size Mean	Mode	Range	No.
Arctic loon	42	20	23	21	2.0	2	-2-	23
Red-throated loon	28	18	25	21	1.8	2	1-2	21
Whistling swan	4	1	12	—	3.0	3	-3-	3
Black brant	11	5	18	12	5.0	5	-5-	4
White-fronted goose	8	5	15	9	4.7	4	3-8	7
Pintail	2	—	—	8	6.0	6	6	1
King eider	32	8	19	10	4.5	4	2-7	17
Spectacled eider	3	—	21	—	4.5	4-5	4-5	2
Oldsquaw	16	9	19	23	6.7	7	6-7	3
Golden plover	13	7	22	9	3.8	4	3-4	10
Black-bellied plover	1	—	20	—	4.0	4	4	1
Ruddy turnstone	1	—	20	—	4.0	4	4	1
Buff-breasted sandpiper	4	17	24	22	3.8	4	3-4	4
Pectoral sandpiper	2	23	26	—	4.0	4	-4-	2
Dunlin	9	20	7	10	4.0	4	-4-	7
Baird's sandpiper	5	—	10	—	3.6	4	3-4	5
Semipalmated sandpiper	34	4	8	6	3.9	4	3-4	29
Red phalarope	46	14	15	15	3.8	4	3-4	30
Northern phalarope	2	14	20	—	4.0	4	-4-	2
Parasitic jaeger	7	14	16	10	2.0	2	-2-	7
Long-tailed jaeger	4	18	18	12	2.0	2	-2-	4
Glaucous gull	3	—	—	10	3.0	3	-3-	2
Lapland longspur	15	2	7	1	5.6	6	3-7	9
Snow bunting	8	9	12	10	6.0	6	-6-	2

because incubating birds were conspicuous and considerable time was devoted to this effort. Data on clutch size shown in Table 4 represent those nests in which egg numbers did not change on subsequent nest checks made about 1 week apart. A red phalarope nest containing eight eggs is not included in Table 4, because two females probably laid in the nest.

The number of avian predators such as jaegers, glaucous gulls, and common ravens *(Corvus corax)* did not appear to vary over the 5 years. Most predation seemed to be by arctic foxes *(Alopex lagopus)* which were present each year but could not be counted. Losses of eggs of loons, eiders, shorebirds, and jaegers were lowest in 1972 when there were fewer sightings of foxes (Table 5). One gray wolf *(Canis lupus)* was observed in 1974, and one barren ground grizzly bear *(Ursus horribilis)* was seen in 1975.

In addition to recruitment of young, emigration and immigration of birds influenced composition and densities (Table 3) of populations in the postnesting period. Changes were most noticeable for sexually dichromatic species. Male king eiders and spectacled eiders *(Somateria fischeri)* abandoned their mates in late June or early July and migrated to sea; females unsuccessful at nesting left by August. Male oldsquaws moved to the coastal waters of the Beaufort Sea in mid-July to pass their flightless stage. However, numbers of oldsquaw increased on the study area in August, because females without young grouped on a large lake during their annual wing molt. Female red phalaropes gathered in large flocks and emigrated in late June or early July, and most adult males were gone by August. Large flocks, presumed to be mainly juveniles, reappeared in August in some years. Increased densities of white-fronted geese and pintails in August (Table 3) resulted from an influx of postmolting birds.

The latest observations were made on 1 and 2 September 1973 when loons, swans, and female oldsquaws occupied the same wetlands they used in August, and flocks of pectoral sandpipers and snow buntings *(Plectrophenax nivalis)* were common. Numbers of other species, however, were considerably reduced from summer levels. Species not seen in September included ruddy turnstone *(Arenaria interpres)*, buff-breasted sandpiper *(Tryngites subruficollis)*, Baird's sandpiper *(Calidris bairdii)*, semipalmated sandpiper, and long-tailed jaeger *(Stercorarius longicaudus)*. Few red phalaropes were on the study area, but several groups of immatures occupied coastal waters of the Beaufort Sea.

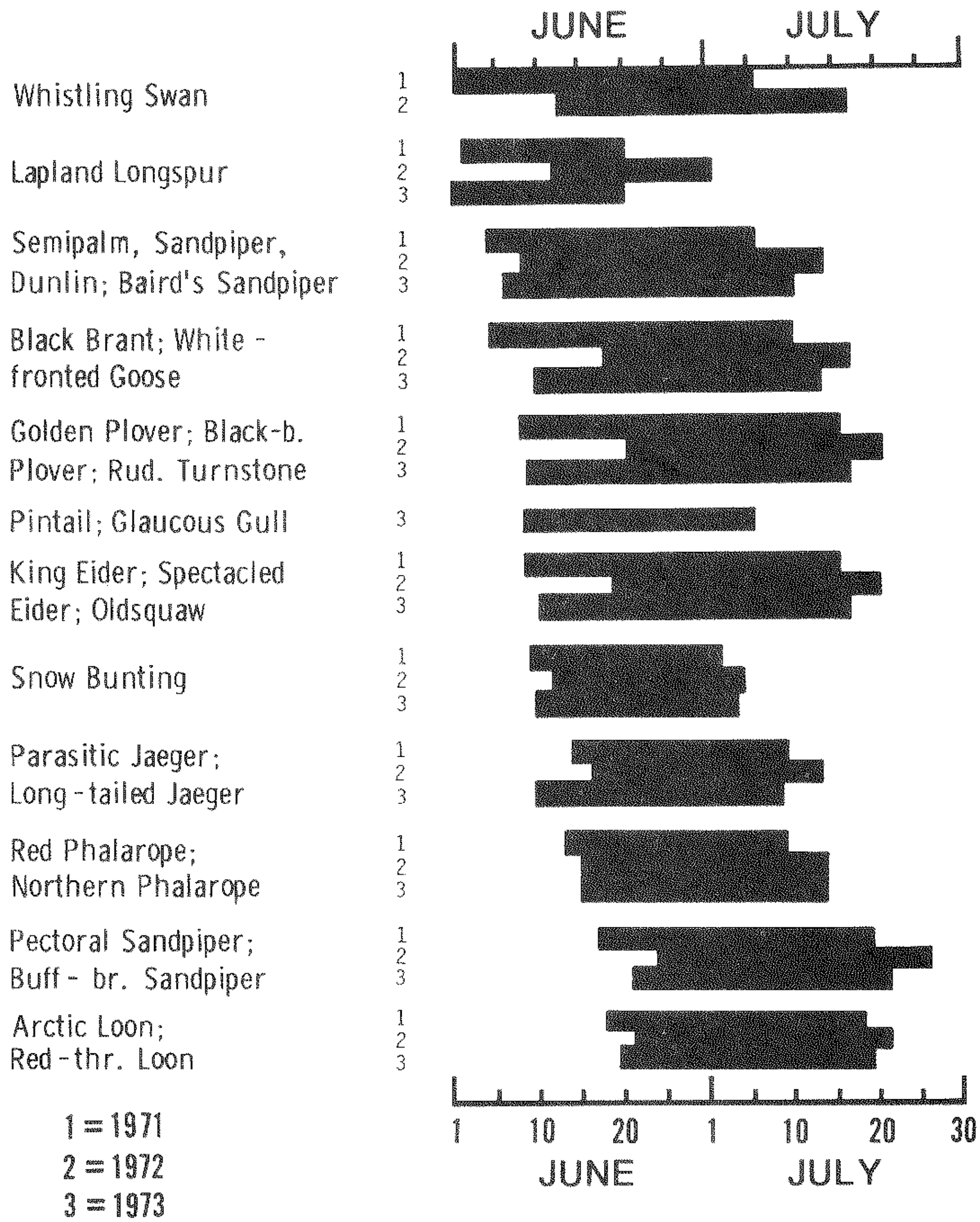

Fig. 3. Chronology and duration of nesting at Storkersen Point, 1971-73.

Table 5. *Estimates of nest success and production for birds in the Storkersen Point area, 1971-73.*

	1971		1972		1973	
Species	Percent nest success (No.)	Average young per km²	Percent nest success (No.)	Average young per km²	Percent nest success (No.)	Average young per km²
Arctic loon	28(14)	0.4	92(12)	0.7	53(15)	0.6
Red-throated loon	33(6)	0.3	78(9)	0.6	45(9)	0.4
Whistling swan	100(1)	0.2	100(1)	0.2	100(1)	0.2
Black brant	0(4)	—	0(2)	—	0(2)	—
White-fronted goose	100(1)	0.6	100(4)	1.4	50(2)	0.5
Pintail	—	—	—	—	0(2)	—
King eider	0(3)	0.4	15(13)	1.6	0(16)	0.4
Spectacled eider	—	—	50(2)	0.2	0(1)	—
Oldsquaw	0(4)	—	0(6)	0.3	0(6)	—
Golden plover	25(4)	0.4	60(5)	1.0	33(3)	0.6
Black-bellied plover	—	0.2	100(1)	0.2	—	0.2
Ruddy turnstone	—	—	0(1)	0.2	—	—
Buff-breasted sandpiper	0(1)	—	50(2)	0.4	0(1)	—
Pectoral sandpiper	0(1)	0.4	—	2.7	—	3.9
Dunlin	0(2)	1.6	100(4)	13.3	33(3)	9.8
Baird's sandpiper	—	0.4	67(3)	2.0	0(1)	1.2
Semipalmated sandpiper	18(13)	2.3	88(8)	3.9	75(4)	6.6
Red phalarope	17(23)	2.3	80(10)	11.7	25(8)	6.6
Northern phalarope	0(1)	0.4	—	0.4	—	0.4
Parasitic jaeger	0(2)	—	100(2)	0.6	50(2)	0.2
Long-tailed jaeger	0(1)	—	100(1)	0.2	0(1)	—
Glaucous gull	100(1)	0.2	100(1)	0.2	—	—
Lapland longspur	0(4)	1.2	80(5)	3.1	67(6)	5.9
Snow bunting	67(3)	0.8	100(3)	0.8	100(2)	0.8
Total		12.1		45.7		38.3

Visitors

In addition to the 25 species of birds known to breed at Storkersen Point, 47 species of birds were observed but not found nesting (Table 6). Some obviously visited from nearby nesting or roosting areas: Canada goose *(Branta canadensis)*, lesser snow goose *(Chen caerulescens)*, common eider *(Somateria mollissima)*, glaucous gull, arctic tern, and common raven. Based on brood sightings, a few Canada geese nested on the mainland about 10 to 15 km south of Storkersen Point and in the Kuparuk River delta. In 1973, nests of 40 lesser snow geese were found on Howe Island in the Sagavanirktok River delta. The colony seemingly was first established in 1971 (Gavin 1975) and is the only known nesting colony of lesser snow geese on the North Slope of Alaska although single pairs were known to nest (King 1970). Common eiders, king eiders, glaucous gulls, and arctic terns nested on gravel islands a few kilometers off the mainland coast (Schamel 1974). Although snowy owls *(Nyctea scandiaca)* were observed in all months of the study, their occurrence was irregular during weekly censuses.

Discussion

The bird fauna near Storkersen Point reflects the preponderance of aquatic habitats as opposed to the scarcity of other avian habitats. Only 25 of 72 species nested on or near the study area. Of these, 20 species were water-related birds (loons, waterfowl, shorebirds, and gulls). The only terrestrial birds observed nesting on the study area were lapland longspurs and snow buntings, probably because tall brush and dwarf shrub habitats used by other species (Kessel and Cade 1958) did not exist on this portion of the coastal plain. Neither snowy nor short-eared owls nested on the area during this study but snowy owls hunted in the area and may nest in high lemming years.

The number and composition of breeding birds near Storkersen Point is comparable to information published about other arctic coastal tundra areas. Kessel and Cade (1958) listed 51 species in the coastal region, but at least 15 were considered rare and sporadically distributed. Andersson (1973) reported 30 species possibly nesting at Nuvagapak Point, 270 km east on the Beaufort Sea coast, and status and densities of birds were similar to birds found in this study. Gavin (1975) observed 67 species on the entire plain and suggested some breeding by at least 23 species. A thorough analysis of published data through 1974 by Pitelka (1974) indicates that, of 97 species known to breed on the entire North Slope, 44 species breed regularly on the coastal zone. However, only 22 breed regularly at Point Barrow and 13 breed occasionally.

The apparent geological and vegetational homogeneity of the coastal plain in the Prudhoe Bay tundra indicates that numbers and status of birds at Storkersen Point is fairly representative of the region. Studies just a few kilometers inland (Norton et al. 1975) reflect similar dominant breeding birds but also some casual migrants that we did not observe on the coastal areas. Number of species probably is even higher along inland river valleys where habitat diversity is greater, but coastal areas, of which the Arctic Coastal Plain habitat at Storkersen Point is an important segment, are exceptionally valuable to breeding birds such as black brant, king eiders, oldsquaws, and many shorebirds.

Part II—Wetland Types in Relation to Water Birds

Procedures

Physical and vegetational characteristics of aquatic habitats were appraised during late June and early August of 1972 and 1973. Wetlands (defined here as clearly-defined basins holding water part of the summer) sampled were those encountered while walking along seven east-west lines spaced approximately 1 km apart; four of these transects were 3.2 km long and three were 1.6 km long. In August 1972, measurements of water depth and plant distribution were made in all wetlands within the 7.8 km^2 areas used to census loons and waterfowl. Sampling procedure in 1972 involved determining water depths, hydrogen ion concentration (pH), and free carbon dioxide. Water depths, recorded as the distance from water surface to the surface of basin sediments, were measured 1 m from the eastern and western shores and in the center of the basin. The two shoreward measurements and two measurements in the center of the basin were used to calculate mean water depth of each wetland. Hydrogen-ion concentration was determined with a Hach pH Kit (Model 17-N)[1]. In 1973, specific conductance of surface water was measured in 18 ponds with a Hach Conductivity Meter (Model 2510) that recorded in micromhos per centimeter. Temperature was recorded in ponds of different sizes with Marshalltown Model 1000 continuous-recording thermographs.

In June 1972, two lines were established across each wetland in east-west and north-south directions, and the presence or absence of various plants was recorded at 10-cm intervals along each line. During August of 1972, visual estimates were made of the percentage of each wetland supporting vegetation.

Use of wetlands by loons and waterfowl was appraised by weekly or biweekly ground surveys via the same techniques used for assessment of populations of small birds. Base maps prepared from the U.S. Geological Survey 1:24,000 series Orthophotomap (Topographic) were used to record locations of water birds.

Characteristics of Wetlands

Characteristics of wetlands useful in deriving a classification system were size, depth, species, and abundance of vascular aquatic plants and water chemistry. Data on thermal regimes also were collected.

Size and depth.—Wetlands near Storkersen Point varied from small, flooded tundra depressions a few meters long to open lakes or marshy, partially-drained lake basins over 1 km long. Still larger lakes were prominent further inland and in the western part of the plain. Depths ranged from a few centimeters in flooded tundra to a maximum of 1.1 m in the larger lakes. Flooded depressions and small, shallow ponds rimmed with sedge *(Carex aquatilis)* were the most numerous wetlands, representing nearly one-half of the total wetland area during the period of available aquatic habitat. Their small size lessened their use by large water birds. Large lakes and marshy areas in partially-drained basins provided the largest units of permanent aquatic habitat.

The relationship between surface area and water depth of wetlands (Fig. 4) revealed that mean depth of the smaller classes of first generation basins increased directly with increasing surface area. The relationship was less predictable in the large size classes because of partial drainage of these wetlands or union with adjacent basins lying at a lower level.

[1]Reference to trade names does not imply Government endorsement of commercial products.

Table 6. *Birds observed at Storkersen Point that did not nest in the study area.*

Species	Date of first observation 1971	1972	1973	1974	1975	Status[a]	Maximum number seen
Common loon *(Gavia immer)*	—	2 July	—	—	6 June	E	6
Yellow-billed loon *(G. adamsii)*	—	4 June	—	11 June	—	C	4
Canada goose *(Branta canadensis)*	19 June	4 June	4 June	12 June	16 June	A	110
Lesser snow goose *(Chen caerulescens)*	4 June	4 June	8 June	8 June	29 June	A	105
Mallard *(Anas platyrhynchos)*	4 June	2 Aug.	20 June	13 June	—	C	5
American wigeon *(A. americana)*	2 June	9 June	2 June	31 May	—	C	145
Northern shoveler *(A. clypeata)*	—	—	9 June	—	—	C	10
Green-winged teal *(A. crecca carolinensis)*	4 June	8 Aug.	6 June	—	—	C	65
Greater scaup *(Aythya marila)*	4 June	—	14 June	—	18 June	C	7
Common eider *(Somateria mollissima)*	7 June	—	9 June	30 May	3 June	A	3
Steller's eider *(Polysticta stelleri)*	8 June	12 June	7 June	—	—	C	36
Surf scoter *(Melanitta perspicillata)*	7 June	1 July	25 June	7 July	—	C	66
Red-breasted merganser *(Mergus serrator)*	—	28 June	—	7 July	—	C	2
Rough-legged hawk *(Buteo lagopus)*	5 Aug.	29 June	8 June	—	—	C	5
Golden eagle *(Aquila chrysaetus)*	—	9 July	—	—	28 July	C	1
Peregrine falcon *(Falco peregrinus)*	27 June	27 July	11 July	—	—	C	5
Rock ptarmigan *(Lagopus mutus)*	—	[b]	[b]	—	—	D	17
Semipalmated plover *(Charadrius semipalmatus)*	—	—	8 June	—	—	C	1
Common snipe *(Capella gallinago)*	4 June	—	—	—	—	C	1
Lesser yellowlegs *(Tringa flavipes)*	—	—	6 June	—	—	C	1
Stilt sandpiper *(Micropalama himantopus)*	30 July	1 Aug.	24 July	2 Aug.	—	B	180
Whimbrel *(Numenius phaeopus)*	—	—	—	—	17 July	C	1
White-rumped sandpiper *(Calidris fuscicollis)*	2 June	—	—	—	—	C	20
Bar-tailed godwit *(Limosa lapponica)*	—	4 June	—	—	—	C	2
Pomarine jaeger *(Stercorarius pomarinus)*	[b]	2 June	1 June	31 May	3 June	B	180
Thayer's gull *(Larus thayeri)*	—	15 June	9 Aug.	—	—	C	2
Sabines's gull *(Xema sabini)*	6 June	6 June	4 June	9 Aug.	—	C	50
Arctic tern *(Sterna paradisaea)*	4 June	9 June	5 June	5 June	7 June	A	250
Murre *(Uria* sp.*)*	20 July	—	—	—	—	E	30
Tufted puffin *(Lunda cirrhata)*	—	12 Aug.	—	—	—	E	1
Snowy owl *(Nyctea scandiaca)*	[b]	[b]	[b]	[b]	[b]	B	40
Short-eared owl *(Asio flammeus)*	[b]	3 June	4 June	11 June	4 June	C	21
Horned lark *(Eremophila alpestris)*	—	—	6 June	—	—	C	2
Cliff swallow *(Petrochelidon pyrrhonota)*	7 June	—	—	—	7 June	C	1
Bank swallow *(Riparia riparia)*	—	9 June	—	—	5 June	C	1
Common raven *(Corvus corax)*	[b]	16 June	5 June	30 May	5 June	B	150
American robin *(Turdus migratorius)*	—	—	[b]	—	—	C	1
Wheatear *(Oenanthe oenanthe)*	—	8 June	—	—	1 July	C	1
Yellow wagtail *(Motacilla flava)*	—	5 July	—	—	—	C	1
Water pipit *(Anthus spinoletta)*	—	—	—	—	7 June	C	1

Continued

Table 6. *Birds observed at Storkersen Point that did not nest in the study area.—Continued*

Species	Date of first observation					Status[a]	Maximum number seen
	1971	1972	1973	1974	1975		
Wilson's warbler *(Wilsonia pusilla)*	—	—	1 Sept.	—	—	C	1
Redpoll *(Acanthis* sp.*)*	—	2 June	6 June	8 June	8 June	C	100
Savannah sparrow *(Passerculus sandwichensis)*	2 June	—	11 June	—	9 June	C	4
Dark-eyed junco *(Junco hyemalis)*	—	—	—	5 June	—	C	1
Tree sparrow *(Spizella arborea)*	—	4 June	5 June	2 June	—	C	2
White-crowned sparrow *(Zonotrichia leucophrys)*	—	2 June	—	—	—	C	2
Fox sparrow *(Passerella iliaca)*	—	9 June	—	—	—	C	1

[a] Status: A = Visitor from nearby nesting or roosting sites.
B = Regular summer visitor.
C = Casual or accidental visitor.
D = Winter visitor.
E = Individuals observed over coastal water of the Beaufort Sea.
— = Not seen.

[b] Birds on study area when investigators arrived on 30 or 31 May.

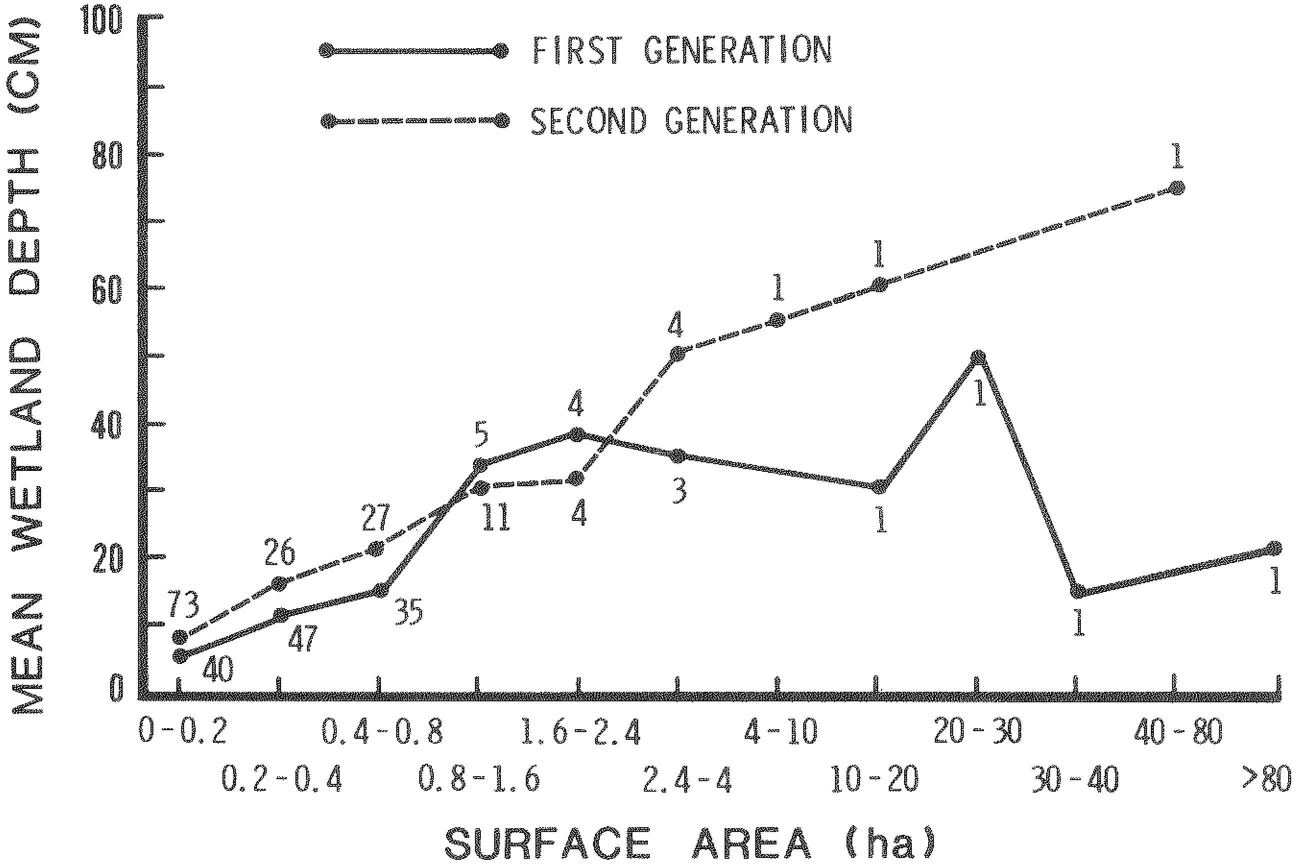

Fig. 4. Relationship between mean water depth and surface area of first and second generation wetlands, 2–8 August 1973. Sample size shown by points.

In contrast, second generation wetlands formed in drained basins showed a uniform increase in mean depth as basin area increased. Presumably, drainage of these newer basins was rare because of their low elevation.

First generation wetlands can attain considerable size before drainage occurs. Several lakes of more than 150 ha and more than 1.5 m deep occurred within 10 km of the study site. Consequently, the depth-area curve for that region would differ markedly from Fig. 4.

Factors other than drainage also contributed to variations in the direct relationship between basin area and water depth. Carson and Hussey (1962) ascribed differences in depth of similar size thaw lakes near Barrow, Alaska (Lat. 71°20′N, Long. 156°50′W), to irregularities in ground ice distribution, particle size of sediments, and individual basin histories. In the Storkersen Point area, a noticeable cause was recent coalescence of two or more basins which, in effect, increased surface area relative to water depth.

Vascular aquatic plants.—Distribution of vascular plants in wetlands on the coastal plain is influenced by water depth (Britton 1957). Fig. 5 illustrates the occurrence of *Carex aquatilis* (water sedge) and *Arctophila fulva* (pendant grass) in relation to water depth of wetlands near Storkersen Point; depth measurements were taken at the shallow and deep water margins of stands. Of 69 stands examined, *C. aquatilis* was prevalent on moist soils and progressively less so at increasing water depth; plants were not found at water depths greater than 30 cm. Optimal depths for *A. fulva* (52 stands) occurred between 20 and 45 cm, and plants were absent in depths exceeding 80 cm. Few stands were encountered that contained large numbers of both species, and an obvious belted pattern in wetlands resulted where *C. aquatilis* formed shoreward stands abutting deeper water stands of *A. fulva*. The intersection of depth-frequency lines in Fig. 4 indicates that 15 cm is the most frequent depth interface between the two species. Because *C. aquatilis* and *A. fulva* are dominant vascular plants

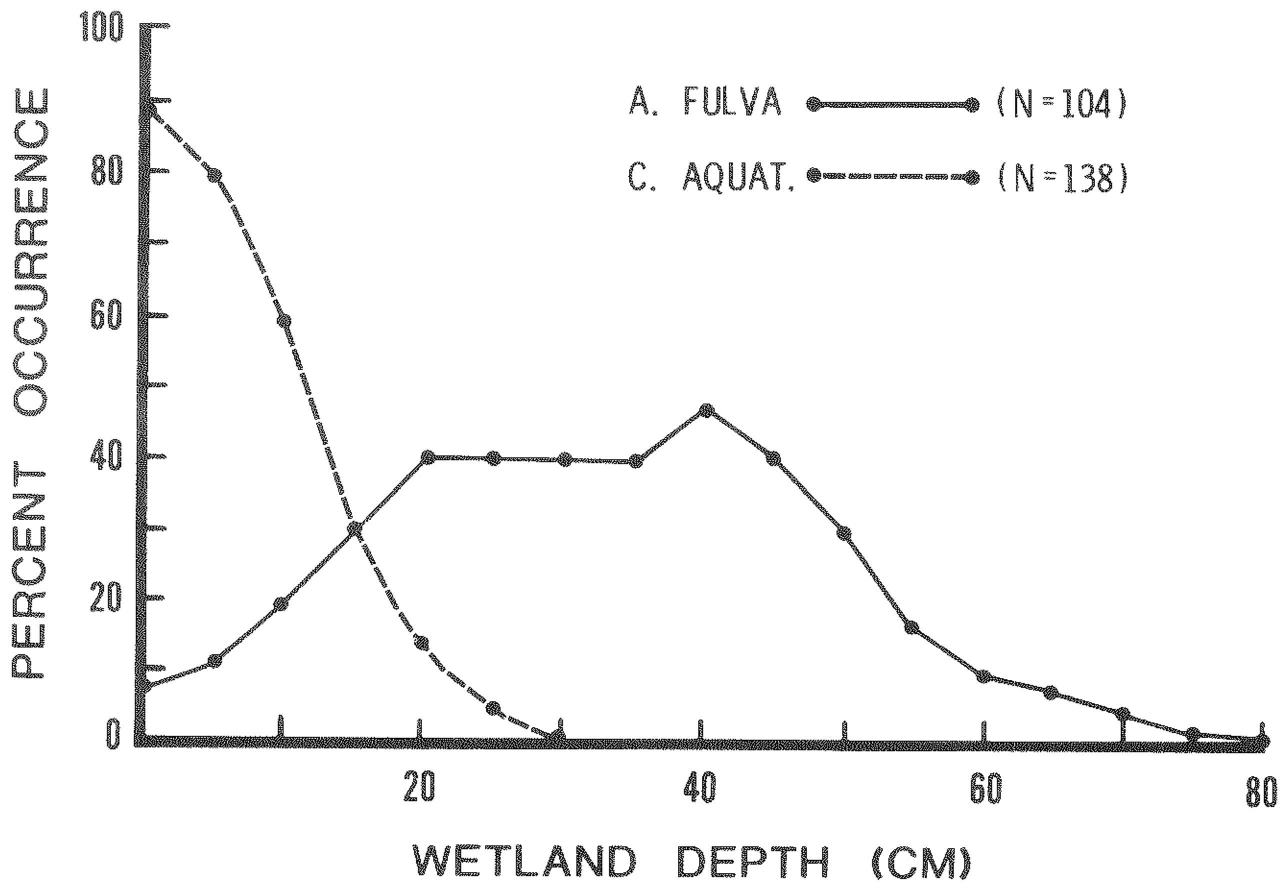

Fig. 5. Occurrence of *Carex aquatilis* and *Arctophila fulva* in relation to water depths. Measurements are an average of minimum and maximum depths in stands found in 80 wetlands, 2–3 August 1973.

in freshwater habitats near Storkersen Point and throughout the coastal plain (Spetzman 1959), the distribution of these emergents is a good indicator of changes in wetland basins resulting from thawing of the permafrost.

Other vascular plants found in freshwater wetlands near Storkersen Point were less widely distributed than *Carex aquatilis* and *Arctophila fulva*: *Eriophorum angustifolium*, *E. russeolum* and *E. scheuchzeri* often formed mixed stands with *C. aquatilis* but were less tolerant of standing water; few such plants grew in depths greater than 10 cm. *E. angustifolium* frequently formed nearly pure stands on moist soils and on low-center polygon basins covered by a few centimeters of water. *Hippuris vulgaris*, *Caltha palustris*, *Cardamine pratensis*, *Ranunculus pallasii*, *R. gmelini*, and *R. hyperboreus* usually were found submerged and growing from a peat substrate. An aquatic moss, *Drepandocladus* sp., also was common in such situations.

The influence of water chemistry on the distribution and composition of aquatic plants was apparent in coastal wetlands containing brackish or subsaline water. These basins lacked *Carex aquatilis* and *Arctophila fulva*. Moreover, the only plants found in these wetlands were a sedge *(Carex subspathacea)* and a grass *(Puccinellia phryganodes)*, two relatively prostrate and diminutive species that inhabit shallow water and adjacent uplands. At Storkersen Point, neither was found outside zones occasionally flooded by sea water, a pattern in agreement with Wiggins and Thomas (1962).

Water chemistry.—Wetlands were ranked by salinity groupings used by Stewart and Kantrud (1972) for classification of prairie ponds. Basins connected to the sea or periodically flooded by sea water during tides or storms (coastal lowlands in Table 7) contained brackish or subsaline water (3,800 to 20,000 micromhos/cm; $n = 10$, 2 to 9 August 1973). Specific conductivity of coastal sea water in

Table 7. *Specific conductance and hydrogen ion concentration of wetlands near Storkersen Point in early August 1972.*

Location of wetlands	Specific conductance (micromhos/cm)			pH		
	Mean	Range	No.	Mean	Range	No.
Coastal lowlands	>14,440[a]	3,800 - >20,000[a]	11	8.9	8.9	3
Coastal uplands	730	405 - 1,370	17	8.7	8.5-8.9	11
Inland (>1.609 km)	365	220-550	50	8.5	6.2-9.0	43

[a] Maximum meter reading was 20,000 micromhos/cm.

August varied from 16,000 to more than 20,000 micromhos/cm (the scale limit of the conductivity meter, $n = 3$), values which are within the normal subsaline range (14,000 to 45,000 micromhos/cm). Wetlands lying within a few meters of the coast, but situated above sea level, were slightly brackish, and measurements were never higher than 1,370 micromhos/cm in August. As distance from the sea increased, conductivity of waters decreased, and a level of 500 micromhos/cm between slightly brackish and freshwater wetlands occurred approximately 1.5 km inland from the coast.

The pH of surface water (Table 7) in aquatic habitats ranged from slightly acid (6.2) to very basic (9.0). Waters of coastal lowlands had pH values of 8.9 ($n = 3$), measurements identical to coastal Beaufort Sea water. Seasonal increases in specific conductance of wetlands were evident from measurements taken in late June and early August 1972. Presumably, this seasonal change results from dilution by relatively pure melt water during spring breakup, followed by declining water levels during summer. Seasonal variation in water chemistry (Table 8) shows the effects of seasonal drying.

Thermal regimes.—Because ice forms to depths of about 2 m in coastal plain lakes (Brewer 1958), wetlands near Storkersen Point were completely frozen until late May or early June. Open water first occurred where snow melt filled tundra depressions and where snow and surface ice thawed on shallow ponds. Once thaw began, ice in these shallow wetlands melted from top to bottom within a few days. Mean daily temperature of shallow waters often exceeded the mean for surrounding air due to differential warming and cooling rates (Danks 1971). Large, deep lakes thawed last and were completely open by late June 1971 and early July in other years. In contrast to smaller wetlands, ice on lakes floated after it had melted sufficiently to become free from the bottom. This resulted in a moat of open water surrounding a central cake of ice which persisted as long as 2 weeks.

Most arctic lakes and probably all coastal plain wetlands are essentially isothermal in summer. Livingstone et al. (1958) found no thermal stratification even in arctic mountain lakes 18 m deep. Near Point Barrow, constant mixing of waters by wind maintains an isothermal condition in all wetlands (Brewer 1958), although Carson and Hussey (1962) did find some stratification in shallow, marshy portions of lakes where water was free from intense wave agitation.

The magnitude of diurnal temperature fluctuations in wetlands was inversely related to basin volume

Table 8. *Seasonal changes in some chemical variables of aquatic habitats at Storkersen Point, 1972.*

	1 June - 14 June	15 June - 14 July	15 July - 8 August
pH	6.9 (6.2- 7.9)[a]	7.6 (6.2- 8.5)	8.0 (6.7- 8.7)
Total hardness (ppm $CaCO_3$)	66.5 (17.1-138.8)	95.4 (51.3-153.9)	207.1 (102.6-973.5)
Alkalinity (ppm $CaCO_3$)	43.7 (17.1-102.6)	68.4 (34.2-102.6)	108.6 (68.4-136.8)
Dissolved oxygen (ppm)	14.1 (13 - 15)	13.9 (10 - 15)	13.8 (13 - 15)
Free CO_2 (ppm)	7.8 (5 - 15)	6.6 (5 - 15)	8.5 (5 - 20)

[a] Mean (range).

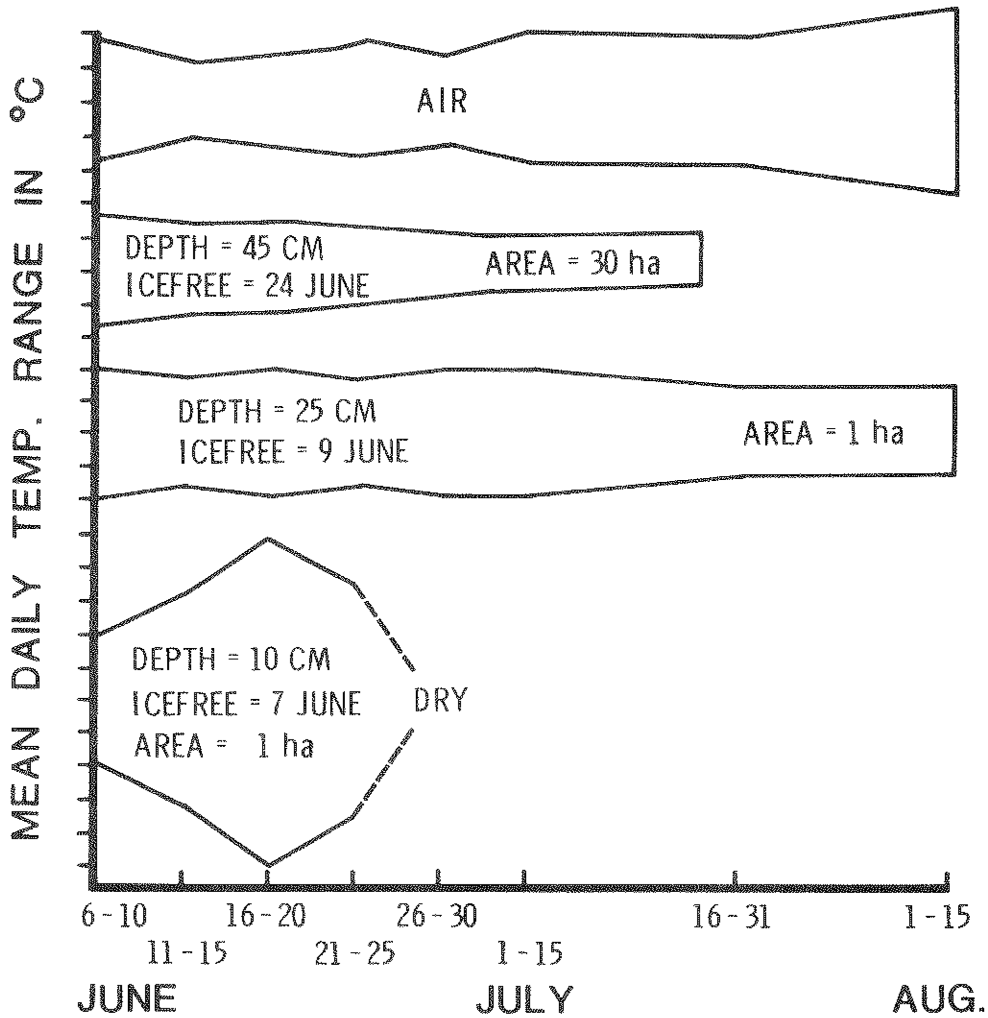

Fig. 6. Mean daily range of temperatures (C) in 1972, measured in three wetlands of different areas and depths compared with data from a weather station 2 m above ground.

(Fig. 6). Temperatures in shallow, flooded depressions underwent daily variations greater than those recorded for temperature of ambient air 2 m above ground, while the largest and deepest wetland exhibited the smallest diurnal temperature change.

Classification of Wetlands

Following the general guidelines established by Martin et al. (1953) for temperature areas, the wetland classification system outlined in Table 9 is designed to: (1) delineate aquatic habitats preferred by conspicuous swimming birds, such as loons and waterfowl, and (2) provide classes of wetlands useful for wetland inventories. Loons and waterfowl were used as indicator species, because they are conspicuous, widely distributed, and feed on a variety of aquatic invertebrates and, therefore, are more easily used to demonstrate change in habitat conditions. This system does not consider large riverbeds and their complex oxbow systems. It considers mainly wetlands that are nonfluvial and those fluvial waters identified as beaded streams by Hussey and Reckendorf (1963). Basin size is used in the system only to distinguish two size categories, ponds and lakes, following the definition by Stewart and Kantrud (1971) that ponds are less than 20 ha and lakes exceed 20 ha. Some classes possess wetlands of only pond or lake size.

Because of the large size range of wetlands, a sliding scale was used to delineate the shoreward and central zones of individual water basins. The shore zone extended approximately 10 m from shore in lakes, 6 m in large ponds, and 2 m in small wetlands.

Table 9. *Criteria used to delineate classes of wetlands near Storkersen Point.*

Wetland designation	Dominant emergents: Shore zone	Dominant emergents: Central zone	Conductivity	Common size
Flooded Tundra (Class I)	*Eriophorum angustifolium* or *Carex aquatilis*	*E. angustifolium* or *C. aquatilis*	Fresh or slightly brackish	Pond
Shallow-*Carex* (Class II)	*C. aquatilis*	Semi open to open	Fresh or slightly brackish	Pond
Shallow-*Arctophila* (Class III)	*C. aquatilis* or *Arctophila fulva*	*A. fulva*	Fresh or slightly brackish	Pond
Deep-*Arctophila* (Class IV)	*A. fulva*	Open	Fresh or slightly brackish	Pond or lake
Deep-open (Class V)	Open	Open	Fresh or slightly brackish	Lake
Basin-complex (Class VI)	Basin interspersed with *C. aquatilis*, *A. fulva*, and open water		Fresh or slightly brackish	Lake
Beaded Streams (Class VII)	*C. aquatilis*, *A. fulva*, or Open	Open or *A. fulva*	Fresh or slightly brackish	Pond=Bead
Coastal Wetlands (Class VIII)	*Puccinellia phryganodes*, *C. subspathacea*, or Open	Open	Brackish or subsaline	Pond or lagoon

The shoreward zone in large lakes is an obvious sublittoral shelf that abruptly fell to the deeper central zone. Depth zones were not distinct in ponds, except that the shoreward zone usually was most shallow and, consequently, vegetation often was found only near shore. Zones of wetlands were considered open if vegetation occurred in less than 5% of the area. The eight classes of wetlands are described as follows:

Class I: Flooded Tundra.—Shallow waters formed during spring thaw when melt water overflows stream basins (Plate I) or is trapped in vegetated tundra depressions (Plate II). Such pools formed in low centers of polygonal ground often produce a mosaic pattern of ridges and flooded sedge (Plate III). Water depths in June rarely exceed 10 cm, and surface water is absent or only a few centimeters deep by August. Unlike other classes, basins of these wetlands are poorly defined because *Carex aquatilis* and other plants tolerant of periodic flooding cover all or most of the basin. It is sometimes convenient to separate flooded tundra as flooded creek flats (Class Ia) or seasonally flooded basins in upland tundra (Class Ib).

*Class II: Shallow-*Carex.—Shallow ponds with a gently sloping shore zone surrounded by and usually containing emergent *Carex aquatilis* with a central open water zone. At Storkersen Point, maximum water depths in June vary between 10 cm and 30 cm. By August, water levels decline due to evaporation or drainage and sediments may be exposed over a large portion of the basin. Such basins also may be very small and may occur in a block mosaic pattern resulting from low center polygons (Plate III). Others are large and lack vegetation in the basin. This class can be subdivided as IIa, vegetated shore zone, and IIb, unvegetated shore zones.

*Class III: Shallow-*Arctophila.—Ponds or pools in beaded streams containing *Arctophila fulva* in the central zone and shoreward stands of *A. fulva* or *Carex aquatilis*. Shores are more abrupt than those of Class II ponds, and maximum water depths typically range from 20 to 50 cm. Pond margins occasionally are exposed during August.

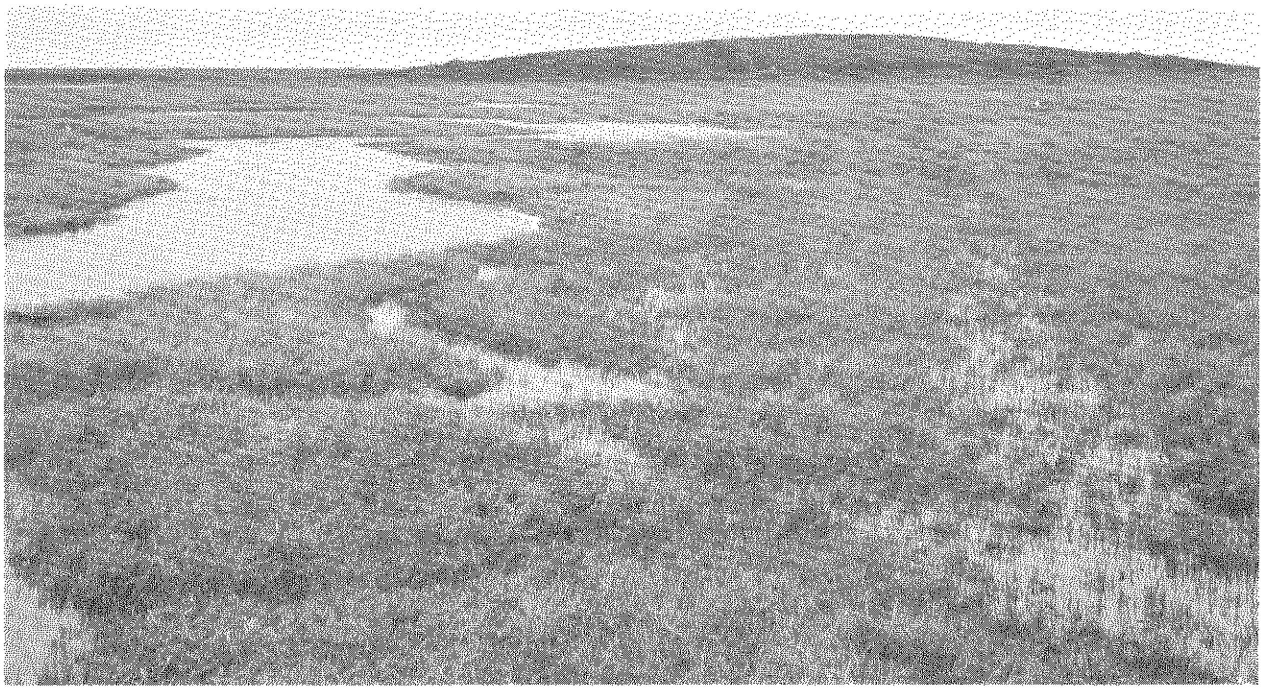

Plate I. Type I flooded tundra in the low-lying areas along Fawn Creek, Storkersen Point study area. Rollagon tracks lead to the highest pingo on the area, which is about 10 m above the level of the surrounding plain.

Plate II. Ground view of low center polygons on Storkersen Point study area, some of which are dry and some still flooded in early July. Open Shallow-*Carex* ponds in the background.

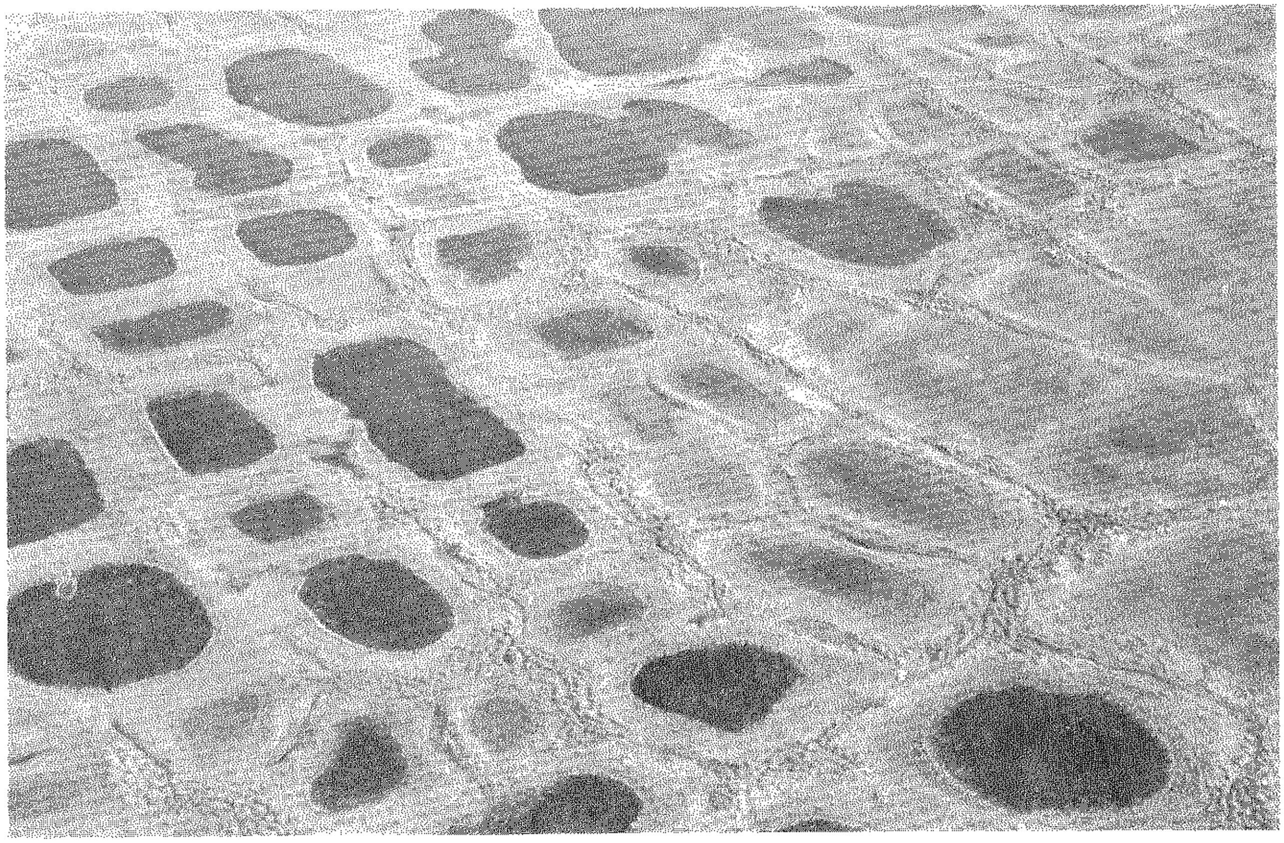

Plate III. Aerial view of Type I flooded tundra in low center polygons at right, and deeper more open Shallow-*Carex* (Type II) ponds at left. Note breakdown of ridges resulting in larger ponds made up of two to six or more polygons. These mosaic type areas are prominent in deltas and are less common at Storkersen Point.

Class IV: Deep-Arctophila.—Wetlands of either large pond or lake size that lack emergents in the central zone and contain stands of *Arctophila fulva* near the shore (Plate IV). These basins have abrupt shore and flat or gently sloping bottoms. Maximum water depths exceed 40 cm. Class IV wetlands are common as second generation basins resulting from melting of ice-rich zones in drained basins.

Class V: Deep-open.—Large, deep lakes that have abrupt shores, sublittoral shelves, and a deep central zone. Water depths are greater than in Deep-*Arctophila* wetlands, and *A. fulva* is absent or present in less than 5% of the shoreline. Maximum water depth found in the largest lake was 1.1 m.

Class VI: Basin-complex.—Large, partially drained basins that may contain nearly continuous water in spring due to flooding of the bottom by melt water. By mid-July, water levels recede leaving a pattern of green *Carex aquatilis* and open water where *Arctophila fulva* may grow along the margin of deeper pools or throughout shallow pools (Plate V). In late summer, relatively upland-like areas are present in some basins, and they are characterized by stands of *Alopecurus alpinus* and *Dupontia fischeri* growing on a moss substrate. Plant communities are most diverse and prolific in this class where the greatest variety of water conditions occur.

Class VII: Beaded Stream.—Small, often intermittent, streams consisting of a series of channels formed in ice-wedges and linked to pools that develop at ice-wedge intersections (Hussey and Reckendorf 1963). Intersection pools often become greatly enlarged as contiguous ice-rich soils thaw and subside (Plate VI). Relationships between water depths and aquatic plants appear to be similar to those in ponds and lakes. Stream pools usually are deeper than nonfluvial wetlands of equivalent size, and vegetation distribution and composition corresponds to Shallow-*Arctophila* and Deep-*Arctophila* wetlands. During the spring thaw, Beaded Streams may flood surrounding lowlands, creating extensive wetlands of the Class I Flooded Tundra. By mid-July, water

Plate IV. Deep-*Arctophila* pond at Storkersen Point.

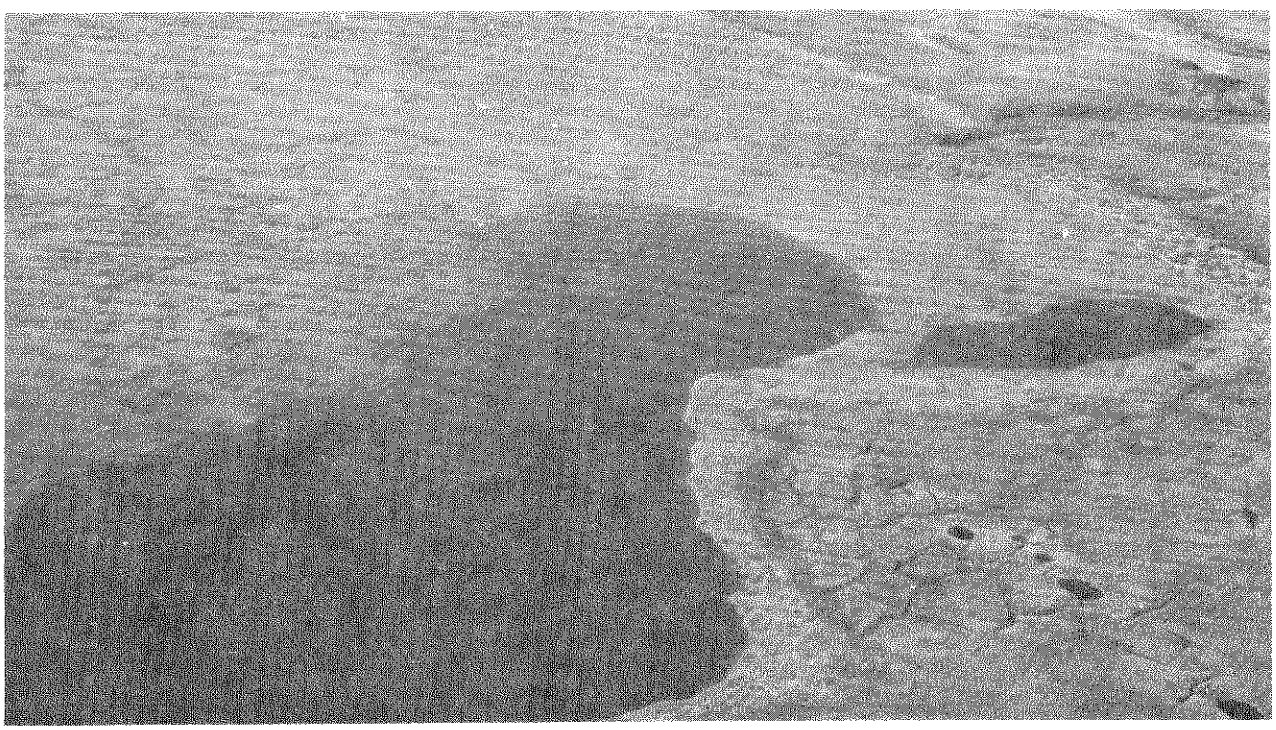

Plate V. Basin-complex showing drained basin, drainage channel, and Deep-*Arctophila* ponds of two sizes. High center polygons and interstitial pools at right.

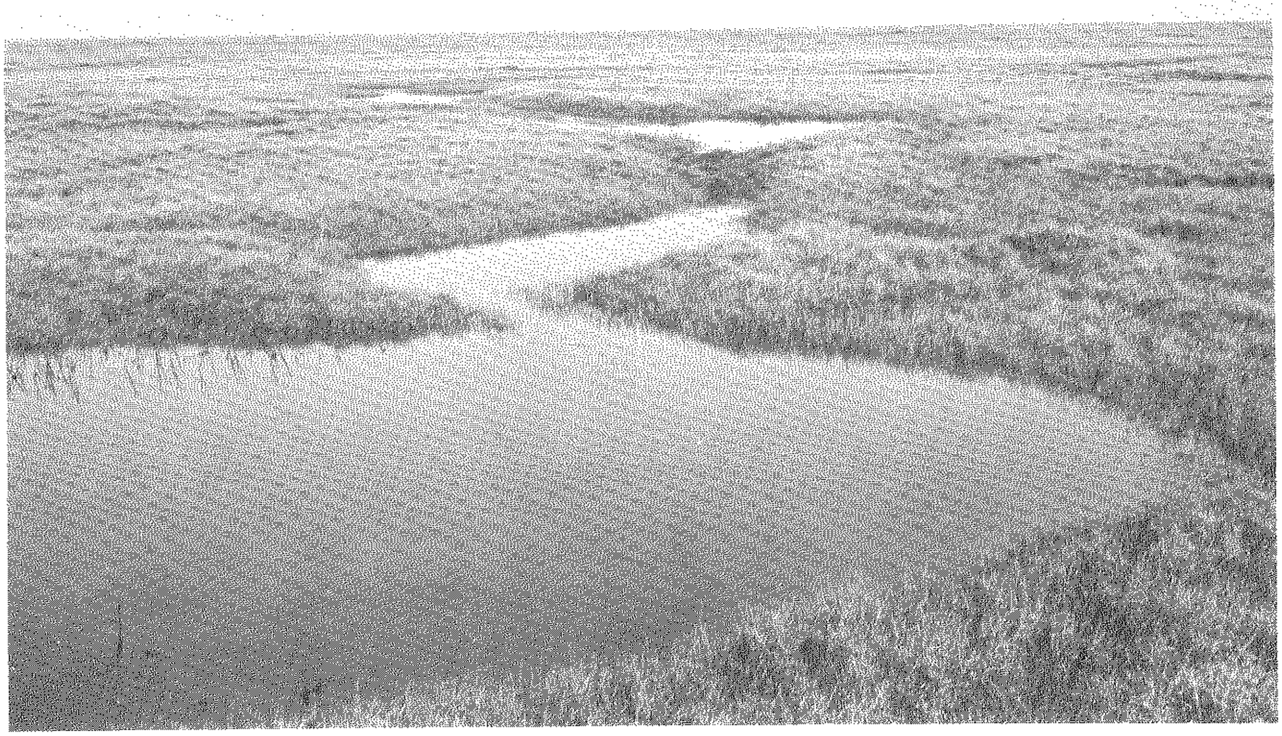

Plate VI. Beaded stream showing very Deep-*Arctophila* pools connected by short lengths of stream between high center polygons. Storkersen Point.

usually is confined to stream channels and beads, and flow may be intermittent. Beaded Streams are common throughout the coastal plain, and they are often the only class of wetlands in large areas of well-drained regions of the interior coastal plain.

Class VIII: Coastal.—Aquatic habitats that occupy low areas bordering the Beaufort Sea and within a zone directly influenced by sea water (Plate VII). Wetlands vary from lagoons confluent with the sea to ponds periodically inundated by high wind tides. Unlike all other classes, Coastal wetlands are brackish or subsaline in specific-conductance, and have a characteristic vegetation dominated by *Carex subspathacea* and *Puccinellia phryganodes* at basin margins and on adjacent flats. Two general modes of origin probably account for most Coastal wetlands: (1) thaw basins breached by outward thawing through the dam between the basin and the sea beach or from inward erosion by sea ice or water, and (2) lagoons and ponds resulting from the formation of sand or gravel spits or barrier beaches by currents.

Abundance and Development of Wetlands

A summary of the areal and numerical importance of wetland classes appears in Table 10 with mean values of basin size, water depth, and occurrence of plants. The small, shallow Class I and II wetlands were by far most numerous, constituting one-half of the total area of all wetlands on the Storkersen Point study area. Class V and VI lakes were few but their large size contributed 26% of the total wetland area. The number of Coastal wetlands (Class VIII) averaged 2 per km^2 over the entire study area; however, all 29 basins sampled were in one 50-ha area bordering the sea.

The following sequential description places wetlands of Classes I through VI into the perspective of basin development (Fig. 7). Water impounded in low center polygons or other tundra depressions (Class I-Flooded Tundra) initiates the insolation-thawing process that deepens the basin. As water depth increases, tundra plants (dominantly *Carex aquatilis* and *Eriophorum angustifolium*) are reduced in the deeper central zone and restricted to shallow shoreward zones; wetlands of this stage are Shallow-*Carex* (Class II) ponds. As shoreward subsidence continues, *Arctophila fulva* becomes established throughout the basin, forming Shallow-*Arctophila* (Class III) ponds. Further thawing of the central zone causes depths not tolerated by *A. fulva*; consequently, distribution of *A. fulva* is confined to shore, and these basins are Deep-*Arctophila* wetlands (Class IV). Deep-open (Class V) lakes result when shoreward zones become too deep to support extensive stands of

Plate VII. Coastal wetlands along Bering Sea at Storkersen Point showing drift line.

Table 10. *Characteristics of classes of wetlands in the Storkersen Point study area, August 1972.*

	Percent of total wetland area	Basins per km²	Basins in sample	Wetland volume: Area (ha) x̄ (S.D.)	Wetland volume: August depth (cm) x̄ (S.D.)	Percent occurrence in wetland: Sedges x̄ (S.D.)	Percent occurrence in wetland: Arct. x̄ (S.D.)
Flooded Tundra (I)	29	>100	47	0.1 (0.2)	3 (3)	84 (18)	1 (4)
Shallow-*Carex* (II)	21	35	263	0.3 (0.3)	12 (7)	7 (7)	0 (0)
Shallow-*Arctophila* (III)	4	6	19	0.6 (0.7)	22 (10)	7 (6)	52 (23)
Deep-*Arctophila* (IV)	11	5	39	1.8 (2.3)	35 (13)	2 (4)	14 (11)
Deep-open (V)	9	<1	2	46.0 (25.4)	60 (28)	0 (0)	1 (0)
Basin-complex (VI)	17	<1	3	46.4 (39.1)	22 (8)	32 (10)	18 (10)
Beaded Stream (VII)	5	2	3	3.8 (3.9)	47 (20)	4 (2)	32 (43)
Coastal Wetland (VIII)	3	2	3	0.6 (0.6)	22 (11)	0 (0)	0 (0)

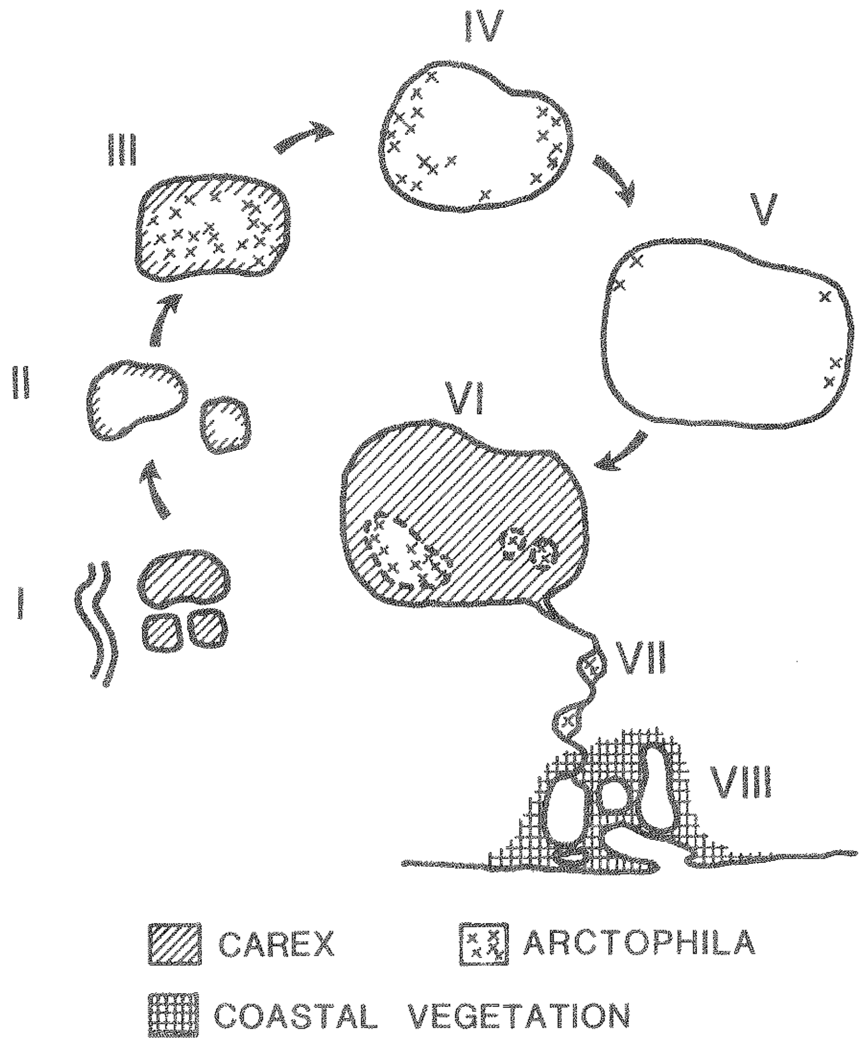

Fig. 7. Evolution of tundra wetlands showing relationships between size and vegetation. (Classes are in Roman numerals.)

A. fulva. The final stage of first generation basins occurs when shores erode and partial drainage lowers water levels to depths conducive for growth of aquatics (Basin-complex) (Class VI). Further drainage exposes areas where thawing processes create second generation wetlands.

Functional use of the classification system requires wetland indicators that are readily identifiable from either air or ground. Distribution of *Carex aquatilis* and *Arctophila fulva* provides the best determination of the stage of basin development in the classes of nonfluvial, freshwater thaw basins (Class I-VI). The two species are readily distinguished by late June because *A. fulva* becomes distinctly red while *C. aquatilis* is bright green. Coastal wetlands are easily identified because of their occurrence in low areas connected to the sea beach, their deep reddish-brown vegetation, and a characteristic line of driftwood and other debris windrowed by storm tides (Plate VII).

Occasionally, wetlands have two or more regions that are morphologically and vegetationally distinct. This occurs where two wetlands originally of different classes coalesce, or where embayments of Deep-open lakes are more shallow than the lake itself. Because differences were apparent in use of such portions of wetlands by birds, these regions were classified as separate units.

Other wetlands not considered in this system are incised and braided streams, their deltas, and associated nonfluvial wetlands. Such waters significantly influence bird species on coastal plain wetlands (Kessel and Cade 1958).

Water-bird Use of Various Wetland Classes

Frequencies of wetland use by water birds during 1971 to 1973 (Table 11) were evaluated using a Chi-square 1 × 2 contingency table test. Differential utilization of a wetland class by a species was indicated if the number of birds recorded on surveys as using wetlands in that class was significantly greater than the number of birds expected on those wetlands. The expected value was calculated by multiplying the total number of birds using wetlands in the class by the percentage of the total wetland area covered by wetlands in the class. For example, of 31 arctic loons in the sample, 16 (52%) were observed in Deep-*Arctophila* wetlands (Table 11). This class constitutes 11% of the wetlands of the study area (Table 10), so 31 × 0.11 = 3.4 loons expected on such wetlands. Because observations of whistling swans using wetlands were few, they were not tested statistically.

Class I: Flooded Tundra.—Pintails fed and loafed on Flooded Tundra before and after their wing molt in July (Table 11), but they made most intensive use of this class during spring thaw when other wetlands were frozen. Primary use of Flooded Tundra seemed to be by red phalaropes. Birds frequently were seen feeding or swimming in Class I basins throughout spring and summer.

*Class II: Shallow-*Carex.—Although most species of waterfowl occurred on Shallow-*Carex* ponds, only adult oldsquaws and king eider hens with broods used the ponds in significant frequencies (Table 11). Use by oldsquaws, primarily pairs, was significant before nesting ($p < 0.01$) and during nesting ($p < 0.05$). Feeding was a common activity of oldsquaws on Class II ponds. Twelve of the 19 (69%) observations of king eider broods were on Shallow-*Carex* ponds. Birds were seen feeding in water or loafing on or near shore. Although their frequencies of use were not significant, adult king eiders often were seen feeding in waters of Class II ponds.

Six of the eight white-fronted goose nests were less than 4 m from the edge of Shallow-*Carex* ponds. Other species constructed nests close to ponds or on islets, but frequencies of use were low: 2 of 42 arctic loon nests; 5 of 28 red-throated loon nests; 1 of 11 black brant nests; and 6 of 32 king eider nests.

*Class III: Shallow-*Arctophila.—Use of Shallow-*Arctophila* ponds by pintails was significant ($p < 0.01$) before and after their wing molt in July (Table 11). Shallow water and extensive stands of *A. fulva* provided feeding habitat and cover for birds. Most other species were on Class III wetlands, but less frequently than pintails; use by king eiders was significant ($p < 0.05$), both before and during nesting. One arctic loon nest and three red-throated loon (*Gavia stellata*) nests were on detritus platforms in Class III ponds.

*Class IV: Deep-*Arctophila.—Deep-*Arctophila* ponds and lakes were principal aquatic habitats for all waterfowl except white-fronted geese and pintails (Table 11). In 1971 and 1972, a pair of whistling swans nested adjacent to a large complex of Class IV ponds, and used Deep-*Arctophila* wetlands for escape cover. King eiders and spectacled eiders favored Class IV wetlands in all phases of their reproductive cycle at Storkersen Point (Table 11). Frequencies of use by king eiders were significant, ranging from 26% for hens with broods to 52% for postnesting females without young. Birds usually were seen loafing on shore. Of the 36 observations of adult spectacled eiders throughout their summer residence, 33 (92%) were on Class IV wetlands. Birds were swimming or loafing but were not observed feeding.

Oldsquaws preferred ($p < 0.01$) Deep-*Arctophila* wetlands before and during nesting (Table 11). Densities of pairs were highest on portions of drained lakes possessing a network of second generation Class IV ponds. A 50-ha complex of basins was used each year by 4 pairs; that density extrapolates to 16 birds per km^2 compared to mean peak densities of 4.3 to 5.1 birds per km^2 for the entire study area. Because oldsquaws are highly territorial (Alison 1975), the ridges that commonly separate ponds probably provide visual isolation from neighbors. Oldsquaws often were seen diving in Class IV wetlands.

Ten of the 11 black brant nests and 2 of the 3 spectacled eider nests found in 1971–73 were at Deep-*Arctophila* wetlands. Nests were placed on tundra or islets next to an abrupt shore. All nest-ponds were second generation wetlands in drained basins.

Preferential use of Class IV wetlands by arctic loons and red-throated loons was obvious throughout summer (Table 11); however, red-throated loons showed an even greater preference for Basin-complex ponds (Class VI). The proportion of observations of arctic loons on Class IV wetlands ranged from 52% before and after nesting to 59% during the nesting period. Sightings of red-throated loons were less frequent: prenesting (22%); nesting (33%); and postnesting (24%). Adult arctic loons fed or captured food for young in freshwater wetlands, whereas red-throated loons captured food at sea and returned to brood-ponds with fish for their young. Because of relatively deep water in Class IV wetlands, nests of arctic and red-throated loons were placed on islands or shores rather than on detritus platforms such as those used in more shallow wetlands.

Class V: Deep-open.—Deep-open lakes were used most frequently by water birds in July and August when they were ice-free. Principal use in June was by oldsquaws loafing on banks or ice and diving in the moat of water near shore.

Table 11. *Percentage frequency of occurrence that loons and waterfowl used various classes of wetlands in broods are in parentheses.*

Classes	Arctic loon			Red-throated loon			Black brant			White-fronted goose
	Pre-nest (31)	Nest (79)	Post-nest[a] (57)	Pre-nest (55)	Nest (115)	Post-nest[a] (65)	Pre-nest (55)	Nest (22)	Post-nest[a] (12)	Post-nest (189)
Flooded Tundra (I)	—	—	—	—	—	—	—	—	—	—
Shallow-*Carex* (II)	—	5	9	2	6	2	—	9	—	—
Shallow-*Arctophila* (III)	—	3	—	3	8	3	—	—	—	3
Deep-*Arctophila* (IV)	52**	59**	52**	22**	33**	24**	9	91**	—	—
Deep-open (V)	—	5	16*	—	—	3	—	—	—	94**
Basin-complex (VI)	36**	18	16	73**	51**	65**	18	—	—	3
Beaded Stream (VII)	6	5	2	—	2	3	—	—	—	—
Coastal Wetland (VIII)	6	5	5	—	—	—	73**	—	100**	—

[a] Adults and young.
[b] Adults only.
* Chi-square value significant ($P<0.05$).
** Chi-square value highly significant ($P<0.01$).

Use of Class V lakes by arctic loons was significant ($p<0.05$) following nesting. Birds observed were adults, usually in small flocks, that presumably were unsuccessful at nesting or brood-rearing.

Deep-open lakes and adjacent tundra were used by Canada geese and white-fronted geese during their wing molt in the last half of July and during August. In 1973, a flock of Canada geese, numbering about 100 flightless adults and 20 goslings, resided in the vicinity of two large lakes (175 ha and 200 ha) located 10–15 km southeast of Storkersen Point. Groups of white-fronted geese, containing mostly parents and broods, were counted in the study area on 21 occasions, and, of these, 19 involved groups on or near a 60-ha Class V lake. Similar-sized flocks of white-fronted geese were seen on other Deep-open lakes in the Prudhoe Bay area. While undisturbed, Canada geese and white-fronted geese rested or grazed in upland tundra near lake shores. Flightless geese responded to disturbance from men on the ground or low-flying aircraft by moving offshore to open water or by moving overland to another lake.

Oldsquaws, predominantly females, gathered on Deep-open lakes in the last week of July or the first week of August to pass their flightless stage. The oldsquaw population at this time was composed of about 95% females. Of the birds counted after the nesting period (Table 11), 85% were on the largest lake (60 ha) in the study area. Moreover, all flightless oldsquaws in the study area used two lakes of the class. Peak use of the lake occurred in mid-August when numbers varied from 45 to 70.

Class VI: Basin-complex.—Nonbreeding pintails preferred ($p<0.1$) Basin-complex ponds throughout their residence (Table 11). Use by pintails was greatest during the wing molt in July; 92% of the flightless pintails counted were in the largest (85 ha) Class VI lake near Storkersen Point. Pintails usually were well hidden in the cover created by stands of *Arctophila fulva* and *Carex aquatilis*. Based on birds

1971-73. Numbers of birds observed during phases of summer residence and the number of king eider

Pintail			King eider				Spectacled eider			Oldsquaw			
Pre-molt (544)	Molt (270)	Post-molt[b] (871)	Pre-nest (23)	Nest (188)	Post-nest[b] (87)	Brood (19)	Pre-nest (20)	Nest (9)	Post-nest[b] (7)	Pre-nest (223)	Nest (261)	Post-nest[b] (345)	Total (3,763)
8	—	9	—	—	—	—	—	—	—	—	1	—	3
7	—	14	14	22	26	64**	—	—	—	31**	28**	5	12
26**	6	12**	7*	8*	8	5	—	—	—	5	3	—	10**
14	2	13	30**	42**	52**	26**	90**	89**	100**	40**	36**	9	22**
1	—	—	—	8	6	—	—	11	—	2	10	85**	14**
37**	92**	46**	39**	9	5	5	—	—	—	10	9	—	32**
5	—	3	3	3	—	—	10	0	0	8*	10**	1	3
2	—	3	7**	8**	3	—	—	—	—	4	3	—	4

observed during June (Fig. 6), feeding is a major activity of pintails on Basin-complex lakes.

King eiders, usually paired, gathered in large numbers on Class VI lakes during the first half of June. As a result, frequency of use by king eiders was significant ($p<0.05$) before nesting (Table 11). Shallow areas of Class VI lakes frequently were used for feeding by king eiders (Fig. 6). As the thaw progressed, king eider pairs dispersed to other wetlands, especially the Deep-*Arctophila* class.

In 1973, a pair of whistling swans nested and raised young in a Class VI basin. The nest was placed on a detritus platform surrounded by shallow water and emergents. Adults and cygnets were able to conceal themselves in stands of *Arctophila fulva*.

Other waterfowl, especially visitors (Table 6), often were seen in Basin-complex wetlands during June.

Frequencies for arctic and red-throated loons using Basin-complex lakes were most significant before nesting (Table 11). Presumably, the higher frequencies in early summer resulted because loons were able to use the extensive areas of shallow water before deeper wetlands thawed. Both species used Class VI lakes for nesting and brood-rearing, but only use by red-throated loons was significant ($p<0.01$). Pairs occupied isolated pools within basins and constructed nest platforms of dead vegetation. Feeding activities of loons corresponded with activities at Class IV wetlands.

Class VII: Beaded Streams.—All species of loons and ducks that resided in the study area occasionally used on larger Beaded Streams (Table 11), especially those vegetated by *Arctophila*. Pintails and eiders used portions of the flood plain temporarily inundated by water during spring breakup. Oldsquaw pairs established territories on segments of the stream during the prenesting and nesting periods.

Class VIII: Coastal.—Coastal wetlands were predominantly used by migrating black brant. During the first half of June, flocks of as many as 100 brant migrated east along the coast and often used open water and snow-free shores of Class VIII wetlands. During mid-summer, brant often visited wetlands on the study area. Fall migration of brant did not pass Storkersen Point until after field seasons terminated in mid-August. However, during a visit to the study area on 2 September 1973, a flock of more than 350 black brant stopped to rest and feed along

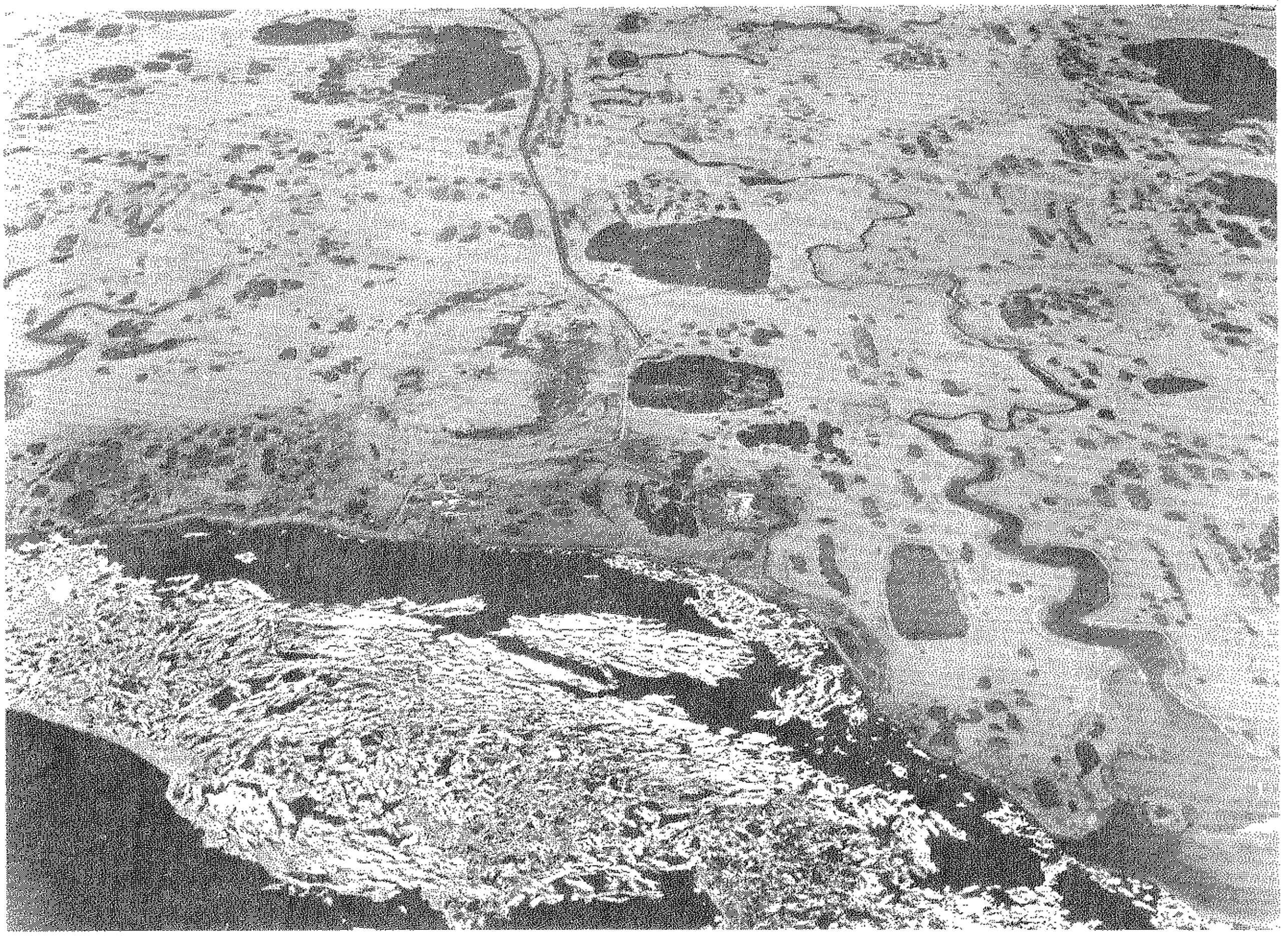

Plate VIII. Aerial view (south) of the Storkersen Point study area showing various wetland classes, the DEW-line site along the shore at left center, and Storkersen Point Well at right. Ice at the Beaufort Sea is at bottom. Photo by C. D. Evans.

shores of the Coastal wetlands. Presumably, *Carex subspathacea* or *Puccinellia phryganodes* form principal foods of black brant.

Black brant families moved to coastal habitats within a few days after their young had hatched. Two families were observed from 11 July to 17 July 1973 in a complex of Coastal wetlands. The birds fed and rested on flats between ponds and on a point jutting into the sea.

Part III—Macroinvertebrates of Tundra Wetlands and Their Use By Water Birds

Procedures

Aquatic macroinvertebrates were sampled weekly in selected wetlands from about 5 June to 8 August in 1972 and 1973. Chronology of thawing, drying of temporary wetlands, and logistical problems prevented sampling of all stations weekly. Nevertheless, a composite representation of seasonal changes in availability of various organisms was provided by the overlap of sampling schedules from the two field seasons.

In 1972, 10 sampling stations were established in ponds of differing morphometry and use by water birds. In 1973, the number of stations was expanded to 18 to insure coverage of all major wetland types. Sampling points at each station were random within either the open water areas or stands of emergent vegetation (usually *Carex aquatilis* and *Arctophila fulva*). Additional samples were taken from areas that were free of ice earliest in the season, from feeding sites where water birds were collected, and from waters disturbed by industrial activity.

Aquatic invertebrates were collected from open water with an Ekman dredge (15.2 cm × 15.2 cm) and in emergent vegetation with an aquatic sweep net described by Weller (1972). The sweep net measured 7.6 cm × 30.5 cm and had 7.9 meshes/cm. Sweeps were 3 m in length and were possible in water as shallow as 10 cm. Benthic samples were washed through the aquatic net to standardize the size of organisms taken by the two methods. Occasional "grab" samples were taken to facilitate identification of casually observed organisms. With few exceptions, living organisms were separated from vegetation and debris soon after collection. Invertebrates were preserved in a formaldehyde solution for later analysis.

Various physical and chemical variables were recorded as described in Part II in wetlands sampled for invertebrates. Depth of water, thickness of bottom sediments, and water temperature were taken at each sampling.

Activity and distribution of birds were noted during invertebrate sampling and on weekly bird surveys. Specific efforts were made to study feeding behavior of resident waterfowl, to record brood activities, and to quantitate wetland use for feeding. Seventeen birds of four species were collected for food analysis from areas outside the bird survey plots. All but two of the birds collected had fed at least 20 min. Birds were opened shortly after collection and contents of esophagi, proventriculi, and gizzards were separately preserved in a formaldehyde solution for later examination.

Aquatic Invertebrate Samples

Most aquatic macroinvertebrate specimens from Storkersen Point belong to 18 taxonomic groups. Individuals representing other taxa were collected (Table 12), but were considered of little value as food for water birds and were placed into a single group for analyses. One aquatic vertebrate, the fourhorn sculpin *(Myoxocephalus quadricornis)*, was found in brackish ponds connected to the sea, and other unidentified fish were seen in stream channels or wetlands connected to streams. Large and deep lakes south of the coastal tundra zone contained the nine-spined stickleback *(Pungitius pungitius)*. Taxonomic diversity and total volume of invertebrates available within taxa generally increased with seasonal warming of waters until late July. Mean total numbers and mean total volume of potential food organisms taken by the Ekman dredge and by net under 1 m^2 of water surface indicated a greater relative abundance of bottom-dwelling organisms than free-swimming forms (Fig. 8).

The weekly mean numbers/m^2 of the most numerous and frequently occurring taxa for each sample type generally increased from June to August (Figs. 9 and 10). Relatively high numbers of midge larvae of family Chironomidae in early sweep samples were caused by extensive sampling of shallow melt pools. The activity threshold of midge larvae is near 0 C, so they became active in flooded depressions and pond margins immediately after thawing (Danks 1971). Other organisms of potential importance as food items, either because of their high local populations or their large size, included snails (Gastropoda), tadpole shrimp (Notostraca), cranefly larvae (Tipulidae), stonefly larvae (Plecoptera), and caddisfly larvae (Trichoptera).

Relative occurrences of the major groups of invertebrates differed significantly ($p < 0.005$) among stands of *Carex aquatilis*, *Arctophila fulva*, mixed stands, and open water (x^2 = 251.97, d f = 60). Numbers and volume of invertebrates were greatest in stands of *Arctophila fulva* or in the edge between stands of *A. fulva* and *Carex aquatilis* stands (Table 13). Variations in wetland depth and vegetation density of wetlands accounted for much of the difference in invertebrate abundance among vegetation stands of like species. Fairy shrimp (Anostraca) and water fleas (Cladocera) were characteristic of open portions of wetlands and were of greatest potential as water-bird food during late summer, when these invertebrates were concentrated as a result of falling water levels in shallow, open ponds.

Limited samples by R. Howard (unpublished data) in other regions of the coastal plain indicated the same general composition of bottom organisms with midge larvae, earthworms (Oligochaeta), cranefly larvae, and caddisfly larvae contributing most in numbers and volume. Other large invertebrates found farther inland included large scuds (Amphipoda), additional species of snails, and clams (Pelecypoda).

Samples from a Class II pond near the Storkersen well that had been severely contaminated by crude oil and drilling wastes contained no macroinvertebrates. All vegetation below the high-water limit of the basin was dead. Sediments appeared heavily contaminated by oil residues, and oil slicks were produced when sediments were disturbed. A small amount of oil spread from this pond into other basins during snow melt.

Feeding Behavior of Resident Birds

The first water birds to arrive at Storkersen Point concentrated on or near the first available open water of flooded depressions and shallow ponds near the Beaufort Sea. Birds rapidly dispersed to other areas as open water became available and used all wetland types for feeding. Partially-drained Basin-complexes were favored throughout the season. Deep-open lakes were especially important as molting areas for female oldsquaws, white-fronted geese, and Canada geese.

Table 12. *Macroinvertebrates from Storkersen Point ponds, 1972 and 1973*[a].

Class—Hydrozoa
  Order—Hydroida
    Family—Hydridae
Phylum—Nematoda

Class—Oligochaeta

Class—Crustacea
  Subclass—Branchiopoda
    Order—Anostraca
      Family—Branchinectidae
          Branchinecta paludosa (O. F. Muller)
      Family—Polyartemiidae
          Polyartemiella hazeni (Murdock)
    Order—Notostraca
          Lepidurus arcticus (Pallas)
    Order—Cladocera
      Family—Daphinidae
          Daphnia pulex (de Geer)
      Family—Chydoridae
          Eurycerus lamellatus (O. F. Muller)
    Order—Copepoda
      Suborder—Calanoida
      Suborder—Cyclopoida
    Order—Ostracoda

Class—Arachnida
    Order—Acari (Hydracarina)
    Order—Araneae

Class—Insecta
    Order—Collembola
      Family-Hypogastruridae
    Order—Ephemeroptera
    Order—Plecoptera
      Family—Nemouridae
          Nemoura sp.
    Order—Trichoptera
      Family—Limnephilidae
    Order—Coleoptera
      Family—Dytiscidae
    Order—Diptera
      Family—Tipulidae
          Tipula sp.
          Prionocera sp.
      Family—Culicidae
          Culiseta sp.
      Family—Chironomidae
      Family—Muscidae
          Mydaeina obscura

Class—Gastropoda
    Order—Pulmonata
      Family—Lymnaeidae
          Lymnaea sp.
      Family—Physidae
          Physa sp.

[a] Nomenclature based on Pennak (1953) and Usinger (1971).

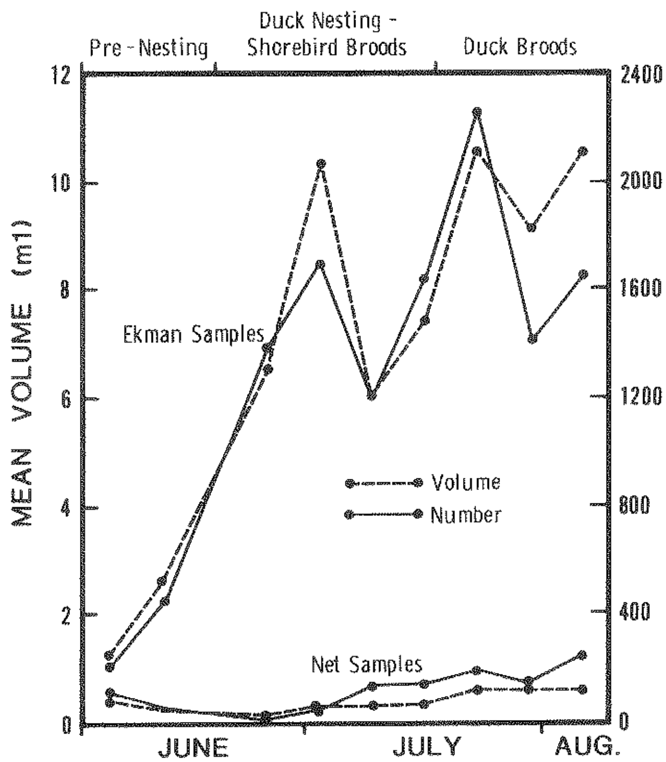

Fig. 8. Relationship of total invertebrates per m^2 to reproductive activity of dominant water birds.

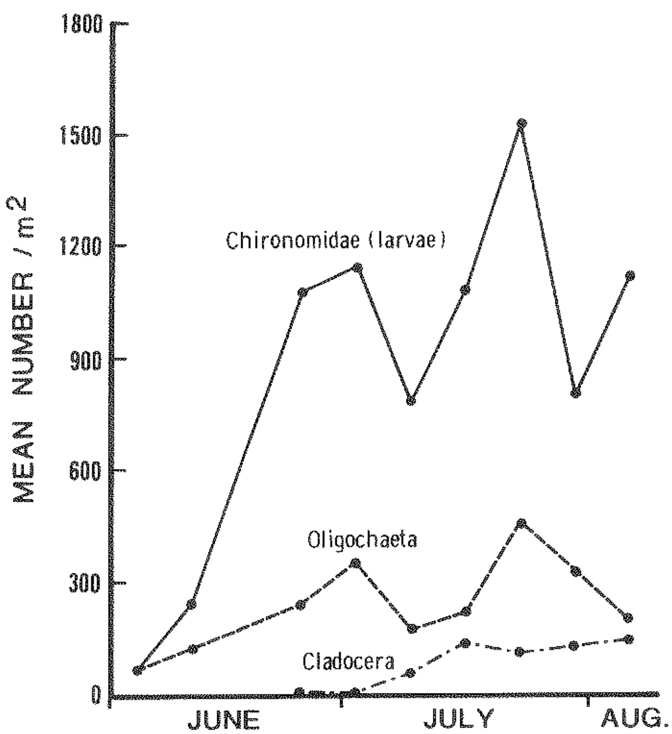

Fig. 9. Seasonal changes in abundance of important invertebrate groups, derived from Ekman dredge samples, 1973.

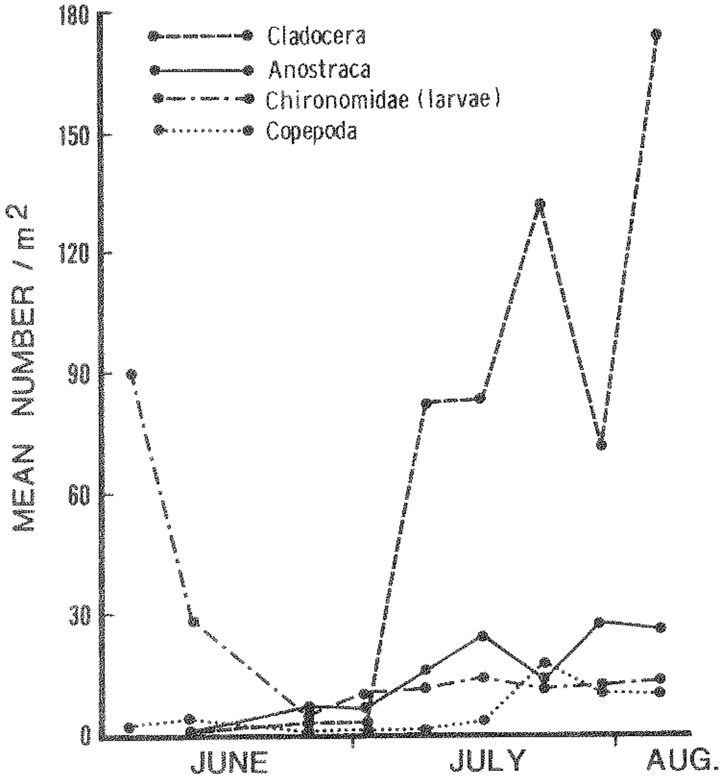

Fig. 10. Seasonal changes in abundance of some important invertebrates, taken in sweep-net samples, 1973.

Table 13. *Summary of invertebrates per m² for different vegetation stands, 1972–73.*

Vegetation	Sweep samples N	Total mean volume (ml) M.	Total mean volume (ml) S.D.	Total mean number M.	Total mean number S.D.	Ekman samples N	Total mean volume (ml) M.	Total mean volume (ml) S.D.	Total mean number M.	Total mean number S.D.
None	124	0.24	0.47	111.1	269.7	115	6.96	6.96	1371.3	1908.3
Arctophila fulva	67	0.54	0.71	182.1	293.0	33	13.04	11.30	2034.3	1498.3
Carex aquatilis	76	0.45	0.38	85.5	89.7	36	6.96	6.09	1431.3	1772.2
Mixed edge	11	0.59	0.39	206.4	244.0	1	10.86	0.0	3000.0	0.0

Late in the season, shallow ponds became increasingly important as feeding sites, when decreasing water levels concentrated free-swimming organisms and increased the total area of bottom surface that could be easily reached by swimming and wading birds.

Chironomidae and Trichoptera were the most important invertebrate foods for oldsquaw and king eider (Table 14). Earthworms did not occur in food samples as frequently as in bottom samples, while caddisfly larvae occurred at a higher frequency—suggesting feeding selectivity. The frequency of occurrence of water fleas in food materials was inflated by the presence of overwintering ephippia, which probably were picked up along with bottom detritus. Seven of the 17 birds collected had gravel in esophageal contents.

Oldsquaw.—Feeding was observed on all types of wetlands, including Flooded Tundra depressions. Edges of Deep-open lakes were used by small flocks of nonbreeding yearlings as well as adults. Nonbreeding yearlings left the study area near the end of June. By mid-July, most males had departed, and molting flocks were forming offshore in the Beaufort Sea. Single females were observed feeding in Shallow-*Carex* ponds throughout the nesting season. One nesting female under observation left her nest daily to forage in nearby ponds.

Feeding by diving accounted for 83% of 248 oldsquaw feeding observations. Early in June, oldsquaws commonly dived under floating ice and explored the newly exposed bottom. Diving seemed the preferred method of feeding in all but the most shallow wetlands where birds were able to reach the bottom by swimming with the head and neck submerged. One pair exhibited a third type of feeding by picking stonefly larvae from the surface of flooded ice at the edge of a Shallow-*Carex* pond.

Information on food habits of oldsquaws at Storkersen Point (Table 14) is in basic agreement with that from other breeding areas (Bengtson 1971*a*, 1971*b*). Midge larvae were dominant in the diet of adult birds, and the only brood observed was feeding by diving in a Class II pond with high populations of water fleas and fairy shrimp. Bengtson (1971*a*) reported that young oldsquaws fed almost exclusively on water fleas until half grown. During the first half of the field season, oldsquaws at Storkersen Point frequented areas where caddisfly larvae were abundant. One male and one female collected after feeding on such areas had consumed noticeable volumes of these insects.

King eider.—King eiders reached the study area during the first week of June and concentrated their feeding activity in Basin-complex ponds until they dispersed to nesting sites. Males left the area in late June after incubation started. Females fed in Shallow-*Carex* ponds and shoreward zones of Deep-*Arctophila* ponds throughout the nesting season, some of them in areas near known active nests. Because Lamothe (1973) found that king eider females incubated for extended periods without feeding, females observed feeding during the nesting season at Storkersen Point may have been unsuccessful nesters.

Only females with broods remained on the study area by the second week of August. Broods moved overland feeding in Shallow-*Carex* ponds, Basin-complexes, and Deep-*Arctophila* ponds. Total feeding observations for both sexes of all ages followed the same trend: 46% of 107 observations occurred in Shallow-*Carex* ponds; 40% in Basin-complexes; and 8% in Deep-*Arctophila* ponds.

Feeding behavior of king eiders in freshwater ponds resembled that of dabbling ducks and was described by Lamothe (1973) for birds observed on Bathurst Island. Bottom feeding by submerging the head and neck accounted for 70% of 131 observations at Storkersen Point. Downy young often upended to reach the bottom. Young eiders also dived readily, but diving by adults was observed on only three occasions. Surface dabbling also was employed mostly by downy young. One Class Ib (faded, downy stage) young was observed grabbing at specific targets in a pond where fairy shrimp were abundant.

Information on food habits (Table 14) is in agreement with that from other studies, i.e., that adult king eiders feeding in fresh water have a mixed diet of animal and plant material (Manniche 1910; Hanson et al. 1956; Lamothe 1973). Most vegetation, however, resembled dead material found in bottom detritus of feeding sites, and may have been ingested incidentally. Gizzard contents were included in earlier analyses reported in the literature, biasing results toward vegetative material (Swanson and Bartonek 1970). Manniche (1910) found indeterminable remnants of crustaceans in the stomachs of downy young. Young king eiders fed regularly in Shallow-*Carex* ponds with high populations of fairy shrimp and water fleas; these organisms also were noted in stomach contents (Table 14).

Pintail.—Male pintails, common throughout the summer, used all types of wetlands, but Basin-complexes accounted for 81% of 423 recorded feeding observations. Use shifted from Coastal wetlands and temporary wetlands to the marshy basins and vegetated zones of deep *Arctophila*-rimmed ponds and stream pools as the spring thaw progressed. Large areas with good emergent cover were important to pintails during the molt period in July. During late July and early August, there was increased use of Shallow-*Carex* ponds where fairy shrimp and tadpole shrimp were concentrated.

Table 14. *Percentage volume (ml) of some foods of 17 birds collected at Storkersen Point, 1972 and 1973.*

Digestive contents	Species:	Oldsquaw					King eider				Pintail					Red phalarope		
	Number:	1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3
Acari		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0
Anostraca		0.0	0.0	0.0	0.0	0.0	tr[a]	23.1	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	96.9	0.0
Araneae		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	27.0
Cladocera		0.0	tr	tr	tr	tr	tr	tr	0.0	2.2	tr	tr	0.0	tr	0.0	0.0	tr	tr
Copepoda		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	tr	tr	tr	0.0	0.0	0.0	0.0	0.0
Muscidae		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	tr	6.6	0.0	0.0	0.0	0.0	0.0
Chironomidae		tr	tr	52.4	61.3	36.5	1.5	0.0	4.9	0.0	7.9	17.4	6.6	0.0	0.0	tr	0.0	61.0
Tipulidae		0.0	3.6	0.0	0.0	tr	0.0	0.0	0.0	0.0	0.0	0.0	30.6	0.0	0.0	77.8	0.0	5.5
Other Diptera		0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	tr	tr	0.0	tr	0.0	0.0	tr	0.0	tr
Gastropoda		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	tr	0.0	0.0	0.0	tr	0.0	0.0
Nematoda		0.0	tr	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Notostraca		0.0	0.0	0.0	0.0	0.0	0.0	tr	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oligochaeta		0.0	0.0	tr	tr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	0.0	tr	0.0	1.4
Trichoptera		80.2	39.2	tr	tr	tr	24.3	tr	tr	0.0	0.4	tr	0.0	tr	2.3	tr	0.0	0.0
Unknown animal		tr	tr	4.3	0.5	tr	tr	tr	0.9	6.7	20.0	8.2	8.8	tr	tr	11.1	1.6	1.6
Vegetation		tr	3.0	3.5	2.5	19.0	13.2	1.5	33.6	tr	26.8	33.6	22.8	44.0	41.9	tr	1.6	0.8
Gravel		19.8	54.2	39.8	35.7	44.4	30.8	75.4	60.8	86.5	41.3	40.8	12.4	56.0	55.8	11.1	tr	2.7
Total volume (ml)		5.30	4.15	5.15	5.55	6.3	3.25	3.25	9.25	4.45	6.30	5.75	6.05	2.50	2.15	0.45	1.60	3.65

[a] Less than 0.1 percent.

Pintails utilized a variety of invertebrate foods (Table 14). On 24 July 1973, two males that could not be observed before collection, were taken in wing molt. Attempts to collect pintails feeding where fairy shrimp and tadpole shrimp were abundant were unsuccessful. Krapu (1974) found fairy shrimp to be an important food resource of pintails in North Dakota, and these easily obtainable items probably are important in tundra areas as well. The few nesting attempts by pintails at Storkersen Point were unsuccessful, and information on preferences of broods for feeding areas was not obtained. Broods were seen on large, marshy lakes inland about 13 km east and 85 km south of the Colville River delta (Lat. 70° 40′N, Long. 151° 15′W).

Other waterfowl.—Spectacled eiders nested in limited numbers near Storkersen Point, but no information on feeding was obtained. Nests and sightings were near Deep-open lakes. Green-winged teal, mallards, and shovelers also used the Basin-complex wetlands preferred by pintails. American wigeon *(Anas americana)* were numerous in Coastal ponds (Class VIII) in June of most years of the study, and were seen ingesting vegetation in areas dominated by *Carex subspathacea* and *Puccinellia phryganodes*. Black brant and white-fronted geese also seemed to rely on these plants. Nesting whistling swans preferred large water areas with substantial vegetative cover where observations of feeding were difficult.

Loons.—Red-throated loons relied on fish from the nearby Beaufort Sea to feed their young, rarely feeding in inland waters. Arctic loons also made flights to sea but more commonly fed in fresh water. Deep-*Arctophila* ponds were the preferred habitat where young were fed invertebrates by their parents. Two young Arctic loons collected for food habits information had eaten caddisflies and tadpole shrimp, and a young red-throated loon contained Arctic cod *(Boreogadus saida)*. An adult arctic loon had eaten tadpole shrimp, caddisfly larvae, fairy shrimp, and water fleas (Cladocera).

Phalaropes.—Shallow-*Carex* ponds accounted for 66% of 102 recorded feeding observations of red and northern phalaropes *(Lobipes lobatus)*. Large, well-vegetated Basin-complexes were second in importance. Shallow-*Carex* ponds received heaviest use in August, when reduced water levels concentrated free-swimming invertebrates; flocks of 20 to 30 were common. Feeding behavior indicated that free-swimming organisms, benthic organisms, and emerging aquatic insects all were eaten. Birds took fairy shrimp and water fleas from shallow ponds and often picked food items from emergent vegetation. Stomach contents of a specimen which had fed in this manner included adult midges and spiders.

Other shorebirds.—Shorebirds at Storkersen Point made use of exposed bottom areas and extremely shallow waters of drying ponds, but no birds were collected for food habit studies. The diet of four species of genus *Calidris* near Barrow, Alaska, relied on midge larvae, cranefly larvae, adult insects, and arachnids (Holmes and Pitelka 1968). Stilt sandpipers *(Micropalama himantopus)* stopped during migration in August and used shallow ponds extensively. Late season feeding concentrations of shorebirds are composed mostly of young birds.

Discussion and Recommendations

The avian community of the Alaskan Coastal Plain at Storkersen Point is characterized by (1) a small number of breeding birds relative to lower latitudes, (2) few resident species, (3) a high percentage of water-related birds, (4) relatively low-density populations that are widely distributed, and (5) dominantly invertebrate feeders with lesser numbers of grazers. Compared with the bird fauna at Point Barrow (Pitelka 1974), there are fewer species breeding and fewer accidentals, especially Asiatic forms.

The Arctic Coastal Plain is of great importance for species restricted in breeding to the arctic, such as red phalaropes, many other shorebirds, whistling swans, white-fronted geese, brant, king eiders, oldsquaws, and arctic and red-throated loons. Recognition of the importance of the coastal plain to usually non-breeding segments of waterfowl populations, particularly pintails, has been increased by the knowledge that drought-displaced prairie ducks often migrate to northern habitats (Hansen and McKnight 1964; Smith 1970; Henny 1973). Several other species of waterfowl and shorebirds use the wet tundra for feeding during migration and seem also to breed in small numbers periodically.

Efforts to preserve the fauna and flora of tundra wetlands are complicated by our incomplete understanding of the roles of moisture levels, frost action, and other physical forces in the creation and continuity of the wet tundra ecosystem. Unfortunately, human-induced change may create permanent damage before we can study, assess, and predict the complications. Much of the damage from human activity on the tundra will take the form of esthetically displeasing local effects on vegetation. Equally uncertain is the effect of the vast network of roads and collecting pipelines that may alter water levels and form new wetlands, thereby influencing vegetative growth and succession.

First order damage resulting from oil development will be direct effects of oil pollution on vegetation and wetland systems. Although most public concern has related to potential damage along the proposed route of the Trans-Alaska Pipeline, oil spills and disturbances will be more frequent in oil or gas fields where pipeline systems and roads link wells to the main pipeline. Oil spills almost anywhere in this area, where slopes are gradual and drainage patterns indefinite, could result in the deposition of oil in many basins during the spring thaw when melt water flows over the impermeable tundra surface. Any major reduction of food organisms through degradation of preferred habitats by industrial activity will be detrimental to local aquatic bird populations.

The results of severe oil pollution are indicated by the destruction of all invertebrate and plant life in the contaminated pond at the Storkersen Point well; the basin is useless to water birds for food, and the contaminated sediments contain pollutants which may spread to adjacent wetlands. Petroleum compounds in bottom sediments break down slowly, especially in cold climates, and oil-loaded sediments can be lethal to important and abundant midge larvae (Bengtsson and Berggren 1972) and small, shrimp-like crustaceans (Blumer et al. 1971). Repopulation of waters over polluted sediments by free-swimming invertebrates is unlikely because most aquatic invertebrates will be subjected to contact with toxic sediments on the bottom of wetlands during the egg or overwintering stage of their life cycle.

Because petroleum development and production may occur over most of the Alaskan wet tundra ecosystem adjacent to the Beaufort Sea, it is vital that efforts be made to (1) preserve some large and totally undisturbed blocks of this unique habitat, and (2) prevent unnecessary destruction of bird populations and habitats even in areas developed for oil or gas removal.

Total protection of large tracts of tundra, including protection from all-terrain vehicles even in winter (see Plate I), is essential to preserve the integrity of these units as reserves and areas for further study.

Although there are other extensive moist tundra areas in Alaska, the northern coastal plain is unique in its geographic position, its climatic regime, and its possible importance to birds moving in east-west migration. We favor saving some large, undisturbed blocks of habitat that will preserve the unique wetlands and upland habitats that vary from the coast into the foothills of the Brooks Range.

In addition, smaller units that are well distributed throughout oil development areas should be preserved. So little is known about habitat requirements and home ranges of resident birds that the optimum size of such preserve units is uncertain. The Storkersen Point study area was large enough to include one pair of whistling swans, but rather small for aggregations of nesting brant or eiders. Therefore, comparable blocks of 42 km^2 would be minimal to satisfy home-range requirements of mobile species like whistling swans. These blocks should be selected from the most diverse and productive areas, irrespective of their potential for oil development. Such units will preserve the essential diversity of organisms and physical features of the plain for bird production and for scientific investigation. The number of such units essential to significantly maintain a specific level of bird production is uncertain.

Throughout the oil development areas, it should be feasible to preserve key water-bird production areas with little modification of operational procedures. Based on data from this study, Deep-*Arctophila* ponds and lakes (Class IV), Basin-complex wetlands (Class VI), and Coastal wetlands (Class VIII) are most intensively used by water birds. While wetlands in other classes are more abundant (Table 10) and less intensively used by loons and waterfowl, their value to other water birds is great.

The following recommendations are based on general observations of the wet tundra ecosystem and could help to minimize conflicts between water birds and petroleum development on the Arctic Coastal Plain: (1) With current drilling technology, it may be possible to choose well sites some distance from choice Class IV, VI, and VIII wetlands to reduce impact on reproductive activity of the larger water birds. (2) Pipeline pump stations, oil wells, and other facilities containing oil should be restricted to sites where leaking oil cannot enter flowing waters or wetlands in Class IV, VI, and VIII. (3) Where facilities must be in watersheds, regular inspection is essential and contingency plans should be ready for rapid containment of oil. (4) Other pollutants such as drilling mud, solid wastes, and fluid wastes should not be discarded into wetlands. (5) During 15 May to 1 October, major construction activities should be prohibited within 1 km of wetlands in Classes IV, VI, and VIII. (6) New roads and pipelines should be constructed so that a minimum number of Class IV, VI, and VIII wetlands are affected by water blockage. (7) Activities that will drain wetlands of high value to water birds should be prohibited. (8) Low-level aircraft activity should be minimized during the breeding season.

Future studies relevant to understanding relationships between birds, wetlands, and petroleum and gas development should include studies of: (1) the use of classes of wetlands by phalaropes and other species of shorebirds; (2) a comparable classification system for uplands, especially in reference to use by plovers and sandpipers; (3) techniques for rapidly and accurately appraising bird production values of wetlands of the coastal plain;

(4) the capacity of melt water to transport oil over the impermeable tundra surface during spring thaw; (5) the toxicity of oil to aquatic food resources of birds; (6) the effect of disturbance on populations and reproductive success of tundra birds; (7) the impact of water-level changes on vegetation and invertebrates in tundra wetlands; (8) determination of the optimal size and distribution of small production units; and (9) an evaluation of the role of barrier islands and lagoons for birds that use the coastal plain as well as those that exclusively nest on these islands or feed in the lagoons.

Summary

Water-related birds and aquatic habitats dominate the natural ecosystem at Storkersen Point in Alaska's Prudhoe Bay oil fields. Of the 25 species of birds that nested in the study area, 11 were swimming birds (loons, waterfowl, and phalaropes) and 4 were sandpipers (*Calidris* spp.) that often wade. Phalaropes and sandpipers were the most abundant species.

A wetland classification system is presented that is based on characteristics of basin morphometry, vegetation, specific conductance of water, and water movement. Eight classes of wetlands are defined: Flooded Tundra (Class I); Shallow-*Carex* (Class II); Shallow-*Arctophila* (Class III); Deep-*Arctophila* (Class IV); Deep-open (Class V); Basin-complex (Class VI); Beaded Stream (Class VII); and Coastal Wetland (Class VIII). Wetlands of Classes I through V represent progressive stages of basin development resulting from thawing of ground ice, and Class VI wetlands form after Class V basins are partially drained. Beaded Streams (Class VII) are the only type of fluvial waters at Storkersen Point and are a widespread feature of the Arctic Coastal Plain. Coastal Wetlands (Class VIII) are distinguished from other classes, because they are periodically flooded by sea water, have unique vegetation, and tend to be brackish.

Deep-*Arctophila* (Class IV) and Basin-complex (Class VI) wetlands were used most frequently by loons and waterfowl. Shores and waters of Deep-open lakes (Class V) were molting-areas for geese and female oldsquaws, and Coastal Wetlands (Class VIII) were preferred nesting and feeding habitats of black brant. The more abundant, smaller wetlands were intensively used by phalaropes and sandpipers.

Data on numbers and volume of invertebrate organisms associated with emergent vegetation support general observations on feeding and other use of wetlands: (1) Classes III, IV, and VI wetlands are of greatest importance to waterfowl and loons that utilize invertebrates, and (2) Class VIII wetlands are of greatest value to herbivorous brant. Production of invertebrates reaches its peak during late summer when shorebirds and waterfowl broods are most abundant. Use of invertebrates by water birds stresses the importance of protecting wetland habitats from disturbance if the avian community is to be perpetuated.

Undisturbed tundra preserves of a size sufficient to support nesting by all bird species are a vital need. Recommendations to reduce conflicts between water birds and oil or gas development are focused primarily on minimizing oil-related activities near wetlands in Classes III, IV, VI, and VIII because these classes are limited in numbers and are intensively used by water birds. Comparable data on habitat selection by upland-nesting shorebirds are of high priority for further research.

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