Habitat ecology of Pacific Black Brant and other geese moulting near Teshekpuk Lake, Alaska

DIRK V. DERKSEN, WILLIAM D. ELDRIDGE and MILTON W. WELLER

Introduction

Moulting areas for waterfowl have received considerably less research effort than either breeding or wintering areas (Fredrickson & Drobney 1979), partly because their importance in the life cycle of waterfowl has not been appreciated, and partly because moulting birds tend to be wary at this period and select remote sites. From a management and conservation standpoint, it is essential to: (a) know the types of areas used and the possible reasons for their selection; and (b) devise systems for protection of such areas which are as vital as breeding or wintering areas.

Moult migration is especially common in geese which do not breed until two to four years of age. Large groups seem to consist of immature non-breeders and presumably unsuccessful breeders whereas pairs rearing young tend to moult separately near the nesting area. Moulting areas often are long distances from the breeding areas, occasionally involving long flights overseas, as in the case of the movement of the Pink-footed Goose *Anser brachyrhynchus* from Iceland to Greenland (Christensen 1967). Moulting concentrations have also been recorded for various species of post-breeding ducks in the northern hemisphere (Hochbaum 1955; Bergman 1973; Joenson 1973; Oelke 1974; Salomonsen 1968), and for non-breeding Sheldgeese in South America (Weller 1972).

A concentration of moulting Pacific Black Brant *Branta bernicla nigricans*, White-fronted Geese *Anser albifrons*, and Canada Geese *Branta canadensis* was discovered by Henry Hansen in 1957 (King 1970) in the shallow lakes of the Arctic Coastal Plain north of Teshekpuk Lake, Alaska. Subsequent banding demonstrated that this area serves breeding populations in Alaska, Canada and Siberia. The White-fronted Geese migrate to Texas and the Canada Geese and Brant winter in Washington/Oregon and Mexico, respectively (Bellrose 1978; King and & Hodges 1979). Hence, it is an area of international as well as national significance.

Petroleum exploration in this area has caused concern that these lakes may be modified by future development and the goose concentrations disturbed to a point where this tradition might be disrupted and geese scattered to less suitable areas. For this reason, a study was established to determine: (1) how and when geese use the area; (2) foods and feeding behaviour; (3) habitat use and resource segregation by species; (4) other factors influencing goose use of this area; (5) impacts of industrial development on goose populations; and (6) preservation and management strategies for the area.

Study areas and goose populations

The area northeast of Teshekpuk Lake (70°30′N, 153°30′W) is dominated by lakes of 1 to 6 km in length oriented about 10° West of North (Figure 1). Many are secondary lakes developed in still larger lake basins. This area is one of few on the Coastal Plain having nearly 50% water area (Sellman *et al.* 1975). East Long Lake is 15 km inland from the Beaufort Sea and Island Lake is about 10 km inland. East Long Lake is one of a pair of lakes of similar size, shape and orientation that are separated by high ground. Each is a remnant of a former large lake basin and, in fact, the two basins may once have been connected. Studies were conducted on the west shore of East Long Lake where predominant easterly winds have produced a beach ridge of peaty material which has formed linear lagoons parallel to the shoreline. Island Lake has less dramatic differences in shoreline elevation and no lagoon system. As a result, both the island and the adjacent shoreline that served as study areas were fairly uniform in vegetation, being moss interspersed with grasses, sedges and forbs.

Distribution of moulting geese over the years 1976–1978 has been reviewed by Derksen *et al.* (1979). Ground studies were conducted at East Long Lake and Island Lake which consistently had high populations of Brant and Canada Geese. Maximum numbers of Black Brant in 1978 were, respectively, 4,360 and 5,200 with a maximum of 1,216 and 1,105 Canada

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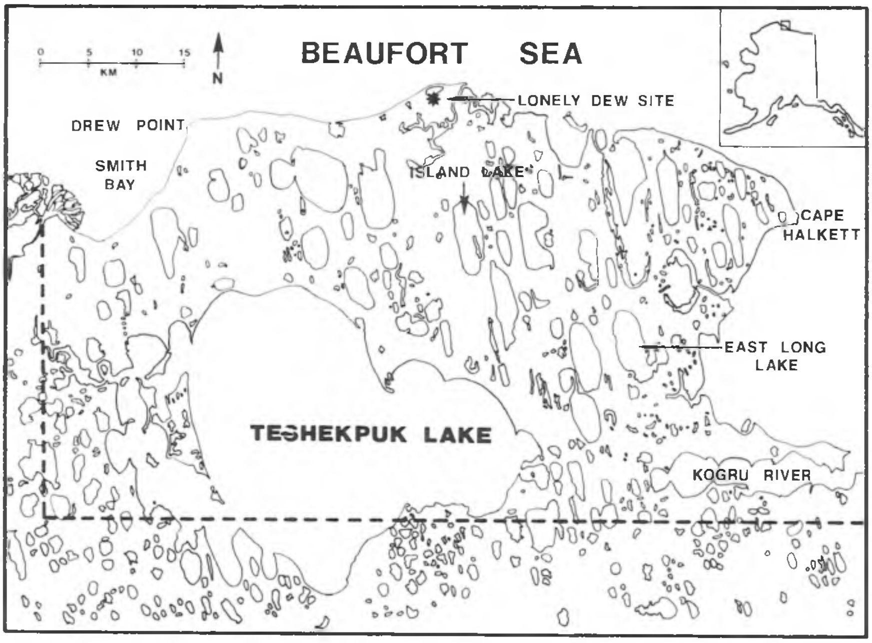

Figure 1. East Long Lake and Island Lake study sites on the Arctic Coastal Plain of Alaska. The Lonely Distant Early Warning (DEW) site was headquarters for petroleum operations in the area. Dashed line indicates proposed boundaries where petroleum development should be precluded.

Geese. There were up to 50 White-fronted Geese at East Long Lake and 470 at a lake 3 km to the southwest. White-fronted Geese nest sparingly as solitary pairs in both areas, and Island Lake had a nesting colony of about 50 pairs of Brant. Canada Geese do not nest in the Cape Halkett area.

Procedures

Plant production and consumption

A stratified sampling design was used in the two major plant zones to measure plant production, intensity of goose use, and actual consumption. Two lines of 1 × 2 m exclosures made of 0·5 m high chickenwire were erected in June at intervals of about 75 m parallel to the shore at East Long Lake (Figure 2). The line through the moss zone centred on the beach, and that in sedge was on the lakeward side of the lagoon. Twenty exclosures were established in the moss zone, but one was lost because a Brant became trapped accidentally and damaged the vegetation while inside the fence. Due to a shortage of construction materials, only 17 exclosures could be established in the sedge zone. At Island Lake 21 sedge and 19 moss exclosures were established at intervals of 138 m along two stratified transects.

Samples were taken by using a 20 × 50 cm frame for subplots. Vegetative parameters taken in each zone or line included stem density, mean height estimate and a cover estimate according to Daubenmire (1969). Green vascular plants were clipped for above-ground biomass estimates.

Vegetation was sampled inside and outside exclosures three times at East Long Lake in 1978: 4–6 July, before geese arrived; 17–20 July, at peak buildup; and 9–11 August, after geese had departed. Samples were taken on 1–5 July and 8–9 August 1978 at Island Lake.

Prior to the arrival of goose flocks at East Long Lake, five control subplots were equally spaced between each pair of exclosures for a total of 100 subplots. All were assessed for cover, height, density, and were clipped. After geese arrived, three subplots were sampled inside each exclosure and three subplots were selected outside by random toss of the frame within 3 m of the exclosure. Data on above-ground standing crop of plants in the moss and sedge zones were gathered by clipping plots inside and outside the exclosures three times per growing season at East Long Lake and twice at Island Lake. Plots clipped in early July reflected the minimal growth of the post-flooding stage. Clippings two weeks later reflected rapid growth of the first weeks of July as goose populations built up. The final clipping in early August reflected the majority of the season's growth and measured consumption following the exodus of most of the geese.

Vegetation clipped from plots was air-dried in paper bags for 30 to 45 days. After sorting into taxonomic groups, samples were placed in a desicator and then weighed to the nearest 0·001 g.

Clippings from exclosures and unfenced controls were compared to assess maximal growth and utilization. No estimates of plants within the exclosure that were removed by lemmings (*Dicrostonyx* and *Lemmus* spp.) are available. A few caribou *Rangifer tarandus* also passed through the area but they fed mostly in the uplands. The estimate of consumption resulting from in-out comparisons of standing crop are, therefore, attributed to geese but are minimal estimates.

Dropping plots

We also evaluated use of vegetation zones by counting and collecting goose droppings in plots located near exclosures and in other areas where moulting geese grazed. One hundred and twenty, 1 m^2 plots were established at East Long Lake and 86 at nearby lakes. At Island Lake we sampled 563, 2 m^2 plots in the moss and sedge zones, and 517, 2 m^2 plots on shores of 12 adjacent lakes.

Plot corners were marked and cleared of droppings before geese arrived then checked periodically during the moult period. Droppings were counted and then air-dried for analysis of composition.

Food availability and use by geese

Availability of various potential food plants was assessed by species identification within exclosures and clipped plots, but the relative abundance of these plants was assessed by cover estimates and frequency of occurrence in sample plots. Utilization by geese as measured by biomass

Figure 2. View of moss zone at East Long Lake. The lake shore is in the upper right and lagoon in the upper left of the photo. Note wire exclosures and time-lapse movie camera mounted on pipe next to person. Goose droppings and primary feathers can also be seen in the foreground.

and plant species consumed was assessed by comparison of data from unprotected plots with that from exclosures. In addition, 60 goose droppings from East Long Lake and 59 from Island Lake were analysed by microscopic cell structure techniques (Hanson *et al.*, 1978).

Nutrient analysis

Plant tissues were oven-dried at 65°C and ground in a Wiley mill to pass through a 20-mesh screen. After grinding, samples were redried at 65°C and capped into a polyethelene jar. A 0·15 g sample of the dried ground tissue was weighed into a digestion tube to which H_2O_2 and a mixture of H_2SO_4 and H_2SeO_3 was added. Following digestion at 400°C for 45 minutes, the sample was analysed for nitrogen (N) and phosphorus (P) on a Technicon Autoanalyzer II System (Anon. 1976). The cations potassium (K), calcium (Ca) and magnesium (Mg) were determined from the digest by atomic absorption spectrophotometry.

Crude fat was determined gravimetrically by ether extraction using a Randall Extractor (Randall 1974). Total non-structural carbohydrates (TNC) were determined by a modified Weinmann method with reducing power, and measured colormetrically on the Autoanalyzer II. Cellulose was determined by an acid-detergent fibre procedure.

Behavioural observations

Brant were so wary that approach within 500 m was impossible. To determine the behaviour of flocks, use of wetlands, response to predators, and response to human disturbance, observations were of three types: (1) those made during censuses and other field work when flock size, species composition and location were mapped to provide general association of birds with wetlands; (2) observations from blinds by telescope of distant flocks to assess general behaviour; and (3) time-lapse camera for close-up assessment and quantification of flocks otherwise too distant to study or document.

Super-8 movie cameras were located in positions where automatic recording of habitat use and activities was possible (Figure 2). Timing of frames at one per minute from the start of the film also permitted an analysis of daily activities according to time of day with little intervening disturbance over the 2·5 days which the film lasted. Films were exposed between 2 July and 4 August.

At East Long Lake, three cameras were established parallel to shore, one each in the sedge and moss zones, and one between to measure inter-zonal movement. Two cameras were used at Island Lake, one on the island, and one on the west shoreline. These were both in moss areas where intensive use by Brant would show typical activity patterns. Camera failure due to excessive humidity reduced the coverage by area and season.

The camera's range of perception and recording was approximately 150 m and delineation of zones for analysis was aided by stakes placed in the field of view as well as by the exclosures (Figure 2). Time-lapse films were analysed frame by frame on a movie projector capable of single frame projection and equipped with a remote digital frame counter. Distant flocks were not tallied during the analysis because the image size prevented determination of species and type of activity. For carding and computer analysis, behavioural categories were: feeding, walking-running, alert, resting/sleeping, and maintenance.

Results

Chronology of gathering and moult

Nesting Brant and White-fronted Geese arrive in the area in late May and early June, and hatch young in early to mid-July. Non-breeding Brant gather in early July, are in full wing moult in the second week of July, and some individuals regained flight by the last week in July (Derksen *et al.* 1979). Regrowth probably takes three to three and a half weeks but, because undisturbed birds fly very little even when they have flight feathers, precise dates and conditions are difficult to establish. Canada Geese may have a slightly earlier chronology and in 1978, some birds were flying with new primaries by 18–20 July. In all species, body moult follows wing moult, but the timing and rate of this were not established in this study.

Geese remained in the lake district until late July or early August when both Brant and Canada Geese gradually shifted to the Beaufort Sea coast. Most of the Pacific Black Brant population gather at Izembek Lagoon on the Alaska peninsula (55°30′N, 162°55′W) in October, so presumably there is adequate time and food reserves and suitable climatic conditions to allow leisurely movements along the coast westward and southward (see Bellrose 1978).

Feeding behaviour

In the post-breeding period, geese became highly social and, during the moult, rarely fed alone. Flocks of 150 to 250 were most common among Brant, varying from a few up to 3,000. Among Canada Geese and White-fronted Geese, flocks up to 1,000 and 250, respectively, were recorded during aerial surveys (Derksen *et al.* 1979).

Flocks of Brant loafed on moss-covered mud bars within 50 m of water at East Long Lake, and fed 100 m or more away from water in wet meadow shorelines (Figure 3).

All three species grazed on moist-soil sites of fine grasses or sedges adjacent to lakes, moving into the wind as they fed. Individuals tended to feed toward open areas rather than behind other birds, leading to the development of broad flocks in the form of an ellipse or reversed 'V' moving in the same general direction. Both Brant and Canada Geese clipped with the nail rather than uprooting vegetation. They moved rapidly (about 6·5 m/min in 5 time periods of 46 min total), seemingly exploiting choice or accessible items rather than standing in one place and removing everything. After moving as a feeding wave over an area, they rested. Flocks may use the same site from once per day to once every three or four days. Such regular clipping would produce a constant supply of the favoured new shoots as opposed to larger less nutritious stalks.

Social behaviour

Resting Brant remained together, but separated when feeding. Awakening Brant tended to wing-flap, search for other flocks, and then run to join nearby feeding flocks.

Flocks remained cohesive in spite of competition for food which tended to separate individuals. Leading birds maintained visual contact with the flock and would turn back if they found themselves too far ahead. Concurrently, birds at the outer rear of flocks tended to feed from forward to backward, which slowed the forward thrust of the flock. Unfortunately, distance of observation prevented photographic analysis of these dynamic social feeding systems.

Resting birds use either ice floes, where they have protection from predators, or relatively dry spits, isthmuses or shores where they can jump into water if disturbed. They tended to face the wind, especially if it was strong, and they did not stray far from water.

Family and species ties were still evident. In disturbed situations, small flocks of Canada Geese, probably family units or multiples thereof, remained together in spite of being outnumbered by large numbers of Brant. Even flocks mixed during trapping and banding gradually segregated by species.

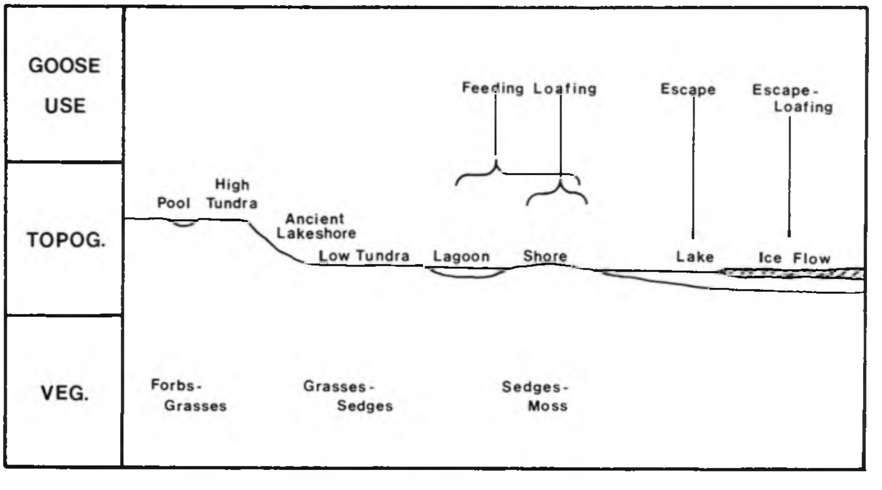

Figure 3. Schematic diagram of East Long Lake shoreline depicting goose use of topographic features and vegetation zones. Adapted from Derksen *et al.* (1979).

Escape behaviour

Birds in feeding flocks, and often those moving toward a specific goal, engaged in running-flapping movements that appeared to be simulated escape reactions. Sometimes such behaviour in several birds created a scare response that caused birds to run to water. Such action was short-lived.

Moulting birds, and often those in pre- or post-moulting flocks, responded to potential predators or human disturbances by going to water. When large ice floes were present, they moved directly to those and ran across them to increase the distance between the intruder and the flock.

Alert or slightly disturbed flocks moved together as a loosely aggregated unit. Flocks disturbed by low-flying aircraft moved to water and formed a tight band. In one case, a series of aircraft disturbances eventually caused such a flock to move eastward about 3 km across East Long Lake. Observations of marked birds in this population demonstrated that all of the flock did not then return to the west side.

Potential natural predators of geese are grizzly bear *Ursus horribilus*, wolf *Canis lupus*, and arctic fox *Alopex lagopus*. Although arctic foxes seem small to attack birds of this size, one surprised and killed a White-fronted Goose fleeing at the approach of a helicopter. One member of the field crew at Island Lake saw several geese taken by foxes and found remains of geese at fox dens. Eskimos may also have been regular pursuers of geese in moult.

Time budget

Data from time-lapse cameras (Table 1) probably are biased toward feeding activity because several camera malfunctions left the favoured feeding area as the major operable camera site. Brant fed 89–95% of the time and Canada Geese fed 71–98% of the time. Very little time was spent in maintenance movements. Birds were disturbed less than 1% of the time, and many of these alert postures may have been a response to camera shutter noise. This may form an important base of data if oil development or other activities create more constant and diverse forms of disturbance.

Observations from blinds also suggest a long activity period for both species during the 24-hour daylight of the Arctic summer. Tallies of birds active at various hours of the day, suggest a period of reduced activity from midnight to 0400 or 0500 hr and from mid-morning until noon, with a peak of feeding either in the morning or evening.

Vegetative characteristics of feeding areas

The west shore of East Long Lake is a sedge tundra flat produced by partial drainage of the lake (Figure 4). Subsequently, the western shoreline has been built up by wave and ice action but is constituted of peaty materials that hold moisture. A series of lagoons or ponds formed by this barrier beach are dominated by *Carex aquatilis* whereas the beach is dominated by mosses and finer grasses.

The moss zone is covered by a moist-soil pioneer community that is constantly stressed by alternate flooding and drying and is enriched by intrusion of vegetative debris. The sedge zone has a more stable water level, less intruded debris, but experiences spring flooding. Whereas the sedge zone is the dominant plant community at East Long Lake (66%), the moss community is prevalent at Island Lake (42%) (Table 2). The distribution of goose droppings found in randomly selected survey plots is a mea-

Table 1. Time budget (% frequency) for moulting Canada Geese and Black Brant at East Long Lake (ELL) and Island Lake (IL) in 1978.

	Canada Geese		Black Brant	
Activity	ELL (n=1,537)*	IL (n=3,286)	ELL (n=111,018)	IL (n=28,137)
Feeding	98·05	71·30	95·22	89·58
Running	1·76	0·06	0·27	0·49
Alert (head up)	0·19	0·03	0·02	0·0
Resting/sleeping	0·0	28·61	4·48	9·92
Maintenance	0·0	0·0	0·01	0·01
TOTALS	100·0	100·00	100·00	100·00

* Number of time-lapse film frames with geese.

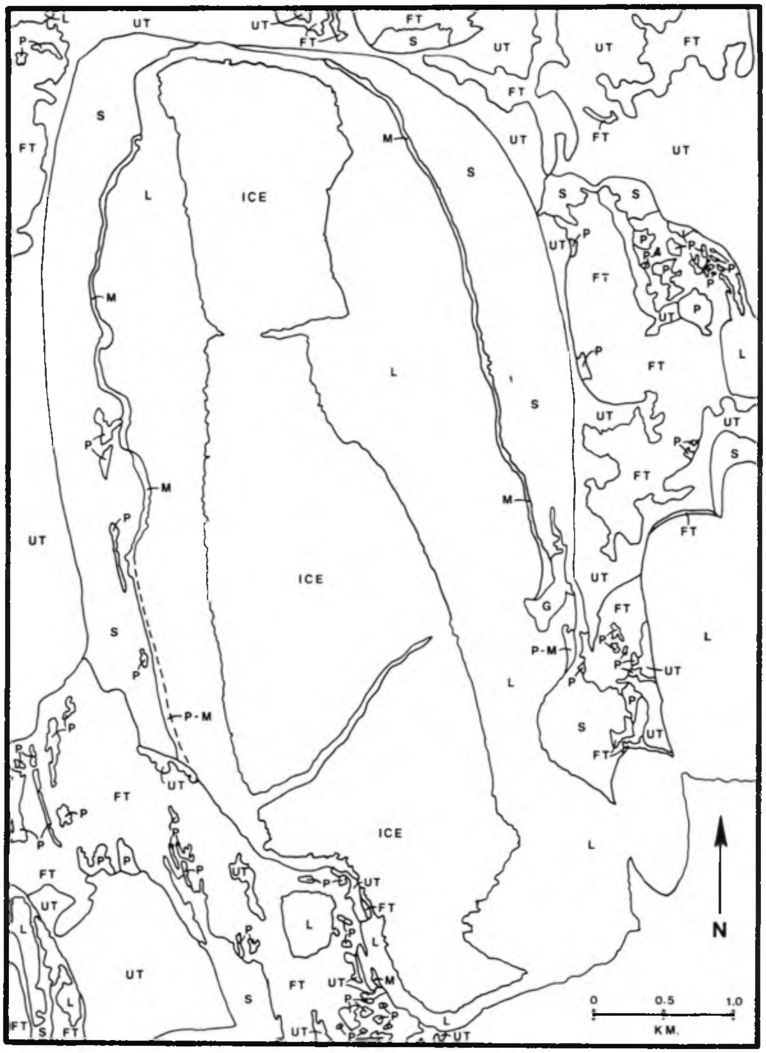

Figure 4. Cover map of East Long Lake made from a 1:24,000 scale colour vertical photograph exposed on 18 July 1976. L = lake, P–M = peat/mud zone, M = moss zone, P = pond, S = sedge zone, FT = flooded tundra and UT = upland tundra. Note the large ice cake which provided a safe resting site for moulting geese.

Table 2. Habitat types used by flightless geese.

Habitat type	East Long Lake Area (ha)	East Long Lake % Total	Island Lake Area (ha)	Island Lake % Total
Peat/mud shoreline	8·31	3·43	34·67	14·20
Moss zone	37·46	15·46	102·27	41·97
Sedge zone	161·21	66·53	50·06	20·57
Flooded tundra	28·26	11·66	29·39	12·07
Pond	5·66	2·34	11·72	3·12
Dry upland tundra	1·40	0·58	19·67	8·07
TOTALS	242·30	100·00	243·66	100·00

sure of relative use of specific areas. These show a higher incidence in moss than in sedge at both lakes and, in fact, at five other lakes (Table 3). They may reflect preference of moss areas as loafing sites because they are dry and because visibility is good. Data on plant species composition and frequency of occurrence gathered from exclosures indicate potential foods. At least 15 species of higher plants occurred in the sedge zone whereas only 10 species occurred in the moss zone (exclusive of the mosses) at Island Lake, and only a few of these were dominant (Table 4).

Table 3. Mean number of goose droppings in moss and sedge zones at Island Lake and East Long Lake study sites in 1978. These were determined from 2 m^2 and 1 m^2 plots at Island Lake and East Long Lake respectively.

Lake complex and number	Lake surface area (ha)	Number of droppings/m^2 Moss zone (n)*	Sedge zone (n)*	Level of significance†
Island Lake Complex				
62 (Island Lake)	1720	8·26 (226)	0·99 (134)	0·01
61	134	4·55 (61)	0·43 (14)	0·01
106	1635	4·03 (80)	0·68 (23)	0·01
110	405	7·02 (31)	2·80 (8)	NS
99	1348	12·93 (67)	4·74 (29)	0·01
East Long Lake Complex				
145 (East Long Lake)	1951	12·80 (60)	8·70 (60)	0·01
87	1194	13·70 (60)	—	

* Number of plots sampled.
† Level of significance determined by Student's t-test.

Table 4. Percent frequency of occurrence of plants in 2 m^2 plots for 13 lakes at the Island Lake study site in 1978.

Plants	Moss zone (n = 658)*	Sedge zone (n = 237)
Unidentified mosses	98·2	89·9
Sedges		
Carex aquatilis	2·6	73·4
Carex sp.	6·5	24·9
Eriophorum sp.	2·0	41·8
Grasses		
Deschampsia caespitosa	67·4	0·8
Dupontia fischeri	21·6	48·1
Arctophila fulva	10·6	5·0
Alopecuris sp.	0·0	3·8
Unidentified grasses	22·0	26·6
Forbs		
Ranunculus palasii	3·5	11·8
Ranunculus gemelini	6·7	0·4
Saxifraga hirculus	5·3	13·1
Saxifraga cernua	19·5	47·3
Caltha palustrus	2·6	17·3
Senecio congestus	7·6	2·9
Cassiope sp.	4·9	0·0
Koenigia islandica	6·5	0·4
Stellaria humifusa	3·4	3·8
Shrubs		
Salix sp.	4·6	21·9
Other species	9·3	25·7
Bare ground	22·0	2·5

* Number of 2 m^2 plots sampled.

Nutrient value of plants

We tested seasonal mineral and organic nutrient concentration in above ground plant parts clipped from 20 × 50 cm plots in moss and sedge zones at both lakes.

Sedges and grasses had highest nitrogen values in early July, and progressively declined through the season at both study sites (Table 5). Grasses had slightly higher values than sedges except during the August sample period at East Long Lake. Total nitrogen in mosses was less than half the values obtained for sedges and grasses there in mid-July. There were few significant differences in sedge and grass nitrogen concentration between the two lakes.

Seasonal declines in percentage of phosphorus and potassium in above ground biomass occurred at both lakes. These results are similar to Chapin *et al.* (1975) who stated that after 25 July at Barrow, Alaska, shoots become a net source rather than sink for mobile nutrients such as nitrogen, phosphorus and potassium. By comparison, calcium levels in sedges and grasses increased at least twofold over the season at our sites. Mosses had especially high calcium values at East Long Lake. We found percent magnesium to be relatively constant in above ground biomass over the season.

Crude fat levels of sedges and grasses were slightly higher in early July than late July and August sample periods at both study sites (Table 6). Mosses collected at East Long Lake had about 7% of the crude fat found in sedges and grasses during the late July sample period.

Total nonstructural carbohydrates (TNC), excluding cellulose, were generally higher in grasses than sedges at the two study sites (Table 6). No trends in seasonal variation are evident from our data.

Species composition of foods determined from droppings

Data from microscopic analysis of plant epidermal fragments from Brant droppings collected in the moss and sedge zones at East Long Lake is shown in Table 7. The percentage of mosses was greatest in droppings collected in the moss zone, and *Carex* sp. was counted more frequently in drop-

Table 5. Seasonal levels of mineral nutrients in above ground plant parts clipped from plots at East Long Lake and Island Lake in 1978. Samples were a composite of all species within a group.

	Mineral nutrient concentration (% dry wgt.)				
	N	P	K	Ca	Mg
Vegetation Group (n)*	X̄ ± SD	X̄ ± SD	X̄ ± SD	X̄ ± SD	X̄ ± SD
EAST LONG LAKE					
Pre-Season					
(4–6 July)					
Sedges (1)	3·10	0·37	1·75	0·08	0·15
Grasses (1)	3·35	0·39	2·00	0·07	0·13
Mid-season					
(17–18 July)					
Sedges (2)	2·96 ± 0·14	0·35 ± 0·01	1·91 ± 0·02	0·09 ± 0·01	0·14 ± 0·01
Grasses (4)	3·40 ± 0·68	0·42 ± 0·05	1·91 ± 0·12	0·11 ± 0·03	0·16 ± 0·01
Mosses (7)	1·09 ± 0·26	0·22 ± 0·05	0·39 ± 0·12	1·47 ± 0·23	0·56 ± 0·10
Post-season					
(9–11 August)					
Sedges (2)	2·58 ± 0·04	0·28 ± 0·02	1·77 ± 0·01	0·13 ± 0·01	0·15 ± 0·01
Grasses (4)	2·47 ± 0·52	0·30 ± 0·07	1·63 ± 0·07	0·16 ± 0·02	0·16 ± 0·04
ISLAND LAKE					
Pre-Season					
(4–6 July)					
Sedges (1)	2·82	0·40	1·94	0·06	0·16
Grasses (1)	3·15	0·44	2·41	0·01	0·14
Post-season					
(8–9 August)					
Sedges (1)	2·51	0·28	1·65	0·24	0·15
Grasses (2)	2·22 ± 0·49	0·30 ± 0·01	1·74 ± 0·10	0·20 ± 0·18	0·15 ± 0·02

* Number of analyses.

Table 6. Seasonal levels of organic nutrients in above ground plant parts clipped from plots at East Long Lake and Island Lake in 1978. Samples were composite of all species within a group.

	Organic nutrient concentration (% dry wgt.)			
	Crude Fat	TNC	Protein	Cellulose
Vegetation Group (n)*	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
EAST LONG LAKE				
Pre-season				
(4–6 July)				
Sedges (1)	3·0	8·6	19·37	23·5
Grasses (1)	2·9	10·2	20·93	22·7
Mid-season				
(17–18 July)				
Sedges (2)	2·55 ± 0·07	3·65 ± 0·07	18·50 ± 0·88	22·55 ± 2·05
Grasses (4)	2·13 ± 0·12	5·03 ± 3·26	21·42 ± 4·16	21·95 ± 3·19
Mosses (6)	0·19 ± 0·10	†	6·80 ± 1·66‡	
Post-season				
(9–11 August)				
Sedges (2)	2·40 ± 0·00	5·35 ± 2·62	16·09 ± 0·23	23·50 ± 2·26
Grasses (4)	2·10 ± 0·24	13·03 ± 4·43	15·04 ± 3·23	20·05 ± 4·99
ISLAND LAKE				
Pre-season				
(1–4 July)				
Sedges (1)	2·2	6·4	17·62	21·1
Grasses (1)	2·0	4·5	19·68	21·3
Post-season				
(8–9 August)				
Sedges (1)	1·9	6·2	15·68	22·4
Grasses (2)	1·95 ± 0·49	8·35 ± 0·92	13·84 ± 3·05	21·95 ± 4·17

* Number of analyses
† All values were less than 0·01.
‡ 7 samples analysed.

Table 7. The percentage of vegetation taxa in Brant droppings* collected from 2 vegetation zones at East Long Lake in 1978.

Plant fragment types	Moss zone $\bar{X} \pm SD$ (n = 30)		Sedge zone $\bar{X} \pm SD$ (n = 30)	
Mosses				
Unidentified sp.	50·26	42·24	26·29	39·17
Horsetail				
Equisetum sp.	0·05	0·27	0·03	0·18
Grasses				
Deschampsia sp.	23·05	33·08	19·67	23·35
Pluropogon sp.	0·09	0·50	0·04	0·22
Poa sp.	0·02	0·10	0·03	0·15
Unidentified sp.	0·43	1·39	0·02	0·11
Sedge				
Carex sp.	22·95	37·01	53·31	38·83
Forbs				
Unidentified sp.	3·15	17·24	0·05	0·21
Shrub				
Salix sp.	—		0·56	3·07
TOTAL		100·00	100·00	

* Possibly may contain a few Canada Goose droppings.

pings from the sedge zone. Grasses made up about 20–25% of the diet of Brant, and *Deschampsia* sp. was the most frequently selected of the grasses identified. Forbs and shrubs were of little importance as Brant food.

Composition of vegetation taxa in Canada Goose and Brant droppings collected at Island Lake was similar except for the higher percentage of *Carex* sp. and lower levels of *Deschampsia* sp. in the Canada Goose (Table 8). These differences support our observations (Derksen *et al.* 1979) that Canada Geese prefer the sedge zone and Brant use the moss zone where grasses such as *Deschampsia caespitosa* are most abundant.

Clippings of grasses and sedges were evident over much of the study area, but utilization of moss was not obvious. However, moss is indicated as the dominant, making up 16–50% of droppings collected. This would suggest a volume too high to be accidental. One explanation is that bias may be introduced in microscopic examination because mosses fragment much more easily than the epidermis of vascular plants (McKendrick, pers. com.) which would inflate moss percentages. Such inflation is suggested by examination of 25 Brant droppings collected in the moss zone at Caribou Lake, north of East Long Lake, to determine the percent volume of moss in individual droppings. Three droppings had no moss, 9 had a trace, 10 had 5% and 1 had 50% moss. These results suggest the slide analysis of cell structure produces high values for moss, although considerable variation in samples is evident. A 3 to 1 factor was used to correct for fragmentation. However, this does not explain differences in moss use between our two sites since the same analysis techniques were employed.

Available standing crop and foods used

Data on cover, height, density and weight are shown in Tables 9, 10, 11 and 12. Data from clipped plots in exclosures were compared with plots grazed by geese (and potentially other herbivores) to assess both biomass production and goose use. Above ground plant production inside exclosures in the moss zone at East Long Lake measured in August was considerably less (17·75 gm/m^2) than in the sedge zone (55·45 gm/m^2). At Island Lake 49·52 and 23·41 gm/m^2 of vascular plants was produced in the moss and sedge zones, respectively.

At East Long Lake, mean sedge cover was 0·0 to 12·2% and mean grass cover was 2·7 to 12·8% inside fenced areas (Table 9). Sedge and grass cover was greater inside than outside exclosures, however the differences were not statistically significant ($P > 0·05$). Mean July forb and shrub cover was 0·7 and 0·5% inside exclosures in the moss and sedge zones respectively, and was unaffected by geese. Vegetation cover was not significantly ($P > 0·05$)

Table 8. The percentage of vegetation taxa in Canada Goose and Brant droppings collected at Island Lake in 1978.

Plant fragment types	Canada Goose $\bar{X} \pm SD$ (n = 29)		Black Brant $\bar{X} \pm SD$ (n = 30)	
Mosses				
Unidentified sp.	16·02	18·37	16·28	24·96
Horsetail				
Equisetum sp.	—		0·20	0·82
Grasses				
Deschampsia sp.	61·03	29·58	79·38	25·73
Dupontia sp.	0·05	0·27	—	
Hierachloe sp.	—		0·02	0·12
Pleuropogon sp.	0·37	1·15	1·12	3·76
Poa sp.	—		0·11	0·37
Unidentified sp.	8·80	16·17	0·21	0·95
Sedge				
Carex sp.	9·63	23·06	1·76	4·77
Forbs				
Unidentified sp.	0·63	1·91	0·92	1·78
Shrub				
Salix sp.	3·47	13·26	—	100·00
TOTAL		100·00		

Table 9. Mean percent cover of vegetation groups inside and outside exclosures by zone and time period at East Long Lake and Island Lake in 1978.

Zone	Sedges Inside X̄* ± SD(n)†	Sedges Outside X̄ ± SD(n)		Grasses Inside X̄ ± SD(n)	Grasses Outside X̄ ± SD(n)		Forbs and Shrubs Inside X̄ ± SD(n)	Forbs and Shrubs Outside X̄ ± SD(n)	
EAST LONG LAKE									
Moss									
4–6 July		0·1 ± 0·6 (276)			4·9 ± 7·9 (276)			0·9 ± 2·0 (276)	
18–20 July	0·0 (132)	0·0 (121)		7·7 ± 12·0 (132)	4·1 ± 6·4 (121)	NS	0·7 ± 1·2 (132)	0·5 ± 1·7 (121)	NS
9–11 August	0·1 ± 0·6 (166)	0·0 ± 0·2 (166)	NS	12·8 ± 22·1 (165)	9·3 ± 15·3 (164)	NS	1·7 ± 3·9 (166)	0·8 ± 1·7 (166)	NS
Sedge									
4–6 July		9·2 ± 16·8 (306)			1·5 ± 3·6 (306)			0·6 ± 2·8 (306)	
18–20 July	6·9 ± 12·4 (196)	4·9 ± 8·8 (211)	NS	2·7 ± 5·5 (196)	1·5 ± 3·8 (210)	NS	0·5 ± 2·3 (196)	0·5 ± 2·0 (211)	NS
9–11 August	12·2 ± 20·2 (206)	7·2 ± 12·2 (199)	NS	3·7 ± 8·0 (206)	2·5 ± 5·9 (200)	NS	1·0 ± 5·9 (206)	0·9 ± 4·8 (200)	NS
ISLAND LAKE									
Moss									
1–5 July		0·5 ± 5·0 (557)			14·1 ± 26·8 (550)			2·0 ± 7·7 (516)	
8–9 August	0·2 ± 1·3 (424)	0·3 ± 3·1 (387)	NS	11·2 ± 22·2 (416)	11·2 ± 22·1 (381)	NS	2·9 ± 8·9 (365)	2·3 ± 7·9 (315)	NS
Sedge									
1–5 July		17·7 ± 31·1 (491)			2·5 ± 10·4 (474)			1·3 ± 4·7 (444)	
8–9 August	9·3 ± 21·2 (362)	10·1 ± 21·8 (338)	NS	1·6 ± 6·7 (360)	1·1 ± 4·1 (328)	NS	1·6 ± 5·8 (299)	2·1 ± 7·1 (282)	NS

* Midpoint of cover classes 1 through 6 was used to determine means and standard deviations. Cover Class 1 = 0–5%, 2 = 6–25%, 3 = 26–50%, 4 = 51–75%, 5 = 76–95%, and 6 = 96–100%.
† Number of 20 × 50 cm plots in which vegetation group occurred.
Note: Level of significance determined by Mann-Whitney U-test; NS = not significant.

Table 10. Mean heights (cm) of vegetation groups inside and outside exclosures by zone and time period at East Long Lake and Island Lake in 1978.

Zone	Sedges Inside $\bar{X} \pm SD(n)$*	Sedges Outside $\bar{X} \pm SD(n)$		Grasses Inside $\bar{X} \pm SD(n)$	Grasses Outside $\bar{X} \pm SD(n)$		Forbs and Shrubs Inside $\bar{X} \pm SD(n)$	Forbs and Shrubs Outside $\bar{X} \pm SD(n)$	
EAST LONG LAKE									
Moss									
4–6 July		2·03 ± 0·48 (10)			1·41 ± 0·42 (96)			0·80 ± 0·40 (70)	
18–20 July	0·0	0·0		2·53 ± 0·57 (48)	0·77 ± 0·38 (50)	xx	0·97 ± 0·53 (29)	1·03 ± 0·61 (18)	NS
9–11 August	2·83 ± 1·13 (6)	1·00 (1)	xx	2·62 ± 0·79 (58)	0·83 ± 0·63 (63)	xx	0·83 ± 0·69 (50)	0·63 ± 0·37 (40)	NS
Sedge									
4–6 July		7·81 ± 3·05 (102)			5·70 ± 1·75 (87)			3·19 ± 2·14 (36)	
18–20 July	9·32 ± 2·82 (79)	6·17 ± 2·47 (84)	xx	8·19 ± 2·01 (50)	4·10 ± 2·11 (51)	xx	2·32 ± 1·25 (17)	2·12 ± 1·30 (26)	NS
9–11 August	11·55 ± 2·76 (88)	7·65 ± 3·00 (95)	xx	9·39 ± 2·56 (48)	5·53 ± 1·55 (44)	xx	3·67 ± 2·20 (21)	2·81 ± 1·70 (18)	NS
ISLAND LAKE									
Moss									
1–5 July		2·06 ± 1·39 (16)			0·82 ± 0·76 (185)			0·24 ± 0·57 (142)	
8–9 August	4·45 ± 1·92 (11)	2·73 ± 1·49 (11)	x	2·61 ± 1·11 (153)	1·76 ± 0·91 (131)	xx	1·48 ± 1·67 (165)	1·05 ± 0·56 (150)	xx
Sedge									
1–5 July		3·57 ± 2·49 (137)			3·28 ± 1·99 (77)			1·18 ± 1·39 (119)	
8–9 August	9·11 ± 2·56 (88)	8·93 ± 2·62 (84)	NS	8·73 ± 4·71 (76)	7·66 ± 4·31 (71)	NS	2·62 ± 3·32 (137)	2·32 ± 2·89 (125)	NS

* Number of 20 × 50 cm plots in which vegetation group occurred.
Note: Level of significance determined by Student's t-test; xx = $p < 0{\cdot}01$, x = $p < 0{\cdot}05$, NS = not significant.

Table 11. Mean densities of vegetation groups inside and outside exclosures by zone and time period at East Long Lake and Island Lake in 1978.

Zone	Sedges Inside $\bar{X} \pm SD(n)$*	Sedges Outside $\bar{X} \pm SD(n)$		Grasses Inside $\bar{X} \pm SD(n)$	Grasses Outside $\bar{X} \pm SD(n)$		Forbs and Shrubs Inside $\bar{X} \pm SD(n)$	Forbs and Shrubs Outside $\bar{X} \pm SD(n)$	
EAST LONG LAKE									
Moss									
4–6 July		2·1 ± 1·3 (10)			146·9 ± 60·3 (95)			6·7 ± 14·3 (69)	
18–20 July	0·0	0·0		274·2 ± 66·1 (31)	258·6 ± 53·9 (29)	NS	8·6 ± 7·9 (15)	15·1 ± 34·0 (13)	NS
9–11 August	4·0 (1)	0·0		276·9 ± 96·2 (11)	1·0 (1)	x	11·0 ± 14·1 (2)	0·0	
Sedge									
4–6 July		37·4 ± 21·6 (102)			62·7 ± 53·7 (87)			8·0 ± 11·7 (36)	
18–20 July	43·0 ± 25·4 (41)	36·7 ± 22·7 (44)	NS	41·5 ± 24·3 (31)	31·5 ± 19·8 (30)	NS	3·5 ± 3·9 (13)	2·6 ± 3·2 (19)	NS
ISLAND LAKE									
Moss									
1–5 July		2·1 ± 5·4 (16)			0·4 ± 2·1 (185)			0·1 ± 0·8 (142)	
8–9 August	0·0	0·0		1·6 ± 4·4 (153)	0·3 ± 1·1 (131)	xx	1·7 ± 5·2 (165)	1·2 ± 4·2 (150)	NS
Sedge									
1–5 July		15·7 ± 7·2 (137)			5·0 ± 5·2 (77)			1·5 ± 2·1 (119)	
8–9 August	15·0 ± 21·6 (88)	12·9 ± 7·3 (84)	NS	3·9 ± 3·9 (76)	4·7 ± 5·0 (71)	NS	2·6 ± 4·1 (137)	4·2 ± 9·3 (132)	NS

* Number of 20 × 50 cm plots in which vegetation group occurred.
Note: Level of significance determined by Student's t-test; xx = $p < 0·01$, x = $p < 0·05$, NS = not significant.

Table 12. Mean weights (gm) of vegetation* groups clipped inside and outside exclosures by zone and time period at East Long Lake and Island Lake in 1978.

Zone	(n)†	Sedges Inside $\bar{X} \pm SD$	Sedges Outside $\bar{X} \pm SD$		Grasses Inside $\bar{X} \pm SD$	Grasses Outside $\bar{X} \pm SD$		Forbs and Shrubs Inside $\bar{X} \pm SD$	Forbs and Shrubs Outside $\bar{X} \pm SD$	
EAST LONG LAKE										
Moss										
18–20 July	(8)	0·0	0·0		0·755 ± 0·183	0·085 ± 0·068	xx	0·0	0·0	
9–11 August	(8)	0·0	0·0		1·744 ± 0·503	0·208 ± 0·223	xx	0·031 ± 0·055	0·0	NS
Sedge										
4–6 July	(94)		1·763 ± 0·824			0·284 ± 0·244			0·060 ± 0·316	
18–20 July	(8)	2·714 ± 0·520	1·777 ± 1·022	xx	1·097 ± 0·771	0·464 ± 0·372	xx			
9–11 August	(8)	4·153 ± 1·745	2·337 ± 1·192	x	1·390 ± 1·528	0·406 ± 0·381	NS	0·0	0·0	
ISLAND LAKE										
Moss										
25 July	(5)	0·015 ± 0·033	0·018 ± 0·040	NS	2·779 ± 0·679	1·832 ± 0·946	NS	0·051 ± 0·057	0·032 ± 0·035	NS
8–9 August	(3)	0·0	0·0		4·265 ± 3·369	2·887 ± 3·369	NS	0·687 ± 0·987	0·248 ± 0·277	NS
Sedge										
1–5 July	(72)		0·803 ± 0·533			0·097 ± 0·127			0·0	
8–9 August	(26)	1·929 ± 0·987	1·947 ± 0·177	NS	0·314 ± 0·328	0·200 ± 0·808	NS	0·098 ± 0·147	0·133 ± 0·445	NS

* Green vegetation only.
† Number of 20 × 50 cm plots inside and outside exclosures.
Note: Level of significance determined by Student's t-test: xx = $p < 0{\cdot}01$, x = $p < 0{\cdot}05$, NS = not significant.

different between fenced and unfenced areas at Island Lake. In some cases cover was judged to be greater outside than inside exclosures.

Mean heights of sedges and grasses were significantly ($P < 0.01$) different between fenced and unprotected areas at East Long Lake (Table 10). Mean heights of grasses in the moss zone where geese had been grazing were less than 1 cm in the mid-July and August sample periods. There was no statistically significant difference ($P > 0.05$) in forb and shrub height inside and outside exclosures. Geese significantly ($P < 0.05$) reduced sedge, grass, forb and shrub heights in the moss zone at Island Lake. Although vegetation was consistently shorter outside than inside exclosures in the sedge zone, these differences were not significant ($P > 0.05$).

Sedge densities were unaffected by grazing geese at either site (Table 11), but grass stem densities were significantly greater inside than outside exclosures in the moss zone during the August sample period. Forb and shrub densities did not change ($P > 0.05$) in response to grazing at either site.

Sedge and grass weights were consistently greater inside exclosures than from adjacent areas grazed by geese at East Long Lake (Table 12). Weight (biomass) reductions of grasses and sedges in unprotected plots ranged from 51% to 88% of that of the exclosure. In some areas, very little plant food remained into the fall and the area gave the general appearance of a closely cut lawn. Although weights of sedges and grasses were usually greater inside than outside fenced areas at Island Lake they were not statistically significant ($P > 0.05$).

It is clear that geese affected plant height and weight but had a less measurable effect on cover and density. It is obvious that the moss shorelines were extensively exploited for foods with little or no pressure occurring in the uplands during this time of year, except that of broods using shores of smaller lakes isolated from flock areas.

Discussion

This unique concentration of moulting geese probably cannot be explained on the basis of the kind of foods found since examination of any treatise on Alaska botany (e.g. Hulten 1968) makes it obvious that the same plant species are widespread. However, this quantity of geese requires very sizeable areas of the preferred grasses and sedges. Such lowland areas tend to be associated with drained basins (see Bergman *et al.* 1977). Because of the size of the basins in this area (Sellman *et al.* 1975) and the frequency of drainage here (Weller & Derksen 1979), no other region of the coastal plain offers more extensive, rich, meadow-like situations. Sedges and grasses had highest values of nitrogen, phosphorus, and potassium in early July (Chapin *et al.* 1975, 1980; this study), which corresponded with the onset of wing moult in Brant and Canada Geese (Derksen *et al.* 1979). Values for these minerals at the two sites were higher than for the same plants at other arctic areas that were not fertilized by geese (Hanson & Jones 1976; Ulrich & Gersper 1978; T. C. Rothe, pers. com.). This suggests that flightless geese act as a nutrient-transport system, concentrating minerals from faeces along a few kilometres of meadow shoreline where they graze, as do some arctic mammalian herbivores (McKendrick *et al.* 1980). In addition, these meadows are adjacent to deep-open lakes which offer refuge in the form of open water or ice floes where flightless geese are relatively safe. In these ways, the Cape Halkett peninsula meets all of the usual requirements of moulting areas noted by Salomonsen (1968) and agrees with other examples of this behaviour.

Moulting areas tend to be reused year after year when undisturbed, and observations on such areas for ducks and geese in North America (Hochbaum 1955; Bergman 1973) and Europe suggest that these are longstanding traditions. Such areas normally are large water areas that are rich in food but that, for some reason, are not suitable for breeding. This results in reduced competition of non-breeders, unsuccessful breeders, or post-breeders with breeding pairs (Salomonsen 1968). This seems to be the situation near Teshekpuk Lake. Although there is a small colony of Brant nesting at Island Lake and some at Goose Lake just southwest of East Long Lake, Brant in this region generally nest as solitary pairs. Major colonies of Brant occur at several river deltas in the Northwest Territory of Canada and in arctic Russia. It is logical that birds moving westward from coastal Canada to lagoons at Point Barrow would cross the large peninsula formed by the area northeast of Teshekpuk Lake. Why, however, should Brant from Russia come eastward to this area? Either this is such a unique region in the Bering Sea-Beaufort Sea area that no other can provide the needs of such large numbers of moulting Brant and geese, or band recoveries are misleading. Birds banded as moulters in this area probably are mostly nonbreeders which may winter and mate with other Brant from Russia. If such birds move west to Russia rather than Alaska or Canada, then band recoveries the following year would be explained. Only continuing banding with colour-marking or radio tracking will resolve this issue.

In conclusion, the geomorphology of the area, with the convenient location of this huge peninsula on the coastal area, the availability of large lakes for protection, and of rich food resources in the abundant drained basins, makes it unlikely that it can be replaced by other areas. Its loss would cause a dispersal of geese with uncertain population consequences. We recommend that the Cape Halkett/Teshekpuk Lake area be identified as a preserve with no petroleum or mineral exploration or development permitted within the boundaries shown in Figure 1. If complete protection of this area is not possible, we make the following recommendations to protect this unique habitat and the geese that moult there:

1. Deep-open lakes (Bergman *et al.* 1977), especially those with adjacent drained basins and wet-sedge meadows (Figure 4), should receive maximum protection. Development should be excluded from within 5 km of these lakes to avoid disturbance and reduce the potential for die-off (loss) from refined fuels, drilling muds and crude oil.
2. Industrial development such as gravel drill pads, waste discharge impoundments, storage pads, airstrips and roadways should be sited on dry upland tundra (Figure 4) away from wet-sedge meadows and drained basins. Such activities should be restricted to those periods when geese are not using the area (i.e. September to May).
3. Water sources for drilling and other industrial activity should be carefully selected to avoid modification of water levels with subsequent influence on growth of food plants along lake shores.
4. Helicopter and fixed-wing aircraft should be required to fly above 1,525 m because of the disturbance caused to moulting geese (Derksen *et al.* 1979).
5. Winter vehicle trails should be restricted to dry upland areas because of the potential for damage to the wet meadows preferred by feeding geese.
6. Because of their importance to geese that have completed moult in August and stage in the area before fall migration (see Derksen *et al.* 1979), coastal wetlands and the intertidal area from the Kogru River to Drew Point (Figure 1) should not be altered.

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Summary

Behaviour, habitat selection, and foods of moulting Pacific Black Brant *Branta bernicla nigricans* and Canada Geese *Branta canadensis* were studied in 1977 and 1978, together with more general observations of White-fronted Geese *Anser albifrons*, at two large freshwater lakes near the Beaufort Sea in arctic Alaska.

Moulting Brant and Canada Geese gathered in large flocks of up to 1,000 and 3,000, respectively, but flock size in White-fronted Geese was much smaller. Feeding flocks moved rapidly along shorelines and returned to the same sites every three to four days. All three species were highly social. Flocks responded to aircraft by moving from feeding or resting sites to the safety of open water or ice floes.

Feeding dominated the 24-hour cycle and seemed most intense in morning and early evening hours. Brant and Canada Geese preferred moss zones immediately adjacent to open water

compared to sedge zones more distant from the security of the lake.

Deschampsia sp. and *Carex* sp. were the most important grass and sedge, respectively, found in Brant and Canada Geese droppings. Mosses were also found in droppings from both species at both sites, but percentages were considered abnormally high probably due to their tendency to fragment more readily than vascular plants. Grasses were higher in nitrogen and non-structural carbohydrates than sedges. Percentage nitrogen, as well as phosphorous and potassium in above ground biomass declined from early July through early August and peaked as geese were in their second week of wing moult. Mosses had low values for all mineral and organic nutrients except calcium which was well above sedges and grasses.

Vegetation cover and density were not significantly altered by flocks of grazing Brant and Canada Geese, but height and weight (biomass) of forage plants were significantly greater inside than outside exclosures. These data also demonstrated that moulting geese grazed the moss zone more intensively than the sedge zone.

Protection of the Cape Halkett peninsula from petroleum development is recommended because of the unique combination of large, isolated lakes that afford protection to moulting geese, and nutrient-rich food supplies that occur in abundant drained basins.

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Dr Dirk V. Derksen and William D. Eldridge, US Fish and Wildlife Service, 1011 E. Tudor Road, Anchorage, Alaska 99503, USA.

Dr Milton W. Weller, Department of Entomology, Fisheries and Wildlife, University of Minnesota, St. Paul, Minnesota 55101, USA.

Present address: Department of Wildlife and Fisheries Sciences, Texas A. & M. University, College Station, Texas 77843, USA.