USE OF WETLANDS BY GRAZING WATERFOWL IN NORTHERN ALASKA DURING LATE SUMMER

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Abstract: The aquatic grass, *Arctophila fulva*, has been identified as an indicator of high quality wetlands in northern Alaska. We investigated grazing rates by waterfowl on *Arctophila* and the sedge, *Carex aquatilis*, in the Colville River delta in northern Alaska. Grazing almost never occurred in wetlands with <10 cm of water or in wetlands >150 m from a large water body. *Arctophila* almost never grew in shallow water but did often occur far from a large water body. The presence of *Arctophila* and proximity to a large water body therefore provided a better indication of grazing rates than presence of *Arctophila* alone. Grazing rates on *Arctophila* and *Carex* were about equal when the 2 species occurred together, suggesting that *Arctophila* was a correlate, rather than a cause, of high grazing rates.

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Bergman et al. (1977) and Derksen et al. (1981) studied avian use of wetlands in northern Alaska. In both studies wetlands with an aquatic grass, *Arctophila fulva*, were highly used by waterfowl, suggesting that this species may be useful as an indicator of high wetland quality for waterfowl. *Arctophila fulva* grows primarily in water 15–50 cm deep (Bergman et al. 1977: 15), is widely distributed in the arctic and subarctic (Hultén 1968), and was also identified by Tikhomirov (1959) as a significant food source for waterfowl in the Soviet Union.

Although these reports documented high avian use of wetlands with *Arctophila*, they did not investigate grazing rates on *Arctophila* nor did they reveal whether wetlands with and without *Arctophila*, but similar in other respects, differed in how they were used by waterfowl.

Our objective was to measure grazing rates on the dominant emergent aquatic plants, *Arctophila fulva* and *Carex aquatilis*, in a series of wetlands on the Colville River delta in northern Alaska. We recorded water depth and other features thought to affect grazing rates. The results were used to determine whether waterfowl preferentially selected *Arctophila* and to identify other variables affecting use of wetlands by waterfowl in northern Alaska. Waterfowl using the wetlands in our study area during late summer included greater white-fronted geese (*Anser albifrons*), tundra swans (*Cygnus columbianus columbianus*), and brant (*Branta bernicla*). Repeated sampling throughout the summer at several sites indicated that most of the grazing occurred in August when flocks of postmolting geese moved into the delta. The study thus provides information on only 1 aspect of wetland quality—value to grazing waterfowl in late summer.

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STUDY AREA

The study area occupied 90 km² of nonglaciated wet coastal tundra (Walker 1985) on the delta of the Colville River (70°20′N, 150°40′W) immediately inland from the halophytic zone. The Colville delta is characterized by an extensive system of channels; numerous polygon ponds and lakes, both tapped (connected to the river by a narrow channel) and untapped; upland areas without ponds; and occasional active or remnant dunes along existing or former river channels. The dominant emergent plants were *Arctophila fulva* and *Carex aquatilis*. The dominant submerged plants were *Ranunculus gmelini* and *R. confervoides* in ponds and untapped lakes, and *Potamogeton* spp. in river channels and tapped lakes. *Hippuris vulgaris* was also common throughout the study area, occurring as either a submerged or emergent form. The dominant upland species were *C. aquatilis* and several other sedges in the lower areas and willows (*Salix* spp.) and forbs in the dunes. Additional descriptions of the vegetation and physiography of the region are provided by Bergman et al. (1977) and Walker (1985).

METHODS

Data were collected August 10–26 during 1986–88. Grazing rates were measured in 1986 and 1987; abundance of different habitats was determined in 1988.

Definitions of Water Body Types.—We defined 4 water body types (Table 1) based on surface area, the ratio of length to width, and an index we called "edge/smooth edge." These types were defined after the first month of fieldwork and were used purely to develop a sampling scheme for our study; we are not suggesting that they be used in place of the classification systems developed by Bergman et al. (1977). Length and width were the pair of perpendicular lines across a water body that maximized the combined length of the 2 lines. Edge was the total length of the perimeter as measured from examining 1:30,000 color infrared aerial photographs. Many perimeters or portions of perimeters were sharply indented where a series of polygon ponds had been joined together by wave-induced erosion. Smooth edge was the length of the perimeter with the resulting long, thin peninsulas ignored. Water bodies formed by the coalescence of several polygon ponds were called polygon series and were defined by the edge/smooth edge ratio; lakes and polygon ponds were defined by size and the ratio of length to width. Old channels were defined by the ratio of length to width and by the edge/smooth edge ratio (Table 1). Flooded meadows were defined as areas with shallow (<10 cm deep) water but without any pond basins or rims. Most flooded meadows occupied many hectares. Uplands included all other terrestrial areas.

Table 1. Definitions of water body types in the Colville River delta, Alaska.

	Variable		
Type of water body	Size (ha)	Length/width[a]	Edge/smooth edge[a]
Lake	>1	<5	<1.2
Polygon pond	<1	<5	
Old channel		>5	<1.2
Polygon series			>1.2

[a] See text for definitions.

Sampling Plan.—Grazing rates, defined as the percentage of leaves that were bitten off, were estimated visually by a single observer on small stands (usually <3 m wide). The stands were selected using a 2-stage sampling plan (Cochran 1977:274) with simple random selection of primary units and systematic selection of secondary units. In the first stage, the study area was partitioned into 133 primary sampling units, each consisting of 1 large (>5 ha) water body and the area less than halfway to the next large water body in each direction, or all the land to the nearest river channel or edge of the study area.

A simple random sample of 50 of these primary units was selected in 1986. In 1987, we selected a new random sample of 52 primary units to avoid pseudoreplication. We constrained this sample to include 15 old channels and 37 units of other water body types. Within each selected primary unit, we selected a systematic sample of parallel transects, equally spaced across the unit, and recorded grazing rates in the water body, and in all polygon ponds or other water bodies, encountered along these transects. Sampling intensities varied between primary units, but we usually measured all the vegetation along water bodies and in at least 50 polygon ponds or in all polygon ponds if there were fewer than 50 in the primary unit.

We weighted the grazing rate from each polygon pond equally in calculating mean rates per primary unit. We also weighted the mean grazing rates from primary units equally in calculating the overall grazing rates. We considered weighting ponds or primary units by some measure of size (e.g., area, number of ponds, amount of vegetation) but felt that the choice between definitions of the weighting factors was arbitrary and that in any case it was more reasonable to view each primary unit as an equally useful opportunity to explore relative use of *Arctophila* and *Carex* in the different wetland types.

Five variables in addition to grazing rates were recorded for each water body: maximum water depth, distance to nearest large (i.e., >5 ha) water body, average density of *Arctophila* and *Carex* stands, and percentage of the surface area covered by emergent vegetation.

Depth and Distance to Large Water Body.—Each water body's maximum water depth was categorized as 1–10, 11–30, or >30 cm. Each water body's distance to the nearest large water body was categorized as 0–20, 21–50, 51–150, or >150 m (categories defined after the first month of fieldwork).

Table 2. Mean grazing rates[a] by waterfowl on the Colville River delta in northern Alaska, 1986–88, on *Arctophila* and *Carex* in different types of water body.

	Type of water body																	
	Lake			Polygon series			Old channel			Polygon pond			Flooded meadow			Upland		
Species	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Arctophila	35	48A[b]	6	20	42A	9	15	18B	8	53	29AB	4	0			15	0C	0
Carex	34	44A	6	19	35A	6	15	19B	5	69	19B	2	10	0C	0	102	0C	0

[a] Percentage of leaves bitten off.
[b] Means within rows with the same letters are not significantly (t-test, $P > 0.05$) different.

Stand Density and Coverage.—Stand density was recorded as sparse, medium, or dense. We analyzed the influence of stand density and coverage by emergent vegetation on grazing rates by calculating, for each pond, the difference between the observed grazing rate and the mean rate for all ponds in the same distance and depth category. This removed the effects of distance and depth. The deviations were then tabulated as a function of stand density and percentage of the pond covered by emergent vegetation. The expected deviation in each cell, under the null hypothesis that neither density nor coverage affected grazing rate, was zero. Negative deviations indicated that the grazing rate was lower than expected on the basis of distance and depth; positive deviations indicated that grazing rates were higher than expected.

Stand Location within Ponds.—In 1987, we estimated grazing rates for the inner (towards the water) and outer (towards the land) thirds of stands <4 m wide bordering the edges of ponds. We subdivided the data according to stand density and overall level of grazing on the pond. Data for sparse and medium density stands were combined because no differences between them were detectable, and then they were compared with data from high density stands.

Percentage of Study Area Grazed.—In 1988, we completely surveyed 35 randomly selected primary sampling units to estimate the area covered by stands of *Arctophila* and *Carex* throughout the study area. We used these data, in conjunction with data on grazing rates, to calculate the percentage of area covered by each species that incurred light, medium, and heavy grazing (defined in Results).

Statistical Tests.—We used simple linear regression and t-tests, employing Fisher's protected least significant difference when making multiple comparisons. Statistical significance was accepted at the 5% level. Means per primary unit were used in all statistical tests (and thus sample size refers to number of primary units).

RESULTS

We obtained data from 1,557 water bodies. Proportions of the sample by water body type were polygon pond 84%, lakes 5%, flooded meadows 7%, polygon series 3%, and old channels 1%.

Arctophila and *Carex* each occurred almost solely as distinct (i.e., single species) stands, but they were frequently found in close proximity to each other. *Carex* usually occurred near the bank in shallow water, and *Arctophila* occurred in deep water. Many sites contained only 1 species. The largest (i.e., most extensive) stands of each species in medium or deep water occurred in old channels. Large stands of *Carex* in shallow water occurred in flooded meadows. *Arctophila* was almost never found in shallow water.

Water Body Type.—Mean grazing rates for both *Arctophila* and *Carex* varied considerably among types of water bodies (Table 2). Rates were highest in lakes and polygon series, lower in old channels and polygon ponds, and essentially zero in flooded meadows and upland areas. Within water body types, average grazing rates on *Arctophila* and *Carex* were about equal.

Depth and Distance to Large Water Body.—Grazing rates in polygon ponds varied substantially in relation to pond depth and distance to the nearest large water body (Fig. 1). Within each pond depth class, grazing rates on each species declined monotonically with increasing distance to the nearest large water body. Similarly, within each distance category, grazing rates declined monotonically with decreasing pond depth. Grazing rates averaged 50–60% in deep ponds close to a large water body, whereas grazing was virtually absent in shallow ponds >150 m from the nearest large water body.

There was little difference, within distance–depth categories, in the grazing rates on *Arctophila* and *Carex*. For example, in deep ponds within 20 m of a large water body, the mean grazing rates on *Arctophila* and *Carex* were 58

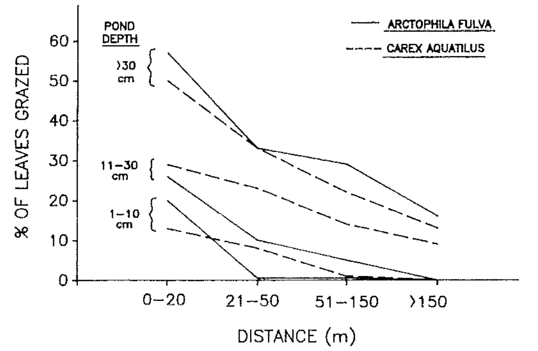

Fig. 1. Effects of distance to nearest large (>5 ha) water body and pond depth on percentage of *Carex* and *Arctophila* stands in polygon ponds grazed by waterfowl in late summer, 1986–88. All trends over distance (within depth classes) and over depth (within distance classes) are statistically significant (linear regression, $P < 0.05$).

and 51%, respectively (Fig. 1). The issue of whether 1 species was preferred over the other can also be addressed by analyzing ponds that contained both species. Among all such ponds, the mean grazing rate for *Arctophila* was 30% and for *Carex* was also 30% (SE of the difference = 4%). These results indicate little preference for either species, and certainly no strong preference for *Arctophila*, when both species occurred together.

Stand Density and Coverage.—Grazing rates were higher than expected in sparse, rather than dense, stands and in ponds with low, rather than high, coverage by emergent vegetation (Table 3). Grazing rates averaged 2–3 times higher in sparse stands, compared to dense stands, and in ponds with <30% emergent vegetation compared to ponds with >70% emergent vegetations.

Stand Location within Ponds.—Large differences also occurred in grazing rates on the inner (towards the water) and outer (towards the land) thirds of stands in polygon ponds. Grazing levels were much higher on the third of the stand adjacent to water than on the third adjacent to land (Table 4). This conclusion held

Table 4. Grazing rates (% of leaves) on the inner (towards the water) and outer (toward the land) edges of *Arctophila* and *Carex* stands in polygon ponds in northern Alaska, 1986–88.

Stand density	Grazing level (%)	*Arctophila*		*Carex*	
		Water	Land	Water	Land
Low or medium	0–30	49A[a]	1B	33A	1B
	31–70	73A	31B	77A	24B
	71–100	73A	57A	88A	53A
High	0–30	56A	0B	73A	0B
	31–70	85A	20B	40A	0B
	71–100	97A	17B		

[a] Values within rows and species with the same letters are not significantly (*t*-test, $P > 0.05$) different.

for combined low and medium stand density, for high stand density, and for each of 3 categories of overall grazing. Most of the contrasts between grazing on the inner and outer third were statistically significant.

Percentage of Study Area Grazed.—We used the results above (Fig. 1) to estimate the amount of habitat in our study area with heavy, medium, and light grazing. Heavily grazed habitat was defined as deep water stands of either *Arctophila* or *Carex* 0–20 m from a large water body. Habitat with medium grazing included deep stands >20 m from a large water body, medium depth stand 0–150 m from a large water body, and shallow stands 0–20 m from a large water body. Lightly grazed habitat included shallow stands >20 m from a large water body, and all stands in flooded meadows.

Using these definitions, and the detailed surveys of habitat in the 35 randomly selected primary sampling units, we estimated that 87% of the area covered by*Arctophila* or *Carex* stands was grazed lightly (Table 5). Only 3% of the area covered by these species was grazed heavily. Almost 90% (23.3/26.3) of the vegetated area in heavily grazed habitats was covered by stands of *Arctophila*, and only about 10% was covered by *Carex*, indicating the importance of *Arctophila*. *Arctophila* alone, however, did not always, or even usually, indicate heavily grazed

Table 3. Effect on grazing rates of stand density and percentage of pond covered by emergent vegetation, Colville River delta, Alaska, 1986–88. Tabulated values are the mean differences between observed grazing rates and rates predicted using pond depth and distance to the nearest lake (see text). Higher values indicate higher grazing rates.

Species	Stand density			% of pond covered by emergent vegetation		
	Sparse	Medium	Dense	0–30	31–70	71–100
Arctophila	8A[a]	7A	−15B	4A	3A	−7A
Carex	5A	5A	−10B	10A	6A	−16B

[a] Values within rows with the same letters are not significantly (*t*-test, $P > 0.05$) different.

Table 5. Occurrence of habitats on the Colville River delta, Alaska, with high, medium, and low levels of grazing by waterfowl in late summer, 1986–88.

Level of grazing	*Arctophila* (ha)	*Carex* (ha)	Both species (ha)	% of total
High	23.3	3.0	26.3	3
Medium	23.0	52.4	75.4	10
Low	25.4	634.5	659.9	87
Totals	71.7	689.9	761.6	

wetlands. For example, only about ⅓ (23.2/71.7) of the area covered by *Arctophila* was grazed heavily. The rest of the area covered by *Arctophila* occurred >20 m from a large water body. About ⅔ of the area covered by *Arctophila* was in heavily or moderately grazed habitat.

DISCUSSION

We concluded that grazing rates by waterfowl on aquatic vegetation during late summer were highest in deep water close to a large water body. Such wetlands were often dominated by *Arctophila*, and this species was grazed heavily. On the other hand, *Carex aquatilis* growing in similar situations was grazed just as heavily as *Arctophila*, and neither species was heavily grazed when growing far from a large water body or in shallow water. *Arctophila* thus appeared to be a correlate, rather than a cause, of high grazing rates. Furthermore, water depth and proximity to a large water body provided a better indicator of high grazing rates than did presence of *Arctophila*.

The most obvious hypotheses to explain the patterns observed in this study are (1) the lakes offer protection from predators or (2) the nutritional value of plants is higher close to large water bodies. Preliminary data (Bart and Earnst, unpubl. data) did not reveal any differences in either species in the nutritional content of leaves collected near to, and far from, large water bodies. Observations did suggest that swans use the large water bodies as refuges throughout the late summer period. The entire issue, however, needs additional study.

The most heavily grazed stands in polygon ponds had open water along 1 side. Grazing rates were highest along the edge of the water and were substantially lower along the landward edge. Many old channels had wide, dense stands of *Arctophila* or *Carex* or both species. We believe that grazing rates were often high along the edge towards the water, but were usually very low in the interiors of these stands, even when the water was >30 cm deep. This pattern explains why the overall grazing rates for old channels were substantially lower than the average rates in ponds where most stands were only a few meters wide. Why grazing waterfowl avoided the inner parts of dense stands is uncertain. Perhaps the vegetation there was too dense to swim in or was of lower nutritional quality, or possibly the dense vegetation made rapid escape difficult.

Our study suggests that programs to establish *Arctophila* artificially, which have been proposed for mitigation purposes, should be evaluated carefully. If *Carex* were replaced with *Arctophila*, our study indicates that the value of the wetland for grazing waterfowl, which might have been either high or low initially, would be little affected. Also, establishing *Arctophila* in wetlands far from lakes would do little to mitigate the loss of *Carex* in deep ponds close to lakes. These conclusions suggest the importance of other similar studies if *Arctophila* is to be used as an indicator of wetland quality for grazing waterfowl. Further study of Bergman et al.'s (1977) finding that *Arctophila* stands support high invertebrate populations would be of particular value.

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