Population Trends and Habitat Use of Tundra Swans Staging at Long Point, Lake Erie

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Abstract.—Long Point, Lake Erie, is an important spring and autumn staging area for Eastern Population Tundra Swans (*Cygnus columbianus columbianus*). Habitat use and trend in numbers of Tundra Swans at Long Point were assessed using data from twelve Tundra Swans fitted with satellite transmitters and tracked locally, aerial surveys of swans on water (1971–1999), and roadside surveys of swans in fields (1998–2000). Mean peak autumn aquatic counts at Long Point increased from 442 Tundra Swans in the 1970s to 7,177 in the 1990s. The proportion of the Eastern Population of Tundra Swans using Long Point during peak one-day autumn counts increased from <1% in the 1970s to nearly 8% in the 1990s. In contrast, there was no change in peak spring aquatic counts. Tundra Swans were located in agricultural fields more often in spring (74% of diurnal satellite locations) than in autumn (9%). During spring, most (65%) swans using terrestrial habitats were observed in corn (*Zea mays*) fields, whereas during autumn, most (67%) were in winter wheat (*Triticum duriem*) fields. Seasonal differences in use of fields appeared to influence wetland habitat use; during spring, when agricultural fields were used extensively, Tundra Swans were located in those aquatic habitats that were closest to fields. However, during autumn, when aquatic plants were their primary forage, swans tended to use aquatic habitats closer to the tip of Long Point. Given the potential for Tundra Swans to influence the structure of waterfowl communities and aquatic habitats, and the overall lack of information about staging Tundra Swans, further research into the ecological importance and use of spring and autumn stopover sites is warranted.

Key words.—*Cygnus columbianus columbianus*, Great Lakes, habitat use, Lake Erie, Long Point, migration, population, staging, Tundra Swan, waterfowl.

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Eastern Population Tundra Swans (*Cygnus columbianus columbianus*) make extensive annual migrations between Atlantic coast wintering areas and arctic breeding areas, which extend from Baffin Island to the western edge of northern Alaska (Sladen 1973). However, Tundra Swans lose weight during winter and depart Atlantic coast wintering areas in spring at their lowest annual body mass (Bortner 1985). Further, due to the temporal and nutritional constraints of breeding at high latitudes, Tundra Swans are likely to arrive on their arctic breeding areas with most of the lipid and protein reserves necessary to begin breeding (Alisauskas and Ankney 1992). Consequently, Tundra Swans are replenishing and acquiring nutrient reserves when they are incurring substantial energetic costs associated with spring migration. During autumn migration, juveniles probably continue to grow, and adults are likely to be replenishing reserves used during reproduction and wing molt. Events and conditions at migratory stopover sites, therefore, are important for Tundra Swan reproductive success, growth and survival.

After being harvested commercially and non-commercially throughout the 1800s and early 1900s, Tundra Swans were given total protection under the Migratory Bird Treaty Act of 1916. Consequently, North American Tundra Swan populations rebounded; the Eastern Population has surpassed 100,000 birds (Serie *et al.* 2002) and a limited sport harvest was initiated in 1983 (Serie and Bartonek 1991). The steady increase in North America's Tundra Swan populations has also been attributed to their declining use of traditional aquatic foods and increased reliance on readily available, highly nutritious agricultural grains on wintering and staging areas (Munro 1981).

Despite the perceived importance of migratory stopover areas to Tundra Swans, and the substantial increase in the Eastern Population over the last half century, little is known about the habitat use or population status of this species at key spring and autumn staging areas (but see Earnst 1994; Thorson *et al.* 2002). Therefore, the objectives of this paper are to (1) document long-term trends in Tundra Swan numbers at Long Point, Ontario, (2) compare macrohabitat (aquatic versus terrestrial) use during spring and autumn migration, (3) describe seasonal differences in use of agricultural fields and (4) provide baseline information for subsequent studies of Tundra Swan staging ecology at Long Point and elsewhere.

STUDY AREA

Long Point is a 35-km sandspit extending into the eastern basin of Lake Erie (80°30'E, 42°35'N to 80°03'E, 42°33'N; Fig. 1). This spit partially encompasses and protects a 280,000-ha lacustrine embayment (Inner Bay) and 24,000 ha of palustrine wetlands. The Inner Bay is shallow (mean depth = 2 m), and over 90% of the bottom is covered by submerged aquatic vegetation (Wilcox 1994; Knapton and Petrie 1999).

Much of the area surrounding Long Point is a sand plain that is farmed intensively for tobacco which provides limited foraging opportunities for waterfowl. However, a 7,600-ha clay plain at the base of Long Point is farmed extensively for corn (*Zea mays*), winter wheat (*Triticum duriem*) and soybeans (*Glycine max*), which provide foraging opportunities for field-feeding ducks, geese and swans.

METHODS

Aerial Surveys (1971-1999)

Waterfowl were surveyed on Long Point's wetlands in the spring and autumn by the Canadian Wildlife Service during 1971, 1975, 1979, 1984, 1986 and 1988, and by the Long Point Waterfowl and Wetlands Research Fund from 1991 to 1999 (Fig. 1). All eight of Long Point's wetland complexes were surveyed extensively by two observers in a fixed-wing aircraft at an altitude of 100 m. Generally five or six survey flights were flown during each spring and autumn in each year. Observers identified and estimated the number of each waterfowl species along each transect. Seasonal waterfowl use was calculated by averaging the number of waterfowl counted during two consecutive surveys and multiplying the mean by the number of days between the two survey days (Dennis *et al.* 1984). Estimates were calculated for spring (1 March–15 May) and autumn (1 September–15 December), and these estimates were then summed to generate total use-days for each species.

To assess the total biomass-days of Tundra Swans (spring and autumn combined), relative to other waterfowl at Long Point, the average mass of each waterfowl species ([male + female]/2; from Bellrose 1980) was multiplied by the number of use-days for that species. Four one-way ANOVAs were used to determine if there were differences in total biomass-days (combined spring and autumn) between Tundra Swans and dabbling ducks (all spp. combined), diving ducks (all spp. combined), Canada Geese (*Branta canadensis*), or Mute Swans (*Cygnus olor*) for the period 1991–1999. All analyses were performed using SYSTAT (Wilkinson 1988).

To determine long-term trends in Tundra Swan use of Long Point, linear regression was performed on peak spring and peak autumn counts and on total Tundra Swan use-days. The percentage of the Eastern Population counted during peak daily counts (for each season) was calculated using data from the annual Midwinter Waterfowl Index (U.S. Fish and Wildlife Service 2000) and analyzed using linear regression. This enabled us to determine if the relative importance of Long Point to staging Eastern Population swans had changed since the 1970s. A Mann-Whitney U-test was used to determine if there were seasonal differences in the proportion of Tundra Swans using each of eight Long Point wetland units, and to determine if there were seasonal differences in number of swans using Long Point's wetlands (all wetland units combined).

Satellite Tracking

Satellite transmitters (Microwave Telemetry, Inc., Columbia, Maryland) were attached by backpack-harness (95 g transmitter) or by neck collar (30 g transmitter) to Tundra Swans captured at Long Point during spring 1998 (N = 4), autumn of 1998 (N = 3) and spring of 1999 (N = 5). Although transmitters were deployed as part of a separate study of migration, in this study we use locations recorded while birds were at Long Point to assess macrohabitat use (aquatic versus terrestrial). Transmitters deployed during 1998 (attached by backpack harness) were programmed to transmit 24 h per day for one month to optimize location information while birds were at Long Point. Transmitters deployed during 1999 (attached by neck collar) had a transmission frequency of 8 h per day during the first month of operation. Bird movements were monitored with the Argos satellite tracking system (Argos 1996). Satellite signals were converted to locations by Argos CLS (Landover, Maryland). Each location was assigned a class which depended on number and quality of messages received. Class 1 (estimated accuracy = 350 to 1,000 m), 2 (150 to 350 m), and 3 (<150 m) locations were included in the analysis of habitat use (Argos 1996). Each bird was considered a separate sampling unit and none of the birds were tracked for more than one season. ArcView and Ontario

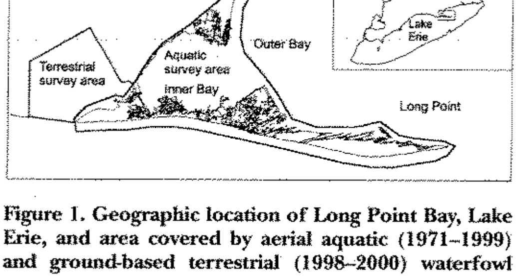

Figure 1. Geographic location of Long Point Bay, Lake Erie, and area covered by aerial aquatic (1971–1999) and ground-based terrestrial (1998–2000) waterfowl surveys.

Base Maps (1:50,000) were used to assign an aquatic or agricultural habitat type to each location.

Due to the possibility of assigning swan locations to the wrong habitat type, based on error estimates of satellite locations, a 1,000-m buffer zone was established along the aquatic-terrestrial interface and all locations occurring in this buffer were excluded from analysis. A Mann-Whitney U-test was used to determine if there were seasonal differences in the proportion of locations received for each bird in aquatic and agricultural habitats.

Terrestrial Roadside Surveys

Based on preliminary results of local satellite tracking, and known field use by swans at Long Point, a 100 km inland roadside survey route was established throughout the clay plain at the base of Long Point. The standardized survey route was driven by one observer 10-32 times per season during autumn in 1998 and 1999 and spring in 1999 and 2000. Starting points (north versus south) and times (between 08.00–16.00 h) were randomized. Flock size, time, field type and location were recorded for each flock observed during surveys. Seasonal comparisons in the number of birds observed (per survey) in agricultural fields were made using Mann-Whitney U-tests. The percentage of swans located in each crop type (corn, winter wheat, soybeans, plowed fields) is reported, but not analyzed statistically as values were not corrected for availability. Means ± SEs are given throughout.

Field reconnaissance was completed during spring and autumn 1998 to identify the total area of each crop type in the terrestrial survey area. Crops were identified and labeled on 1:10000 aerial photographs (1995), and field boundaries were then digitized into a geographic information system.

RESULTS

Peak autumn counts increased from an average of 442 Tundra Swans in the 1970s (i.e., 1971, 1975 and 1979) to an average of 7,177 in the 1990s (1991–1999 inclusive) (b = 322 ± 64.8, r^2_{13} = 0.66, P < 0.001, Fig. 2). In contrast, there was no change in mean peak spring counts during that time (b = 6.1 ± 43.5, r^2_{13} = 0.002, n.s., Fig. 2). Peak autumn counts represented 0.7% (442 of 61,167) of the Eastern Population of Tundra Swans in the 1970s, 2.4% (3,866 of 94,000) in the 1980s and 7.9% (7,177 of 92,500) in the 1990s (b = 0.34 ± 0.08, r^2_{13} = 0.57, P < 0.01, Fig. 3). Annual Tundra Swan use-days (spring and autumn combined) increased from 40,888 use-days in 1975 to 269,448 use-days in 1999 (b = 13,348 ± 2,790, r^2_{12} = 0.66, P < 0.001), corresponding to an increase in biomass-days from 278,035 kg-days in 1975 to 1,832,246 kg-days in 1999. Although, the estimate of Tundra Swan biomass-days was substantially lower than that for diving ducks ($F_{1,16}$ = 9.6, P < 0.01), it was similar to the estimate for dabbling ducks ($F_{1,16}$ = 0.81, n.s), and was greater than estimates for Canada Geese ($F_{1,16}$ = 36, P < 0.001) and Mute Swans ($F_{1,16}$ = 30.6, P < 0.001, Fig. 4).

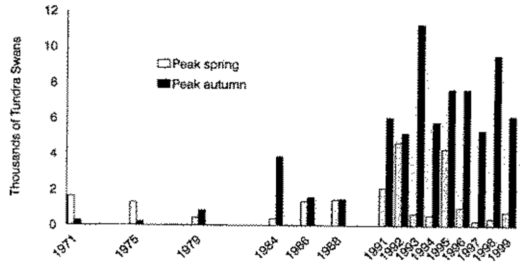

Figure 2. Peak annual spring and autumn counts of Tundra Swans at Long Point, Lake Erie, 1971–1999.

During autumn, 198 satellite locations (class 1, 2 and 3) were received from three Tundra Swans at Long Point, and 80 locations were received from nine swans in spring (Fig. 5). Tundra Swans were located in agricultural fields less often during autumn ($\bar{x}$ = 5% of locations received, range = 1–11% for individual swans) than during spring ($\bar{x}$ = 38%, range = 25–56%, U = 12, P < 0.05). When only daytime locations (06.00–18.00 h) were included, 9% of autumn locations and 74% of spring locations were in agricultural habitats. Similarly, more Tundra Swans were counted in agricultural habitats during spring roadside surveys ($\bar{x}$ = 704 ± 183, N = 24) than during autumn roadside surveys ($\bar{x}$ = 78 ± 23, N = 52, U = 310.5, P < 0.001, Fig. 6). Conversely, more swans were counted in aquatic habitats during autumn aerial surveys ($\bar{x}$ =

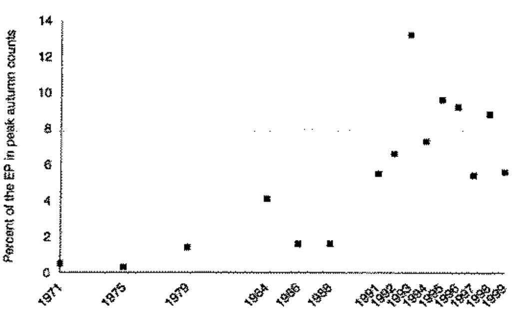

Figure 3. Percentage of Eastern Population (EP) Tundra Swans counted (peak daily count) at Long Point, Lake Erie, during autumn aerial surveys, 1971–1999.

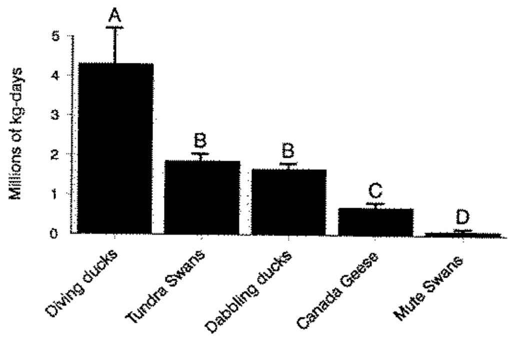

Figure 4. Mean annual biomass-day (± SE) of waterfowl staging at Long Point, Lake Erie, based on waterfowl days (spring and autumn) and average species mass, 1991–1999. Species and species groups not sharing the same letter are statistically different.

6,302 ± 1,094, N = 10) than during spring aerial surveys ($\bar{x}$ = 473 ± 139, N = 6, U = 86, P < 0.001, Fig. 6). With the exception of an 18% reduction in corn availability between spring and autumn in 1998, there were no between-season changes in the relative availability of agricultural crops in the study area (Table 1). During spring, 65% of birds observed in agricultural habitats were in corn, 24% were in winter wheat, 8% were in soybeans, and 2% were in plowed fields. During autumn, 67% were in winter wheat, 7% were in corn, 10% were in soybeans, and 16% were in plowed fields.

During spring, when swans spent considerable time feeding in terrestrial habitats, wetlands close to agricultural fields (Big Creek, U = 1,100, P < 0.001; Crown Marsh, U = 900, P < 0.05; Turkey Point Marsh, U = 911, P = 0.05) had higher proportional use than

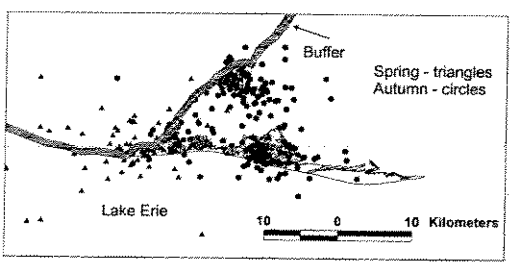

Figure 5. Locations of three Tundra Swans tracked in the autumn and nine in the spring at Long Point, Lake Erie, 1998–2000, using satellite telemetry. Locations within a 1,000-m buffer between aquatic and agricultural habitats are excluded.

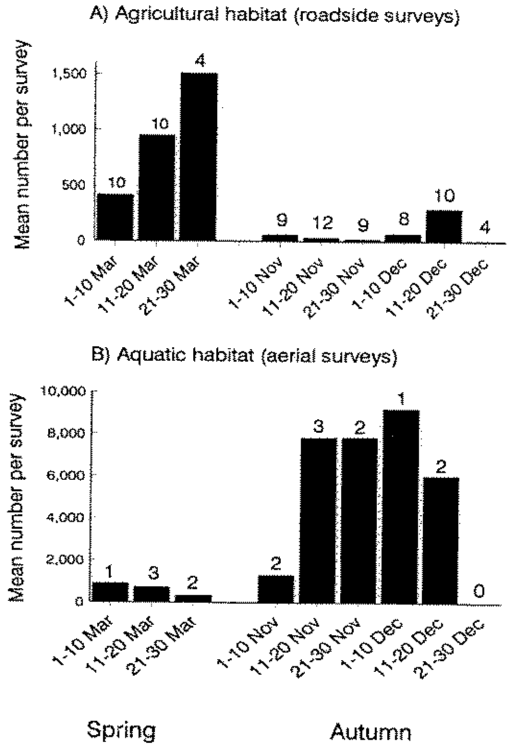

Figure 6. Mean number of Tundra Swans counted at Long Point, Lake Erie, during roadside agricultural (A) and aerial aquatic (B) surveys (1998–1999). Numbers above bars represent total number of surveys for that time period.

they did during autumn (Fig. 7). Conversely, those wetland complexes closer to the tip of Long Point (Long Point Company Marsh, U = 350, P < 0.001; Long Point National Wildlife Area, U = 340, P < 0.001; Tip of Long Point, U = 229, P < 0.001) had higher proportional swan use during autumn (Fig. 7).

DISCUSSION

Population Trends

Long Point Bay is an important spring and autumn staging area for Eastern Population Tundra Swans (Petrie 1998) and autumn use of this area has increased substantially since the 1970s (Fig. 2). Eastern Population Tundra Swan numbers have doubled over the past 40 years (Serie *et al.* 2002) which probably contributed to their increased use of Long Point. However, because

Table 1. Relative availability (ha) of agricultural crops in the Long Point study area during spring and autumn, 1998.

Crop type	Spring	Autumn
Corn	1,720	1,403
Winter wheat	173	173
Soybeans	98	98

mean peak autumn counts increased from 0.7% of the estimated Eastern Population in the 1970s to 7.9% in the 1990s, other factors have probably contributed to the increased use of Long Point in recent years.

Colonization by filter-feeding Zebra Mussels (*Dreissena polymorpha*) and reduced phosphorus inputs to Lake Erie have resulted in increased light penetration, which has changed the aquatic macrophyte communities of Long Point Bay (Knapton and Petrie 1999; Petrie and Knapton 1999). This has resulted in increased abundance and availability of *Vallisneria americana* (Wild Celery), *Elodea canadensis* (Canadian Waterweed), and *Najas* spp. (Naiad), all important foods for waterfowl (Petrie 1998; Knapton and Petrie 1999). This increased availability of aquatic plant foods, most notably *V. americana* (S. S. Badzinski, pers. obs.), has probably increased the carrying capacity of Long Point's wetlands for Tundra Swans.

Temperature data from the National Oceanic and Atmospheric Administration meteorological station at Erie, Pennsylvania (42°05'N, 80°11'W), about 35 km south of Long Point, show that midwinter air temperature (1 November to 1 March) of the lower Great Lakes increased from an average of -1.28°C during 1970–1979 to +1.27°C during 1990–1999. These milder winters in recent years have probably enabled birds to remain at Long Point longer in autumn. Notably, the mean number of Tundra Swans counted during Christmas Bird Counts at Long Point increased from 62 birds during 1970–1979 to 1,819 birds during 1990–1999 (Butcher 1990).

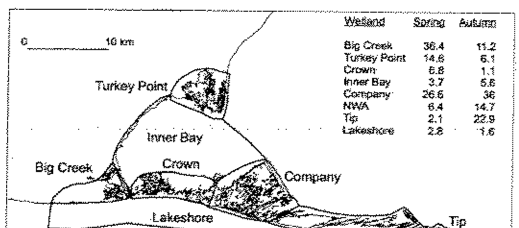

Figure 7. Percentage of Tundra Swans observed in each of eight Long Point, Lake Erie, wetland units during spring and autumn aerial waterfowl surveys conducted during 16 years between 1971 and 2000.

Tundra Swans began consuming cereal grains and the shoots of winter wheat in the 1960s and 1970s (Nagel 1965; Tate and Tate 1966; Munro 1981). This change in diet has quite possibly influenced migratory patterns as well as duration of stay at certain staging areas. There has been a 204% increase in corn production in Norfolk County since 1961 (Government of Canada, unpub. data). This increase may have also influenced duration of stay in the autumn since Tundra Swans appeared to spend more time in fields in late autumn (Fig. 6).

Lack of a long-term trend in peak spring counts may be attributed to more variability in the number of birds staging at Long Point in the spring than in the autumn, quite likely due to annual variation in spring thaw. Also, because Tundra Swans spend considerable time field-feeding in the spring, they are less dependant on large staging wetlands such as Long Point.

Biomass-days and Potential for Interspecific Competition

Tundra Swans were not the most numerous group of spring and autumn staging waterfowl at Long Point, but the estimate of their total biomass-days (i.e., biomass times use-days) was similar to that of all dabbling duck species combined. At Long Point, Tundra Swans and ducks (especially dabbling ducks) coexist on shallow cattail marshes (Petrie 1998; S. S. Badzinski, unpub. data), and rely on aquatic plant parts (Earnst 1994; Limpert and Earnst 1994; Petrie 1998). It has been proposed that swans influence the abundance of dabbling ducks (Oksanen *et al.* 1979), and increased use by Tundra Swans could change the waterfowl community structure at Long Point through interspecific competition (Nudds 1992).

Tundra Swans are large, gregarious birds that feed on submerged aquatic vegetation in shallow wetlands during migration (Earnst 1994; S. S. Badzinski, unpub. data). Because they uproot aquatic vegetation while foraging (Limpert and Earnst 1994), swans may reduce food resources for other waterfowl. Evidence suggests that tuber consumption by migrating swans may result in such dramatic declines in the tuber bank that plant re-growth is inhibited during the next season (Beekman *et al.* 1991; also see Mitchell *et al.* 1998). Further, exploitative competition may explain decreased use of agricultural fields by ducks following grazing by Bewick's Swans (*Cygnus columbianus bewickii*) (Rees 1990). Therefore, although Long Point is an important staging area for migrating Tundra Swans, they may affect the carrying capacity of aquatic and agricultural habitats for staging ducks and geese.

Seasonal Difference in Habitat Use

Whereas Tundra Swans make regular diurnal foraging trips to agricultural fields in spring, they rarely do so in autumn. As Tundra Swans are late autumn and early spring migrants, agricultural grain and winter wheat availability (per unit area) is similar during autumn and spring. Therefore, we suggest that seasonal differences in foraging strategies of swans are determined by an interplay of intrinsic and extrinsic factors unrelated to seasonal changes in availability or quality of agricultural forage. When Tundra Swans arrive at Long Point in autumn, they have large lipid stores (S. A. Petrie, unpub. data) and submerged aquatic vegetation is readily available (S. S. Badzinski, unpub. data). Conversely, when Tundra Swans arrive at Long Point in spring, they have small lipid reserves (S. A. Petrie, unpub. data), and autumn foraging, winter senescence and spring ice-cover would reduce the relative availability of submerged aquatic vegetation at that time. Therefore, we suggest that seasonal differences in field-feeding propensity are due to seasonal differences in submerged aquatic plant availability and may also be influenced by seasonal differences in size of lipid reserves upon arrival at Long Point.

Seasonal differences in propensity to feed in fields appear to influence wetland selection by Tundra Swans at Long Point. During spring, when swans spend considerable time in agricultural fields, they concentrate on wetlands closest to fields, presumably minimizing energetic costs of moving between fields and aquatic roosting sites. Conversely, in autumn, when Tundra Swans are foraging primarily on aquatic vegetation, they often use wetlands up to 30 km from agricultural fields. Use of aquatic habitats far from agricultural fields in autumn may be influenced by patterns of human disturbance (S. S. Badzinski, unpub. data) or by spatial differences in availability of submerged aquatic plants.

Future Research

Although Tundra Swans spend approximately half of their lives on staging areas (Ely *et al.* 1997; Petrie, unpubl. data), little is known about their dietary preferences or changes in body condition during migration. Also, Tundra Swan numbers increased substantially in the latter part of the twentieth century (Serie *et al.* 2002), and because they are large, gregarious birds, are capable of depleting aquatic plant foods at staging areas (Beekman *et al.* 1991; Nolet and Drent 1998; also see Mitchell *et al.* 1998). Therefore, further research into the staging ecology of Tundra Swans, as well as their ecological relationship with other waterfowl species is warranted.

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