

Diet of Mute Swans in Lower Great Lakes Coastal Marshes

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ABSTRACT During the past 30 years, nonnative mute swan (*Cygnus olor*) populations have greatly increased, and continue to increase, in the eastern United States and within the lower Great Lakes (LGL) region. As a result, there is much concern regarding impacts of mute swan on native waterfowl, aquatic plants, and marsh habitats. There are presently only limited dietary data for mute swans in North America and none exist for birds in the LGL region. Thus, in 2001, 2002, and 2004 we collected 132 mute swans from LGL coastal marshes in Ontario, Canada, to determine dietary composition and to evaluate 1) seasonal and sex-related variation in adult diets and 2) age-related dietary differences. Adult diets did not differ among years, collection sites, or seasons, but female diets contained more pondweed spp. (*Potamogeton* spp.) and less slender naiad (*Najas flexilis*) and common waterweed (*Eloea canadensis*) than did diets of males. Adult males, adult females, and cygnets had similar diets during summer and autumn. Overall, mute swan diets mainly consisted of above-ground biomass of pondweed spp., muskgrass (*Chara vulgaris*), coontail (*Ceratophyllum demersum*), slender naiad, common waterweed, wild celery (*Vallisneria americana*), and wild rice (*Zizania palustris*); below-ground parts of wild celery, sago pondweed (*Stuckenia pectinatus*), and arrowhead spp. (*Sagittaria* spp.) were eaten infrequently. Comparison of our findings with those of other diet studies suggested considerable dietary overlap between mute swans and several other species of native waterfowl. Thus, we suggest that mute swans have potential to compete with native waterfowl and impact aquatic plants that are important waterfowl foods within LGL coastal marshes. Further, our results can be used to assess which aquatic plant species may be most impacted by foraging activities of mute swans at other important waterfowl stopover and wintering sites in North America. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):726–732; 2008)

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Coastal marshes associated with the lower Great Lakes (LGL) support hundreds of thousands of waterfowl during spring and autumn migration (Dennis et al. 1984, Prince et al. 1992, Petrie et al. 2002). Staging and breeding waterfowl using those marshes depend on a diverse and abundant array of submerged aquatic plants to build fat and protein reserves for migration and reproduction (Knapton and Petrie 1999, Badzinski and Petrie 2006b). Because the number of wetlands within the LGL region has been considerably reduced since European settlement, it is important to minimize potentially harmful anthropogenic and biological impacts to the remaining wetlands in the region (Crowder and Bristow 1988, Herdendorf 1990).

The introduction of nonnative waterfowl into aquatic habitats can have substantial ecological impacts, especially if the species is prolific, abundant, aggressive, or has similar forage or habitat preferences to native species (Weller 1969, Sondergaard et al. 1996, Hughes et al. 1999, Atlantic Flyway Council 2003). The mute swan (*Cygnus olor*) was brought to North America from Europe and Asia, largely for esthetics and establishment of captive flocks, early during settlement of the continent (Ciaranca et al. 1997). Feral mute swans were first observed on the LGL during the 1960s (Knapton 1993, Badzinski 2007). Between 1980 and 2000, the LGL mute swan population increased by 10% to 18% per year and presently contains $\geq 2,000$ birds (Petrie and Francis 2003). Conservative projections, based on the 10% per annum growth rate, suggest that the LGL

population could double by 2010 (Petrie and Francis 2003). A much larger mute swan population is located in the eastern United States and consists of about 15,000 birds (Allin et al. 1987). Rapid growth and range expansions of mute swan populations within both the LGL and eastern United States regions is due primarily to relatively mild climatic conditions, plus their high reproductive potential, few natural predators, and limited (mainly in the United States) population management (Petrie and Francis 2003, Hindman and Harvey 2004, Badzinski 2007).

Large concentrations of mute swans can have substantial ecological impacts on wetlands and associated native wildlife. At certain times of the year, mute swans can be territorial and aggressive toward other waterfowl species, which has caused nest abandonment, exclusion from food, and in some cases even death (Reese 1980, Therres and Brinker 2004). These very large birds can uproot and consume large amounts of submerged aquatic vegetation, so their foraging activities can eliminate or greatly reduce aquatic macrophyte growth and availability (Gillham 1956, Mathiasson 1973, Allin et al. 1987, Ciaranca et al. 1997). Mute swans are often present in high numbers throughout the year and thus place considerable foraging pressure on local submerged aquatic vegetation, many species of which are important food plants for other breeding, staging, and wintering waterfowl.

Several studies have documented mute swan diets, but none have provided data on foods eaten by different age-sex groups during the entire year on the LGL (Ciaranca et al. 1997, Hindman and Harvey 2004, Perry et al. 2004). Despite the lack of food habits data for mute swans, many researchers have identified numerous aquatic plants that are

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important foods for other waterfowl in the LGL region (Martin and Uhler 1939, Pauls and Knapton 1993, Petrie 1998, Knapton and Petrie 1999).

Our primary objective was to identify which species of submerged aquatic vegetation are being consumed by mute swans throughout the year to assess potential for dietary overlap with native waterfowl using the LGL. We also made dietary comparisons between sexes, seasons, and ages. Specifically, we evaluated seasonal (spring, summer, autumn, winter) and sex-related variation in adult diets, plus age-related (ad M, ad F, cygnet) dietary differences. We expected mute swan diets to differ among seasons due to plant phenology and availability and seasonal changes in nutrient requirements. We also expected that diets of adult males and females would differ due to energetic demands associated with breeding, but that diet of adults and cygnets would be similar because adults typically dislodge food items for their young.

STUDY AREA

We collected mute swans from LGL coastal marshes at Long Point–Lake Erie and the Canadian sides of Lake St. Clair and the Detroit River in southern Ontario (Fig. 1). Long Point was a 35-km sand spit that extended into the eastern basin of Lake Erie and had an associated 24,000 ha of emergent marsh habitat (Knapton and Petrie 1999). Long Point Bay had among the highest waterfowl use-days of all marshes in the LGL region and, thus, provided habitat for hundreds of thousands of waterfowl during autumn and spring migration (Dennis et al. 1984). Over 95% of the bottom in Inner Long Point Bay was covered by submerged aquatic vegetation, which in part accounted for the large concentrations of migrant waterfowl at this location (Knapton and Petrie 1999). The 18,800 ha of emergent marshes associated with Lake St. Clair and the Detroit River were used extensively by several species of waterfowl throughout the year but particularly during autumn and spring migration (Prince et al. 1992).

METHODS

We used shotguns and rifles to collect 356 mute swans throughout spring, summer, autumn, and winter during 2001, 2002, and 2004. We collected specimens under authority of a Scientific–Capture Permit (CA 0093) issued by the Canadian Wildlife Service under section 19 of the Migratory Birds Regulations. We recorded collection date, collection location, sex (via cloacal and internal examination), and age (based on external morphology and plumage color and characteristics) on tags that we then affixed to each bird. After collection, we placed tagged birds into bags and transported them to a laboratory at Bird Studies Canada where we froze and stored them until further processing.

In the laboratory, we thawed birds and removed the upper digestive tract from the carcass. We then removed food items within only the esophagus and proventriculus of each bird, which reduced biases resulting from inclusion of gizzard contents in food habits data (Swanson and Bartonek

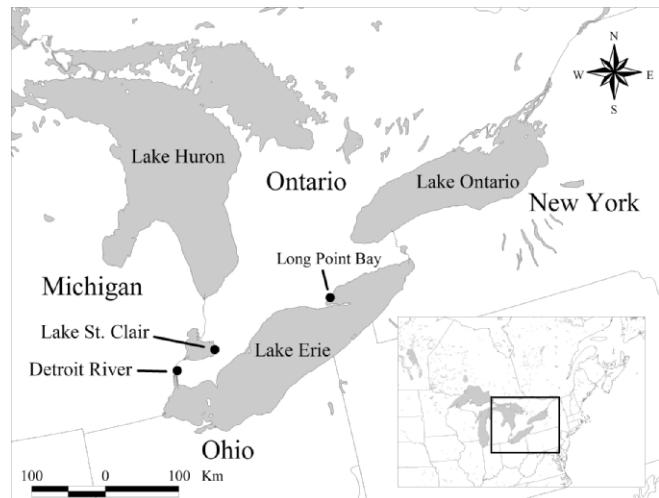


Figure 1. Collection sites for mute swans on the lower Great Lakes in southern Ontario, Canada, during 2001, 2002, and 2004.

1970, Swanson et al. 1974). We then sorted entire diet samples from each bird and identified samples to either genus or species level (Martin 1954, Hotchkiss 1972, Newmaster et al. 1997); we grouped unidentified items as follows: leaves, stems, tubers, seeds, or decaying–digested matter. We then dried sorted diet samples at 60° C to a constant mass (± 0.0001 g).

Many of the mute swans we collected did not contain food items because we did not specifically choose foraging birds for collection. We excluded from analyses birds that did not contain food items and birds that either had <5 identifiable food items or contained a total dry dietary sample mass <0.01 g. Thus, we were able to use diet data for 132 (of 356 total) birds in statistical analyses. We used the collection dates of these 132 birds to assign both adults and cygnets to various levels of an analysis category called “season” as follows: winter = 1 December to 28–29 February ($n = 11$); spring = 1 March to 31 May ($n = 61$); summer = 1 June to 30 August ($n = 41$); and autumn = 1 September to 30 November ($n = 19$).

As in previous waterfowl diet studies, we converted aggregate percent dry mass of food items into proportions and used those as dependent variables (Ross et al. 2005, Badzinski and Petrie 2006a). We applied an arcsine square-root transformation to proportions because error distributions did not conform to a normal distribution (Sokal and Rohlf 1995). These transformations improved error distribution but did not entirely eliminate nonnormality, making data more amenable to normality assumptions of parametric analyses (Sokal and Rohlf 1995). We used parametric, rather than nonparametric, analytical techniques because univariate and multivariate analyses are robust to several violations of linear model assumptions, including minor to moderate deviations from normality present in our data (Johnson 1995, Smith 1995, Hair et al. 1998).

We used 2 multivariate analyses of variance (MANOVA) to evaluate overall variation in 10 major food items, including 1) slender naiad (*Najas flexilis*), 2) coontail

(*Ceratophyllum demersum*), 3) common waterweed (*Elodea canadensis*), 4) pondweed spp. (*Potamogeton* spp.), 5) stoneworts (*Chara* spp. and *Nitella* spp.), 6) wild rice (*Zizania palustris*), 7) wild celery (*Vallisneria americana*), 8) arrowhead spp. (*Sagittaria* spp.) tubers, 9) milfoil spp. (*Myriophyllum* spp.), and 10) total aquatic invertebrates consumed by mute swans throughout the year (PROC GLM, MANOVA option; SAS Institute Inc. 2002). We first evaluated annual (2001, 2002, 2004), site-related (Lake Erie, Lake St. Clair–Detroit River), seasonal (spring [breeding], summer, autumn), and sex-related (F, M) variation in diets of only adults; we also included in this model interactive effects between season and sex on diet. We then evaluated seasonal (summer, autumn) and sex-age-related (ad M, ad F, and cygnet) variation in mute swan diet and tested for an interaction between season and age-sex group; based on results from the preceding adult-only analysis (see results), we combined dietary data for adult age-sex groups in this analysis across lakes and years. We evaluated significance of effects in the global MANOVA models and then conducted a posteriori contrasts on those effects using Tukey–Kramer tests. We considered effects statistically significant at $P \leq 0.10$. We used Wilks' lambda as the multivariate test statistic, and its approximation of the F -statistic, because it is robust to deviations from data normality (Hair et al. 1998). We made all statistical analyses and evaluations of normality and other model assumptions using the Statistical Analysis System software (SAS Institute Inc., Cary, NC). Although we made dietary analyses using transformed values, we present percentages ($\bar{x} \pm \text{SE}$) in text and tables for more meaningful interpretation.

RESULTS

Intake of 10 major food items by adult mute swans differed between sexes (Wilks' $\lambda = 0.86$, $F_{5,75} = 1.95$, $P = 0.081$) but did not vary by year (Wilks' $\lambda = 0.80$, $F_{20,150} = 0.90$, $P = 0.593$), season (Wilks' $\lambda = 0.88$, $F_{10,75} = 1.03$, $P = 0.425$), or collection site (Wilks' $\lambda = 0.82$, $F_{10,75} = 1.63$, $P = 0.115$); the interaction between sex and season also was not significant (Wilks' $\lambda = 0.88$, $F_{10,75} = 1.00$, $P = 0.451$). Tukey–Kramer a posteriori comparisons of food items showed that female diet samples (on an aggregate % dry mass basis) contained more total pondweeds ($P = 0.026$) but less slender naiad ($P = 0.053$) and common waterweed ($P = 0.073$) than did diets of males; we observed no sex-related differences (all $P > 0.10$) for coontail, milfoil spp., wild celery, wild rice, arrowhead spp. tubers, stoneworts, and aquatic invertebrates (Table 1).

The most commonly occurring food items, in rank order, in adult female diet samples were above-ground parts of pondweed spp. (mainly flat-stemmed pondweed [*Potamogeton zosteriformis*]), coontail, common waterweed, muskgrass (*Chara vulgaris*), slender naiad, wild rice, and wild celery (Table 1). Seeds of these species and below-ground parts, particularly of tubers of arrowhead spp., sago pondweed, and

wild celery, were consumed infrequently by adult female mute swans.

Adult males most commonly consumed (in rank order) above-ground parts of common waterweed, pondweed spp. (mainly slender pondweed [*Potamogeton pusillus*], Richardson's pondweed [*Potamogeton richardsonii*]), and flat-stemmed pondweed), coontail, muskgrass, and slender naiad (Table 1). As in females, seeds of these (and other species) and roots and tubers of arrowhead spp. were consumed much less frequently than above-ground parts. Aquatic invertebrates were relatively infrequently consumed and made a minor contribution to diet of both male and female mute swans.

Diets of mute swans did not differ among age-sex (ad M, ad F, and cygnet) groups (Wilks' $\lambda = 0.71$, $F_{20,86} = 0.80$, $P = 0.704$) or between summer and autumn seasons (Wilks' $\lambda = 0.84$, $F_{10,43} = 0.80$, $P = 0.630$); the interaction between season and age-sex group also was not a significant source of variation in mute swan diets (Wilks' $\lambda = 0.61$, $F_{20,86} = 1.20$, $P = 0.274$). Stems and leaves of slender naiad were the most common food item and made up the largest proportion of cygnet diets (Table 1). Above-ground parts of wild celery, coontail, muskgrass, and pondweed spp. (mainly flat-stemmed pondweed and slender pondweed) also were commonly eaten and were major dietary components. Similar to adults, there was some consumption of stems and leaves of common waterweed, milfoil spp., wild rice, arrowhead spp. tubers, and aquatic invertebrates by cygnet swans.

DISCUSSION

Although we did not detect seasonal differences in diets of adult mute swans, there were some sex-related dietary differences. Males tended to consume slightly more slender naiad and common waterweed than did females, whereas females incorporated >2 times the amount of pondweed spp. (mainly flat-stemmed pondweed) into their diets than did males. These differences may reflect sampling error but also may be due to sex-related dietary preferences. For example, some pondweeds might be more easily digested or contain more nutritional value than other submerged aquatic plants, which may aid in meeting the increased energetic demands of egg production, incubation, and brood rearing (Squires 1991).

We did not detect differences between cygnet and adult diets during summer and autumn, which was consistent with our prediction and may be due to the extended parent–offspring association exhibited in mute swans. Mute swan family members often forage in close proximity, and parents often actively aid their young by dislodging submerged vegetation from marsh substrate (Ciaranca et al. 1997). It also may be that adults and their offspring, especially older cygnets, are eating similar forage species because they are the most dominant; thus, abundant or available, submerged macrophytes within shallow marshes. The substantial food requirements needed for mute swans to fulfill daily energetic demands may necessitate a generalist feeding strategy,

Table 1. Percent occurrence and aggregate percent dry mass of the primary food items consumed by mute swans collected from marshes associated with the lower Great Lakes in southern Ontario, Canada, during 2001, 2002, and 2004.

Food item	Ad F (n = 51) ^a			Ad M (n = 57) ^a			Cygnet (n = 24) ^b		
	% occurrence	Aggregate %	SE	% occurrence	Aggregate %	SE	% occurrence	Aggregate %	SE
Submerged aquatic vegetation—total	94	72.4	5.6	93	66.3	5.7	88	71.1	8.9
Slender naiad ^c	22	4.3 A	1.7	33	9.5 B	2.0	42	27.3	8.8
Stem and leaf	20	4.1	1.7	33	9.4	2.0	42	25.3	8.3
Seed	4	0.2	0.2	2	0.1	0.1	13	2.0	1.5
Coontail ^c	29	15.9 A	4.2	33	19.5 A	4.3	25	9.5	4.9
Common waterweed ^c	27	9.9 A	3.5	42	17.4 B	3.4	13	3.6	3.4
Milfoil (<i>Myriophyllum</i> spp.)—total ^c	6	0.7 A	0.7	7	0.7 A	0.6	25	0.6	0.4
Pondweed (<i>Potamogeton</i> spp.)—total ^c	59	27.3 A	3.7	42	12.8 B	3.7	25	6.9	4.5
Richardson's pondweed	6	4.0	2.7	9	0.7	0.5	4		
Slender pondweed				14	6.0	3.0	8	4.6	4.2
Flat-stemmed pondweed	43	19.0	4.9	12	2.9	1.3	13	2.2	1.8
Sago pondweed—total	4	0.3	0.2	4	0.1	0.1			
Stem and leaf	2	0.1	0.1	4	0.1	0.1			
Tuber	2	0.2	0.2						
Pondweed—unidentified stem and leaf	6	4.0	2.6	7	2.5	1.9			
Pondweed—unidentified seeds	8	TR		9	0.6	0.4	4	0.1	0.1
Wild celery—total ^c	12	2.8 A	2.0	7	2.8 A	1.9	21	8.7	4.6
Stem and leaf	10	2.7	2.0	5	2.6	1.9	21	8.7	4.6
Seed	2	TR		2	0.1	0.1			
Tuber	2	TR							
Water starwort (<i>Callitrichia hermaphroditica</i>)				2	0.4	0.4			
Lesser duckweed (<i>Lemna minor</i>)	2	TR		2	TR				
Star duckweed (<i>Lemna trisulca</i>)				2	TR		4	0.3	0.3
Unidentified submerged vegetation—total	53	11.5	3.5	51	3.2	1.1	42	14.8	6.7
Stem and leaf	37	3.9	2.1	46	2.0	0.7	21	4.7	4.0
Seed	6	0.1	0.1	2	TR		8	1.4	1.2
Root	18	0.3	0.2	9	1.2	0.8	4		
Tuber							4	4.2	4.2
Plant matter	20	7.3	2.8	5	TR		8	4.6	4.1
Emergent aquatic vegetation—total	27	12.1	4.1	23	15.7	4.5	25	11.9	6.2
Wild rice ^c	20	9.9 A	3.7	18	7.4 A	3.6	17	3.9	3.2
Arrowhead (<i>Sagittaria</i> spp.)—tuber ^c	2	1.9	1.9	9	8.3	3.6	8	8.0	5.5
Bulrush (<i>Scirpus</i> spp.)—seed	2	TR							
Burreed (<i>Sparganium</i> spp.)—seed	4	0.3	0.2						
Stonewort—total ^c	27	14.7 A	4.6	40	16.9 A	4.4	17	16.3	7.6
Muskgrass (<i>Chara vulgaris</i>)	18	10.5	4.1	32	15.8	4.4	17	16.3	7.6
<i>Chara</i> spp.—unidentified	4	TR		2					
<i>Nitella</i> spp.	12	4.2	2.4	11	1.1	0.9		TR	
Aquatic invertebrates—total ^c	14	0.8 A	0.5	32	1.2 A	0.9	13	TR	

^a We combined dietary data for ad across yr (2001, 2002, and 2004), collection sites (Long Point Bay–Lake Erie and Lake St. Clair–Detroit River), and seasons (spring, summer, autumn, and winter).

^b We combined dietary data for cygnets across collection sites and seasons (summer and autumn); overall diets also did not differ among age–sex groups during summer and autumn.

^c Food items included in multivariate analysis of variance evaluating dietary differences between ad F and ad M; different letters denote significant a posteriori differences ($P \leq 0.10$) based on Tukey–Kramer tests.

^d TR = <0.05% dry mass.

particularly during summer and autumn when above-ground parts of aquatic plants are most abundant.

In our study, as in others, all mute swan age–sex groups primarily ate vegetative structures (leaves and stems) of a wide variety of submerged aquatic plant species (see review by Ciaranca et al. 1997, Perry et al. 2004). Specifically, mute swans using LGL coastal marshes commonly ate several pondweed spp. (mostly flat-stemmed pondweed, Richardson's pondweed, slender pondweed, and sago pondweed), coontail, muskgrass, common waterweed, slender naiad, wild celery, and wild rice. Diets of mute swans in the United

States at Rhode Island, Connecticut, Massachusetts, and Maryland–Chesapeake Bay also contained a wide variety of aquatic plants, including several pondweed spp., slender naiad, wild celery, coontail, and stoneworts plus several other plants found in brackish waters (e.g., widgeon grass [*Ruppia maritima*] and eelgrass [*Zostera marina*]; Willey and Halla 1972, Hindman 1982, Fenwick 1983, Perry et al. 2004). Mute swans we collected on the LGL also ate some below-ground plant structures, including tubers (and rhizomes) of arrowhead spp., wild celery, and sago pondweed, particularly during autumn, winter, and spring, which

was likely a response to biomass reduction of above-ground parts from herbivory, wave-action, and senescence, plus increased availability of tubers at that time (Badzinski et al. 2006).

All of the major plant species consumed by mute swans were also common and important foods for several species of waterfowl that stage and over-winter on the LGL (Jones and Drobney 1986, Custer and Custer 1996, Petrie 1998, Knapton and Petrie 1999, Badzinski and Petrie 2006a). Substantial proportions of the continental population of canvasback (*Aythya valisineria*), redhead (*A. americana*), and scaup (*A. affinis* and *A. marila*) stage and winter on Lake St. Clair, Detroit River, and Long Point Bay–Lake Erie each year where they feed at times in shallow marshes on the stems, leaves, and tubers of wild celery, sago pondweed, and muskgrass to build energy reserves needed for migration and over-winter survival (Jones and Drobney 1986, Petrie 1998, Badzinski and Petrie 2006a, b). Large concentrations of mallard (*Anas platyrhynchos*), American black duck (*A. rubripes*), green-winged teal (*A. crecca*), American wigeon (*A. americana*), gadwall (*A. strepera*), and wood duck (*Aix sponsa*) that stage in LGL coastal marshes eat seeds, stems, and leaves of numerous pondweed spp., wild celery, wild rice, slender naiad, muskgrass, coontail, and common waterweed (Pauls and Knapton 1993, Petrie 1998, Knapton and Petrie 1999). Many Eastern Population tundra swans stage in LGL marshes during spring and autumn and mainly feed on vegetative parts of pondweed species and muskgrass, as well as wild celery, sago pondweed, and arrowhead spp. tubers (Petrie et al. 2002, Badzinski 2003, Badzinski et al. 2006). Consequently, we suggest there is much potential for inter-specific competition for food between mute swans and native waterfowl within the LGL region.

Mute swans are very large birds that have substantial daily nutritional requirements. An individual mute swan can eat an estimated 3.8 kg (wet wt) of aquatic vegetation each day and at times males and females can consume up to 35% and 43% of their respective body masses in food each day (Willey and Halla 1972, Fenwick 1983). Although individual mute swans can uproot a considerable amount of vegetation in a day (approx. 9.0 kg wet wt), they typically eat <50% (approx. 4.0 kg) of what they remove (Mathiasson 1973, Fenwick 1983). Based on the dietary intake estimates above, the approximately 2,000 mute swans presently residing on the LGL may eat about 8,000 kg of plant biomass daily and potentially waste or destroy an additional 10,000 kg of plants. Hindman and Harvey (2004) estimated that about 4,000 mute swans could eat about 5,454,545 kg (12 million pounds; wet wt) of submerged aquatic vegetation per year at Chesapeake Bay, Maryland. Further, mute swan foraging can cause substantial within-season reductions in above- and below-ground plant biomass, which can lead to longer term biomass reductions and compositional changes in the aquatic vegetation community (Cobb and Harlan 1980, Allin 1981, Jonzen et al. 2002), alteration of food-web dynamics, and reduction in the

natural carrying capacity of habitat for native waterfowl (Allin 1981, Idestam-Almquist 1998, Naylor 2004).

During the past 20 years, mute swans have experienced a rapid population increase and substantial range expansion throughout the LGL region of Canada but likely have not yet reached carrying capacity (Petrie and Francis 2003, Badzinski 2007). Thus, ecological effects on plants and wildlife associated with large populations or high densities of mute swans, such as those commonly reported in the United States, have not yet been studied or documented in the LGL region (Allin and Husband 2003, Atlantic Flyway Council 2003, Naylor 2004, Therres and Brinker 2004, Tatut et al. 2007). Because mute swans have been deemed a nonnative and introduced waterfowl species and, thus, not afforded protection under the Migratory Bird Treaty Act in the United States, state wildlife agencies have jurisdiction over this species and can reduce and manage their numbers (United States Fish and Wildlife Service 2005). In Canada, however, mute swans remain a federally protected species under the Migratory Birds Convention Act, which is a major impediment to widespread and effective population management (Petrie and Francis 2003). Thus, as Petrie and Francis (2003) previously suggested, the nonnative mute swan should be removed from the list of protected species in Canada to facilitate initiation of widespread population control programs before swans attain levels where their impacts on the LGL coastal marsh ecosystem becomes prevalent and problematic.

MANAGEMENT IMPLICATIONS

Our results suggest that mute swans and several species of native waterfowl are consuming similar species of submerged aquatic plants, thereby creating potential for interspecific competition at important migratory stopover sites on the LGL. The predicted mute swan population increase and range expansion within this region suggests that future impacts on aquatic plant communities might be significant, thereby exacerbating potential competition with native waterfowl and, thus, necessitating the need for agencies to develop effective strategies to manage feral, nonnative mute swan populations on the LGL. Further, our results can be used to assess which species of aquatic plants may be most impacted by foraging activities of mute swans at other important stopover and wintering sites in North America.

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