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USE OF PONDS AND LAKES BY RESIDENT CANADA GEESE

A Thesis

Presented to

The Faculty of the Department of Biology

The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

by

Phillip D. West

2003

APPROVAL SHEET

This thesis is submitted in partial fulfillment
of the requirements for the degree of

Master of Arts

Phillip West

Approved July, 2003

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ABSTRACT

Resident Canada geese (*Branta canadensis*) have increased significantly in Virginia during the last ten years. Wildlife enthusiasts and waterfowl hunters have generally welcomed resident geese while others, such as waterfront property owners and golf course operators, have objected because of waste products and damage to grass. To better understand what makes particular waterbodies attractive to resident geese, I censused 55 randomly selected ponds and lakes on the Middle Peninsula of southeastern Virginia. Study sites were located in a variety of habitats ranging from forest to sparsely developed agriculture lands and urban parks. These population data were collected during the spring breeding, summer post-breeding molt, and early autumn periods. I examined more than thirty variables relating to pond characteristics and surrounding landscape to determine whether there was a set of biologically relevant factors that predicts intensity of goose use. Multivariate statistical techniques were used to show that goose use can be predicted with a high probability of success by examining combinations of habitat variables. A similar study was also carried out for mallard ducks with inconclusive results.

Key words: Branta canadensis, habitat variables, pond characteristics, resident Canada goose, Virginia.

USE OF PONDS AND LAKES BY RESIDENT CANADA GEESE

CHAPTER I

CANADA GEESE

Natural History

Canada geese (*Branta canadensis*) may be the most watched and among the most visible wildlife species in North America (Rusch et al 1996). They are widely distributed throughout the United States with 11 subspecies (Bellrose 1976) in 19 management populations throughout the continent (USFWS 2002). Canada geese are one of the largest waterfowl species. Ranging in size from 1.27 to 5.68 kg (*B.c. minima* and *B.c. maxima*, respectively; Bellrose 1976), they are long-lived birds that begin to reach sexual maturity at two years of age. The majority, however, do not breed successfully until they are three. Characterized as monogamous maters, Canada geese form mating pair bonds that last for life. If one member of the pair dies, a new mate will usually be found within the same nesting season (Bellrose 1976).

Although able to adapt to a variety of nest sites, Canada geese generally nest near water, either on the ground, on elevated structures such as muskrat houses, or even on nesting platforms or duck blinds. Island nest sites are often preferred (Zenner and Lagrange 1998). Physical and vegetative characteristics of sites are highly variable but nests are generally bowl shaped. The female lines the nest with down she removes from an area of her chest referred to as the brood patch.

Clutch size in 11,786 nests ranged from 1 to 12 with a mean of 5.14 (Bellrose 1976). Nesting occurs in the spring, generally beginning in March in warmer climates. The incubation period is approximately 28 days, during which males aggressively defend females. Young are precocious and upon hatching are led away from the nest by the parents. Adults undergo a complete molt of the wing feathers in mid-summer, which is generally synchronized among successful breeders in a flock. During this period adults are flightless and are vulnerable to predation or capture. Young of the year are feathered and begin flight at approximately the same time adults complete the wing molt.

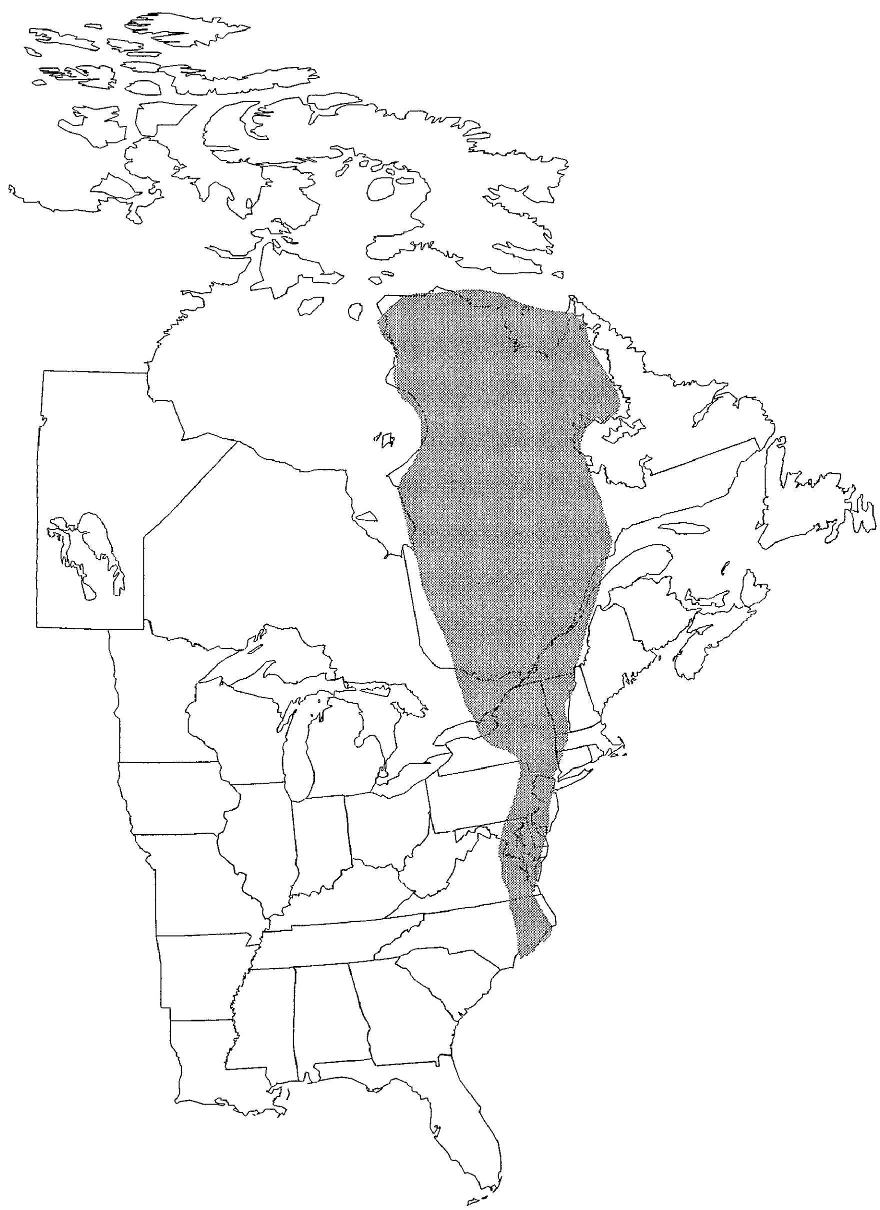
Canada geese are grazers, preferring succulent green vegetation, both aquatic and terrestrial. They also consume agricultural grains. Generally, they are a migratory species. Nesting occurs in the northern latitudes during the warmer months and birds over-winter in more southern latitudes.

Origins of Resident Geese

Canada geese were long regarded as harbingers of fall. Migrant Canada geese have traditionally and currently winter in large numbers around the Chesapeake Bay region of Virginia. These geese, which nest on the Ungava Peninsula on the western shore of the Hudson Bay, typically arrive in late September and depart toward nesting grounds in early March. These birds follow a migration corridor referred to as the Atlantic Flyway (Figure 1).

Populations of geese exist today that are largely non-migratory. In the last 40 to 50 years, a population of Canada geese has become resident year-round in Virginia. Geese that nest within the conterminous United States during the months of March, April, May or June, or geese that reside within the conterminous United States in the months of

Figure 1. Range of Atlantic Population Migrant Geese.



April, May, June, July, or August (USFWS 2002) are hereafter referred to as resident geese. Resident geese originated from a combination of sources. Releases of captive reared birds by both aviculturists and sportsmen were an original source of resident geese (USFWS 2002). Until the practice was outlawed in the 1930's, captive flocks were maintained for use as live decoys for waterfowl hunting. Many of the birds maintained in captive flocks were western (*B.c. moffitti*), Atlantic (*B.c. canadensis*) and interior (*B.c. interior*) subspecies of Canada geese (Lowney et. al 1997). It is estimated that approximately 15,000 Canada geese were released when the practice of live decoys was outlawed (Dill and Lee in USFWS 2002).

Another principle source of resident geese has been restoration (Hanson 1997) and relocation (Blandin and Heusmann 1974) projects by Natural Resources agencies. These efforts were an attempt to establish flocks in areas unoccupied by geese. In Virginia, resident geese were trapped in areas were they were locally abundant and relocated until the early 1990's in an effort to minimize conflicts between humans and geese (pers. comm. G. Askins).

Many relocations involved giant Canada geese (*B.c. maxima*), the largest of the subspecies. Giant geese were once thought to be extinct, but Hanson (1997) "rediscovered" a flock of wintering giant geese in Rochester, Minnesota in 1962. Continuing work by Hanson proved the existence of other giant geese in aviculturist's flocks as well as in the wild.

Giant Canada geese have proven to be a good choice for relocation efforts. Their ability to exploit habitats not formerly associated with migrant Canada geese, such as water retention basins and golf course ponds, has been well documented. Giants are equally at home foraging on succulent sedges and native grasses, the traditional Canada goose diet, as on succulent green lawn growth (Rusch et. al 1996). The Giant Canada goose breeds at a younger age and has high gosling survival rates in urban settings with fewer predators (Nelson and Oetting 1998).

Resident Geese in Virginia

From these two general sources, release of captive decoys and relocation efforts, Canada geese have become well-established year- round residents in Virginia. It is likely that resident geese in Virginia are a hybrid mix of subspecies (USFWS 2002; Lowney et al. 1997) that have retained characteristics that enable them to survive and proliferate. Resident Canada geese are not unique to Virginia. Populations have become established throughout the United States (Nelson and Oetting 1998), Great Britain (Owen et al 1998), Sweden (Sjoberg, K. and Sjoberg, G. 1998) and New Zealand (Holloway et. al. 1998). Currently, resident geese represent a substantial portion of the overall population of Canada geese that winter in the Atlantic Flyway (Sheaffer and Malecki 1998) (Figure 2).

In 1989, there were an estimated 7,694 breeding pairs of Canada geese in Virginia (Sheaffer and Malecki 1998). This population had grown to over 301,416 total geese by 1997 (Lowney et. al 1997). The population of resident geese in Virginia has been increasing by 10%-15% a year (Lowney et. al 1997). The population growth of resident geese contrasts with population declines of Virginia-wintering migrant geese throughout the mid - 1980's.

Currently, resident geese are found throughout the entire state and are considered by some to be a problem statewide (Lowney et. al 1997). The presence of resident

Figure 2. Known Range of Atlantic Population Resident Geese.

Canada geese has been encouraged or at least looked upon favorably by many people including wildlife watchers and waterfowl hunters. In Virginia, special hunting seasons have been established that allow hunters opportunities to harvest resident geese. These seasons have been effective at stabilizing resident geese in areas where they can be hunted (Lowney et. al 1997) but has not been as effective in urban or suburban habitats.

Not everyone has appreciated increases in resident goose numbers. Between 1992 and 1997 the USDA, Animal Plant Health Inspection Service (APHIS), Wildlife Services, Virginia Department of Agriculture and Consumer Services, Office of Plant and Pest Services (VDACS), and Virginia Department of Game and Inland Fisheries (VDGIF) received 2,043 Canada goose damage complaints from Virginia (Lowney and Dewey in Lowney et. al 1997). Problems such as turf damage, feces deposition, water quality degradation, and traffic hazards have been well documented throughout the eastern United States (Conover 1985, Blackwell et al. 1999, and Belant et. al. 1996) including Virginia (Lowney et al 1997).

Justification for this Study

Problems associated with resident geese have led to the development of a variety of control measures. Habitat modifications (Doncaster and Keller 1998), relocation (Conover 1985), repellents (Cummings et al. 1995, Blackwell et al. 1999, Belant et al. 1996), hazing devices (Aguilera et al. 1991), and chasing with dogs (Castelli and Sleggs 2000) are among the non-lethal techniques employed to discourage resident Canada geese from an area. In addition to special hunting seasons, lethal control measures include egg destruction and rounding up geese for euthanasia during the flightless wing molt. Geese euthanized during roundups are occasionally given to programs that then distribute the meat to the needy (USFWS 2002).

Many states or localities have developed integrated management plans (Cooper and Keefe 1997, Lowney et al. 1997) to address growing numbers of resident geese. The United States Fish and Wildlife Service has recently developed a Draft Environmental Impact Statement titled "Resident Canada Goose Management". This document examines various management options and provides a plan to "guide and direct the resident Canada goose population growth and management activities in the conterminous United States."

While substantial information exists to describe methods to manage or control resident geese, relatively little has been published regarding habitat use by resident geese, particularly during the spring and summer growing seasons when many complaints about resident Canada goose damage are made. Cook et. al. (1998) describe habitat use by a flock of mixed resident and migrant Canada geese on a non-hunted complex in southcentral Michigan. Their research, conducted from August to April, describes habitat use on a complex consisting mostly of agricultural and recreational lands. Harvey et. al. (1988) observed habitat use by foraging geese in a telemetry study on the eastern shore of the Chesapeake Bay. They were able to quantify habitat use by foraging geese in a variety of agriculture settings during the winter months.

Although harassment, exclusion, and chemical taste deterrents have been useful at moving geese out of problem areas once they are established (USFWS 2002), new resident goose management strategies are needed that can prevent geese from being attracted to areas in the first place. A better understanding of resident geese and their habitat interactions can lead to more effective methods of preventing problems between humans and resident geese.

My objective was to determine if there is a set of measurable attributes that explains variability of resident Canada goose use of ponds and lakes during the spring, summer, and fall. If successful, this would make it possible to design waterbodies in such a way that they could be more or less attractive to geese, depending on the landowner's intent.

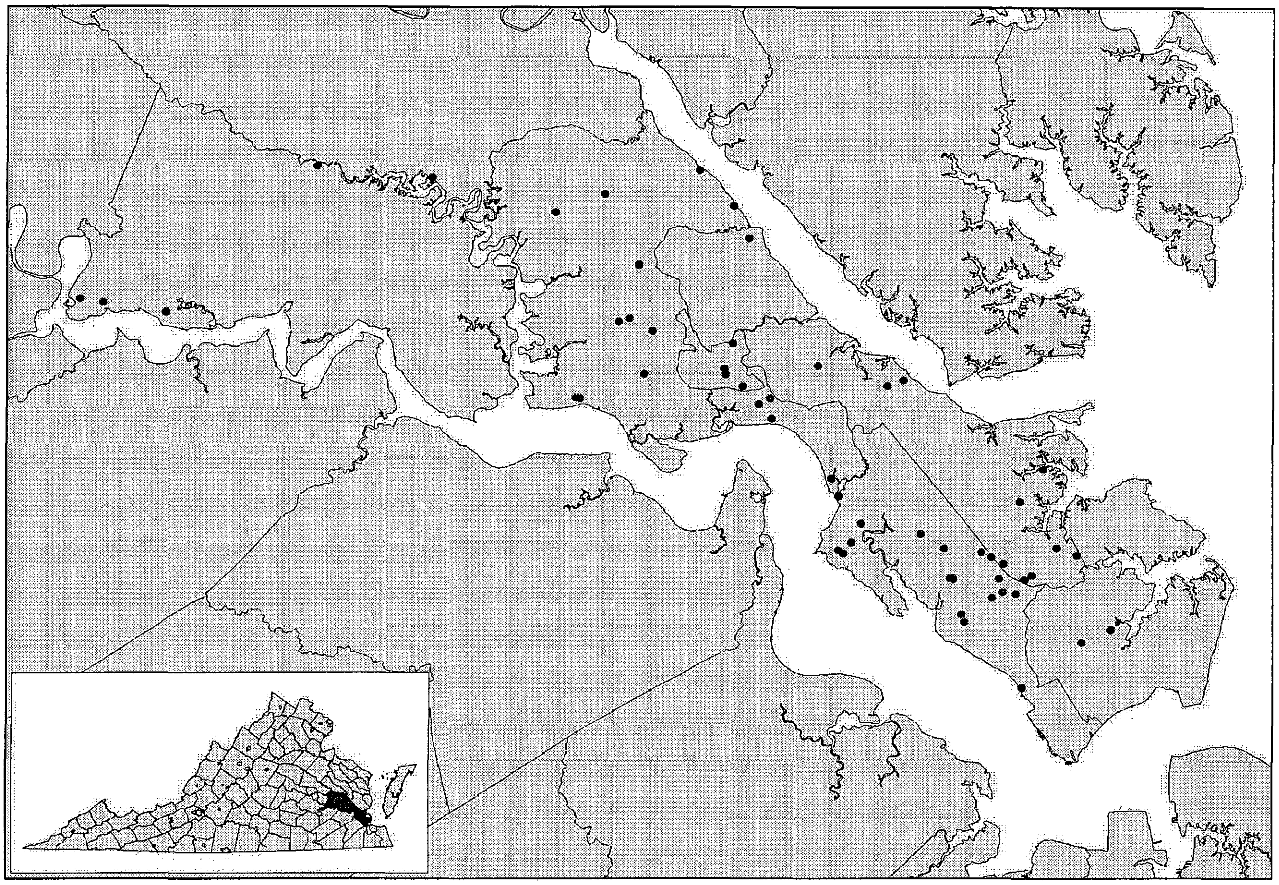
Given the amount of effort people have expended managing geese, it is surprising how little is known about what attracts geese to particular locales. Conover and Kania (1991) looked at relationships between nuisance goose sites (n=19) and habitat correlates (n=9) for urban - suburban goose flocks in Connecticut. They found that nuisance sites were associated with a body of water, that there was a significant relationship between "nuisance sites" and the height of surrounding vegetation, and that nuisance sites had more visual obstructions than did paired random sites. Little is understood about the habitat preferences of Canada geese in our cities and suburbs (Nelson and Oetting 1998).

Methods

Study Site

This study site is in the coastal plain physiographic region of Virginia on the peninsula defined by the James and York Rivers and bordered by New Kent and Charles City counties (Figure 3). I identified all ponds and lakes, hereafter referred to as "waterbodies", bigger than 30 m^2 (n = 494) using ArcView Geographic Information System (GIS) and the national hydrography data set. From this set of waterbodies, I randomly selected 90 ranging in size from 0.005 ha to 2.911 ha as candidate sites.

Figure 3. Study Site Locations.



In March 2001, I attempted to visit and gain permission to access each of these locations. Thirty-three waterbodies were inaccessible for a variety of reasons, including an inability to locate owners, denial of permission to conduct research, or changes since the aerial photography. Thus I was left with the 57 sites included in the study. Of these, I was unable to sample geese at all on two sites, unable to sample in all three time periods (see below) at six other sites, and unable to sample vegetation on five sites, resulting in a total of 47 waterbodies (Table 1) with complete data.

Canada Goose Observations

This study was timed so that it occurred after migrant Canada geese had left the area for spring migration to their arctic breeding grounds. Generally, Virginia migrant geese depart for the breeding grounds by the second week in March (G.R. Askins, pers. comm.). I visited each waterbody six times in order to census resident Canada geese: twice during the nesting period (15 March to 15 June), twice during the molting period (16 June to 15 July), and twice during the post-molt period (16 July to 15 September). Other waterfowl present on the site were also counted and recorded as mallards, mute swans, domestic waterfowl or wood ducks.

A single ten-min point count was used to determine total number of geese and/or other waterfowl present. On larger sites, several point counts located around the lake were used so that the majority of the surface area could be observed, but the total observation time was still 10 min. In all cases I felt confident that I detected all geese present. Canada geese are conspicuous and noisy, so it is unlikely that my sampling procedure missed any birds. Observations were accomplished with the naked eye or with 7x50 binoculars. Ponds were visited in a haphazard order and at haphazardly chosen

Table 1. List of study sites and their coordinates in decimal degrees WGS 84.

WATERBODY_	LONGITUDE	LATITUDE
BASF Pond	-76.61035	37.18022
Berkley Pond	-77.18012	37.32381
Bland Ave.	-76.51573	37.12480
Bridgewater	-76.40180	37.05041
Brown's Pond	-76.58659	37.14615
Cannon	-76.47006	37.10056
Chisel Run	-76.75921	37.29506
Colonel's Pond	-76.60468	37.16686
Concord Pond	-76.45612	37.08887
Cottrell's	-76.83874	37.38599
Coventry; Harvest Lake	-76.44804	37.09884
Custom Concrete Pond	-77.04389	37.42730
Denbigh K-Mart	-76.53579	37.13632
Ed Allen's Pond	-76.94441	37.41508
F.E. Golf Course	-76.59539	37.13228
Ford's Colony Main	-76.77906	37.30532
Ford's Colony, Courd	-76.78844	37.30281
Fort Eustis Airfield	-76.60321	37.12443
Fort Eustis Marsh	-76.60797	37.12707
Golden Horseshoe, Big	-76.69819	37.26040
Golden Horseshoe, Sm	-76.69870	37.26474
Kiln Creek #2	-76.48393	37.12077
Kiln Creek #7	-76.47545	37.11659
Kiln Creek Shopping Center	-76.46550	37.11137
Kingsmill Entrance	-76.66049	37.24134
Kingsmill Marina	-76.65951	37.22649
Kingsmill Pond	-76.67054	37.23788
Kitchum	-76.82500	37.24774
Lake Biggins	-76.45538	37.01893
Little Coventry	-76.44133	37.10163
Little Denbigh	-76.50378	37.07507
Massey	-76.76879	37.34429
Meanly Pond	-76.50158	37.06934
NWS #12	-76.61764	37.26418
NWS Indian Field	-76.55869	37.24701
NWS Roosevelt Pond	-76.54423	37.25068
O.P. Main	-76.47674	37.08681

Table 1, Continued. List of study sites and their coordinates in decimal degrees WGS 84.

WATERBODY_	LONGITUDE	LATITUDE
O.P. North America	-76.46740	37.09044
O.P. Town Center	-76.28413	37.28413
Powhatan Plantation	-76.76869	37.26358
Riverview Pond	-76.68387	37.38494
Running Man	-76.41904	37.12132
Shirley	-77.25314	37.33591
Skimino	-76.67145	37.36054
Stonehouse Pond	-76.79519	37.39756
Tidemill	-76.37654	37.05900
Tutter's Neck	-76.68333	37.25153
Wendwood North	-76.50972	37.10275
Wendwood Small	-76.50913	37.10155
Wendwood South	-76.51206	37.10235
Westbury	-77.23342	37.33262
Whitakers Pond	-76.82855	37.24852
Whitehead	-76.42695	37.18031
Winder's Pond	-76.44854	37.15696
Wmbg Motel	-76.69036	37.28319
Wood's of Tabb	-76.40220	37.11520

times of day with the constraint that ponds located very close to one another were visited consecutively.

Census data from both visits in each time period were combined into one mean value per time period, and these were combined into one mean for the entire season. If one visit was missed (n = 13 sites), the remaining observation for that time period was substituted for the time period mean in calculating the season mean. Mean values were then divided by the water surface area to calculate a seasonal goose density. Waterbodies visited at least once at which at least one goose was recorded were classified as "geese present". Waterbodies visited at least five times at which geese were never recorded were classified as "geese absent".

Habitat Data

Beginning on 30 May, each waterbody was visited to collect habitat data. I gathered four general types of information: vegetation within 1 m of the shoreline (hereafter "shoreline"); vegetation covering the zone from 3 m to 30 m (hereafter "buffer"); aquatic vegetation; and physical features of each site (e.g. steepness, depth, etc.). Each site was also classified as to whether food was being provided for waterfowl. Global Positioning System (GPS) coordinates accurate to within 5 m were obtained and I made a detailed sketch of the shape of each site for future reference.

Shoreline Vegetation

The following shoreline vegetation categories were visually estimated to within 10% and recorded as a percent of total coverage: short herbaceous (<10 cm), tall herbaceous (>10cm), shrubs, shrubs overhanging the water, and trees. Unvegetated shoreline was also estimated and classified. This category included not only bare dirt but also human constructed features such as rock-hardened shores. Estimates of coverage in some cases exceeded 100% because of layering (i.e. trees overhanging lawns or trees with unvegetated ground beneath such as pine straw).

Buffer Vegetation

I used the same categories as shoreline vegetation with the exception of shrubs overhanging the water.

Aquatic vegetation

I visually estimated the percent coverage of emergent vegetation, submerged vegetation, and floating vegetation (to within 10%).

Physical Features

The final type of information collected at each site concerned various physical features. A canoe or one-person watercraft was used to facilitate collection of these data. The maximum water depth of each pond was recorded using a marked weighted line. To standardize measurements, water depth recordings were taken adjacent to the water control structure or at the center if no structure was present. Turbidity was measured using a Secchi disk.

I obtained two water chemistry measurements: pH (using a pH meter) and dissolved oxygen. I estimated the steepness of banks of the shoreline (in degrees from horizontal) above and below the waterline using a 1.6 m metal rod with a protractor attached and a bubble level. These two slopes were then combined into one mean slope. I obtained the orientation of the long axis of each pond using a magnetic compass. To determine the length of the long axis I used a laser rangefinder (Bushmaster made by Bushnell Corporation). In addition, I measured the short axis of each pond perpendicular to the long axis at its approximate mid-point. Finally, I recorded the number of islands in each waterbody.

Aquatic invertebrates

I sampled aquatic invertebrates by making a 180-degree sweep with an aquatic bottom kick net (Wildco Manufacturers, 800x900 micron mesh) at each point where a cardinal direction intersected the perimeter of the pond. The total number of aquatic invertebrates in all four net sweeps was combined and used as an index for aquatic invertebrate density.

Potential Escape Angle

Conover and Kania (1991) describe a method for determining the minimum angle a Canada goose would have to fly to escape an area. I used a similar but revised method. I took a series of clinometer readings (Suunto Instruments model PM-5/360) from four points around the perimeter of the pond. I read the clinometer from a sitting position each time. The four locations used for clinometer readings were where the cardinal directions approximately intersected the pond's perimeter. The clinometer was used to determine the angle between ground level and the highest obstruction (e.g. tree top) within line of site. At each of the four locations I made five clinometer readings at 0 degrees, 45 degrees, 90 degrees, 135 degrees, and 180 degrees off the cardinal direction (Figure 4). The mean of all twenty readings was recorded as the overall escape angle for each site.

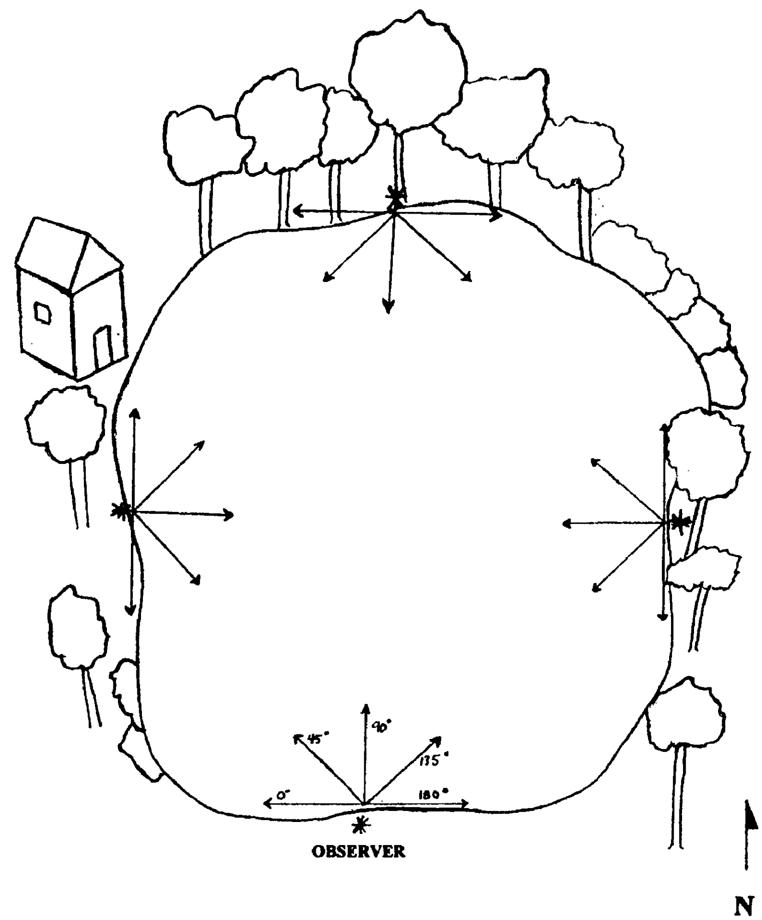
ArcView GIS was used to estimate land cover around each site. Pond and lake boundaries were digitized and land cover data was determined for three sizes of buffer (0.5 km, 1 km, and 3 km using the National Landcover Data Set). These landcover data are of 30-m pixel size and were derived from satellite imagery. I classified landcover into four types as follows: (1) developed (low- and high-intensity residential, commercial, bare substrate, quarries), (2) forested (deciduous, evergreen, and mixed forest, woody wetlands, and transitional [i.e. regenerating clearcuts]), (3) wetland (open water and emergent herbaceous wetlands), and (4) agriculture (orchards, vineyards, grasslands, pasture, row crops, grains, fallow, recreational grasslands ([i.e. athletic fields]).

Results

Occurrence of geese by season

Canada geese were observed during at least one of the observations periods on 32 (69%) of 55 waterbodies. During nesting season observations (15 March through 15 June) a mean of 5.4 ± 8.5 geese were observed on 29 (54%) of the 54 waterbodies that were censused twice. Geese were also detected on two additional waterbodies that were visited only once. During the molting period (16 June through 15 July) a mean of 5.4 ± 11.7 geese were observed on 16 (33%) of the 49 waterbodies censused twice. Geese were also observed on 5 of the 6 waterbodies censused only once. During the post-molt period (16 July through 15 September) a mean of 10.8 ± 24.1 geese were observed on 21

Figure 4. Clinometer Reading Illustration.



(40%) of 52 waterbodies censused twice. In addition, geese were found on 3 of 5 waterbodies censused only once.

Waterbody Characteristics and Intensity of Goose Use

Shoreline and Waterbody Characteristics

To determine whether intensity of goose use correlated highly with particular shoreline variables, I calculated correlation coefficients between the estimated mean density of geese and the proportional representation of each vegetation type, as well as the average steepness of the bank (calculated as mean of above and below waterline slopes) and other physical characteristics (Table 2). The density of geese was highly positively correlated (0.58) with proportion of short herbaceous vegetation (i.e. grass) on the shoreline, and was negatively correlated with proportion of trees (-0.48) and shrubs (-0.44). All other correlation coefficients were <0.40. It should be noted that because many of these variables are interrelated, a univariate analysis such as this may be misleading.

To reduce the number of variables in preparation for a multivariate analysis (see below) I used principle components analysis on the highly interrelated measurements of vegetation cover. This analysis reduced the six variables to three linear combinations, each with an eigenvector >1.0, that together explained 86% of the variation among the original variables (Table 3). Principle Component (hereafter "PC") 1 loaded positively on trees and shrubs, so I refer to it as "woodsiness". PC 2 loaded positively on unvegetated ground (i.e. dirt, concrete or pine needles), so I refer to it as "bareness". PC

Table 2. Correlation coefficients between Canada goose density and waterbody characteristics, shoreline vegetation variables, buffer zone vegetation variables, vegetation principle components, and surrounding land cover variables.

Variable	**Correlation**
Number of islands	-0.16
Escape angle (degrees)	+0.06
Turbidity	-0.10
pH	+0.39
Dissolved Oxygen	-0.16
% emergent veg.	-0.07
% submerged veg.	+0.02
% floating veg.	-0.21
Shoreline	
Steepness of slope (degrees)	+0.01
% unvegetated	+0.07
% short herbaceous	+0.58
% tall herbaceous	-0.15
% shrub	-0.44
% overhang. shrub	-0.38
% tree	-0.48
PC1 (woodsiness)	-0.39
PC2 (bareness)	+0.04
PC3 (tallness)	-0.30
Buffer zone	
% unvegetated	-0.40
% short herbaceous	+0.42
% tall herbaceous	-0.06
% shrub	-0.03
% tree	-0.28
PC1 (woodsiness)	-0.39
PC2 (tallness)	-0.16
PC3 (shrubiness)	+0.10
Surrounding land cover	
0.5 km % developed	-0.06
0.5 km % forested	-0.04
0.5 km % wetland	+0.14
0.5 km % agriculture	+0.05

Table 2, Continued. Correlation coefficients between Canada goose density and waterbody characteristics, shoreline vegetation variables, buffer zone vegetation variables, vegetation principle components, and surrounding land cover variables.

Variable	Correlation
1 km % developed	-0.11
1 km % forested	+0.09
1 km % wetland	+0.10
1 km % agriculture	-0.05
3 km % developed	-0.09
3 km % forested	+0.16
3 km % wetland	-0.19
3 km % agriculture	+0.32

Table 3. Eigen values and Eigenvectors for principle components of shoreline vegetation cover.

Shoreline	PC1 (woodsiness)	PC2 (bareness)	PC3 (tall herbaceous)
Eigen Value	2.68	1.29	1.18
Variance explained (%)	44.74	21.57	19.65
Eigenvector for:			
% unvegetated	+0.09	**+0.83**	-0.04
% short herbaceous	-0.33	-0.22	**-0.70**
% tall herbaceous	-0.34	-0.24	**+0.70**
% shrub	**+0.55**	-0.29	-0.02
% overhang. shrub	**+0.55**	-0.27	-0.05
% tree	**+0.41**	+0.21	+0.11

3 loaded positively on tall herbaceous vegetation and negatively on grass, so I refer to it as "tallness of herbaceous vegetation".

It should be noted that each principle component includes a contribution from each variable (called the "Eigen value"). In coming up with my descriptors, such as "woodsiness", I considered only those variables with Eigen vectors > 0.5 or < -0.5. Shoreline woodsiness and tallness of herbaceous vegetation were nearly negatively correlated with estimated goose density (see Table 2), but both had correlation coefficients < 0.40.

Buffer vegetation

Buffer vegetation was estimated for a band from 3-30 m out from the shoreline. As with shoreline vegetation, I calculated correlation coefficients between the estimated mean density of geese and the proportional representation of each vegetation type in the buffer, as well as the average escape angle (calculated as mean of the twenty measurements around the pond or lake). The density of geese was positively correlated (0.42) with proportion of short herbaceous vegetation in the buffer zone, and other variables had correlation coefficients <0.40 (Table 4).

As before, to reduce the number of variables in preparation for a multivariate analysis I used principle components analysis. This analysis reduced the five variables to three linear combinations, each with an Eigen Value >1.0, that together explained 92% of the variation among the original variables (Table 4). PC 1 loaded positively on trees and unvegetated ground and negatively on short herbaceous, so I refer to it as "open woodsiness" (Table 4). PC 2 loaded positively on tall herbaceous vegetation and negatively on short herbaceous, so I refer to it as "tallness of herbaceous vegetation". PC

Table 4. Eigen values and Eigenvectors for principle components of buffer zone vegetation cover.

Buffer zone	PC1 (open woodsiness)	PC2 (tall herbaceous)	PC3 (shrubiness)
Eigen Value	2.46	1.15	1.00
Variance explained (%)	49.11	22.95	20.05
Eigenvector for:			
% unvegetated	**+0.57**	-0.01	-0.38
% short herbaceous	**-0.56**	**-0.42**	+0.11
% tall herbaceous	0.14	**+0.89**	+0.16
% shrub	+0.24-	-0.09	**+0.89**
% tree	**+0.53**	-0.15	+0.15

3 loaded positively on shrubs and negatively on bare ground, so I refer to it as "shrubiness".

Land cover

Land cover variables were proportions of developed, forested, wetland or agricultural cover types in a zone extending 0.5, 1 or 3 km from the boundaries of the waterbody. As with other vegetation zones, I calculated correlation coefficients between the estimated mean density of geese and the proportional representation of each land cover type (see Table 2). None of the correlation coefficients was > 0.40.

Principle components analysis reduced the four land cover classes to three linear combinations, each with an Eigen Value >0.9, that (by definition) explained all of the variance in the data set (Table 5). Thus, little variable reduction was achieved by use of this technique and I used the more easily interpretable percent land cover types.

Multivariate Analysis

I combined the six PC's of shoreline and buffer vegetation described above, plus escape angle and percentage of each land cover type into a mixed stepwise multiple regression to determine which variables explained goose density when simultaneously holding other variables constant. I did this separately using the GIS data from 0.5, 1 and 3 km, respectively, to determine which of these non-mutually exclusive data sets explained the biggest percentage of the variation in goose densities.

Log-transformation could not normalize the distribution of goose densities because of the disproportionate number of waterbodies with zero geese. Therefore, I analyzed the data in two ways. In the first case I considered the untransformed data

Table 5. Eigen values and Eigenvectors for principle components of surrounding land cover.

Land cover	PC1	PC2	PC3
0.5 km:			
Eigen Value	1.75	1.14	1.09
Variance explained (%)	43.62	28.55	27.45
Eigenvector for:			
% developed	**-0.73**	-0.25	-0.04
% forested	+0.61	-0.27	**-0.48**
% wetland	+0.00	**+0.93**	-0.11
% agriculture	+0.31	-0.04	**+0.87**
1 km:			
Eigen Value	1.79	1.24	0.96
Variance explained (%)	44.86	31.11	24.04
Eigenvector for:			
% developed	**-0.69**	-0.34	-0.03
% forested	**+0.59**	-0.16	**-0.60**
% wetland	-0.04	**+0.89**	+0.10
% agriculture	**+0.42**	-0.25	**+0.79**
3 km:			
Eigen Value	1.60	1.48	0.92
Variance explained (%)	39.89	37.00	23.11
Eigenvector for:			
% developed	-0.15	**-0.81**	0.00
% forested	**+0.66**	+0.25	**-0.48**
% wetland	**-0.60**	**+0.53**	+0.09
% agriculture	**+0.42**	+0.09	**+0.88**

including the zero values, with the understanding that I was violating one of the assumptions of the statistical technique. Alternately, I omitted all ponds without geese and analyzed just that subset at which geese were seen at least once. It should be noted that in both cases my sample size was smaller than is commonly recommended for a multivariate analysis with 12 variables, so results of this initial model should be regarded with caution.

For all waterbodies, the version of the model with the 3 km land cover data was best. The first variable entered and retained was the percentage of surrounding agricultural land cover, followed by shoreline PC1 (woodsiness), buffer PC1 (open woodsiness), shoreline PC 3 (tallness of herbaceous vegetation), shoreline slope and percent of surrounding forested land cover (Table 6a). Only the shoreline PC's explained a significant amount of variation by themselves, but together these variables explained 33% (r^2 adjusted for multiple variables) of the variation in goose density.

When considering only those ponds with geese, the model explained more of the variation in densities, and the 0.5 km surrounding land cover data outperformed the 3 km data (Table 6b). The first variable entered was shoreline PC1 (woodsiness), followed by shoreline PC2 (bareness), surrounding wetland land cover, and buffer PC's 2 (tallness of herbaceous vegetation), 1 (open woodsiness) and 3 (shrubiness). Together these variables explained 50% (adjusted r^2) of the variation in goose densities among the waterbodies that had geese.

Table 6. Results of mixed stepwise multiple regression to evaluate relationship between habitat variables and number of geese for a) all waterbodies, and b) only those waterbodies with geese present.

a) all waterbodies[1]	Cumulative r^2	F	P
3 km % agriculture	0.26	6.87	0.01
Shoreline PC1 (woodsiness)	0.30	11.40	0.002
Shoreline PC3 (herb tallness)	0.36	5.30	0.03
Slope steepness	0.38	1.84	0.18
3 km % forested	0.41	1.70	0.20

[1]Variables listed in order entered and retained in model

b) goose present ponds[1]	Cumulative r^2	F	P
Shoreline PC1 (woodsiness)	0.14	1.44	0.24
Shoreline PC2 (bareness)	0.25	18.06	0.0003
0.5 km % wetland	0.31	12.75	0.002
Buffer PC2 (herb tallness)	0.46	12.33	0.002
Buffer PC1 (open woodsiness)	0.55	7.33	0.01
Buffer PC3 (shrubiness)	0.61	3.39	0.08

[1]Variables listed in order entered and retained in model

Goose absence

Geese were absent from 17 (31%) of 55 waterbodies that were visited adequately (5 times over 6 months). To learn more about what made a waterbody unattractive to geese I compared goose-absent and goose-present waterbodies in terms of each of the measured variables (Table 7). Making such a large number of comparisons is not an ideal method of analyzing these results, because 1-in-20 differences are expected to be significant due only to chance sampling events. In addition, some of the independent variables were not normally distributed, making the *P*-values from a *t*-test suspect. However, as a first attempt to determine which variables are worth including in a multivariate analysis, this method is appropriate, with the statistical results being used only as a way of identifying variables that might affect goose presence.

Where geese were absent there was less short grass on the shoreline and in the buffer zone, more trees on the shoreline, and more bare ground in the buffer zone. This is reflected in the higher principle component scores for buffer zone PC1, which indicates an abundance of trees and bare ground (such as pine forest with pine straw underneath or heavily used park-like deciduous stands). In addition, goose-absent ponds had notably higher shoreline PC3 scores (indicating more tall herbaceous vegetation and less short grass), and a higher escape angle (as the result of more and/or closer and/or taller trees). Means for all other variables were similar or variance was so high as to make interpretation difficult (e.g. floating and emergent vegetation; Table 7).

I used logistic regression to examine whether different combination of these potential explanatory variables could explain presence or absence of geese when other variables were considered simultaneously. First I tried the combinations of variables

Table 7. Mean ± SD of each variable and principle component for goose-absent and goose-present waterbodies.

Variable	Goose-absent	Goose-present	*t*	P
Size (m^2)	16722 ± 20041 (17)	38700 ± 56751 (37)	2.39	0.13
Number of islands	0.2 ± 0.4 (13)	0.4 ± 1.5 (29)	1.59	0.54
Escape angle (degrees)	24.9 ± 16.0 (16)	13.2 ± 9.3 (34)	10.62	0.002
Turbidity	0.6 ± 1.1 (13)	0.7 ± 0.9 (28)	0.02	0.89
pH	7.4 ± 0.8 (13)	7.8 ± 1.1 (26)	1.13	0.29
Dissolved Oxygen	6.2 ± 2.7 (13)	6.3 ± 2.0 (26)	0.01	0.91
% emergent veg.	7.7 ± 14.2 (13)	2.5 ± 5.7 (32)	3.12	0.08
% submerged veg.	18.2 ± 27.8 (13)	8.7 ± 24.0 (32)	1.34	0.25
% floating veg.	8.46 ± 27.6 (13)	0.2 ± 0.9 (32)	3.00	0.09
Shoreline				
Steepness angle	17.4 ± 5.8 (16)	19.3 ± 8.4 (34)	0.62	0.44
% unvegetated	25.0 ± 33.8 (16)	18.2 ± 26.3 (36)	0.62	0.44
% short herbaceous	8.1 ± 15.9 (16)	25.8 ± 27.3 (36)	5.77	0.02
% tall herbaceous	34.1 ± 37.6 (16)	27.1 ± 26.5 (36)	0.59	0.45
% shrub	32.8 ± 34.4 (16)	23.9 ± 30.4 (36)	0.87	0.36
% overhang. shrub	29.1 ± 33.8 (16)	25.6 ± 31.4 (36)	0.62	0.44
% tree	51.6 ± 34.4 (16)	23.3 ± 34.0 (36)	7.59	0.008
PC1 (woodsiness)	0.49 ± 1.69 (16)	-0.22 ± 1.59 (36)	2.08	0.16
PC2 (bareness)	0.24 ± 1.29 (16)	-0.11 ± 1.07 (36)	1.02	0.32
PC3 (tallness)	0.50 ± 1.07 (16)	-0.22 ± 1.03 (36)	5.25	0.03
Buffer zone				
% unvegetated	71.3 ± 16.3 (16)	50.1 ± 31.4 (36)	6.41	0.015
% short herbaceous	19.1 ± 16.7 (16)	41.1 ± 31.9 (36)	6.79	0.01
% tall herbaceous	3.4 ± 13.8 (16)	3.2 ± 15.1 (36)	0.003	0.96
% shrub	6.3 ± 4.4 (16)	4.4 ± 4.8 (36)	1.37	0.25
% tree	50.3 ± 31.0 (16)	41.0 ± 31.5 (36)	0.98	0.32
PC1 (woodsiness)	0.74 ± 1.08 (16)	-0.33 ± 1.65 (36)	5.63	0.02
PC2 (tallness)	0.17 ± 1.02 (16)	-0.07 ± 1.10 (36)	0.56	0.46
PC3 (shrubiness)	0.01 ± 1.09 (16)	-0.003 ± 0.98 (36)	0.001	0.98
Surround. land cover				
0.5 km % developed	0.26 ± 0.23 (17)	0.19 ± 0.24 (38)	0.97	0.33
0.5 km % forested	0.53 ± 0.24 (17)	0.54 ± 0.19 (38)	0.03	0.87
0.5 km % wetland	0.11 ± 0.12 (17)	0.13 ± 0.14 (38)	0.31	0.58
0.5 km % agriculture	0.15 ± 0.24 (17)	0.20 ± 0.22 (38)	0.58	0.45
1 km % developed	0.28 ± 0.24 (17)	0.19 ± 0.22 (38)	1.79	0.19

Table 7, Continued. Mean ± SD of each variable and principle component for goose-absent and goose-present waterbodies.

Variable	Goose-absent	Goose-present	*t*	P
1 km % forested	0.48 ± 0.21 (17)	0.53 ± 0.17 (38)	0.93	0.34
1 km % wetland	0.12 ± 0.13 (17)	0.14 ± 1.6 (38)	0.22	0.64
1 km % agriculture	0.12 ± 0.12 (17)	0.14 ± 0.12 (38)	0.19	0.66
3 km % developed	0.18 ± 0.18 (17)	0.21 ± 0.17 (38)	0.39	0.53
3 km % forested	0.48 ± 0.15 (17)	0.50 ± 0.17 (38)	0.15	0.70
3 km % wetland	0.24 ± 0.20 (17)	0.17 ± 0.18 (38)	1.43	0.24
3 km % agriculture	0.10 ± 0.07 (17)	0.12 ± 0.07 (38)	0.46	0.50

[1]Sample size shown in parenthesis

indicated by the stepwise linear regression described in the first section, which explained significant portions of the variation in numbers of geese on all waterbodies or just those with geese present. Neither of these models was significant as a logistic regression, nor were any of the component variables.

Next I tried all of the variables (listed in Table 7), that differed between goose-present and goose-absent waterbodies. There was some overlap of variables because the principle components were based on the percent vegetative cover data, so I used two alternate versions. Including escape angle, shoreline short herbaceous vegetation, and buffer zone bare, short and tall vegetation, along with all two way interactions, produced a significant model (df = 14, X^2 = 35.26, P = 0.0013). When each non-significant interaction was removed sequentially, the model remained significant (df = 5, X^2 = 16.7, P = 0.005) and only escape angle remained as a significant variable by itself (df = 1, X^2 = 4.4, P = 0.36, Table 8a).

In the alternate model, using shoreline PC3 and buffer PC1 instead of the individual vegetation components, the overall model was again significant (df = 7, X^2 = 19.3, P = 0.007). Sequentially removing the non-significant interactions resulted in a significant overall model (df = 3, X^2 = 14.3, P = 0.0025), and escape angle was the only individual variable that was even close to significant (Table 8b).

Discussion

There was extensive variation in the presence of geese and the intensity of goose use across the waterbodies sampled monthly for approximately 6 months. Examining only those ponds at which I had ever detected geese, I could explain 50% of the variation

Table 8. Logistic regression model results for a) variables including percentage cover of each vegetation type, and b) with relevant principle components substituted for vegetation cover variables.

a) % cover	X^2	P
Escape angle	4.40	0.04
Shoreline % shrub	0.45	0.50
Buffer % short herb	1.22	0.27
Buffer % tall herb	0.44	0.51
Buffer % unvegetated	0.51	0.48

b) PC's	X^2	P
Escape angle	3.49	0.06
Shoreline PC3 (tall herb)	1.73	0.19
Buffer PC1 (open woodsiness)	2.40	0.12

in the mean goose density in a stepwise regression procedure with variables that described the amount of trees and bare ground within 3 m of the shoreline, amount of tall herbaceous vegetation, shrubs, and forest in the 3-30 m surrounding buffer zone, and amount of wetland in the surrounding 0.5 km. Given the numerous possibilities for unexplained variation due to disturbance, sampling events, etc., explaining half of the variation in goose use is striking. This suggests that ponds away from other wetlands and surrounded by trees and other tall vegetation experience reduced goose use.

These data support much of what is known about resident Canada goose ecology; geese are grazers and prefer a diet of succulent green herbaceous plant material. Manicured lawns, golf courses, and other maintained grassy areas provide a desirable source of food for resident Canada geese. Tall vegetation provides a visual screen that impairs a goose's ability to view its surroundings. This is important because vigilance is a goose's primary protection against predation. Isolated ponds may not be as attractive to Canada geese because they may not provide the full spectrum of daily nutritional and habitat requirements of Canada geese. Ponds that occur as component pieces of larger complexes have a higher probability of providing all goose life cycle requirements in a smaller area than isolated waterbodies. Therefore they are more appealing to resident Canada geese.

When broadening the analysis to include all waterbodies, the model including the land cover data for the surrounding 3 km explained more of the variation than did that including the 0.5 km land cover data. Shoreline trees and amount of unvegetated cover (often bare forest understory) in the buffer zone continued to be important, but the amount of agricultural and forested land in the surrounding area were also included (both were positively related to goose use), as was steepness of the shoreline. This analysis is less reliable than for the goose-present waterbodies, because it explains less of the variation (33% vs. 50%), and also because the assumption of normality was violated by including the 17 waterbodies with goose densities of zero. Together these analyses confirm the conventional wisdom that ponds surrounded by lawns attract more geese, and they suggest that no single factor stands out as a "magic bullet" that can explain goose densities.

In contrast to other habitat use studies of Canada geese (Harvey et. al. 1988 and Cook et. al. 1998), which were conducted during the winter months, my research focused on the spring and summer period. However, elements of my findings are consistent with their research. Canada geese, at various times, readily use perennial herbaceous plantings such as turf grass and pastures. My research suggests that if this habitat type is a component of the local landscape or if conditions that seem to promote the occurrence of this habitat type are present (i.e. absence of forest) than it can be expected that goose use of an area will be higher. In addition, both earlier researchers found geese using a variety of agriculture fields. I too found the presence of agriculture fields on the local landscape to be a factor that contributed to goose habitat use.

From a management perspective, identifying physical factors of waterbodies that reduce goose use to zero would be very valuable, because it would allow the construction of ponds that require no further goose management (i.e. hazing or euthanasia). At a minimum, identifying habitat attributes that discourage resident Canada goose use would make habitat modification of existing waterbodies a viable management tool, particularly when included in an integrated (i.e. repellents and hazing techniques) management approach.

I attempted to identify such factors using logistic regression with waterbodies classified as goose-present or goose-absent. Numerous combinations of factors produced models that explained significant portions of the variation, but one factor stood out as being important in all cases - escape angle. Escape angle is a measurement of the average minimum flight path a goose could use to leave a waterbody, so it is an indicator of how many tall trees are near the waterbody. It is interesting that escape angle was not an explanatory factor in models of goose density, but was very important in explaining why some ponds had no geese.

This suggests that resident Canada geese select and use warm season habitats in a methodical fashion. First, geese generally avoid waterbodies that are "closed in" or surrounded by tall trees. This was substantiated by the absence of geese on ponds that had a severe flight angle. Second, if the escape angle of a waterbody is gradual enough to attract geese, a second tier of attributes becomes important in determining the density of geese that will use the waterbody. Attributes on the lower end of the scale of goose density include isolation from other ponds, and woodsiness of surrounding edges, which limit herbaceous vegetation geese require for foraging. Attributes on the upper end of the density scale include ponds occurring as a wetland complex and increased "openness" in the immediate buffers and on the local landscape.

Conover and Kania (1991) used a series of clinometer measurements taken from the center of feeding sites (i.e. lawns). They describe their land-based measurement as a flight clearance angle. When looking only at the angle a goose would have to fly to escape a land-based feeding site, they found significant differences between goose "nuisance sites" and random sites. The importance of escape angle in my study concurs with these findings.

Although the presence of trees at various distances from waterbodies, and unvegetated understory (which was often indicative of deep shade or leaf litter) were important predictors of goose density, the height of these trees or their distance from the pond may not have been as important in predicting goose density. Instead, the fact that these trees harbor predators or, more likely, prevent the growth of grass that geese can eat, is probably how they exerted their negative influence on goose density. But if trees are sufficiently tall and close to a pond, they may prevent use altogether, because geese cannot easily clear them if they make a hasty takeoff.

Conover and Kania (1991) based their work on sites that had been declared nuisance sites due to large numbers of geese reported by landowners. In contrast to my research, their sites were upland feeding sites. They found common habitat attributes among their sites. All sites were described as "lawns". Specific sites on lawns used by geese offered the most "openness" and provided the lowest angle for flighted departure. Although the studies were somewhat dissimilar in design, my data also supports the idea that resident geese prefer habitats which incorporate, in relatively close proximity, herbaceous food sources, ponds with a sufficiently low perimeter to promote ingress or egress by flight, and habitats which are open so that geese can see potential predators.

This study makes several contributions to our understanding of what determines resident goose use of waterbodies. First, I have established that there are a substantial number of waterbodies that geese will not use during the warm seasons of the year. The main focus of the study was whether the pattern of use was predictable, and I found that it was. Not surprisingly, there is no single variable that predicts goose use, but I was able to find combinations of variables that explained a strikingly large proportion of the variation in intensity of use on those ponds that attracted geese.

My research suggests that wildlife biologists can make modifications in the design of waterbodies to limit resident Canada goose use during the non-winter periods. Based on my research, if the objective is to have no-to-as-few geese as possible, waterbodies need a high perimeter of trees. Behind this perimeter, the buffer out to 30 m should be primarily wooded or shrubby. In the context of minimizing Canada goose use, ponds should not be built close to or adjacent to other wetlands. Conversely, by knowing which habitat attributes to avoid, wildlife managers can use this information to develop and improve resident goose habitat in areas where they are not in conflict with humans.

It has been suggested that people are receptive to resident Canada geese when they occur in low numbers (Conover and Kania 1991). Resident Canada geese at relatively low population densities or occurring at sites where they can be tolerated are an asset. It is not until numbers swell that complaints are registered. It is possible that this research, combined with further work examining resident Canada geese habitat use, could lead to a body of information that helps empower wildlife specialists to manage this wildlife resource in the best interests of the public.

CHAPTER II

MALLARDS

In addition to Canada geese, mallards (*Anas platyrhynchos*) are often observed as residents on ponds and lakes in eastern Virginia. Throughout the continent mallards are the most abundant duck. Population estimates place the continental population at over 9 million (USFWS 1998). Generally, mallards are a migratory species (Bellrose 1976). Mallards breed in northern latitudes and winter in southern latitudes. Historically, mallards were confined to the western two thirds of the North American continent. In the east, the black duck (*Anas rubripes*), an extremely close relative of the mallard, was the predominant duck. In the last century, a gradual eastward movement of the breeding range of mallards has occurred (Heusmann 1974). In the Atlantic flyway mallards now outnumber black ducks.

Like Canada geese, mallards have proven adaptable and are now common nesters in areas such as Virginia, which are far removed from traditional breeding grounds. The origin of local nesting mallards is not as well documented but is often attributed to several sources including state-sponsored mallard propagation and private release programs designed to increase duck populations for hunters.

In the Chesapeake Bay region, Maryland maintained a mallard release program for many years, as did Pennsylvania. Mallards have long been privately propagated for sale as pets and as ornamental additions to ponds and lakes. Progeny of the birds often become established as feral populations. Released mallards, perhaps because they do not learn migration routes, become year-round residents. Virginia's resident mallard population has increased to the point that the USDA-APHIS-Wildlife Services recorded 140 complaints of duck damage from October 1992 through September 1997 (Lowney and Dewey 1997). This population is augmented in the winter by migratory stocks of mallards.

Ducks are generally divided into two groups: dabblers and divers. Dabblers tip up to feed in shallow areas. Dabblers are adept at walking on land and, when taking flight, spring straight up from the surface. Divers completely submerge to feed in deeper waters. Divers' legs and feet are set further to the rear of their bodies to aid with under-water propulsion. When taking flight, divers appear to run across the surface of the water before beginning a gradual ascent, just as Canada geese do.

Mallards are considered dabbling ducks. They tip up to feed and generally forage in shallow areas. Mallards are relatively large ducks, averaging 1.25 kg (Bellrose 1976). The species is sexually dimorphic. When fully plumed, males have an iridescent green head separated from the body by a white neck ring. The breast is chestnut, the sides grey and rump black. Females are drab brown except for a purple and white wing "speculum".

Females are sexually mature in their first breeding season. Mallards are ground nesters but will also use a variety of man-made structures for nesting. Nests are usually found adjacent to or near water. Average clutch size is nine and the incubation period is 28 days. Young are precocious and leave the nest soon after hatching (Bellrose 1976).

Mallards are primarily seed eaters as opposed to Canada geese, which primarily graze succulent green vegetation. Seeds consumed by mallards come from a variety of wetland plants including emergents such as smartweeds and aquatic millets as well as submerged plants such as widgeon grass (*Ruppia maritima*). Mallards will also readily consume cereal grains and have been observed consuming animal matter such as small minnows, mussels, and clams.

Feral mallard populations have increased in some areas to the point where they come in conflict with humans. Problems similar to those described between resident Canada geese and humans have been documented. These problems include fecal droppings, aircraft strikes, disease threats to wildlife and humans and excessive browsing. Locally, resident mallards have been involved in disease outbreaks involving duck viral enteritis, a highly virulent waterfowl disease.

During preliminary phases of this project I observed mallards in close association with resident Canada geese on many waterbodies in the study area. These associations suggested that recording mallard numbers would be useful to determine if patterns of habitat predictability exist with resident mallards in eastern Virginia. Although ancillary to the primary objective, my goal was to determine if habitat use by resident mallards is predictable and to detect and contrast differences between habitat use between resident mallards and resident Canada geese.

Methods

In general the methods used for gathering mallard numbers and habitat data were identical to those used for Canada geese (Chapter 1). Thirty-three waterbodies in eastern Virginia were visited a minimum of six times from 15 March to 15 September to census mallards. These were the same sites used for Canada goose census data and were chosen in the manner described in "Methods" of Chapter 1. A modified point count was used during each of the six visits. Observations lasted ten minutes each. Sites was visited once more to measure habitat variables. Vegetative cover in the area immediately surrounding the pond was estimated as was the buffer area extending out to 30 m. Flight angle measurements were obtained at each site. The slopes of the pond banks above and below the water were recorded. GIS data for landcover in a buffer extending to 3 km was also obtained.

Results

Occurrence of mallards by season

Mallards were observed at least once on 27 (53%) of the 51 waterbodies sampled at least five times. During Chesperiod of 15 March through 15 June a mean of 1.7 ± 5.2 mallards were observed on 19 (36%) of the 53 waterbodies that were censused twice. None were detected on the two additional waterbodies that were visited only once. During the period 16 June through 15 July a mean of 4.9 ± 11.1 ducks were observed on 17 (36%) of the 47 waterbodies censused twice. They were not observed on the three waterbodies censused only once. During the period 16 July through 15 September a mean of 3.4 ± 6.8 mallards were observed on 19 (37%) of 51 waterbodies censused twice. In addition, they were found on one of the four waterbodies censused only once.

Waterbody Characteristics and Intensity of Mallard Use

Shoreline and Waterbody Characteristics

To determine whether intensity of duck use correlated highly with particular water quality and shoreline variables I calculated correlation coefficients between the estimated mean density of mallards and the proportional representation of each vegetation type, as well as the average steepness of the bank (calculated as mean of above and below waterline slopes) and other characteristics such as water quality measurements and density of geese (Table 9). The density of ducks was not highly correlated (correlation coefficient < 0.40) with any of these variables. It should be noted that because many of these variables are interrelated, a univariate analysis such as this may be misleading.

To reduce the number of variables in preparation for a multivariate analysis I used principle components analysis on the highly interrelated measurements of vegetation cover for the buffer zone and shoreline (see Chapter 1 for description of this analysis). None of the three shoreline vegetation PC's were highly correlated with mallard density (Table 9).

Buffer vegetation

Buffer vegetation was estimated for a band from 3-30m out from the shoreline. As with shoreline vegetation, I calculated correlation coefficients between the estimated mean density of mallards and the proportional representation of each vegetation type in the buffer, as well as the average escape angle (calculated as mean of the six measurements around the pond or lake). The density of mallards was not highly correlated with any buffer variables or escape angle (all coefficients < 0.40, Table 9). None of the three buffer zone vegetation PC's was highly correlated either.

Land cover

Land cover variables were proportions of developed, forested, wetland or agricultural cover types in a zone extending 0.5, 1 or 3 km from the boundaries of the

Table 9. Correlation coefficients between mallard density and waterbody characteristics, shoreline vegetation variables, buffer zone vegetation variables, vegetation principle components, and surrounding land cover variables.

Variable	Coefficient
Density of geese	-0.18
Number of islands	+0.10
Escape angle	-0.02
Turbidity	-0.01
pH	-0.09
Dissolved Oxygen	-0.17
% emergent vegetation	-0.07
% submerged aquatic vegetation	-0.13
% floating vegetation	-0.05
Shoreline	
Steepness of slope (angle)	-0.06
% unvegetated	+ 0.36
% short grass	- 0.10
% shrubs	+ 0.14
% tall herbaceous	- 0.03
% overhanging shrubs	+ 0.07
% trees	- 0.04
PC1 (woodsiness)	+0.12
PC2 (bareness)	+ 0.23
PC3 (tallness)	-0.02
Buffer zone	
% unvegetated	+ 0.08
% short grass	- 0.02
% shrubs	- 0.07
% tall herbaceous	- 0.07
PC1 (woodsiness)	-0.03
PC2 (tallness)	-0.03
PC3 (shrubiness)	-0.14
Surrounding land cover	
0.5 km % developed	+ 0.34
0.5 km % forested	- 0.15
0.5 km % wetland	- 0.15
0.5 km % agriculture	- 0.19

Table 9, Continued. Correlation coefficients between mallard density and waterbody characteristics, shoreline vegetation variables, buffer zone vegetation variables, vegetation principle components, and surrounding land cover variables.

Variable	Coefficient
1km % developed	+ 0.38
1km % forested	- 0.20
1km % wetland	-0.13
1km % agriculture	-0.25
3km % developed	+0.09
3km % forested	-0.07
3km % wetland	-0.05
3km % agriculture	+0.08

water body. As with other vegetation zones, I calculated correlation coefficients between the estimated mean density of mallards and the proportional representation of each land cover type (see Table 9). None of the correlation coefficients was > 0.40. Principle components analysis did not effectively reduce variable numbers, so was not used.

Multivariate Analysis

The individual correlation analysis described above did not point to any factors that, by themselves, were highly correlated with mallard densities. In an attempt to determine whether the same factors that explained variation in goose numbers might also explain mallard densities, I combined the six PC's of shoreline and buffer vegetation described above, plus escape angle and percentage of each land cover type into a mixed stepwise multiple regression. I did this separately using the GIS data from 0.5, 1 and 3 km, respectively, to determine which of these non-mutually exclusive data sets explained the biggest percentage of the variation in mallard densities. Log-transformation could not normalize the distribution of mallard densities because of the disproportionate number of waterbodies with zero mallards. Therefore, I analyzed the data in two ways. In the first case I considered the untransformed data including the zero values, with the understanding that I was violating one of the assumptions of the statistical technique. Alternately, I omitted all ponds without mallards and analyzed just that subset at which mallards were seen at least once. It should be noted that in both cases my sample size was smaller than is commonly recommended for a multivariate analysis with 11 variables, so results of this initial model should be regarded with caution.

For all waterbodies, the version of the model with the 1 km land cover data was best (Table 10a). The first variable entered and retained was the percentage of surrounding developed land cover, followed by shoreline PC2 (tallness of herbaceous vegetation). No other variables led the model to explain more variation. Only the percentage of developed land explained a significant amount of variation by itself (15%, $P = 0.008$), and together these two variables explained only 16% of the variation in mallard density.

The results were almost identical when considering only those ponds with mallards (Table 10b). The first variable entered and retained was the percentage of surrounding developed land cover, followed by shoreline PC2 (tallness of herbaceous vegetation). No other variables led the model to explain more variation. Neither the percentage of developed land nor shoreline PC2 explained a significant amount of variation, and together these two variables explained only 16% of the variation in mallard density.

Mallard absence

Ducks were absent from 20 (39%) of 51 waterbodies that were visited adequately (five times over six months). To learn more about what made a waterbody unattractive to ducks I compared duck-absent and duck-present waterbodies in terms of each of the measured variables (Table 11). Making such a large number of comparisons is not an ideal method of analyzing these results, because 1-in-20 differences are expected to be significant due only to chance sampling events. In addition, some of the independent variables were not normally distributed, making the *P*-values from a *t*-test suspect.

Table 10. Results of mixed stepwise multiple regression to evaluate relationship between habitat variables and number of mallards for a) all waterbodies, and b) only those waterbodies with mallards present.

a) all waterbodies[1]	Cumulative r^2	F	P
1 km % development	0.15	7.60	0.009
Shoreline PC2 (bareness)	0.21	2.91	0.10

[1]Variables listed in order entered and retained in model

b) mallard-present ponds[1]	Cumulative r^2	F	P
1 km % development	0.12	3.40	0.08
Shoreline PC2 (bareness)	0.23	3.18	0.09

[1]Variables listed in order entered and retained in model

Table 11. Mean ± SD of each variable and principle component for mallard-absent and mallard-present waterbodies[1].

Variable	**Mallard-absent**	**Mallard-present**	***t***	**P**
Size (m^2)	34951 ± 69187 (20)	29790 ± 35258 (30)	0.34	0.73
Number of islands	0.2 ± 0.4 (16)	0.5 ± 1.6 (24)	0.64	0.52
Escape angle (degrees)	17.7 ± 12.2 (19)	15.3 ± 12.2 (28)	0.65	0.51
Turbidity	0.6 ± 0.7 (16)	0.7 ± 1.1 (23)	0.48	0.63
pH	7.6 ± 1.1 (15)	7.6 ± 0.9 (22)	0.17	0.87
Dissolved Oxygen	6.8 ± 2.3 (16)	5.9 ± 2.1 (22)	1.24	0.22
% emergent veg.	3.7 ± 5.2 (15)	4.6 ± 11.4 (26)	0.30	0.76
% submerged veg.	23.1 ± 38.4 (16)	5.9 ± 10.6 (26)	2.16	0.03
% floating veg.	0.33 ± 1.3 (15)	4.2 ± 19.6 (26)	0.76	0.44
Geese/m^2	6.5 ± 10.2 (18)	8.6 ± 11.2 (29)	0.65	0.52
Shoreline				
Steepness angle	17.5 ± 5.2 (18)	19.5 ± 9.3 (28)	0.84	0.40
% unvegetated	17.6 ± 24.9 (19)	21.2 ± 31.9 (29)	0.41	0.68
% short herbaceous	20.5 ± 24.7 (19)	21.6 ± 27.6 (29)	0.13	0.90
% tall herbaceous	32.9 ± 33.1 (19)	25.3 ± 28.8 (29)	0.84	0.41
% shrub	28.2 ± 31.7 (19)	24.1 ± 30.6 (29)	0.44	0.66
% overhang. shrub	25.6 ± 32.9 (19)	25.9 ± 30.3 (29)	0.02	0.98
% tree	40.3 ± 39.5 (19)	27.6 ± 32.3 (29)	1.20	0.23
PC1 (woodsiness)	0.05 ± 1.77 (19)	-0.08 ± 1.53 (29)	0.26	0.79
PC2 (bareness)	-0.07 ± 1.00 (19)	0.05 ± 1.22 (29)	0.34	0.74
PC3 (tallness)	0.11 ± 1.12 (19)	-0.14 ± 1.10 (29)	0.76	0.45
Buffer zone				
% unvegetated	53.2 ± 30.0 (19)	56.2 ± 28.4 (29)	0.36	0.72
% short herbaceous	32.6 ± 31.9 (19)	38.6 ± 29.0 (29)	0.67	0.50
% tall herbaceous	7.6 ± 23.6 (19)	0.5 ± 2.8 (29)	1.60	0.11
% shrub	6.3 ± 5.0 (19)	4.0 ± 4.5 (29)	1.70	0.10
% tree	40.3 ± 39.5 (19)	27.6 ± 32.3 (29)	1.06	0.30
PC1 (woodsiness)	0.03 ± 1.68 (19)	-0.23 ± 1.49 (29)	0.55	0.58
PC2 (tallness)	0.26 ± 1.71 (19)	-0.18 ± 0.34 (29)	1.33	0.19
PC3 (shrubiness)	0.33 ± 0.80 (19)	-0.22 ± 0.92 (29)	2.13	0.04

Table 11, Continued. Mean ± SD of each variable and principle component for mallard-absent and mallard-present waterbodies[1].

Variable	**Mallard-absent**	**Mallard-present**	*t*	**P**
Surrounding land cover				
0.5 km % developed	0.11 ± 0.12 (20)	0.30 ± 0.27 (31)	2.97	0.005
0.5 km % forested	0.59 ± 0.16 (20)	0.47 ± 0.20 (31)	2.20	0.031
0.5 km % wetland	0.12 ± 0.13 (20)	0.12 ± 0.13 (31)	0.13	0.89
0.5 km % agriculture	0.07 ± 0.25 (20)	0.14 ± 0.20 (31)	1.97	0.054
1 km % developed	0.14 ± 0.13 (20)	0.30 ± 0.25 (31)	2.73	0.009
1 km % forested	0.55 ± 0.14 (20)	0.47 ± 0.19 (31)	1.50	0.14
1 km % wetland	0.13 ± 0.16 (20)	0.12 ± 0.15 (31)	0.26	0.80
1 km % agriculture	0.19 ± 0.11 (20)	0.11 ± 0.10 (31)	2.40	0.02
3 km % developed	0.22 ± 0.19 (20)	0.18 ± 0.17 (31)	0.69	0.50
3 km % forested	0.48 ± 0.18 (20)	0.51 ± 0.16 (31)	0.75	0.46
3 km % wetland	0.20 ± 0.20 (20)	0.18 ± 0.18 (31)	0.45	0.65
3 km % agriculture	0.10 ± 0.08 (20)	0.12 ± 0.07 (31)	1.07	0.29

[1]Sample size shown in parenthesis

However, as a first attempt to determine which variables are worth including in a multivariate analysis this method is appropriate, with the statistical results being used only as a way of identifying variables that might affect goose presence.

Where mallards were absent there was more submerged aquatic vegetation. In the 30 m buffer zone there was a higher value of PC3 (shrubiness) in ponds that never had mallards. In addition, mallard-absent ponds had less development and more trees around them in the 0.5 km circle, less development and more agriculture in the 1 km circle. Means for all other variables were similar or variance was so high as to make interpretation difficult (see Table 11).

I used logistic regression to examine whether different combination of these potential explanatory variables could explain presence or absence of ducks when other variables were considered simultaneously. Including submerged aquatic vegetation, 1 km percentage agriculture and development, along with all two-way interactions, produced a significant model (Table 12; df = 6, $X^2 = 16.61$, $P = 0.011$), but no single factor explained a significant portion of the variance. Removing each interaction sequentially led to a highly significant whole model, but still no significant individual factors.

Discussion

Like geese, mallards were absent from some ponds, and occurred at others with varying densities. However, the factors that predicted goose densities, and to some extent goose presence and absence, had little or no predictive power for mallards. This is not unexpected, because these factors had to do with escape angle, or ease of takeoff, something that probably has less effect on mallards than geese. Mallards can rise almost

Table 12. Logistic regression model results for mallard duck presence/absence and relevant independent variables.

Variable	X^2	P
Submerged aquatic vegetation	2.86	0.09
1 km % development	1.53	0.22
1 km % agriculture	2.19	0.14

vertically from a pond and do not need to make long, laborious takeoffs over the shoreline and buffer zone trees.

Several factors appeared to differ between ponds that never had mallards and those that did. However, when these factors were combined into a logistic regression, none explained a significant portion of the variation (although the whole model did). Because the factor coming closest to predicting absence of mallards was a large amount of submerged aquatic vegetation, something that should be attractive to ducks, this analysis does not shed much light on what causes mallards to avoid particular ponds.

I suspect that differences in submerged aquatic vegetation and some of the other factors that appeared to differ between mallard-present and mallard-absent ponds may have been due simply to chance variation, as I made 43 comparisons. I conclude that mallard density and occurrence is not predictable with the variables I measured. This may be because my variables were chosen based on suspected importance for geese, rather than mallards, so another set of independent variables might predict mallards better. Alternatively, mallards, being smaller, more agile, less likely to travel in large flocks, and generally being more adaptable in terms of diet and nest site, may be limited by fewer variables in a habitat. Fortunately, few landowners are concerned with whether mallards are using their waterbodies, so there is no urgent need, at this time, for wildlife managers to figure out how to preclude duck use. In some ways, the failure of escape angle to predict mallard use supports my conclusion that its importance for geese is due to their take-off requirements.

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