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Effects of predator activity on the nesting of American Black Ducks and other birds on barrier islands in the mid-Atlantic coast

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EFFECTS OF PREDATOR ACTIVITY ON THE NESTING OF
AMERICAN BLACK DUCKS AND OTHER BIRDS ON
BARRIER ISLANDS IN THE MID-ATLANTIC COAST

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Dedication

For my mother and father, Catherine and Lee Arquilla, from 5:30 am hockey practices to my Master's defense, your belief, support, and encouragement have skated with me every inch of the ice. All my love.

And to the memory of Fr. P.J. Kelly (1926 – 2006). I can still hear us laughing and sharing stories on the jetty in Rossmore. Love you and miss you.

Do not stand at my grave and weep,

I am not there, I do not sleep.

I am a thousand winds that blow.

I am the diamond glint on snow.

I am the sunlight on ripened grain.

I am the gentle autumn rain.

When you wake in the morning hush,

I am the swift, uplifting rush

Of quiet birds in circling flight.

I am the soft starlight at night.

Do not stand at my grave and weep.

I am not there, I do not sleep

Mary Frye 1932

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Abstract

Landscape change throughout North America has resulted in heightened nest predator population and declining avian productivity. Essential to establishing effective management design is an understanding of differential predation pressure among avian groups as group specific responses to predation impact may exist.

The objective of this study was to examine the efficacy of predator trapping on the nest success and density of ground nesting avifauna in 2004-2005 in the Virginia Coast Reserve, specifically dabbling ducks, Canada Goose and Willet. Second, we determine the impact of predation on ground nesting birds by relating indices of predator abundance to nest density and nest success for island plots.

Overall Mayfield nest success for dabbling ducks was 54.4% (n = 12) in 2004 and 17.7% (n = 30) in 2005. Green Transformed nest success for dabbling ducks was 34.5% (n = 25) in 2004 and 23.0% (n = 42). For Canada goose, overall Mayfield nest success was 53.1 (n = 37) in 2004 and 47.7% (n = 39) in 2005. Overall Green Transformed nest success for Canada Goose was 59.5% (n = 57) in 2004 and 50.6% (n = 51) in 2005. Finally, overall Green Transformed nest success for Willet was 53.7% (n = 110) in 2004 and 46.0% (n = 118) in 2005.

Nest success estimates on island plots varied greatly. There was no difference in nest success between trapped and non-trapped islands for dabbling ducks ($P = 0.1990$), Canada Goose ($P = 0.4860$), Willet ($P = 0.4920$) and artificial nest success ($P = 0.4200$). Likewise, there was no difference in nest density between trapped and non-trapped islands for dabbling ducks ($P = 0.2408$), Canada Goose ($P = 0.2950$), and Willet ($P = 0.1381$). Several factors may explain this result including a lack of trapping efficacy, design flaws, low intensity of trapping, and differences in island habitat affecting avian nest site selection and sample size.

Nest success for both dabbling ducks ($P = 0.0225$) and Willets ($P < 0.0001$) was inversely related to predator activity, as measured by artificial nest success. In contrast, Canada Goose ($P = 0.6686$) showed no relationship between nest success and predator activity. For Canada Goose ($P = 0.0064$) and Willet ($P = 0.0029$), nest density decreased with increasing predator activity on island plots. Biased nest detection, philopatry to islands with reduced predation risk, and active selection for reduced predator environments may explain the higher nest density on islands with reduced predator activity.

On barrier islands in Virginia, dabbling duck nest densities are independent of predator activity ($P = 0.1981$). I hypothesize that, in this system, the availability of brood rearing habitat for ducks govern island selection above predation risk.

Introduction

Populations of American Black Duck (*Anas rubripes*) have declined since systematic surveys were initiated in 1955 (Heusmann and Sauer 2000, Conroy et al. 2002). American Black Ducks are a centerpiece species of concern in the North American Waterfowl Management Plan, with a joint venture designed to conduct research into the causes of the population decline (NAWMP 1986).

Most hypothesized causes for the population decline invoke a decrease in population production due to altered breeding habitat (Kaczynski and Chamberlain 1968, Denis et al. 1989, Diefenbach and Owen 1989, Dwyer and Baldassarre 1994), competition with Mallards (*Anas platyrhynchos*), whose breeding range is spreading eastward (Johnsgard 1967, Ankney et al. 1987, Conroy et al. 2002, Petrie et al. 2000), and hybridization with Mallards (Johnsgard 1967, Heusmann 1974, Johnsgard and Disilvestro 1976, Brodsky and Weatherhead 1984). However, at the local scale, the single factor most responsible for poor production is predation of nests (Stotts and Davis 1960, Coulter and Miller 1968, Krementz et al. 1991, Drever 2004). In this regard, American Black Ducks may be similar to mid-continent Mallards, where nest success, hen success, and brood survival are the three critical determinants of variation in population growth rates (Greenwood et al. 1987, Johnson et al. 1992, Hoekman et al. 2002).

With European colonization came accelerated landscape change and agricultural expansion. This has lead to an increase in mammal populations throughout North America (Whitaker and Hamilton 1998). Perhaps equally important, the change in the North American landscape has caused a change in mammal community composition with generalist predators replacing specialists (Johnson et al. 1989, Sargeant et al. 1993). Changes to habitat have resulted in a 15 to 20 fold increase in the continental raccoon (*Procyon lotor*) population since the 1930s

(Ray 2000). Land clearing and extirpation of wolves have led to a heightened abundance and range expansion of the red fox (*Vulpes vulpes*) (Ray 2000). These changes in predator abundance, composition and ranges have been accompanied by a decline in nest success for prairie nesting ducks (Cowardin et al. 1985, Greenwood 1986, Johnson et al. 1987, Sargeant et al. 1993, Beauchamp et al. 1996). Rimmer and Deblinger (1990) suggest that mammalian predation on island nesting avifauna causes declines in annual breeding success and may reduce the size of local breeding population.

Environmental factors shaping coastal systems can affect succession and population structure. Mid-Atlantic barrier islands have been subject to great rates of change due to the dynamic influence of abiotic factors such as wind, storm surge, and tide (Hayden et al. 1991). Together, the barrier islands and lagoon marsh system of Virginia's Eastern Shore provide important breeding and wintering habitat for many waterbirds (Wilke 2005). This coastal archipelago is among the least disturbed coastal ecosystems of its kind along the Atlantic coast of North America (Deuser 1990). The US Park Service, US Fish and Wildlife Service, and The Nature Conservancy have protected several of these coastal islands and their associated marshlands through purchase.

Barrier Islands on the Virginia segment of the Eastern Shore represent traditional wintering habitat for the American Black Duck. This area has also been one of the southernmost breeding sites for the species (Heusmann and Sauer 2000). Stotts and Davis (1960) noted that southern breeding sites may gain the advantage of an extended frost free period, higher fertility in local crop fields for nesting and foraging, a shorter harvest season, a reduced energetic expense of migration, and comparatively stable water levels. Several studies have documented high densities of American Black Duck nests on islands (Stotts and Davis 1960, Reed 1975,

Belanger et al. 1998). However, in recent years the protected habitat of Virginia's coastal islands has not supported large populations of American Black Ducks (Heusmann and Sauer 2000, G. Costanzo, pers. comm).

Previous work on these barrier islands has concentrated on the ecology of colony or beach nesting birds (Williams et al. 2003, 2004, Wilke 2005). Erwin et al. (2000) documented an increase in the range of raccoon and red fox on the Virginia barrier islands between 1977 and 1998. During this same period the number of breeding colonies of beach nesting birds in this system exhibited a marked decline. Erwin et al. (2000) concluded that nest site selection and nest success of colonial beach nesters is regulated by mammalian predation in the Virginia Coast Reserve. Colonial nesting birds on Virginia barrier islands avoid islands of high predator abundance (Keiss 2000). Coastal Virginia colonial water bird surveys between 1993 and 2003 recorded a 16% decline in overall populations (Williams et al. 2003). Declines occurred in 17 of 24 species, with 10 species exhibiting declines of over 40%, and 4 species exceeding declines of 70%. These declines in the colonial bird community in coastal Virginia were attributed to increasing predator populations on the islands of the Virginia Coast Reserve (Williams et al. 2003, 2004). Predator control was recommended in addressing declines in these colonial nesting populations (Keiss 2000, Williams et al. 2003, 2004, Wilke 2005).

Little is known about the population status of upland nesting birds of the Virginia Coast reserve, their relative abundance between islands, breeding distributions or survival rates. Even less is known concerning the impact of mammalian predators on the productivity of upland nesting birds on coastal Virginia islands. The impact of mammalian predator on island nesting avifauna has been well documented in other systems (VanderWerf 2001, Liebherr and Takumi 2002, Martin and Joron 2003). Field managers familiar with the Virginia Coast Reserve believe

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that dense populations of mammalian predators, particularly raccoon and red fox, are causing

high nest loss and presumably keeping several bird populations well below potential levels for

these habitats (B. Truitt, TNC, pers comm.). As recently as the mid 1970s, red foxes had not

been recorded, even on most of the larger islands (Dueser et al. 1979). Currently these islands

support a varied community of nest, duckling and adult predators (Deuser et al. 1979, Keiss

2000). While raccoon and red fox are primarily responsible for nest failure of ground nesting

birds in the Virginia Coast Reserve, secondary mammalian nest predators in this system include

Northern river otter (*Lutra canadensis*), Eastern coyote (*Canis latrans*), and mink (*Mustela

vison*). Estimating the impact that nest predators have on ground nesting birds is critical in

calculating species-specific production and constructing management plans.

In the prairie pothole region, recent experiments have convincingly demonstrated that

both duck nest success and duckling survival can be substantially elevated when predator

populations are reduced by lethal trapping (Duebbert and Lokemoen 1980, Garrettson and

Rohwer 2001, Pearse and Ratti 2004, Rohwer et al. 2004). Similarly, decreased nest success and

recruitment of shorebirds has been attributed to mammalian predation (Hothem and Welsh 1994,

Helmers and Gratto-Trevor 1996). Alternative management techniques to enhance nest success,

such as establishment of dense nesting cover (Reynolds et al. 2001), are not feasible on the

Virginia barrier islands because most of the regional habitat is already protected natural habitat

(Hayden et al. 1991).

Variation in predation risk among species can alter habitat use, species assemblage and

population and community patterns (Duebbert and Kantrud 1974, Slagsvold 1982, Martin 1987).

The impact of predation on avian productivity between groups of birds differs with microhabitat,

between island and mainland sites, and habitat patch size (Ricklefs 1969, Loiselle and Hoppes

1983, Wilcove 1985). The barrier islands of Virginia are nesting habitat for a variety of upland

nesting birds including waterfowl, shorebirds, and passerines (Williams 1996, Keiss 2000). The

impact of mammalian predation on species specific nest mortality may yield information on the

susceptibility of different avian groups to predation risk. However, in this system, few studies

have attempted to address comparative nest density and nest success among avian groups.

Essential to establishing effective management design is an understanding of differential

predation pressure between avian groups as group specific responses to predation impact may

exist.

The objective of this study was to examine the efficacy of predator trapping on the nest

success and density of ground nesting avifauna, specifically dabbling ducks, Canada Goose and

Willet. Secondly, we determine the impact of predation on ground nesting birds by relating

indices of predator abundance to nest density and nest success for islands plots.

Methods

<u>Study Area</u>

This study was conducted on the Virginia coastal islands in the mid-Atlantic, during the months of April – August, 2004 and 2005. The archipelago consists of a series of low-lying coastal islands that have been left relatively undisturbed by direct human activity. The islands are part of the Virginia Coast Reserve and are managed primarily by The Nature Conservancy. Within the archipelago, Fishermans Island is owned and managed by United States Fish and Wildlife Service's (USFWS) National Refuge Program as part of the Eastern Shore of Virginia National Wildlife Refuge (ESVNWR). Another island, Wreck Island Natural Area Preserve, is owned by the State of Virginia, Department of Conservation and Recreation (DCR), Division of Natural Heritage.

Study plots on the islands were selected based on historic nesting records and apparent suitability as upland nest sites for American Black Duck, Canada Goose, and Willet (Longcore et al. 2000, Lowther et al. 2001, Costanzo, pers. comm.). These species appear to prefer high marsh as nesting sites, dominated by the dense nesting cover of Beach Grass (*Ammpholia brevigulata*), Salt Grass (*Distichilis spicata*), Short Dune Grass (*Panicum spp*), Saltmeadow Cordgrass (*Spartina patens*) and Smooth Cordgrass (*Spartina alterniflora*). Islands were surveyed via air and ground surveys and suitable nesting habitat was identified. Plot perimeters were then recorded into Global Positioning System units. Positions were downloaded into ArcView GIS to derive the area in each plot. I used a total of nine plots within the Virginia Coast Reserve ranging in size from 6.3 ha to 65.5 ha. One plot was selected on each of the following islands: Fishermans Island, Smith Island, Wreck Island, Metompkin Island, and Parramore Island. The remaining four plots were on Cobb Island, Little and South Cobb Island,

Hog Island, and Rogue Island and South Hog Island. One plot each was on the north and south end of Cobb Island. On the south end of Cobb Island the plot extended on to the nearby small island of Little Cobb. Likewise, I placed a plot on the north end of Hog Island. A second plot on the south end of Hog Island was a shared plot with the adjacent small island of Rogue.

All plots were separated by at least 1.6 km of upland habitat, which is greater than the mean distance moved by raccoons, the island's most common predator (Keiss 2000, Deuser, pers. comm.). Keiss (2000) recorded average distance moved by raccoons on Virginia barrier islands and the adjacent mainland was 1.414 km (n = 25). An average distance of 1.175 km (n = 21) was observed for raccoon movements on islands alone (Keiss 2000).

Predator Trapping

Both the USFWS and The Nature Conservancy (TNC) had mammalian predator trapping programs on several of the islands during segments of the study period. USFWS and TNC personnel selected islands for trapping based in part on the perception of high predator activity. During part of the study period, trapping of raccoon and red fox occurred on Fishermans Island, Metompkin Island, Parramore Island and Smith Island. Trapping was conducted by United States Department of Agriculture (USDA) officers and occurred during the winter of 2003, spring 2003, winter 2004 and spring 2005. Islands were not trapped continuously during this period (Table 1). The remaining island plots, consisting of Cobb Island, Little and South Cobb Islands, Hog Island, Rogue and South Hog Islands and Wreck Island were not trapped during the study period.

Nest Searching

Nest searching began in early April and extended through the duration of the breeding season, which ended in late July. Nest searching was performed by walking transects that were spaced by about 2 meters to systematically search potential nesting cover within a study plot. Nests were located by either flushing the attending bird or visually locating nests that were hatched or depredated. Nests of all waterfowl, shorebirds and near-ground nesting passerines were marked using a 1 m lath placed 15 meters from the nest. Nest searches were conducted between 7 A.M.-3 P.M. when female waterfowl are most likely to be in attendance at the nest (Ringelman et al. 1982, Gloutney et al. 1993, Loos and Rohwer 2004). All waterfowl eggs were marked to insure the accuracy of clutch size recorded during the laying period due to possible subsequent laying and predation. A cylindrical candler, held against the egg shell, was used to estimate developmental stage (Weller 1956). Egg and nestling counts were recorded for all shorebird and passerine nests. Waterfowl nests were covered following discovery because hens cover their nests when they take incubation recesses. Marked nests of all species were checked every 5-22 days until nest fate was determined.

Predator Activity Indices

I used artificial nest success as an index of predator activity to generate independent estimates of predator activity for each island plot. The index allowed comparisons of predator activity between plots (Sieving and Wilson, 1998, Wilson et al. 1998). Artificial nest success was only used as an index of comparative predator activity and was not as an estimate of nest success. This index provides a measure of predator activity that is inexpensive, not subject to environmental constraints (i.e. rainfall, wind), and allowed practical monitoring of predator

activity throughout the barrier island chain. In upland areas, the use of artificial nests achieves an effective estimate of predator activity where scat transects may be biased due to non random deposition, scent stations are weather dependant and subject to time constrains, and mark recapture efforts are labor intensive..

A waterfowl nest was determined to be successful with evidence of an eggshell membrane separated from the eggshell (Klett et al. 1986). Successful shorebird nests were indicated by the presence of eggshell fragments in the nest bowl as a result of compaction by nestlings (Hill 1985, Page et al. 1985, Paton 1995).

An ArcView GIS random point generator program was used to create 233 artificial nest positions for the 9 plots in both years. A nest density of 1.3 nests/ha was maintained for all plots. Plot size ranged from 6.3 ha. to 65.5 ha.; corresponding artificial nest numbers ranged from 5 nests/plot to 48 nests/plot. Simulated nests were placed as close to the randomly selected GPS coordinates as possible while still placing the nest in typical cover for American Black Duck and Willet. Typical cover was qualitatively assessed by the investigator, based on observations of actual nest sites. Artificial nests consisted of 4 chicken eggs and were created by making a slight depression in the soil and then lining the simulated nest with cover that matched the cover at the nest. Eggs were covered with a thin layer of vegetation that mimicked what hens do when they leave their nest. Duck scent (Cabela's Duck Scent, Cabela's Inc.) was added to all active nests on the first and third nest checks to simulate the smell of a real nest. Artificial nests were monitored once every 9-22 days over a 30 day period until nest fate was determined. A nest was recorded as successful if all 4 eggs survived the 30 day monitoring period without evidence of predation. The 30 day nest monitoring period matches the approximate nesting period of American Black Duck, Canada Goose and Willet (Longore et al. 2000, Lowther et al. 2001).

Data Analysis

      I used Contingency Table Analysis (Proc FREQ, SAS Institute, 2002) to determine if there was a significant difference between the fate of active and post hatch nests for each avian group. I compared Mayfield estimates and Green-transformed estimates of nest success for dabbling ducks, Canada Goose and Willet on trapped and non-trapped islands using t-tests (PROC t-test, SAS Institute, 2002). I performed linear regression analyses (Proc GLM, SAS Institute, 2002) with artificial nest success, henceforth referred to as predator activity index, as the predictor variable and nest success and nest density as the response variables in separate analyses. The effect of year was examined for all linear regression analyses and t-tests. I calculated nest success and nest density estimates for three groups comprised of dabbling ducks, Canada Goose and Willet. I calculated Mayfield nest success for waterfowl nests on each of the islands (Johnson 1979). Some nests were discovered only after they had hatched or were depredated, so I also calculated apparent nest success. To allow inclusion of nests discovered post-fate, I transformed apparent nest success estimates to Mayfield estimates (Green 1989). Means are reported ± 1.0 standard error. Finally, island plots were assigned to either having the presence or absence of brood rearing pond(s) within 1.6 km of plot boundaries. Brood rearing ponds were described as those providing foraging habitat and sufficient water depth as to provide a mechanical barrier from mammalian predation. A general linear regression (Proc GLM, SAS Institute 2002) was performed with dabbling duck nest density as the predictor variable and the proximity of brood rearing pond(s) as the response variable.

Results

In the two year study, 488 nests were marked (2004 n=227, 2005 n=261), which includes the nests of thirteen ground nesting or near-ground nesting species. Willets were the most abundant nesting species (228), followed by Canada Goose (98). I found 67 dabbling duck nests, including 41 American Black Duck, 14 Mallard, 2 Gadwall (*A. strepera*) and 10 unknown dabbling duck nests discovered after the nest was no longer active so species identification was not possible. In addition, two American Black Duck nests and two Canada Goose nests were found off our study plots. Average nest initiation date for American Black Duck was April 23 in 2004 (n = 8) and April 23 in 2005 (n = 17). Average nest initiation date for Canada Goose was April 3 in 2004 (n = 41) and April 4 in 2005 (n = 36). Year effect was not significant in any statistical model ($P > 0.05$) for dabbling ducks, Canada Goose or Willet and so was removed from all analyses.

We also marked 71 other nests including Clapper Rail (*Rallus longirostris,* n = 10), Eastern Meadowlark (*Sturnalia magna*, n = 7*)*, Common Nighthawk (*Chordeiles minor,* n = 6), Common Yellowthroat (*Geothlypis trichas,* n = 6), Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus,* n = 4), American Oystercatcher (*Haematopus palliates,* n = 2), Chuck-Will's-Widow (*Caprimulgus carolinensis,* n = 2), Northern Harrier (*Circus cyaneus,* n = 2), and Black Vulture (*Coragyps atratus,* n = 1). A further 27 unknown nests were also recorded. Apparent nest success for all passerines combined on all islands was 50.0% (n = 26) in 2004 and 40.6% (n = 32) in 2005.

Trapping efforts were focused on raccoon, but red fox were also trapped on barrier islands (Table 1). Trapping effort was not consistent across islands. Trapping on Parramore

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Table 1. Trap effort and animals removed from Virginia Barrier islands during 2003-2005

Trapping Period	Island	Trap Nights	Red Fox Removed	Raccoon Removed
November – December, 2003	Parramore [a]	2185	10	270
March 29 – April 23, 2004	Fishermans [b]	410	0	5
March –May, 2004	Metompkin [a]	360	2	1
	Smith [a]	896	0	57
January 1 - January 7, 2005	Fishermans [b]	75	0	0
March 29 - April 14, 2005	Fishermans [b]	147	0	2
March – April, 2005	Metompkin [a]	106	0	2
	Smith [a]	6	0	0
November – December, 2005[c]	Parramore [a]	1005	5	93
	Smith [a]	201	0	24

[a] Data provided by B. Truitt, The Nature Conservancy, unpublished data.
[b] Data provided by Pamela Denmon, Eastern Shore of Virginia National Wildlife Refuge, United States Fish and Wildlife Service, unpublished data.
[c] Trapping occurred after the final field season (2005).

Island accounted for 80.0% of raccoons and 88.2% of red fox removed (Table1), but comprised only 59.2% of the total trapping effort between winter 2003 and spring 2005.

Mayfield and Green transformed nest success estimates on island plots were highly varied, ranging from 0.0% to 100.0% (Table 2). However, some plot estimates of Mayfield nest success are based on as few as one nest. Overall Mayfield nest success (pooled nest success for all island plots) for dabbling ducks was substantially higher in 2004 compared to 2005 (Table 3). In contrast, overall Mayfield and Green transformed nest success estimates were similar for both for Canada Goose and Willets between years (Table 3). Between years, overall nest density varied considerably for dabbling ducks but remained fairly consistent for both Canada Goose and Willet (Table 3). In both 2004 and 2005, Willet nest density was higher than Canada Goose nest density, which in turn was higher than dabbling duck nest density (Table 3). Contingency analysis revealed no significant relationship between the success of active and post fate nests for ducks ($X^2 = 2.57$, $P = 0.1092$) and Canada Goose ($X^2 = 0.13$, $P = 0.7175$). For Willets, there appeared to be a marginally significant detection bias between the fate of active and post hatch nests ($X^2 = 3.40$, $P = 0.0653$). Therefore, the twenty-five post hatch Willet nests were eliminated from analyses.

There was no difference in Mayfield nest success estimates for either dabbling ducks or Canada Goose on trapped and non-trapped islands (Table 4). Likewise, Green transformed nest success estimates based on the larger sample size of total duck or goose nests, also revealed no difference between trapped and non-trapped islands. As with the two waterfowl groups, Green transformed nest success for Willet was not different between trapped and non-trapped islands (Table 4). Predator activity was not different between trapped (34.12 ± 11.33) and non-trapped islands (37.09 ± 9.91; t = -0.20, $P = 0.4230$).

Table 2. Nest success summary for dabbling ducks, Canada Goose and Willets on Virginia barrier islands in 2004 and 2005. Green Transformed nest success converts apparent nest success to a Mayfield equivalent (Green 1989). A dash indicates that no estimate was possible. Parramore Island was trapped prior to the 2004 nesting season, but not prior to the 2005 nesting season.

Island Plot	% Dabbling Duck Mayfield (n)		% Dabbling Duck Green (n)		% Canada Goose Mayfield (n)		% Canada Goose Green (n)		% Willet Green (n)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Trapped										
Fishermans	1.8 (2)	12.6 (7)	14.9 (3)	11.8 (7)	29.8 (8)	63.2 (13)	60.4 (13)	60.4 (13)	46.7 (6)	14.9 (6)
Metompkin	100 (4)	26.6 (10)	100 (5)	40.5 (13)	29.7 (12)	100 (8)	43.8 (14)	100 (10)	68.1 (24)	69.6 (34)
Parramore	-	-	-	-	-	-	-	-	0 (1)	-
Smith	-	0.7 (1)	-	0 (1)	100 (1)	-	28.5 (2)	-	46.6 (6)	14.9 (2)
Non-trapped										
Cobb	51.1 (4)	19.9 (8)	46.7 (6)	28.5 (12)	100 (3)	0.2 (2)	65.5 (5)	14.9 (3)	74.0 (7)	22.2 (7)
Hog	-	7.8 (3)	8.1 (9)	4.4 (7)	100 (2)	3.0 (2)	74.0 (7)	74.0 (7)	19.8 (5)	0 (3)
Little and S Cobb	-	-	-	-	100 (7)	9.7 (9)	77.0 (8)	19.8 (10)	50.9 (19)	60.4 (13)
Parramore	-	-	-	-	-	-	-	-	-	0 (3)
Rogue and S Hog	100 (1)	-	100 (1)	-	100 (1)	-	100 (1)	0 (1)	14.9 (5)	12.7 (7)
Wreck	100 (1)	100 (1)	100 (1)	100 (2)	46.3 (4)	58.4 (5)	65.0 (5)	70.2 (6)	65.0 (25)	86.7 (31)

Table 3. Nesting summary for dabbling ducks, Canada Goose and Willet nesting on Virginia Barrier Islands in 2004 and 2005. Total area of all plots combined was 306.4 ha. Active nests included only those found while active; post fate nests are those discovered after they hatched or failed. Green transformed nest success converts apparent nest success to a Mayfield equivalent (Green 1989).

	Active Nests	Post Fate Nests	% Apparent Success (n)	% Mayfield Success (n)	% Green's Trans. Success (n)	Nest Density nests/ha
2004						
Dabbling ducks	12	13	52.0 (25)	54.4 (12)	34.5 (25)	0.082
Canada Goose	34	21	76.4 (55)	53.0 (37)	59.5 (55)	0.157
Willets	103	7	72.1 (110)		53.7 (110)	0.339
Overall	152	41	-	-	-	0.597
2005						
Dabbling ducks	30	12	47.6 (42)	17.7 (30)	23.0 (42)	0.137
Canada Goose	39	11	74.0 (50)	49.5 (39)	50.6 (50)	0.163
Willets	100	18	66.1 (118)		46.0 (118)	0.385
Overall	169	41	-	-	-	0.685

Table 4. Mean nest success estimates for dabbling ducks, Canada Goose and Willets on trapped and non-trapped plots on Virginia barrier islands in 2004 and 2005. Green transformed nest success converts apparent nest success to a Mayfield equivalent (Green 1989).

	Mean Mayfield Nest Success (X ± SE)	Mean Green Nest Success (X ± SE)
Dabbling Ducks [a]		
Trapped	28.3 ± 18.5	33.4 ± 17.9
Non-trapped	63.1 ± 17.5	55.4 ± 16.6
Canada Goose [b]		
Trapped	64.5 ± 15.7	58.6 ± 11.9
Non-trapped	57.5 ± 14.9	59.7 ± 9.3
Willets [c]		
Trapped		37.3 ± 10.4
Non-trapped		37.0 ± 9.4

[a] Mean Mayfield: $t_9 = -1.4$, $P = 0.1031$; Mean Green: $t_{10} = -0.9$, $P = 0.1990$.

[b] Mean Mayfield: $t_{12} = 0.3$, $P = 0.3835$; Mean Green: $t_{13} = 0.04$, $P = 0.4863$.

[c] Mean Green: $t_{16} = -0.02$, $P = 0.4920$.

Dabbling ducks tended to have higher nest success on islands with lower predator activity (higher artificial nest success) (Figure 1; Mayfield: $F_{1, 9} = 4.28$, $P = 0.069$, $\beta = 0.803$; Green: $F_{1, 10} = 7.27$, $P = 0.0225$, $\beta = 0.887$). There was no relationship between predator activity and nest success for Canada Goose (Figure 1; Mayfield: $F_{1, 12} = 0.51$, $P = 0.4909$; Green: $F_{1, 13} = 0.19$, $P = 0.6686$). Willets had higher Green transformed nest success on islands with lower predator activity than on islands with higher predator activity (Figure 1; $F_{1, 16} = 28.06$, $P < 0.0001$, $\beta = .752$).

There was no difference in nest density between trapped (0.07 ± 0.03) and non-trapped (0.15 ± 0.06) islands for dabbling ducks ($t_{16} = -1.08$, $P = 0.1477$). Canada Goose nest density also yielded no difference between trapped (0.13 ± 0.05) and non-trapped islands (0.20 ± 0.03; $t_{16} = -1.25$, $P = 0.1149$). As with waterfowl groups, Willet nest density did not differ between trapped (0.33 ± 0.08) and non-trapped islands (0.54 ± 0.17; $t_{16} = -1.05$, $P = 0.1553$). Willet nest density was inversely related to predator activity (Figure 2; $F_{1, 16} = 12.31$, $P = 0.0029$, $\beta = 0.756$). Canada Goose nest density was also higher on islands with lower predator activity (Figure 2; $F_{1, 16} = 9.83$, $P = 0.0064$, $\beta = 0.233$). However, there was no relationship between dabbling duck nest density and predator activity (Figure 2; $F_{1, 16} = 1.80$, $P = 0.1981$).

Lastly, there is a marginally significant relationship between dabbling duck nest density and the proximity of sufficient brood rearing ponds within 1.6 km from the respective plot boundary ($F_{1, 7} = 3.88$, $P = 0.0896$, $\beta = -0.163$).
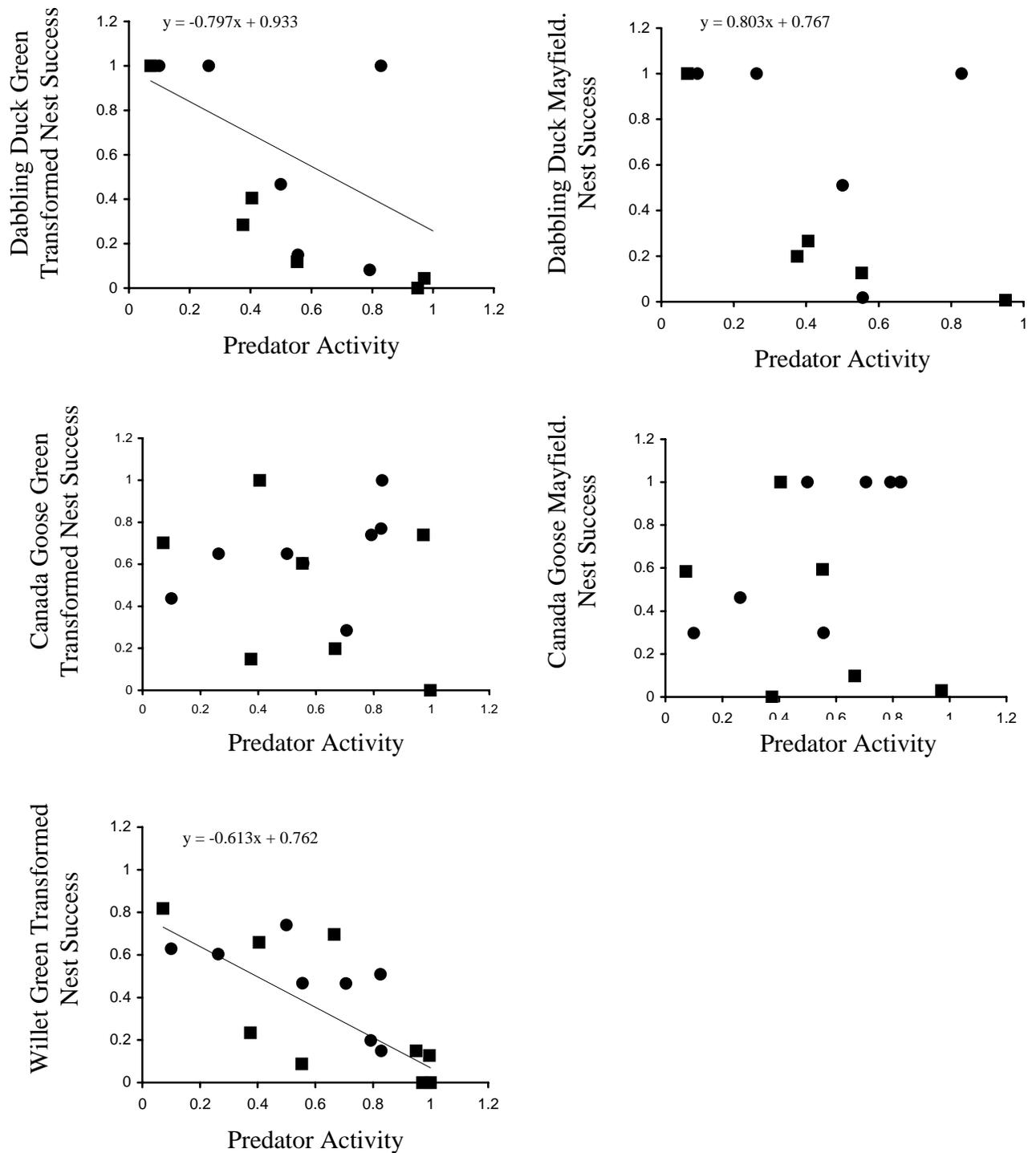
Figure. 1. The relationship between nest success and predator activity (artificial nest success) for dabbling ducks, Canada Goose and Willet nesting on barrier islands in Virginia in 2004 and 2005. The Green transformation is derived from apparent nest success and provides a Mayfield equivalent estimate of nest success (Green 1986). Squares represent 2004 data; circles represent 2005 data. Years were combined for analysis. Year effect was not significant in any model (P>0.05).

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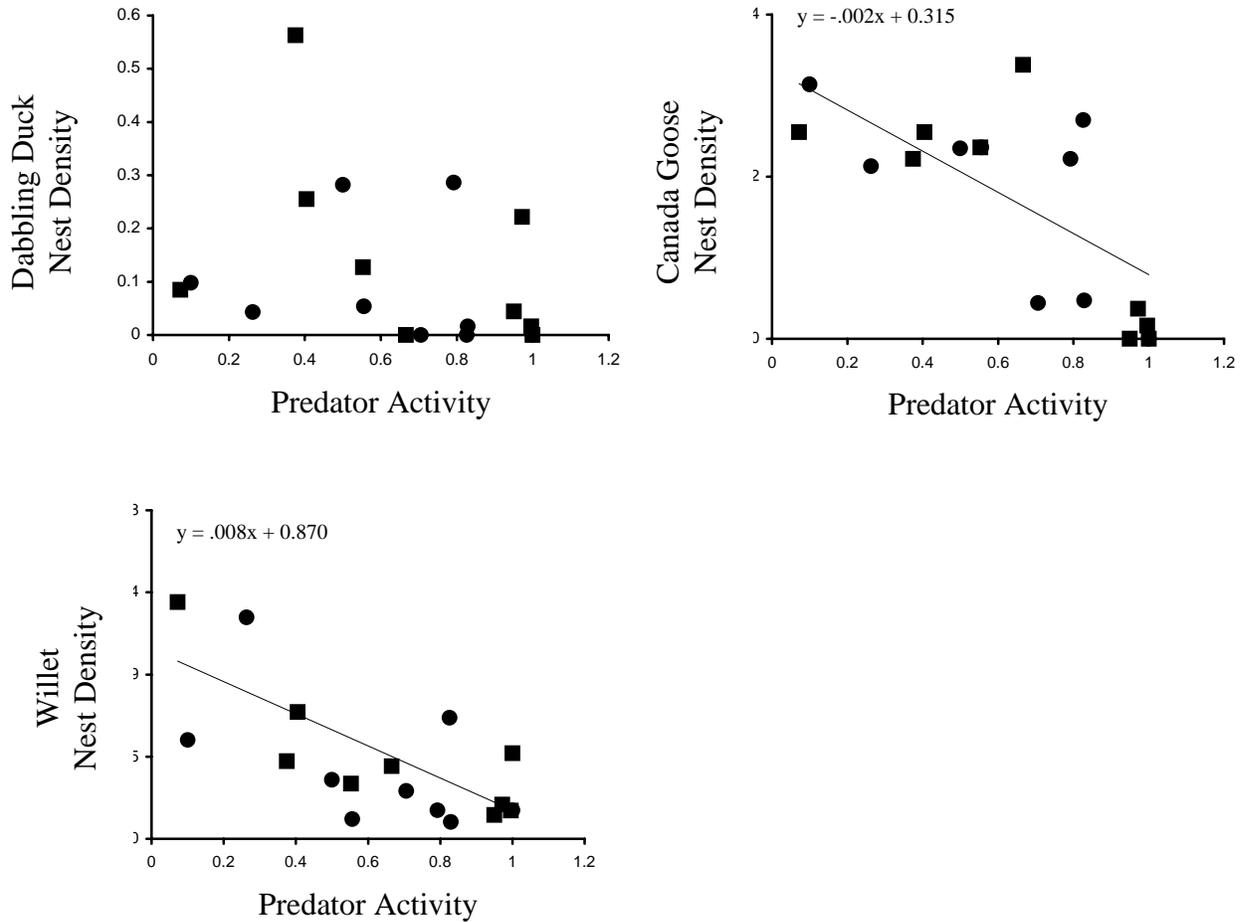
Figure. 2. The relationship between nest density and predator activity (artificial nest success) for dabbling ducks, Canada Goose and Willet nesting on Virginia barrier islands in 2004 and 2005. Squares represent 2004 data; circles represent 2005 data. Years were combined for analyses. Year effect was not significant in any model (P>0.05).

Table 5. Nest density summary for dabbling ducks, Canada Goose and Willet on Virginia barrier islands in 2004 and 2005.

Island	Dabbling Duck Density (nests/ha)		Canada Goose Density (nests/ha)		Willet Density (nests/ha)	
	2004	2005	2004	2005	2004	2005
Trapped						
Fishermans	0.05	0.13	0.24	0.24	0.11	0.16
Metompkin	0.10	0.26	0.31	0.20	0.59	0.71
Smith	0.00	0.04	0.04	0.00	0.27	0.13
Parramore	0.00	-	0.00	-	0.16	-
Non Trapped						
Cobb	0.28	0.56	0.24	0.14	0.33	0.42
Hog	0.29	0.22	0.22	0.22	0.16	0.19
Little and S Cobb	0.00	0.00	0.27	0.34	0.68	0.41
Rogue and S Hog	0.02	0.00	0.05	0.02	0.10	0.16
Wreck	0.04	0.09	0.21	0.26	1.23	1.75
Parramore	-	0.00	-	0.00	-	0.48

Discussion

This study represents one of the first comprehensive investigations of avian nesting in upland habitats of barrier islands in the Virginia Coast Reserve. Further, this study is the most detailed investigation of waterfowl breeding ecology in this mid-Atlantic archipelago to date. Nest success of dabbling ducks in the Virginia Coast Reserve was intermediate for both 2004 and 2005 compared with previous American Black Duck studies (Table 6). My work occurred at the southern extent of the American Black Duck breeding range. In the coastal mid-Atlantic, the American Black Duck is the most common species of breeding dabbling duck. Nearing the limits of its range, the relatively few dabbling duck nests found in this study may reflect the diminished concentration of American Black Duck found in this region.

Nest Success and Predator Trapping

I found no relationship between nest success and trapping for dabbling ducks, Canada Goose and Willet. The results of this study differed from previous work examining the effect of trapping on waterfowl nest success (Duebbert and Lokemoen 1980, Sargeant et al. 1995, Beauchamp et al. 1996, Garrettson and Rohwer 2001, Rohwer et al. 2004). Several reasons may account for this discrepancy including design flaws, intensity of trapping, differences in island habitat affecting avian nest site selection and sample size.

My finding of higher nest success on non-trapped islands compared with trapped islands suggests a design flaw in attempting to measure trapping efficacy. This study evaluated trapping that targeted islands with perceived high predator densities and islands important to colonial breeding birds. The non-random assignment of trapping to islands with high predator densities makes it difficult to evaluate trapping efficacy in this system, though it is possible to conclude

Table 6. Nest success estimates of American Black Duck.

Mayfield	n	Region	Years	Habitat	Reference
18*	574	MD	1953-58	Estuarine islands	Stotts & Davis 1960
33*	28	ON	1965-67	Forest	Young 1968
47-71*	326	VT	1951-63	Lake islands	Coulter and Mendall 1968
33*	349	VT		Forest & peatland	Coulter and Mendall 1968
32*	112	QC	1968-72	River islands	Laperle 1974
30*	29	QC	1963-73	Coastal islands	Reed 1975
23*	478	QC	1963-73	Coastal islands	Reed 1975
11*	83	QC	1963-73	Agroforest	Reed 1975
32*	446	MD	1953-89	Estuarine marsh	Krementz et al. 1991
36	159	MD	1986-89	Estuarine islands	Krementz et al. 1992
40*	6	NY	1990-91	Forest	Dwyer and Baldassare 1993
15*	106	QC	1963-91	Coastal marsh	Bélanger et al. 1998
28*	503	QC	1963-91	Estuarine islands	Bélanger et al. 1998
58*	59	NS	1973-92	Agroforest	Seymour and Jackson 1996
16*	17	NB	1992-94	Agriculural	Petrie 2000
100*	<10	QC	1994-96	Peatland	Maisonneuve et al. 2000
12	22	QC	1994-96	Agroforest	Maisonneuve et al. 2000
25*	41	VA	2004-05	Coastal islands	This study 2007

Adapted from Maissoneuve et al. 2000.
* denotes Mayfield estimates derived from apparent nest success via the Green transformation (Green 1989)

that trapping, as applied, did not raise nest success to high levels on the trapped islands. Prior research in the Virginia Coast Reserve suggested that predator reduction may be ineffective on large islands with dense predator populations, small islands adjacent to those large islands, and islands close to the mainland (Keiss 2000). Mammalian predator populations may further benefit from high nutrient resources and elevated productivity available in coastal environments (Rose and Polis 1998). Within the Virginia Coast Reserve, islands suggested by Keiss (2000) as potentially "lost to predators" include the large islands of Hog, Metompkin, Parramore, Smith and Rogue. Of these five islands, Hog Island and Rogue Island have never been trapped, trapping intensity was low on Smith Island, and nest success was high on the trapped island of Metompkin. While trapping may not efficiently reduce predators on all barrier islands, management efforts with sufficient trapping intensity throughout the duration of the season would better assess the efficacy of predator reduction on these five islands in the Virginia Coast Reserve.

Low trapping intensity may be another possible reason for the lack of an effect of trapping on nest success (Table 1). During the winter prior to my first field season, Parramore Island was trapped for 2185 nights, yielding 1.0 trap nights/ha. No further trap effort was applied to Parramore Island during our study period. Trap effort on Metompkin Island averaged 0.64 trap nights per ha per year during our study period. Fishermans Island received an average of 0.49 trap nights/ha./year. Finally, Smith Island experienced 0.41 trap nights/ha./year. In contrast to the trap effort applied to the Virginia Coast Reserve, trapping intensity in the prairie pothole region of North America averages 6.75 trap nights/ha./year on 36 square mile blocks. Timing of trapping may also affect success as prairie efforts generally extend throughout the duration of the breeding season.

Finally, the small sample of nesting ducks and reduced power of my tests may have contributed to the inability to detect a significant result for measuring the impacts of trapping on island nesting ducks. My sample size of Canada Goose and Willet nests was substantially larger than for ducks, yet both species failed to show a significant difference in nest success between trapped and non-trapped islands.

Predator Index and Trapping

Predator activity was not significantly lower on islands that were trapped possibly due to design flaws and low trapping intensity. In our study, treatment was not randomly applied as trapped islands were selected due to perceived predation risk to colonial nesting birds. The relative similarity in estimates of predator activity between trapped and untrapped island treatments lends to the earlier suggestion of a design flaw. However, artificial nest success, my measure of predator activity, corresponded well to previous estimates of mean raccoon track frequencies (Keiss 2000) on the same study islands (Table 7).

Nest predators were diverse on the Virginia barrier islands (Table 8). I found evidence of raccoon on eight of nine islands, and they were the most common predator observed (Deuser 1979, Keiss 2000). Only Wreck Island appeared to have no raccoon. Red fox were present on five of the nine islands, including Cobb Island, Hog Island, Metompkin Island, Parramore Island and Smith Island. On several islands I found black rat snakes (*Elaphe obsoleta obsoleta*), which are predators of both eggs (Stotts and Davis 1960, Kremmentz et al. 1991) and ducklings (Krementz and Pendleton 1991) on Chesapeake Bay Islands. I observed black rat snakes eating artificial nest eggs while Stotts and Davis (1960) observed a single black racer (*Coluber constrictor*) in an empty nest bowl on Chesapeake Bay islands. I also observed black racers on

Table 7. Comparison of averaged artificial nest success between islands in 2004-2005 and averaged mean percent frequencies of raccoon tracks detected during systematic surveys between 1998-2000 by Keiss (2000).

Island	Averaged Artificial Nest Failure (%)	Rank	Averaged Raccoon Mean Track Frequencies (%)	Rank
Wreck	16.7	1	8.0	3
Metompkin	25.2	2	0.0	1
Fishermans	55.5	3	5.0	2
Cobb	59.1 [a]	4	10.4	4
Smith	82.8	5	14.8	5
Hog	88.8 [b]	6	52.6	6
Parramore	100.0	7	96.0	7

[a] Average of Cobb Island and Little and South Cobb Island estimates.
[b] Average of Hogg Island and Rogue and South Hog Island estimates.

Table 8. Predator presence on Virginia barrier islands between 1970 and 2005. Adapted from Keiss 2001.

| Island | 1970-1980 | | 1981-1990 | | 1991-2000 | | this study: 2004-2005 | | |
	raccoon	red fox	raccoon	red fox	raccoon	red fox	raccoon	red fox	other
Cobb	+	-	+	+	+	-	+	+	W
Fishermans	na	na	na	na	+	-	+	-	C, S
Hog	+	+	+	+	+	-	+	+	O, M, S
Little Cobb	+	-	na	na	-	-	+	-	-
Metompkin	+	+	+	+	+	+	+	+	
Parramore	+	+	+	+	+	+	+	+	S
Rogue	na	na	na	na	+	-	+	-	-
Smith	+	-	+	-	+	+	+	+	S
Wreck	-	-	na	na	+	-	-	-	O

+ Evidence of predator presence through either track surveys, scat counts or visual observations.
- No detection.
C – Eastern Coyote (*Canis latrans var.*), S – Black Rat snake (*Elaphe obsolete*), O – Great Horned Owl (*Bubo virginianus*) , M – mustelidae (unknown), W –Long tailed weasel (*Mustela frenata*).

several of the barrier islands. The extent to which predation by snakes affects nest success of

dabbling ducks, Canada Goose and Willet is unknown, but is perceived to be minimal due to the

infrequency of both predation events and actual sightings. Other observations of predators on

the barrier islands included coyote, Great Horned Owl (*Bubo virginianus*), long tailed weasel

(*Mustela frenata*) and a single observation of an unknown member of the family *Mustelidae,*

most likely a mink (*Mustela vison*).

Nest Success and Predator Activity

For both dabbling ducks and Willets, increased nest success was correlated with reduced

predator activity. In contrast, Canada Goose nest success showed no response to my measure of

predator activity. Unlike dabbling ducks and Willets, both Canada Goose parents actively

defend nests from predators. Dual parenting by geese likely assists in deterring nest predation.

In contrast, when discovered by a predator, dabbling duck hens flush from the nest and display

no nest defense.

Many studies have attempted to address mammalian predation impact on nesting geese

(Robertson 1995, Samelius and Lee 1998, Samelius and Alisauskas 2000). Although breeding

geese will avoid predation risk, adult and egg mortality is low relative to other ground nesting

birds (Lokemoen and Woodward 1992, Bety and Gauthier 2001, Zoellick et al. 2004).

Preferential nesting by King Eiders (*Somateria spectabilis*) on islands with incubating Lesser

Snow Geese (*Chen caerulescens caerulescens*) reduces predation risk through proximity

protection (Robertson 1995). Robertson (1995) also found that artificial nest success decreased

with distance from incubating geese. My study agrees with previous work suggesting predation

does not strongly impact nest success in large, North American breeding geese.

On my study plots, predation was the dominant cause of nest failure in waterfowl.

Canada Geese had higher average nest success than dabbling ducks on eight of the nine islands

The exception was Wreck Island, the island with the lowest predator activity (Table 8). The

large size of resident Canada Geese and their rigorous nest defense likely makes them less

susceptible to most predators in the Virginia Coast Reserve. An inability to assess predator

activity or failing to avoid high predator environments would have more impact on ducks than

geese due to differences in susceptibility to predation. This discrepancy in susceptibility to

predation risk may explain the variation in nest success between the two waterfowl groups.

Willet nest success is correlated with reduced predator activity on barrier islands in

Virginia. Several studies have documented the impact of predators on breeding shorebird

populations. Howe (1981) documented most Willet nests on Wallops Island in coastal Virginia

were depredated by red fox. Predation is also responsible for most nest failure of endangered

Piping Plovers on Chincoteague Island, another barrier island on the Virginia coast (Ailes 1985).

In California grasslands, predation impacted both shorebird and duck nest success. Several

studies have found predation to be the leading cause of nest failure in California grassland

(Hothem and Welsh 1994), Atlantic coast (MacIvor et al. 1987, Cairns 1982, Rimmer and

Deblinger 1990) and arctic breeding populations of shorebirds (Sandercock and Gratto-Trevor

1997, Ruthrauff 2002, Niehaus 2004). Helmers and Gratto-Trevor (1996) provided evidence of

reduced recruitment in shorebird populations impacted by predation on arctic breeding grounds.

Thus, with shorebirds as with ducks, the vulnerability of breeding populations to predation can

have strong impacts on both nest success and recruitment. Unable to defend nests to predation

risk, it is no surprise that the predator activity maps well to Willet nest success. Predator

reduction has lead to higher nest success in several studies of prairie ducks (Duebbert and

Lokemoen 1980, Sargeant et al. 1995, Beauchamp et al. 1996, Garrettson and Rohwer 2001). Predator exclusion has been successful in increasing shorebird nest success, especially of endangered Piping Plovers (Melvin et al. 1992, Larson et al. 2002, Murphy et al. 2003). Such studies suggest that if predator trapping could substantially reduce predator abundance it would probably benefit both dabbling ducks and Willet populations in the Virginia Coast Reserve.

The response to predation observed in previous studies of duck, Canada Goose and Willet nesting are consistent with explaining the group specific nest success observed in this study. Variation in morphology and behavior between avian groups may dictate differential predation risk. Canada Geese benefit from both size and dual parenting and had the highest nest success of the three avian groups (Table 4). In turn, Willets benefit from both crypsis and dual parenting and yielded higher nest success than ducks (Table 4). The low relative success of dabbling ducks may be due to their comparatively conspicuous nests and lack of nest defense. This comparison lends to the suggestion of differential effect of predator impacts between avian groups on island environments.

Nest Density

A. Nest Density and Trapping

As with nest success, I found no difference in nest density between trapped and non-trapped plots for dabbling ducks, Canada Goose and Willet. Estimates of trapping efficacy on nest density may have been confounded by the study design that had trapping occur on islands that were perceived to have predation problems. As with nest success, nest density was actually higher on non-trapped islands than trapped islands for all three groups. Though these results were non-significant, such findings suggest a design flaw was evident in the study.

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Nest density of dabbling ducks increases with available habitat for brood rearing (Crissy 1969, Bethke and Nudds 1995, Miller 1996). In the continental mid-west, fresh water ponds that impair predation risk to broods, by providing a physical obstruction, are available in most landscapes. While most islands in my study contain bottomland areas that are ephemerally wet or marginally flooded, only five of the nine study plots were proximate (<1.6 km) to deep, fresh water ponds. These ponds provided a sufficient mechanical barrier to mammalian predation risk throughout the duration of the brood rearing period. Two of the four islands on which trapping occurred included Smith Island and Wreck Island, where there were no fresh water ponds near the plots. I found no dabbling duck nests on Smith Island in 2004 and only one in 2005. Wreck Island yielded one duck nest in 2004 and two in 2005. Of the five islands with fresh water wetlands considered sufficient for dabbling duck brood rearing habitat, only three were trapped. Included among these three trapped plots is Parramore Island, which had high predator activity. Estimates of nest density and nest success on Parramore may be confounded by the relatively small area of nesting habitat available to upland, ground nesting birds and the island's high estimates of predator abundance. Together, these two factors would effectively result in a saturation of the study plot area by predation risk.

B. Nest Density and Predator Activity

Both Canada Goose and Willet nest density decreased with increasing predator activity on island plots. In the Virginia Coast Reserve, island selection by Canada Geese was related to predator activity while nest success was not. Though less vulnerable to predation than other ground nesting birds, geese do avoid sites with heightened predation risk (Robertson 1995, Trembley et al. 1997, Zoellick et al. 2004). For Willets, both nest density and nest success are

subject to predator activity in this island system. Predation risk during the breeding season can influence nest site selection of shorebirds. In Scotland, the introduction of predatory hedgehogs (*Erinaceus europaeus*) to island communities impacted shorebird nest site distribution (Jackson and Green 2004). Skeel (1983) found increased nest success in Manitoba Whimbrels (*Numenius phaeopus*) nesting in reduced predator risk environments. My work, like previous studies, indicates a negative correlation between predation and nest density in both Canada Goose and Willet. However, the mechanism governing correlation between predation and nest density, either through nest detection by observers, breeding philopatry on previously successful islands, or active selection of islands remains unknown.

One possible explanation of this correlation is that there may exist a detection bias between islands of varying predation risk. If observers are only detecting nests that are active, than in reduced predator environments there will be more detected nests than on islands where nests fail more rapidly. For future efforts examining nest densities, recording avian territories prior to the laying period may alleviate the suspicion of such a bias.

A second explanation regards the fact that both Canada geese and Willets show philopatry (Bellrose 1976, Lowther et al. 2001). Breeding and natal philopatry could explain differences in nest density between islands. Through philopatry, differential productivity between island populations of varying predator abundance would lead to skewed densities and distributions. However, if Canada Goose nest success is not related to predator activity (as found in this study), then philopatry alone would not explain nest density distributions between islands.

Finally, active selection by both Canada Goose and Willet may also account for the difference in nest density between trapped and non-trapped islands. While geese may incur a reduced risk of nest predation than other ground nesting birds, they may still preferentially nest

on island sites with reduced predator abundance. Vigilant behavior by waterfowl toward

predation risk may detract from time spent foraging, attending nests and other costs. Forslund

(1993) documented a correlation between heightened vigilance and predation risk in Baltic

breeding Barnacle Geese (*Branta leucopsis*). In Lesser Snow Geese breeding in Alaska, Fowler

and Ely (1997) observed predation threat determined the amount of time nesting geese spent

vigilant. Such studies suggest geese may be able to detect predator abundance once territories

have been established. Other studies have noted geese preferentially nest on islands to avoid

predation threats (Trembley et al. 1997, Zoellick et al. 2004). Maximizing nest success, reducing

predation risk and lessening the costs incurred through vigilance may account for the relationship

between Canada Goose nest density and predator activity observed in the Virginia Coast

Reserve.

Little information exists regarding active selection of nest sites by shorebirds due to

predation risk. Keiss' (2000) work on colonial nesting birds on Virginia barrier islands found

birds avoided islands with raccoons and red fox. Keiss also revealed that islands with large bird

colonies had low predation risk. However, based on current evidence, caution should be

observed when inferring if active selection is, in fact, the driving mechanism of nest site

selection in shorebirds.

In concordance with these previous shorebird studies, my work found a strong

relationship between nest density and predator activity for Willets. These results suggest that in

the Virginia Coast Reserve, both Willets and Canada Goose nest density is influenced by

predation risk, though the mechanism for selection remains unknown (Figure 2).

Although nest densities for Willets and Canada Goose were correlated with predator

activity estimates, I found no relationship between dabbling duck nest density and predator

activity in this system (Figure 2). Several factors may account for this difference including sample size, nest detection, and active selection. First, the small sample size of dabbling duck nests found in this study may compromise statistical power in evaluating the relationship between nesting density and predator activity. However it should be noted that results between the three avian groups produced similar slopes suggesting increased sample size would still yield a non-significant result. Second, it may be that Anatinae are not able to detect predator densities during nesting. Unlike ducks, both Canada Geese and Willets maintain active territorial defense by both parents prior to and during nesting. This strategy may allow breeding adults an ability to gauge predation risk and avoid islands of high predator abundance through active selection. Third, other factors specific to dabbling duck breeding ecology may prove important in determining island selection than predator activity. Habitat determinants or differences in habitat composition (i.e. presence of fresh water ponds, adequate grass area) governing breeding requirements in ducks may impact island selection more than predation risk on the Virginia barrier islands. In this study, trapping targeted islands of perceived high predator densities without accounting for fresh water habitat needed for brood rearing.

I found selection of islands for nesting by ducks was independent of predation risk but coincided with access to fresh water habitat (Table 9). Shorebirds, like geese, will also use salt marsh habitat for early chick development (Howe 1981). In the Virginia Coast Reserve an abundance of brood rearing habitat for Willets and Canada Geese may not constrain island selection for these two groups unlike dabbling ducks. It is my hypothesis that the lack of fresh water for brood rearing, not predation risk, affects duck nest densities on reduced predator islands in the Virginia Coast Reserve.

Table 9. Trapping, presence of adequate fresh water and avian group densities on Virginia barrier islands in 2004 – 2005.

Island Plot	Presence of adequate fresh water to to plot border (<1.6 km)	Dabbling Duck nest density (nests/ha.)	rank of nest density	Canada Goose nest density (nests/ha.)	rank of nest density	WILL nest density (nests/ha.)	rank of nest density
Trapped							
Fisherman	yes	.09	4	.24	3	.14	8
Metompkin	yes	.18	3	.26	2	.65	3
Parramore	yes	.00	8	.00	9	.32	5
Smith	no	.02	6	.02	8	.20	6
Non Trapped							
Cobb	yes	.42	1	.19	6	.38	4
Hog	yes	.25	2	.22	5	.18	7
Wreck	no	.07	5	.23	4	1.04	1
Rogue and S. Hog	no	.02	7	.03	7	.13	9
Little and S. Cobb	no	.00	8	.30	1	.54	2

On the barrier islands of Virginia, fresh water ponds are almost exclusively eutrophic. Seymour and Jackson (1996) found that American Black Duck hens fledged more young when broods were raised at inland, fresh water sites than at tidal marshes, despite lower nutrient availability at inland sites. The authors further note most duckling mortality occurred within or in transit to tidal marshes. These results suggest heightened recruitment of Atlantic breeding American Black Ducks may be achieved at interior wetlands. In turn, philopatry would account for higher nest densities in subsequent years on successful island in the Virginia Coast Reserve.

Overview and Management Implications

Overall American Black Duck nest success (Mayfield: 46.2 %, n = 12; Green: 25.0%, n = 41) was medium to high compared with previous American Black Duck nest success estimates. In response to mammalian predation limiting nest success of colonial beach nesting on Virginia barrier islands, Erwin et al. (2000) recommend predator removal on selected islands. Keiss (2000) suggested targeting small islands within the archipelago for predator reduction to help enhance avian productivity. While trapping may help colonial waterbirds on barrier islands in Virginia it may not assist dabbling ducks, Canada Goose and Willet. These upland, ground nesting species appear to be greatly impacted by predation so there is potential for predation reduction to increase nest success. However, more intensive trapping and trapping throughout the duration of the breeding season may be required. Trapping on small islands yields greater efficiency of predator removal compared with larger islands due to reduced rates of extinction and higher mammalian population numbers (Burkey 1995). Thus, concentrating trap efforts on smaller islands with viable numbers of breeding birds may prove most efficient.

In this study Cobb Island and Hog Island, yielded the highest overall dabbling duck nest density yet both islands were not trapped (Table 5). Together these two islands alone accounted for 50.7% of all duck nests discovered in two years on these islands. Two trapped islands, Fishermans Island and Metompkin Island, provided the next highest nest densities for dabbling ducks and accounted for another 41.8% of all dabbling duck nests found. These four islands along with Parramore Island provide adequate water for brood rearing among the islands in my study. Currently Parramore Island is dominated by *Pinus* spp and *Myrtus* spp. and has little grassland habitat to support a nesting dabbling duck population, especially given the islands high predator index. Concentrated trapping efforts on Cobb Island, Hog Island, Fishermans Island and Metompkin Island is recommended in increasing dabbling duck, and specifically American Black duck, nest density and success in the Virginia Coast Reserve.

In this study, dabbling duck, Canada Goose and Willet displayed uniquely different trends with respect to the relationships between nest density, nest success and artificial nest success. Variation between nest density and nest success may reflect unique differences in group specific susceptibility to predation. While avian nest density and nest success on islands may benefit from predator management, responses by particular groups may be subject to habitat determinants. In concordance with previous studies (Greenwood et al. 1995, Lariviere and Olson 2004), effective predator management in the Virginia Coast Reserve may be best applied in conjunction with, and not a substitute for, habitat considerations.

Literature Cited

Ailes, I. 1985. Piping Plover population distribution and management report. Unpublished report, USFWS. Chincoteague, Virginia.

Ankney, C.D., D.G. Dennis and R.C. Bailey. 1987. Increasing Mallards, decreasing American Black Ducks: coincidence or cause and effect? Journal of Wildlife Management 51:523-529.

Bélanger, L., A. Reed and J.L. Desgranges. 1998. Reproductive variables of American Black Ducks along the St. Lawrence estuary, 1963-1991. Canadian Journal of Zoology 76: 1165-1173.

Belrose. F.C. 1976. Ducks, geese and swans of North America. 2nd ed. Stackpole Books. Harisburg, PA.

Beauchamp, W.D., R.R. Koford, T.D. Nudds, R.G. Clark and D.H. Johnson. 1996. Nest success decline in prairie ducks detected using long-term data. Journal of Wildlife Management 60: 247-257.

Bethke, R.W. and T.D. Nudds. 1995. Effects of climate change on and land use on duck abundance in Canadian prairie pothole region. Journal of Wildlife Management 60:247-257.

Bêty, J. and G. Gauthier. 2001. Effects of nest visits on predator activity and predation rate in a Greater Snow Goose colony. Journal of Field Ornithology 72(4): 573–586.

Burkey, T.V. 1995. Extinction rates in Archipelagoes: Implications for populations in fragmented habitats. Conservation Biology 9(3): 527-541.

Brodsky, L.M. and P.J. Weatherhead. Behavioral and ecological factors contributing to American black duck-mallard hybridization. Journal of Wildlife Management 48(3): 846-852.

Cairns, W.E. 1982. Biology and behavior of breeding Piping Plovers. Wilson Bulletin 94: 531-545.

Conroy, M. J., M. W. Miller and J. E. Hines. 2002. Identification and synthetic modeling of factor s affecting American Black Duck populations. Wildlife Monographs 150:1-64.

Coulter, M. W. and W. R. Miller. 1968. Nesting biology of black ducks and mallards in New England. Vermont Fish Game Department Bulletin No. 68-2.

Coulter, M.W. and H.L. Mendall. 1968. Northeastern States. Pages 90-101 in P. Barske (ed.) Black Duck: Evaluation, Management, and Research - A symposium. Atlantic Flyway Council, Chestertown, MD.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92: 1-37.

Crissy, W.F. 1969. Prairie potholes from a continental viewpoint. Pages 161-171 in Saskatoon Wetlands Seminar. Canadian Wildlife Service, Report Series, no. 6. Ottawa, Ontario.

Dennis D.G., G.B. McCullough, N.R. North and B. Collins. 1989. Surveys of breeding waterfowl in southern Ontario. Canadian Wildlife Service Progress Note No. 180, Ottawa.

Diefenbach, D.R. and R.B. Owen, Jr. 1989. A model of habitat use by breeding American Black Ducks. Journal of Wildlife Management 53:383-389.

Drever, M.C., A. Wins-Purdy, A., T.D. Nudds and R.G. Clark. 2004. Decline of Duck Nest Success Revisited: Relationships with Predators and Wetlands in Dynamic Prairie Environments. The Auk 121(2): 497-508.

Duebbert, H.F. and H.A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. Journal of Wildlife Management 38:257-265.

Duebbert, H. F. and J. T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. Journal of Wildlife Management 44:729-740.

Dueser, R. D., W. C. Brown, G. S. Hogue, C. McCaffrey, S. A. McCuskey and G. J. Hennessey. 1979. Mammals on the Virginia barrier islands. Journal of Mammalogy 60: 425-429.

Deuser, R.D. 1990. Biota pf the Virginia barrier islands: Symposium Introduction. Virginia Journal of Science 41: 257-258.

Dwyer, C.P. and G.A. Baldasarre. 1994. Habitat use by sympatric female mallards and American black ducks breeding in a forested environment. Canadian Journal of Zoology 72(9): 1538-1542.

Erwin, R. M., B. R. Truitt and J. E. Jimenez. 2001. Nowhere to hide: ground nesting waterbirds and mammalian carnivores in the Virginia barrier island region. Journal of Coastal Research 17(2): 292–296.

Forslund, P. 1993. Vigilance in relation to brood size and predator abundance in the barnacle goose, Branta leucopsis. Animal Behaviour 45(4): 965-973.

Fowler A.C. and C.R. Ely. 1997. Behavior of Cackling Canada Geese during brood rearing. Condor 99(2): 406-412

Garrettson, P. R. and F. C. Rohwer. 2001. Effects of mammalian predator removal on upland-nesting duck production in North Dakota. Journal of Wildlife Management 65:445-452.

Gloutney, M. L., R. G. Clark, A. D. Afton and G. J. Huff. 1993. Timing of nest searching for upland-nesting waterfowl. Journal of Wildlife Management 57:597-601.

Green, R.E. 1989. Transformation of crude proportions of nests that are successful for comparison with Mayfield estimates of nest success. Ibis 131: 306-306.

Greenwood, R.E. 1986. Influence of striped skunk removal on upland duck nest success in North Dakota. Wildlife Society Bulletin 14: 6-11.

Greenwood, R.J., A.B. Sargent, D.H. Johnson, L.M. Cowardin and T.L. Shaffer. 1987. Mallard Nest Success and Recruitment in Prairie Canada. Transactions of North American Wildlife and Natural Resources Conference 52:298-308.

Greenwood, R.J., A.B. Sargent, D.H. Johnson, L.M. Cowardin and T.L. Shaffer. 1995 Factors Associated with Duck Nest success in the Prairie Pothole Region of Canada. Wildlife Mongraphs 128:1-57.

Hayden, B. P., R. D. Dueser, J. T. Callahan and H. H. Shugart. 1991. Long-term research at the Virginia Coast Reserve. Bioscience 41:310-318.

Helmers, D. L. and C. L. Gratto-Trevor. 1996. Effects of predation on migratory shorebird recruitment. Transactions of the North American Wildlife and Natural Resources Conference 61: 50-61.

Heusmann, H. W. 1974. Mallard-black duck relationships in the Northeast. Wildlife Society Bulletin 2:171-177.

Hill, L. 1985. Breeding ecology of Interior Least Terns, Snowy Plovers, and American Avocets at Salt Plains National Wildlife Refuge, Oklahoma. M.S. Thesis. Oklahoma State University, Stillwater Oklahoma.

Heusmann, H. W. and J. R. Sauer. 2000. The Northeastern States' Waterfowl Breeding Population Survey. Wildlife Society Bulletin 28: 355-364.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries and I. J. Ball. 2002. Sensitivity analysis of the life cycle of mid-continent mallards. Journal of Wildlife Management 66: 883-900

Hothem and Welsh. 1994. Duck and shorebird reproduction in the grasslands of central California. California Fish and Game 80(2): 68-79.

Howe, M.A. 1981. Social organization in a nesting population of eastern Willet (Catoptrophorus semipalmatus). The Auk 99: 88-102.

Jackson, D.B. and R.E. Green. 2000. The importance of the introduced hedgehog (*Erinaceus europaeus*) as a predator of the eggs of waders (Charadrii) on machair in South Uist, Scotland. Biological Conservation 17(2) 151-166.

Johnsgard, P.A. 1967. Sympatry changes and hybridization incidence in mallards and black ducks. American Midland Naturalist 77:51-63.

Johnsgard, P.A. and R. Disilvestro. 1976. Seventy-five years of changes in Mallard-Black Duck ratios in eastern North America. Am. Birds 30: 906-908.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Johnson, M.A., T.C. Hinz and T.L. Luck. 1987. Duck nest success an predators in North Dakota, South Dakota, and Montana: the Central Flyway study. Pages 123-133 in Eighth Great Plains in Wildlife damage control workshop proc., Rapid City, S.D. United States Forest Service General. Technical Report. RM – 154.

Johnson, D.H., A.B. Sargeant and R.J. Greenwood. 1989. Importance of individual species of predators on nesting success of ducks in the Canadian Prairie Pothole Region. Canadian Journal of Zoology 67(2): 291-297.

Johnson, D. H., J. D. Nichols and M. D. Schwartz. 1992. Population dynamics of breeding waterfowl. Pages 446-485 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, USA.

Kaczynski, C.F., and E.B. Chamberlain. 1968. Aerial surveys of Canada Geese and Black Ducks in eastern Canada. U.S. Fish and Wildlife Service Special Scientific Report - Wildlife No. 118, Washington, DC.

Keiss, O. 2000. Mammalian Predator Abundance on the Virginia Barrier Islands in Relation to Breeding Habitats of Colonial Birds. Masters of Science Thesis. Utah State University.

Klett, A.T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitatas in the Prairie Pothole Region. U.S. Fish and Wildlife Service, Washington, D.C.

Krementz, D.G. and G.W Pendleton. 1991. Movements and survival of American black ducks and Mallard broods on Chesapeake Bay. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Administration 45: 156-166.

Krementz, D. G., V. D. Stotts, D. B. Stotts, J. E. Hines and S. L. Funderburk. 1991. Historical changes in laying date, clutch size, and nest success of American Black Bucks. Journal of Wildlife Management 55:462-466.

Krementz, D. G., V. D. Stotts, Pendleton, G.W. and J. E. Hines. 1992. Comparative productivity of American black ducks and mallards nesting on Chesapeake Bay islands. Canadian Journal of Zoology 70 225-228.

Laperle, M. 1974. Effects of water level fluctuation on duck breeding success. Pages 18-30 in H. Boyd, ed. Canadian Wildlife Service waterfowl studies in eastern Canada, 1969-73. Report Series No. 29. Canadian Wildlife Service.

Larson, M.A., M.R. Ryan and R.K. Murphy. 2002. Population viability of piping plovers: Effects of predator exclusion. Journal of Wildlife Management 66(2): 361-371.

Liebherr, J.K. and R. Takumi. 2002. Introduction and Distributional Expansion of Trechus obtusus (*Coleoptera Carabidae*) in Maui, Hawai'i. Pacific Science 56(4): 365-375.

Lokemoen, John T. and Robert O. Woodward. 1992. Nesting waterfowl and water birds on natural islands in the Dakotas and Montana. Wildlife Society Bulletin 20:163-171.

Longcore, J. L., D. G. McAuley, G. R. Hepp and J. M. Rhymer. 2000. American Black Duck (*Anas rubripes*) *In* The Birds of North America, No 481 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philapelphia, PA.

Loiselle, B.A. and W.G. Hopps. 1983. Nest Predation in Insular and Mainland Lowland Rainforest in Panama. Condor 85(1): 93-95.

Loos, E. R. and F. C. Rohwer. 2004. Laying stage nest attendance and the onset of incubation in prairie nesting ducks. The Auk 121: 587-589.

Lowther, P., H. D. Douglas III and C. L. Gratto-Trevor. 2001. Willet (*Catoptrophorus semipalmatus*) *In* The Birds of North America, No 579 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philapelphia, PA.

Mabee, T.J. 1997. Using eggshell evidence to determine nest fate of shorebirds. Wilson Bulletin 109(2): 307-313.

MacIvor, L.H., C.R.Griffin and S. Melvin. 1987. Management, habitat selection, and population dynamics of Piping Plovers on outer Cape Cod, Massachusetts, 1985-87. Unpubl. report. Department of Forestry and Wildlife Management, Univ. of Massachusetts, Amherst, Massachusetts.

Maissoneuve, C., A. Desrosiers and R. McNicoll. Habitat Use, Movements, and Survival of American Black Duck, Anas rubripes, and Mallard, *A. platyrhynchos*, Broods in Agricultural Landscapes of Southern Quebec. Canadian Field-Naturalist 114(2): 201-210.

Martin, T.E. 1987. Artificial Nest Experiments: Effects of Nest Appearance and Type of Predator. Condor 89(4): 925-928.

Martin, J.L. and M. Joron. 2003. Nest predation in forest birds: influence of predator type and predator's habitat quality. Oikos 102(3): 641-653.

Melvin S., L. MacIvor and C. Griffin. 1992. Predator exclosures: a technique to reduce predation at Piping Plover nests. Wildlife Society Bulletin. 20:143–148.

Miller, M.W. 1996. Effects of habitat change on population dynamics of waterfowl in mid-continental North America: A landscape approach. Ph.D. Dissertation, University of Guelph, Guelph, Ontario.

Murphy, R.K., R.J. Greenwood, J.S. Ivan and K.A,.Smith. 2003. Predator Exclusion Methods for Managing Endangered Shorebirds: Are Two Barriers Better than One? Waterbirds 26(2): 156–159.

Niehaus, A. C., D.R. Ruthrauff, and B.J. McCaffery. 2004. Response of Predators to Western Sandpiper Nest Exclosures. Waterbirds 27(1): 79-82.

North American Waterfowl Management Plan. 1986. Environment Canada. Ottawa, Ontario, Canada.

Page, G.W. and L.E. Stenzel and C.A. Ribic. 1985. Nest site selection and clutch predation in the Snowy Plover. Auk 102:347-353.

Paton, P.W.C. 1995. Breeding biology of Snowy Plovers at Great Salt Lake, Utah. Wilson Bull. 107:275-288.

Petrie, M. J., R. D. Drobney and D. T. Sears. 2000. Mallard and black duck breeding parameters in New Brunswick: a test of the reproductive rate hypothesis. Journal of Wildlife Management 64:832-838.

Pöysä, H. 2003. Parasitic common goldeneye (*Bucephala clangula*) females lay preferentially in safe neighborhoods. Behavioral Ecology and Sociobiology 54(1): 30–35.

SAS version 9.00. 2002. PROC t-test. SAS Institute,

Pearse, A.T., and J.T. Ratti. 2004. Effects of predator Removal on Mallard Duckling Survival. Journal of Wildlife Management 68(2) 342 – 350.

Ray, J. 2000. Mesocarnivores of Northeastern North America: Status and Conservation Issues. WCS working Paper No. 15.

Reed, A. 1975. Reproductive output of Black Ducks in the St. Lawrence estuary. Journal of Wildlife Management. 39: 243-255.

Reynolds, R. E., T. L. Shaffer, R. W. Renner, W. E. Newton and B. D. J. Batt. 2001. Impact of the conservation reserve program on duck recruitment in the U.S. prairie pothole region. Journal of Wildlife Management 65:765-780.

Ricklefs, R.E. 1969. Preliminary Models for Growth Rates in Altricial Birds. Ecology 50(6): 1031-1039.

Rimmer, D.W. and Deblinger, R.D. 1990. Use of predator exclosures to protect Piping Plover nests. Journal of Field Ornithology 61: 217–223.

Ringelman, J. K., J. R. Longcore and R. B. Owen, Jr. 1982. Nest and brood attentiveness in female black ducks. Condor 84:110-116.

Robertson, G. 1995. Factors affecting nest site selection and nesting success in the common eider (*Somateria mollissima)*. Ibis 137(1): 109-115.

Rose, M. D. and G. A. Polis. 1998. The distribution and abundance of coyotes: the effects of allochtonous food subsidies from the sea. Ecology 79:998 –1007.

Ruthrauff D. R. 2002. Seasonal and age-related trends in the reproductive output of Western Sandpipers (Calidris mauri) Kanaryarmiut, Alaska. Unpublished M.Sc. Thesis. Department of Wildlife, Humboldt State University, Arcata, CA.

Rohwer, F. C., J. Scarth and R. Olson. 2004. Seasonal reduction of medium-sized mammalian predator populations to enhance waterfowl production – an evaluation of biological factors and barriers to adoption. Transactions of the 69th North American Wildlife and Natural Resources Conference 69

Samelius, G. and M. Lee. 1998. Arctic Fox, (*Alopex lagopus*), Predation on Lesser Snow Geese, Chen caerulescens, and their Eggs. Canadian Field-Naturalist 112(4): 700-701.

Samelius, G. and Ray T. Alisauskas. 2001. Deterring arctic fox predation: the role of parental nest attendance by lesser snow geese. Canadian Journal of Zoology 79(5): 861-866.

Samelius, G. and R.T. Alsauskas. 2000. Foraging Patterns of Arctic foxes at a large snaow goose colony. Arctic 53(3): 279-288.

Sandercock, B.K. and C.L. Gratto-Trevor. Local survival in semipalmated sandpipers, Calidris pusilla, breeding at La Perouse Bay, Canada. Ibis 139(2): 305-312.

Sargeant, A.B., R.J. Greenwood, M.A. Sovada and T.L. Shaffer. 1993. Distribution and abundance of predators that affect duck production in the prairie pothole region. United States Department of the Interior, Fish and Wildlife Service. No .194.

Sargeant A.B., M.A. Sovada and T.L. Shaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildlife Society Bulletin 23:507–513.

Seymour, N. and W. Jackson. 1996. Habitat-related variation in movements and fledging success of American black duck broods in northeastern Nova Scotia. Canadian Journal of Zoology 74(6): 1158-1164.

Sieving, K.E. and M.F. Willson. 1998. Nest predation and avian species diversity in northwestern forest understory. Ecology 79(7): 2391-2402.

Skel, M.A. 1983. Nesting success, density, philopatry, and nest-site selection of the Whimbrel (Numenius phaeopus) in different habitats. Canadian Journal of Zoology 61(1): 218-225.

Slagsvold, T. 1982. Clutch size variation in passerine birds: The nest predation hypothesis. Oecologia 54(2): 159-169.

Stotts, V.D. and D.E. Davis. 1960. The black duck in the Chesapeake Bay of Maryland: breeding behavior and biology. Chesapeake Science 1:127-154.

Tremblay, J.P., G. Gauthier, D. Lepage and A. Desrochers. 1997. Factors affecting nesting success in Greater Snow Geese: Effects of habitat association with Snowy Owls. Wilson Bulletin 109(3): 449-461.

VanderWerf, E.A. 2001. Rodent control reduces predation on artificial nests in O`ahu `Elepaio habitat. Journal of Field Biology 72:448-457.

Weller, M.L. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20:111-113.

Whitaker Jr., J. O. and W. J. Hamilton, Jr. 1998. Mammals of the Eastern United States. Third edition. Cornell University Press, Ithaca, New York.

Wilcove, D.S. 1985. Nest predation on forest tracts and the decline of migratory songbirds. Ecology 66(4): 1211-1214.

Wilke, A.L., B.D. Watts, B.R. Truitt and R. Boettcher. 2005. Breeding Season Status of the American Oystercatcher in Virginia, USA. Waterbirds 28(3): 308-315.

Williams, B., J. W. Akers, R. A. Beck and J. W. Via. 1996. The 1996 beach-nesting and colonial waterbird survey of the Virginia barrier islands. Raven 68(1):85 –88.

Williams, B., B. Akers, M. Beck, R. Beck and J. Via. 2003. The 2003 Beach-nesting and colonial waterbirds survey of the Virginia barrier islands. Raven 74(1): 61-66.

Williams, B., B. Akers, M. Beck, R. Beck and J. Via. 2004. A summary of the 2004 beach-nesting and colonial waterbirds survey of the Virginia barrier islands. Raven 75(2): 53-57.

Wilson, G.R., M.C. Brittingham and L.J. Goodrich. 1998. How Well Do Artificial Nests Estimate Success of Real Nests? Condor 100(2):. 357-364

Zoellick, B.W., H.M. Ulmschneider, B.S. Cade, and A.W. Stanley. Isolation of Snake River Islands and Mammalian Predation of Waterfowl Nests. Journal of Wildlife Management 68(3): 650-662.

Appendix: Island Summaries

Metompkin Island

In two field seasons, Metompkin Island yielded 123 nests including ten Mallard nests, five American Black Duck nest and 2 unknown dabbling duck nests. In both 2004 and 2005, Metompkin Is. supported the largest number of Willet nests and maintained the second highest shorebird nest density among all nine plots. The high artificial nest success observed in 2004 of 90.0%, fell sharply in 2005 to 59.5% (n=36). These findings mirrored the decrease in apparent, Mayfield and adjusted apparent nest success for dabbling ducks between the two years (Table 2). There was evidence of both raccoon and fox activity during the study including tracks, cached waterfowl parts and both artificial and real deprecated nests. Metompkin Island was trapped in both 2004 and 2005. (plot = 50.9 ha)

Wreck Island

In both years, Wreck Island produced the highest Willet nest density and second highest number of Willet nests. However, only one American Black Duck nest was found on the plot in each year. Much driven by Willet nesting, Wreck Island had provided the highest total nest density among all nine plots for both years. In both years, predator activity appeared to be fairly low, with artificial nest success of 73.7 % in 2004 and 92.8% in 2005 (n = 19). (plot = 23.5 ha.)

Cobb Island

Cobb Island had the second highest overall nest density in 2004 and the third highest in 2005 among all plots. This plot also produced the second highest number of nest attempts for dabbling ducks in both years (Table 4). Apparent nest success decreased between 2004 and 2005 for all groups. Predator activity appears to be moderate, with Artificial nest success of 50.0% in 2004 and 62.5% in 2005 (n = 16). (plot = 21.3 ha.)

Hog Island

Despite having total land area, nesting cover and inland fresh water comparable to Cobb Island, predator activity in both years was higher on Hog Island and appeared to impact duck production. Artificial nest success on Hog Island was 20.8% in 2004 and 2.8% in 2005 (n = 24). The apparent nest success for dabbling ducks on Hog Island was 22.2% in 2004 and 14.3% in 2005 (Table 5). While nine duck nests were found on Hog in 2004, none were active so Mayfield calculations for dabbling ducks were not possible for that year. In comparison, apparent duck nest success on Cobb Island was 66.7% in 2004 and 50.0% in 2005 (Table 4). Despite similar habitat on the two islands and relatively high nest density on Hog Island, high predator activity had a strong impact on duck production on Hog Island. The differences in predator activity and nest success between Hog and Cobb Island, juxtaposed with fairly high densities of duck nests suggest that predator activity has a strong impact on duck production. (plot = 31.47 ha.)

Fishermans Island

Mayfield nest success for dabbling ducks was low on Fishermans Island in both 2004 (4.8%) and 2005 (14.0%, Table 5). A variety of nest predators including raccoon, coyote, freshwater otters and black rat snakes have been observed in both seasons on Fishermans Island. Predator activity was similar in both years with artificial nest success rates of 44.4% in 2004 and 44.7% in 2005 (n = 40). (plot = 55.17 ha.)

Smith Island

Despite abundant inland fresh water and relatively good nesting cover, only a single American Black Duck nest and one Canada Goose nest was found on the Smith Island plot over the two year study period. Artificial nest success was low on Smith Island with 29.4% in 2004

and 5.0% in 2005 (n = 17). Nest predators observed on the island included raccoons, foxes and black rat snakes. (plot = 22.49 ha.)

South Cobb Island

No dabbling duck nests were found on the island during the two-year study period. Although nest density was consistent for Canada Goose over the two years, they experienced large variation in nest success (Table 8). Almost no mammal scat was observed on this plot despite the significantly low levels of artificial nest success (2004 = 17.4%, 2005 = 33.37%, n = 26)). The discrepancy between predator activity and nest success may be due to a difference in the predator community on Smith Island. South Cobb Island supported a large gull colony and least weasel tracks were also observed. Avian predators and small carnivorous mammals may impact artificial nests while not impacting real nest success because of the presence of attending parents at real nests. (plot = 29.62 ha.)

Rogue and South Hog Island

The Rogue and South Hog Island plot provided the lowest nest density and the second lowest artificial nest success for both 2004 (17.1%) and 2005 (0.04%) of all the nine study plots (n = 48). The small sample size of both real and artificial nests on Parramore Island likely bias the results. In both years, a single successful dabbling duck nest yielded inflated Mayfield nest success estimates for that group. (plot = 63.5 ha.)

Parramore Island

This small island plot (6.3 ha) has limited searchable habitat and is mostly dominated by wetland, deciduous hardwood and coastal beach. A lack of nesting habitat resulted in very low sample sizes for both real nests and artificial nests. No dabbling duck nests were found on the plots in either years. Only 1 Willet nest was found during 2004 and 3 Willet nests were found in

2005. Thus, the resulting high predation rates of and low artificial nest success (0.0% in both

years) may not be comparable to other plots (n = 6). (plot = 6.3 ha.)

Vita

Brian has a strong education in both theoretical and applied science complimented with wildlife research and site assessment experience throughout North America and the Caribbean. His graduate course work has included Environmental Conflict Resolution and Statistical Analysis of Biological Data. His experience includes technical and analytical expertise in habitat assessments, EIA, mitigation, site prescriptions and advanced mapping techniques. Brian's written abilities include funding proposals and publications in both refereed and popular journals. He has enjoyed previous positions with municipal, provincial, state and federal agencies in Canada and the United States. His opportunities for professional collaborations have involved native peoples and international partnerships.