MAMMALIAN PREDATOR DISTRIBUTION AND ABUNDANCE ON THE VIRGINIA BARRIER ISLANDS IN RELATION TO BREEDING HABITATS OF COLONIAL BIRDS

by

Oskars Keišs

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Ecology

Approved:

Raymond D. Dueser
Major Professor

James A. MacMahon
Committee Member

Michael R. Conover
Committee Member

Eric M. Gese
Committee Member

Thomas L. Kent
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2001

ABSTRACT

Mammalian Predator Abundance on the Virginia Barrier Islands

in Relation to Breeding Habitats of Colonial Birds

by

Oskars Keišs, Master of Science

Utah State University, 2000

Major Professor: Dr. Raymond D. Dueser
Department: Fisheries and Wildlife

The predator distribution, abundance, and impact on colonial nesting birds on the Virginia barrier islands (Virginia, USA) were studied by track surveys and live-trapping of raccoons (*Procyon lotor*). Six surveys on 23 islands were carried out between October 1998 and June 2000, and 57 raccoons were captured during 1062 trapnights on 8 islands and 2 mainland sites. Raccoons were found on 18 islands, American mink (*Mustela vison*) on 8, red fox (*Vulpes vulpes*) on 6, and northern river otter (*Lutra canadensis*) on 6. Birds avoided islands with raccoons and red foxes (Spearman rank correlation 1999: $n = 13$; $r_s = -0.56$; $p = 0.05$; 2000: $n = 14$; $r_s = -0.79$; $p < 0.002$). Raccoon relative abundance was best correlated ($r = 0.99$, $p < 0.001$) with the area of the salt marsh. Islands with raccoons had more shrubs and were higher in elevation than islands without. One possible management solution to protect birds on some smaller islands is the removal of predators.

(98 pages)

To the memory of my friend Juris Ceihners (1973–1998)

ACKNOWLEDGMENTS

This project was 49% funded by the Virginia Coastal Resources Management Program of the Department of Environmental Quality through Grant #NA77OZ0204 of the National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the author and do not necessarily reflect the views of NOAA or any of its subagencies. Virginia Coast Reserve Long Term Ecological Research Program (VCR–LTER) at the University of Virginia provided boat–time and accommodations for researchers during the study. The Nature Conservancy (TNC) provided boat–time and accommodations on Hog Island. The Jack H. Berryman Institute and Utah State University (USU) provided field equipment for trapping and tracking animals. During the study the author was supported by the Fulbright Scholarship and research grant mentioned above.

I am grateful to my committee: Michael Conover, Raymond Dueser, Eric Gese, and James MacMahon for comments on earlier drafts of the manuscript. I especially thank my major professor, Raymond Dueser, for introducing me to the Virginia barrier island ecosystem. Discussions and comments from Nancy Moncrief (Virginia Museum of Natural History) were encouraging in early stage of writing. Ruth Beck (College of William and Mary, Virginia) and Bill Williams (Virginia Ornithological Society) also provided valuable comments on the earlier drafts of the manuscript.

Eli Fenichel, Randall Schultz, Jr., Erica Peterson, and I carried out most of the fieldwork. Working on the islands would not have been possible without the help of Barry Truitt (TNC), who shared his field experience on the islands and operated many boat rides. Boats were operated also by Richard Ayers, Ricky Kellam and Marcus Killmon (TNC), and Randolph Carlson and James Spitler (VCR-LTER). Patrick Brannon (Virginia Museum of Natural History), Mads Thomsen (University of Virginia), Ruth Beck (College of William and Mary), Justin Crump (USU), Philip Smith (TNC), and Calvin Brennan (Fishermans Island National Wildlife Refuge) also did some of the predator track surveys. Crews of 25th and 26th colonial waterbird surveys – Bill Akers, Michael Beck, Ruth Beck, Sue Rice, Jerry Via, and Bill Williams – allowed us to participate in the surveys and provided to me their unpublished data of colony and bird numbers on the islands as well as kindly shared observations of predators and their tracks during their bird survey.

Thomas DeLiberto trained me and Raymond Dueser in handling and immobilizing mammalian predators at the Millville station of USU. John Porter, director of the VCR-LTER program, assisted with the sampling design and provided the C-CAPS satellite imagery.

Janis Viksne and Aivars Mednis (University of Latvia) shared their experience on waterfowl management. Fellow graduate student Brian Silliman (University of Virginia and Brown University) provided valuable comments and personal observations on salt marsh invertebrate fauna. Janis Skujinš (USU) corrected my English from a Latvian perspective, before final corrections by my committee members. He and his wife, Irena Skujina, also helped me solve logistic problems during my studies in Logan, Utah. Finally, thanks to my family and all friends in Latvia for remembering me and giving me moral support while I was so far away from home.

Oskars Keišs

FOREWORD

Birds inhabiting wetlands have experienced overhunting, habitat loss, and disturbance during breeding, migration, and wintering seasons. Market-hunting, agriculture, and recreation have contributed to this destruction, serving the unsatisfied appetite of humans. Introductions of exotic species and an increase in the numbers of ubiquitous species taking advantage of human-altered habitats have also contributed to the loss of biodiversity.

The Atlantic Coast of North America has experienced large-scale human disturbance. Hardly any undisturbed landscapes remain with the exception of the Virginia Coast Reserve of The Nature Conservancy. Still, ecosystems are connected, and even protected areas suffer from the consequences of human-caused changes outside these reserves. We believe that raccoon populations have flourished as a result of an unlimited food supply in combination with reduced hunting by modern-day people. The increase in small- to medium-sized predator numbers have placed heavy pressure on wild bird populations in all of temperate North America.

The management of predators on the Virginia barrier islands represents a major challenge to biodiversity protection in the modern world, where ecosystems are heavily impacted by direct and indirect consequences of actions of a single, widespread, and opportunistic species – *Homo sapiens*.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Predators and Waterbirds

The influence of humans on various ecosystems has caused changes in predator populations (Whitaker and Hamilton 1998). Several species of predators have declined in human-modified ecosystems [e.g., wolf (*Canis lupus*), Peregrine Falcon (*Falco pregrinus*)], while others [both native predators, e.g., red fox (*Vulpes vulpes*) in Western Europe, and human-introduced predators, e.g., American mink (*Mustela vison*) in Europe] have increased in numbers and are causing severe problems for other species (Reynolds and Tapper 1996).

The negative impacts of mammalian predators on waterfowl (*Anatidae*, Sovada et al. 1995; V? ksne 1997), gulls (*Laridae*, Craik 1997) and waders (*Charadridae*, Patterson et al. 1991) have been documented worldwide. Various species of predators have had different levels of impact in each situation. When introduced to predator-free islands, predators often cause complete reproductive failure in avian colonies (Craik 1997; V? ksne 1997). Although breeding birds or their eggs may not be the major part of the diet of predators, frequent predation during the breeding season can cause serious declines of bird populations (Yanes and Su?rez 1996).

The red fox is a very efficient predator on ground-nesting birds (Sargeant et al. 1984). It both depredates nests and kills breeding female ducks (Fleskes and Klaas 1993; Sovada et al. 1995), gulls (Southern et al. 1985), and shorebirds (Loegering and Fraser 1995). In northern circumpolar regions, the arctic fox (*Alopex lagopus*) is a common predator of nesting birds (e.g., Bailey 1992). When introduced in southern boreal and temperate forests of Europe, the raccoon-dog (*Nyctereutes procyonoides*) also has been shown to be an efficient predator on ground-nesting birds (V? ksne 1997). In temperate North America, the raccoon (*Procyon lotor*) depredates nests of both arboreal and ground-nesting birds (Gaston and Masselink 1997; Hartman et al. 1997). An important predator in wetlands is the American mink (Sayler and Willms 1997). Birds are much more vulnerable to predation by exotic predators—such as the arctic fox on Aleutian Islands (Bailey 1992) and the American mink, raccoon-dog, and raccoon in Europe (Kauhala 1996; Craik 1997; V? ksne 1997).

Small, isolated islands often lack mammalian predators, or even any terrestrial mammals, because of isolation and insufficient food resources. For example, Kadlec (1971) indicated that it is difficult to maintain mammalian predator populations on islands off the Massachusetts coast. However, coastal habitats may receive sufficient nutrient resources from the sea to sustain animal populations at high densities relative to the same area of inland habitat (Rose and Polis 1998). Coastal ecosystems are also subject to severe weather events, such as hurricanes and "northeasters," which may cause periodic extinction of terrestrial mammals. Mainland mammalian populations in coastal habitats quickly reestablish themselves after such extinctions (Swilling et al. 1998) due to a lack of dispersal barriers and sufficient source populations. Coastal islands, however, have a serious barrier for non-flying terrestrial animals: the water (Lomolino 1986). Allen and Sargeant (1993) in North Dakota found that even a terrestrial barrier, such as an interstate highway, could play a significant role in preventing dispersal of red foxes.

Predator control in both mainland and island habitats has been an ongoing issue in waterfowl management for years, escalated by a decline in interest in hunting and trapping of furbearers (Whitaker and Hamilton 1998) and introduced predator species, especially in Europe (Scotland– Craik 1997; Finland– Kauhala 1996; and Latvia– V? ksne 1997). Different methods have been applied to reduce mammalian predator numbers and to reduce the impact of these predators on birds, including removal of predators, translocation of predators, and fencing of nesting areas.

Removal of predators can increase nesting success of waterfowl (Balser et al. 1968). It is especially effective when conducted on islands before the start of the breeding season. Unfortunately, it is labor-intensive and requires constant annual effort, particularly in areas where ice bridges form between islands and the mainland during the winter (V? ksne 1997).

Under pressure from animal rights groups, predator translocation has been tried as an alternative to killing predators and nuisance animals. Mosillo et al. (1999) showed that survival of translocated raccoons was comparable to that of non-translocated animals. Furthermore, none of the translocated raccoons returned to the initial capture site [distance between capture and release site not given (Mosillo et al. 1999)]. Thus translocation of mammals might be effective in reducing predator numbers in one location, but may inflate predator numbers in the release area. Kaufmann (1990) reported that translocated raccoons did not show homing ability; homing by translocated avian predators has been frequently documented (e.g., V? ksne 1997). There are also growing concerns about the role of translocations in the spread of diseases (Cunningham 1996) and mixing of gene pools (Griffiths et al. 1996).

Construction of artificial barriers, such as fences and moats, in combination with removal of mammalian predators may significantly increase nesting success of ducks (Lokemoen and Woodward 1993). However, construction of fences, especially for exclusion of climbing mammals such as raccoons, is an expensive undertaking. Electrified fences are effective (Forster 1975), but difficult to use in a saltwater environment.

Background

The Virginia barrier islands ecosystem, including the barrier islands, salt marshes, lagoons, and adjacent mainland, has experienced far less human disturbance than any other barrier island – salt marsh system on the Atlantic coast of North America (Dueser 1990). Commercial hunting for meat and plume had almost expatriated many bird species from the islands at the turn of the century, but avian populations recovered after the implementation of hunting regulations and conservation at the beginning of the 20^{th} century (Barrier Island Avian Partnership, in litt.). All permanent human inhabitants abandoned the islands in the late 1930s - early 1940s after a series of disastrous hurricanes in the middle of 1930s (Barnes and Truitt 1997).

Colonial waterbird populations on the Virginia barrier islands, specifically common terns (*Sterna hirundo*), gull-billed terns (*Gelochelidon nilotica*), royal terns (*Sterna maxima*), sandwich terns (*Sterna sandvicensis*), least terns (*Sterna antillarum*), and black skimmers (*Rynchops niger*), have been studied for the last 2 decades (Williams et al. 1990; Barrier Island Avian Partnership, in litt.). Continuous population declines have been observed (Fig. 1). From 1977 to 1998 the number of tern

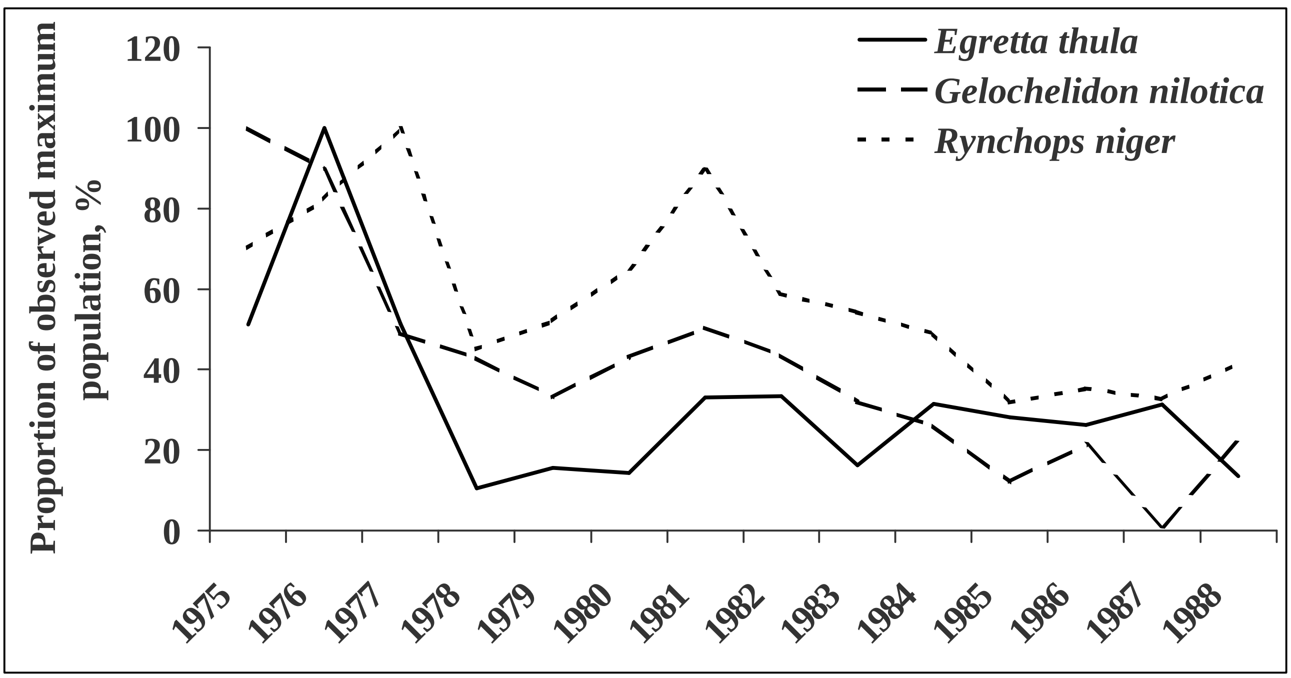

Fig. 1.–Changes in numbers of 3 bird species: snowy egret (*Egretta thula*), gull-billed tern (*Gelochelidon nilotica*), and black skimmer (*Rynchops niger*) on the Virginia barrier islands between 1975 and 1988 (Williams et al. 1990).

and black skimmer (Fig. 2) colonies declined from 23 on 11 islands to 13 on 10 islands, and populations of 4 of the 6 species studied decreased (Erwin et al., in press.).

Predation by mammalian predators is believed to be one of the major reasons for this decline, in combination with storms and tidal flooding, food limitation, and competition with species of larger size (Erwin et al. 1998). Erwin et al. (in press.)

Fig. 2.–Black skimmer (*Rynchops niger*) on Ship Shoal Island, July 5, 1999 (photo by the author).

blamed 2 mammalian predator species: the raccoon and the red fox. A 3rd species, the American mink, may also be involved. Craik (1997: 303) indicated that "mink predation is widespread but difficult to detect and should be considered as a possible cause when seabird colonies near the mainland decline and disappear."

Eleven islands were surveyed in the 1970s: Assawoman, Metompkin, Dawson Shoals, Parramore, Hog, Cobb, Little Cobb, Wreck, Myrtle, Smith, and Fisherman's. Raccoons were present on six of these islands: Assawoman, Parramore, Hog, Cobb, Little Cobb, and Smith. Red foxes were present on 3 islands: Assawoman, Parramore, and Hog (Dueser et al. 1979; Erwin et al., in press.).

An October 1998 survey showed that the raccoon was found on all 7 study islands (Cobb, Hog, Myrtle, Ship Shoal, Smith, Parramore, and Wreck), and the red fox on 2 [Parramore and Smith (Jim?nez, in litt.)]. A March 1999 survey of these 7 islands plus Metompkin Island, Cedar Sandbar and Little Cobb Island (Jim?nez et al., in litt.), detected raccoon tracks on Cedar Sandbar, Cobb, Hog, Myrtle, Ship Shoal, Smith, Parramore, and Wreck and red fox tracks on Cedar Sandbar, Metompkin, and Parramore. Red fox tracks were not found on Smith Island in the March 1999 survey (Jim?nez et al., in litt.). Using information from U.S. Fish and Wildlife Service (USFWS) personnel, Erwin et al. (in press.) concluded that there were no mammalian predators on Fishermans Island in 1998. Thus surveys of mammalian predators on islands in October 1998 and March 1999 indicated that predators might have colonized more islands since the 1970s.

Objectives

The primary objective of this study was to compile the information required to develop a predation management strategy for protection of nesting colonial waterbirds on the Virginia barrier islands, including information on predator distribution and movements. Specific objectives include the following:

(1) Document the interaction between mammalian predators and nesting colonial waterbirds on the Virginia barrier islands, including any apparent cases on island avoidance and abandonment by the birds;

(2) Describe predator distribution and abundance on the Virginia barrier islands and document any change between the 1970s and 1990s;

(3) Examine the relationship between predator abundance on the islands and island area, available habitat and isolation (distance from nearest mainland and distance from nearest island);

(4) Describe raccoon movements using radio-telemetry and examine possible island colonization scenarios;

(5) Examine differences in red fox and raccoon distribution on the Virginia barrier islands;

(6) Recommend possible management solutions for protection of nesting sites of colonial waterbirds.

Theoretical Hypotheses

(1) Bird numbers in colonies will be higher on islands with low predator abundance;

(2) Predator immigration rate varies inversely with island isolation – the more isolated the island, the lower will be the immigration rate;

(3) It is likely that the effect of "stepping stones" (MacArthur and Wilson 1967) will be observed. Thus both the minimum over-water distance from the mainland and the minimum over-water distance from the next island determine isolation;

(4) Predator extinction rates vary with island area – bigger islands will have fewer extinction events, lower turnover rates, and higher population numbers;

(5) Extinction rate varies inversely with the areas of different habitat types. Specifically, increased areas of forest and salt marsh could be beneficial for raccoons and red foxes; thus we would expect to see lower extinction rates and higher predator abundance on islands with increased forest and salt marsh areas;

(6) The predator population on a given island might be either a self-sustaining population or a sink population, in the terms of Pulliam (1988). In the first scenario, the population would rarely if ever reach carrying capacity, because of extreme seasonal events or frequent environmental disturbance by weather events (disturbance hypothesis of McGuinness 1984). In the 2nd scenario, seasonal shortages of resources (e.g., food during the breeding season) might prevent population increase. If the sink scenario is true, we expect to see lower numbers of animals when immigration is restricted (e.g., by open water barrier) and higher numbers when immigration is unrestricted.

(7) Islands (including the small ones) close to the mainland experience "rescue effect" (Brown and Kodric-Brown 1977; Hanski 1999); thus we expect to see predators there most of the time.

MATERIAL AND METHODS

Study Site

The Virginia barrier islands are located between the Delmarva Peninsula and Atlantic Ocean [centered approximately 37º 30' N and 75º 40' W (McCaffrey and Dueser 1990a)], in Accomac and Northhampton Counties, Virginia, USA (Fig. 3). The Virginia barrier islands are a chain of Atlantic coastal islands, ranging in size from 10 to 2000 ha (Table 1). The physiography of these islands consists of rolling, low-lying sand dunes and sand flats. Grasslands [mostly American beachgrass (*Ammophila breviligulata* Fern.)] and shrub thickets of southern wax myrtle (*Myrica cerifera* L.) and

Table 1.–*Area (ha) of 4 cover categories, total length (km), isolation (km) and elevation (m) of 23 Virginia barrier and marsh islands.*

Island	Bare sand	Shrubs and forest	Grass land	Sub-total	Salt marsh	Total area	Length km	Isolation, km: Main -land	Isolation, km: Next island	Elev m
Assawoman	102.8	9.6	1.7	114.1	101.4	215.5	5.1	1.7	0.1	
Cedar	217.7	12.5	7.9	238.1	1586.7	1824.8	11.1	2.9	0.4	3.4
Cedar Sandbar	39.5	0.0	0.0	39.5	0.0	39.5	1.9	2.5	0.1	
Chimney Pole	18.7	0.0	0.3	19.0	84.7	103.7	1.5	7.9	0.7	1.5
Cobb	157.4	74.5	124.1	356.0	232.4	588.4	9.2	11.8	0.9	2.1
Fishermans	93.1	106.5	154.4	354.0	286.8	640.8	6.8	(0.6)	2.0	3.1
Godwin	0.0	0.0	0.0	0.0	300.6	300.6	2.5	8.8	0.1	0.7
Hog	190.8	157.7	412.0	760.5	582.8	1343.3	13.6	11.6	0.9	3.0
Holly Bluff	0.0	1.0	3.2	4.2	8.9	13.1	0.9	0.2	0.2	
Little Cobb	19.0	0.0	1.5	20.5	5.9	26.4	1.4	10.5	0.7	0.9
Metompkin	229.1	0.0	0.0	229.1	133.9	363.0	11.3	1.2	0.1	2.1
Mink	0.3	0.6	1.1	2.0	250.9	252.9	0.7	10.2	0.8	1.2
Mockhorn	0.0	42.9	40.1	83.0	1350.6	1433.6	9.9	2.8	2.5	3.1
Myrtle	50.7	1.0	46.6	98.3	250.4	348.7	4.2	10.0	0.3	3.7
Parramore	225.6	433.6	3.9	663.1	1531.4	2194.5	12.1	7.5	0.4	9.1
Raccoon	0.0	8.7	7.0	15.7	42.3	58.0	0.8	0.4	0.2	1.9
Revel	0.7	12.8	0.6	14.1	425.6	439.7	3.0	7.3	0.3	3.0
Rogue	0.2	5.9	6.4	12.5	88.6	101.1	2.1	11.7	0.5	1.5
Sandy	10.5	0.0	0.0	10.5	42.5	53.0	1.9	7.5	0.7	
Ship Shoal	32.0	0.8	19.7	52.5	198.4	250.9	4.5	10.3	0.7	1.9
Skidmore	1.0	11.9	4.7	17.6	19.0	36.6	1.3	0.9	0.4	3.3
Smith	74.5	102.4	178.0	354.9	757.6	1112.5	12.4	2.8	1.8	2.4
Wreck	53.2	17.0	42.3	112.5	185.5	298.0	6.8	10.3	0.7	2.7

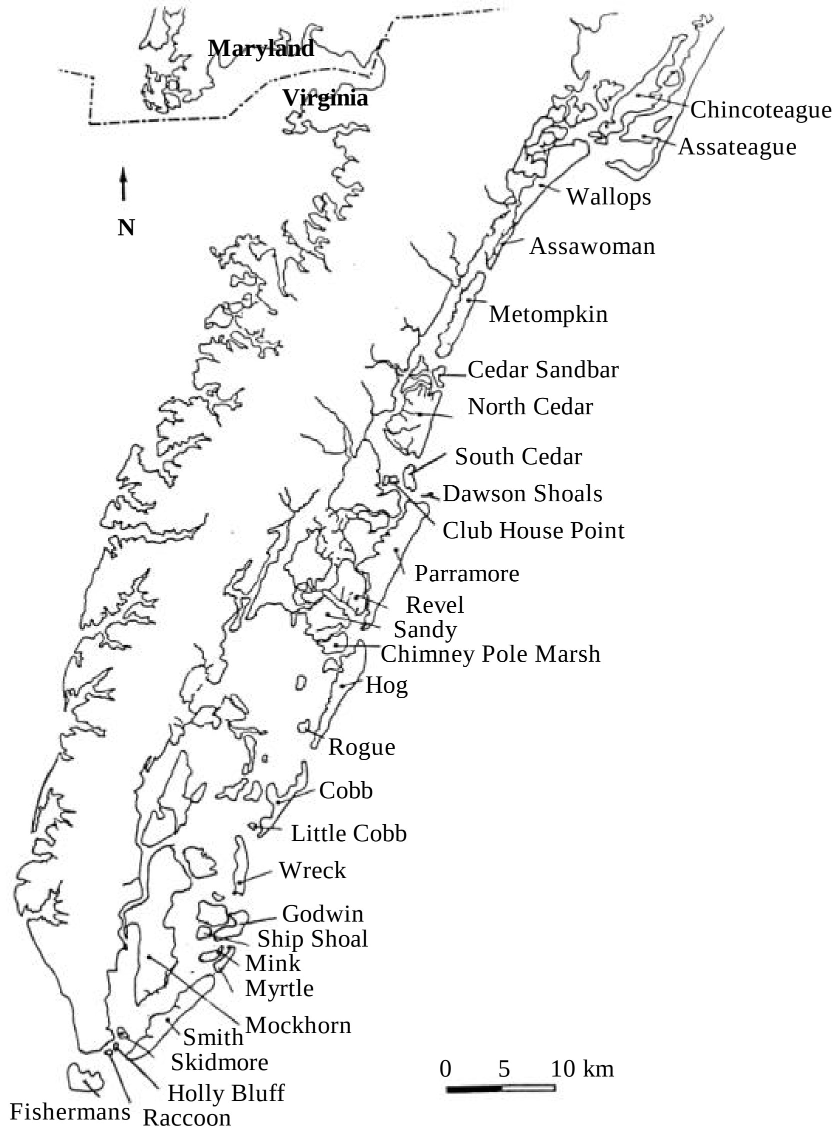

Fig. 3.–Delmarva Peninsula and Virginia barrier islands

northern bayberry (*Myrica pensylvanica* Loisel.) are the dominant vegetation types on most islands (Fig. 4). Forests of loblolly pine (*Pinus taeda* L.) and deciduous trees (*Acer rubrum* L., *Prunus maritima* Marshall, *Prunus serotina* Ehr., *Quercus* spp.) have developed on only two islands, Parramore and Smith, although scattered trees occur on several islands. Extensive salt marsh dominated by smooth cordgrass (*Spartina alterniflora* Loisel.) and saltmeadowcordgrass [*Spartina patens* (Aiton) Muhl.] occurs on the lagoon side of the islands. Shell (external skeleton of *Bivalvia*) formations are common on islands, building remarkable dune-like structures on Wreck Island (Fig. 5).

Fig. 4.–North end of Hog Island (photo by the author).

Fig. 5.–Shell piles on Wreck Island (photo by the author).

Predator Track Surveys on Islands

Mammalian predator presence and/or abundance was determined with a combination of sampling procedures. Systematic mammalian predator track surveys were initiated in October 1998 by Jiménez (in litt.), and continued periodically between March 1999 (Jiménez, in litt.) and June 2000 (Table A1). Systematic track surveys were performed on every island having a beach long enough (≥ 1.5 km) to accommodate this standard survey method. Each survey line consisted of five ~300 m segments (one line ~1500 m in total; distance determined by pacing). The number of lines per island was determined by island length, ranging from 2 lines on Myrtle and Ship Shoal islands up to 10 lines on Hog Island. Systematic track surveys were performed by walking on the beach immediately above the mean high tide line and scanning ~3 m wide swath of sand. Presence or absence of predator tracks was recorded on each segment. In addition to the October 1998 (Jiménez, in litt.) and March 1999 (Jiménez et al., in litt.) surveys, there were as many as 4 other potential survey periods during the present study: May–July 1999, September– November 1999, March 2000, and June 2000 (Table A1). There was one survey on each island per survey period. Mean percent frequency of tracks was calculated for each island for each survey period by taking the average of all lines on that island. Under most conditions this mean percent frequency provides a time-specific index of animal abundance and/or activity, with these variables confounded. In reality the interpretation of these data is subject to several constraints and limitations (see Discussion). Under the conditions of the present study, mean percent track frequency ("track frequency") appears to be closely related to animal abundance, and is therefore interpretable as an index of the relative abundance of animals on an island. Live trapping also was used to assess mammalian predator abundance (Table 2).

On small islands or islands where habitat type prevented systematic track surveys (no sandy beaches), presence or absence of mammalian predators was determined by observation of isolated tracks or presence of scat.

Trapping and Monitoring of Predators

Eight islands and 2 mainland sites were chosen for live trapping: Cobb, Hog, Mink, Myrtle, Parramore, Rogue, Ship Shoal, and Smith islands, and Brownsville and Cushman's Landing on the mainland. The islands were selected for sampling either

Table 2.–*Methods used to detect predator species presence and abundance on 23 Virginia barrier and marsh islands in 1999 – 2000.*

Island	Systematic track surveys	Presence / absence survey	Live trapping
Assawoman	x	x	-
Cedar	x	x	-
Cedar Sandbar	-	x	-
Chimney Pole	-	x	-
Cobb	x	x	x
Fishermans	x	x	-
Godwin	-	x	-
Hog	x	x	x
Holly Bluff	-	x	-
Little Cobb	-	x	-
Metompkin	x	x	-
Mink	-	x	x
Mockhorn	-	x	-
Myrtle	x	x	x
Parramore	x	x	x
Raccoon	-	x	-
Revel	-	x	-
Rogue	-	x	x
Sandy	-	x	-
Ship Shoal	x	x	x
Skidmore	-	x	-
Smith	x	x	x
Wreck	x	x	-

because of the apparent abundance of predators (Cobb, Hog, Myrtle, Parramore, Ship Shoal) or because they were immediately adjacent to other, populated, islands (Mink adjacent to Myrtle, Rogue adjacent to Hog). Trapping was conducted May through August 1999, except on Smith Island, where trapping continued in October and November 1999 in an attempt to recover nonfunctional radio-collars (Table 3).

Traps were placed in trapping stations (Fig. 6), 3 traps in each station. Traps in stations were approximately 200 m apart (distance was determined by pacing in the

Table 3.–*Trapping effort for mammalian predators on 8 barrier islands and 2 mainland areas of the Virginia Coast Reserve in 1999.*

Site	Location	Trapping session	Dates	No. of nights	No. of stations	No. of trap-nights	Tot.
Brownsville	Mainland	I	AUG 3 – AUG 5	3	5	39	
Cobb	Island	I	JUL 16 – JUL 19	4	13	152	
Cushman's	Mainland	I	AUG 2 – AUG 4	3	5	41	
Hog	Island	I	JUL 8 – JUL 10	3	14	103	
-"-	-"-	II	JUL 11 – JUL 14	4	13	138	=241
Mink	-"-	I	JUN 5 – JUN 7*	3	2	16	
Myrtle	-"-	I	JUN 5 – JUN 7*	3	6	51	
-"-	-"-	II	JUL 22 – JUL 23	2	2	12	=63
Parramore	-"-	I	JUL 28 – JUL 30	3	13	98	
Rogue	-"-	I	JUL 11 – JUL 14	4	2	21	
Ship Shoal	-"-	I	MAY 29 – JUN 1*	4	6	66	
-"-	-"-	II	JUL 22 – JUL 23	2	1	6	=72
Smith	-"-	I	JUN 15 – JUN 17	3	14	98	
-"-	-"-	II	JUN 26 – JUN 28	3	13	105	
-"-	-"-	III	JUL 1 – JUL 3	3	14	95	=298
-"-	-"-	-**	OCT 28 – OCT 29	2	3	12	
-"-	-"-	-**	NOV 10 – NOV 11	2	2	9	=21
Total:				51	128	1062	

* traps pre–baited for 2 nights before trapping
** trapping session to recover non-working radio–collars

Fig. 6.–Live-trap set on Cushman's landing trapping site (photo by the author).

field with a precision of ? 10 m). Trapping stations were 200– 400 m (distance chosen randomly) apart from each other. The number of trapping stations created on each island was determined by (1) beach length on the island and (2) total area of the island. All islands were sampled roughly proportional to their area and length, except Parramore, which was undersampled relative to the other islands. Trapping took place in all upland habitat types on each island, but the habitats were not proportionally sampled (Table 4). Most trapping occurred on the beach or ? 200 m behind the beach. Because most islands are = 1 km in width, the beach was sometimes adjacent to the bayshore marsh (Fig. 3.). We trapped primarily on the beach both because this is the

Table 4.–*Trapping effort for mammalian predators by habitat on the Virginia barrier islands in 1999.*

	Bare land/sand				Shrubs/forest				Grassland				Saltmarsh			
Island	area, %	trapsites, %	trap-nights, %	captures, %	area, %	trapsites, %	trap-nights, %	captures, %	area, %	trapsites, %	trap-nights, %	captures, %	area, %	trapsites, %	trap-nights, %	captures, %
Cobb	26.8	52.6	52.6	0.0	12.7	7.9	7.9	0.0	21.1	26.3	26.3	0.0	39.5	13.2	13.2	0.0
Hog	14.2	45.2	46.9	16.7	11.7	16.1	12.0	0.0	30.7	32.3	34.9	83.3	43.4	6.5	6.2	0.0
Mink	0.1	16.7	12.5	0.0	0.2	16.7	18.8	0.0	0.4	33.3	31.3	0.0	99.3	33.3	37.5	0.0
Myrtle	14.5	25.0	22.2	0.0	0.3	0.0	0.0	0.0	13.4	30.0	34.9	0.0	71.8	45.0	42.9	100.0
Parramore	10.3	39.5	39.8	13.3	19.8	55.3	56.1	73.3	0.2	0.0	0.0	0.0	69.8	5.3	4.1	13.3
Rogue	0.2	0.0	0.0	0.0	5.8	16.7	19.1	0.0	6.3	33.3	33.3	0.0	87.6	50.0	47.6	100.0
Ship Shoal	12.8	27.8	30.6	0.0	0.3	0.0	0.0	0.0	7.9	22.2	27.8	0.0	79.1	50.0	41.7	0.0
Smith	6.7	45.2	43.6	61.5	9.2	11.3	6.6	11.5	16.0	32.3	38.6	26.9	68.1	11.3	11.3	0.0
Total:	11.8	41.6	41.9	38.0	12.5	17.2	12.6	28.0	12.8	25.6	30.7	24.0	62.9	16.4	15.1	10.0

locus of interaction between mammalian predators and nesting colonial waterbirds and because raccoons are so frequently observed actively foraging on the beach. For example, we observed 5 animals foraging on Parramore Island on March 14, 1999 (Jim? nez et al., in litt.).

Forty-three wire live traps ("Havahart," Woodstream Corporation, 69 N. Locust Street, Lititz, PA 17543, USA and Tomahawk Live Trap Co., P.O. Box 323, Tomahawk, WI 54487, USA) were used in trapping. Traps had following dimensions: 105x38x38 cm (3 traps), 100x30x30 cm (5 traps), 80x30x25 cm (19 traps), 100x20x20 (15 traps), and 75x30x30 (1 trap). Traps were baited with canned cat food, sardines, and maple syrup in summer, and fruits of wild common persimmon (*Diospyros virginiana* L.), apples, fish, and shrimp during the autumn trapping on Smith Island. On some islands, traps were pre-baited before actual trapping (Table 3), but this practice was discontinued because it did not increase capture success. Traps were set during the day and inspected the following morning. To avoid overheating of trapped animals, traps were covered with marsh wrack and shrub branches collected on the site (Fig. 6).

Each captured animal (Fig. 7) was immobilized by intramuscular injection of ketamine/acepromazine solution [10mL 100mg/mL ketamine (Ketaset®, Fort Dodge Laboratories, Inc., Fort Dodge, IA 50501, USA) + 1 mL acepromazine], using 0.1 mL solution per 1 kg of animal. Mass was estimated subjectively before immobilization. The animal was aged, sexed, weighed (with 5 kg spring-balance with 0.05 kg precision: Pesola AG, Rebmattli Straße 19, CH-6340 Baar, Switzerland), ear-tagged (tag style 893

Jiffy, size 3; National Band & Tag Co., 721 York Street, Newport, KY 41072, USA), and ear-clipped for future genetic study. The first premolar tooth was pulled

Fig. 7.–Animals were handled with care to avoid potential infection of the handler with rabies (photo by the author).

from each adult animal and sent to Matson's Laboratory (8140 Flagler Rd., Milltown, MT 59851) for age determination. Adult island and mainland animals were subjectively selected for radio-collaring, but we about equal numbers of males and females were radio-collared. Thirty radio-transmitters were used, including 20 manufactured by AVM Instrument Company, Ltd. (model P2RLM-4 Mortality; 2356 Research Drive, Livermore, CA 94550, USA) and 10 by Wildlife Materials, Inc. (model HLPM-2124; 1031 Autumn Ridge Road Carbondale, IL 62901, USA) with frequencies ranging between 150.800–151.800 MHz.

Radio-collared animals were tracked with collapsible, hand-held Yagi antennas and two radio-receivers (model: TRX-1000S, Wildlife Materials, Inc.). Island animals were tracked as often as possible, given the constraints of transportation and access (high tide). Animals on the mainland sites were radio-tracked periodically for 12 weeks. Three or more bearings of an animal were attempted on each tracking occasion to facilitate triangulation of exact location. Locations were computed with the "Locate" program. Attempts were made to incorporate all bearings collected in the field for determination of the estimated location of an animal. However, I estimated a location even when all bearings did not match perfectly: some bearings were arbitrarily dropped until a location was obtained.

Bird Surveys

The 25th and 26th annual colonial waterbird surveys were conducted by Williams et al. (in litt.) on June 20–23, 1999 and June 18–21, 2000, respectively. All islands were surveyed using the general methods of Williams et al. (1996). During the surveys, attempts were made to detect possible depredation of nests and/or adult colonial nesting birds by mammalian predators.

Data Analyses

The physical dimensions and land cover (habitat) composition on each island were determined using ArcView 3.1 analysis of National Oceanic and Atmospheric Administration Coastal Change Analysis Program (C-CAP) classified Landsat Thematic Mapper imagery (Dobson et al. 1999). Images of classified habitats for the southern islands from Hog Island southward were available from a 1993 satellite image; for islands from Parramore Island northward classified images of habitats were available from 1988 satellite images only. Island borders in continuous salt marsh were determined by locations of deep tidal creeks. In some cases, however, there were no clear borders between the adjacent salt marsh and the next island since large expanses of *Spartina* spp. grow between islands. In those cases, the borderline was drawn subjectively. Island length was measured as the length of the seaside beach for most islands, but was simply the maximum distance across for islands without beach (e.g., Mockhorn Island).

A Spearman rank correlation coefficient (Liepa 1974; Zar 1996) was calculated to test the hypothesized relationship between raccoon abundance and abundance of colonial waterbirds on the islands. Pearson product-moment correlation coefficients (Liepa 1974; Zar 1996) were calculated to test the hypothesized relationships between raccoon abundance and island characteristics. Predator and bird distribution on the islands in relation to island characteristics was tested by Kruskal-Wallis test (Zar 1996).

RESULTS

Track Surveys on Islands

Four wild mammalian predator species were recorded during at least 1 survey between October 1998 and June 2000: red fox on 6 islands (Assawoman, Cedar, Cedar Sandbar, Metompkin, Parramore, and Smith), raccoon on 19 (all but Assawoman, Godwin, Little Cobb, and Mink), American mink on 8 (Cobb, Fishermans, Hog, Mink, Myrtle, Ship Shoal, Smith, and Wreck), and northern river otter (*Lutra canadensis*) on 6 (Cobb, Hog, Metompkin, Mockhorn, Myrtle and Parramore). Wild mammalian predators thus were recorded on all but 2 of the all sampled islands, Little Cobb and Godwin (Table 5). One species was recorded on 10 islands, 2 on 6 islands, and 3 on 5. None of the islands had all 4 species recorded. Additionally, domestic dog (*Canis familiaris*) tracks were recorded on 9 islands (Table 5), where dogs frequently accompany their owners to the islands for day visits.

The total number of all surveys on each island ranged from 1 to 6 (Table 6). Surveys always detected the presence of raccoon tracks on Cedar, Fishermans, Hog, Parramore, and Smith islands, and always failed to detect raccoon tracks on Assawoman, Godwin, Little Cobb, Metompkin (but see Table 5), and Mink islands. Thus surveys in different seasons yielded the same results for raccoons on 66.7% of all islands. Surveys always detected red fox on Cedar, Metompkin, and Parramore islands, and always failed to detect the presence of red fox tracks on Chimney Pole, Cobb, Fishermans, Godwin, Hog, Little Cobb, Mink, Mockhorn, Myrtle, Raccoon, Rogue, Sandy, Ship Shoal, Skidmore, and Wreck islands.

Systematic track surveys in different seasons yielded the same results for red fox on 85.7% of all islands (Table 6). Systematic track surveys detected high variability in raccoon track abundance, both spatially and temporally (Table 7). Track on occupied islands ranged from 5% on Fishermans Island to 100% on Parramore and Smith islands. Track frequency declined from 80% in October 1998 to 22% in June 1999 on Hog Island, and from 70% in March 1999 to 0% in June 2000 on Myrtle Island (Table 7). This decline appeared to be independent of the amount of precipitation recorded during the 2 days prior to the survey (see Discussion for details). On average, raccoon tracks

Table 5.–*Mammalian predator species detected in track surveys on 23 Virginia barrier and marsh islands, October 1998 – June 2000 (including data from Jiménez, in litt. and Jiménez et al., in litt.).*

Island	Red fox	Domestic dog	Raccoon	American mink	River otter	Number of predator species*
Assawoman	x	–	–	–	–	1
Cedar	x	x	x	–	–	2
Cedar Sandbar	x	–	x	–	–	2
Chimney Pole	–	–	x	–	–	1
Cobb	–	x	x	x	x	3
Fishermans	–	–	x	x	–	2
Godwin	–	–	–	–	–	0
Hog	–	x	x	x	x	3
Holly Bluff	–	x	x	–	–	1
Little Cobb	–	–	–	–	–	0
Metompkin	x	x	–[1]	–	x	2
Mink	–	–	–	x	–	1
Mockhorn	–	–	x	–	x	1
Myrtle	–	x	x	x	x	3
Parramore	x	x	x	–	x	3
Raccoon	–	–	x	–	–	1
Revel	–	–	x	–	–	1
Rogue	–	–	x	–	–	1
Sandy	–	–	x	–	–	1
Ship Shoal	–	x	x	x	–	2
Skidmore	–	–	x	–	–	1
Smith	x	x	x	x	–	3
Wreck	–	–	x	x	–	2

* excluding domestic dog

[1] report from Virginia Wildlife Services program of the United States Department of Agriculture indicated raccoon tracks on the island on the night of 18/19 of April, 1999.

Table 6.–*Mammalian predator species detected in track surveys on 23 Virginia barrier and marsh islands, October 1998 – June 2000.*

Island	Red fox	Domestic dog	Raccoon	American mink	Northern river otter
Assawoman	0,0,+,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–
Cedar	0,+,+,0,0,+	0,–,+,0,0,+	0,+,+,0,0,+	0,–,–,0,0,–	0,–,–,0,0,–
Cedar Sandbar	0,+,+,0,0,–	0,–,–,0,0,–	0,+,–,0,0,–	0,–,–,0,0,–	0,–,–,0,0, –
Chimney Pole	0,0,–,–,0,–	0,0,–,–,0,–	0,0,–,+,0,–	0,0,–,–,0,–	0,0,–,–,0,–
Cobb	–,–,–,0,–,–	+,–,+,0,–,–	+,+,–,0,+,+	+,+,–,0,+,–	+,–,–,0,–,–
Fishermans	0,0,0,–,0,–	0,0,0,–,0,–	0,0,0,+,0,+	0,0,0,+,0,–	0,0,0,–,0,–
Godwin	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–
Hog	–,–,–,0,–,–	+,–,–,0,–,–	+,+,+,+,+,+	+,–,–,0,–,–	+,+,–,0,–,–
Holly Bluff	0,0,0,–,0,0	0,0,0,+,0,0	0,0,0,+,0,0	0,0,0,–,0,0	0,0,0,–,0,0
Little Cobb	0, –,–,0,0,–	0,–,–,0,0,–	0,–,–,0,0,–	0,–,–,0,0,–	0,–,–,0,0,–
Metompkin	0,+,+,0,+,+	0,–,+,0,–,–	0,–,–,0,–,–	0,–,–,0,–,–	0,+,–,0,–,–
Mink	0,0,–,0,0,–	0,0,–,0,0,–	0,0,–,0,0,–	0,0,+,0,0,–	0,0,–,0,0,–
Mockhorn	0,0,0,–,0,–	0,0,0,–,0,–	0,0,0,+,0,+	0,0,0,–,0,–	0,0,0,+,0,–
Myrtle	–,–,–,–,–,–	–,+,–,–,–,–	+,+,+,+,+,–	+,–,–,–,+,–	+,+,–,–,–,–
Parramore	+,+,+,0,+,+	–,–,–,0,–,+	+,+,+,+,+,+	–,–,–,0,–,–	–,+,–,0,–,–
Raccoon	0,0,0,–,0,–	0,0,0,–,0,–	0,0,0,+,0,+	0,0,0,–,0,–	0,0,0,–,0,–
Revel	0,0,0,–,0,0	0,0,0,–,0,0	0,0,0,+,0,0	0,0,0,–,0,0	0,0,0,–,0,0
Rogue	0,0,–,0,0,–	0,0,–,0,0,–	0,0,+,0,0,+	0,0,–,0,0,–	0,0,–,0,0,–
Sandy	0,0,–,–,0,–	0,0,–,–,0,–	0,0,+,+,0,–	0,0,–,–,0,–	0,0,–,–,0,–
Ship Shoal	–,–,–,–,–,–	–,+,–,–,–,–	+,+,+,–,–,–	+,–,–,+,+,+	–,–,–,–,–,–
Skidmore	0,0,0,–,0,–	0,0,0,–,0,–	0,0,0,+,0,+	0,0,0,–,0,–	0,0,0,–,0,–
Smith	+,–,–,–,–,–	–,–,+,+,–,–	+,+,+,+,+,+	–,–,–,–,+,–	–,–,–,–,–,–
Wreck	–,–,–,0,–,–	–,–,–,0,–,–	+,+,–,0,–,–	–,–,+,0,–,–	–,–,–,0,–,–

+ presence,
– not detected,
0 not surveyed

In a sequence: October 1998 (Jiménez, in litt.),
March 1999 (Jiménez et al., in litt.),
June/July/August 1999,
September/October/November 1999,
March 2000,
June 2000

were observed on 49.3– 53.8% of all survey lines on occupied islands or on 23.2– 53.8% of all lines on all surveyed islands (Table 7). The numbers were always high for certain islands, particularly Parramore and Smith islands, ranking 1 and 2 for all survey periods. Track frequencies declined considerably and consistently on Hog Island between October 1998 and June 1999, but then increased and stabilized in March and June 2000. No raccoon tracks were recorded on Ship Shoal and Wreck islands after March 1999.

With the exception of Parramore Island, summer frequencies were lower than those recorded in spring for the 6 islands surveyed in all periods (1-sample t-test, t_5 = 3.11, P = 0.026). This pattern also appeared to be independent of precipitation events during the 2 days prior to the survey. Averages of occupied islands only did not vary significantly with season (Table 7).

Table 7.–*Mean percent frequencies of raccoon tracks detected during systematic track surveys on 11 Virginia barrier islands, October 1998 – June 2000 (including data from Jiménez, in litt. and Jiménez et al., in litt.).*

Island	October 1998	March 1999	June 1999	March 2000	June 2000
Assawoman	–	–	–	–	0.0
Cedar	–	–	64.0	–	52.0
Cobb	13.3	26.7	0.0	12.0	0.0
Fishermans	–	–	–	–	5.0
Hog	80.0	45.0	22.0	57.5	58.6
Metompkin	–	0.0	0.0	–	0.0
Myrtle	40.0	70.0	10.0	20.0	0.0
Parramore	100.0	100.0	95.0	85.0	100.0
Ship Shoal	20.0	10.0	0.0	0.0	0.0
Smith	93.3	100.0	64.1	72.0	40.0
Wreck	30.0	10.0	0.0	0.0	0.0
Average (total)	53.8	45.2	28.3	35.2	23.2
Average (occupied)	53.8	51.7	51.0	49.3	51.1

The mean percent frequency of red fox tracks on Parramore Island declined from 100% in the October 1998 survey to 5% in the March and June surveys of 2000 (Table 8). It is important to note, however, that the sandy beach in front of the forested portion of Parramore Island has greatly eroded since autumn 1998 and thus detectability of tracks has decreased considerably. Red fox tracks have not been detected on Smith Island since October 1998, when they were recorded on average on 13% of the survey lines (Table 8). Red fox track frequency on occupied islands varied between 5% and 57.5% (Table 8), but the scarce distribution of the red fox on the islands as well as the change in track detectability on Parramore Island makes this decrease biased.

Table 8.–*Mean percent frequencies of red fox tracks detected during systematic track surveys on 7 Virginia barrier islands, October 1998 – June 2000 (including data from Jiménez, in litt. and Jiménez et al., in litt.).*

Island	October 1998	March 1999	Summer 1999	March 2000	June 2000
Assawoman	–	–	–	–	0.0
Cedar	–	–	0.0	–	–
Cobb	0.0	0.0	0.0	0.0	0.0
Fishermans	–	–	–	–	0.0
Hog	0.0	0.0	0.0	0.0	0.0
Metompkin	–	55.0	37.5	–	0.0
Myrtle	0.0	0.0	0.0	0.0	0.0
Parramore	100.0	60.0	50.0	5.0	5.0
Ship Shoal	0.0	0.0	0.0	0.0	0.0
Smith	13.3	0.0	0.0	0.0	0.0
Wreck	0.0	0.0	0.0	0.0	0.0
Average (total)	16.2	14.4	9.7	0.7	0.6
Average (occupied)	56.65	57.5	43.75	5.0	5.0

Bird Survey

Altogether 16,749 and 14,253 birds of 24 species (*Pelecaniformes, Ciconiformes, Charadriformes*) were counted during 25th and 26th Colonial Waterbird surveys in 1999 and 2000, respectively (Williams, in litt.; Tables A5 and A6). Seven mixed colonies of herons (*Ardeidae, Ciconiformes*) were found in 1999 (six in 2000) on five islands: Chimney Pole Marsh, Cobb, Club House Point, Fishermans and Wreck. One mixed colony of gulls (*Laridae*) and brown pelicans (*Pelecanus occidentalis*) and 23 colonies (18 in 2000) of gulls and terns were found on 16 islands (14 in 2000): Assawoman, Cedar, Chimney Pole Marsh, Cobb, Dawson Shoals (not in 2000), Fishermans, Godwin (not in 2000), Hog, Little Cobb, Metompkin, Mink, Myrtle, Sandy, Ship Shoal, and Wreck. No colonies were found on Holly Bluff, Parramore, Raccoon, Revel, Rogue, Skidmore, and Smith. The size of the least tern colony on Hog Island (11 pairs in 1999) was small in comparison to the area of the island (~1300 ha), so essentialy Hog Island also was without birds in the summer of 1999.

When ranked from most to fewest nesting colonial waterbirds, islands without predators in summer 1999 (Table 9, n = 17) have ranks 2, 3, 4, 6, 7, 9, and 10 (average 5.9). Islands with raccoons only have ranks 1, 5, 13, 14, 16, and 16 (average: 10.8). Islands with red foxes have ranks 8, 11, 12, and 16 (average: 11.8). Islands without predators in summer 2000 (Table 10, n = 21) have ranks 1, 2, 4, 5, 6, 7, 9, 11, 17.5, and 17.5 (average: 7.8). Islands with raccoons only have ranks 3, 8, 12, 17.5, 17.5, 17.5, and 17.5 (average: 13.3). Islands with foxes have ranks 10, 13, 17.5, and 17.5 (average: 14.5).

Table 9.–*Ranks of islands by number of nesting waterbirds relative to island area and occurrence of 2 mammalian predators in the summer of 1999.*

Rank	Island	Herons by area	Gulls and terns by area	Total number by area	Raccoon	Red fox
1	Fishermans	0.63	15.61	16.24	Yes	No
2	Little Cobb	0	10.95	10.95	No	No
3	Chimney P.	1.43	5.75	7.18	No	No
4	Wreck	0.92	5.79	6.71	No	No
5	Sandy	0	5.15	5.15	Yes	No
6	Cobb	0.92	0.44	1.36	No	No
7	Ship Shoal	0	0.39	0.39	No	No
8	Cedar	0	0.24	0.24	Yes	Yes
9	Mink	0	0.17	0.17	No	No
10	Godwin	0	0.14	0.14	No	No
11	Metompkin	0	0.08	0.08	No	Yes
12	Assawoman	0	0.03	0.03	Yes	Yes
13	Hog	0	0.02	0.02	Yes	No
14	Myrtle	0	0.01	0.01	Yes	No
16	Parramore	0	0	0	Yes	Yes
16	Rogue	0	0	0	Yes	No
16	Smith	0	0	0	Yes	No

Islands without predators had significantly more birds than islands with raccoons in both 1999 ($n_1 = 10, n_2 = 7, U = 57, P < 0.05$) and 2000 ($n_1 = 11, n_2 = 10, U = 85, P < 0.05$, Wilcoxon-Mann-Whitney test, Zar 1996). The Spearman rank correlation (Zar 1996) between bird abundance and raccoon track frequency was negative and statistically significant in 1999 ($n = 13$, $r_s = –0.56$, $P = 0.05$) and 2000 ($n = 14$, $r_s = –0.79$, $P < 0.002$). The Spearman rank correlation between capture success of raccoons on 8 islands and ranked bird data in 1999 was also negative and statistically significant ($n = 8$, $r_s = –0.81$, $P < 0.05$).

Table 10.–*Ranks of islands by number of nesting waterbirds relative to island area and occurrence of 2 mammalian predators in the summer of 2000.*

Rank	Island	Herons by area	Gulls and terns by area	Total number by area	Raccoon	Red fox
1	Cedar Sandbar	0	27.063	27.063	No	No
2	Little Cobb	0	19.811	19.811	No	No
3	Fishermans	0.69	13.018	13.705	Yes	No
4	Sandy	0	12.453	12.453	No	No
5	Wreck	2.85	3.829	6.675	No	No
6	Chimney Pole	1.48	4.339	5.815	No	No
7	Ship Shoal	0	1.554	1.554	No	No
8	Cobb	0.58	0.445	1.025	Yes	No
9	Myrtle	0	0.143	0.143	No	No
10	Metompkin	0	0.129	0.129	No	Yes
11	Assawoman	0	0.102	0.102	No	No
12	Hog	0	0.101	0.101	Yes	No
13	Cedar	0	0.004	0.004	Yes	Yes
17.5	Godwin	0	0	0	No	No
17.5	Mink	0	0	0	No	No
17.5	Mockhorn	0	0	0	Yes	No
17.5	Parramore	0	0	0	Yes	Yes
17.5	Raccoon	0	0	0	Yes	Yes
17.5	Rogue	0	0	0	Yes	No
17.5	Skidmore	0	0	0	Yes	No
17.5	Smith	0	0	0	Yes	No

Trapping and Monitoring of Predators

We captured 57 raccoons during 1062 trap-nights (Table 3 and 11; Fig. 8), including 5 recaptures. Most captured individuals were adults (n = 47 or 90%); only 5 (10%) were juveniles. Males (n = 25) and females (n = 22) were approximately equally represented among adults (χ^2 = 0.66, P = 0.42). Four of 5 juveniles were males. Juveniles and adults were captured both on the islands and the mainland. All 5 recaptures occurred on islands, and none of these animals were recaptured more than once.

Table 11.–*Raccoons captured on eight barrier islands and two mainland areas of the Virginia Coast Reserve in 1999.*

		First captures							Recaptures							Total captures							Trapping
		juv.			*Ad.*				*juv.*			*Ad.*				*juv.*			*Ad.*				success
Site	Loc	?	?	tot	?	?	tot	tot	?	?	tot	?	?	tot	tot	?	?	tot	?	?	tot	tot	capt/tn*
Brownsville	M	0	0	0	2	3	5	5	0	0	0	0	0	0	0	0	0	0	2	3	5	5	1.28
Cobb	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Cushman’s	M	0	1	1	0	1	1	2	0	0	0	0	0	0	0	0	1	1	0	1	1	2	0.49
Hog	I	2	0	2	3	0	3	5	0	0	0	1	0	1	1	2	0	2	4	0	4	6	0.24
Mink	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Myrtle	I	0	0	0	1	1	2	2	0	0	0	0	0	0	0	0	0	0	1	1	2	2	0.49
Parramore	I	1	0	1	7	7	14	15	0	0	0	0	0	0	0	1	0	1	7	7	14	15	1.53
Rogue	I	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.48
Ship Shoal	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Smith	I	1	0	1	11	10	21	22	0	0	0	2	2	4	4	1	0	1	13	12	25	26	0.82
Total:		4	1	5	25	22	47	52	0	0	0	3	2	5	5	4	1	5	28	24	52	57	0.54

M – mainland

I – island

capt/tn* – captures per 10 trap-nights

All dead animals (whole body or at least skull) were collected for the Virginia Museum of Natural History

Five raccoons (untagged animals) were found dead on the beaches of Cobb, Parramore, and Smith islands (Tables 12 and A2). Cause of death in all cases remains unknown, but in 3 cases (Smith Island and both Parramore Island animals) the bodies were untouched without obvious marks of predation. Two carcasses on Cobb Island in March and August 2000 were not freshly dead and had been at scavenged by mink or another raccoon. In an attempt to recover radio-collars, 2 animals (untagged animals) were shot on Smith Island in October 1999. One fresh road-killed raccoon was found on the mainland near Cheriton, Virginia.

Fig. 8.–Captured raccoon in a live-trap (photo by the author).

Table 12.–*Raccoons captured, radio-collared or found dead on the Virginia barrier islands and mainland areas of the Virginia Coast Reserve in 1999*.

		First captures							Radio-collared							Found dead								
		juv.			*ad.*				*juv.*			*ad.*				*juv.*			*ad.*					
Site	Loc	?	?	tot	?	?	tot	Tot	?	?	tot	?	?	tot	Tot	?	?	tot	?	?	ind	tot	Tot
Brownsville	M	0	0	0	2	3	5	5	0	0	0	2	1	3	3	0	0	0	0	0	0	0	0
Cheriton	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
Cobb	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
Cushman's	M	0	1	1	0	1	1	2	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Hog	I	2	0	2	3	0	3	5	0	0	0	3	0	3	3	0	0	0	0	0	0	0	0
Mink	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtle	I	0	0	0	1	1	2	2	0	0	0	1	1	2	2	0	0	0	0	0	0	0	0
Parramore	I	1	0	1	7	7 (1)	14 (1)	15	0	0	0	7	5	12	12	0	0	0	1	1	0	2	2
Rogue	I	0	0	0	1	0	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
Ship Shoal	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smith	I	1	0	1	11 (1)	10	21 (1)	22	0	0	0	4	4	8	8	1*	0	1	0	1*	1	2	3
Total:		4	1	5	25 (1)	22 (1)	47 (2)	52	0	0	0	18	12	30	30	1	0	1	2	2	3	7	8

M – mainland
I – island

number in parentheses ( ) indicates that animal died shortly after capture

* shot in attempts to recover non working radiocollars

Trapping success (captures per 10 trapnights) on islands with at least 1 capture ranged between 0.24 on Hog Island to 1.53 on Parramore Island (Table 11). When all 8 of the islands listed in Table 11 are included, trapping success is positively correlated with area of contiguous salt marsh (r = 0.87, P = 0.005, Fig. 9A), area of shrubs and forest (r = 0.81, P = 0.015, Fig 9B), and total island area (r = 0.78, P = 0.026, Fig. 9C). When the largest island (Parramore) was excluded from these analyses, however, these correlations declined to 0.53 (P = 0.225, Fig. 9A'), 0.21 (P = 0.649, Fig. 9B') and 0.32 (P = 0.480, Fig 9C'), respectively. Correlations between trapping success and the areas of other cover types were relatively weak even with Parramore Island included: area of upland habitat (bare sand, grassland and forest; r = 0.47, P = 0.240), area of bare sand (r = 0.46, P = 0.246), area of vegetated upland (grassland, shrubs and forest; r = 0.457, P = 0.254), and area of grassland (r = –0.14, P = 0.734).

There was a strong, positive correlation between area of salt marsh and raccoon track frequency in 5 survey periods (October 1998 – June 2000; Table 13). This correlation is strong and statistically significant, even if Parramore Island is excluded from analysis (Table 14). There was also a statistically significant (P < 0.05) positive correlation in some survey periods between mean percent frequency of raccoon tracks and (1) area of forest and shrubs, (2) total area of upland habitats, (3) total area of the island, (4) island length, and (5) island elevation above sea level. Correlations with other island parameters (area of sand, area of grasslands, isolation from mainland, and isolation from the next island) were not statistically significant (Table 13 and Table 14).

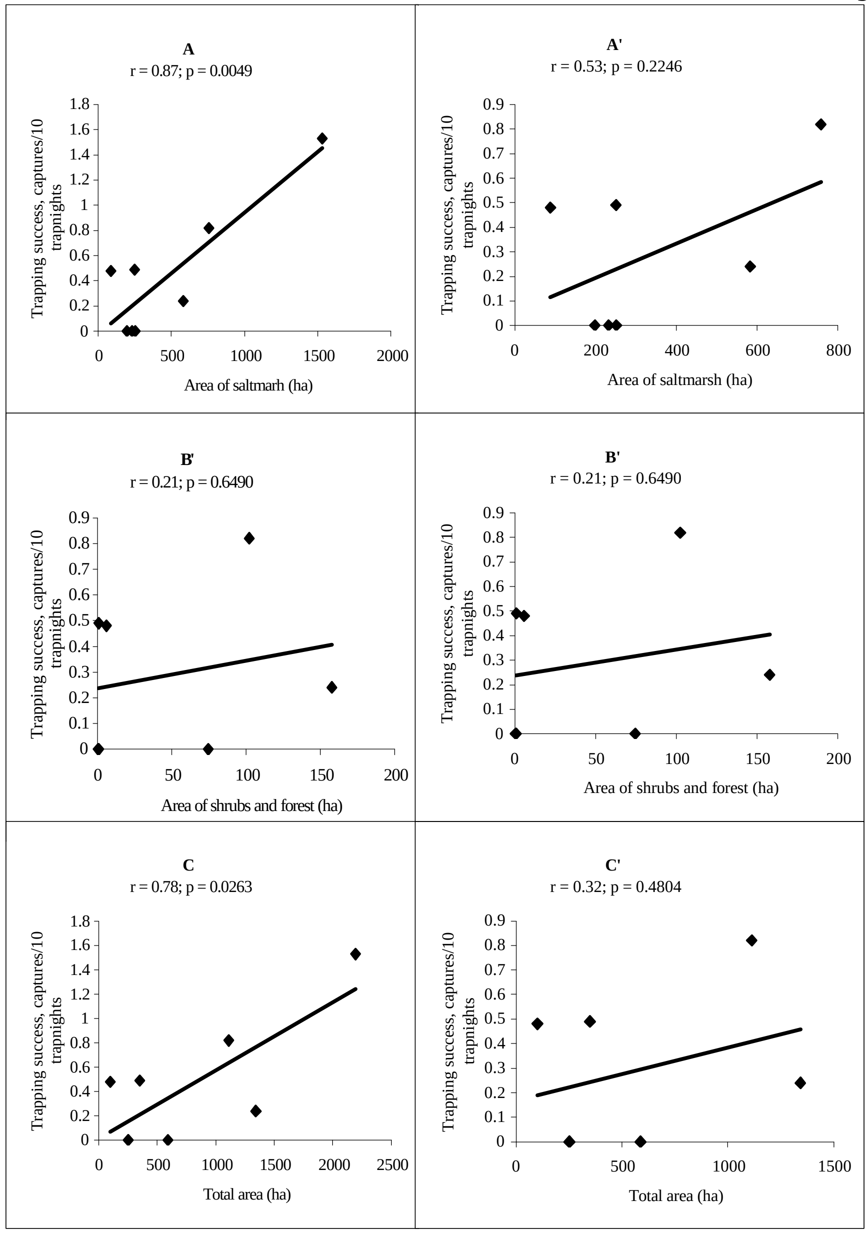

Fig. 9.–Correlation between trapping success and island area including Parramore (A, B, C) and without Parramore (A', B', C').

Table 13.–*Pearson product-moment correlation r (p value) between mean percent frequencies of raccoon tracks on Virginia barrier islands (n) and island parameters in 5 survey periods (including Parramore Island).*

Period	Bare sand	Forest/ Shrubs	Grass-land	Sub-total	Salt marsh	Total	Length	Isolation (mainl.)	Isolation (next isl.)	Elevation	n
October 1998	.53 (.223)	.74 (.057)	.34 (.454)	.72 (.066)	**.86 (.014)**	**.87 (.011)**	**.78 (.038)**	.65 (.111)	.30 (.512)	.60 (.154)	7
March 1999	.06 (.890)	.66 (.078)	.17 (.695)	.47 (.237)	**.80 (.018)**	**.73 (.039)**	.35 (.398)	.16 (.698)	.39 (.342)	.63 (.095)	8
June 1999	**.56 (.031)**	**.76 (<.001)**	.16 (.580)	**.64 (.010)**	**.93 (<.001)**	**.92 (<.001)**	**.66 (.008)**	.26 (.356)	.27 (.323)	**.79 (.002)**	15
March 2000	.65 (.113)	**.81 (.027)**	.33 (.467)	**.79 (.034)**	**.90 (.006)**	**.93 (.003)**	**.83 (.021)**	.62 (.137)	.30 (.513)	.64 (.125)	7
June 2000	**.66 (.004)**	**.85 (<.001)**	.35 (.168)	**.80 (<.001)**	**.89 (<.001)**	**.95 (<.001)**	**.71 (.001)**	.04 (.872)	.09 (.720)	**.81 (<.001)**	17

Table 14.–*Pearson product-moment correlation r (p value) between mean percent frequencies of raccoon tracks on Virginia barrier islands (n) and island parameters in 5 survey periods (excluding Parramore Island).*

Period	Bare sand	Forest/ Shrubs	Grass-land	Sub-total	Salt marsh	Total	Length	Isolation (mainl.)	Isolation (next isl.)	Elevation	n
October 1998	.26 (.614)	.71 (.116)	.69 (.127)	.62 (.192)	**.96 (.002)**	**.86 (.030)**	.75 (.085)	.65 (.165)	.66 (.151)	.28 (.589)	6
March 1999	.28 (.545)	.46 (.295)	.40 (.369)	.27 (.563)	**.80 (.029)**	.59 (.166)	.22 (.629)	.15 (.746)	.65 (.114)	.48 (.274)	7
June 1999	.40 (.152)	.44 (.113)	.34 (.228)	.45 (.107)	**.90 (<.001)**	**.87 (<.001)**	**.63 (.016)**	.37 (.195)	.49 (.075)	.51 (.088)	14
March 2000	.42 (.405)	.80 (.055)	.75 (.089)	.71 (.116)	**.99 (<.001)**	**.92 (.009)**	**.83 (.041)**	.62 (.188)	.73 (.103)	.19 (.717)	6
June 2000	**.56 (.023)**	**.64 (.008)**	.67 (.004)	**.73 (.001)**	**.83 (<.001)**	**.92 (<.001)**	**.73 (.001)**	.10 (.707)	.28 (.286)	.47 (.102)	16

Thirty adult raccoons were radio-collared, including 26 on five islands and 4 at two mainland localities (Table 12). The number of days of tracking effort per individual ranged from 5 to 50 (average 15, Table A3). Many of the AVM manufactured collars were no longer detectable after only a brief period of time (Table A3): on average an animal wearing an AVM collar disappeared after 24.7 days (*SE* = 5.3). An animal wearing Wildlife Materials, Inc., collar was detected on average of 292.6 days (*SE* = 77.0). Either there was mass movement of AVM radio-collared animals to locations where they could not be monitored, or many of the radio-collars simply failed after only a short time in the field. The latter case is supported by the observations of 12 collared animals on Parramore Island: 3 males and 3 females were collared with AVM collars and 4 males and 2 females were collared with Wildlife Materials, Inc., collars. While all of animals wearing Wildlife Materials, Inc., collars were still detectable on Parramore in June 2000, while none of the animals with AVM collars were detectable after September 1999 (Table A3).

Considering these constraints, we detected no movement of raccoons between the islands and mainland or between adjacent islands, even islands less than 1 km apart. Maximum distances moved were measured as the greatest straight-line distance between any pair of locations ever observed for an individual. Maximum distances moved ranged from 181– 5550 m (Table 15 and Table A4). An average male was observed to move a shorter distance (1236 m, *SE* = 124) than an average female (1680 m, *SE* = 571). An average mainland animal moved a greater distance (2666 m, *SE* = 1072), than an average island animal (1175 m, *SE* = 172). However, these results are biased because the failure of AVM radio-transmitters resulted in small numbers of locations for all island animals (Table A4). The record one-day, straight-line movement for an island animal was "Ray Raitis" (150.967 MHz) on Smith Island: 1788 m in 24 hours (Table A4).

The record one-day, straight-line movement for a mainland animal was "Sue Subate" (151.395 MHz) on Brownsville Farm: 3044 m in 12 hours (Table A4). None of the maximum distances observed would have been long enough to carry an animal from the mainland directly to a remote island (see Table 1 for distances from mainland to islands), but given only the distance, raccoons could easily reach islands in close proximity to the mainland (e.g., Smith).

Predators and Waterbirds

We observed no evidence of direct mammalian predation on colonial waterbirds (Table 16). However, bird colonies were not found on islands with high raccoon abundance, e.g., Parramore and Smith (Fig. 10). Birds were absent from these islands despite the availability of extensive areas of suitable nesting habitat for colonial waterbirds (sand with sparse vegetation) on both islands, and despite the fact that both

Table 15.–*Distances (m) moved by individual raccoons on Virginia barrier islands and mainland areas of the Virginia Coast Reserve Summer 1999 – Spring 2000.*

Category	Min.	Max.	Average	SE	SD	n
All animals	181	5550	1414	237.1	1185.6	25
Mainland	950	5550	2666	1072.3	2144.6	4
All islands	181	3294	1175	172.3	789.7	21
Hog and Rogue	406	1038	752	130.2	260.3	4
Parramore	181	3475	1285	307.7	973.0	10
Smith	325	1888	1261	261.0	690.6	7
Males	406	1838	1236	124.0	480.1	15
Females	181	5550	1680	570.8	1805.1	10

islands have supported active nesting in the past (Beck et al. 1990).

In 1999, islands with bird colonies had smaller areas of shrubs and forest, than islands without colonies (P = 0.05, Kruskal-Wallis test). In 2000, islands with bird colonies had larger areas of sand (P < 0.002) and all upland habitat (sand+ shrubs+grasslands) than islands without colonies (P < 0.05, Kruskal-Wallis test).

In both seasons, raccoons and/or red foxes were present on islands with larger areas of shrubs and forest (in 1999: P < 0.05; in 2000: P = 0.001, Kruskal-Wallis test) and higher in elevation (in 1999: P < 0.002; in 2000: P < 0.05, Kruskal-Wallis test) than islands without these two predator species. In 1999, islands without the two predator species were more isolated (P < 0.02, Kruskal-Wallis test) than islands hosting them. In 2000, predators were present on larger islands (P < 0.05, Kruskal-Wallis test) than islands without predators. The influence of other island characteristics was not statistically significant.

Table 16.–*Observed predation events on birds during the 26th annual Colonial Waterbird survey June 18 – 21, 2000 on Virginia barrier islands.*

Island	Bird species	Number of kills	Predators
Fishermans	*Larus atricilla*	~30	Gulls
Fishermans	*Sterna maxima*	11	Gulls
Fishermans	*Rallus longirostris*	5	Gulls
Little Cobb	*Larus argentatus*	(dead) 3	–
Little Cobb	*Larus atricilla*	2	Gulls
Little Cobb	*Rallus longirostris*	1	Gulls

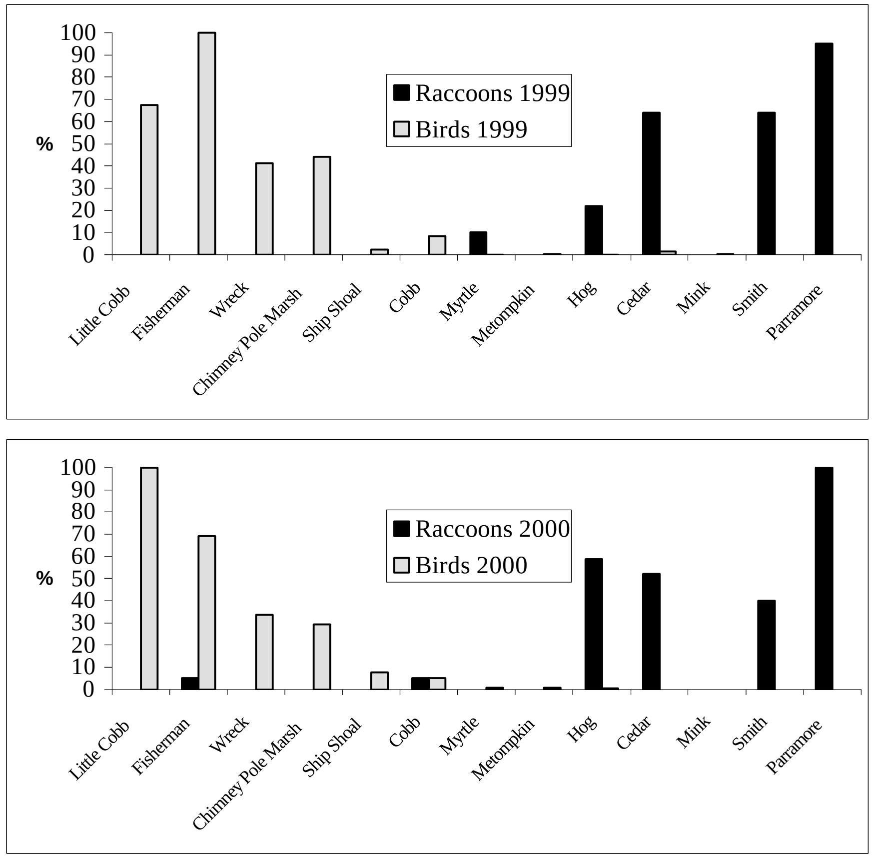

Fig. 10.–Relative abundance of breeding colonial birds and raccoons on 13 Virginia barrier islands in the summers of 1999 and 2000 (relative abundance of raccoons was measuredby track counts, bird relative abundance was calculated by the number of birds on the most populated island set to 100%).

DISCUSSION

Predator Impact on Waterbirds

Because we did not detect direct depredation during our study, it might not be obvious why mammalian predators are responsible for declines of nesting waterbird populations on the Virginia barrier islands. At least two factors might explain this: (1) depredated birds are quickly scavenged and are therefore not found by observers (Hartman et al. 1997) and (2) frequent disturbance by mammalian predators, but not direct depredation, might be the main cause of abandonment of colony sites. Disturbance by mammalian predators might be important on Virginia barrier islands. Islands with large bird colonies in both seasons (1999 and 2000) had few or no predators, and islands with high raccoon abundance had few or no bird colonies (Fig. 9). In July 1997, Barry Truitt observed nearly 500 nesting black skimmers, along with 250 nesting common terns and 50 nesting gull-billed terns abandon a colony on Ship Shoal Island when raccoons found the colony (B. Truitt, pers. comm.).

Nest site abandonment by gulls and terns in response to predators has been described elsewhere (Emlen et al. 1966; Kadlec 1971; Aivars Mednis, pers. comm.). Kadlec (1971) has shown that the introduction of predators on islands off the Massachusetts coast greatly reduced colony sizes of herring gulls, and sometimes led to island abandonment as a colony site. These experiments, however, were relatively short term (2 – 4 years) and predators were not able to maintain themselves on the experimental islands (Kadlec 1971). The herring gulls, therefore, probably experienced less disturbance in the long term than in this study on Virginia barrier islands, where predators have been present at least since the 1970s. On a regional scale, however, Kadlec (1971) observed no significant predator impact on the herring gull breeding populations. Kadlec's (1971: 634) conclusion that "…the displacement and movement of breeding adults is probably the most significant effect of the predators" is relevant to the findings of this study. Although there are few other potential breeding sites left for colonial waterbirds on the Delmarva Peninsula, some of the birds might have moved to nest on small dredge-spoil islands off the coast of mainland Virginia (Ruth Beck, pers. comm.). Unfortunately we do not have evidence of banded bird recoveries due to a lack of an ongoing bird banding on the islands. Erwin et al. (1998), however, reported results that do not support displacement of breeding terns by predators: nesting success in year *t* had little effect on the occupancy of the same nesting site in the year *t+1*.

Observations of the behavior and nesting success of a peninsular colony of ring-billed gulls (*Larus delawarensis*) at Rogers City, Michigan, "revealed that the raccoon, apparently a single animal, was causing very little direct destruction, but was indirectly responsible for the extensive egg and chick mortality …by inciting 'panic flights' which took the entire adult population … away from their nests for up to four hours at a time" (Emlen et al. 1966: 677-678). The adult birds were alert and restless even during the nights when raccoon did not visit the colony. This clearly shows that, even when not directly preying upon colonial waterbirds, raccoons still may be responsible for reproductive failure of a colony.

Based on observations in Lake Engure, Latvia (Aivars Mednis, pers. comm.), black-headed gulls (*Larus ridibundus*) abandon islands where the raccoon-dog has been present for extensive periods of time during the previous breeding season. Raccoon dogs, however, are primarily depredating duck nests, thus causing little direct impact on breeding gulls (Aivars Mednis, pers. comm.).

The fact that we found no mammal-killed birds, however, does not necessarily mean there was no mammalian predation. Studies by Hartman et al. (1997) showed that bird carcasses in such an environment (e.g., waterbird colony) disappear very quickly; only 8% of carcasses persisted till day 3 of carcass observations, with all the rest scavenged by avian predators. This also reveals the problem of identifying the killer. Birds that might seem to have been killed by an avian predator may have been killed by a raccoon or mink and then scavenged by a gull afterwards. The difficulty of detecting American mink predation was already mentioned (Craik 1997). Burness and Morris (1993) in Lake Erie, Ontario, Canada, observed that an adult mink was responsible for death of 20–40% of chicks in the common tern colony. Viksne (1997) found that a female mink with blind cubs in its den on Lopsalrova Island in Lake Engure, Latvia, in 10 days killed 40 breeding black-headed gulls, 5 breeding ducks of various species, and 1 gosling of greylag goose (*Anser anser*). American mink was found on 8 of the Virginia barrier islands (Table 5); however, sampling procedures on sandy beaches might not be appropriate for recording mink, given the aquatic habits of this species (Whitaker and Hamilton 1998).

Piping plover nest depredation is well documented on the Virginia barrier islands. Patterson et al. (1991) attributed 91% of all known (31% of nest losses were by unknown cause) nest losses on Assateague Island in 1986 and 1987 to predators: 47.6% were depredated by red fox, 28.6% by raccoons, 14.3% by avian predators, and 9.5% by unidentified mammalian predators. In 1998, predation on Assateague Island caused

55.6% (5 nests) of all known nest losses or 50% of all nest losses (U.S. Fish and Wildlife Service, Chincoteague National Wildlife Refuge, in litt.). However, on Cedar and Metompkin Islands in 1998, Cross (in litt.) found that only 21.4% (3 nests) of all known nest losses were due to predation by red fox.

Predation by avian predators also might be an important source of mortality. Yorio and Quintana (1997) showed that kelp gulls (*Larus dominicanus*) were responsible for 99% of observed predation events on nests of royal terns and cayenne terns (*Sterna eurygnatha*) in Patagonia, Argentina. Predation by bigger larids (e.g., gulls) on smaller ones (e.g., terns) is well known. Even medium-size gulls might eventually depredate nests of smaller species or even show cannibalistic behavior. For example, medium-sized black-headed gulls have been observed to eat chicks and eggs of small-sized little gulls (*Larus minutus*) in Lake Engure, Latvia (Janis Viksne, pers. comm.). Probably the most efficient predacious larids are the glaucous gull (*Larus hyperboreus*, e.g., Gilchrist and Gaston 1997), great black-backed gull (*Larus marinus*, del Hoyo et al. 1996; Janis Viksne, pers. comm.) and herring gull (*Larus argentatus*, Hario 1994; Janis Viksne, pers. comm.). The latter two species are common on the Virginia barrier islands. We might only guess what is the rate of predation by these two gull species on local nesting tern colonies. Other avian predators, e.g., great horned owl (*Bubo virginianus*) and northern harrier (*Circus cyaneus*), which prey upon terns and gulls (Morris and Wiggins 1986; Janis Viksne, pers. comm.), were also observed on the Virginia barrier islands in the summer of 1999. Predation by a single Eurasian eagle owl (*Bubo bubo*) on adult birds in a colony of black-headed gulls might be persistent for an entire breeding season and result in very few fledged young in a whole gull colony

(Janis Viksne, pers. comm.). Observations on Asaateague Island in 1992 (U.S. Fish and Wildlife Service, Chincoteague National Wildlife Refuge, in litt.) attributed 21% of piping plover egg losses to avian predators (crows, gulls, grackles).

The results of this study show that there are no bird colonies on islands with high raccoon abundance, e.g., Parramore and Smith (Fig. 9). In the past, however, both islands have supported waterbird colonies (Beck et al. 1990). The negative correlations found between abundance of raccoons and waterbirds suggest that birds are avoiding islands with predators [support for hypothesis (1)]. There are very few safe nesting sites for birds on the Virginia barrier islands because even a single raccoon might cause major breeding failure (Emlen et al. 1966).

Predator Distribution

Since the first records of mammalian predator distribution in 1970's (Dueser et al. 1979; Truitt and Peterson, in litt.), raccoons have been found on all islands except Godwin and Mink (Table 17). Even Little Cobb Island, which was apparently predator-free during this study and supported a big gull colony, had predators recorded on it from 1970s (Dueser et al. 1979). Some of the historic predator observations compiled by Truitt and Peterson (in litt.) should be accepted only with caution (e.g., "two foxes (red?) observed" and "possible fox and rat tracks"). Neither Jim?nez (in litt.; Jim?nez et al., in litt.) nor this study detected red fox on Cobb and Hog islands, where this species has been observed in the past. There is obviously some questions whether "possible fox tracks" on Ship Shoal in 1995 provides evidence for red fox presence on that island. One should notice also that in the past the predator observations were occasional observations, not systematic surveys and thus might have overlooked mammalian predator presence on some less populated islands. Therefore, a conclusion that predator distribution has increased during the past decades might have be an overestimate. However, an increase of suitable habitat for raccoons, namely areas of shrubs on the islands (McCaffrey and Dueser 1990b; Shao et al. 1998; Young et al. 1995), suggests

Table 17.–*Raccoon and red fox distribution on the Virginia barrier islands between 1970 and 2000 (Dueser et al. 1979; Dueser and Porter, in litt.; Jim? nez, in litt.; Jim? nez et al., in litt.; Truitt and Peterson, in litt.; Raymond Dueser, pers. obs.; this study).*

	1971–1980		1981–1990		1991–1997		1998–2000	
Island	raccoon	red fox	raccoon	red fox	raccoon	red fox	raccoon	red fox
Assawoman	+	+	+	+	+	+	–	+
Cedar	+	–	+	–	+	+	+	+
Cedar Sandbar	n/a	n/a	n/a	n/a	n/a	n/a	+	+
Chimney Pole Marsh	n/a	n/a	n/a	n/a	n/a	n/a	+	–
Cobb	+	–	+	+	n/a	n/a	+	–
Fishermans	n/a	n/a	n/a	n/a	n/a	n/a	+	–
Godwin	n/a	n/a	n/a	n/a	n/a	n/a	–	–
Hog	+	+	+	+	+	–	+	–
Holly Bluff	n/a	n/a	n/a	n/a	n/a	n/a	+	–
Little Cobb	+	–	n/a	n/a	n/a	n/a	–	–
Metompkin	+	+	+	+	+	+	+	+
Mink	–	–	n/a	n/a	n/a	n/a	–	–
Mockhorn	n/a	n/a	+	–	+	–	+	–
Myrtle	–	–	+	–	+	–	+	–
Parramore	+	+	+	+	n/a	n/a	+	+
Raccoon	–	–	n/a	n/a	n/a	n/a	+	–
Revel	+	+	+	+	+	+	+	–
Rogue	n/a	n/a	n/a	n/a	n/a	n/a	+	–
Sandy	n/a	n/a	n/a	n/a	+	+	+	–
Ship Shoal	n/a	n/a	n/a	n/a	+	+	+	–
Skidmore	–	–	+	–	n/a	n/a	+	–
Smith	+	–	+	–	+	–	+	+
Wreck	–	–	n/a	n/a	n/a	n/a	+	–

\+ presence
– absence

n/a no available data

that conditions may have been favorable for raccoons to expand their range and abundance on the islands. Today, at least 5 large islands sustain persistent raccoon populations: Cedar, Hog, Mockhorn, Parramore and Smith. Failure to detect predators on small islands (e.g., Little Cobb and Ship Shoal) where raccoons or red foxes have been observed in the past indicates that small islands cannot support long-term predator populations. Mammalian predators may be only transient visitors to these small islands (see red fox dispersal abilities discussed later).

Predator Abundance and Island Characteristics

Track surveys provide a relatively inexpensive method for detecting the presence of mammals (e.g., Lindén et al. 1996), but are subject to a variety of limitations. In the first track surveys on the islands, Jim?nez (in litt.) used both the scent station method (Linhart and Knowlton 1975) and the systematic survey procedure reported here. The scent station method records only tracks made during the survey period, and thus provides a measure of predator abundance/activity over a given period of time (e.g., a night) and under a given set of environmental circumstances (e.g., a period without rainfall). Neither method is able to determine how many animals are represented by a given set of track counts. Jim?nez (in litt.) found that the 2 methods yielded the same quantitative results, i.e., the same general estimates of track frequency. Because of the logistical constraints involved in working along the full length of each island, Jim?nez (in litt.) and Jim?nez et al. (in litt.) adopted the systematic survey procedure for work on the Virginia barrier islands. Track frequency as determined by the systematic method and trapping success (captures per 10 trapnights) on 7 islands during summer 1999 were positively correlated (r = 0.96, P = 0.0005), validating the use of mean percent track frequency as a measure of raccoon relative abundance on the islands.

Tracks in sand are subject to disturbance by wind, rain, and overwash. My field work was scheduled to avoid the potential effects of overwash. Rain disturbance can be reduced by constructing canopy over the sample transect (Bider 1968). This was impossible in the present study (and might cause predator avoidance as well). The VCR–LTER Program operates a recording weather station on Hog Island, in the middle of the Virginia barrier island complex. Based on the precipitation records from this station, the majority of the systematic track surveys were conducted during periods of dry weather. There was no significant correlation between the amount of rainfall on Hog Island in the 2 days before the survey and observed mean raccoon track frequency (Fig. 11). In fact, the highest track frequency ever observed on Cobb Island (26.7%) was recorded on March 16, 1999, after a 2-day total of 52.58 mm of rainfall. Rainfall appears to have had little effect on either track detectability or raccoon activity. Furthermore, the tracks of white-tailed deer (*Odocoileus virginianus*) were almost always recorded even when predator tracks were not (Table A1), suggesting that mammalian tracks were detectable during all survey periods.

Ideally, each survey would detect only tracks accumulated over a standard 1-2 day/night period before the survey. Unfortunately, it was necessary to schedule the surveys when transportation to the islands was available. It was not possible to standardize the survey schedule around rain events or lunar phase. The surveys thus detected tracks that may have accumulated over an unknown number of days and

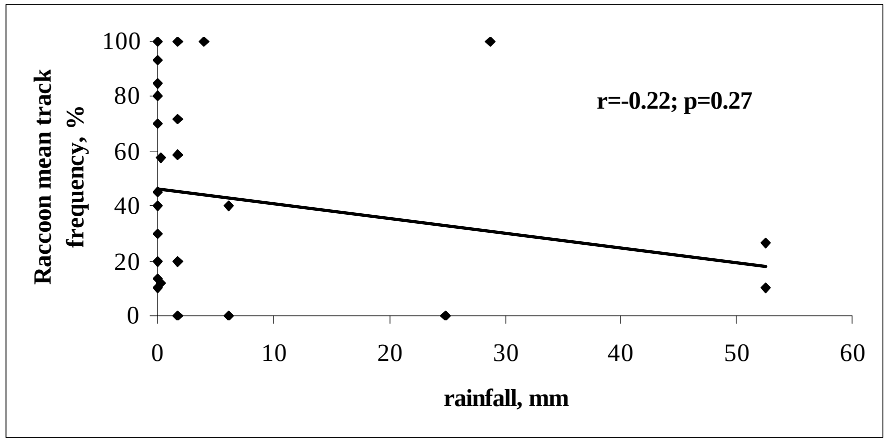

Fig. 11.–Relationship between mean raccoon track frequency on 7 Virginia barrier islands and cumulative rain fall since 2 days before the survey date (measured at Hog Island station, Hog Island, VA). The 2 points with the highest amount of rainfall represent Cobb and Wreck islands and have the highest ever measured track frequency on those islands.

nights. Because each period was only a few days in length, lunar phase did not change significantly during 1 survey period. Lunar cycles were different on the 5 survey periods (October 1998, March 1999, June 1999, March 2000, and June 2000) but no obvious influence by lunar cycles on track frequency was observed.

Despite the fact that we have only 2 years of relative abundance (i.e., track frequency) data, it appears that raccoons are less active on beaches in summer, than in spring (*P* < 0.05, 1-tailed t-test) and probably also in fall and winter. This has important management implications. Also out of 10 raccoons directly observed on the beach, 7 were in March and 3 in June, despite that much more time was spent in field in June, July, and August. Nine of the 10 observations were on overcast days. DeVitt-Ivey

(1948) observed raccoons being active in a Florida salt marsh during the day, and raccoon activity followed the tide cycle more closely than the diurnal cycle.

It is worth noting that raccoon abundance declined on all islands except Parramore on which systematic surveys were carried out in all 5 periods between October 1998 and June 2000 (Table 7, Fig. 12). Also, overall track frequency declined if we compare the October 1998 survey with the June 2000 survey (2-tailed t-test, $P < 0.01$). Raccoons were not detected on Ship Shoal and Wreck islands after March 1999, despite the extensive amount of time spent on these islands during summer 1999. Ship Shoal and Wreck islands apparently had no raccoons living on them after spring 1999.

Raccoon abundance was always strongly positively correlated with the amount of salt marsh adjacent to the island ($r = 0.83$ to $r = 0.99$ in different periods; Table 13 and Table 14). This observation agrees with earlier reports of raccoons foraging in salt marsh (e.g. DeWitt-Ivey 1948), and suggests that salt marsh provides a source of food for raccoons. Raccoons regularly prey upon fiddler crabs (*Uca* spp.), but small snails (often *Melampus* spp.), as well as ribbed mussels (*Geukensia demissa*) will also be

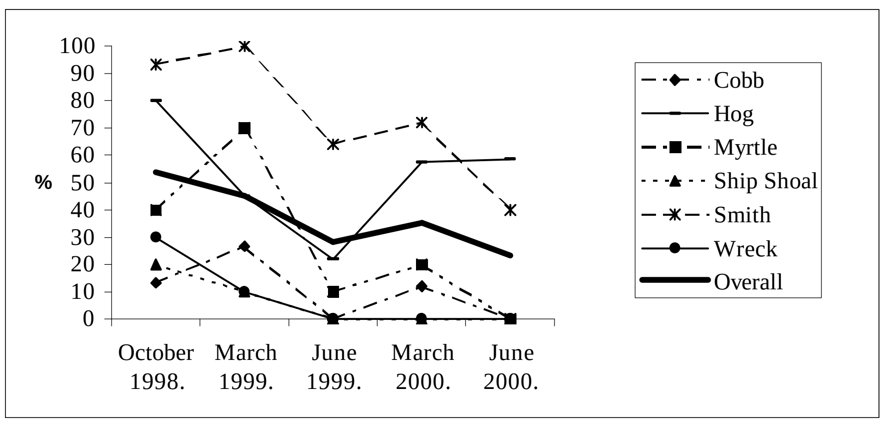

Fig. 12.–Dynamics of relative abundance of raccoons on 6 Virginia barrier islands between October 1998 and June 2000.

taken (Brian Silliman, pers. comm.). A variety of invertebrates are available in the salt marsh for most of the year, while other food sources [e.g., Blackberries (*Rubus argutus* Link), eggs of nesting birds] are only seasonal delicatessen. Fiddler crabs are not available for raccoons in winter, except on warm days when they may emerge from their deep burrows. *Melampus* spp. and *Geukensia demissa* are available for raccoons during all seasons, including the winter (Brian Silliman, pers. comm.). These invertebrates might reach high densities in the salt marsh – up to 205 individuals/m^2 for *Uca pugnax* (Wolf et al. 1975), 645.2 individuals/m^2 for *Melampus* (Daiber 1982), and 45.5 individuals/m^2 for *Geukensia demissa* (Daiber 1982). *Geukensia demissa* has been characterized as the most important food source for raccoons in some tidal marshes in Louisiana (Daiber 1982). It is not surprising, therefore, that raccoon relative abundance is so strongly correlated with area of salt marsh.

The other habitat type correlated with raccoon relative abundance is shrubs and forest. This is easy to explain, because the raccoon is presumably a forest inhabitant (Whitaker and Hamilton 1998). Shrubs provide cover, denning sites, and also food (e.g., blackberries, persimmons, bird eggs and young) in the barrier island environment.

Predator Movements and Island Colonization

Although we detected no movements of marked raccoons between islands, observations and translocation experiments by Hanlon et al. (1989) showed that male and female raccoons crossed the Swash (~300 m wide, 2–4 m deep at mean low tide) between Parramore and Revel islands regularly. Kaufmann (1990) reported raccoons regularly swimming between keys in Florida Everglades and across rivers and lakes up to 300 m wide. Kauhala (1996) reports that rivers more than 300 m wide serve as dispersal barriers for introduced raccoons in Germany. However, Hartman and Eastman (1999) found raccoons swimming in saltwater up to 950 m to reach the next island in Haida Gwaii archipelago, British Columbia, Canada. Raccoons were found on 86% of islands isolated by less than 400 m of water, on 29% of islands isolated by 400–800 m, and on 25% of islands isolated by more than 800 m of water (Hartman and Eastman 1999).

According to this information, raccoons might easily move between most of the adjacent islands in the Virginia barrier island complex. Presence of predators was dependent on island isolation [support for hypothesis (2)]: islands with raccoons and red foxes were farther from mainland in 1999 ($P < 0.02$; Kruskal-Wallis test). Conversely, there was no significant correlation between raccoon relative abundance and island isolation (Table 13 and Table 14). Extensive *Spartina* spp. marshes connect some of the islands, and only tidal creeks isolate them from each other. This might make raccoon dispersal between islands easier.

Both the trapping data and the systematic track surveys indicate pronounced differences in raccoon relative abundance among islands (Table 7, Table 11, Fig. 9, Fig. 10). Large islands (e.g., Parramore and Smith) had high raccoon abundance, and small islands (e.g., Ship Shoal and Myrtle) had much lower raccoon abundance [support for hypothesis (4)]. Larger populations have much smaller risk of extinction. That leads to a basic prerequisit of metapopulation concept – asynchronous population fluctuations (Levins 1969; Harrison and Taylor 1997), which we can observe on the Virginia barrier islands (Fig. 12). Some of the populations clearly went extinct during our study, because of repeated failure to detect presence of animals since spring 1999 on Ship Shoal and Wreck islands.

Our observations show that foxes have colonized fewer Virginia barrier islands than raccoons. The dispersal abilities of the red fox are very good. In the Southern Finnish archipelago, Bergman (1966) observed foxes voluntarily swimming between islands 100 m apart in winter conditions in an atmospheric temperature of −7°C and 2 km apart in summer conditions. He also found that "foxes seldom swim out to treeless skerries when these lie quite close to the forested islands, but often cross the sounds (up to 300 m) between forested islands" (Bergman 1966: 40). Foxes in the Southern Finnish archipelago are only occasionally found on islands smaller than 40 ha (there is no salt marsh on the islands in Finnish archipelago, only upland habitat; Bergman 1966). This suggests that red fox has a certain area (food) requirements to be able to successfully colonize an island. Sargeant (1978) reports that an adult red fox requires 2.25 kg food per week, but no free water. Krim et al. (1990) observed that Assateague Island red fox consumed mostly mammals (87%), which might not be available in sufficient quantities on small barrier islands. Foxes also are not observed to feed in salt marsh (Kaufmann 1990), thus the red fox distribution on Virginia barrier islands is most probably limited by the available upland food resources on each particular island.

Management Implications

There are several potential management options for avian habitat restoration on

Virginia barrier islands: habitat-oriented management, bird-oriented management, and predator-oriented management. Habitat management would be cutting and/or burning the shrubs on islands to create suitable breeding sites for colonial waterbirds and indirectly decrease predator populations. Despite the potential effectiveness of this action, this management option is not realistic because of ongoing studies of natural vegetation dynamics on the islands (Shao et al. 1998). Bird-oriented management might include creation of artificial islands for nesting and protecting existing colonies. This also might be unrealistic because artificial islands might have a very short lifespan, considering the dynamics of natural islands (e.g., the northern 25% of Myrtle Island has been lost to the Atlantic Ocean in 5 years). Additionally, mammalian predators might also reach artificial islands. Any construction on sites where colonial waterbirds prefer to nest (i.e., on the low-elevation beaches and marshes) will have very short persistence time, because of the frequent destructive power of hurricanes and northeasters. Predator-oriented management might be effective only if predator manipulation could effectively keep the predators from depredating bird nests and disturbing breeding adults. Because we know that disturbance by predators might be an important source of indirect chick mortality (Emlen et al. 1966) – even a single animal can still create problems – the goal would be the elimination of predators. This might be a possible option, but only for some islands.

Large islands with large populations of predators, such as Cedar, Hog, Mockhorn, Parramore, and Smith islands, probably are unmanageable by any acceptable method and should be considered as "lost to predators." At least 3 years of attempts to control red foxes on Metompkin Island, which is relatively large and close to the mainland, apparently have failed, because there were still observations of fox tracks on that island after management actions (Barry Truitt, pers. comm.).

Small islands near the mainland (Assawoman, Holly Bluff, Raccoon, Skidmore) or near to a large island with stable raccoon populations (Myrtle, Revel, Rogue) most likely also have no management options. It is clear enough by study on Parramore and Revel islands that raccoons will frequently cross water < 300 m wide (Hanlon et al. 1989).

Small- to medium-sized, relatively isolated islands might be the only islands on which predators could be kept under control. Those islands include Chimney Pole Marsh, Cobb, Godwin, Little Cobb, Sandy, Ship Shoal, and Wreck. Apparently they do not have high raccoon populations, if at all at this time, and frequent overwashes and flooding are helping to keep the islands more or less free of predators.

The 2 basic alternatives to predator management on Virginia barrier islands appear to be translocation or euthanasia of live-trapped animals. Because the mentioned concerns about dangers of consequences of wildlife translocation – spreading of disease, mixing gene pools (Cunningham 1996; Griffiths et al. 1996) – it would be preferable to kill (euthanase) nuisance animals. Knowing the ubiquitous distribution and high densities of raccoons (Mosillo 1999), the question – where to release translocated animals without harassing both local and translocated animals – is very important. Euthanasia, however, may raise public concerns, because raccoons are charismatic animals to the public and level of public understanding of "conservation biology" is not uncommon to be equal with "individual animal conservation" regardless of the status and distribution of the species. However, in specific circumstances public opinion might tolerate euthanasia. Messmer et al. (1999) found that the majority of the public supported or strongly supported control of skunks, raccoons, and foxes to protect duck species in danger of extinction (81.3%), control of gulls and crows to protect nesting piping plowers (71.5%), control of foxes to protect nesting piping plowers (66.8%), and control of skunks, raccoons, and foxes to improve duck nesting success (58.9%). This means that control of raccoons and red foxes on Virginia barrier islands to protect nesting birds – terns and shorebirds – might be well received by the public. But even with total removal of raccoons and red foxes on manageable islands, other predators, e.g., American mink, will remain on the islands and mink management, given the aquatic habits of mink, would be very hard, if at all possible on Virginia barrier islands.

When choosing the best time for raccoon trapping on the islands, fall, winter, or spring is strongly recommended. Trapping in summer has little trapping success, which might be connected with behavior of raccoons during the summer, and also it is a much more difficult task in hot and humid conditions than in any other season.

REFERENCES

Allen, S. H., and A. B. Sargeant. 1993. Dispersal patterns of red foxes relative to population density. The Journal of Wildlife Management 57:526–533.

Bailey, E. P. 1992. Red foxes, *Vulpes vulpes*, as biological control agents for introduced Arctic foxes, *Alopex lagopus*, on Alaskan islands. Canadian Field-Naturalist 106:200–205.

Balser, D. S., H. H. Dill, and H. K. Nelson. 1968. Effect of predator reduction on waterfowl nesting success. The Journal of Wildlife Management 32:669–682.

Barnes, B. M., and B. R. Truitt. 1997. Seashore chronicles: three centuries of the Virginia barrier islands. University Press of Virginia, Charlottesville, Virginia.

Beck, R. A., J. W. Akers, J. W. Via, and B. Williams. 1990. Status and distribution of the least tern in Virginia – 1975 to 1988. Virginia Journal of Science 41:404–418.

Bergman, G. 1966. Occurance and living habits the fox (*Vulpes vulpes*) in Finnish island areas, and its effect on birds. In Finnish with English summary. Suomen Riista 18:30–41.

Bider, J. R. 1968. Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Ecological Monographs 38:27–308.

Brown, J. H., and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology 58:445–449.

Burness, G. P., and R. D. Morris. 1993. Direct and indirect consequences of mink presence in a common tern colony. The Condor 95:708–711.

Craik, C. 1997. Long-term effects of North American mink *Mustela vison* on seabirds in western Scotland. Bird Study 44:303–309.

Cunningham, A. A. 1996. Disease risks of wildlife translocations. Conservation Biology 10:349–353.

Daiber, C. F. 1982. Animals of the tidal marsh. Van Nostrand Reinhold company, New York.

del Hoyo, J., A. Elliott, and J. Sargatal (eds.). 1996. Handbook of the birds of the world. Vol. 3. Hoatzin to Auks. Lynx Edicions, Barcelona, Catalonia.

DeWitt-Ivey, R. 1948. The raccoon in the salt marsh of northeastern Florida. Journal of Mammalogy 29:290–291.

Dobson, J. E., E. A. Bright, R. L. Ferguson, D. W. Field, K. D. Haddad, H. Iredale III, J.R. Jensen, V. V. Klemas, R. J. Orth, and J. P. Thomas. 1999. The coastal change analysis (C–CAP) program. Protocol documents: guidance for regional implementation. NOAA technical report NMFS 123, A Technical Report of the Fishery Bulletin, U.S. Department of Commerce, Beaufort, North Carolina.

Dueser, R. D. 1990. Biota of the Virginia barrier islands: Symposium Introduction. Virginia Journal of Science 41:257–258.

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

Emlen, J. T., D. E. Miller, R. M. Evans, and D. H. Thompson. 1966. Predator-induced parental neglect in a ring-billed gull colony. The Auk 83:677–679.

Erwin, R. M., J. D. Nichols, T. B. Eyler, D. B. Stotts, and B. R. Truitt. 1998. Modeling colony-site dynamics: a case study of gull-billed terns (*Sterna nilotica*) in coastal Virginia. The Auk 115:970–978.

Erwin, R. M., B. R. Truitt, and J. E. Jiménez. In press. Nowhere to hide: ground-nesting waterbirds and mammalian carnivores in the Virginia barrier island region. Journal of Coastal Research.

Fleskes, J. P., and E. E. Klaas. 1993. Remains of duck and other prey found near fox and mink dens on an Iowa wildlife refuge. Prairie Naturalist 25:43–50.

Forster, J. A. 1975. Electric fencing to protect sandwich terns against foxes. Biological Conservation 7:85.

Gaston, A. J., and M. Masselink. 1997. The impact of raccoons *Procyon lotor* on breeding seabirds at Englefield Bay, Haida Gwaii, Canada. Bird Conservation International 7:35–51.

Gilchrist, H. G., and A. J. Gaston. 1997. Effects of mure nest site characteristics and wind conditions on predation by glaucous gulls. Canadian Journal of Zoology 75:518–524.

Griffiths, H. I., A. Davison, and J. Birks. 1996. Species reintroductions. Conservation Biology 10:923.

Hanlon, C.L., D. E. Hayes, A. N. Hamir, D. E. Snyder, S. Jenkins, C. P. Hable, and C. E. Rupprecht. 1989. Proposed field evaluation of a rabies recombinant vaccine for raccoons (*Procyon lotor*): site selection, target species characteristics, and placebo baiting trials. Journal of Wildlife Diseases 25:555–567.

Hanski, I. 1999. Metapopulation ecology. Oxford University Press, Oxford, England.

Hario, M. 1994. Reproductive performance of the nominate lesser black-backed gull under the pressure of herring gull predation. Ornis Fennica 71:1–10.

Harrison, S., and A. D. Taylor. 1997. Empirical evidence for metapopulation dynamics. Pp. 27–42 in Metapopulation biology: ecology, genetics, and evolution (I. A. Hanski and M. E. Gilpin, eds.). Academic Press, San Diego, California.

Hartman, L. H., and D. S. Eastman. 1999. Distribution of introduced raccoons *Procyon lotor* on the Queen Charlotte Islands: implications for burrow-nesting seabirds. Biological Conservation 88:1–13.

Hartman, L. H., A. J. Gaston, and D. S. Eastman. 1997. Raccoon predation of ancient murrelets on East Limestone Island, British Columbia. The Journal of Wildlife Management 61:377–388.

Kadlec, J. 1971. Effects of introducing foxes and raccoons on the herring gull colonies. The Journal of Wildlife Management 35:625–636.

Kaufmann, J. H. 1990. Raccoon and allies. Pp. 567–585 in Wild Mammals of North America: Biology, Management, and Economics (J. A. Chapman and G. A. Feldhamer, eds.). The John Hopkins University Press, Baltimore, Maryland.

Kauhala, K. 1996. Introduced carnivores in Europe with special reference to central and northern Europe. Wildlife Biology 2:197–204.

Krim, P. M., T. L. Bashore, and G.L. Kirkland, Jr. 1990. Den characteristics and food habits of the red fox (Vulpes vulpes) on Assateague Island, Maryland. Virginia Journal of Science 41:340–351.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15:237–240.

Liepa, I. 1974. Biometrija. Zvaigzne, Rīga, Latvia.

Lindén, H., E. Helle, P. Helle, and M. Wikman. 1996. Wildlife triangle scheme in Finland: methods and aims for monitoring wildlife populations. Finnish Game Research 49:4–11.

Linhart, S. B., and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildlife Society Bulletin 3:119–124.

Loegering, J. P., and J. D. Fraser. 1995. Factors affecting piping plover chick survival in different brood–rearing habitats. The Journal of Wildlife Management 59:646–655.

Lokemoen, J. T., and R. O. Woodward. 1993. An assessment of predator barriers and predator control to enhance duck nest success on peninsulas. Wildlife Society Bulletin 21:275–282.

Lomolino, M. V. 1986. Mammalian community structure on islands: the importance of immigration, extinction and interactive effects. Biological Journal of the Linnean Society 28:1–21.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey.

McCaffrey, C. A., and R. D. Dueser. 1990a. Preliminary vascular flora of the Virginia barrier islands. Virginia Journal of Science 41:259–281.

McCaffrey, C. A., and R. D. Dueser. 1990b. Plant associations on the Virginia barrier islands. Virginia Journal of Science 41:282–299.

McGuinness, K.A. 1984. Species–area relations of communities on intertidal boulders: testing the null hypothesis. Journal of Biogeography 11:439–456.

Messmer, T. A., M. W. Brunson, D. Reiter, and D. G. Hewitt. 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27:75–85.

Morris, R. D., and D. A. Wiggins. 1986. Ruddy turnstones, great horned owls, and egg loss from common tern clutches. The Wilson Bulletin 98:101–109.

Mosillo, M., E. J. Heske, and J. D. Thompson. 1999. Survival and movements of translocated raccoons in northcentral Illinois. The Journal of Wildlife Management 63:278–286.

Patterson, M. E., J. D. Fraser, and J. W. Roggenbuck. 1991. Factors affecting piping plover productivity on Assateague Island. The Journal of Wildlife Management 55:525–531.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. The American Naturalist 132:652–661.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127–156.

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.

Sargeant, A. B. 1978. Red fox prey demands and implications to prairie duck reproduction. The Journal of Wildlife Management 42:520–527.

Sargeant, A. B., S. H. Allen, and R. T. Eberhardt. 1984. Red fox predation on breeding ducks in midcontinent North America. Wildlife Monographs 89:1–41.

Sayler, R. D., and M. A. Willms. 1997. Brood ecology of mallards and gadwalls nesting on islands in large reservoirs. The Journal of Wildlife Management 61:808–815.

Shao, G., D. R. Young, J. P. Porter, and B. P. Hayden. 1998. An integration of remote sensing and GIS to examine the response of shrub thicket distributions to shoreline changes on Virginia barrier islands. Journal of Coastal Research 14:299–307.

Southern, W. E., S. R. Patton, L. K. Southern, and L. A. Hanners. 1985. Effects of nine years of fox predation on two species of breeding gulls. The Auk 102:827–833.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. The Journal of Wildlife Management 59:1–9.

Swilling, W. R. Jr., M. C. Wooten, N. R. Holler, and W. J. Lynn. 1998. Population dynamics of Alabama beach mice (Peromyscus polionotus ammobates) following hurricane Opal. American Midland Naturalist 140:287–298.

V? ksne, J. 1997. Predation control. Pp. 89–94 in The bird lake Engure (J. V? ksne, ed.). J? ? a S? ta, R? ga, Latvia.

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

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 68:85–88.

Williams, B., R. A. Beck, J. W. Akers, and J. W. Via. 1990. Longitudinal surveys of the beach-nesting and colonial waterbirds of the Virginia barrier islands, 1975–1987. Virginia Journal of Science 41:381–388.

Wolf, P. L., S. F. Shanholtzer, and R. J. Reimold. 1975. Population estimates for *Uca pugnax* (Smith, 1870) on the duplin estuary marsh, Georgia, U.S.A. Crustaceana 29:79–91.

Yanes, M., and F. Suárez. 1996. Incidental nest predation and lark conservation in an Iberian semiarid shrubsteppe. Conservation Biology 10:881–887.

Yorio, P., and F. Quintana. 1997. Predation by kelp gulls *Larus dominicanus* at a mixed-species colony of royal terns *Sterna maxima* and cayenne terns *Sterna eurygnatha* in Patagonia. The Ibis 139:536–541.

Young, D. R., G. Shao, and J. H. Porter. 1995. Spatial and temporal growth dynamics of barrier island shrub thickets. American Journal of Botany 82:638–645.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice Hall, Upper Saddle River, New Jersey.

APPENDIX

Table A1.–*Predator track survey on 23 Virginia barrier and marsh islands in June 1999 – 2000.*

Island	Date	Line	Segment	Species	Observer
Assawoman	22.06.1999	*	-	*Vul vul*	Bill Williams
Assawoman	20.06.2000	1	1	-	Justin Crump, Oskars Keišs, Bill Williams
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	*Syl flo*	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	-	-“-
Cedar	06.06.1999	*	-	*Vul vul* (observed w/kit)	Marcus Killmon
Cedar	22.06.1999	1*	1	*Can fam*	Randall Schultz
(N-S)	-“-	-“-	2	-	-“-
(North Cedar only)	-“-	-“-	3	*Can fam*	-“-
-“-	-“-	-“-	4	*Can fam*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	2*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	3*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	4*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	5*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	6*	1	*Pro lot*	-“-
Cedar	20.06.2000	1	1	-	Oskars Keišs
(N-S)	-“-	-“-	2	*Pro lot*	-“-
(North Cedar only)	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	2	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot, Odo vir*	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Cedar	20.06.2000	2	4	*Pro lot, Odo vir, Vul vul*	Oskars Keišs
(N-S)	-“-	-“-	5	*Pro lot*	-“-
(North Cedar only)	-“-	3	1	*Odo vir, Pro lot*	-“-
(continued)	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Odo virt*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	-	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
Cedar (south)	20.06.2000	-	-	*Vul vul, Odo vir, Can fam, Pro lot*	Justin Crump, Bill Williams
Cedar Sandbar	04.08.1999	*	-	-	Barry Truitt
Cedar Sandbar	24.08.1999	*	-	*Vul vul*	-“-
Cedar Sandbar	20.06.2000	*	-	-	Philip Smith, Ruth Beck
Chimney Pool	23.06.1999	*	-	-	Eli Fenichel
Chimney Pool	14.10.1999	*	-	*Pro lot*	Oskars Keišs, Mads Thomsen
ChimneyPool	21.06.2000	-	-	-	Justin Crump
Club House Point	20.06.00	-	-	-	Philip Smith, Ruth Beck
Cobb *(N-S)*	18.07.1999	1	1	*Lep cal, Odo vir, Can fam*	Oskars Keišs
-“-	-“-	-“-	2	*Lep cal, Can fam*	-“-
-“-	-“-	-“-	3	*Lep cal, Can fam*	-“-
-“-	-“-	-“-	4	- (washed out)	-“-
-“-	-“-	-“-	5	*Odo vir*	-“-
-“-	-“-	2	1	- (washed out)	-“-
-“-	-“-	-“-	2	*Can fam*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Can fam*	-“-
-“-	-“-	3	1	*Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	3	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	4	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	5	*Odo vir, Can fam*	-“-
-“-	-“-	4	1	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	2	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Lep cal*	-“-
-“-	-“-	-“-	5	*Lep cal, Odo vir*	-“-
Cobb *(N-S)*	24.03.2000	1	1	-	Patrick Brannon, Erika Peterson
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Pro lot* (dead)	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	-	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Cobb *(N-S)*	24.03.2000	2	3	-	Patrick Brannon, Erika Peterson
(continued)	-“-	-“-	4	*Mus vis*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	3	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir*	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	*Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir, Mus vis*	-“-
-“-	-“-	-“-	3	*Odo vir, Mus vis*	-“-
-“-	-“-	-“-	4	*Odo vir, Mus vis*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5	1	-	-“-
-“-	-“-	-“-	2	*Mus vis*	-“-
-“-	-“-	-“-	3	*Mus vis, Lep cal*	-“-
-“-	-“-	-“-	4	*Mus vis, Odo vir, Lep cal*	-“-
-“-	-“-	-“-	5	*Lep cal, Mus vis*	-“-
-“-	-“-	6	1	-	-“-
Cobb *(N-S)*	15.06.2000	1	1	-	Oskars Keišs, Philip Smith
-“-	-“-	-“-	2	*Lep cal*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Lep cal*	-“-
-“-	-“-	-“-	5	*Lep cal, Odo vir*	-“-
-“-	-“-	2	1	*Lep cal, Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	3	*Lep cal*	-“-
-“-	-“-	-“-	4	*Lep cal, Odo vir*	-“-
-“-	-“-	-“-	5	*Lep cal, Odo vir*	-“-
-“-	-“-	3	1	*Lep cal, Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir, Lep cal*	-“-
-“-	-“-	-“-	3	*Lep cal, Odo vir*	-“-
-“-	-“-	-“-	4	*Lep cal*	-“-
-“-	-“-	-“-	5	*Lep cal*	-“-
-“-	-“-	4	1	*Lep cal*	-“-
-“-	-“-	-“-	2	*Lep cal*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Lep cal*	-“-
-“-	-“-	-“-	5	*Lep cal*	-“-
Cobb *(N-S)*	19.06.2000	1	1	-	Justin Crump
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Can fam*	-“-
-“-	-“-	-“-	5	*Can fam*	-“-
-“-	-“-	2	1	*Odo vir*	-“-
-“-	-“-	-“-	2	*Pro lot, Lep cal, Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir, Lep cal* (observed)	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	*Odo vir*	-“-
-“-	-“-	3	1	*Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Cobb *(N-S)*	19.06.2000	3	3	*Odo vir*	Justin Crump
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	4	1	-	-"-
-"-	-"-	-"-	2	-	-"-
Cobb	02.08.2000	–*	–*	*Pro lot* (found dead)	Barry Truitt
Fishermans	19.11.1999	1	1	*Odo vir*	Oskars Keišs
(E-W)	-"-	-"-	2	*Mus vis, Odo vir*	-"-
(Southern shore)	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Odo vir, Pro lot, Mus vis*	-"-
-"-	-"-	-"-	5	*Mus vis, Odo vir, Pro lot*	-"-
-"-	-"-	2	1	*Mus vis, Pro lot, Odo vir*	-"-
-"-	-"-	-"-	2	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	4	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	5	*Odo vir, Pro lot*	-"-
-"-	-"-	3	1	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	2	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	3	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Odo vir, Pro lot*	-"-
-"-	-"-	4	1	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	2	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	3	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	5	*Pro lot, Odo vir*	-"-
Fishermans	16.06.2000	1	1	-	Oskars Keišs, Calvin Brennan
(E-W)	-"-	-"-	2	-	-"-
(Southern shore)	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	2	1	-	-"-
-"-	-"-	-"-	2	*Odo vir*	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	*Odo vir*	-"-
-"-	-"-	3	1	*Odo vir*	-"-
-"-	-"-	-"-	2	*Odo vir*	-"-
-"-	-"-	-"-	3	*Odo vir*	-"-
-"-	-"-	-"-	4	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	5	*Odo vir*	-"-
-"-	-"-	4	1	*Odo vir*	-"-
-"-	-"-	-"-	2	*Odo vir*	-"-
-"-	-"-	-"-	3	*Odo vir*	-"-
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	-	-"-
Godwin	23.07.1999	* -	-		Raymond Dueser, Eli Fenichel, John Porter, Randall Schultz
Godwin	19.06.2000	-	-	-	Oskars Keišs
Hog *(N-S)*	21.06.1999	1	1	-	Raymond Dueser
-"-	-"-	-"-	2	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	3	*Pro lot, Odo vir*	-"-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Hog *(N-S)*	21.06.1999	1	4	*Pro lot, Odo vir*	Raymond Dueser
-“-	-“-	-“-	5	*Pro lot, Odo vir*	-“-
-“-	-“-	2	1	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	4	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5*	1	*Pro lot*	Randall Schultz
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	6*	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	7*	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	8*	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	9*	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	10*	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
Hog	14.10.1999	*	-	*Pro lot*	Oskars Keišs, Mads Thomsen
Hog *(N-S)*	24.03.2000	1	1	*Pro lot*	Oskars Keišs
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Hog *(N-S)*	24.03.2000	1	4	*Pro lot*	Oskars Keišs
(continued)	-“-	-“-	5	-	-“-
-“-	-“-	2	1	*Pro lot*	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	*Odo vir*	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	4	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	5	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Odo vir*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	6	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	7	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	8	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Odo vir, Pro lot*	-“-
Hog *(N-S)*	14.06.2000	1	1	*Odo vir,*	Justin Crump
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	*Odo vir*	-“-
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	4	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	3	1	*Pro lot, Can fam*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Hog *(N-S)*	14.06.2000	3	5	*Pro lot*	Justin Crump
(continued)	-"-	4	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	*Pro lot, Odo vir*	-"-
-"-	-"-	5	1	*Pro lot*	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	6	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	7	1	-	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
-"-	-"-	-"-	4	-	-"-
Holly Bluff	19.10.1999	*	-	*Pro lot, Can fam*	Oskars Keišs
Little Cobb	18.07.1999	*	-	-	Randall Schultz
Little Cobb	15.06.2000	1	1	-	Patrick Brannon, Justin Crump
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
Metompkin	22.06.1999	1*	1	-	Randall Schultz
N-S, Southern	-"-	-"-	2	*Vul vul*	-"-
part only, Channel	-"-	-"-	3	*Vul vul*	-"-
marker 71–S	-"-	-"-	4	*Vul vul*	-"-
(starting from	-"-	-"-	5	-	-"-
Metompkin inlet)	-"-	2*	1	-	-"-
-"-	-"-	-"-	2	*Vul vul*	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Vul vul*	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	3*	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	*Can fam*	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	4*	1	-	-"-
-"-	-"-	-"-	2	*Vul vul*	-"-
Metompkin	13.04.2000	*	-	*Vul vul* (observed)	Barry Truitt
Metompkin	19.05.2000	*	-	*Vul vul*	Barry Truitt
Metompkin	20.06.2000	1	1	-	Philip Smith
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	2	1	-	-"-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Metompkin	20.06.2000	2	2	-	Philip Smith
(continued)	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	3	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	4	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	5	1	-	-"-
-"-	-"-	-"-	2	-	Justin Crump
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	6	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	7	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	8	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
Mink	04.06.1999	*	-	*Mus vis*	Eli Fenichel
Mink	19.06.2000	-	-	-	Oskars Keišs
Mockhorn	19.10.1999	*	-	*Pro lot*, *Lut can*	Oskars Keišs, Randall Carlson
Mockhorn	12.06.2000	*	-	*Pro lot*	Oskars Keišs, Patrick Brannon, Justin Crump
Myrtle *(N-S)*	21.06.1999	1*	1	*Pro lot*	Ruth Beck
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	2*	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
Myrtle	05.07.1999	*	-	-	Eli Fenichel
Myrtle	07.10.1999	*	-	*Pro lot*	Raymond Dueser
Myrtle *(N-S)*	20.03.2000	1	1	-	Oskars Keišs
-"-	-"-	-"-	2	- (overwashed)	-"-
-"-	-"-	-"-	3	- (overwashed)	-"-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Myrtle *(N-S)*	20.03.2000	1	4	-	Oskars Keišs
(continued)	-“-	-“-	5	*Mus vis* (overwashed)	-“-
-“-	-“-	2	1	*Mus vis, Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
Myrtle *(N-S)*	19.06.2000	1	1	-	Philip Smith, Ruth Beck
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir*	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	*Odo vir*	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
Parramore *(N-S)*	30.07.1999	1*	1	*Pro lot*	Randall Schultz
-“-	-“-	-“-	2	*Pro lot, Vul vul*	-“-
-“-	-“-	-“-	3	*Pro lot, Vul vul*	-“-
-“-	-“-	-“-	4	*Pro lot, Vul vul*	-“-
-“-	-“-	-“-	5	*Pro lot , Vul vul*	-“-
-“-	-“-	2*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot , Vul vul*	-“-
-“-	-“-	-“-	3	*Pro lot , Vul vul*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot, Vul vul*	-“-
-“-	-“-	3*	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot , Vul vul*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot, Vul vul*	-“-
-“-	-“-	4*	1	*Pro lot , Vul vul*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	-	-“-
Parramore	22.09.1999	*	-	*Pro lot*	Oskars Keišs
Parramore *(N-S)*	25.03.2000	1	1	*Pro lot, Odo vir, Vul vul*	Patrick Brannon
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	5	*Odo vir, Pro lot*	-“-
-“-	-“-	2	1	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
-“-	-“-	3	1	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Parramore *(N-S)* *(continued)*	25.03.2000	3	4	*Pro lot*	Patrick Brannon
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	4	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
Parramore *(N-S)*	14.06.2000	1	1	*Pro lot*	Philip Smith
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot* observed feeding on beach	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	2	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	3	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	3	*Pro lot, Vul vul, Odo vir*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	4	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot, Can fam*	-"-
Raccoon	28.10.1999	*	-	*Pro lot*	Oskars Keišs
Raccoon	12.06.2000	*	-	*Pro lot*	Oskars Keišs, Patrick Brannon, Justin Crump
Revel	26.10.1999	*	-	*Pro lot*	Barry Truitt
Rogue	22.06.1999	*	-	*Pro lot*	Eli Fenichel, Oskars Keišs
Rogue	16.06.2000	-	-	*Pro lot, Odo vir*	Justin Crump
Sandy	23.06.1999	*	-	*Pro lot*	Oskars Keišs, Ruth Beck
Sandy	14.10.1999	*	-	*Pro lot*	Oskars Keišs, Mads Thomsen
Sandy	21.06.2000	*	-	-	Oskars Keišs, Philip Smith, Ruth Beck
Ship Shoal *(N-S)*	21.06.1999	1	1	-	Oskars Keišs
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Odo vir*	-"-
-"-	-"-	-"-	5	*Odo vir*	-"-
-"-	-"-	2	1	*Odo vir*	-"-
-"-	-"-	-"-	2	*Odo vir*	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
Ship Shoal	05.07.1999	*	-	-	Oskars Keišs
Ship Shoal	04.08.1999	*	-	*Pro lot*	Barry Truitt, Erica Peterson
Ship Shoal (S)	09.09.1999	*	-	*Mus vis*	Oskars Keišs, Patric Brannon
Ship Shoal	07.10.1999	*	-	-	Raymond Dueser
Ship Shoal *(N-S)*	23.03.2000	1*	1	-	Barry Truitt
-"-	-"-	-"-	2	-	-"-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Ship Shoal *(N-S)* *(continued)*	23.03.2000	1*	3	-	Barry Truitt
	-“-	-“-	4	*Mus vis*	-“-
-“-	-“-	-“-	5	*Mus vis, Lut can*	-“-
-“-	-“-	2*	1	*Mus vis*	-“-
-“-	-“-	-“-	2	*Mus vis*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
Ship Shoal *(N-S)*	15.06.2000	1	1	*Odo vir*	Oskars Keišs, Philip Smith
-“-	-“-	-“-	2	*Odo vir, Mus vis*	-“-
-“-	-“-	-“-	3	*Mus vis, Odo vir*	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	*Mus vis, Odo vir*	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	*Mus vis*	-“-
Skidmore	19.10.1999	*	-	*Pro lot*	Oskars Keišs
Skidmore	12.06.2000	-	-	*Pro lot*	Oskars Keišs, Patrick Brannon, Justin Crump
Smith *(N-S)*	25.06.1999	1	1	*Odo vir, Pro lot*	Oskars Keišs
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	5	*Odo vir*	-“-
-“-	-“-	4	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot*	-“-
-“-	-“-	-“-	3	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	4	*Pro lot*	-“-
-“-	-“-	-“-	5	*Odo vir, Pro lot*	-“-
-“-	-“-	5	1	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	4	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	5	*Odo vir, Pro lot*	-“-
-“-	-“-	6	1	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	2	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	3	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	4	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	5*	-	Eli Fenichel
-“-	-“-	7*	1	*Pro lot*	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Smith *(N-S)*	25.06.1999	7*	2	*Pro lot*	Eli Fenichel
(continued)	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	8*	1	-	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
Smith	27.10.1999	*	-	*Pro lot*	Oskars Keišs
Smith *(N-S)*	20.03.2000	1	1	-	Oskars Keišs
-"-	-"-	-"-	2	*Pro lot* (observed)	-"-
-"-	-"-	-"-	3	*Pro lot, Mus vis*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	2	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	3	1	- (overwashed)	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	4	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	3	- (overwashed)	-"-
-"-	-"-	-"-	4	*Pro lot* (overwashed)	-"-
-"-	-"-	-"-	5	-	-"-
-"-	-"-	5	1	*Pro lot*	-"-
-"-	-"-	-"-	2	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	3	*Odo vir, Pro lot*	-"-
-"-	-"-	-"-	4	*Pro lot, Odo vir*	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	6	1	- (overblown by wind)	-"-
-"-	-"-	-"-	2	- (overblown by wind)	-"-
-"-	-"-	-"-	3	- (overblown by wind)	-"-
-"-	-"-	-"-	4	- (overblown by wind)	-"-
-"-	-"-	-"-	5	- (overblown by wind)	-"-
Smith *(N-S)*	19.06.2000	1	1	-	Oskars Keišs
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	2	1	*Pro lot* (dead on the beach)	-"-
-"-	-"-	-"-	2	-	-"-
-"-	-"-	-"-	3	-	-"-
-"-	-"-	-"-	4	-	-"-
-"-	-"-	-"-	5	*Pro lot*	-"-
-"-	-"-	3	1	-	-"-
-"-	-"-	-"-	2	*Pro lot*	-"-
-"-	-"-	-"-	3	*Odo vir*	-"-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Smith *(N-S)*	19.06.2000	3	4	*Odo vir*	Oskars Keišs
(continued)	-“-	-“-	5	-	-“-
-“-	-“-	4	1	*Pro lot*	-“-
-“-	-“-	-“-	2	*Odo vir*	-“-
-“-	-“-	-“-	3	*Odo vir, Pro lot*	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	*Odo vir, Pro lot*	-“-
-“-	-“-	5	1	*Pro lot, Odo vir*	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	*Pro lot*	-“-
-“-	-“-	-“-	4	*Odo vir*	-“-
-“-	-“-	-“-	5	*Pro lot*	-“-
Wreck *(N-S)*	21.06.1999	1	1	-	Oskars Keišs
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5	1	-	-“-
Wreck	06.07.1999	*		*Mus vis*	Eli Fenichel, Oskars Keišs, Randall Schultz
Wreck (N-S)	23.03.2000	1	1	-	Oskars Keišs, Patrick Brannon
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	- (overwashed)	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	*Odo vir* (overwashed)	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	-	-“-
-“-	-“-	-“-	2	-	-“-

Table A1.–*Continued.*

Island	Date	Line	Segment	Species	Observer
Wreck (N-S) *(continued)*	23.03.2000	4	3	-	Oskars Keišs, Patrick Brannon
	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5	1	-	-“-
-“-	-“-	-“-	2	-	-“-
Wreck *(N-S)*	15.06.2000	1	1	-	Justin Crump, Patrick Brannon
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	-	-“-
Wreck *(N-S)*	19.06.2000	1	1	-	Oskars Keišs, Philip Smith
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	2	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	3	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	4	1	-	-“-
-“-	-“-	-“-	2	-	-“-
-“-	-“-	-“-	3	-	-“-
-“-	-“-	-“-	4	-	-“-
-“-	-“-	-“-	5	-	-“-
-“-	-“-	5	1	-	-“-

*	only predator tracks registered	
Lep cal -	*Lepus californicus* -	Black-tailed Jackrabbit
Syl flo -	*Sylvilagus floridans* -	Eastern Cottontail
Vul vul -	*Vulpes vulpes* -	Red Fox
Can fam -	*Canis familiaris* -	Domestic Dog
Pro lot -	*Procyon lotor* -	Raccoon
Mus vis -	*Mustela vison* -	American Mink
Lut can -	*Lutra canadensis* -	Northern River Otter
Odo vir -	*Odocoileus virginianus* -	White-tailed Deer

Table A2.–*Raccoons* Procyon lotor *sampled for DNA analyses on the Virginia Barrier Islands and mainland areas of the Virginia Coast Reserve in 1999.*

Bottle Nr.	Sex	Age	Date	Capture site[1]	Right eartag	Left eartag	Radio frequency	Weight, g	Name	Recapture date, site
PR 01	?	*Ad.*	JUN 15	SM 13	0004	0003	150.897	3700	Rocky Rokis	–
PR 02	?	*Ad.*	JUN 15	SM 22	0006	0005	150.908	3300	Nancy Nara	–
PR 03	?	*Ad.*	JUN 15	SM 32	0008	0007	150.967	4550	Ray Raitis	JUN 17, SM 35
PR 04	?	*Ad.*	JUN 17	SM 35	0020	0019	–	2800	Jane Janta	–
PR 05	?	*Ad.*	JUN 16	SM 14	0002	0001	150.987	3800	Stormy Stogis	–
PR 06	?	*Ad.*	JUN 15	SM 42	0010	0009	150.929	3300	Lil Lize	JUN 26, SM 37
PR 07	?	*Ad.*	JUN 16	SM 04	0012	0011	151.135	4300	Dan Daris	–
PR 08	?	*Ad.*	JUN 16	SM 30	0016	0015	–	4400	Randy Rancis	–
PR 09	?	*Ad.*	JUN 16	SM 24	0014	0013	–	4700	Barry Balvis	–
PR 10	?	*Ad.*	JUN 16	SM 33	0017	0018	–	4100	Sandy Sanda	JUN 27, SM 32
PR 11 *	?	*Ad.*	JUN 27	SM 31	0022	0021	–	4100	John Johans	–
PR 12 *	–	*Ad.*	JUN 30	SM 07[+]	–	0026	–	4900	Kaupens Kaupens	–
PR 13	?	*Ad.*	JUN 28	SM 33	0023	0024	–	3500	Dazy Dace	–
PR 14	?	*Ad.*	JUL 2	SM 32	0027	0025	–	3350	Bonnie Bonifacija	–
PR 15	?	*Ad.*	JUL 3	SM 49	0029	0028	151.047	3150	Lia Lia	–
PR 16	?	*Ad.*	JUL 3	SM 48	0030	0031	151.175	3500	Tracy Trine	–
PR 50	?	*Ad.*	OCT 28	SM 59	0096	0097	–	3900	Grieta Grieta	–
PR 51	?	*Ad.*	OCT 28	SM 44	0098	0099	–	4700	Rasma Rasma	–
PR 52*	?	*Juv.*	OCT 28	SM 58[+]	–	0101	–	1650	Rinalds Rinalds	–
PR 53*	?	*Ad.*	OCT 28	SM 58[+]	–	0100	–	3900	Olga Olga	–
PR 54	?	*Ad.*	OCT 29	SM 40	0102	0103	–	4000	Armands Armands	NOV 11, SM 40
PR 55	?	*Ad.*	OCT 29	SM 58	0104	0105	–	6200	Didzis Didzis	–
PR 56	?	*Juv.*	OCT 29	SM 60	0106	0107	–	1600	Erlens Erlens	–

Table A2.–*Continued.*

Bottle Nr.	Sex	Age	Date	Capture site[1]	Right eartag	Left eartag	Radio frequency	Weight, g	Name	Recapture date, site
VV01 (57)	?	*Ad.*	NOV 10	SM 48	0108	0109	–	4300	Varis Varis	–
PR 58	?	*Ad.*	NOV 10	SM 57	0110	0111	–	4850	Mareks Mareks	–
PR 17	?	*Ad.*	JUL 8	HG 21	0033	0032	151.028	4500	Sud Surmis	–
PR 18	?	*Ad.*	JUL 9	HG 14	0035	0034	151.075	4550	Harvey Harijs	JUL 14, HG 15
PR 19	?	*Ad.*	JUL 11	HG 16	0037	0036	150.943	5400	George Georgs	–
PR 21	?	*Juv.*	JUL 13	HG 21	0041	0040	–	850	Tom Tonijs	–
PR 22	?	*Juv.*	JUL 13	HG 21	0043	0042	–	700	Jerry Jezups	–
PR 20	?	*Ad.*	JUL 12	RO 01	0039	0038	151.180	4050	Ricky Ritvars	–
PR 23	?	*Ad.*	JUL 23	MY 14	0045	0044	151.017	3850	Sonny Solis	–
PR 24	?	*Ad.*	JUL 23	MY E	0047	0046	151.106	3900	Cher Ciepa	–
PR 42*	?	*Ad.*	JUL 31	–[§]	0081	–	–	4300	Jukums Jukums	–
PR 25	?	*Ad.*	JUL 28	PA 01	0049	0048	151.117	3650	Roxy Roga	–
PR 26	?	*Ad.*	JUL 28	PA 02	0051	0050	151.002	2750	Priscilla Princese	–
PR 27	?	*Ad.*	JUL 28	PA 09	0052	0053	–	2500	Debbie Dekla	–
PR 28	?	*Ad.*	JUL 28	PA 12	0054	0055	151.087	4300	Phil Pilkis	–
PR 29	?	*Ad.*	JUL 28	PA 13	0056	0057	151.150	3750	Peter Peteris	–
PR 30	?	*Ad.*	JUL 28	PA 17	0059	0058	150.957	4000	Forest Fogts	–
PR 31*	?	*Ad.*	JUL 28	PA 20	0061	0060	–	3250	Kerja Kerija	–
PR 32	?	*Ad.*	JUL 29	PA 11	0062	0063	151.363	4000	Marley Martinš	–
PR 33	?	*Ad.*	JUL 29	PA 15	0065	0064	151.745	4550	Eddie Edgars	–
PR 34*	?	*Ad.*	JUL 29	PA 22[+]	–	0074	–	5000	Maigonis Maigonis	–
PR 35	?	*Ad.*	JUL 29	PA 31	0066	0067	151.060	3750	Madonna Madara	–
PR 36*	?	*Ad.*	JUL 29	PA 22[+]	0073	–	–	4800	Lavize Lavize	–
PR 37	?	*Ad.*	JUL 30	PA 05	0069	0068	151.602	4550	Bud Burvis	–
PR 38	?	*Ad.*	JUL 30	PA 09	0071	0070	151.436	4400	Boris Bronislavs	–

Table A2.–*Continued*.

Bottle Nr.	Sex	Age	Date	Capture site[1]	Right ear tag	Left ear tag	Radio frequency	Weight, g	Name	Recapture date, site
PR 39	?	*Juv.*	JUL 30	PA 24	0076	0072	–	1250	Junior Juris	–
PR 40	?	*Ad.*	JUL 30	PA 25	0077	0078	151.552	4700	Sarah Saiva	–
PR 41	?	*Ad.*	JUL 30	PA 29	0080	0079	151.496	2950	Rosie Rozalija	–
PR 43	?	*Juv.*	AUG 2	CU 09	0082	0083	–	1300	Jillian Jilde	–
PR 45	?	*Ad.*	AUG 4	CU 02	0087	0086	151.291	4250	Betsy Bella	–
PR 44	?	*Ad.*	AUG 3	BR 07	0085	0084	151.645	5700	Arnold Arnis	–
PR 46	?	*Ad.*	AUG 5	BR 07	0093	0092	–	4600	Tina Tina	–
PR 47	?	*Ad.*	AUG 4	BR 08	0088	0089	151.395	3650	Sue Subate	–
PR 48	?	*Ad.*	AUG 4	BR 12	0091	0090	151.316	4200	Frank Francis	–
PR 49	?	*Ad.*	AUG 5	BR 09	0094	0095	–	4400	Garfielda Gandrene	–
PR 59*	–	*Ad.*	MAR 24	CO[†]	–	–	–	–	Kazimirs Izidors	–

[1]Localities:

BR – Brownsville (mainland), CO – Cobb Island, CU – Cushman's landing (mainland), HG – Hog Island, MY – Myrtle Island, PA – Parramore Island, RO – Rogue Island, SM – Smith Island

* dead, whole animal collected for Virginia Museum of Natural History

[+] not captured but found dead near the trap site

[§] roadkill on highway 13 at Cheriton, VA (mainland; UTM 18415355 E 4130925 N)

[†] northern part of Cobb Island, precise location unknown, found dead, half-rotten, skull collected for Virginia Museum of Natural History

Table A3.–*History of radio-tracking of adult raccoons on the 5 barrier islands and 2 mainland areas of the Virginia Coast Reserve in Fall 1999 and Spring 2000.*

Radio frequency	Collar type[1]	Name	Sex	Date collared	Trap site captured[2]	Total tracking effort (days)	Number of days of reception	Last date of reception	Number of days collar known to work
150.897	AVM	Rocky Rokis	?	JUN 15	SM 13	16	1*	AUG 12	0
150.908	-“-	Nancy Nara	?	JUN 15	SM 22	16	8	AUG 12	69
150.929	-“-	Lil Lize	?	JUN 15	SM 42	17	9	AUG 12	69
150.943	-“-	George Georgs	?	JUL 11	HG 16	7	2	JUL 13	2
150.957	-“-	Forest Fogts	?	JUL 28	PA 17	7	2	AUG 24	27
150.967	-“-	Ray Raitis	?	JUN 15	SM 32	14	5	JUL 2	17
150.987	-“-	Stormy Stogis	?	JUN 16	SM 14	16	5	JUN 28	12
151.002	-“-	Priscilla Princese	?	JUL 28	PA 02	7	3	AUG 24	27
151.017	-“-	Sonny Solis	?	JUL 23	MY 14	11	0	JUL 23	0
151.028	-“-	Sud Surmis	?	JUL 8	HG 21	8	3	JUL 12	4
151.047	-“-	Lia Lia	?	JUL 3	SM 49	10	2	AUG 12	40
151.060	-“-	Madonna Madara	?	JUL 29	PA 31	7	1*	AUG 17	19
151.075	-“-	Harvey Harijs	?	JUL 9	HG 14	9	4	JUL 14	3
151.087	-“-	Phil Pilkis	?	JUL 28	PA 12	7	1*	AUG 24	27
151.106	-“-	Cher Ciepa	?	JUL 23	MY E	11	0	JUL 23	0
151.117	-“-	Roxy Roga	?	JUL 28	PA 01	7	3	AUG 24	27
151.135	-“-	Dan Daris	?	JUN 16	SM 04	16	7	AUG 12	68
151.150	-“-	Peter Peteris	?	JUL 28	PA 13	7	4	SEP 13	47
151.175	-“-	Tracy Trine	?	JUL 3	SM 48	11	2	AUG 6	34
151.180	-“-	Ricky Ritvars	?	JUL 12	RO 01	7	2	JUL 14	2
151.291[†]	WMI	Betsy Bella	?	AUG 4	CU 02	48	48	FEB 27[†]	207[†]

Table A3.–*Continued.*

Radio frequency	Collar type[1]	Name	Sex	Date collared	Trap site captured[2]	Total tracking effort (days)	Number of days of reception	Last date of reception	Number of days collar known to work
151.316	WMI	Frank Francis	?	AUG 4	BR 12	50	49	NOV 14	102
151.363	-"-	Marley Martinš	?	JUL 29	PA 11	7	7	JUN 14	321
151.395	-"-	Sue Subate	?	AUG 4	BR 08	45	40	JUN 17	318
151.436	-"-	Boris Bronislavs	?	JUL 30	PA 09	7	7	JUN 14	320
151.496	-"-	Rosie Rozalija	?	JUL 30	PA 29	6	5	JUN 14	320
151.552‡	-"-	Sarah Saiva	?	JUL 30	PA 25	–	–	–	54‡
151.602	-"-	Bud Burvis	?	JUL 30	PA 05	6	5	JUN 14	320
151.645	-"-	Arnold Arnis	?	AUG 3	BR 07	47	47	JUN 17	319
151.745	-"-	Eddie Edgars	?	JUL 29	PA 15	7	7	JUN 14	321

[1]two types of collars were used:

AVM – raccoon collars, manufactured by "AVM instrument company ltd."

WMI – fox collars, manufactured by "Wildlife Materials Inc."

[2] Localities:

BR – Brownsville (mainland); CU – Cushman's landing (mainland); HG – Hog Island; MY – Myrtle Island; PA – Parramore Island; RO – Rogue Island; SM – Smith Island

*signal very weak

† killed by car on the highway 13

‡ collar dropped

Table A4.–*Maximum distances (m) between 2 locations of radio-collared raccoons on 5 barrier islands and 2 mainland areas of the Virginia Coast Reserve in Fall 1999 and Spring 2000.*

Trapping site	Radio frequency	Name	Sex	Dates of locations of maximum distance movement	Days between	Distance	Total number of locations[1]
Brownsville 07	151.645	Arnold Arnis	?	SEP 30 – OCT 8	8	1119	49
Brownsville 08	151.395	Sue Subate	?	AUG 9 – AUG 10*	1	3044	40
Brownsville 12	151.316	Frank Francis	?	AUG 6 – SEP 26	51	950	50
Cushman's 02	151.291	Betsy Bella	?	OCT 16 – FEB 27	134	5550	49
Hog 14	151.075	Harvey Harijs	?	JUL 12 – JUL 14***	2	1038	6
Hog 16	150.943	George Georgs	?	JUL 11 – JUL 13***	2	775	3
Hog 21	151.028	Sud Surmis	?	JUL 8 – JUL 12***	4	406	4
Myrtle 14	151.017	Sonny Solis	?	No successful locations	–	–	1
Myrtle E	151.106	Cher Ciepa	?	No successful locations	–	–	1
Parramore 01	151.117	Roxie Roga	?	JUL 28 – AUG 17***	20	625	4
Parramore 02	151.002	Priscilla Princese	?	JUL 28 – AUG 17***	20	316	4
Parramore 05	151.602	Bud Burvis	?	SEP 13 – JUN 14	285	1660	8
Parramore 09	151.436	Boris Bronislavs	?	MAR 25 – JUN 14	81	2130	9
Parramore 11	151.363	Marley Martinš	?	AUG 17 – OCT 26	70	950	7
Parramore 12	151.087	Phil Pilkis	?	No successful locations	–	–	1
Parramore 13	151.150	Peter Peteris	?	AUG 6 – AUG 17	11	925	5
Parramore 15	151.745	Eddie Edgars	?	JUL 29 – AUG 6***	8	1163	8
Parramore 17	150.957	Forest Fogts	?	JUL 28 – AUG 6***	9	1425	3
Parramore 25	151.552	Sarah Saiva	?	JUL 30 – AUG 6[†]	?8	181	2[†]
Parramore 29	151.496	Rosie Rozalija	?	AUG 6 – SEP 3	38	3475	8
Parramore 31	151.060	Madona Madara	?	No successful locations	–	–	1
Rogue 01	151.180	Ricky Ritvars	?	JUL 12 – JUL 14***	2	788	3

Table A4.–*Continued.*

Trapping site	Radio frequency	Name	Sex	Dates of locations of maximum distance movement	Days between	Distance	Total number of locations[1]
Smith 04	151.135	Dan Daris	?	JUL 2 – AUG 12	40	1588	7
Smith 13	150.897	Rocky Rokis	?	no successful locations	–	–	1
Smith 14	150.987	Stormy Stogis	?	JUN 17 – JUN 27*	10	1838	6
Smith 22	150.908	Nancy Nara	?	JUN 18 – AUG 12	55	1050	9
Smith 32	150.967	Ray Raitis	?	JUN 27 – JUN 28**	1	1788	7
Smith 42	150.929	Lil Lize	?	JUN 21 – AUG 12	52	1888	8
Smith 48	151.175	Tracy Trine	?	JUL 3 – JUL 7***	4	350	2
Smith 49	151.047	Lia Lia	?	JUL 3 – JUL 7***	4	325	2

[1] including capture location

* is night observation;
** both observations are night observations;
*** one of observations is capture, which is equal to night observation

† collar dropped

Table A5.–*Bird colonies on Virginia barrier islands in 1999 (Williams, in litt.).*

	Herons			Larids		
Island	No. of colonies	No. of species	No. of individ.	No. of colonies	No. of species	No. of individ.
Assawoman	0	0	0	1	1	6
Cedar	0	0	0	0	0	0
Cedar Sandbar	0	0	0	4	4	428
Chimney Pole Marsh	2	5	148	1	2	596
Club House Point	1	7	257	1	3	462
Cobb	1	9	540	4	3	260
Dawson Shoals	0	0	0	1	2	749
Fishermans	2	10	406	1	7	10000
Godwin	0	0	0	1	1	42
Hog	0	0	0	1	1	22
Holly Bluff	0	0	0	0	0	0
Little Cobb	0	0	0	1	5	289
Metompkin	0	0	0	1	4	29
Mink	0	0	0	1	2	42
Mockhorn	0	0	0	0	0	0
Myrtle	0	0	0	1	1	4
Parramore	0	0	0	0	0	0
Raccoon	0	0	0	0	0	0
Revel	0	0	0	0	0	0
Rogue	0	0	0	0	0	0
Sandy	0	0	0	2	4	373
Ship Shoal	0	0	0	1	4	98
Skidmore	0	0	0	0	0	0
Smith	0	0	0	0	0	0
Wreck	1	9	273	2	8	1725
Total:	7		1624	24		15125

Table A6.–*Bird colonies on Virginia barrier islands in 2000 (Williams, in litt.).*

	Herons			Larids		
Island	No. of colonies	No. of species	No. of individ.	No. of colonies	No. of species	No. of individ.
Assawoman	0	0	0	2	1	22
Cedar	0	0	0	1	1	8
Cedar Sandbar	0	0	0	1	4	1069
Chimney Pole Marsh	1*	6	603*	*	2	*
Club House Point	1	9	243	1	3	830
Cobb	1	10	341	3	3	262
Fishermans	2	7	440	2	7	8342
Godwin	0	0	0	0	0	0
Hog	0	0	0	1	3	136
Holly Bluff	0	0	0	0	0	0
Little Cobb	0	0	0	1	5	523
Metompkin	0	0	0	2	1	47
Mink	0	0	0	0	0	0
Mockhorn	0	0	0	0	0	0
Myrtle	0	0	0	2	3	50
Parramore	0	0	0	0	0	0
Raccoon	0	0	0	0	0	0
Revel	0	0	0	0	0	0
Rogue	0	0	0	0	0	0
Sandy	0	0	0	2	4	660
Ship Shoal	0	0	0	1	2	390
Skidmore	0	0	0	0	0	0
Smith	0	0	0	0	0	0
Wreck	1	9	848	3	6	1141
Total:	5		1872	18		12381

* mixed colony of cormorants, herons and gulls