EFFECTS OF HERRING GULLS AND GREAT BLACK-BACKED GULLS ON BREEDING PIPING PLOVERS, SOUTH MONOMOY ISLAND, MASSACHUSETTS

by
Shannon E. Keane

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
In partial fulfillment of the requirements for the degree of

Master of Science
in
Fisheries and Wildlife Sciences

APPROVED:

Dr. James D. Fraser, Chair
Dr. P. A. Buckley, Committee Member
Dr. Roy L. Kirkpatrick, Committee Member
Dr. Dean F. Stauffer, Committee Member
Dr. Donald J. Orth, Department Head

September 18, 2002
Blacksburg, Virginia

Keywords: *Charadrius melodus*, gull control, *Larus argentatus*, *Larus marinus*, Monomoy

Michael St. Germain

EFFECTS OF HERRING GULLS AND GREAT BLACK-BACKED GULLS ON BREEDING PIPING PLOVERS, SOUTH MONOMOY ISLAND, MASSACHUSETTS

by

Shannon E. Keane

James D. Fraser, Chair

Fisheries and Wildlife Sciences

(ABSTRACT)

The large population of breeding Herring Gulls and Great Black-backed Gulls on South Monomoy Island, Cape Cod, Massachusetts has been thought to negatively affect the breeding success of the threatened Piping Plover. Following the Piping Plover Recovery Plan's call for gull colonies to be removed from Piping Plover breeding sites, in 1996, the USFWS conducted gull removal on part of South Monomoy Island. We determined relative gull abundance on South Monomoy Island from 1998-2000 by counting gulls within 100-m radius plots located on the shoreline. We quantified Piping Plover behavior and habitat use by conducting instantaneous and 5-minute behavioral observations. We quantified characteristics of Piping Plover nesting habitat by measuring characteristics along random transects. We measured gull abundance, beach width, and prey abundance, and then used logistic regression to determine what habitat characteristics influenced Piping Plover nesting area selection. We monitored Piping Plover reproductive success and population fluctuations on South Monomoy Island.

Gull abundance in the gull-removal area was lower than gull abundance in the reference area throughout the Piping Plover breeding season. The difference in gull abundance between the areas did not affect Piping Plover behavior, nest success, chick survival, or productivity. We found that gull removal did not result in an increased Piping Plover population on the island. In both management areas, prenesting plovers preferred to forage in moist substrate habitats. Wide backshore and open vegetation habitats characterized nesting areas. Broods spent most of their time foraging and preferred moist substrate habitats when available. Plovers were not prevented from occupying more suitable habitat by large gulls.

Fewer large gulls were observed near prenesting plovers, plover nests, and plover broods than near random plots. Fewer large gulls were observed in plover nesting areas than in unused

areas when the nesting areas were defined by all area within 100-m or 500-m of a plover nest. We argue that this apparent spatial separation between Piping Plovers and large gulls is due to different habitat preferences among the species. We found that gull removal on South Monomoy Island did not result in increased Piping Plover reproductive success, and large gulls did not affect breeding Piping Plovers on South Monomoy Island from 1998-2000.

ACKNOWLEDGEMENTS

I cannot thank my advisor, Dr. James D. Fraser, enough for being my mentor and friend throughout this project. Jim was always very helpful, patient, enthusiastic, encouraging, and supportive throughout all phases of the study. I am especially grateful to Jim for making his students his priority, and for always keeping his door open to us.

I am extremely grateful to my committee members Dr. P. A. Buckley of USGS Patuxent Wildlife Research Center and Dr. Dean Stauffer and Dr. Roy Kirkpatrick of the Department of Fisheries and Wildlife Sciences at Virginia Tech for their invaluable input throughout the study and for their careful review of this thesis.

I would like to thank Anne Hecht of USFWS, Scott Melvin of Massachusetts Division of Fish and Game, Ian Nisbet of I.C.T. Nisbet and Co., and Jay Hestbeck of USGS for spending considerable time and energy reviewing reports and this thesis, discussing and refining methodology, and providing useful information.

Special thanks go to Bud Oliveira, Stephanie Koch, Sharon Fish, Deborah Long, Sharon Ware, Jennifer Casey, and all USFWS staff and volunteers at Monomoy National Wildlife Refuge who gave valuable input, information, logistical support, assistance in the field, and access to the study area. I would also like to thank Rick Schauffler of USFWS Region 5 for valuable discussion of research methodology over a pot of steamers, and for access to georeferenced aerial photographs of Monomoy.

I thank Jeff Spendelow of USGS, Carolyn Mostello of Massachusetts Division of Fish and Game, and Steve Manos of the Department of Fisheries and Wildlife Sciences at Virginia Tech for information and assistance. I thank Frank and Pat Facchetti, John Huether, and all the folks at Outermost Harbor Marine for their assistance with *R/V Charadrius*, as the logistics surrounding the boat were most important for carrying out this study. Special thanks go to Ian Nisbet for donating the trusty 12-foot aluminum skiff, *Sterna*, which safely returned the crew to the mainland time and time again. I give thanks to Stuart Smith for setting the mooring 8 miles from the harbor and the folks at Cape Fishermen's Supply, Inc. and Chatham Printing Service for keeping us in operation. Thanks go to Richard Hall and Kathleen Edwards for great conversation and great chocolate chip cookies. Thanks go to the Lincoln family for emergency

transportation to and from the island, and for providing valuable local knowledge of the waters surrounding Monomoy. It was always a great pleasure to see friendly faces when coming in from long stints on the island. Special thanks go to Brian Tague for permission to use his beautiful photographs for presentations. Warm thanks go to the Poirier family for being great neighbors on South Monomoy. I will fondly remember card games in the cabin during periods of thick fog, and the stories shared of life in Whitewash Village. The cabin will always be a special place.

I give a very special thanks to James Hall, Ellen Jedrey, Peter Kappes, Mary Paul, Vanessa Smith, Michael St. Germain and Alison Van Vort for their high spirits and long, tedious hours devoted to data collection. I am especially grateful for their patience, enthusiasm, and friendship. Thanks to Larry Houghton for teaching me software tricks, SAS code, the proper way to spread Tanglefoot insect trap onto paint stirrers, and especially for being there when I needed a shoulder to lean on. Thanks go to Jon Cohen, Scott Klopfer, Danielle Le Fer, Sylvia Schmidt, Pat Devers and Darroch Whitaker for their friendship and assistance, Julie Boyles, Sybille Klenzendorf, Colleen Olfenbuttel, Gyasi Quince, Mandy Rosenberger, Andy Strickland, and Erin Sullivan for being there, and to all of the graduate students, faculty, and staff of Fisheries and Wildlife Sciences at Virginia Tech for support and friendship.

Warm thanks and appreciation go to Mike St. Germain for his encouragement, patience, support, and love, and for photographs and drawings that will always take me back to Monomoy, and to my family and friends for their support and love and for believing that I would eventually graduate.

I thank the U.S. Geological Survey (USGS), Patuxent Wildlife Research Center for providing financial support for this project. Special thanks go to P. A. Buckley, Jay Hestbeck, and Richard Jachowski of USGS for administrative support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

In 1986, the Atlantic Coast Piping Plover population (*Charadrius melodus*) was listed as Threatened under the Endangered Species Act of 1973 (USFWS 1985). The decline of this species has been attributed to loss and degradation of breeding habitat. Predation, disturbance, and destruction of nests and young by human activities reduced reproductive rates (e.g., Wilcox 1959, Arbib 1979, Cairns 1977, MacIvor 1990, Goldin 1993, Hoopes 1993). Since listing, a variety of management interventions have been employed to reduce the effects of habitat degradation, resulting in population increases throughout much of the Atlantic Coast region. One of the recovery goals for the Atlantic Coast Piping Plover population is to increase the population to 2,000 breeding pairs, sustained for 5 consecutive years (USFWS 1996a). Overall, the Atlantic Coast population has increased from 790 breeding pairs at the time of listing to approximately 1,400 pairs in 2000 (USFWS 2002). Most of the population increase has been in New England, where pairs have increased >300% (USFWS 2002). Approximately 80% of the New England subpopulation breeds in Massachusetts (Mostello and Melvin 2001).

The Atlantic Coast Recovery Plan states that gulls should be prevented from establishing and expanding nesting colonies at Piping Plover nesting areas (USFWS 1996a). The plan states that existing gull colonies at plover nesting sites should be removed because gulls depredate plover eggs and chicks and take over plover nesting sites. Following recovery plan recommendations, the prevention of gull nesting at Breezy Point, Gateway National Recreation Area, Brooklyn, NY was identified as a "Conservation Recommendation" for Piping Plovers by the USFWS in 1989 (USDA Animal Damage Control 1993). A long-term gull control project was initiated in 1992 using nonlethal harassment methods and nest and egg destruction to reduce the Great-black Backed Gull (*Larus argentatus)* and Herring Gull (*L. marinus*) populations (Olijnyk and Brown 1999). Lauro and Tanacredi (2002) reported that gull predation accounted for 6% of Piping Plover egg loss from 1992 to 1996. However, based on their artificial nest study, crows (*Corvis* spp.) took significantly more eggs than gulls, and may be a more serious potential predator to Piping Plover eggs. The success of the Breezy Point gull control project in increasing Piping Plover breeding success has not been shown.

Similar to the Breezy Point site, the large population of nesting Great Black-backed Gulls and Herring Gulls at Monomoy National Wildlife Refuge in Chatham, Massachusetts has been thought to prevent or limit other species from nesting on the island (USFWS 1988, USFWS 1996b). The refuge Master Plan states that, without gull removal, gulls would interfere with Piping Plover courtship rituals, prevent establishment of nesting territories, and depress the plover population (USFWS 1988). MacIvor (1990) asserted that large numbers of roosting and nesting gulls occupied habitats that were physically suitable for plover nesting on South Monomoy Island. She argued that given the amount of habitat that appears physically suitable, numbers of nesting Piping Plovers were surprisingly low. She suggested that this was a consequence of both predation by gulls on Piping Plover eggs and chicks and occupancy of potential plover nesting habitats by large numbers of gulls.

The aim of our research was to determine whether Herring Gulls and/or Great Black-backed Gulls have any effect on the number and/or productivity of breeding Piping Plovers on South Monomoy Island. We studied Piping Plover behavior and breeding success in relation to gulls and other factors on South Monomoy Island from 1998 to 2000. A summary of Piping Plover reproductive success during our study is presented in Table 1.

GOALS

The goals of this project were to:

(1) Determine factors affecting Piping Plover distribution, habitat use and productivity.

(2) Determine the distribution of gulls with respect to plover habitats.

(3) Describe gull-plover interactions and determine whether gulls alter plover behavior, nest site selection and survival, or chick survival.

(4) Determine if effects of gulls on plovers are reduced with gull removal.

NULL HYPOTHESES

(1) Herring Gulls and/or Great Black-backed Gulls do not limit the Piping Plover breeding population on South Monomoy Island.

(2) Piping Plover reproductive rates are not limited by Herring Gulls and/or Black-backed Gulls.

PREDICTIONS

If gulls are limiting Piping Plover numbers and/or productivity on South Monomoy Island then one or more of the following predictions will be true: (1) Piping Plover habitat use will differ between low- and high-gull abundance areas (gull-removal area and reference area), (2) Piping Plover reproductive rates will be greater in suitable habitat in low-gull abundance areas than in high-gull abundance areas, (3) Piping Plovers will avoid gulls when foraging or nesting, (4) Predation by gulls will be greater in high-gull abundance areas than in low-gull abundance areas, (5) Gull harassment of Piping Plovers will be greater in high-gull abundance areas than in low-gull abundance areas and (6) Piping Plover foraging rates will be lower in high-gull abundance areas than in low-gull abundance areas of equivalent habitat quality.

STUDY AREA

South Monomoy Island is part of Monomoy National Wildlife Refuge in Chatham, Massachusetts, near the southeastern corner of Cape Cod (Figure 1). Natural processes have frequently changed the shoreline and location of Monomoy. During the first half of the 20th century, Monomoy was a barrier spit extending south from Chatham Harbor between the Atlantic Ocean and Nantucket Sound. In 1958, a storm breached the spit, forming Monomoy Island. In February of 1978, a northeaster split Monomoy Island into North and South Monomoy Islands.

During this study, South Monomoy Island was 9.5 km from north to south, and 2.0 km from west to east at the widest point, comprising 655 ha (Figure 1). Large tidal ponds and extensive sand flats provided foraging habitat for shorebirds and wading birds. Most mammalian predators of beach-nesting birds such as red fox (*Vulpes fulva*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*) were not present on South Monomoy throughout our study. Coyotes (*Canis latrans*) were present, but USFWS personnel conducted coyote control, focusing on denning animals, during all years of our study (USFWS 1999, USFWS 2000, USFWS in prep). Pedestrian use on South Monomoy was low compared to other Cape Cod beaches.

Piping Plovers on Monomoy Island

From 1983 to 1993, the number of Piping Plovers nesting at Monomoy National Wildlife Refuge (both North and South Monomoy Islands) fluctuated between 2 and 5 pairs. The number of observed nesting pairs increased from 4 nesting pairs in 1993 to 30 nesting pairs in 2000 (USFWS 1996b, Megyesi 1998, USFWS 1999, USFWS 2000a, this study, Figure 2).

Large Gulls on Monomoy Island

An increase in the human population in coastal areas during the 20th century and the consequent increase in refuse and fish offal has lead to the southward range expansion and invasion of Herring Gulls and Great Black-backed Gulls into Massachusetts (Hunt 1972, Blodget 1988, Drury 1973 *cited in* Cavanagh 1992). Kadlec and Drury (1968) reported 5 pairs of Herring

Gulls on Monomoy Island in 1963. Seventy-five pairs of Great Black-backed Gulls were recorded in 1965 (USFWS 1988). By 1984, an estimated 15,300 pairs of Herring Gulls and 4,200 pairs of Great Black-backed Gulls nested on Monomoy National Wildlife Refuge (USFWS 1988) but in 1990, the Herring Gull population had declined to 9,600 pairs while the Great Black-backed Gull population increased to 8,200 pairs (Cavanagh 1992, USFWS 1996b).

Gull-removal at Monomoy National Wildlife Refuge

In an attempt to maintain the tern colony (*Sterna spp.*) on North Monomoy Island, gull control was implemented from 1980 to 1984. Methods used in an attempt to control gulls included harassment, nest and egg destruction, shooting, and limited use of the avicide DRC-1339. Despite these attempts, the gull population continued to increase. From 1993 to 1994, at least 1,000 gulls were shot and at least 3,500 gull nests were destroyed on the refuge. Removal of gulls took place in areas within and surrounding potential and used Piping Plover nesting habitat, including the Powder Hole area. Gull removal methods followed the 1988 Master Plan protocols (USFWS 1988, USFWS unpublished data). The impact on the gull population or the effects of removing gulls on Piping Plover reproductive success was not reported.

In 1996, the U.S. Fish and Wildlife Service (USFWS) began an intensive program of removing gulls from South Monomoy Island. Gull control was conducted on the north end of the island to restore avian diversity by making nesting habitat available for several species, and to increase numbers of Piping Plovers (USFWS 1996b). During the 1996 breeding season, USFWS baited approximately 2,850 gull nests with Purina Starlicide Technical DRC-1339, shot 448 adult gulls, and used nonlethal harassment in the gull-removal area and buffer areas (Figure 1). This resulted in the removal of at least 1,185 Herring Gulls and 726 Great Black-backed Gulls (USFWS 1996b). In 1997, USFWS used nonlethal harassment in conjunction with trapping and shooting 148 territorial gulls in the gull-removal area. Productivity was suppressed in the buffer area by puncturing eggs (Megyesi 1998). From 1998-2000, USFWS was permitted to prevent Herring Gulls and Great Black-backed Gulls from successfully nesting in the gull-removal area by destroying nests and using nonlethal harassment, and to reduce gull productivity in the buffer area by puncturing eggs (USFWS 1999, USFWS 2000a, USFWS in prep.). During

our study, 1 immature Herring Gull was shot by USFWS under in the gull-removal area in 1998 (USFWS 1999).

Sampling Areas

Sampling areas for this study were based on the USFWS Restoration of Avian Diversity Project management areas (USFWS 1996b; Table 2, Figure 1). The gull-removal area (USFWS Area A) includes the northernmost tip of the island. It comprises approximately 45 ha and has approximately 3.3 km of shoreline. The buffer area (USFWS Area B) comprises approximately 35 ha and has approximately 1.6 km of shoreline. The buffer area includes a tidal pond area (Hospital Pond). The reference area makes up the remainder of the island, comprising approximately 575 ha and approximately 14.9 km of shoreline. This area includes a tidal pond (Powder Hole) adjacent to 1.2 km of sound-side backshore. We refer to all areas west of the northernmost and southernmost tips of the island as the sound side (Nantucket Sound) and all areas east of the northernmost and southernmost tips of the island as the ocean side (Atlantic Ocean).

METHODS

We excluded data from 1998 where methods differed from 1999 and 2000.

SELECTING RANDOM POINTS

For several sampling procedures, we used randomly selected points on the midbeach to mark transect locations and 100-m radius plot locations. We selected random points on the shoreline using georeferenced aerial photographs of South Monomoy Island taken in 1994 (Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.) with ArcView GIS, version 3.1 and a random number table, using the random numbers to represent points on the shoreline. We used Garmin 12 GPS units and the coordinates of each random point to navigate to points during data collection.

PRENESTING PIPING PLOVERS

The first nests found on South Monomoy Island each season from 1998-2000 were initiated no earlier than 1 May (Appendix A). Thus, we considered the period through 1 May each year as the "prenesting period" and adults seen through 1 May as "prenesting Piping Plovers."

Distribution and Abundance of Prenesting Piping Plovers

Instantaneous Observations-- We began searching for Piping Plovers in early March of 1999 and 2000, before plovers were expected to arrive on South Monomoy Island for the breeding season. We attempted to walk the shoreline of South Monomoy Island daily. To minimize tide and observer bias in our surveys, we altered direction traveled, time of day, and observers from day to day. Whenever we observed a plover we recorded date, time, temperature (^{o}C), cloud cover (%), visibility (0-0.1 km, 0.1-1 km, 1-3 km, rain, clear), wind direction (N, S, E, W, NE, NW, SE, SW), wind speed (kph, using a Kestrel 1000 wind meter), and time of the most recent high tide at Monomoy Point. We also recorded the management area and the plover's initial habitat occupied, and the plover's behavior plus source of disturbance if disturbed (Tables 2 and 3). We noted the number of other plovers within 100 m, and whether or not the plover appeared to be with a mate. When groups of plovers were observed in the same habitat and behavior, each bird was recorded individually, but time and weather data were identical for all individuals within the group. We recorded approximate latitude and longitude coordinates of all Piping Plovers and groups of Piping Plovers using Garmin 12 handheld GPS units, and plotted the locations onto georeferenced aerial photographs using ArcView.

Distribution and Abundance of Large Gulls During the Prenesting Period

We counted Great Black-backed Gulls and Herring Gulls within 100 m-radius circular plots for indices of gull abundance and distribution among the management areas. We included immature Herring Gulls and Great Black-backed Gulls in counts, but did not identify them to species. Identification was too difficult to accurately identify species of immature gulls when instantaneously estimating the number of gulls in a 100-m radius plot. Hereafter, Great Black-backed Gulls, Herring Gulls and immature gulls of these species will be jointly referred to as "large gulls" to distinguish them from smaller gulls such as Laughing Gulls (*L. atricilla*) and Ring-billed Gulls (*L. delewarensis*).

Random points were located on the backshore-open vegetation line along the perimeter of the island. Latitude-longitude coordinates of each random point were stored in hand-held GPS

units. We used GPS units to navigate to the unmarked random points on the beach. This feature displayed the distance to the random point as we approached it. All counts were conducted from the edge of the circular plot (100 m from the plot center) to minimize and standardize observer disturbance to gulls and other species. We began recording data when we arrived at the edge of the 100 m-radius plot. We counted the number of each species of large gulls, (and of other species, Appendix B) including birds in flight, in a standard order. If the entire plot was not visible, we walked along the perimeter of the plot far enough to count gulls and other species within the entire plot.

To maintain independence among the samples, we spatially and temporally separated the plots by conducting only 2 counts/day in both the gull-removal and buffer areas and 4 counts/day in the reference area. If a plot center was within 300 m of another plot center on the same day, we discarded one plot and used the next random point on our list. Counts were conducted approximately 5 times/week.

We calculated the percent of random plots in which at least one gull was present (including flying gulls) and compared large gull presence among the management areas using chi-square tests. We also used the Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances, using the BLOSSOM Statistical Package, Version W2001 to compare relative gull abundance among the management areas (Cade and Richards 1999, Mielke and Berry 2001, Pages 1-12; BLOSSOM 2001: http://www.mesc.usgs.gov/products/pubs/10002/intro.html).

Euclidean-distance based statistics have greater power (the probability of rejecting the null hypothesis when it is false) to detect central tendency shifts among skewed distributions than do parametric statistics (Cade and Richards 1999, Mielke and Berry 2001, Pages 42-46, BLOSSOM 2001). Also, MRPP does not require that the data be normally distributed or that variances be equal among the populations being compared. MRPP is less sensitive to outliers than standard parametric tests, and can be used even if there are many tied values (Cade and Richards 1999, Mielke and Berry 2001, Page 3; BLOSSOM 2001) whereas nonparametric equivalents of the standard parametric tests can not. The Blossom Statistical Package does not compute exact probabilities in the default setting, but uses an approximation of the exact distribution of the test statistic to estimate the *P*-value. We used the default setting because computations would have been excessively timely to obtain exact *P*-values. The approximation

is based on the mean, variance, and skewness of the permutation distribution evaluated as a Pearson type III distribution (Cade and Richards 1999, Mielke and Berry 2001, Pages 22-26; BLOSSOM 2001).

To compare relative gull abundance near prenesting Piping Plovers among the areas, we counted all large gulls within 100 m of Piping Plovers as an index to gull abundance. We did not count large gulls near more than one plover where the 100 m-radius plots around several plovers overlapped. Instead, we recorded the number of additional plovers within each plot to obtain the plover group size within that plot. This way, we did not have to recount the same gulls for 2 or more Piping Plovers near each other, but an individual plover could be linked to a gull count since all plovers in a group were recorded. Gulls were counted within 100 m of the plover nearest the center of the group. We used MRPP to compare relative gull abundance within 100 m of plovers among the management areas. We compared proportions of plovers with at least one large gull present within 100 m among the management areas using chi-square tests.

To determine if Piping Plovers and large gulls were randomly distributed on South Monomoy Island, we compared the number of large gulls near Piping Plovers to the number of large gulls near random points surveyed during the prenesting period. We used MRPP to compare relative gull abundance between plovers and random locations by management area. We compared the proportion of plovers with at least one large gull within 100 m to the proportion of random points with at least one large gull present using chi-square tests.

Prenesting Piping Plover Habitat Availability and Habitat Use

Habitat Availability

To estimate the availability of each habitat to Piping Plovers on South Monomoy Island, we measured the width of each habitat on randomly located transects perpendicular to the shoreline following methods similar to Elias et al. (2000). We included the sound-side intertidal zone, fresh wrack, backshore, old wrack and open vegetation, the ocean-side intertidal zone, fresh wrack, backshore, old wrack and open vegetation, and tidal pond intertidal zone as available habitats (Table 2). We did not pool transects from the ocean and sound sides of the island in these analyses. For habitats other than wrack, we counted the number of steps taken within each habitat from the water's edge to dense vegetation, then converted steps to meters for

each observer's pace. We measured the width of the wrack habitats to the nearest 0.1 m using measuring tape. We recorded 0 m for habitat width if the habitat was not encountered along the transect. We used MRPP to compare habitat availability among years and among the management areas.

Habitat Use

To assess habitat use, we calculated the proportion of instantaneous observations of prenesting Piping Plovers seen in each habitat out of all plovers in all habitats seen during daily surveys of the entire island during the prenesting period. We assumed that every plover present on the island was observed in a habitat, and that the likelihood of observing a plover was equal among the habitats. Observations of plovers were assumed to be independent because individual plovers were not marked and identified. We used chi-square tests to compare habitat use between the 1999 and 2000 breeding seasons and to compare habitat use among the management areas. We conducted separate analyses for observations of all prenesting plovers, plovers that were foraging, and plovers that were not foraging (Table 3).

Habitat Use vs. Habitat Availability

We compared the proportion of use of each habitat (% of instantaneous observations of plovers within each habitat) to the proportion of availability of each habitat (mean % of total beach width estimated from transect data). We used chi-square tests to examine if plovers used habitat in proportion to availability. We assumed habitats to be equally available to each prenesting plover on South Monomoy Island. Observations of plovers were assumed to be independent because individual plovers were not marked and identified. Thus, habitat use and availability were measured at the population level (Thomas and Taylor 1990). We then determined if each habitat was preferred or avoided based on confidence intervals of use and availability. If the confidence interval for use was entirely above the confidence interval for availability, we concluded that that habitat was preferred. If the confidence interval for use was entirely below the confidence interval for availability, we concluded that that habitat was avoided. If confidence intervals for use and availability overlapped, we concluded that there was no evidence that habitat was not used in equal proportion to availability (Neu et al. 1974, Marcum and Loftsgaarden 1980).

Prenesting Piping Plover Behavior and Disturbance

We conducted 5-minute time-budget observations on randomly selected prenesting Piping Plovers each day to estimate time spent in different behaviors by habitat (Altmann 1974, Lehner 1979, Tyler 1979, Loegering 1992, Elias-Gerken 1994, Elias et al. 2000). We observed a focal bird from a distance with a Bushnell Spacemaster 40x zoom spotting scope on a tripod and continuously recorded behavior (and habitat) into an audiocassette recorder during the timed 5-minute period. We included foraging, disturbed, resting, alert, moving, and courting as behaviors for prenesting plovers (Table 3). We conducted timed observations only when the observer did not appear to be causing disturbance to the plover. Timed observations were conducted after the plover's initial behavior (including disturbed by observer) and habitat were recorded, after weather data were recorded, and after large gulls (and other species, Appendix B) within 100 m of the plover were counted and recorded. We recorded the estimated initial distance (m) between the observer and the plover for each observation. If we lost sight of the plover but the habitat was known, we recorded habitat but not behavior. If we were not sure of the habitat or behavior, we recorded "out-of-sight" until we relocated the bird. Later, we recorded the habitat and behavior at every 10-second interval within the 5-minute period. We did this by transcribing the taped data onto datasheets while a timer sounded every 10 seconds. We discarded observations from analyses if the plover was out of sight for >1/3 of the 5-minute period. We used MRPP to compare the percent time Piping Plovers were in different behaviors among the management areas. We also calculated the percent time large gulls and other species disturbed Piping Plovers, and used MRPP to test whether there was more disturbance to plovers in any of the management areas.

Prenesting Piping Plover Foraging Rates

During the same 5-minute period in which we observed behavior, we continuously recorded foraging rate (attempts/min; Tyler 1979, Tacha et al. 1985). "Foraging attempts" included pecks, aerial snaps, and gleans—regardless of whether prey was captured or consumed. Foraging rates and prey abundance have been considered good indicators of prey availability for

other shorebirds (Goss-Custard 1970, Goss-Custard 1977, Myers et al. 1980, Pienkowski 1983, Maron and Myers 1985, Wilson 1990). We used MRPP to compare foraging rates of prenesting plovers among habitats and among the management areas. Habitats were included in multiple and pair-wise comparisons if there were $\geq$3 observations (n) within the habitat. We repeated these analyses for plovers engaged in foraging behavior only, as foraging rates were low in habitats, such as the ocean backshore, where plovers spent a greater percentage of time in behaviors other than foraging.

NESTING PIPING PLOVERS

Distribution and Abundance of Nesting Piping Plovers

We searched for Piping Plovers and their nests by walking the perimeter of the island daily. We noted locations of courtship behavior and active nest scrapes on sketches of the island and on aerial photographs. We observed pairs that exhibited territorial, courtship, and nesting behavior until we located the nest. We often found nests by watching an adult return to incubate after being flushed from the nest by the observer. We also found nests by following high concentrations of Piping Plover tracks. We determined the latitude and longitude coordinates to 0.001 min. of each nest using hand-held Garmin 12 GPS units and recorded the management area, habitat type, and nesting substrate.

Nest Observations

We attempted to check each known Piping Plover nest at least once but not more than twice each day during the 1998-2000 seasons. On South Monomoy Island, Piping Plovers usually laid a clutch of 4 eggs in 6-7 days. Eggs hatched approximately 27 days after the last egg was laid. We attempted to find all nests before the fourth egg was laid to most accurately estimate the hatch date. We did not check nests in rain and/or wind >40 kph).

We recorded temperature (^{o}C), cloud cover (%), visibility (0-0.1 km, 0.1-1 km, 1-3 km, rain, clear), wind direction (N, S, E, W, NE, NW, SE, SW), wind speed (kph using a Kestrel 1000 wind meter), and the time of the most recent high tide at Monomoy Point, for each nest

check. We recorded the number of eggs, the nest status (incubating, partial hatch, hatch, abandoned, lost, or unknown), and the number of adults seen with the nest. If the clutch was incomplete at the time of the previous nest check, we approached the nest to determine clutch size. We only approached complete clutches when the status of the nest was unknown. We recorded the behavior of the attending adult. If an incubating bird left the nest because the observer disturbed it, we recorded the distance from the observer to the nest at the time the bird flushed (flush distance).

Large Gulls near Piping Plover Nests

In 1999 and 2000, we recorded the number of Great Black-backed, Herring, and immature gulls (and other species, Appendix B) within 100 m of each known Piping Plover nest at a random time each day. Gulls and other species in flight were included in the counts. To standardize the level of disturbance to plovers, large gulls, and other species near the plover nest sites, we conducted counts from an observation point on the backshore located approximately 100 m from the nest. If not all of the plot was visible, we maintained our distance of 100 m from the nest and walked to where we could see the remainder of the plot. As we surveyed the island, our distance and position relative to nests were determined using hand-held Garmin 12 GPS units with the nest locations loaded in the memory. We recorded the number of large gulls of each species within 100 m of the plover nest. We used MRPP to test whether there were more large gulls near nests in one management area than another. We also recorded the number of Great Black-backed, Herring, and immature gulls within an estimated 100 m of random points during the Piping Plover nesting period of 2 May to 21 July. We used MRPP to compare relative gull abundance in random plots to relative gull abundance near nests.

Piping Plover Nesting Areas vs. Unused Areas

We considered all beach area within 500 m of a Piping Plover nest excluding inland habitats beyond the dense vegetation boundary as "nesting area," and the beach area beyond 500 m from a nest as "unused area." A clutch of at least one egg was considered a nest. "Unused" referred to nesting habitat only, as plovers may have used these areas for foraging. We chose

500 m from plover nests to be the nesting area/unused area boundary based on Jones's (1997) recommendation to set off-road vehicle closures at 500 m from nests to protect 95% of the broods. He found that the mean maximum distance broods moved from nests was 485.8 m at Cape Cod National Seashore, Massachusetts (Jones 1997). We examined the effects of choosing a 500-m boundary to define the nesting area by reanalyzing the data using a 100-m boundary (Appendix C). For each year, we classified all randomly located points and transects as "nesting" or "unused," depending on the point's location relative to Piping Plover nests.

Large Gulls

We counted the number of Great Black-backed, Herring, and immature gulls (and other species, Appendix B) within 100 m of random points in nesting and unused areas. For island-wide comparisons between the nesting and unused areas, we randomly selected a subset of the data to standardize the number of transects/km of shoreline within each management area in order to control for sampling intensity bias. We used MRPP to test for differences in gull abundance between the nesting and unused areas within each management area and island-wide. We also calculated the percent of random plots in which at least one large gull was present and compared gull presence between the nesting and unused areas within each management area and island-wide using chi-square tests.

Available Habitat

To compare available habitat between the nesting and unused areas, we used the same transect data for which we compared available habitat to prenesting plovers among the management areas. All years were combined for these analyses to increase sample size and because change in island physiography was minimal. We used MRPP to examine differences in habitat availability between the nesting and unused areas within each management area and island-wide.

Available Prey

To examine Piping Plover prey distribution and abundance among the habitats within each management area, we obtained an index of arthropod abundance by setting insect traps (and taking core samples, Appendix D) along random transects, similar to methods used by Loegering

and Fraser (1995) and Elias et al. (2000). Once habitat measurements were recorded, we set insect traps along transects to quantify available prey. We sampled the tidal pond intertidal zone and the ocean- and sound-side intertidal zone, fresh wrack, backshore, old wrack, and open vegetation habitats for arthropod abundance. We coated paint stirrers (except for the handles) with Tanglefoot Insect Trap Coating (The Tanglefoot Company), and set them in pairs in each habitat encountered along the transect. Within a pair, we set one paint stirrer vertical and facing the water and one horizontal and parallel to the shoreline. The area of stirrers exposed to trapping was approximately 70 cm^2 for horizontal stirrers and 140 cm^2 for vertical stirrers. Individual stirrers in a pair were placed approximately 10 cm apart, and each pair was set in the middle of all habitats on the transect line except the intertidal zone. We sampled at all stages of the tide. For intertidal zone habitat, we placed pairs of stirrers where the tide most likely would not wash them away during trapping. We left traps for 3 hours, and discarded prey samples (the pair of stirrers in a habitat) if one or both stirrers were wet, misplaced, lost, or covered in debris due to wind (approximately 5% of all samples). We counted and classified arthropods to taxonomic order while in the field.

We compared prey abundance among the habitats within each management area and island-wide. We used a technique based on the Kruskal-Wallis method of ranking described by Nemenyi (1963, *cited in* Miller 1980 pages 165-169) to conduct simultaneous comparisons among the habitats. Ranks of the arthropod abundance samples were used rather than actual values recorded to conduct a nonparametric equivalent to a one-way analysis of variance (ANOVA). We used this method because arthropod abundance data were not normally distributed. We proceeded with pairwise comparisons of arthropod abundance (still using the ranks of the samples in each habitat) using Fisher's Least Significant Difference tests. We also compared prey availability between the nesting and unused area using Kruskal-Wallis tests.

Nesting Area Models

We constructed multiple logistic regression models to examine variables that discriminate nesting areas from unused areas. We performed univariate analyses on all variables obtained from the transect data and corresponding 100-m radius plot count data to compare nesting vs. unused areas using MRPP. Variables included habitat widths, prey availability, and numbers of gulls within 100 m of the point determining the location of the transect. If the univariate test had

a *P*-value of <0.25, the variable was considered as a candidate for the mutlivariate model (Hosmer and Lemeshow 1989; pages 84-86). We then performed the stepwise logistic regression procedure (forward selection with backward elimination, SAS 1999-2001) using the candidate variables to select the best fitting model.

Models often are validated by developing one model based on a subset of the data, then assessing the goodness-of-fit using a model constructed from the remainder of the data. Since our model was unstable (variables entered into the model changed each time a new random subset was selected), we repeated the stepwise logistic regression procedure 100 times, each time using a new random 50% subset of the data. We then evaluated our original model by examining the percent occurrence of each regressor in the final model.

South Monomoy Island Models--We constructed a model to examine habitat variables that were influential in Piping Plover nesting area selection on South Monomoy Island. We used all candidate variables except number of gulls to construct the model. We could not include number of gulls as a candidate when our model included data from the gull-removal or buffer areas because gull removal by wildlife managers within known plover nesting areas would have erroneously inflated the apparent importance of gull presence in predicting plover nesting areas. Later, we constructed a reference area model to examine the effects of numbers of gulls (see Reference Area Models). To determine the percent of transects predicted correctly by the model, we chose the probability level corresponding to the greatest value of "percent correct" listed in the classification table (an option of PROC LOGISTIC, SAS). We then determined how the model classified each transect based on how the predicted value for each transect compared to the probability level obtained from the classification table. We examined the percent of all transects island-wide predicted correctly by the model as well as the percent of transects predicted correctly in both the nesting and unused areas. As an alternative to the subjective 500-m boundary between nesting and unused areas, we constructed an additional South Monomoy Island model based on a 100-m boundary from nests defining the nesting area following the same methods to see if minimizing the nesting area size increased predictability (See Appendix C for further analyses).

Reference Area Models—To construct a model to predict nesting areas based on characteristics of the reference area, we used the same variables selected as candidates for the South Monomoy Island model using only reference area data. We then used the significant explanatory variables from that run with the number of Great Black-backed Gulls included as a candidate variable to see if the number of large gulls influenced the nesting areas. (We did not include the number of Herring Gulls and immature gulls as additional candidate variables because univariate analyses resulted in no evidence of a difference in the number of these gulls between the nesting and unused areas at alpha = 0.25. We examined the percent of transects that were predicted correctly by the model island-wide and within the nesting and unused areas. Because the model was unstable, we evaluated the model by running it with a new random subset of the data 100 times as we did for the South Monomoy Island model. We constructed an additional reference area model based on a 100-m boundary from nests defining the nesting area as we did for the South Monomoy Island model.

We constructed graphs of all 4 models showing the probability that plovers would nest in an area given different levels of each regressor. We used the minimum, median, and maximum values in the data for each regressor to represent the most favorable, the median, and the most unfavorable conditions for Piping Plover nesting habitat. We held 2 of the 3 variables constant at the minimum, median, or maximum values and used a range of values for the 3rd variable to examine the influence of the 3rd variable on the probability plovers would nest in an area.

Disturbance to Incubating Piping Plovers

To determine if disturbance by large gulls or other sources differed among the management areas, we conducted 5-minute time-budget behavioral observations on incubating Piping Plovers following the same methods used to examine prenesting Piping Plover behavior. We randomly selected incubating Piping Plovers within each management area that were observable with a spotting scope. We considered incubating plovers to be disturbed if they stood up or left the nest at any time unless the plover was relieved of incubating by its mate. We continued observations of the plover even if the bird left the nest. We calculated the percent time

incubating plovers were disturbed by various sources, using the nest as the sampling unit, and compared disturbance to incubating plovers among the management areas using MRPP.

Piping Plover Nest Success

We considered a nest successful if at least one egg hatched. We calculated the number of nests that were successful/nest attempt (nest success), the number of eggs laid/nest attempt, the number of eggs hatched/number of eggs laid (hatching success), and the number of eggs hatched/pair within each management area. We calculated the daily and interval survival rate of nests (the probability that a nest will survive a day and the probability that a nest initiated will survive to hatching, Mayfield 1975, Johnson 1979, Heisey and Fuller 1985). We calculated and the percentage of nests lost due to various causes for both exclosed and unexclosed nests in each management area and for the entire island.

If a nest or eggs were missing or destroyed, we searched the nest scrape and surrounding area for evidence to determine the cause of loss. We recorded the distance to the nearest potential predator trail. We considered a nest to be lost due to predation only if identifiable, fresh predator tracks were seen at the nest. We considered a nest lost due to avian predation if the depredated remains of eggs exhibited clear damage by a bird's bill. Avian predators in this category most likely did not include large gulls, as nests known to be depredated by large gulls were not found with eggshells remains with bill punctures. We considered a nest abandoned if eggs were intact and no adults were seen incubating or defending a territory for at least two days, eggs were buried in sand, and/or Piping Plover tracks were not seen around the nest site for multiple days. Using counts of gulls (and other species, Appendix B) within 100 m of active nests, we tested for differences in gull abundance within 100 m of successful and unsuccessful nests using MRPP.

PIPING PLOVER BROODS

We attempted to locate each brood daily after hatch for $\geq$ 25 days to estimate survival and to determine habitat use and foraging behavior in the presence of gulls. If a brood or chicks were

missing, we searched all potential brood-rearing habitats within the plover areas for up to one hour per day, taking care not to disturb other broods. If we did not find them again during the pre-fledging period, we presumed they were dead. Broods were considered successful if at least one chick fledged (reached 25 days old or was seen in sustained flight). Even though adults and chicks were not individually marked, in most cases broods separated themselves well enough in time and space as to allow us to keep track of individual broods. We did not search for broods in rain and/or wind > 40 kph.

Instantaneous Observations--We recorded the temperature (^{o}C), cloud cover (%), visibility (0-100 m, 100 m-1 km, 1-3 km, rain, clear), wind direction (N, S, E, W, NE, NW, SE, SW), wind speed (kph using a Kestrel 1000 wind meter), and the time of the last high tide at Monomoy Point when we observed a brood. We recorded the brood's age (days), the number of chicks within the brood seen, the number of adults seen with the brood, and habitat (Table 2), behavior (Table 3), and source of disturbance (if any) to the brood. We used Garmin 12 hand-held GPS units to obtain latitude and longitude of the brood's general location and the approximate distance between the brood and it's nest site location. Nest site latitude and longitude coordinates were stored in the memory of the GPS units.

Large Gulls near Piping Plover Broods

We recorded the number of Great Black-backed, Herring, and immature gulls of both species (and the number of other species, Appendix B) within 100 m of each brood at the time we first observed the brood each day. Gulls and other species within 100 m in flight were included in the counts. We attempted to randomize the time of day we observed broods by altering our survey route each day. We conducted counts from where we were when we first observed the brood, and estimated the distance between the observer and the brood. If we could not see all area within 100 m of the brood, we maintained our minimum distance from the brood and viewed the remainder of the area. We used MRPP to examine differences in the mean number of gulls within 100 m of broods among the management areas. We also recorded the number of Great Black-backed, Herring, and immature gulls within 100 m of random points

during the brood-rearing period (5 June to the date the last chick fledged). We compared the number of gulls within 100 m of random points during the brood-rearing period to the number of gulls within 100 m of broods by management area using MRPP.

Piping Plover Brood Behavior, Habitat Use, and Foraging Rates

We recorded behavior and habitat use of broods during 5-minute time-budget observations. We attempted to conduct 5-minute observations on all broods, every day, until fledging. For each observation we randomly chose a chick as the focal chick to represent the brood. We recorded the brood number, date, and time of the observation using an audiocassette recorder. We recorded all habitats, behaviors, and foraging attempts of the focal chick during the timed 5-minute period, following methods used to record behavior of prenesting and incubating plovers. If we lost sight of the focal chick but the habitat was known, it was recorded as "out-of-sight" until we relocated the focal chick or classified another chick within the same brood as the new focal chick.

Behavior and Disturbance--Behavior categories included foraging, disturbed, resting, alert, moving, and brooding (Table 3). We separated broods into age groups of 0-2 days, 3-10 days, 11-25 days, 3-25 days and 0-25 days following Elias-Gerken (1994), and compared behavior among the age groups using MRPP. We then compared behavior among the management areas by age group using MRPP. We also compared disturbance by large gulls and other species among the management areas using MRPP.

Habitat Use--We included ocean- and sound-side intertidal zone, fresh wrack, backshore, old wrack, and open vegetation, tidal pond intertidal zone, and seal carcass as potential habitats used by plover broods (Table 2). We included "seal carcass" as a foraging habitat because some broods were seen foraging in and around maggot and fly infested carcasses. Since not all broods had access to all habitats, we categorized broods into 5 groups based on access to certain habitats to compare habitat use within each access group. We considered a brood to have access to habitats if there were no physical barriers such as scarps or dense vegetation blocking access, and the habitats were within the brood's range determined by GPS locations of each brood. We used

(1) access to ocean-side habitats, (2) access to ocean- and sound-side habitats, (3) access to ocean-side habitats and a seal carcass, (4) access to sound-side and tidal pond habitats, and (5) access to sound-side and tidal pond habitats and a seal carcass as access groups. We first examined habitat use among the habitats using the ranks of the mean percent use of habitats for each brood (n) to conduct a nonparametric equivalent to a one-way analysis of variance (ANOVA). We proceeded with pairwise comparisons of use in each habitat (still using the ranked means of percent use for each brood for each habitat) using Fisher's Least Significant Difference tests. We also examined habitat preference within each access group, based on use-availability analysis following Aebischer et al. (1993) for broods of age 0-25 days and age 3-25 days old. For this procedure, we used a SAS program written in 1997 by Peter Ott and Fred Hovey (http://nhsbig.inhs.uiuc.edu/wes/habitat.html).

Foraging Rates—We calculated foraging rates as attempts/min as we did for prenesting plovers. We compared foraging rates by age group among the habitats. We also compared foraging rates by habitat among the management areas for broods of all ages. All foraging rate data were analyzed using MRPP. We examined foraging rates of broods of age 3-10 days from this study and from other studies.

Piping Plover Brood Success

We compared the number of large gulls within 100 m of successful broods to the number of gulls within 100 m of unsuccessful broods using MRPP. We calculated daily survival of chicks using methods described by Flint et al. (1995). We compared survival among the years and among the management areas by year using Z-tests when comparing 2 daily survival rates, and a generalized chi-square statistic that addresses the null hypothesis of homogeneity (Sauer and Williams 1989) when comparing >2 daily survival rates. We calculated overall productivity (chicks fledged/pair) for the entire island and by management area.

RESULTS

We claim differences when p-values for tests were <0.05. When there were multiple comparisons in one statistical test (e.g., tests for differences among the 3 management areas), and the multi-sample test was significant, we followed with pair-wise tests when appropriate. Tables and figures show means and standard errors, even though most statistical tests were nonparametric.

PRENESTING PIPING PLOVERS

Distribution and Abundance of Prenesting Piping Plovers

We began searching for Piping Plovers on South Monomoy Island on 14 March and 9 March in 1999 and 2000, respectively. We did not observe plovers until 25 March in 1999 and 16 March in 2000. During the prenesting period of 1999, we observed 64 individuals within 22 groups of 1 or more plovers in the gull-removal area, and 197 individuals within 81 groups in the reference area. Group size ranged from 1-7 plovers in the gull-removal area ($\bar{x}$ = 2.1, SE = 0.39), and from 1-9 plovers in the reference area ($\bar{x}$ = 1.7, SE = 0.13). During the prenesting period of 2000, we observed 168 individuals within 78 groups of 1 or more plovers in the gull-removal area, and 402 individuals within 176 groups in the reference area. Group size ranged from 1-7 plovers in the gull-removal area ($\bar{x}$ = 2.0, SE = 0.15), and from 1-12 plovers in the reference area ($\bar{x}$ = 2.1, SE = 0.10). We found no difference in group size between the gull-removal and reference areas or between the years. We did not observe plovers in the buffer area during the prenesting period in either year. The mean estimated distance between the observer and observed Piping Plovers during instantaneous observations was 61 m (n = 750, SE = 1.69).

Distribution and Abundance of Large Gulls during the Prenesting Period

Random 100-m radius plots were centered on 215 random locations from 27 March 1999 to 1 May 1999, and 234 random locations from 9 March 2000 to 1 May 2000. In 1999-2000, we

observed nearly 4 times as many large gulls in reference area plots than in gull-removal plots (Table 4, Figures 3 and 4). The difference was greatest in 2000, where there were nearly 8 times as many gulls in reference area plots than in gull-removal plots. In 1999, the difference was only 3-fold, and there was no difference in Herring Gull numbers among the management areas (Table 4).

In all years combined, gull presence near random points was lower in the gull-removal area than in the reference area. However, 67% of the plots in the gull-removal area had at least one gull present (Table 5). Great Black-backed Gull presence near random points was lower in the gull-removal area than the reference area throughout the study, whereas Herring Gull presence was lower in the gull-removal area than in the reference area only in 2000 and when both years were combined (Table 5).

Large Gull Abundance near Prenesting Piping Plovers

We counted fewer adult Great Black-backed Gulls near prenesting Piping Plovers in the gull-removal area than near plovers in the reference area. However, we found no difference in the numbers of total large gulls, Herring Gulls and immature gulls near plovers between the management areas in both years (Table 6). In 1999-2000 we did not observe $\geq$1 Great Black-backed Gulls near plovers as frequently in the gull-removal area as in the reference area. However, in both years we observed $\geq$1 Herring Gulls or $\geq$1 immature gulls near plovers in the gull-removal area as frequently as in the reference area (Table 7).

Overall, we observed fewer Great Black-backed Gulls and Herring Gulls near plovers than near random points in the reference area. We observed fewer Great Black-backed Gulls near plovers than near random points in the gull-removal area. However, in 2000 in the gull-removal area, there were more Herring Gulls near plovers than near random points (Table 8). We observed the presence of $\geq$1 large gulls near prenesting plovers less frequently than expected if gull presence between plovers and random points were equal (Table 9).

Prenesting Piping Plover Habitat Availability and Habitat Use

Habitat Availability

We found more ocean-side fresh wrack, ocean-side old wrack, and sound-side fresh wrack habitats available to plovers in 2000 than in 1999. Island-wide, fresh wrack increased 50% from 1999 to 2000, whereas ocean-side old wrack increased more than 4 times from 1999 to 2000. We found no difference in the widths of all other habitats between the years (Table 10).

We found more ocean-side intertidal zone and ocean-side backshore habitat available to plovers in the gull-removal area than in the reference area. We found more sound-side fresh wrack, sound-side backshore, sound-side old wrack, sound-side open vegetation and tidal pond intertidal zone habitat available in the reference area than in the gull-removal area. The only sound-side habitat that was more abundant in the gull-removal area than in the reference area was the intertidal zone (Table 11, Figure 5).

Habitat Use

We observed prenesting Piping Plovers using habitats in different proportions between 1999 and 2000 (Table 12). Foraging plovers and plovers in all behaviors were observed in the tidal pond intertidal zone habitat more often in 1999 than in 2000 (Table 12). We also observed prenesting Piping Plovers using habitats in different proportions among the management areas (Table 13). Foraging plovers in the gull removal area were observed more often in the sound-side intertidal zone habitat (and used it almost exclusively, in 95% of observations) compared to plovers in the reference area. Foraging plovers in the reference area were observed most often in the tidal pond intertidal zone habitat. Seventy-eight percent of observations of foraging plovers in the reference area were in the tidal pond intertidal zone habitat. The tidal pond intertidal zone habitat covered less than half of 1% of the gull-removal area and was not used by plovers there (Tables 13 and 14, Figures 6a and 7). Of the nonforaging prenesting Piping Plovers, birds in the gull-removal area were observed more often in the ocean-side backshore than in that habitat in the reference area and in the sound-side backshore habitat in the reference area than in that habitat in the gull removal area. (Table 13, Figure 6b).

Habitat Use vs. Habitat Availability

Overall, Piping Plovers did not use habitats in proportion to availability (Table 14). Foraging plovers in the gull-removal area avoided the wrack, backshore, and open vegetation and preferred the intertidal zone. More than 95% of foraging plovers in the gull-removal area were observed in the intertidal zone. Foraging plovers in the reference area avoided the intertidal zone, backshore and open vegetation, and preferred the tidal pond intertidal zone. Although the tidal pond intertidal zone was <7% of the total habitat available within the reference area, >78% of foraging plovers were observed in this habitat. Island wide, foraging plovers preferred the tidal pond intertidal zone and avoided all other habitats except the intertidal zone (Table 14). Nonforaging plovers in the gull-removal area avoided the intertidal zone and open vegetation and preferred the backshore. Nonforaging plovers in the reference area and island-wide preferred the backshore and tidal pond intertidal zone habitats and avoided all other habitats (Table 14).

Prenesting Piping Plover Behavior and Disturbance

In all years, during the 5-minute behavioral observations we observed prenesting Piping Plovers spending the majority of their time foraging, resting, or alert (Table 15, Figure 8). In 1999 and 2000, plovers spent similar amounts of time foraging, disturbed, resting, moving, and courting between the gull-removal and reference areas. When both years were combined, plovers spent similar amounts of time alert between the management areas (Figure 8). However, in 1999, plovers were alert more often in the reference area than in the gull-removal area (Table 15).

Prenesting Piping Plovers were never disturbed by Great Black-backed, Herring, or immature large gulls during 5-min behavioral observations. The percent time Piping Plovers were disturbed by all birds was not different between the gull-removal area and the reference area during both years (Table 16).

Prenesting Piping Plover Foraging Rates in Different Habitats

Foraging rates in each habitat were not different between the gull-removal area and the reference area (Tables 17 and 18). In the gull-removal area, foraging rates were greater in the ocean- and sound-side intertidal zone habitats than on the ocean-side backshore. In the reference area, foraging rates were greater in the ocean-side, sound-side, and tidal pond intertidal zone habitats, and in the sound-side fresh wrack habitats than in the ocean-side backshore and old wrack, and sound-side backshore habitats (Table 17). However, when calculated from observations of foraging plovers only, foraging rates were not different among the habitats, except during the 2000 season in the reference area. During this season, foraging rates were greater in the ocean-side intertidal zone (but n = 3, $\bar{x}$ = 27.7, SE = 7.14) than in most other habitats. Foraging rates in the tidal pond intertidal zone habitat were also high, and more birds were observed foraging in this habitat (n = 9, $\bar{x}$ = 19.1, p = 0.05; Table 18).

NESTING PIPING PLOVERS

Piping Plover Nesting Population

We found 27, 26, and 28 Piping Plover breeding pairs in 1998, 1999, and 2000, respectively (Table 1). In 1998, we recorded 12 nest attempts by 9 breeding pairs in the gull-removal area, 2 nest attempts by 1 breeding pair in the buffer area, and 24 nest attempts by 17 breeding pairs in the reference area. In 1999, we found 10 nest attempts by 9 breeding pairs in the gull-removal area, 1 nest attempt by 1 breeding pair in the buffer area, and 20 nest attempts by 16 breeding pairs in the reference area. In 2000, we found 11 nest attempts by 7 breeding pairs in the gull-removal area and 28 nest attempts by 21 breeding pairs in the reference area (Table 1, Figure 9). We did not find nests in the buffer area in 2000, even though pair(s) were observed in the area for a portion of the nesting period. The number of known breeding pairs decreased in the gull-removal area and increased in the reference area from 1998 to 2000 (Table 1, Figure 9).

Large Gulls near Piping Plover Nests

We counted more large gulls within 100 m of Piping Plover nests in the reference area than within 100 m of nests in the gull-removal area during the 1999 and 2000 nesting periods. Each year, adult Great Black-backed Gulls were more abundant near nests in the reference area than near nests in the gull-removal area. In 1999, Herring Gulls and immature gulls were more abundant near Piping Plover nests in the reference area than near Piping Plover nests in the gull-removal area. However, there was no difference in Herring Gulls and immature gull abundance near nests between the management areas in 1998 and 2000 (Table 19).

In both years, we counted more large gulls within 100 m of random points than within 100 m of nests. On average, we counted approximately 24 gulls near random points vs. 5.5 gulls near plover nests in the reference area. In the gull-removal area, the mean number of Great Black-backed Gulls near random points and plover nests was <2 gulls (Table 20). Island wide, Herring Gulls were more abundant near random points than near plover nests, and an average of fewer than 5 gulls were counted near random points (Table 20).

Piping Plover Nesting Areas vs. Unused Areas

Piping Plover nests were located in 4 general areas on South Monomoy Island (Figure 10). Most pairs in the gull-removal area nested on the ocean side along the northeast beach; a few nests were found on the sound side towards the end of the nesting period. Most pairs in the reference area nested on the sound side adjacent to the tidal pond, or on the ocean side along southeast beach. A few pairs used the overwash area, the narrow point in the middle of the island where waves reached from ocean to sound side during severe storms (Figure 10).

Large Gulls

Island-wide, relative adult large gull abundance was lower in the Piping Plover nesting areas than in the unused areas. We found no evidence of a difference between the number of immature gulls in the nesting areas vs. unused areas. In the gull-removal area, we found no difference between the number of large gulls in nesting areas vs. the unused areas (Table 21, Figure 11). Similarly, island-wide, unused areas were more likely than nesting areas to have $\geq$1

gull present. This was not true for immature gulls island-wide, nor for total large gulls in the gull-removal area (Table 22).

Available Habitat

Over the entire island, the width of the ocean- and sound-side backshore and open vegetation habitats, as well as the width of the tidal pond intertidal zone habitat, was greater in the nesting areas than in the unused areas. The width of the sound-side fresh wrack was greater in the unused areas than the nesting areas (Table 23, Figure 12). The gull-removal area beach was almost entirely Piping Plover nesting area (62 transects vs. 2 transects in the unused area), rendering comparisons between nesting areas and unused areas meaningless.

Available Prey

We sampled arthropod abundance from 16 May to 8 August, 27 March to 16 August, and 28 April to 5 August in 1998, 1999, and 2000, respectively (all years were pooled). Fresh wrack and sound-side intertidal zone habitats were richest in total arthropod abundance. Ocean- and sound-side backshore and open vegetation and ocean intertidal zone habitats were poorest in arthropod abundance (Table 24). Dipterans were most abundant in fresh and old wrack habitats, and coleopterans were most abundant in fresh wrack and all sound-side habitats other than open vegetation. Amphipods were more abundant in the intertidal zone and fresh wrack habitats, and other species were more abundant in the open vegetation (Table 25).

We found no difference in available prey between the nesting and unused areas in the gull-removal area (Table 26). However, sample size was limited for the unused area, as most of the gull-removal area was used for nesting. Contrary to what we would expect if Piping Plovers chose to nest where prey was more abundant, we found that in some habitats, arthropod abundance was greater in the unused area than in the nesting area. Island-wide, we counted more arthropods in the sound-side old wrack in the unused areas than in the nesting areas (Table 26).

Nesting Area Models

Univariate analyses of all potential variables resulted in the selection of 7 candidates for construction of the South Monomoy Island logistic regression models (Table 27). We included distance (m) from the transect to moist substrate habitats (Figure 13), access to sound-side

habitats (if the transect was adjacent to the sound side), and widths (m) of the intertidal zone, fresh wrack, backshore, old wrack, and open vegetation as candidate variables. We were unable to use width of the tidal pond intertidal zone as a candidate, even though univariate analysis suggested inclusion, because all of the transects with > 0 m of this habitat were classified as nesting area. This resulted in no overlap in the distribution between the two outcome groups (complete separation), so a maximum likelihood estimate could not be calculated (Hosmer and Lemeshow 1989: 129-131).

In validating the data, 100 runs of the stepwise logistic regression procedure using a new random selection of 50% of the data each time resulted in 6 of the 7 variables entering the model at least once. Seventy percent of the runs resulted in including the width of the backshore as a significant regressor. Fifty-one percent of the runs resulted in including distance to moist substrate habitat, and 34% of runs resulted in including width of the open vegetation.

South Monomoy Island Models--Width of the backshore (positive coefficient), distance to moist substrate (negative coefficient), and width of the open vegetation (positive coefficient) were significant explanatory variables in the island models when we used both the 500 m- and 100-m boundary to define the nesting area (Table 28). These variables also appeared most frequently in the 100 runs of random subsets of data, boosting our confidence in validity. Percent of all transects predicted correctly was greater when we used the 100-m boundary to define the nesting area than when we used the 500-m boundary to define the nesting area (85.8% vs. 66.7%, respectively; Table 29; See Appendix C for further analyses).

Reference Area Models--Width of the backshore (positive coefficient), number of Great Black-backed Gulls (negative coefficient), and width of the open vegetation (positive coefficient) were significant explanatory variables in the reference area models when we used both the 500 m- and 100 m-boundary to define the nesting area (Table 28). Like the South Monomoy Island models, the percent of all transects predicted correctly was greater when we used the 100-m boundary to define the nesting area than when we used the 500-m boundary to define the nesting area (86.6% vs. 76.2%, respectively; Table 29; See Appendix C for further analyses).

Regressor Influence in the Models-- South Monomoy Island models showed that if 2 of the 3 significant regressors (vegetation width, backshore width, or distance to moist substrate) were in the most favorable condition for plovers to nest, then there would be a high probability of nesting within 500 m or 100 m, regardless of the value of the 3rd regressor (Figures 14 and 15, top line). Reference area models behaved similarly, except when the number of Great Black-backed Gulls was >175 gulls for the 500 m model or was >130 gulls for the 100 m model. If Great Black-backed Gulls were this abundant, the chance that a plover would nest there would decrease to below 50%, even if the width of the open vegetation and backshore habitats were most favorable (Figures 16 and 17).

Disturbance to Incubating Piping Plovers

On average, individual incubating plover pairs were disturbed <1.5 % of the 5-min observation time. We found no difference among the management areas in percent time incubating plovers were disturbed by large gulls (Figure 18). Incubating plovers were disturbed by other plovers more often in the reference area than in the gull-removal area, and were disturbed more often by sources other than large gulls in the gull-removal area than in the reference area (Table 30, Figure 18). Other sources of disturbance included a Willet (*Catoptrophorus semipalmatus*; 40 seconds during one observation), a pedestrian (10 seconds during one observation), and Northern Harriers (*Circus cyaneus*; 20 seconds during 2 observations on different pairs).

Piping Plover Nest Success

From 1998 to 2000, 15 of 33 nests were successful (45.5%) in the gull-removal area, 1 of 3 nests was successful (33.3%) in the buffer area, and 40 of 72 nests were successful (55.6%) in the reference area. Eggs hatched/eggs laid in the gull-removal, buffer, and reference areas were 46.4%, 36.4%, and 52.3%, respectively (Table 1).

Daily and interval survival estimates (the probability that a nest will survive a day and the probability that a nest initiated will survive to hatching) for South Monomoy Island were greater in 1999 and 2000 than in 1998 (Table 31). In all years pooled, daily and interval survival

estimates were greater for nests protected by predator exclosures than for unprotected nests. However, in 1999 we found no difference in daily and interval survival estimates between exclosed and unexclosed nests (Table 32). Overall, both exclosed and unexclosed nests had greater daily and interval survival estimates in the reference area than in the gull-removal area (Table 33).

Causes of Nest Loss

Between 1998 and 2000, 7 of the 33 known Piping Plover nests in the gull-removal area (21.2%) were depredated, and 7 of the 72 known nests in the reference area (9.7%) were depredated. All depredated nests and nests found missing with incomplete evidence to determine the cause of loss were not protected by predator exclosures (Table 34, Figure 19). Of the depredated unexclosed nests lost in the gull-removal area, 3 nests were lost to gulls, 1 to an American Oystercatcher, and 3 to unidentified avian predators (Table 35). Of the depredated unexclosed nests lost in the reference area, 1 nest was lost to a gull, 2 to coyotes, 1 to an American Oystercatcher, and 3 to unidentified avian predators (Table 35).

Gulls Near Successful vs. Unsuccessful Nests

We found no difference between the number of gulls near successful nests and the number of gulls near unsuccessful nests (Table 36, Figure 20). This was consistent in all management areas and during all years of the study, with the exception of the 1999 season in the gull-removal area, where we found more immature gulls near successful Piping Plover nests than near unsuccessful nests (Table 36).

PIPING PLOVER BROODS

Large Gulls near Piping Plover Broods

In 1999 and 2000 combined, we counted fewer adult Great Black-backed Gulls near broods in the gull-removal area than near broods in the reference area, and more immature gulls near broods in the gull-removal area than near broods in the reference area (Table 37). In both 1999 and 2000, in the reference area only, we counted more adult Great Black-backed Gulls and

total large gulls near random points than near broods (Table 38). When both years were combined, we counted more adult Great Black-backed, Herring Gulls and immature gulls near random points than near broods in the reference area (Table 38).

Piping Plover Brood Behavior and Habitat Use

Overall, we observed broods 3-25 days old spending more time foraging than broods 0-2 days old (Table 39). Broods spent the most amount of time brooding when 0-2 days old, and the least amount of time brooding when 11-25 days old (Table 40). Island wide, broods 0-2 days old spent equal amounts of time foraging and being brooded (38% each, Table 40). Broods 3-10 days old spent most of their time foraging (72%). Broods 11-25 days old also spent most of their time foraging (68%), but spent a considerable amount of time alert and resting (15% and 9%, respectively; Table 40). We observed broods 3-10 days old in the reference area foraging more often than broods 3-10 days old in the gull-removal area, but there were no differences in percent time spent in all other behaviors between the gull-removal and reference areas (Table 41).

We found no differences among the management areas in percent time broods were disturbed (Table 41), nor did we find differences among the management areas in the percent time Great Black-backed Gulls, Herring Gulls, immature large gulls, or Laughing Gulls disturbed broods (Table 42). Common Terns disturbed Piping Plover broods more frequently in the gull-removal area than in the reference area in all years, but disturbance to broods by terns was minimal (<1%; Table 43).

Habitat Use--Broods 0-25 days old with access only to ocean-side habitats were observed most often in backshore (46%), open vegetation (24%), and old wrack (20%) habitats. Broods 0-25 days old with access only to ocean-side habitats and a seal carcass were also observed most often in the backshore habitat (54%), but were often observed at seal carcasses (16%). Broods of age 0-25 days with access only to the sound-side habitats and the tidal pond intertidal zone habitats were observed most often in the tidal pond intertidal zone (40%) and the sound side backshore (31%; Table 44). Habitat use by broods of age 3-25 days was similar to broods of age 0-25 days (Table 45).

Brood habitat preferences depended upon the habitat to which broods had access. Broods of all ages with access to ocean-side habitats only preferred the old wrack to all other habitats based on habitat ranking. Backshore and open vegetation habitats were preferred second and third, respectively. The intertidal zone was the least preferred habitat. Broods with access to both the ocean- and sound-side habitats preferred the sound-side old wrack to all other habitats. Sound-side intertidal zone and open vegetation habitats ranked second and third, respectively. Ocean-side backshore, intertidal zone and open vegetation were the least preferred habitats. Broods with access to ocean-side habitats and a seal carcass preferred the seal carcass to all other habitats, and like broods with access to only the ocean-side, they preferred the backshore and open vegetation habitats second and third, respectively. Broods with access to sound-side habitats and the tidal pond intertidal zone preferred the tidal pond intertidal zone to all other habitats. Sound-side backshore and fresh wrack habitats were ranked second and third, respectively, and the sound-side intertidal zone was the least preferred habitat. Broods with access to sound-side habitats, the tidal pond intertidal zone, and a seal carcass preferred the seal carcass to all other habitats. Sound-side old wrack and the tidal pond intertidal zone ranked second and third, respectively. Sound intertidal zone was the least preferred habitat (Tables 46 and 47).

Piping Plover Brood Foraging Rates

Foraging rates were greatest in fresh wrack, tidal pond intertidal zone, and at seal carcasses (Table 48). There were no differences in foraging rates within each habitat between the gull-removal area and the reference area (Table 49).

Piping Plover Brood Success

We found no difference in numbers of Great Black-backed, Herring or Laughing Gulls near successful versus unsuccessful broods (Table 50). From 1998 to 2000, overall daily survival of chicks on South Monomoy Island was 96.3%. We found no difference in daily survival among the years (Table 51). Daily survival was greater in the reference area (98.4%)

than in the gull-removal area (94.7%) in 1999 only (Table 52). We found no difference in daily survival among the habitat access groups (Table 53).

Causes of Piping Plover chick loss are difficult to determine because dead chicks are rarely found. We found one dead fledgling with a small puncture wound located right and caudal in 1998 and one dead 5-day-old chick with no apparent injuries in 1999. The 5-day-old chick was found just after a 3-day period of severe thunderstorms. Both carcasses were collected and sent by USFWS personnel to USGS Biological Resources Division National Wildlife Health Center in Madison, WI for necropsies. Necropsy reports are available in USFWS files.

DISCUSSION

DISTRIBUTION AND ABUNDANCE OF GULLS

We counted fewer large gulls in the gull-removal area than in the reference area throughout all stages of the Piping Plover breeding season and in all years of the study. No large gulls nested successfully in the gull-removal area.

Despite different methods used, gull surveys in 1990, 1995 and 1998 (USFWS census data 1995, USFWS 2000b) suggest that the Monomoy Herring Gull and Great Black-backed Gull populations were declining. Based on population models of Monomoy gulls that did not consider gull control, Cavanagh (1992) predicted that the Herring Gull population would decline and the Great Black-backed Gull population would increase. He found that landfills were a primary food source for Monomoy Herring Gulls, whereas Monomoy Great Black-backed Gulls used landfills only as a supplementary food source, mostly in the winter. He predicted that closing landfills on Cape Cod was likely to affect Herring Gulls more than Great Black-backed Gulls. He suggested that the reduced refuse available to Herring Gulls and the higher productivity, lower mortality, and earlier nesting of Great Black-backed gulls would contribute to the projected replacement of Herring Gulls by Great Black-backed Gulls on Monomoy. The cumulative effects of gull removal, harassment, and suppression of gull productivity in the gull-removal and buffer areas on South Monomoy Island may explain why Great Black-backed Gulls also declined through 1998, contradicting Cavanagh's predictions.

Although we counted fewer large gulls in the gull-removal area than in the reference area, large gulls continued to use the intertidal zone and backshore habitats of the gull-removal area for foraging and loafing. During the Piping Plover prenesting period, most of the gulls seen in the gull-removal area were adult Herring Gulls in the sound-side intertidal zone, where they foraged close to plovers and other shorebirds. Herring Gulls commonly foraged for soft-shell clams (*Mya arenaria*) left exposed by commercial shellfishermen, and are known to follow the retreating tide to capture worms in the flats (Pierotti and Good 1994). Drury and Nisbet (1972) found that New England Herring Gulls traveled up to 40 km to foraging sites. Cavanagh (1992)

found that Monomoy Herring Gulls traveled a mean distance of 26 km to landfills on the mainland of Cape Cod. It is likely that as landfills were capped and transfer stations were opened during the 1990s, the Monomoy sand flats in the gull-removal area became an increasingly important foraging area for Herring Gulls in the region.

The 1992-1998 management of Herring Gulls and Great Black-backed Gulls at Breezy Point, Gateway National Recreation Area, New York, was implemented to protect nesting species, specifically Piping Plovers. Management included gull harassment with pyrotechnics and destruction of eggs and nests. Adult gulls were not killed (USDA Animal Damage Control 1993, Olijnyk and Brown 1999). At first, the firing of pyrotechnics discouraged gulls from landing in the colony, but gulls became more persistent and more difficult to harass as their breeding season progressed (USDA Animal Damage Control 1993). Harassment had no effect on the number of loafing gulls within a breeding season, and there was no correlation between the number of rounds of pyrotechnics discharged and the number of gulls loafing on the colony site the following morning (Olijnyk and Brown 1999). Harassment was discontinued upon the arrival of terns each season; gulls continued to nest in the area (USDA Animal Damage Control 1993). Egg puncturing significantly reduced gull reproduction, and after 3 years of gull management at Breezy Point, the number of gulls began to decrease. In conclusion, harassment had little or no effect on the nesting population of gulls at Breezy Point, but nest and egg destruction may have contributed to the decline in nesting and loafing gulls (Olijnyk and Brown 1999).

IMPACT OF GULL REMOVAL ON PIPING PLOVERS

Despite the difference in gull abundance between the gull-removal and the reference management areas, Piping Plovers on South Monomoy Island used both the gull-removal and reference areas throughout the study.

Although Piping Plover nest loss to gull predation has been observed at other beaches along the Atlantic Coast, loss to gulls has generally been low. For example, MacIvor (1990) found only 8 of 168 nests lost to gull predation from 1985-1988 on outer Cape Cod, Massachusetts beaches (including South Monomoy Island). Loegering (1992) found 1 of 81 nests lost to gull predation from 1988-1990 at Assateague National Seashore, Maryland. Elias-

Gerken (1994) found 1 of 237 nests lost to gull predation from 1993-1994 on Long Island, New York beaches. Jones (1997) found 1 of 81 nests lost to gull predation from 1994-1995 at Cape Cod National Seashore, Massachusetts. Plover nest loss to large gull predation on South Monomoy Island was minimal over the entire island compared to other sources of nest failure; only 1 nest was found lost to gull depredation in the reference area vs. 3 nests in the gull-removal area. Nests lost to unidentified avian predators were characterized by small puncture holes in remaining eggshells, rendering it unlikely that the avian predator was a large gull. There was no evidence that the reduction of nesting large gulls in the gull-removal area resulted in greater Piping Plover nest success compared to the reference area. We found no difference in the number of large gulls near successful Piping Plover nests vs. unsuccessful nests. Survival rates of both exclosed and unexclosed plover nests were greater in the reference area than in the gull-removal area (Table 33).

Although some disturbance to plovers from large gulls was observed in both the gull-removal area and the reference area, there was no evidence that prenesting plovers, incubating plovers, or plover broods were disturbed by large gulls more frequently in the reference area than in the gull-removal area. Broods in the reference area were disturbed by Great Black-backed Gulls 0.13%, Herring Gulls 0.11%, and immature gulls 0.01% of 5-minute behavioral observations. On Long Island, NY, Elias-Gerken (1994) and Houghton (2000) found that gulls disturbed broods for up to 1% of 5-minute observations. Therefore, disturbance to broods by gulls in the reference area of South Monomoy was similar to disturbance at other plover sites that lacked great abundance of nesting gulls.

We found no evidence that the reduction of large gulls in the gull-removal area resulted in greater Piping Plover chick survival compared to the reference area. Daily survival rates of plover chicks in the reference area were similar to survival rates in the gull removal area except in 1999, when daily survival was greater in the reference area than in the gull-removal area (Table 53). We found no difference in the number of large gulls near successful Piping Plover broods vs. unsuccessful broods. These results bolster the conclusion that gull-removal program on South Monomoy Island did not improve Piping Plover reproductive success. Likewise, despite gull predation upon a plover chick in 1995 (Hake 1995, Lauro and Tanacredi 2002) and a decrease in plover pairs in 1996 and 1997 (Gilmore 2000), we have seen no evidence that the

Piping Plover population at Breezy Point, New York, was depressed or prevented from growing by large gulls.

SPATIAL SEPARATION BETWEEN PIPING PLOVERS AND LARGE GULLS

Large gulls and Piping Plovers were spatially separated on South Monomoy Island. However, this was not necessarily because plovers avoided gulls, or because gulls avoided plovers. Aggression between gulls and plovers was never observed during the prenesting periods, and was minimal throughout the study, confirming that plovers were not forced out of preferred areas by gulls. Areas with low gull abundance are optimal Piping Plover nesting habitat, not because of fewer gulls, but because of the physical characteristics there. We argue below that the most reasonable explanation for the spatial separation of gulls and plovers is that they select different habitats.

Piping Plover Habitat

Foraging Habitat

Prenesting Piping Plovers--Available prey often is greater in wrack and moist substrate habitats than in other habitats (Loegering and Fraser 1995, Elias et al. 2000). Moist substrate foraging habitat was accessible and abundant in both the gull-removal area and the reference area on South Monomoy Island for prenesting Piping Plovers. Foraging birds were found concentrated in and around moist substrate habitats, and preferred them to all other habitats. In the gull-removal area, prenesting plovers foraged on sand flats on the sound side, which extended up to 2 km from the upland at low tide. In the reference area, prenesting plovers foraged in the tidal pond intertidal zone, a large area that was periodically flooded during our study. Moist substrate habitats may have been preferred during the prenesting period because prey may have been more consistently available, especially early in the Piping Plover breeding season when most insect species had not yet emerged, and birds relied on polychaetes and other infauna for food.

Piping Plover Broods--In previous studies, Piping Plover broods that foraged on bayside sand flats or at ephemeral pools often had greater survival rates than broods that were limited to ocean-side habitats (Patterson et al. 1991, Loegering and Fraser 1995, Goldin et al. 1998 and Elias et al. 2000). Jones (1997) did not find a significant difference in chick survival between chicks with and without access to the bayside, but he stated that broods limited to the ocean-front beaches at Cape Cod National Seashore might have had access to ample prey-rich wrack habitat as a suitable alternative. Brood foraging rates observed in moist substrate habitat on South Monomoy Island were high, and broods preferred these habitats to others when it was available to them. In the reference area of South Monomoy Island, extensive nesting habitat (wide backshore and open vegetation, see below) was adjacent to moist substrate (tidal pond intertidal zone habitat), giving broods access to these habitats. About 75% of broods in the reference area had access to the tidal pond intertidal zone (Appendix A). For broods 3-10 days old, foraging rates in the tidal pond intertidal zone on South Monomoy were similar to foraging rates observed in ephemeral pools on Long Island, New York, by Elias-Gerken (1994) in 1992-1993 and Houghton (unpublished data) in 1993-2000. However, foraging rates in the sound-side backshore habitat appeared lower than foraging rates in the bayside backshore habitat on Long Island (Table 54).

Even though moist substrate habitat was available on the sound side of the gull-removal area, most plover broods there did not have access to the sound side because dense vegetation and/or other territorial plovers blocked movement from the nesting areas to the sand flat. Nests on the sound side adjacent to the gull-removal sand flat often were flooded since the backshore and open vegetation were narrow (< 6 m combined) causing plovers to nest close to the water.

Foraging rates were lowest in ocean backshore and open vegetation habitats, where broods with ocean access only were found most often. Wrack, a preferred foraging habitat on ocean-side beaches (Goldin 1993, Hoopes 1993, Elias et al. 2000), was sparse on the Atlantic Ocean side of South Monomoy Island. Elias et al. (2000) found that broods that did not have access to ephemeral pools or bayside foraging habitats preferred wrack and open vegetation habitats to all other habitats available. She found that a 43% decrease in arthropods in open vegetation coincided with a 55% decrease in the amount of time broods spent foraging in that habitat. Arthropod abundance in open vegetation was greater on Long Island, New York, than

on South Monomoy Island. Ocean-side open vegetation on South Monomoy Island may not be optimal foraging habitat for broods when arthropod abundance is low.

When a seal carcass infested with maggots and flies was within a brood's foraging territory, the carcass provided a valuable food source to broods. Adults aggressively defended carcasses from other plover broods. Broods spent >17% of their time foraging at the carcasses, and foraging rates were high and similar to rates observed in moist substrate habitats.

Prey abundance on South Monomoy Island, as characterized by the number of insects trapped on Tanglefoot-coated paint stirrers, was not predictive of Piping Plover nesting areas. Prey abundance was greatest in some areas not used for nesting, specifically on the sound-side buffer area and the northern section of the sound-side reference area. These areas had narrow backshore and narrow open vegetation habitats and dense, piled wrack. Most likely, plovers did not nest in these areas due to the lack of suitable nest sites (see below). The width of backshore and open vegetation was < 8 m on average in these areas.

Nesting Habitat Models

Logistic regression models showed that backshore width, open vegetation width, and distance to moist substrate habitat were most predictive of Piping Plover nesting areas. However, all three characteristics did not have to be optimal for an area to be classified as suitable nesting habitat. South Monomoy Piping Plovers were predicted to nest in areas with wide backshore habitat that were close to moist substrate, regardless of the width of the open vegetation. Likewise, plovers were predicted to nest in areas with wide-open vegetation habitat that were close to moist substrate, regardless of the width of the backshore. Apparently, the attraction to moist substrates was strong enough to overcome marginal values of backshore and vegetation widths, and Piping Plovers could find suitable nest sites in either open vegetation or backshore habitat.

Logistic regression models predicted that Piping Plovers on South Monomoy Island nest in areas where open vegetation and backshore habitats were wide, regardless of the distance to moist substrate (Figures 14c and 15c). Piping Plover nesting habitat along the Atlantic Coast usually coincides with wide backshore and/or open vegetation habitats. Elias-Gerken (1994) found that on Long Island, New York beaches, the mean width of open vegetation habitat in 1-km beach segments used by plovers was greater than the mean width of open vegetation habitat

in 1-km beach segments not used by plovers. Where plovers did not have access to moist substrate, the width of the open vegetation was important in predicting plover use (Elias-Gerken 1994). Jones (1997) found that on other Cape Cod, Massachusetts beaches, widths of the open vegetation and backshore habitats were significantly greater at nest sites than at random points. In these areas, the expanse of the nesting area (wide stretches of open vegetation and backshore habitats) may provide ample prey when nesting territories are large enough.

If widths of open vegetation and backshore habitats were at median values, our logistic regression models predicted that the number of Great Black-backed Gulls would only affect the probability of plovers nesting in the area at extreme gull abundance. When widths of the open vegetation and backshore habitats were optimal for nesting, the probability that plovers would nest in the area would decrease rapidly as the number of Great Black-backed Gulls increased beyond 80 gulls (Figures 16c and 17c). However, the number of Great Black-backed Gulls within 100 m of random points on South Monomoy Island beaches rarely exceeded 80 gulls. In fact, 96.5% (551/571) of the random points on South Monomoy Island had fewer than 80 gulls within 100 m.

Gulls often fled as observers approached plovers, nests, broods, or random points, resulting in a lower count than the number of gulls that might have been present before the observer arrived. We assumed that equal proportions of gulls would flee among the management areas if we kept our distance to the points at the time of counting constant, so that indices of gull abundance would not be biased. We assumed that USFWS gull harassment activities in the gull-removal area did not affect the probability of a gull being counted disproportionately to the reference area.

Gull Habitat

Herring Gulls

Greater abundance of Herring Gulls were found in sound-side habitats than in ocean side habitats (Figure 3). We observed Herring Gulls foraging for crabs along the sound side of the reference area. Even though the sound side of the reference area lacks an extensive sand flat, the shallow intertidal zone may be better-quality foraging habitat for Herring Gulls than the ocean-side intertidal zone, where the slope is steep and wave energy great. Pierotti (1988) found that

Herring Gulls do not dive below 1-2m, so a shallow intertidal zone like the sound side of the island may provide access to prey. Herring Gulls on South Monomoy also nested on the tops of scarps where the backshore habitat was eroded, and there was very little open vegetation. On South Monomoy Island, this Herring Gull habitat is located outside of areas where our models predicted plover nesting.

Tinbergen (1960) noted that Herring Gulls usually nest near some plants or bushes. Pierotti (1982) found that Herring Gull populations with the highest breeding success often occured in vegetated areas with adequate cover for young. On South Monomoy Island, woody vegetation is abundant close to the sound side of the reference area, but not adjacent to the tidal pond intertidal zone where plovers were nesting. If Herring Gulls prefer to nest in vegetation, this also may contribute to the greater abundance of Herring Gulls on the sound side than on the ocean side. Again, on South Monomoy Island, this Herring Gull habitat is located outside of areas where our models predicted plover nesting.

Great Black-backed Gulls

Great Black-backed Gulls prefer more open habitat for nesting than Herring Gulls (Good 1998). On South Monomoy Island, Great Black-backed Gulls often nested on the tops of dunes or ridges and on sandy or flat lightly vegetated inland areas. These areas were more abundant on the ocean side of the reference area. Where the island was narrow (<300 m between the sound and ocean sides), Great Black Backed Gulls were observed loafing on both sides of the island and nesting on the high point in the middle (Figure 3, USFWS 2000b). Bent (1921) noted that Great Black-backed Gull nests were located on the higher portions of the beaches in Newfoundland. Bent (1921) quoted Howard H. Cleaves' notes saying, "All (nests) seemed to have been situated with a view to afford (the gulls) a clear outlook…." We observed large groups of Great Black-backed Gulls loafing in areas where the slope of the beach was steep or the beach was backed by a scarp. Steep beaches may also provide gulls better visibility. These large groups of loafing Great Black-backed Gulls influenced our logistic regression models in that the gulls concentrated in areas where the beach slope was steep due to high-energy waves from the Atlantic Ocean. These areas were not ideal Piping Plover nesting areas. Where backshore/open vegetation is wide, it is also flat. Gull visibility would thus have been reduced in these areas that were, on the other hand, ideal for nesting Piping Plovers.

Immature gull abundance was greater during the Piping Plover brood rearing period compared to the prenesting and nesting periods, especially in 2000 when gull fledglings were loafing in large groups near plover broods in the gull-removal area. However, immature gull abundance was still low in all management areas.

PLOVER POPULATION DYNAMICS ON SOUTH MONOMOY ISLAND

Mean Piping Plover productivity (chicks fledged/pair) on South Monomoy Island from 1992 to 1997 (the years prior to our study) was approximately 1.63 chicks/pair (USFWS census data; Table 55). Mean Piping Plover productivity in Massachusetts from 1992 to 1997 was approximately 1.68 chicks/pair (USFWS 1996a; Table 56). These productivity values exceed the recovery goal of an average of 1.5 chicks/pair maintained for 5 years (USFWS 1996a), believed sufficient for population increase. On South Monomoy, the worst year reported since 1992 was 1995, the year prior to gull removal, when productivity was only 0.93 chicks/pair (USFWS census data). During that year, low productivity resulted from poor nest success. Thirty-five percent (6/17) of all nests were abandoned, 6% (1/17) nests were lost to gull predation (gull tracks near nest), and the cause of loss for 6% of the nests were unknown. Particularly high Piping Plover productivity rates on South Monomoy Island were obtained in 1996 and 1997 (2.21 and 1.76 chicks fledged/pair, respectively; Table 56). This may be related to the gull-removal program, but high productivity rates were obtained in both the gull-removal area and the reference area, suggesting that Piping Plover breeding success can be attributed to factors other than gull removal. Also, the extremely high rates of productivity did not continue beyond 1997, even though large gulls were still prevented from nesting in the gull-removal area.

A graph of the Piping Plover population in Massachusetts since listing as an endangered species reveals a sigmoidal curve, characteristic of a population reaching carrying capacity (Figure 2, USFWS 2002). The curve depicting the Piping Plover population on the Monomoy islands follows the same pattern (Figure 2, USFWS 2002). The initial lag in population increase on South Monomoy Island compared to Massachusetts as a whole may be reflective of survey effort, or it may suggest that habitat quality on South Monomoy is not as good as habitat quality elsewhere in Massachusetts.

The maximum number of Piping Plover pairs that can be sustained (carrying capacity) on South Monomoy Island may be a function of the amount of suitable nesting habitat. Nesting habitat fluctuates naturally with overwash caused by storms and vegetation succession. A reduction of nesting habitat near moist substrate foraging habitats due to natural vegetation succession and/or beach erosion may contribute to a decline in nesting plover pairs. Likewise, a reduction in available moist substrate adjacent to nesting habitat due to succession may contribute to a decline in nesting pairs. For example, if the tidal inlet of the tidal pond intertidal zone closes, and the moist substrate succeeds into dense vegetation, numbers of plover pairs in this area will most likely decrease.

CONCLUSIONS

Through our study, we found no evidence that the Monomoy National Wildlife Refuge gull removal program resulted in increases in Piping Plover reproductive output, survival or population numbers. We found no evidence that Herring or Great Black-backed Gulls affected Piping Plover distribution on the island. Piping Plovers nested in areas where the backshore and open vegetation habitats were wide, and where moist substrate foraging habitat was near by. We believe that spatial separation between large gulls and Piping Plovers is due to different habitat selection among the species.

LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from radio-tracking data. Ecology 74:1313-1325.

Arbib, R. 1979. The Blue List for 1980. Am. Birds 33:830-835.

Altmann, J. 1974. Observational study of behavior sampling methods. Behaviour 49:227-267.

Bent, A. C. 1921. Life histories of North American gulls and terns. Dover Publications, inc., New York, Pp 79-80.

Blodget, B. G. 1988. The East Coast gull explosion. Massachusetts Wildlife 38:12-19.

BLOSSOM Statistical Package. 2001. Version W2001. http://www.mesc.usgs.gov/products/pubs/10002/intro.html).

Cairns, W. E. 1977. Breeding biology of the Piping Plover in southern Nova Scotia. M.S. Thesis, Dalhousie University, Halifax, Nova Scotia. 115pp.

Cade, B.S, and J. Richards, 1999, User Manual for Blossom Statistical Software: Fort Collins, CO, U.S. Geological Survey, 107pp.

Cavanagh, P. M. 1992. Population dynamics, foraging ecology, and management of gulls on Monomoy NWR. Ph.D. Dissertation, University of Massachusetts, Amherst, Massachusetts. 105pp.

Drury, W. H. and I. C. T. Nisbet. 1972. The importance of movements in the biology of Herring Gulls in New England. Pp 173-212 *in* Population Ecology of Migratory Birds: A Symposium. USFWS Wildl. Res. Rep. 2. 278pp.

Elias-Gerken, S. P. 1994. Piping Plover habitat suitability on central Long Island, New York barrier islands. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Virginia. 247pp.

Elias, S. P., J. D. Fraser, and P. A. Buckley. 2000. Piping plover brood foraging ecology on New York barrier islands. Journal of Wildlife Management 64:346-354.

Flint, P. L., K. H. Pollack, D. Thomas, and J. S. Sedinger. 1995. Estimating prefledging survival: allowing for brood mixing and dependence among brood mates. Journal of Wildlife Management 59:448-455.

Gilmore, S. 2000. Summary of the Piping Plover management program at Gateway NRA, Breezy Point site. Unpublished document submitted to National Park Service, Gateway National Recreation Area. 20pp.

Goldin, M. R. 1993. Effects of human disturbance and off-road vehicles on Piping Plover reproductive success and behavior at Breezy Point, Gateway National Recreation Area, New York. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts. 128pp.

Goldin, M. R. and J. V. Regosin. 1998. Chick behavior, habitat use, and reproductive success of Piping Plovers at Goosewing Beach, Rhode Island. Journal of Field Ornithology 69:228-234.

Good, T. P. 1998. Great Black-backed Gull (*Larus marinus*). *In* The Birds of North America, No. 330 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Goss-Custard, J. D. 1970. The responses of redshanks (*Tringa totanus* (L.) to spatial variations in the density of their prey. Journal of Animal Ecology 39:91-113.

Goss-Custard, J. D. 1977. Responses of redshanks, *Tringa totanus*, to the absolute and relative densities of two prey species. Journal of Animal Ecology 46:867-874.

Hake, M. 1995. 1995 Summary of Piping Plover and colonial waterbird management program, Breezy Point District. Unpublished document submitted to National Park Service, Gateway National Recreation Area. 45pp.

Heisey, D. M. and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668-674.

Hoopes, E. M. 1993. Relationships between human recreation and Piping Plover foraging ecology and chick survival. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts. 106pp.

Hosmer, D. W. Jr. and S. Lemshow. 1989. Applied Logistic Regression. Wiley, New York, New York. 307pp.

Houghton, L. M. unpublished data. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Hunt, G. L. Jr. 1972. Influence of food distribution and human disturbance on the reproductive success of Herring Gulls. Ecology 53:1051-1061.

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

Jones, K. L. 1997. Piping Plover habitat selection, home range, and reproductive success at Cape Cod National Seashore, Massachusetts. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts. 96pp.

Kadlec, J. A. and W. H. Drury. 1968. Structure of the New England herring gull population. Ecology 49:644-676.

Koch, S. L. Personal Communication. U. S. Fish and Wildlife Service, Great Meadows National Wildlife Refuge, Weir Hill Road, Sudbury, Massachusetts, 01776.

Lauro, B. and J. Tanacredi. 2002. An examination of predatory pressures on Piping Plovers nesting at Breezy Point, New York. Waterbirds 25:401-409.

Lehner, P. N. 1979. Handbook of ethologica1 methods. Garland STPM Press, New York, New York. 403pp.

Loegering, J. P. 1992. Piping plover breeding biology, foraging ecology, and behavior on Assateague Island National Seashore, Maryland. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 248pp.

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

MacIvor, 1990. Population dynamics, breeding ecology, and management of Piping Plovers on outer Cape Cod, Massachusetts. M.S. Thesis, University of Massachusetts, Amherst, Massachusetts. 100pp.

Marcum, C. L. and D. O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. Journal of Wildlife Management 44:963-968.

Maron, J. L., and J. P Myers. 1985. Seasonal changes in feeding success, activity patterns, and weights of non-breeding sanderlings (*Calidris alba*). The Auk 102:580-586.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Megyesi, J. L. 1998. Management for avian nesting diversity on the northern end of South Monomoy Island 1997 field season report. Environment Cape Cod 1:13-37.

Mielke Jr., P. W. and K. J. Berry. 2001. Permutation Methods: A distance function approach. Springer-Verlag Inc., New York. 352pp.

Miller, R. G., Jr. 1980. Simultaneous Statistical Inference, second ed. Springer-Verlag Inc. New York. 299pp.

Mostello, C. S. and S. M. Melvin. 2001. Summary of the 2000 Massachusetts piping plover census data. Massachusetts Division of Fisheries and Wildlife. Westborough, Massachusetts. 28pp.

Myers, J. P., S. L. Williams, and F. A. Pitelka. 1980. An experimental analysis of prey availability for sanderlings (*Aves:Scolopacidae*) feeding on sandy beach crustaceans. Canadian Journal of Zoology 58:1564-1574.

Nemenyi, P. 1963. Distribution-free multiple comparisons. Unpublished doctoral thesis, Princeton University, New Jersey. Cited in Miller (1980).

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Olijnyk, C. G. and K. M. Brown. 1999. Results of a seven year effort to reduce nesting by Herring and Great Black-backed Gulls. Waterbirds 22:285-289.

Patterson, M. E., J. D. Fraser and J. W. Roggenbuck. 1991. Factors affecting Piping Plover productivity on Assateague Island. Journal of Wildlife Management 55:525-531.

Pienkowski, M. W. 1983. Changes in the foraging pattern of plovers in relation to environmental factors. Animal Behaviour 31:244-264.

Pierotti, R. J. 1982. Habitat selection and its effects on reproductive output in the Herring Gull in Newfoundland. Ecology 63:854-868.

Pierotti, R. 1988. Associations between marine birds and mammals in the Northwest Atlantic Ocean. Pp. 31-58 *in* Seabirds and other marine vertebrates (J. Burger, ed.). Columbia University Press, New York.

Pierotti, R. and T. P. Good. 1994. The Herring Gull (*Larus argentatus*). *In* The Birds of North America, No. 124 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

SAS Institute Inc. 1999-2001. SAS Software Release 8.2 Licensed to Virginia Polytechnic Institute and State University, Campuswide. Cary, NC, USA.

Sauer J. R. and B. K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. Journal of Wildlife Management 53:137-142.

Tacha, T. C., P. A. Vohs, and G. C. Iverson. 1985. A comparison of interval and continuous sampling methods for behavioral observations. Journal of Field Ornithology 56:258-264.

Thomas, D. L. and Taylor, E. J. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322-330

Tinbergen, N. 1960. The Herring Gull's world, second ed. Basic Books, New York. 297pp.

Tyler, S. 1979. Time-sampling: a matter of convention. Animal Behaviour 27: 801-810.

U.S. Department of Agriculture, Animal Damage Control. 1993. Management of Herring and Greater Black-backed Gulls to protect nesting Piping Plovers on the Breezy Point Unit of the Gateway National Recreation Area, Brooklyn, New York, 1993. Technical Report submitted to the National Park Service. 25pp.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants: Determination of endangered and threatened Status for the Piping Plover: Final rule. Federal Register 50:50726-50734.

U.S. Fish and Wildlife Service. 1988. Environmental assessment: master plan, Monomoy National Wildlife Refuge. Chatham, Massachusetts. 186pp.

U.S. Fish and Wildlife Service. 1996a. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts. 258pp.

U.S. Fish and Wildlife Service. 1996b. Environmental assessment: restoration of avian diversity on Monomoy National Wildlife Refuge. U. S. Fish and Wildlife Service. Chatham, Massachusetts. 94pp.

U.S. Fish and Wildlife Service. 1999. Summary of field season activities in 1998, Monomoy National Wildlife Refuge. Unpublished Report to U.S. Fish and Wildlife Service, Chatham, Massachusetts. 53pp.

U.S. Fish and Wildlife Service. 2000a. Summary of field season activities in 1999, Monomoy National Wildlife Refuge. Unpublished Report to U.S. Fish and Wildlife Service, Chatham, Massachusetts. 63pp.

U.S. Fish and Wildlife Service. 2000b. South Monomoy Island 1998 Gull Count. Prepared by Region 5 Cartography and Spatial Data Services, Hadley, Massachusetts. Presented at the November, 2000 Waterbird Meeting, Plymouth, Massachusetts.

U.S. Fish and Wildlife Service. 2002. 2000-2001 status update: U.S. Atlantic Coast piping plover population. Sudbury, Massachusetts. 9pp.

U.S. Fish and Wildlife Service. In prep. Summary of field season activities in 2000, Monomoy National Wildlife Refuge. Unpublished Report to U.S. Fish and Wildlife Service, Chatham, Massachusetts.

Wilson, W. H. Jr. 1990. Relationship between prey abundance and foraging site selection by Semipalmated Sandpipers on a Bay of Fundy mudflat. Journal of Field Ornithology 61:9-19.

Wilcox, L. 1959. A twenty year banding study of the Piping Plover. Auk 79:129-152.

TABLES

Table 1. Summary of known Piping Plover reproductive success on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Gull-removal Area		Buffer Area		Reference Area		South Monomoy Island	
1998								
Breeding Pairs	9		1		17		27	
Known Nest Attempts	12		2		24		38	
1st Attempts	9		1		17		27	
2nd Attempts	2		1		6		9	
3rd Attempts	1		0		1		2	
Nests Lost	7		2		13		22	
Successful Nests	5		0		11		16	
Eggs Laid [a]	36		7		90		133	
Eggs Lost	17		7		52		76	
Eggs Hatched	19		0		34		53	
Eggs Left In Scrape After Hatch	0		0		4		4	
Daily Survival of Nests and Variance (Mayfield 1975)	0.9600 2.1943E-04		0.7500 2.3438E-02		0.9744 4.9277E-05		0.9681 4.4735E-05	
Chicks Fledged	4		0		15		19	
Daily Survival of Chicks and Standard Error (Flint et al. 1995)	0.8900 0.0736		- -		0.9614 0.0151		0.9459 0.0176	
Successful Nests/Nest Attempt (%)	5/12	41.67	0/2	0.00	11/24	45.83	16/38	42.11
Eggs Laid/Nest Attempt [a]	36/12	3.00	7/2	3.50	90/24	3.75	133/38	3.50
Eggs Hatched/Eggs Laid (%)[a]	19/36	52.78	0/7	0.00	34/90	37.78	53/133	39.85
Eggs Hatched/Pair	19/9	2.11	0/1	0.00	34/17	2.00	53/27	1.96
Chicks Fledged/Eggs Hatched (%)	4/19	21.05	0/0	0.00	15/34	44.12	19/53	35.85
Broods Fledged/ Successful Nest (%)	2/5	40.00	0/0	0.00	8/11	72.73	10/16	62.50
Chicks Fledged/Pair	4/9	0.44	0/1	0.00	15/17	0.88	19/27	0.70

Continued.

[a] Number of eggs laid in the gull-removal area did not include the broken eggshells found on May 26, 1998.

[b] One first nest attempt in the reference area was found relocated 23 m from its original site after a flood. This relocated nest was not considered to be a second nest attempt.

[c] One egg in a nest in the gull-removal area was laid 1 m from the other 3 eggs, and was attended occasionally. This egg was not considered an additional nest, but was considered an egg lost.

[d] One egg in a nest in the gull-removal area was found lost before hatch was determined complete. This egg was assumed hatched.

Table 1, Continued. Summary of known Piping Plover reproductive success on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Gull-removal Area		Buffer Area		Reference Area		South Monomoy Island	
1999								
Breeding Pairs	9		1		16		26	
Known Nest Attempts	10		1		20		31	
1st Attempts [b]	9		1		16		26	
2nd Attempts	1		0		4		5	
3rd Attempts	0		0		0		0	
Nests Lost	5		0		8		13	
Successful Nests	5		1		12		18	
Eggs Laid	37		4		77		118	
Eggs Lost	18		0		32		50	
Eggs Hatched	16		4		43		63	
Eggs Left In Scrape After Hatch	3		0		2		5	
Daily Survival of Nests and Variance (Mayfield 1975)	0.9753 1.1892E-04		1.0000 -		0.9830 3.5674E-05		0.9813 2.6260E-05	
Chicks Fledged	5		0		30		35	
Daily Survival of Chicks and Standard Error (Flint et al. 1995)	0.9468 0.0152		- -		0.9840 0.0083		0.9726 0.0094	
Successful Nests/Nest Attempt (%)	5/10	50.00	1/1	100.00	12/20	60.00	18/31	58.06
Eggs Laid/Nest Attempt	37/10	3.70	4/1	4.00	77/20	3.85	118/31	3.81
Eggs Hatched/Eggs Laid (%)	16/37	43.24	4/4	100.00	43/77	55.84	63/118	53.39
Eggs Hatched/Pair	16/9	1.78	4/1	4.00	43/16	2.69	63/26	2.42
Chicks Fledged/Eggs Hatched (%)	5/16	31.25	0/4	0.00	30/43	69.77	35/63	55.56
Broods Fledged/ Successful Nest (%)	3/5	60.00	0/1	0.00	10/12	83.33	13/18	72.22
Chicks Fledged/Pair	5/9	0.56	0/1	0.00	30/16	1.88	35/26	1.35

Continued.

[a] Number of eggs laid in the gull-removal area did not include the broken eggshells found on May 26, 1998.

[b] One first nest attempt in the reference area was found relocated 23 m from its original site after a flood. This relocated nest was not considered to be a second nest attempt.

[c] One egg in a nest in the gull-removal area was laid 1 m from the other 3 eggs, and was attended occasionally. This egg was not considered an additional nest, but was considered an egg lost.

[d] One egg in a nest in the gull-removal area was found lost before hatch was determined complete. This egg was assumed hatched.

Table 1, Continued. Summary of known Piping Plover reproductive success on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Gull-removal Area	Buffer Area	Reference Area	South Monomoy Island
2000				
Breeding Pairs	7	0	21	28
Known Nest Attempts	11	0	28	39
1st Attempts	7	0	21	28
2nd Attempts	4	0	7	11
3rd Attempts	0	0	0	0
Nests Lost	6	0	11	17
Successful Nests	5	0	17	22
Eggs Laid [c]	39	0	99	138
Eggs Lost [c]	21	0	33	54
Eggs Hatched [d]	17	0	62	79
Eggs Left In Scrape After Hatch	1	0	4	5
Daily Survival of Nests	0.9730	-	0.9831	0.9805
and Variance (Mayfield 1975)	1.1793E-04	-	2.5673E-05	2.1946E-05
Chicks Fledged	9	0	28	37
Daily Survival of Chicks	0.9711	-	0.9604	0.9630
and Standard Error (Flint et al. 1995)	0.0207	-	0.0141	0.0115

Successful Nests/Nest Attempt (%)	5/11	45.45	0/0	0.00	17/28	60.71	22/39	56.41
Eggs Laid/Nest Attempt	39/11	3.55	0/0	0.00	99/28	3.54	138/39	3.54
Eggs Hatched/Eggs Laid (%)	17/39	43.59	0/0	0.00	62/99	62.63	79/138	57.25
Eggs Hatched/Pair	17/7	2.43	0/0	0.00	62/21	2.95	79/28	2.82
Chicks Fledged/Eggs Hatched (%)	9/17	52.94	0/0	0.00	28/62	45.16	37/79	46.84
Broods Fledged/ Successful Nest (%)	4/5	80.00	0/0	0.00	11/17	64.71	15/22	68.18
Chicks Fledged/Pair	9/7	1.29	0/0	0.00	28/21	1.33	37/28	1.32

Continued.

[a] Number of eggs laid in the gull-removal area did not include the broken eggshells found on May 26, 1998.

[b] One first nest attempt in the reference area was found relocated 23 m from its original site after a flood. This relocated nest was not considered to be a second nest attempt.

[c] One egg in a nest in the gull-removal area was laid 1 m from the other 3 eggs, and was attended occasionally. This egg was not considered an additional nest, but was considered an egg lost.

[d] One egg in a nest in the gull-removal area was found lost before hatch was determined complete. This egg was assumed hatched.

Table 1, Continued. Summary of known Piping Plover reproductive success on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Gull-removal Area		Buffer Area		Reference Area		South Monomoy Island	
1998-2000								
Breeding Pairs	25		2		54		81	
Known Nest Attempts	33		3		72		108	
1st Attempts [b]	25		2		54		81	
2nd Attempts	7		1		17		25	
3rd Attempts	1		0		1		2	
Nests Lost	18		2		32		52	
Successful Nests	15		1		40		56	
Eggs Laid [a, c]	112		11		266		389	
Eggs Lost [c]	56		7		117		180	
Eggs Hatched [d]	52		4		139		195	
Eggs Left In Scrape After Hatch	4		0		10		14	
Daily Survival of Nests and Variance (Mayfield 1975)	0.9700 4.8500E-05		0.9394 1.7252E-03		0.9803 1.1872E-05		0.9770 9.9597E-06	
Chicks Fledged	18		0		73		91	
Daily Survival of Chicks and Standard Error (Flint et al. 1995)	0.9451 0.0178		- -		0.9695 0.0071		0.9627 0.0070	
Successful Nests/Nest Attempt (%)	15/33	45.45	1/3	33.33	40/72	55.56	56/108	51.85
Eggs Laid/Nest Attempt [a]	112/33	3.39	11/3	3.67	266/72	3.69	389/108	3.60
Eggs Hatched/Eggs Laid (%)[a]	52/112	46.43	4/11	36.36	139/266	52.26	195/389	50.13
Eggs Hatched/Pair	52/25	2.08	4/2	2.00	139/54	2.57	195/81	2.41
Chicks Fledged/Eggs Hatched (%)	18/52	34.62	0/4	0.00	73/139	52.52	91/195	46.67
Broods Fledged/ Successful Nest (%)	9/15	60.00	0/1	0.00	29/40	72.50	38/56	67.86
Chicks Fledged/Pair	18/25	0.72	0/2	0.00	73/54	1.35	91/81	1.12

[a] Number of eggs laid in the gull-removal area did not include the broken eggshells found on May 26, 1998.
[b] One first nest attempt in the reference area was found relocated 23 m from its original site after a flood. This relocated nest was not considered to be a second nest attempt.
[c] One egg in a nest in the gull-removal area was laid 1 m from the other 3 eggs, and was attended occasionally. This egg was not considered an additional nest, but was considered an egg lost.
[d] One egg in a nest in the gull-removal area was found lost before hatch was determined complete. This egg was assumed hatched.

Table 2. Terms used to describe the management areas and Piping Plover nesting and foraging habitats on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Backshore	A zone of dry sand, shell, and/or cobble (<10% vegetative cover) between the high tide line and the toe of the dune, open vegetation zone (early successional habitat), or dense vegetation zone (late succession habitat).
Buffer Area	The area defined as a buffer area to the gull-free area or Area B by USFWS. Management actions during 1998-2000 included suppressing productivity of gulls by puncturing gull eggs.
Dense Vegetation	A zone of live and/or dead, thick and matted vegetation impermeable to Piping Plover chicks. Dense vegetation is mostly composed of American beach grass (*Ammophila breviligulata*) and characteristic of mid to late succession. Percent cover generally ranges from 90-100%.
Fresh Wrack	Fresh, wet masses of organic matter, mostly composed of eelgrass (*Zostera marina*) deposited at the peak of the last high tide, normally associated with the mean high water line. Fresh wrack typically washes out with the following high tide.
Gull-removal Area	The area defined as gull-free or Area A by USFWS. In 1996, USFWS management actions included the lethal removal of nesting gulls. Since removal, the USFWS has used harassment techniques to maintain this area free of nesting gulls.
Immature Gulls	Immature Great Black-backed Gulls and Immature Herring Gulls
Intertidal Zone	A zone between high and low tides with damp to saturated substrate.
Large Gulls	Great Black-backed Gulls, Herring Gulls, and immature gulls of both species
Nesting Habitat	The area where a Piping Plover nest was found, including all adjacent area up to the dense vegetation, to the waterline, and 500 meters on either side of the nest.
Ocean Side	The beach area of South Monomoy Island that is in contact with the Atlantic Ocean. All area east of the northernmost and southernmost points of the island.
Old Wrack	Any dry mass of organic matter, mostly composed of eelgrass, deposited during spring or storm tides. Typically located on the backshore or scattered among open vegetation.
Open Vegetation	A zone of vegetation mostly composed of American beach grass (*Ammophila breviligulata*). Open vegetation is characteristic of early succession. Percent cover generally ranges from 10-90%.
Reference Area	Includes the area defined as the experimental control or Area C by USFWS as well as the remaining area of South Monomoy Island.
Sound Side	The beach area of South Monomoy Island that is in contact with Nantucket Sound. All area west of the northernmost and southernmost points of the island.
Tidal Pond	A brackish body of water connected to salt water and inundated by ocean tides but fed by fresh water.
Total Gulls	The number of Large Gulls regardless of species
Unused Habitat	The area not classified as “Nesting Habitat”.

Table 3. Behavior categories used in the analyses of Piping Plover behavioral observations on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Behavior Categories	Behaviors or Behavior Sequences
Alert	Undisturbed, standing still, and not foraging
Brooding	Adult brooding chick(s) or chick(s) being brooded by adult
Courting	Displaying, making and maintaining nest scrapes, courtship flight, and copulating
Disturbed	Crouching, standing disturbed, walking disturbed, running disturbed, or flying disturbed
Foraging	Peck while standing, peck while walking, peck while running, glean, aerial snap, or foot tremble; standing, walking, or running between pecks
Moving	Undisturbed and not foraging while walking, running, or flying
Resting	Sitting or preening

Table 4. Mean counts of large gulls within 100 m of random points during the prenesting period, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means with the same letters were not significantly different ($P < 0.05$).

Year	Management Area	n	Total Large Gulls $\bar{x}$		SE	Great Black-backed Gulls $\bar{x}$		SE	Herring Gulls $\bar{x}$	SE	Immature Gulls $\bar{x}$	SE
1999												
	Gull-removal	54	9.69	B	2.41	2.72	B	0.70	6.54	2.17	0.43	0.13
	Buffer	54	20.93	A	3.01	17.09	A	2.50	3.52	0.87	0.31	0.17
	Reference	107	28.94	A	2.67	22.41	A	2.06	5.79	1.40	0.75	0.33
			$T = -13.19$, $P < 0.0001$			$T = -24.54$, $P < 0.0001$			$T = 0.21$, $P = 0.48$		$T = -0.22$, $P = 0.33$	
2000												
	Gull-removal	58	2.02	B	0.47	0.93	B	0.22	0.81	B 0.27	0.28	0.12
	Buffer	58	12.03	A	1.72	7.45	A	1.08	4.41	A 0.97	0.17	0.07
	Reference	118	15.86	A	2.01	9.94	A	1.14	4.97	A 1.09	0.95	0.33
			$T = -18.54$, $P < 0.0001$			$T = -21.58$, $P < 0.0001$			$T = -6.12$, $P = 0.0005$		$T = -1.83$, $P = 0.06$	
1999-2000												
	Gull-removal	112	5.71	B	1.24	1.79	B	0.36	3.57	1.08	0.35	A 0.09
	Buffer	112	16.32	A	1.75	12.10	A	1.40	3.98	0.65	0.24	A 0.09
	Reference	225	22.08	A	1.70	15.87	A	1.22	5.36	0.88	0.85	A 0.23
			$T = -28.59$, $P < 0.0001$			$T = -41.78$, $P < 0.0001$			$T = -0.91$, $P = 0.15$		$T = -1.97$, $P = 0.05$	

Table 5. Percent of random points with at least one gull present within 100 m during the prenesting period, among management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Chi-square tests were used to test for differences in proportions.

Year	Management Area	n	Plots With Large Gulls					Plots With Great Black-backed Gulls					Plots With Herring Gulls					Plots With Immature Gulls				
			Obs. Value[a]	(%)	Exp. Value[b]	(%)	Partial χ^2 [c]	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2
1999																						
	Gull-removal	54	41	(76)	49	(91)	11.26	26	(48)	44	(81)	39.42	30	(56)	30	(56)	0.01	13	(24)	9	(17)	1.79
	Buffer	54	47	(87)	49	(91)	0.44	45	(83)	44	(81)	0.13	26	(48)	30	(56)	1.45	6	(11)	9	(17)	1.41
	Reference	107	105	(98)	96	(90)	8.15	104	(97)	87	(84)	17.64	65	(61)	60	(56)	0.87	18	(17)	18	(17)	0.01
			$df = 2, \chi^2 = 19.85, P < 0.0001$					$df = 2, \chi^2 = 57.19, P < 0.0001$					$df = 2, \chi^2 = 2.33, P = 0.31$					$df = 2, \chi^2 = 3.21, P = 0.20$				
2000																						
	Gull-removal	58	34	(59)	48	(83)	25.50	25	(41)	43	(74)	31.89	19	(33)	28	(48)	5.91	9	(16)	9	(16)	<0.01
	Buffer	58	51	(88)	48	(83)	0.88	50	(86)	43	(74)	4.53	30	(52)	28	(48)	0.21	6	(10)	9	(16)	1.13
	Reference	118	110	(93)	98	(83)	8.31	99	(84)	87	(74)	6.08	65	(55)	58	(49)	1.91	21	(18)	18	(15)	0.53
			$df = 2, \chi^2 = 34.69, P < 0.0001$					$df = 2, \chi^2 = 42.51, P < 0.0001$					$df = 2, \chi^2 = 8.04, P = 0.02$					$df = 2, \chi^2 = 1.66, P = 0.44$				
1999-2000																						
	Gull-removal	112	75	(67)	97	(87)	36.09	50	(45)	87	(78)	69.38	49	(44)	59	(53)	3.31	22	(20)	18	(16)	0.94
	Buffer	112	98	(88)	97	(87)	0.11	95	(85)	87	(78)	3.44	56	(50)	59	(53)	0.25	12	(3)	18	(16)	2.53
	Reference	225	215	(96)	194	(86)	16.01	203	(90)	174	(77)	20.87	130	(58)	118	(52)	2.67	39	(9)	37	(16)	0.19
			$df = 2, \chi^2 = 52.22, P < 0.0001$					$df = 2, \chi^2 = 93.69, P < 0.0001$					$df = 2, \chi^2 = 6.23, P = 0.04$					$df = 2, \chi^2 = 3.66, P = 0.16$				

[a] Observed number of random 100 m-radius plots with at least one gull present.
[b] Expected number of random 100 m-radius plots with at least one gull present.
[c] Partial Chi-square for observed vs. expected values for each management area.

Table 6. Mean counts of large gulls within 100 m of Piping Plovers during the prenesting period, between the gull-removal and reference areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number plovers observed. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal	22	8.00	3.77	0.41	0.20	6.59	2.90	1.00	0.95
	Reference	81	15.81	3.64	5.58	1.04	9.01	2.59	1.22	0.58
			T = -0.33, P = 0.25		T = -8.07, P = 0.0002		T = 0.49, P = 0.59		T = 0.75, P = 0.82	
2000										
	Gull-removal	78	2.51	0.45	0.55	0.12	1.79	0.39	0.17	0.05
	Reference	176	3.98	1.19	1.42	0.39	2.27	0.80	0.29	0.09
			T = 0.10, P = 0.40		T = -4.10, P = 0.008		T = -1.00, P = 0.13		T = 0.27, P = 0.46	
1999-2000										
	Gull-removal	100	3.72	0.92	0.52	0.11	2.85	0.72	0.35	0.21
	Reference	257	7.71	1.44	2.73	0.44	4.39	1.00	0.58	0.19
			T = -1.38, P = 0.09		T = -13.87, P < 0.0001		T = -0.63, P = 0.19		T = 0.26, P = 0.48	

Table 7. Percent of instantaneous observations of Piping Plovers with at least one gull present within 100 m during the prenesting period, between the gull-removal and reference areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of plovers observed. Chi-square tests were used to test for differences in proportions.

Year	Management Area	n	Plots With Large Gulls					Plots With Great Black-backed Gulls					Plots With Herring Gulls					Plots With Immature Gulls				
			Obs. Value [a]	(%)	Exp. Value [b]	(%)	Partial χ^2 [c]	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2
1999																						
	Gull-removal	22	14	(64)	18	(82)	3.46	5	(23)	14	(64)	14.52	12	(55)	12	(55)	0.01	2	(9)	3	(14)	0.38
	Reference	81	68	(84)	64	(79)	0.94	59	(73)	50	(62)	3.94	43	(53)	43	(53)	<0.01	12	(15)	11	(14)	0.10
			df = 1, χ^2 = 4.40, P = 0.04					df = 1, χ^2 = 18.47, P < 0.0001					df = 1, χ^2 = 0.01, P = 0.90					df = 1, χ^2 = 0.48, P = 0.49				
2000																						
	Gull-removal	78	43	(55)	47	(60)	0.99	20	(26)	30	(38)	5.83	28	(36)	22	(28)	1.95	11	(14)	10	(13)	0.03
	Reference	176	111	(63)	107	(63)	0.44	79	(45)	69	(39)	2.58	45	(26)	50	(28)	0.86	23	(13)	24	(14)	0.02
			df = 1, χ^2 = 1.43, P = 0.23					df = 1, χ^2 = 8.42, P = 0.004					df = 1, χ^2 = 2.81, P = 0.09					df = 1, χ^2 = 0.05, P = 0.82				
1999-2000																						
	Gull-removal	100	57	(57)	66	(66)	3.70	25	(25)	46	(46)	17.20	40	(40)	36	(36)	0.75	13	(13)	13	(13)	0.02
	Reference	257	179	(70)	170	(66)	1.44	138	(54)	117	(46)	6.69	88	(34)	92	(36)	0.29	35	(14)	35	(14)	<0.01
			df = 1, χ^2 = 5.14, P = 0.02					df = 1, χ^2 = 23.89, P < 0.0001					df = 1, χ^2 = 1.04, P = 0.31					df = 1, χ^2 = 0.02, P = 0.88				

[a] Observed number of prenesting plovers with at least one gull present within 100 m.
[b] Expected number of prenesting plovers with at least one gull present within 100 m.
[c] Partial Chi-square for observed vs. expected values for each management area.

Table 8. Mean counts of large gulls within 100 m of Piping Plovers compared to mean counts of large gulls within 100 m of random points during the prenesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of plovers observed or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal									
	Piping Plovers	22	8.00	3.77	0.41	0.20	6.59	2.90	1.00	0.95
	Random Points	54	9.69	2.41	2.72	0.70	6.54	2.17	0.43	0.13
			T = 0.13, P = 0.41		T = -3.34, P = 0.01		T = 0.99, P = 1.00		T = -0.32, P = 0.26	
	Reference									
	Piping Plovers	81	15.81	3.64	5.58	1.04	9.01	2.59	1.22	0.58
	Random Points	107	28.94	2.67	22.41	2.06	5.79	1.40	0.75	0.33
			T = -17.28, P < 0.0001		T = -32.88, P < 0.0001		T = 0.06, P = 0.37		T = 0.62, P = 0.68	
2000										
	Gull-removal									
	Piping Plovers	78	2.51	0.45	0.55	0.12	1.79	0.39	0.17	0.05
	Random Points	58	2.02	0.47	0.93	0.22	0.81	0.27	0.28	0.12
			T = 0.20, P = 0.43		T = -1.03, P = 0.12		T = -2.22, P = 0.04		T = 0.73, P = 0.83	
	Reference									
	Piping Plovers	176	3.98	1.19	1.42	0.39	2.27	0.80	0.29	0.09
	Random Points	118	15.86	2.01	9.94	1.14	4.97	1.09	0.95	0.33
			T = -47.57, P < 0.0001		T = -64.70, P < 0.0001		T = -10.01, P < 0.0001		T = -2.71, P = 0.02	
1999-2000										
	Gull-removal									
	Piping Plovers	100	3.72	0.92	0.52	0.11	2.85	0.72	0.35	0.21
	Random Points	112	5.71	1.24	1.79	0.36	3.57	1.08	0.35	0.09
			T = -0.82, P = 0.16		T = -6.98, P = 0.0005		T = 1.00, P = 1.00		T = -0.48, P = 0.21	
	Reference									
	Piping Plovers	257	7.71	1.44	2.73	0.44	4.39	1.00	0.58	0.19
	Random Points	225	22.08	1.70	15.87	1.22	5.36	0.88	0.85	0.23
			T = -66.66, P < 0.0001		T = -95.51, P < 0.0001		T = -5.36, P = 0.002		T = 0.02, P = 0.36	

Table 9. Percent of instantaneous observations of Piping Plovers with at least one large gull present within 100 m compared to the percent of random points with at least one large gull present within 100 m, during the prenesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of plovers observed or the number of random points. Chi-square tests were used to test for differences in proportions.

Year, Management Area		Plots With Large Gulls					Plots With Great Black-backed Gulls					Plots With Herring Gulls					Plots With Immature Gulls				
	n	Obs. Value [a]	(%)	Exp. Value [b]	(%)	Partial χ^2 [c]	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2
1999																					
Gull-removal																					
Piping Plovers	22	14	(64)	16	(73)	0.84	5	(23)	9	(41)	2.97	12	(55)	12	(55)	<0.01	2	(9)	4	(18)	1.57
Random Points	54	41	(76)	39	(72)	0.34	26	(48)	22	(41)	1.21	30	(56)	30	(56)	<0.01	13	(24)	11	(20)	0.64
		df = 1, χ^2 = 1.18, P= 0.28					df = 1, χ^2 = 4.18, P = 0.04					df = 1, χ^2 = 0.01, P = 0.94					df = 1, χ^2 = 2.22, P = 0.14				
Reference																					
Piping Plovers	81	68	(84)	75	(93)	7.19	59	(73)	70	(86)	13.50	43	(53)	47	(58)	0.63	12	(15)	13	(16)	0.08
Random Points	107	105	(98)	98	(92)	5.44	104	(97)	93	(87)	10.22	65	(61)	61	(57)	0.48	18	(17)	17	(16)	0.06
		df = 1, χ^2 = 12.63, P = 0.0004					df = 1, χ^2 = 23.72, P < 0.0001					df = 1 χ^2 = 1.11, P = 0.29					df = 1, χ^2 = 0.14, P = 0.71				
2000																					
Gull-removal																					
Piping Plovers	78	43	(55)	44	(56)	0.07	20	(26)	25	(32)	1.61	28	(36)	27	(35)	0.06	11	(14)	11	(14)	0.02
Random Points	58	34	(59)	33	(57)	0.09	24	(41)	19	(33)	2.16	19	(33)	20	(34)	0.08	9	(16)	9	(16)	0.03
		df = 1, χ^2 = 0.17, P = 0.68					df = 1, χ^2 = 3.76, P = 0.05					df = 1, χ^2 = 0.14, P = 0.70					df = 1, χ^2 = 0.05, P = 0.82				
Reference																					
Piping Plovers	176	111	(63)	132	(75)	13.81	79	(45)	107	(61)	18.06	45	(26)	66	(38)	10.55	23	(13)	26	(15)	0.50
Random Points	118	110	(93)	89	(75)	20.60	99	(84)	71	(60)	26.94	65	(55)	44	(37)	15.73	21	(18)	18	(15)	0.74
		df = 1, χ^2 = 34.41, P < 0.0001					df = 1, χ^2 = 45.00, P < 0.0001					df = 1, χ^2 = 26.28, P < 0.0001					df = 1, χ^2 = 1.24, P = 0.27				

Continued.

[a] Observed number of random points and prenesting plovers with at least one gull present within 100 m.
[b] Expected number of random points and prenesting plovers with at least one gull present within 100 m.
[c] Partial Chi-square for observed vs. expected values for Piping Plovers or Random Points.

Table 9, Continued. Percent of instantaneous observations of Piping Plovers with at least one large gull present within 100 m compared to the percent of random points with at least one large gull present within 100 m, during the prenesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of plovers observed or the number of random points. Chi-square tests were used to test for differences in proportions.

Year, Management Area		Plots With Large Gulls					Plots With Great Black-backed Gulls					Plots With Herring Gulls					Plots With Immature Gulls				
	n	Obs. Value [a]	(%)	Exp. Value [b]	(%)	Partial χ^2 [c]	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2	Obs. Value	(%)	Exp. Value	(%)	Partial χ^2
1999-2000																					
Gull-removal																					
Piping Plovers	100	57	(57)	62	(62)	1.18	25	(25)	35	(35)	4.71	40	(40)	42	(42)	0.16	13	(13)	17	(17)	0.89
Random Points	112	75	(67)	70	(63)	1.05	50	(45)	40	(36)	4.21	49	(44)	47	(42)	0.14	22	(20)	18	(16)	0.80
		df = 1, $\chi^2 = 2.23$, $P = 0.14$					df = 1, $\chi^2 = 8.92$, $P = 0.003$					df = 1, $\chi^2 = 0.31$, $P = 0.58$					df = 1, $\chi^2 = 1.69$, $P = 0.19$				
Reference																					
Piping Plovers	257	179	(70)	210	(82)	25.18	138	(54)	182	(71)	36.10	88	(34)	116	(45)	12.52	35	(14)	39	(15)	0.59
Random Points	225	215	(96)	184	(82)	28.76	203	(90)	159	(71)	41.24	130	(58)	102	(45)	14.30	39	(17)	35	(16)	0.68
		df = 1, $\chi^2 = 53.95$, $P < 0.0001$					df = 1, $\chi^2 = 77.34$, $P < 0.0001$					df = 1, $\chi^2 = 26.83$, $P < 0.0001$					df = 1, $\chi^2 = 1.27$, $P = 0.26$				

[a] Observed number of random points and prenesting plovers with at least one gull present within 100 m.
[b] Expected number of random points and prenesting plovers with at least one gull present within 100 m.
[c] Partial Chi-square for observed vs. expected values for Piping Plovers or Random Points.

Table 10. Mean width (m) of foraging habitats measured along random transects, among years, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Habitat	Year	Ocean-side Transects			Sound-side Transects		
		n	$\overline{x}$ (m)	SE	n	$\overline{x}$ (m)	SE
Intertidal Zone							
	1999	55	19.89	2.41	60	33.20	10.85
	2000	71	22.00	2.36	67	40.00	13.61
			T = -1.11, *P* = 0.12			*T* = 0.86, *P* = 1.00	
Fresh Wrack							
	1999	55	0.60	0.37	60	1.45	0.43
	2000	71	0.89	0.21	67	2.02	0.29
			T = -3.10, *P* = 0.02			*T* = -4.52, *P* = 0.005	
Backshore							
	1999	55	28.96	3.36	60	10.33	1.96
	2000	71	23.66	2.13	67	13.88	2.10
			T = -0.72, *P* = 0.17			*T* = -0.63, *P* = 0.18	
Old Wrack							
	1999	55	0.20	0.09	60	2.67	0.30
	2000	71	0.86	0.17	67	2.78	0.35
			T = -6.60, *P* = 0.0009			*T* = 0.80, *P* = 0.86	
Open Vegetation							
	1999	55	15.71	1.93	60	5.13	1.32
	2000	71	13.26	1.23	67	6.92	1.40
			T = 0.24, *P* = 0.26			*T* = -0.11, *P* = 0.31	
Tidal Pond Intertidal Zone							
	1999				60	10.16	4.84
	2000				67	5.17	1.63
						T = -0.14, *P* = 0.31	

Table 11. Mean width (m) of foraging habitats measured along random transects, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means with the same letters were not significantly different ($P < 0.05$).

Year	Habitat	Management Area	Ocean-side Transects[a]			Sound-side Transects[b]		
			n	$\bar{x}$ (m)	SE	n	$\bar{x}$ (m)	SE
1999								
	Intertidal Zone							
		Gull-removal	27	34.60 A	7.65	32	111.54 A	25.45
		Buffer	34	19.20 B	1.82	24	115.50 A	34.42
		Reference	59	17.34 B	1.21	65	9.69 B	3.08
				T = -4.39, P = 0.002			T = -15.46, $P < 0.0001$	
	Fresh Wrack							
		Gull-removal	27	0.57	0.24	32	0.39 B	0.16
		Buffer	34	0.10	0.06	24	1.35 A	0.39
		Reference	59	0.49	0.34	65	1.44 A	0.42
				T = -0.98, P = 0.14			T = -3.25, P = 0.01	
	Backshore							
		Gull-removal	27	34.83 A	6.73	32	3.37 B	0.68
		Buffer	34	27.64 B	1.85	24	1.43 C	0.49
		Reference	59	23.85 A	2.70	65	10.34 A	1.80
				T = -4.63, P = 0.002			T = -10.59, $P < 0.0001$	
	Old Wrack							
		Gull-removal	27	0.19	0.09	32	0.55 C	0.11
		Buffer	34	0.06	0.04	24	6.96 A	2.45
		Reference	59	0.21	0.08	65	2.87 B	0.26
				T = 0.26, P = 0.49			T = -21.84, $P < 0.0001$	
	Open Vegetation							
		Gull-removal	27	15.93 AB	2.65	32	2.16 B	0.75
		Buffer	34	21.56 A	2.62	24	0.20 C	0.14
		Reference	59	13.43 B	1.57	65	6.39 A	1.29
				T = -2.41, P = 0.03			T = -9.28, $P < 0.0001$	
	Tidal Pond Intertidal Zone							
		Gull-removal				32	2.91	2.11
		Buffer				24	0.19	0.19
		Reference				65	9.38	4.48
							T = -0.81, P = 0.17	

Continued.

[a] All beach area east of the northernmost tip and southernmost tip of South Monomoy Island.

[b] All beach area west of the northernmost tip and southernmost tip of South Monomoy Island.

Table 11, Continued. Mean width (m) of foraging habitats measured along random transects, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means with the same letters were not significantly different ($P < 0.05$).

Year	Habitat	Management Area	Ocean-side Transects[a]			Sound-side Transects[b]		
			n	$\bar{x}$ (m)	SE	n	$\bar{x}$ (m)	SE
2000								
	Intertidal Zone							
		Gull-removal	23	28.35	6.58	32	112.26 A	28.73
		Buffer	28	24.43	2.37	28	178.83 A	41.56
		Reference	57	20.36	1.40	56	6.25 B	0.62
				T = -0.10, P = 0.36			T = -16.26, P < 0.0001	
	Fresh Wrack							
		Gull-removal	23	0.78	0.42	32	0.50 B	0.19
		Buffer	28	1.04	0.32	28	3.22 A	0.91
		Reference	57	0.90	0.25	56	2.30 A	0.33
				T = 0.37, P = 0.55			T = -10.98, P < 0.0001	
	Backshore							
		Gull-removal	23	31.43 A	6.26	32	4.53 B	0.66
		Buffer	28	19.90 B	1.98	28	1.92 C	0.43
		Reference	57	23.43 B	1.73	56	18.04 A	2.49
				T = -3.17, P = 0.01			T = -17.75, P < 0.0001	
	Old Wrack							
		Gull-removal	23	1.00	0.26	32	1.26 C	0.21
		Buffer	28	3.45	1.48	28	4.21 B	0.36
		Reference	57	0.91	0.20	56	3.40 A	0.42
				T = -1.71, P = 0.07			T = -13.74, P < 0.0001	
	Open Vegetation							
		Gull-removal	23	19.15 AB	2.43	32	1.49 B	0.76
		Buffer	28	27.35 A	8.83	28	3.55 B	1.64
		Reference	57	13.50 B	1.46	56	7.91 A	1.48
				T = -2.86, P = 0.02			T = -6.10, P = 0.0005	
	Tidal Pond Intertidal Zone							
		Gull-removal				32	0.00 B	0.00
		Buffer				28	0.91 B	0.70
		Reference				56	8.80 A	2.29
							T = -6.89, P = 0.0002	

Continued.

[a] All beach area east of the northernmost tip and southernmost tip of South Monomoy Island.
[b] All beach area west of the northernmost tip and southernmost tip of South Monomoy Island.

Table 11, Continued. Mean width (m) of foraging habitats measured along random transects, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means with the same letters were not significantly different ($P < 0.05$).

Year	Habitat	Management Area	Ocean-side Transects[a]			Sound-side Transects[b]		
			n	$\bar{x}$ (m)	SE	n	$\bar{x}$ (m)	SE
1999-2000								
	Intertidal Zone							
		Gull-removal	50	31.72 A	5.09	64	111.90 A	19.04
		Buffer	62	21.56 B	1.49	52	149.60 A	27.54
		Reference	116	18.82 B	0.93	121	8.10 B	1.68
				T = -5.09, P = 0.001			T = -32.59, P < 0.0001	
	Fresh Wrack							
		Gull-removal	50	0.67	0.23	64	0.45 B	0.12
		Buffer	62	0.53	0.16	52	2.36 A	0.53
		Reference	116	0.69	0.21	121	1.84 A	0.28
				T = 0.94, P = 0.89			T = -12.90, P < 0.0001	
	Backshore							
		Gull-removal	50	33.26 A	4.60	64	3.95 B	0.48
		Buffer	62	24.14 B	1.43	52	1.69 C	0.32
		Reference	116	23.65 C	1.61	121	13.90 A	1.54
				T = -6.45, P = 0.0003			T = -26.23, P < 0.0001	
	Old Wrack							
		Gull-removal	50	0.56	0.14	64	0.90 C	0.13
		Buffer	62	1.59	4.21	52	5.48 A	1.15
		Reference	116	0.55	0.11	121	3.11 B	0.24
				T = -0.45, P = 0.25			T = -35.27, P < 0.0001	
	Open Vegetation							
		Gull-removal	50	17.41 AB	1.81	64	1.82 B	0.53
		Buffer	62	24.17 A	4.21	52	2.01 B	0.91
		Reference	116	13.46 B	1.07	121	7.09 A	0.97
				T = -5.50, P = 0.001			T = -12.74, P < 0.0001	
	Tidal Pond Intertidal Zone							
		Gull-removal				64	1.46 B	1.06
		Buffer				52	0.57 B	0.38
		Reference				121	9.11 A	2.62
							T = -5.79, P = 0.0008	

[a] All beach area east of the northernmost tip and southernmost tip of South Monomoy Island.
[b] All beach area west of the northernmost tip and southernmost tip of South Monomoy Island.

Table 12. Prenesting Piping Plover habitat use (%) between years by foraging, nonforaging, and plovers in all behaviors during the prenesting period, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the total number of plovers observed in each behavior group. Chi-square tests were used to test for differences in proportions of use between years.

Behavior, Habitat	1999					2000				
	Observed Use[a]	(%)	Exp. Use[b]	(%)	Partial χ^2 [c]	Observed Use	(%)	Exp. Use	(%)	Partial χ^2
Foraging Plovers	n = 113					n = 162				
Ocean Intertidal Zone	0	(0.0)	2	(1.8)	2.47	6	(3.7)	4	(2.5)	1.72
Ocean Backshore	0	(0.0)	1	(0.9)	0.82	2	(1.2)	1	(0.6)	0.57
Sound Intertidal Zone	38	(33.6)	38	(33.6)	<0.01	55	(34.0)	55	(34.0)	<0.01
Sound Fresh Wrack	2	(1.8)	8	(7.1)	4.32	17	(10.5)	11	(6.8)	3.01
Sound Backshore	1	(0.9)	3	(2.7)	1.22	6	(3.7)	4	(2.5)	0.85
Sound Old Wrack	0	(0.0)	0	(0.0)	0.41	1	(0.6)	1	(0.6)	0.29
Tidal Pond Intertidal Zone	72	(63.7)	60	(53.1)	2.23	75	(46.3)	87	(53.7)	1.55
	n = 275, df = 6, χ^2 = 19.47, P = 0.003									
Nonforaging Plovers	n = 148					n = 408				
Ocean Intertidal Zone	2	(1.4)	2	(1.4)	<0.01	6	(1.5)	6	(1.5)	<0.01
Ocean Fresh Wrack	0	(0.0)	1	(0.7)	1.06	4	(1.0)	3	(0.7)	0.39
Ocean Backshore	37	(25.0)	42	(28.4)	0.55	120	(29.4)	115	(28.2)	0.20
Ocean Old Wrack	0	(0.0)	1	(0.7)	0.80	3	(0.7)	2	(0.5)	0.29
Ocean Open Vegetation	0	(0.0)	4	(2.7)	3.73	14	(3.4)	10	(2.5)	1.35
Sound Intertidal Zone	12	(8.1)	8	(5.4)	2.37	17	(4.2)	21	(5.1)	0.86
Sound Fresh Wrack	0	(0.0)	2	(1.4)	1.60	6	(1.5)	4	(1.0)	0.58
Sound Backshore	81	(54.7)	76	(51.4)	0.35	204	(50.0)	209	(51.2)	0.13
Sound Old Wrack	2	(1.4)	5	(3.4)	1.41	15	(3.7)	12	(2.9)	0.51
Sound Open Vegetation	0	(0.0)	1	(0.7)	1.33	5	(1.2)	4	(1.0)	0.48
Tidal Pond Intertidal Zone	14	(9.5)	7	(4.7)	5.75	14	(3.4)	21	(5.1)	2.09
	n = 556, df = 10, χ^2 = 25.83, P = 0.004									
Plovers In All Behaviors	n = 261					n = 570				
Ocean Intertidal Zone	2	(0.8)	4	(1.5)	1.31	12	(2.1)	10	(1.8)	0.60
Ocean Fresh Wrack	0	(0.0)	1	(0.4)	1.26	4	(0.7)	3	(0.5)	0.58
Ocean Backshore	37	(14.2)	50	(19.2)	3.35	122	(21.4)	109	(19.1)	1.54
Ocean Old Wrack	0	(0.0)	1	(0.4)	0.94	3	(0.5)	2	(0.4)	0.43
Ocean Open Vegetation	0	(0.0)	4	(1.5)	4.40	14	(2.5)	10	(1.8)	2.01
Sound Intertidal Zone	50	(19.2)	38	(14.6)	3.56	72	(12.6)	84	(14.7)	1.63
Sound Fresh Wrack	2	(0.8)	8	(3.1)	4.36	23	(4.0)	17	(3.0)	2.00
Sound Backshore	82	(31.4)	92	(35.2)	1.03	210	(36.8)	200	(35.1)	0.47
Sound Old Wrack	2	(0.8)	6	(2.3)	2.36	16	(2.8)	12	(2.1)	1.08
Sound Open Vegetation	0	(0.0)	2	(0.8)	1.57	5	(0.9)	3	(0.5)	0.72
Tidal Pond Intertidal Zone	86	(33.0)	55	(21.1)	17.53	89	(15.6)	120	(21.1)	8.02
	n = 831, df = 10, χ^2 = 60.74, P < 0.0001									

[a] Observed number of prenesting plovers within the habitat.
[b] Expected number of prenesting plovers within the habitat.
[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 13. Prenesting Piping Plover habitat use (%) between the management areas by foraging, nonforaging, and plovers in all behaviors during the prenesting period, by year, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the total number of plovers observed in each behavior group. Prenesting plovers were observed in all habitats included in analyses. Chi-square tests were used to test for differences in proportions between the management areas.

Year, Behavior, Habitat	Gull-removal Area					Reference Area				
	Observed Use[a]	(%)	Exp. Use[b]	(%)	Partial χ^2 [c]	Observed Use	(%)	Exp. Use	(%)	Partial χ^2
1999, Foraging Plovers	n = 35					n = 78				
Sound Intertidal Zone	35	(100.0)	12	(34.3)	45.85	3	(3.8)	26	(33.3)	20.57
Sound Fresh Wrack	0	(0.0)	1	(2.9)	0.62	2	(2.6)	1	(1.3)	0.28
Sound Backshore	0	(0.0)	0	(0.0)	0.31	1	(1.3)	1	(1.3)	0.14
Tidal Pond Intertidal Zone	0	(0.0)	22	(62.9)	22.30	72	(92.3)	50	(64.1)	10.01
	n = 113, df = 3, $\chi^2 = 100.08$, $P < 0.0001$									
1999, Nonforaging Plovers	n = 29					n = 119				
Ocean Intertidal Zone	2	(6.9)	0	(0.0)	6.60	0	(0.0)	2	(1.7)	1.61
Ocean Backshore	23	(79.3)	7	(24.1)	34.22	14	(11.8)	30	(25.2)	8.34
Sound Intertidal Zone	3	(10.3)	2	(6.9)	0.18	9	(7.6)	10	(8.4)	0.04
Sound Backshore	1	(3.4)	16	(55.2)	13.94	80	(67.2)	65	(54.6)	3.40
Sound Old Wrack	0	(0.0)	0	(0.0)	0.39	2	(1.7)	2	(1.7)	0.10
Tidal Pond Intertidal Zone	0	(0.0)	3	(10.3)	2.74	14	(11.87)	11	(9.2)	0.67
	n = 148, df = 5, $\chi^2 = 72.21$, $P < 0.0001$									
1999, Plovers In All Behaviors	n = 64					n = 197				
Ocean Intertidal Zone	2	(3.1)	0	(0.0)	4.65	0	(0.0)	2	(1.0)	1.51
Ocean Backshore	23	(35.9)	9	(14.1)	21.38	14	(7.1)	28	(14.2)	6.95
Sound Intertidal Zone	38	(59.4)	12	(18.8)	54.26	12	(6.1)	38	(19.3)	17.56
Sound Fresh Wrack	0	(0.0)	0	(0.0)	0.49	2	(1.0)	2	(1.0)	0.16
Sound Backshore	1	(1.6)	20	(31.3)	18.2	81	(41.1)	62	(31.5)	5.90
Sound Old Wrack	0	(0.0)	0	(0.0)	0.49	2	(1.0)	2	(1.0)	0.16
Tidal Pond Intertidal Zone	0	(0.0)	21	(32.8)	21.09	86	(43.7)	65	(33.0)	6.85
	n = 261, df = 6, $\chi^2 = 159.37$, $P < 0.0001$									

Continued.

[a] Observed number of prenesting plovers within the habitat.
[b] Expected number of prenesting plovers within the habitat.
[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 13, Continued. Prenesting Piping Plover habitat use (%) between the management areas by foraging, nonforaging, and plovers in all behaviors during the prenesting period, by year, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the total number of plovers observed in each behavior group. Prenesting plovers were observed in all habitats included in analyses. Chi-square tests were used to test for differences in proportions between the management areas.

Year, Behavior, Habitat	Gull-removal Area					Reference Area				
	Observed Use[a]	(%)	Exp. Use[b]	(%)	Partial χ^2 [c]	Observed Use	(%)	Exp. Use	(%)	Partial χ^2
2000, Foraging Plovers	n = 52					n = 110				
Ocean Intertidal Zone	0	(0.0)	2	(3.8)	1.93	6	(5.5)	4	(3.6)	0.91
Ocean Backshore	2	(3.8)	1	(1.9)	2.87	0	(0.0)	1	(0.9)	1.36
Sound Intertidal Zone	48	(92.3)	18	(34.6)	52.16	7	(6.4)	37	(33.6)	24.66
Sound Fresh Wrack	0	(0.0)	5	(9.6)	5.46	17	(15.5)	12	(10.9)	2.58
Sound Backshore	2	(3.8)	2	(3.8)	<0.01	4	(3.6)	4	(3.6)	<0.01
Sound Old Wrack	0	(0.0)	0	(0.0)	0.32	1	(0.9)	1	(0.9)	0.15
Tidal Pond Intertidal Zone	0	(0.0)	24	(46.2)	24.07	75		51	(46.4)	11.38
	n = 162, df = 6, χ^2 = 127.85, P < 0.0001									
2000, Nonforaging Plovers	n = 116					n = 292				
Ocean Intertidal Zone	5	(4.3)	2	(1.7)	6.36	1	(0.3)	4	(1.4)	2.53
Ocean Fresh Wrack	4	(3.4)	1	(0.9)	7.21	0	(0.0)	3	(1.0)	2.86
Ocean Backshore	86	(74.1)	34	(29.3)	78.90	34	(11.6)	86	(29.5)	31.34
Ocean Old Wrack	0	(0.0)	1	(0.9)	0.85	3	(1.0)	2	(0.7)	0.34
Ocean Open Vegetation	9	(7.8)	4	(3.4)	6.33	5	(1.7)	10	(3.4)	2.51
Sound Intertidal Zone	8	(6.9)	5	(4.3)	2.07	9	(3.1)	12	(4.1)	0.82
Sound Fresh Wrack	0	(0.0)	2	(1.7)	1.71	6	(2.1)	4	(1.4)	0.68
Sound Backshore	2	(1.7)	58	(50.0)	54.07	202	(69.2)	146	(50.0)	21.48
Sound Old Wrack	2	(1.7)	4	(3.4)	1.20	13	(4.5)	11	(3.8)	0.48
Sound Open Vegetation	0	(0.0)	1	(0.9)	1.42	5	(1.7)	4	(1.4)	0.56
Tidal Pond Intertidal Zone	0	(0.0)	4	(3.4)	3.98	14	(4.8)	10	(3.4)	1.58
	n = 408, df = 10, χ^2 = 229.29, P < 0.0001									
2000, Plovers In All Behaviors	n = 168					n = 402				
Ocean Intertidal Zone	5	(3.0)	4	(2.4)	3.54	7	(1.7)	8	(2.0)	0.25
Ocean Fresh Wrack	4	(2.4)	1	(0.6)	6.75	0	(0.0)	3	(0.7)	2.82
Ocean Backshore	88	(52.4)	36	(21.4)	75.32	34	(8.5)	86	(21.4)	31.48
Ocean Old Wrack	0	(0.0)	1	(0.6)	0.88	3	(0.7)	2	(0.5)	0.37
Ocean Open Vegetation	9	(5.4)	4	(2.4)	5.76	5	(1.2)	10	(2.5)	2.41
Sound Intertidal Zone	56	(33.3)	21	(12.5)	57.00	16	(4.0)	51	(12.7)	23.82
Sound Fresh Wrack	0	(0.0)	7	(4.2)	6.78	23	(5.7)	16	(4.0)	2.83
Sound Backshore	4	(2.4)	62	(36.9)	54.15	206	(51.2)	148	(36.8)	22.63
Sound Old Wrack	2	(1.2)	5	(3.0)	1.56	14	(3.5)	11	(2.7)	0.65
Sound Open Vegetation	0	(0.0)	1	(0.6)	1.47	5	(1.2)	4	(1.0)	0.62
Tidal Pond Intertidal Zone	0	(0.0)	26	(15.5)	26.23	89	(22.1)	63	(15.7)	10.96
	n = 570, df = 10, χ^2 = 335.36, P < 0.0001									

Continued.

[a] Observed number of prenesting plovers within the habitat.

[b] Expected number of prenesting plovers within the habitat.

[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 13, Continued. Prenesting Piping Plover habitat use (%) between the management areas by foraging, nonforaging, and plovers in all behaviors during the prenesting period, by year, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the total number of plovers observed in each behavior group. Prenesting plovers were observed in all habitats included in analyses. Chi-square tests were used to test for differences in proportions between the management areas.

Year, Behavior, Habitat	Gull-removal Area					Reference Area				
	Observed Use[a]	(%)	Exp. Use[b]	(%)	Partial χ^2 [c]	Observed Use	(%)	Exp. Use	(%)	Partial χ^2
1999-2000, Foraging Plovers	n = 87					n = 188				
Ocean Intertidal Zone	0	(0.0)	2	(2.3)	1.90	6	(3.2)	4	(2.1)	0.88
Ocean Backshore	2	(2.3)	1	(1.1)	2.95	0	(0.0)	1	(0.5)	1.37
Sound Intertidal Zone	83	(95.4)	29	(33.3)	97.57	10	(5.3)	64	(34.0)	45.15
Sound Fresh Wrack	0	(0.0)	6	(6.9)	6.01	19	(10.1)	13	(6.9)	2.78
Sound Backshore	2	(2.3)	2	(2.3)	0.02	5	(2.7)	5	(2.7)	0.01
Sound Old Wrack	0	(0.0)	0	(0.0)	0.32	1	(0.5)	1	(0.5)	0.15
Tidal Pond Intertidal Zone	0	(0.0)	47	(54.0)	46.51	147	(78.2)	100	(53.2)	21.52
	n = 275, df = 6, χ^2 = 227.13, $P < 0.0001$									
1999-2000, Nonforaging Plovers	n = 145					n = 411				
Ocean Intertidal Zone	7	(4.8)	2	(1.4)	11.57	1	(0.2)	6	(1.5)	4.08
Ocean Fresh Wrack	4	(2.8)	1	(0.7)	8.38	0	(0.0)	3	(0.7)	2.96
Ocean Backshore	109	(75.2)	41	(28.3)	113.12	48	(11.7)	116	(28.2)	39.91
Ocean Old Wrack	0	(0.0)	1	(0.7)	0.78	3	(0.7)	2	(0.5)	0.28
Ocean Open Vegetation	9	(6.2)	4	(2.8)	7.84	5	(1.2)	10	(2.4)	2.76
Sound Intertidal Zone	11	(7.6)	8	(5.5)	1.56	18	(4.4)	21	(5.1)	0.55
Sound Fresh Wrack	0	(0.0)	2	(1.4)	1.56	6	(1.5)	4	(1.0)	0.55
Sound Backshore	3	(2.1)	74	(51.0)	68.45	282	(68.6)	211	(51.3)	24.15
Sound Old Wrack	2	(1.4)	4	(2.8)	1.34	15	(3.6)	13	(3.2)	0.47
Sound Open Vegetation	0	(0.0)	1	(0.7)	1.30	5	(1.2)	4	(1.0)	0.46
Tidal Pond Intertidal Zone	0	(0.0)	7	(4.8)	7.30	28	(6.8)	21	(5.1)	2.58
	n = 556, df = 10, χ^2 = 301.95, $P < 0.0001$									
1999-2000, Plovers In All Behaviors	n = 232					n = 599				
Ocean Intertidal Zone	7	(3.0)	4	(1.7)	2.45	7	(1.2)	10	(1.7)	0.95
Ocean Fresh Wrack	4	(1.7)	1	(0.4)	7.44	0	(0.0)	3	(0.5)	2.88
Ocean Backshore	111	(47.8)	44	(19.0)	99.95	48	(8.0)	115	(19.2)	38.71
Ocean Old Wrack	0	(0.0)	1	(0.4)	0.84	3	(0.5)	2	(0.3)	0.32
Ocean Open Vegetation	9	(3.9)	4	(1.7)	6.63	5	(0.8)	10	(1.7)	2.57
Sound Intertidal Zone	94	(40.5)	34	(14.7)	105.48	28	(4.7)	89	(14.9)	40.86
Sound Fresh Wrack	0	(0.0)	7	(3.0)	6.98	25	(4.2)	18	(3.0)	2.70
Sound Backshore	5	(2.2)	82	(35.3)	71.83	287	(47.9)	210	(35.1)	27.82
Sound Old Wrack	2	(0.9)	5	(2.2)	1.82	16	(2.7)	13	(2.2)	0.71
Sound Open Vegetation	0	(0.0)	1	(0.4)	1.40	5	(0.8)	4	(0.7)	0.54
Tidal Pond Intertidal Zone	0	(0.0)	49	(21.1)	48.86	175	(29.2)	126	(21.0)	18.92
	n = 831, df = 10, χ^2 = 490.66, $P < 0.0001$									

[a] Observed number of prenesting plovers within the habitat.
[b] Expected number of prenesting plovers within the habitat.
[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 14. Availability (mean % of total beach width measured along random transects), and use (% of instantaneous observations of Piping Plovers in each habitat during the prenesting period), among habitats, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Chi-square tests for homogeneity were used to test if plovers were using habitat in proportion to availability. Confidence intervals were used to determine if habitats were used in greater proportion than availability ("P" = preferred) if habitats were used in less proportion than availability ("A" = avoided), or used in proportion to availability ("="; Neu et al. 1974, Marcum and Loftsgaarden 1980).

Behavior, Habitat Management Area	Habitat Availability			Habitat Use by Piping Plovers during the Prenesting Period							
	$\bar{x}$ %	Lower Confidence Limit	Upper Confidence Limit	Observed Use[a]	(%)	Expected Use[b]	(%)	Partial χ^2 [c]	Lower Confidence Limit	Upper Confidence Limit	Preferred/ Avoided
Foraging, Gull-removal Area											
Intertidal Zone	59.00%	52.37%	65.63%	83	95.40%	51	59.00%	19.54	94.80%	96.00%	P
Wrack	3.93%	2.41%	5.45%	0	0.00%	3	3.93%	3.42	0.00%	0.00%	A
Backshore	24.19%	19.33%	29.05%	4	0.05%	21	24.19%	13.80	4.00%	5.20%	A
Open Vegetation	12.68%	9.31%	16.05%	0	0.00%	11	12.69%	11.04	0.00%	0.00%	A
Tidal Pond Intertidal Zone	0.20%	-0.13%	0.53%	0	0.00%	0	0.20%	0.17	0.00%	0.00%	=
Transects (n for availability) = 114, Plovers (n for use) = 87, df = 4, $\chi^2 = 47.97$, $P < 0.0001$											
Foraging, Reference Area											
Intertidal Zone	30.71%	27.81%	33.60%	16	8.51%	58	30.71%	30.17	8.14%	8.88%	A
Wrack	11.73%	9.73%	13.74%	20	10.64%	22	11.73%	0.19	10.23%	11.05%	=
Backshore	35.76%	33.24%	38.27%	5	2.66%	67	35.76%	57.60	2.45%	2.87%	A
Open Vegetation	18.21%	15.99%	20.42%	0	0.00%	35	18.76%	35.27	0.00%	0.00%	A
Tidal Pond Intertidal Zone	3.60%	1.97%	5.23%	147	78.19%	7	3.60%	2905.59	77.65%	78.74%	P
Transects (n for availability) = 227, Plovers (n for use) = 188, df = 4, $\chi^2 = 3028.82$, $P < 0.0001$											
Foraging, South Monomoy Island											
Intertidal Zone	36.20%	32.71%	39.68%	99	36.00%	100	36.20%	0.00	35.57%	36.43%	=
Wrack	10.35%	8.45%	12.25%	20	7.27%	28	10.35%	2.52	7.04%	7.51%	A
Backshore	34.35%	31.64%	37.06%	9	3.27%	94	34.35%	77.32	3.11%	3.43%	A
Open Vegetation	16.53%	14.39%	18.66%	0	0.00%	45	16.53%	45.46	0.00%	0.00%	A
Tidal Pond Intertidal Zone	2.57%	1.27%	3.88%	147	53.45%	7	2.57%	2770.58	53.00%	53.91%	P
Transects (n for availability) = 247, Plovers (n for use) = 275, df = 4, $\chi^2 = 2895.88$, $P < 0.0001$											

Continued.

[a] Observed number of prenesting plovers within the habitat.

[b] Expected number of prenesting plovers within the habitat, calculated by multiplying the number of plovers (n) by mean availability.

[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 14, Continued. Availability (mean % of total beach width measured along random transects), and use (% of instantaneous observations of Piping Plovers in each habitat during the prenesting period), among habitats, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Chi-square tests for homogeneity were used to test if plovers were using habitat in proportion to availability. Confidence intervals were used to determine if habitats were used in greater proportion than availability ("P" = preferred) if habitats were used in less proportion than availability ("A" = avoided), or used in proportion to availability ("="; Neu et al. 1974, Marcum and Loftsgaarden 1980).

Behavior, Management Area / Habitat	Habitat Availability			Habitat Use by Piping Plovers during the Prenesting Period							
	$\bar{x}$ %	Lower Confidence Limit	Upper Confidence Limit	Observed Use[a]	(%)	Expected Use[b]	(%)	Partial χ^2 [c]	Lower Confidence Limit	Upper Confidence Limit	Preferred/ Avoided
Nonforaging, Gull-removal Area											
Intertidal Zone	59.00%	52.37%	65.63%	18	12.41%	86	59.00%	53.34	11.85%	12.98%	A
Wrack	3.93%	2.41%	5.45%	6	4.14%	6	3.93%	0.02	3.80%	4.48%	=
Backshore	24.19%	19.33%	29.05%	112	77.24%	35	24.19%	168.73	76.52%	77.96%	P
Open Vegetation	12.68%	9.31%	16.05%	9	6.21%	18	12.69%	4.80	5.79%	6.62%	A
Tidal Pond Intertidal Zone	0.20%	-0.13%	0.53%	0	0.00%	0	0.20%	0.29	0.00	0.00%	=
Transects (n for availability) = 114, Plovers (n for use) = 145, df = 4, $\chi^2 = 227.17$, $P < 0.0001$											
Nonforaging, Reference Area											
Intertidal Zone	30.71%	27.81%	33.60%	19	4.62%	126	30.71%	91.08	4.50%	4.75%	A
Wrack	11.73%	9.73%	13.74%	24	5.84%	48	11.73%	12.16	5.70%	5.98%	A
Backshore	35.76%	33.24%	38.27%	330	80.29%	147	35.76%	227.92	80.05%	80.53%	P
Open Vegetation	18.21%	15.99%	20.42%	10	2.43%	77	18.76%	58.40	2.34%	2.53%	A
Tidal Pond Intertidal Zone	3.60%	1.97%	5.23%	28	6.81%	15	3.60%	11.78	6.66%	6.96%	P
Transects (n for availability) = 227, Plovers (n for use) = 411, df = 4, $\chi^2 = 401.34$, $P < 0.0001$											
Nonforaging, South Monomoy Island											
Intertidal Zone	36.20%	32.71%	39.68%	37	6.65%	201	36.20%	134.07	6.54%	6.77%	A
Wrack	10.35%	8.45%	12.25%	30	5.40%	58	10.35%	13.19	5.29%	5.50%	A
Backshore	34.35%	31.64%	37.06%	442	79.50%	191	34.35%	329.91	79.32%	79.68%	P
Open Vegetation	16.53%	14.39%	18.66%	19	3.42%	92	16.53%	57.83	3.34%	3.50%	A
Tidal Pond Intertidal Zone	2.57%	1.27%	3.88%	28	5.04%	14	2.57%	13.16	4.94%	5.13%	P
Transects (n for availability) = 247, Plovers (n for use) = 556, df = 4, $\chi^2 = 548.16$, $P < 0.0001$											

Continued.

[a] Observed number of prenesting plovers within the habitat.

[b] Expected number of prenesting plovers within the habitat, calculated by multiplying the number of plovers (n) by mean availability.

[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 14, Continued. Availability (mean % of total beach width measured along random transects), and use (% of instantaneous observations of Piping Plovers in each habitat during the prenesting period), among habitats, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Chi-square tests for homogeneity were used to test if plovers were using habitat in proportion to availability. Confidence intervals were used to determine if habitats were used in greater proportion than availability ("P" = preferred) if habitats were used in less proportion than availability ("A" = avoided), or used in proportion to availability ("="; Neu et al. 1974, Marcum and Loftsgaarden 1980).

Plover Behavior, Habitat, Management Area	Habitat Availability			Habitat Use by Piping Plovers during the Prenesting Period							
	$\bar{x}$ %	Lower Confidence Limit	Upper Confidence Limit	Observed Use[a]	(%)	Expected Use[b]	(%)	Partial χ^2 [c]	Lower Confidence Limit	Upper Confidence Limit	Preferred/ Avoided
All Behaviors, Gull-removal Area											
Intertidal Zone	59.00%	52.37%	65.63%	101	43.53%	137	59.00%	9.41	43.00%	44.07%	A
Wrack	3.93%	2.41%	5.45%	6	2.59%	9	3.93%	1.07	2.42%	2.76%	=
Backshore	24.19%	19.33%	29.05%	116	50.00%	56	24.19%	63.90	49.46%	50.54%	P
Open Vegetation	12.68%	9.31%	16.05%	9	3.88%	29	12.69%	14.18	3.67%	4.09%	A
Tidal Pond Intertidal Zone	0.20%	-0.13%	0.53%	0	0.00%	0	0.20%	0.46	0.00%	0.00%	=
Transects (n for availability) = 114, Plovers (n for use) = 232, df = 4, $\chi^2 = 89.02$, $P < 0.0001$											
All Behaviors, Reference Area											
Intertidal Zone	30.71%	27.81%	33.60%	35	5.84%	184	30.71%	120.61	5.75%	5.94%	A
Wrack	11.73%	9.73%	13.74%	44	7.35%	70	11.73%	9.82	7.24%	7.45%	A
Backshore	35.76%	33.24%	38.27%	335	55.93%	214	35.76%	68.12	55.72%	56.13%	P
Open Vegetation	18.21%	15.99%	20.42%	10	1.67%	112	18.76%	93.26	1.62%	1.72%	A
Tidal Pond Intertidal Zone	3.60%	1.97%	5.23%	175	29.22%	22	3.60%	1091.76	29.03%	29.40%	P
Transects (n for availability) = 227, Plovers (n for use) = 599, df = 4, $\chi^2 = 1383.57$, $P < 0.0001$											
All Behaviors, South Monomoy Island											
Intertidal Zone	36.20%	32.71%	39.68%	136	16.37%	301	36.20%	90.31	16.26%	16.48%	A
Wrack	10.35%	8.45%	12.25%	50	6.02%	86	10.35%	15.08	5.95%	6.09%	A
Backshore	34.35%	31.64%	37.06%	451	54.27%	285	34.35%	96.01	54.12%	54.42%	P
Open Vegetation	16.53%	14.39%	18.66%	19	2.29%	137	16.57%	101.99	2.24%	2.33%	A
Tidal Pond Intertidal Zone	2.57%	1.27%	3.88%	175	21.06%	21	2.57%	1105.33	20.94%	21.18%	P
Transects (n for availability) = 247, Plovers (n for use) = 831, df = 4, χ^2 1408.72, $P < 0.0001$											

[a] Observed number of prenesting plovers within the habitat.
[b] Expected number of prenesting plovers within the habitat, calculated by multiplying the number of plovers (n) by mean availability.
[c] Partial Chi-square for observed vs. expected values for each habitat.

Table 15. Mean percent time Piping Plovers were observed in different behaviors during 5-minute observations during the prenesting period, between the gull-removal and reference areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Area		Foraging		Disturbed		Resting		Alert		Moving		Courting	
		n	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE
1999														
	Gull-removal	21	45.36	10.54	5.91	3.18	18.57	7.57	23.97	7.44	3.97	1.47	2.22	1.92
	Reference	38	26.46	5.89	1.58	0.64	18.60	5.24	47.30	6.18	4.74	1.58	1.32	1.08
			T = -1.31, P = 0.09		T = -0.71, P = 0.19		T = 0.78, P = 0.89		T = -2.94, P = 0.02		T = 0.40, P = 0.53		T = 1.02, P = 0.86	
2000														
	Gull-removal	32	28.35	7.39	5.10	2.86	25.83	6.72	34.51	7.41	6.21	2.10	0.00	0.00
	Reference	55	28.85	5.67	3.22	1.95	31.94	5.26	28.90	4.84	4.78	1.36	2.31	1.59
			T = 0.74, P = 1.00		T = 0.50, P = 0.62		T = 0.43, P = 0.54		T = 0.33, P = 0.47		T = 0.26, P = 0.73		T = -1.22, P = 0.12	
1999-2000														
	Gull-removal	53	35.09	6.16	5.42	2.12	22.95	5.02	30.33	5.36	5.32	1.39	0.88	0.76
	Reference	93	27.87	4.11	2.55	1.18	26.49	3.82	36.42	3.91	4.76	1.03	1.91	1.04
			T = -0.01, P = 0.32		T = -0.66, P = 0.19		T = 0.49, P = 0.58		T = -0.14, P = 0.28		T = 0.68, P = 0.77		T = 0.53, P = 0.63	

Table 16. Mean percent time Piping Plovers were observed disturbed by various sources during 5-minute observations during the prenesting period, between the gull-removal and reference areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Area	n	Great Black-backed Gulls		Herring Gulls		Immature Gulls		Piping Plovers		Other [a]		Unknown	
			$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE
1999														
	Gull-removal	21	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.56	0.00	0.00	5.11	2.66
	Reference	38	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.09	0.00	0.00	1.49	0.64
				-		-		-	T = -0.73, P = 0.20			-	T = -0.53, P = 0.22
2000														
	Gull-removal	32	0.00	0.00	0.00	0.00	0.00	0.00	1.79	1.19	1.00	0.90	2.31	1.61
	Reference	55	0.00	0.00	0.00	0.00	0.00	0.00	1.30	1.24	0.00	0.00	1.92	0.96
				-		-		-	T = 0.20, P = 0.52		T = -1.75, P = 0.05		T = 0.81, P = 0.83
1999-2000														
	Gull-removal	53	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.75	0.60	0.54	3.42	1.43
	Reference	93	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.73	0.00	0.00	1.74	0.62
				-		-		-	T = -1.22, P = 0.11		T = -1.77, P = 0.05		T = 0.18, P = 0.42

[a] Other disturbances in the gull-removal area in 2000 include an airplane during one observation.

Table 17. Mean foraging rates (attempts per minute) of prenesting Piping Plovers in different habitats during 5-minute observations, between the gull-removal and reference area (across rows) and among the habitats (down columns), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means for habitats with the same letters were not significantly different ($P < 0.05$). Statistical tests were not performed if n < 3. Habitats with n < 3 were not included in pair-wise comparisons.

Year	Habitat	Foraging Rates of Plovers Engaged in All Behaviors						
		Gull-removal Area			Reference Area			
		n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	Contrasts Between Management Areas
1999								
	Sound Fresh Wrack	0	-	-	1	11.80	-	-
	Sound Intertidal Zone	9	11.48 A	1.79	2	6.20	2.20	$T = -0.37$, $P = 0.26$
	Tidal Pond Intertidal Zone	0	-	-	18	4.11 A	1.01	-
	Sound Old Wrack	0	-	-	2	0.94	0.94	-
	Sound Backshore	0	-	-	14	0.76 B	0.40	-
	Ocean Backshore	11	0.45 B	0.31	7	0.00 B	0.00	$T = -1.17$, $P = 0.12$
	Ocean Intertidal Zone	2	0.00	0.00	0	-	-	-
	Sound Open Vegetation	0	-	-	2	0.00	0.00	-
	Ocean Fresh Wrack	0	-	-	0	-	-	-
	Ocean Old Wrack	0	-	-	0	-	-	-
	Ocean Open Vegetation	0	-	-	0	-	-	-
	Contrasts Within Management Areas		$T = -10.73$, $P < 0.0001$			$T = -5.09$, $P = 0.001$		
2000								
	Ocean Intertidal Zone	2	16.54	1.14	3	19.32 A	1.27	-
	Tidal Pond Intertidal Zone	0	-	-	10	15.98 AB	4.81	-
	Ocean Fresh Wrack	1	0.00	-	1	8.20	-	-
	Sound Fresh Wrack	1	9.00	-	5	6.28 B	1.71	-
	Sound Intertidal Zone	10	11.60 A	2.84	2	4.57	4.57	$T = 0.12$, $P = 0.49$
	Sound Old Wrack	1	3.00	-	6	3.68 BCD	2.82	-
	Ocean Backshore	19	0.16 B	0.13	7	0.49 C	0.25	$T = -0.98$, $P = 0.14$
	Ocean Old Wrack	1	0.00	-	4	0.07 CD	0.07	-
	Sound Backshore	1	12.00	-	24	0.54 D	0.54	-
	Ocean Open Vegetation	2	0.00	0.00	1	0.00	-	-
	Sound Open Vegetation	0	-	-	1	0.00	-	-
	Contrasts Within Management Areas		$T = -11.88$, $P < 0.0001$			$T = -9.32$, $P < 0.0001$		

Continued.

Table 17, Continued. Mean foraging rates (attempts per minute) of prenesting Piping Plovers in different habitats during 5-minute observations, between the gull-removal and reference area (across rows) and among the habitats (down columns), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means for habitats with the same letters were not significantly different ($P < 0.05$). Statistical tests were not performed if n < 3. Habitats with n < 3 were not included in pair-wise comparisons.

Year	Habitat	Foraging Rates of Plovers Engaged in All Behaviors						
		Gull-removal Area			Reference Area			
		n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	Contrasts Between Management Areas
1999-2000								
	Ocean Intertidal Zone	4	8.27 A	4.80	3	19.32 A	1.27	$T = -1.21$, $P = 0.11$
	Sound Fresh Wrack	1	9.00	-	6	7.20 B	1.67	-
	Tidal Pond Intertidal Zone	0	-	-	28	8.35 BC	2.09	-
	Ocean Fresh Wrack	1	0.00	-	1	8.20	-	-
	Sound Intertidal Zone	19	11.54 A	1.67	4	5.38 BC	2.12	$T = -0.96$, $P = 0.14$
	Sound Old Wrack	1	3.00	-	8	3.00 CD	2.12	-
	Sound Open Vegetation	0	-	-	3	0.00 CD	0.00	-
	Ocean Backshore	30	0.27 B	0.14	14	0.24 D	0.14	$T = 0.65$, $P = 0.71$
	Sound Backshore	1	12.00	-	38	0.62 D	0.37	-
	Ocean Old Wrack	1	0.00	-	4	0.07 D	0.07	-
	Ocean Open Vegetation	2	0.00	0.00	1	0.00	-	-
	Contrasts Within Management Areas		$T = -14.43$, $P < 0.0001$			$T = 11.58$, $P < 0.0001$		

Table 18. Mean foraging rates (attempts per minute) of foraging prenesting Piping Plovers in different habitats during 5-minute observations, between the gull-removal and reference area (across rows) and among the habitats (down columns), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means for habitats with the same letters were not significantly different ($P < 0.05$). Statistical tests were not performed if n < 3. Habitats with n < 3 were not included in pair-wise comparisons.

		Foraging Rates of Plovers Engaged in Foraging Behavior Only						
Year	Habitat	Gull-removal Area			Reference Area			
		n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	Contrasts Between Management Areas
1999								
	Sound Backshore	0	-	-	3	20.60	9.96	-
	Sound Fresh Wrack	0	-	-	1	11.80	-	-
	Ocean Backshore	3	14.13	8.10	0	-	-	-
	Tidal Pond Intertidal Zone	0	-	-	13	9.16	0.92	-
	Sound Intertidal Zone	9	12.12	1.71	2	8.63	4.63	$T = 0.78$, $P = 0.77$
	Sound Old Wrack	0	-	-	1	2.50	-	-
	Ocean Intertidal Zone	0	-	-	0	-	-	-
	Ocean Fresh Wrack	0	-	-	0	-	-	-
	Ocean Old Wrack	0	-	-	0	-	-	-
	Ocean Open Vegetation	0	-	-	0	-	-	-
	Sound Open Vegetation	0	-	-	0	-	-	-
	Contrasts Within Management Areas			$T = 1.02$, $P = 0.91$			$T = -1.27$, $P = 0.11$	
2000								
	Ocean Intertidal Zone	2	22.97	7.57	3	27.72	A 7.14	-
	Tidal Pond Intertidal Zone	0	-	-	9	19.13	AB 5.03	-
	Ocean Backshore	2	20.25	3.75	0	-	-	-
	Sound Intertidal Zone	8	14.46	2.79	2	4.57	4.57	$T = -0.48$, $P = 0.26$
	Sound Backshore	1	12.00	-	1	13.00	-	-
	Sound Old Wrack	1	3.00	-	2	12.49	4.73	-
	Ocean Fresh Wrack	0	-	-	1	8.20	-	-
	Sound Fresh Wrack	1	9.00	-	5	6.79	B 2.05	-
	Ocean Old Wrack	0	-	-	0	-	-	-
	Ocean Open Vegetation	0	-	-	0	-	-	-
	Sound Open Vegetation	0	-	-	0	-	-	-
	Contrasts Within Management Areas			-			$T = -1.85$, $P = 0.05$	

Continued.

Table 18, Continued. Mean foraging rates (attempts per minute) of foraging prenesting Piping Plovers in different habitats during 5-minute observations, between the gull-removal and reference area (across rows) and among the habitats (down columns), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means for habitats with the same letters were not significantly different ($P < 0.05$). Statistical tests were not performed if n < 3. Habitats with n < 3 were not included in pair-wise comparisons.

Year	Habitat	Foraging Rates of Plovers Engaged in Foraging Behavior Only						
		Gull-removal Area			Reference Area			
		n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	Contrasts Between Management Areas
1999-2000								
	Ocean Intertidal Zone	2	22.98	7.57	3	27.72	7.14	-
	Sound Backshore	1	12.00	-	4	18.70	7.29	-
	Tidal Pond Intertidal Zone	0	-	-	22	13.24	2.32	-
	Sound Old Wrack	1	3.00	-	3	9.16	4.31	-
	Ocean Fresh Wrack	0	-	-	1	8.20	-	-
	Sound Fresh Wrack	1	9.00	-	6	7.63	1.87	-
	Sound Intertidal Zone	17	13.22	1.57	4	6.60	2.90	$T = -0.88$, $P = 0.16$
	Ocean Backshore	5	16.58	4.83	0	-	-	-
	Ocean Old Wrack	0	-	-	0	-	-	-
	Ocean Open Vegetation	0	-	-	0	-	-	-
	Sound Open Vegetation	0	-	-	0	-	-	-
	Contrasts Within Management Areas		$T = 0.54$, $P = 0.63$			$T = -1.11$, $P = 0.13$		

Table 19. Mean counts of large gulls within 100 m of Piping Plover nests, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal	10	1.35	0.34	0.70	0.14	0.54	0.21	0.11	0.05
	Buffer	1	15.42	-	11.21	-	1.71	-	2.50	-
	Reference	21	10.43	2.16	7.08	1.50	1.73	0.50	1.62	0.49
			T = -4.68, P = 0.004		T = -4.87, P = 0.004		T = -2.84, P = 0.02		T = -2.86, P = 0.02	
2000										
	Gull-removal	11	2.64	1.09	0.64	0.18	0.53	0.17	1.46	0.79
	Buffer	0	-	-	-	-	-	-	-	-
	Reference	28	7.00	1.24	4.43	0.87	0.98	0.32	1.59	0.34
			T = -3.76, P = 0.01		T = -6.55, P = 0.0007		T = 0.32, P = 0.53		T = 0.41, P = 0.55	
1999-2000										
	Gull-removal	21	2.03	0.60	0.67	0.11	0.54	0.13	0.82	0.43
	Buffer	1	15.42	-	11.21	-	1.71	-	2.50	-
	Reference	49	8.47	1.18	5.57	0.82	1.30	0.28	1.60	0.28
			T = -2.39, P = 0.04		T = -10.79, P < 0.0001		T = -2.17, P = 0.04		T = -2.39, P = 0.04	

Table 20. Mean counts of large gulls within 100 m of Piping Plover nests compared to mean counts of large gulls within 100 m of random points, during the nesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal									
	Nests	10	1.35	0.34	0.70	0.14	0.54	0.21	0.11	0.05
	Random Points	134	3.87	0.61	1.64	0.22	1.46	0.25	0.77	0.30
			T = -1.78		T = -1.96		T = -0.79		T = -0.68	
			P = 0.06		P = 0.05		P = 0.15		P = 0.13	
	Buffer									
	Nests	1	15.42	-	11.21	-	1.71	-	2.50	-
	Random Points	132	23.11	1.88	16.62	1.36	5.95	0.84	0.53	0.14
	Reference									
	Nests	21	10.43	2.16	7.08	1.50	1.73	0.50	1.62	0.49
	Random Points	263	34.30	1.79	27.95	1.55	4.81	0.66	1.54	0.33
			T = -10.55		T = -11.64		T = -2.20		T = -1.00	
			P < 0.0001		P < 0.0001		P = 0.04		P = 0.12	
	South Monomoy [a]									
	Nests	32	7.75	1.62	5.22	1.12	1.35	0.35	1.18	0.35
	Random Points	243	31.59	1.98	24.74	1.70	5.20	0.71	1.65	0.37
			T = -14.04		T = -13.70		T = -4.43		T = -0.35	
			P < 0.0001		P < 0.0001		P = 0.006		P = 0.24	

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 20, Continued. Mean counts of large gulls within 100 m of Piping Plover nests compared to mean counts of large gulls within 100 m of random points, during the nesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2000										
	Gull-removal									
	Nests	11	2.64	1.09	064	0.18	0.53	0.17	1.46	0.79
	Random Points	139	3.42	0.66	1.38	0.27	0.72	0.15	1.32	0.47
				T = 0.27		T = -1.20		T = -1.45		T = -0.36
				P = 0.42		P = 0.10		P = 0.08		P = 0.16
	Buffer									
	Nests	0	-	-	-	-	-	-	-	-
	Random Points	141	23.21	2.04	14.24	1.13	6.60	0.82	2.37	0.55
	Reference									
	Nests	28	7.00	1.24	4.43	0.87	0.98	0.32	1.59	0.34
	Random Points	276	26.76	2.34	20.06	1.90	5.62	0.92	1.08	0.28
				T = -10.29		T = -10.34		T = -3.26		T = -9.73
				P < 0.0001		P < 0.0001		P = 0.02		P = 0.0001
	South Monomoy [a]									
	Nests	39	5.77	0.99	3.36	0.68	0.85	0.23	1.55	0.33
	Random Points	328	22.13	1.51	16.41	1.18	4.54	0.71	1.18	0.26
				T = -12.56		T = -13.09		T = -4.75		T = -8.62
				P < 0.0001		P < 0.0001		P = 0.005		P = 0.0002

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 20, Continued. Mean counts of large gulls within 100 m of Piping Plover nests compared to mean counts of large gulls within 100 m of random points, during the nesting period, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year / Management Area	n	Total Large Gulls $\bar{x}$	SE	Great Black-backed Gulls $\bar{x}$	SE	Herring Gulls $\bar{x}$	SE	Immature Gulls $\bar{x}$	SE
1999-2000									
Gull-removal									
Nests	21	2.03	0.60	0.67	0.11	0.54	0.13	0.82	0.43
Random Points	273	3.64	0.45	1.51	0.17	1.08	0.14	1.05	0.28
		T = -0.94		*T* = -3.54		*T* = -1.98		*T* = -0.24	
		P = 0.13		*P* = 0.01		*P* = 0.05		*P* = 0.22	
Buffer									
Nests	1	15.42	-	11.21	-	1.71	-	2.50	-
Random Points	273	23.16	1.39	15.39	0.88	6.29	0.59	1.48	0.30
Reference									
Nests	49	8.47	1.18	5.57	0.82	1.30	0.28	1.60	0.28
Random Points	539	30.44	1.49	23.91	1.24	5.23	0.57	1.30	0.21
		T = -21.23		*T* = -22.33		*T* = -5.58		*T* = -8.93	
		P < 0.0001		*P* < 0.0001		*P* = 0.002		*P* = 0.0001	
South Monomoy [a]									
Nests	71	6.66	0.91	4.20	0.63	1.08	0.20	1.38	0.24
Random Points	571	26.15	1.22	19.95	1.01	4.82	0.51	1.38	0.22
		T = -25.55		*T* = -25.75		*T* = -9.11		*T* = -7.13	
		P < 0.0001		*P* < 0.0001		*P* = 0.0001		*P* = 0.0006	

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 21. Mean counts of large gulls within 100 m of random points in nesting areas compared to mean counts of large gulls within 100 m of random points in unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal									
	Nesting Area	131	3.79	0.62	1.61	0.22	1.41	0.25	0.76	0.31
	Unused Area	3	7.33	1.45	3.00	1.15	3.33	1.33	1.00	0.58
			T = -2.39, P = 0.04		T = -0.47, P = 0.21		T = -1.58, P = 0.06		T = -0.61, P = 0.05	
	Buffer									
	Nesting Area	70	12.66	1.90	9.99	1.50	2.13	1.50	2.13	0.65
	Unused Area	62	34.90	2.70	24.11	1.95	10.27	1.47	0.52	0.16
			T = -29.27, P < 0.0001		T = -26.53, P < 0.0001		T = -22.34, P < 0.0001		T = -0.03, P = 0.35	
	Reference									
	Nesting Area	143	23.64	2.04	19.52	1.71	2.45	0.40	1.67	0.55
	Unused Area	120	47.01	2.66	38.00	2.42	7.63	1.33	1.38	0.29
			T = -31.61, P < 0.0001		T = -25.31, P < 0.0001		T = -11.05, P < 0.0001		T = -0.64, P = 0.19	
	South Monomoy [a]									
	Nesting Area	134	19.43	2.19	14.84	1.80	2.63	0.42	1.95	0.64
	Unused Area	109	46.54	2.92	36.90	2.66	8.36	1.45	1.28	0.29
			T = -36.62, P < 0.0001		T = -33.13, P < 0.0001		T = -11.49, P < 0.0001		T = -0.87, P = 0.15	

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 21, Continued. Mean counts of large gulls within 100 m of random points in nesting areas compared to mean counts of large gulls within 100 m of random points in unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2000										
	Gull-removal									
	Nesting Area	132	3.48	0.69	1.39	0.28	0.71	0.15	1.38	0.49
	Unused Area	7	2.29	0.68	1.29	0.36	0.86	0.46	0.14	0.14
			T = -0.37, P = 0.19		T = -0.76, P = 0.14		T = 0.44, P = 0.54		T = -0.19, P = 0.13	
	Buffer									
	Nesting Area	0	-	-	-	-	-	-	-	-
	Unused Area	141	23.21	2.04	14.24	1.13	6.60	0.82	2.37	0.55
	Reference									
	Nesting Area	150	16.50	3.38	11.18	2.75	4.07	0.94	1.25	0.38
	Unused Area	126	38.97	2.82	30.63	2.25	7.47	1.66	0.87	0.41
			T = -44.55, P < 0.0001		T = -53.19, P < 0.0001		T = -2.79, P = 0.02		T = -0.25, P = 0.29	
	South Monomoy [a]									
	Nesting Area	171	10.54	1.30	6.91	0.90	2.29	0.50	1.35	0.38
	Unused Area	157	34.75	2.45	26.75	1.96	6.99	1.36	1.01	0.37
			T = -56.59, P < 0.0001		T = -60.61, P < 0.0001		T = -10.89, P < 0.0001		T = 0.20, P = 0.44	

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 21, Continued. Mean counts of large gulls within 100 m of random points in nesting areas compared to mean counts of large gulls within 100 m of random points in unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999-2000										
	Gull-removal									
	Nesting Area	263	3.63	0.46	1.50	0.18	1.06	0.15	1.07	0.29
	Unused Area	10	3.80	0.98	1.80	0.47	1.60	0.60	0.40	0.22
			T = -0.86, P = 0.14		T = -1.01, P = 0.13		T = -0.61, P = 0.18		T = -0.07, P = 0.17	
	Buffer									
	Nesting Area	70	12.66	1.90	9.99	1.50	2.13	0.65	0.54	0.23
	Unused Area	203	26.78	1.68	17.26	1.04	7.72	0.73	1.80	0.39
			T = -15.71, P < 0.0001		T = -12.68, P < 0.0001		T = -15.00, P < 0.0001		T = -2.66, P = 0.03	
	Reference									
	Nesting Area	293	19.98	2.01	15.25	1.65	3.28	0.52	1.46	0.33
	Unused Area	246	42.89	1.95	34.23	1.66	7.55	1.07	1.11	0.25
			T = -73.69, P < 0.0001		T = -72.85, P < 0.0001		T = -12.62, P < 0.0001		T = 0.40, P = 0.54	
	South Monomoy [a]									
	Nesting Area	305	14.45	1.23	10.40	0.96	2.44	0.34	1.61	0.35
	Unused Area	266	39.58	1.90	30.91	1.61	7.55	1.00	1.12	0.25
			T = -88.21, P < 0.0001		T = -87.68, P < 0.0001		T = -22.49, P < 0.0001		T = 0.23, P = 0.45	

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 22. Percent of random points with at least one gull present within 100 m, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Chi-square tests were used to test for differences in proportions. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Plots With Large Gulls				Plots With Great Black-backed Gulls				Plots With Herring Gulls				Plots With Immature Gulls			
		n	%	Obs. Value [b]	Exp. Value [c]	Row χ^2 [d]	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2
1999																		
	Gull-removal																	
	Nesting Area	131	70%	92	93	0.03	54%	71	72	0.06	44%	57	59	0.08	14%	18	20	0.14
	Unused Area	3	100%	3	2	1.23	100%	3	2	2.43	100%	3	1	3.70	67%	2	0	6.33
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 1.26$				$\chi^2 = 2.49$				$\chi^2 = 3.78$				$\chi^2 = 6.47$
						$P = 0.26$				$P = 0.11$				$P = 0.05$				$P = 0.01$
	Buffer																	
	Nesting Area	70	93%	65	67	1.09	91%	64	66	1.49	47%	33	47	12.01	14%	10	13	0.71
	Unused Area	62	98%	61	59	1.23	98%	61	59	1.68	89%	55	41	13.56	23%	14	11	0.71
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 2.32$				$\chi^2 = 3.17$				$\chi^2 = 25.56$				$\chi^2 = 1.52$
						$P = 0.13$				$P = 0.08$				$P < 0.0001$				$P = 0.22$
	Reference																	
	Nesting Area	143	94%	134	138	2.43	99%	119	115	3.83	53%	76	88	3.92	24%	34	43	2.67
	Unused Area	120	99%	119	115	2.78	92%	132	136	3.22	71%	85	73	4.67	38%	45	36	3.18
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 5.32$				$\chi^2 = 7.05$				$\chi^2 = 8.60$				$\chi^2 = 5.85$
						$P = 0.02$				$P = 0.008$				$P = 0.003$				$P = 0.02$
	South Monomoy [a]																	
	Nesting Area	134	86%	115	122	5.20	79%	106	117	9.05	57%	77	85	2.02	23%	31	39	2.40
	Unused Area	109	98%	107	100	6.40	98%	107	96	11.13	71%	77	69	2.48	37%	40	32	2.95
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 11.60$				$\chi^2 = 20.18$				$\chi^2 = 4.50$				$\chi^2 = 5.35$
						$P = 0.0007$				$P < 0.0001$				$P = 0.03$				$P = 0.02$

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.
[b] Observed number of prenesting plovers with at least one gull present within 100 m.
[c] Expected number of prenesting plovers with at least one gull present within 100 m.
[d] Partial Chi-square for observed vs. expected values for each management area.

Table 22, Continued. Percent of random points with at least one gull present within 100 m, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Chi-square tests were used to test for differences in proportions. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Plots With Large Gulls				Plots With Great Black-backed Gulls				Plots With Herring Gulls				Plots With Immature Gulls			
		n	%	Obs. Value [b]	Exp. Value [c]	Row χ^2 [d]	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2
2000																		
	Gull-removal																	
	Nesting Area	132	58%	77	78	0.02	44%	58	60	0.10	24%	32	33	0.06	19%	25	25	0.005
	Unused Area	7	71%	5	4	0.45	71%	5	3	1.93	43%	3	2	1.16	14%	1	1	0.09
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 0.47$				$\chi^2 = 2.03$				$\chi^2 = 1.22$				$\chi^2 = 0.09$
						$P = 0.49$				$P = 0.15$				$P = 0.27$				$P = 0.76$
	Buffer																	
	Nesting Area	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Unused Area	141	97%	137	137	0.00	96%	136	136	0.00	62%	88	88	0.00	31%	43	43	0.00
						-				-				-				-
	Reference																	
	Nesting Area	150	91%	136	142	4.44	83%	125	135	7.00	54%	81	80	0.01	23%	34	30	0.71
	Unused Area	126	99%	125	136	5.28	98%	123	113	8.33	53%	67	68	0.01	17%	21	25	0.84
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 9.72$				$\chi^2 = 15.33$				$\chi^2 = 0.02$				$\chi^2 = 1.55$
						$P = 0.002$				$P < 0.0001$				$P = 0.89$				$P = 0.21$
	South Monomoy [a]																	
	Nesting Area	171	82%	140	154	12.30	73%	124	144	17.34	47%	80	87	1.00	24%	41	36	0.89
	Unused Area	157	99%	155	141	13.40	97%	152	132	18.89	55%	86	79	1.09	18%	28	33	0.97
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 25.70$				$\chi^2 = 36.23$				$\chi^2 = 2.09$				$\chi^2 = 1.86$
						$P < 0.0001$				$P < 0.0001$				$P = 0.15$				$P = 0.17$

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.
[b] Observed number of prenesting plovers with at least one gull present within 100 m.
[c] Expected number of prenesting plovers with at least one gull present within 100 m.
[d] Partial Chi-square for observed vs. expected values for each management area.

Table 22, Continued. Percent of random points with at least one gull present within 100 m, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Chi-square tests were used to test for differences in proportions. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Year	Management Area		Plots With Large Gulls				Plots With Great Black-backed Gulls				Plots With Herring Gulls				Plots With Immature Gulls			
		n	%	Obs. Value [b]	Exp. Value [c]	Row χ^2 [d]	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2	%	Obs. Value	Exp. Value	Row χ^2
1999-2000																		
	Gull-removal																	
	Nesting Area	263	64%	169	171	0.04	49%	129	132	0.14	34%	89	92	0.11	16%	43	44	0.05
	Unused Area	10	80%	8	6	1.00	80%	8	5	3.56	60%	6	3	2.80	30%	3	2	1.23
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 1.05$				$\chi^2 = 3.69$				$\chi^2 = 2.91$				$\chi^2 = 1.28$
						$P = 0.31$				$P = 0.05$				$P = 0.09$				$P = 0.26$
	Buffer																	
	Nesting Area	70	93%	65	67	2.40	91%	64	67	2.90	47%	33	45	9.17	14%	10	17	3.98
	Unused Area	203	98%	198	169	0.83	97%	197	194	1.00	70%	143	131	3.16	28%	57	50	1.37
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 3.23$				$\chi^2 = 3.91$				$\chi^2 = 12.34$				$\chi^2 = 5.35$
						$P = 0.07$				$P = 0.05$				$P = 0.0004$				$P = 0.02$
	Reference																	
	Nesting Area	293	92%	270	279	6.83	88%	257	271	10.10	54%	157	168	1.68	23%	68	73	0.43
	Unused Area	246	99%	244	235	8.14	98%	242	228	12.02	62%	152	141	2.00	27%	66	61	0.51
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 14.97$				$\chi^2 = 22.12$				$\chi^2 = 3.68$				$\chi^2 = 0.94$
						$P = 0.0001$				$P < 0.0001$				$P = 0.06$				$P = 0.33$
	South Monomoy [a]																	
	Nesting Area	305	84%	255	276	17.14	75%	230	261	25.95	51%	157	171	2.58	24%	72	75	0.14
	Unused Area	266	99%	262	241	19.65	97%	259	228	29.76	61%	163	149	2.96	26%	68	65	0.16
						df = 1				df = 1				df = 1				df = 1
						$\chi^2 = 36.79$				$\chi^2 = 55.71$				$\chi^2 = 5.54$				$\chi^2 = 0.29$
						$P < 0.0001$				$P < 0.0001$				$P = 0.02$				$P = 0.59$

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.
[b] Observed number of prenesting plovers with at least one gull present within 100 m.
[c] Expected number of prenesting plovers with at least one gull present within 100 m.
[d] Partial Chi-square for observed vs. expected values for each management area.

Table 23. Mean width (m) of foraging habitats on random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Habitat	Gull-removal Area			Buffer Area			Reference Area			South Monomoy Island [a]		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Ocean Intertidal Zone												
Nesting Area	48	32.06	5.29	34	19.20	1.82	64	17.88	1.23	72	21.78	2.78
Unused Area	2	23.72	10.35	28	24.43	2.37	52	19.98	1.41	54	20.15	1.39
		T = 0.26, P = 0.37			T = -1.19, P = 0.11			T = 0.23, P = 0.44			T = -0.04, P = 0.35	
Ocean Fresh Wrack												
Nesting Area	48	0.69	0.24	34	0.10	0.06	64	0.84	0.34	72	0.88	0.31
Unused Area	2	0.00	0.00	28	1.04	0.32	52	0.51	0.22	54	0.61	0.22
		T = -0.29, P = 0.16			T = -5.53, P = 0.002			T = 0.08, P = 0.39			T = 0.06, P = 0.37	
Ocean Backshore												
Nesting Area	48	34.11	4.75	34	27.64	1.85	64	26.40	2.11	72	30.10	2.80
Unused Area	2	13.04	0.30	28	19.90	1.98	52	20.26	2.40	54	20.47	2.20
		T = -0.75, P = 0.20			T = -4.63, P = 0.005			T = -3.21, P = 0.02			T = -3.99, P = 0.008	
Ocean Old Wrack												
Nesting Area	48	0.54	0.14	34	0.06	0.04	64	0.63	0.17	72	0.66	0.16
Unused Area	2	1.00	1.00	28	3.45	1.48	52	0.45	0.13	54	0.46	0.13
		T = 1.06, P = 0.97			T = -8.01, P < 0.0001			T = 0.51, P = 0.60			T = 0.36, P = 0.50	
Ocean Open Vegetation												
Nesting Area	48	17.24	1.88	34	21.56	2.62	64	16.07	1.49	72	17.20	1.53
Unused Area	2	21.63	3.85	28	27.35	8.83	52	10.26	1.43	54	10.50	1.39
		T = -0.15, P = 0.41			T = -1.38, P = 0.09			T = -3.62, P = 0.01			T = -4.56, P = 0.005	

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 23, Continued. Mean width (m) of foraging habitats on random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Habitat	Gull-removal Area			Buffer Area			Reference Area			South Monomoy Island [a]		
	n	$\overline{x}$	SE	n	$\overline{x}$	SE	n	$\overline{x}$	SE	n	$\overline{x}$	SE
Sound Intertidal Zone												
Nesting Area	62	99.72	16.75	0	-	-	65	6.35	0.63	67	39.88	13.49
Unused Area	2	489.36	230.91	52	149.60	27.54	56	10.12	3.56	60	33.35	11.05
		T = -2.75, P = 0.03				-		T = 0.52, P = 0.62			T = 0.62, P = 0.69	
Sound Fresh Wrack												
Nesting Area	62	0.46	0.13	0	-	-	65	1.85	0.47	67	1.43	0.43
Unused Area	2	0.00	0.00	52	2.36	0.53	56	1.82	0.25	60	2.11	0.26
		T = -0.35, P = 0.11				-		T = -1.32, P = 0.10			T = -8.07, P = 0.0002	
Sound Backshore												
Nesting Area	62	3.89	0.49	0	-	-	65	20.48	2.55	67	18.01	2.49
Unused Area	2	5.68	2.16	52	1.69	0.32	56	6.27	0.64	60	5.71	0.60
		T = 0.32, P = 0.55				-		T = -16.50, P < 0.0001			T = -14.18, P < 0.0001	
Sound Old Wrack												
Nesting Area	62	0.92	0.13	0	-	-	65	3.41	0.38	67	2.57	0.36
Unused Area	2	0.35	0.35	52	5.48	1.15	56	2.77	0.27	60	2.90	0.29
		T = 0.13, P = 0.48				-		T = -0.77, P = 0.16			T = -1.46, P = 0.08	
Sound Open Vegetation												
Nesting Area	62	1.54	0.45	0	-	-	65	11.74	1.58	67	9.45	1.58
Unused Area	2	10.46	10.46	52	2.01	0.91	56	1.70	0.30	60	2.30	0.80
		T = 1.36, P = 1.00				-		T = -22.34, P < 0.0001			T = -11.53, P < 0.0001	
Tidal Pond Intertidal Zone												
Nesting Area	62	0.00	0.00	0	-	-	65	16.96	4.68	67	14.26	4.49
Unused Area	2	46.60	13.26	52	0.57	0.38	56	0.00	0.00	60	0.00	0.00
		T = -44.18, P < 0.0001				-		T = -13.16, P < 0.0001			T = -10.45, P < 0.0001	

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 24. Mean counts of total arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Habitat	Total Arthropods [a]			
	n	$\bar{x}$		SE
Gull-removal Area				
Sound Fresh Wrack	27	66.44	A	12.61
Tidal Pond Intertidal Zone	2	49.50	AB	41.50
Ocean Fresh Wrack	23	30.00	AB	5.19
Sound Old Wrack	42	41.17	ABC	8.40
Sound Backshore	54	43.69	ABC	9.23
Sound Intertidal Zone	46	33.02	ABC	5.16
Ocean Old Wrack	25	25.00	BC	4.26
Sound Open Vegetation	21	18.57	BCD	3.29
Ocean Intertidal Zone	49	14.84	CD	2.45
Ocean Open Vegetation	55	13.07	CD	1.74
Ocean Backshore	54	12.11	D	1.97
		$F = 6.77$, $P < 0.0001$		
Reference Area				
Sound Fresh Wrack	95	69.44	A	21.91
Sound Intertidal Zone	86	33.94	A	4.12
Ocean Fresh Wrack	48	19.90	A	2.21
Sound Old Wrack	131	31.90	B	10.42
Tidal Pond Intertidal Zone	28	18.96	B	4.96
Ocean Open Vegetation	114	12.83	BC	1.27
Ocean Old Wrack	36	18.03	BC	4.57
Sound Open Vegetation	88	12.49	BCD	1.48
Ocean Intertidal Zone	106	12.73	BCD	1.59
Sound Backshore	133	41.59	CD	22.90
Ocean Backshore	134	10.34	D	1.22
		$F = 13.24$, $P < 0.0001$		

Management Area and Habitat	Total Arthropods [a]			
	n	$\bar{x}$		SE
Buffer Area				
Sound Fresh Wrack	26	270.65	A	124.76
Sound Old Wrack	53	108.60	AB	30.76
Sound Open Vegetation	21	55.00	ABC	19.39
Sound Intertidal Zone	28	41.46	ABC	7.64
Sound Backshore	27	62.89	BC	19.17
Tidal Pond Intertidal Zone	4	23.25	BC	7.92
Ocean Old Wrack	18	17.67	CD	3.15
Ocean Fresh Wrack	12	15.50	CD	2.76
Ocean Open Vegetation	60	10.12	DE	1.43
Ocean Intertidal Zone	45	10.60	E	2.20
Ocean Backshore	60	11.00	E	3.38
		$F = 16.56$, $P < 0.0001$		
South Monomoy Island [b]				
Sound Fresh Wrack	101	76.73	A	20.82
Sound Intertidal Zone	98	35.21	AB	3.77
Ocean Fresh Wrack	65	23.98	AB	2.42
Ocean Old Wrack	52	22.98	BC	3.69
Sound Old Wrack	140	36.57	CD	9.97
Sound Open Vegetation	81	15.70	CD	2.23
Ocean Open Vegetation	139	13.14	DE	1.15
Tidal Pond Intertidal Zone	24	16.08	DE	4.58
Ocean Intertidal Zone	125	14.13	DE	1.50
Sound Backshore	140	49.12	DE	21.97
Ocean Backshore	156	11.53	E	1.20
		$F = 13.93$, $P < 0.0001$		

[a] Total Arthropods includes Amphipoda, Arachnida, Coleoptera, Diptera, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.
[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\bar{x}$		SE
Gull-removal, Diptera	Tidal Pond Intertidal Zone	2	48.50	A	40.50
	Sound Fresh Wrack	27	43.56	A	10.94
	Ocean Fresh Wrack	23	19.17	A	2.46
	Sound Old Wrack	42	32.93	AB	6.69
	Ocean Old Wrack	25	19.80	ABC	3.82
	Sound Backshore	54	29.44	ABC	7.34
	Sound Intertidal Zone	46	26.41	ABC	4.90
	Sound Open Vegetation	21	14.76	ABC	2.92
	Ocean Open Vegetation	55	9.91	BC	1.51
	Ocean Intertidal Zone	49	10.10	BC	1.75
	Ocean Backshore	54	9.02	C	1.45
				$F = 5.54$, $P < 0.0001$	
Gull-removal, Coleoptera	Sound Fresh Wrack	27	14.37	A	6.37
	Sound Backshore	54	12.44	AB	4.57
	Sound Open Vegetation	21	2.29	ABC	0.67
	Ocean Fresh Wrack	23	7.74	ABC	3.70
	Sound Intertidal Zone	46	3.02	ABC	0.95
	Sound Old Wrack	42	6.71	ABC	2.96
	Ocean Old Wrack	25	3.36	ABC	1.28
	Ocean Intertidal Zone	49	2.12	ABC	0.68
	Ocean Backshore	54	2.43	ABC	1.25
	Tidal Pond Intertidal Zone	2	0.50	BC	0.50
	Ocean Open Vegetation	55	1.24	C	0.40
				$F = 3.23$, $P = 0.0005$	
Gull-removal, Amphipoda	Sound Fresh Wrack	27	6.48	A	2.61
	Ocean Fresh Wrack	23	2.26	A	0.79
	Ocean Intertidal Zone	49	2.24	AB	0.64
	Sound Intertidal Zone	46	2.52	AB	0.93
	Sound Old Wrack	42	0.88	AB	0.23
	Sound Backshore	54	0.80	ABC	0.22
	Ocean Old Wrack	25	0.84	BCD	0.51
	Ocean Backshore	54	0.06	CD	0.06
	Ocean Open Vegetation	55	0.02	CD	0.02
	Tidal Pond Intertidal Zone	2	0.00	D	0.00
	Sound Open Vegetation	21	0.00	D	0.00
				$F = 8.65$, $P < 0.0001$	

Continued.

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25, Continued. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\bar{x}$		SE
Gull-removal, Other [a]	Ocean Open Vegetation	55	1.91	A	0.28
	Sound Open Vegetation	21	1.52	AB	0.43
	Ocean Old Wrack	25	1.00	ABC	0.24
	Sound Fresh Wrack	27	6.48	ABC	2.61
	Sound Backshore	54	1.00	ABC	0.25
	Ocean Fresh Wrack	23	0.83	ABC	0.26
	Tidal Pond Intertidal Zone	2	0.50	ABC	0.50
	Sound Old Wrack	42	0.64	BC	0.20
	Sound Intertidal Zone	46	1.07	BC	0.51
	Ocean Backshore	54	0.61	BC	0.16
	Ocean Intertidal Zone	49	0.37	C	0.16
					$F = 4.88$, $P < 0.0001$
Buffer, Diptera	Sound Fresh Wrack	26	147.50	A	53.08
	Sound Old Wrack	53	49.06	AB	9.81
	Sound Intertidal Zone	28	31.64	ABC	5.89
	Sound Open Vegetation	21	49.05	BC	19.51
	Tidal Pond Intertidal Zone	4	18.75	BC	6.50
	Ocean Old Wrack	18	15.56	BC	2.77
	Sound Backshore	27	48.33	BC	18.69
	Ocean Fresh Wrack	12	10.83	CD	1.85
	Ocean Open Vegetation	60	7.97	DE	1.26
	Ocean Intertidal Zone	45	8.60	E	2.12
	Ocean Backshore	60	9.30	E	3.33
					$F = 13.70$, $P < 0.0001$
Buffer, Coleoptera	Sound Fresh Wrack	26	32.65	A	15.42
	Sound Old Wrack	53	44.58	AB	27.65
	Sound Backshore	27	8.74	ABC	4.24
	Ocean Fresh Wrack	12	4.33	ABCD	2.23
	Tidal Pond Intertidal Zone	4	3.75	BCDE	2.59
	Sound Intertidal Zone	28	8.39	BCDE	3.52
	Ocean Old Wrack	18	1.39	CDE	0.48
	Sound Open Vegetation	21	1.00	CDE	0.28
	Ocean Backshore	60	1.53	DE	0.51
	Ocean Open Vegetation	60	0.97	E	0.31
	Ocean Intertidal Zone	45	0.71	E	0.24
					$F = 7.21$, $P < 0.0001$

Continued.

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25, Continued. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\overline{x}$		SE
Buffer, Amphipoda	Sound Old Wrack	53	10.13	A	3.22
	Sound Fresh Wrack	26	85.96	A	72.86
	Ocean Intertidal Zone	45	1.24	AB	0.33
	Sound Backshore	27	4.00	BC	3.70
	Sound Open Vegetation	21	0.19	C	0.15
	Ocean Fresh Wrack	12	0.25	C	0.25
	Sound Intertidal Zone	28	0.11	C	0.08
	Ocean Old Wrack	18	0.17	C	0.17
	Ocean Backshore	60	0.02	C	0.02
	Tidal Pond Intertidal Zone	4	0.00	C	0.00
	Ocean Open Vegetation	60	0.00	C	0.00
					$F = 12.58$, $P < 0.0001$
Buffer, Other [a]	Sound Open Vegetation	21	4.76	A	1.40
	Tidal Pond Intertidal Zone	4	0.75	AB	0.25
	Sound Backshore	27	1.81	AB	0.47
	Sound Old Wrack	53	4.83	AB	1.92
	Ocean Open Vegetation	60	1.18	AB	0.30
	Sound Fresh Wrack	26	4.54	AB	2.27
	Sound Intertidal Zone	28	1.32	BC	0.59
	Ocean Old Wrack	18	0.56	BC	0.22
	Ocean Backshore	60	0.15	C	0.05
	Ocean Fresh Wrack	12	0.08	C	0.08
	Ocean Intertidal Zone	45	0.04	C	0.03
					$F = 6.84$, $P < 0.0001$
Reference, Diptera	Sound Fresh Wrack	95	43.27	A	19.36
	Ocean Fresh Wrack	48	15.38	A	1.94
	Sound Old Wrack	131	19.45	B	6.27
	Ocean Old Wrack	36	15.19	B	4.01
	Ocean Open Vegetation	114	10.50	BC	1.12
	Tidal Pond Intertidal Zone	28	16.79	BCD	4.87
	Sound Open Vegetation	88	10.53	BCDE	1.45
	Ocean Backshore	134	8.92	BCDE	1.13
	Sound Intertidal Zone	86	9.20	CDE	1.90
	Sound Backshore	133	27.04	DE	19.15
	Ocean Intertidal Zone	106	7.11	E	0.92
					$F = 8.39$, $P < 0.0001$

Continued.

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25, Continued. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\overline{x}$		SE
Reference, Coleoptera	Sound Fresh Wrack	95	18.39	A	8.35
	Sound Intertidal Zone	86	5.64	AB	1.55
	Ocean Fresh Wrack	48	2.19	AB	0.74
	Sound Backshore	133	13.97	AB	8.12
	Ocean Old Wrack	36	2.14	AB	0.99
	Sound Old Wrack	131	11.43	ABC	6.38
	Tidal Pond Intertidal Zone	28	1.25	ABC	0.45
	Sound Open Vegetation	88	0.91	BCD	0.18
	Ocean Open Vegetation	114	0.73	CD	0.21
	Ocean Intertidal Zone	106	0.92	D	0.29
	Ocean Backshore	134	0.63	D	0.17
				$F = 4.93$, $P < 0.0001$	
Reference, Amphipoda	Sound Intertidal Zone	86	18.81	A	3.25
	Sound Fresh Wrack	95	7.47	A	1.67
	Ocean Intertidal Zone	106	4.50	B	1.12
	Ocean Fresh Wrack	48	1.94	B	0.53
	Sound Old Wrack	131	0.69	C	0.16
	Sound Backshore	133	0.29	CD	0.07
	Ocean Old Wrack	36	0.14	DE	0.07
	Tidal Pond Intertidal Zone	28	0.36	DE	0.27
	Sound Open Vegetation	88	0.02	E	0.01
	Ocean Open Vegetation	114	0.02	E	0.02
	Ocean Backshore	134	0.00	E	0.00
				$F = 56.12$, $P < 0.0001$	
Reference, Other [a]	Ocean Open Vegetation	114	1.59	A	0.25
	Sound Open Vegetation	88	1.03	AB	0.17
	Tidal Pond Intertidal Zone	28	0.57	BC	0.19
	Ocean Old Wrack	36	0.56	CD	0.23
	Ocean Backshore	134	0.80	CDE	0.26
	Ocean Fresh Wrack	48	0.40	CDEF	0.18
	Sound Backshore	133	0.29	CDEF	0.05
	Sound Old Wrack	131	0.34	DEF	0.09
	Sound Intertidal Zone	86	0.29	DEF	0.10
	Ocean Intertidal Zone	106	0.20	EF	0.05
	Sound Fresh Wrack	95	0.32	F	0.17
				$F = 10.35$, $P < 0.0001$	

Continued.

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25, Continued. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\overline{x}$		SE
South Monomoy,[b] Diptera	Sound Fresh Wrack	101	48.64	A	18.41
	Ocean Fresh Wrack	65	17.09	A	1.62
	Ocean Old Wrack	52	19.02	AB	3.25
	Sound Old Wrack	140	22.28	BC	6.02
	Sound Open Vegetation	81	13.03	CD	2.07
	Ocean Open Vegetation	139	10.71	CD	1.02
	Tidal Pond Intertidal Zone	24	13.92	CD	4.49
	Sound Intertidal Zone	98	13.07	CD	2.15
	Sound Backshore	140	32.45	D	18.38
	Ocean Backshore	156	9.52	D	1.04
	Ocean Intertidal Zone	125	8.54	D	0.93
				$F = 8.57$, $P < 0.0001$	
South Monomoy,[b] Coleoptera	Sound Fresh Wrack	101	18.85	A	7.87
	Ocean Fresh Wrack	65	4.32	AB	1.43
	Sound Backshore	140	15.89	AB	7.85
	Sound Intertidal Zone	98	5.74	AB	1.43
	Sound Old Wrack	140	11.84	AB	6.01
	Ocean Old Wrack	52	2.60	BC	0.85
	Tidal Pond Intertidal Zone	24	1.54	BCD	0.62
	Sound Open Vegetation	81	1.09	BCD	0.22
	Ocean Open Vegetation	139	0.91	CD	0.22
	Ocean Intertidal Zone	125	1.14	D	0.28
	Ocean Backshore	156	1.21	D	0.45
				$F = 6.44$, $P < 0.0001$	
South Monomoy,[b] Amphipoda	Sound Intertidal Zone	98	16.01	A	2.91
	Sound Fresh Wrack	101	8.16	A	1.78
	Ocean Intertidal Zone	125	4.26	B	0.97
	Ocean Fresh Wrack	65	2.02	B	0.44
	Sound Old Wrack	140	1.28	C	0.49
	Sound Backshore	140	0.35	CD	0.08
	Ocean Old Wrack	52	0.54	DE	0.26
	Tidal Pond Intertidal Zone	24	0.13	EF	0.13
	Sound Open Vegetation	81	0.02	F	0.02
	Ocean Open Vegetation	139	0.02	F	0.02
	Ocean Backshore	156	0.03	F	0.02
				$F = 48.49$, $P < 0.0001$	

Continued.

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 25, Continued. Mean counts of Diptera, Coleoptera, Amphipoda, and other arthropods trapped during 3-hour trapping periods in habitats along random transects, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. ANOVAs were conducted on ranked values of the samples. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Management Area and Arthropod Order	Habitat	n	$\bar{x}$		SE
South Monomoy,[b] Other [a]	Ocean Open Vegetation	139	1.51	A	0.19
	Sound Open Vegetation	81	1.56	A	0.28
	Ocean Old Wrack	52	0.83	B	0.20
	Tidal Pond Intertidal Zone	24	0.50	BC	0.19
	Ocean Fresh Wrack	65	0.55	BCD	0.16
	Sound Backshore	140	0.43	CD	0.08
	Ocean Backshore	156	0.77	CD	0.23
	Sound Old Wrack	140	1.18	CD	0.44
	Sound Fresh Wrack	101	1.08	CD	0.58
	Sound Intertidal Zone	98	0.39	CD	0.12
	Ocean Intertidal Zone	125	0.19	D	0.04
				$F = 12.52$, $P < 0.0001$	

[a] Other Arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.
[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Gull-removal, Ocean Intertidal Zone											
Nesting Area	47	15.06	2.54	10.26	1.82	2.21	0.70	2.23	0.66	0.36	0.16
Unused Area	2	9.50	7.50	6.50	5.50	0.00	0.00	2.50	2.50	0.50	0.50
			$P = 0.90$		$P = 0.96$		$P = 0.27$		$P = 0.76$		$P = 0.35$
Gull-removal, Ocean Fresh Wrack											
Nesting Area	23	30.00	5.19	19.17	2.46	7.74	3.70	2.26	0.79	0.83	0.24
Unused Area	0	-	-	-	-	-	-	-	-	-	-
Gull-removal, Ocean Backshore											
Nesting Area	53	12.09	2.01	8.94	1.48	2.47	1.28	0.06	0.06	0.62	0.17
Unused Area	1	13.00	-	13.00	-	0.00	-	0.00	-	0.00	-
			$P = 0.68$		$P = 0.46$		$P = 0.46$		$P = 0.89$		$P = 0.54$
Gull-removal, Ocean Old Wrack											
Nesting Area	24	25.46	4.42	20.04	3.98	3.50	1.32	0.88	0.53	1.04	0.25
Unused Area	1	14.00	-	14.00	-	0.00	-	0.00	-	0.00	-
			$P = 0.68$		$P = 0.94$		$P = 0.40$		$P = 0.62$		$P = 0.33$
Gull-removal, Ocean Open Vegetation											
Nesting Area	53	13.08	1.79	9.89	1.55	1.26	0.41	0.02	0.02	1.91	0.29
Unused Area	2	13.00	10.00	10.50	7.50	0.50	0.50	0.00	0.00	2.00	2.00
			$P = 0.82$		$P = 0.79$		$P = 0.81$		$P = 0.85$		$P = 0.98$

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Gull-removal, Sound Intertidal Zone											
Nesting Area	44	33.02	5.33	26.14	5.05	3.14	0.99	2.64	0.97	1.11	0.53
Unused Area	2	33.00	26.00	32.50	26.50	0.50	0.50	0.00	0.00	0.00	0.00
			$P = 0.81$		$P = 0.79$		$P = 0.46$		$P = 0.29$		$P = 0.35$
Gull-removal, Sound Fresh Wrack											
Nesting Area	27	66.44	12.61	43.56	10.94	14.37	6.37	6.48	2.61	2.04	1.01
Unused Area	0	-	-	-	-	-	-	-	-	-	-
Gull-removal, Sound Backshore											
Nesting Area	52	44.94	9.55	30.29	7.60	12.87	4.74	0.83	0.23	0.96	0.26
Unused Area	2	11.00	1.00	7.50	0.50	1.50	1.50	0.00	0.00	2.00	1.00
			$P = 0.35$		$P = 0.32$		$P = 0.64$		$P = 0.32$		$P = 0.11$
Gull-removal, Sound Old Wrack											
Nesting Area	41	42.10	8.55	33.68	6.81	6.88	3.03	0.90	0.23	0.63	0.21
Unused Area	1	3.00	-	2.00	-	0.00	-	0.00	-	1.00	-
			$P = 0.22$		$P = 0.20$		$P = 0.33$		$P = 0.45$		$P = 0.26$
Gull-removal, Sound Open Vegetation											
Nesting Area	20	18.45	3.45	14.80	3.07	2.35	0.70	0.00	0.00	1.30	0.38
Unused Area	1	21.00	-	14.00	-	1.00	-	0.00	-	6.00	-
			$P = 0.62$		$P = 0.87$		$P = 0.93$		$P = 1.00$		$P = 0.10$
Gull-removal, Tidal Pond Intertidal Zone											
Nesting Area	0	-	-	-	-	-	-	-	-	-	-
Unused Area	2	49.50	41.50	48.50	40.50	0.50	0.50	0.00	0.00	0.50	0.50

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat			Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Buffer, Ocean Intertidal Zone												
	Nesting Area	30	6.70	1.86	4.90	1.73	0.57	0.32	1.20	0.43	0.03	0.03
	Unused Area	15	18.40	5.00	16.00	4.92	1.00	0.31	1.33	0.54	0.07	0.07
				P = 0.03		*P* = 0.03		*P* = 0.01		*P* = 0.49		*P* = 0.61
Buffer, Ocean Fresh Wrack												
	Nesting Area	3	17.33	6.06	14.00	3.51	3.33	3.33	0.00	0.00	0.00	0.00
	Unused Area	9	14.89	3.27	9.78	2.17	4.67	2.85	0.33	0.33	0.11	0.11
				P = 0.64		*P* = 0.31		*P* = 0.63		*P* = 0.56		*P* = 0.56
Buffer, Ocean Backshore												
	Nesting Area	32	6.44	1.78	5.13	1.52	1.22	0.64	0.03	0.03	0.06	0.04
	Unused Area	28	16.21	6.88	14.07	6.88	1.89	0.80	0.00	0.00	0.25	0.10
				P = 0.05		*P* = 0.10		*P* = 0.30		*P* = 0.35		*P* = 0.08
Buffer, Ocean Old Wrack												
	Nesting Area	4	19.50	6.64	17.00	5.45	1.25	0.95	0.75	0.75	0.50	0.50
	Unused Area	14	17.14	3.70	15.14	3.30	1.43	0.57	0.00	0.00	0.57	0.25
				P = 0.52		*P* = 0.52		*P* = 0.91		*P* = 0.06		*P* = 0.80
Buffer, Ocean Open Vegetation												
	Nesting Area	33	8.48	1.54	7.03	1.42	0.88	0.31	0.00	0.00	0.58	0.16
	Unused Area	27	12.11	2.53	9.11	2.20	1.07	0.57	0.00	0.00	1.93	0.62
				P = 0.23		*P* = 0.36		*P* = 0.68		*P* = 1.00		*P* = 0.02

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat			Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Buffer, Sound Intertidal Zone												
	Nesting Area	1	44.00	-	44.00	-	0.00	-	0.00	-	0.00	-
	Unused Area	27	41.37	7.93	31.19	6.09	8.70	3.64	0.11	0.08	1.37	0.61
				$P = 0.76$		$P = 0.42$		$P = 0.41$		$P = 0.78$		$P = 0.50$
Buffer, Sound Fresh Wrack												
	Nesting Area	0	-	-	-	-	-	-	-	-	-	-
	Unused Area	26	270.65	124.76	147.50	53.08	32.65	15.42	85.96	72.86	4.54	2.27
Buffer, Sound Backshore												
	Nesting Area	1	23.00	-	17.00	-	6.00	-	0.00	-	0.00	-
	Unused Area	26	64.42	19.86	49.54	19.39	8.85	4.41	4.15	3.84	1.88	0.48
				$P = 0.95$		$P = 0.70$		$P = 0.43$		$P = 0.68$		$P = 0.34$
Buffer, Sound Old Wrack												
	Nesting Area	2	24.50	12.50	13.00	4.00	10.50	7.50	0.50	0.50	0.50	0.50
	Unused Area	51	111.90	31.89	50.47	10.15	45.92	28.73	10.51	3.34	5.00	1.99
				$P = 0.41$		$P = 0.29$		$P = 0.33$		$P = 0.59$		$P = 0.74$
Buffer, Sound Open Vegetation												
	Nesting Area	1	15.00	-	13.00	-	0.00	-	1.00	-	1.00	-
	Unused Area	20	57.00	20.28	50.85	20.43	1.05	0.29	0.15	0.15	4.95	1.46
				$P = 0.41$		$P = 0.87$		$P = 0.37$		$P = 0.004$		$P = 0.86$
Buffer, Tidal Pond Intertidal Zone												
	Nesting Area	1	35.00	-	23.00	-	11.00	-	0.00	-	1.00	-
	Unused Area	3	19.33	9.74	17.33	8.97	1.33	1.33	0.00	0.00	0.67	0.33
				$P = 0.18$		$P = 0.65$		$P = 0.16$		$P = 1.00$		$P = 0.56$

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Reference, Ocean Intertidal Zone											
Nesting Area	63	13.29	2.17	8.37	1.42	0.83	0.30	3.94	1.36	0.16	0.06
Unused Area	43	11.91	2.33	5.28	0.84	1.05	0.56	5.33	1.93	0.26	0.08
			P = 0.45		*P* = 0.34		*P* = 0.72		*P* = 0.51		*P* = 0.26
Reference, Ocean Fresh Wrack											
Nesting Area	29	22.03	3.23	16.55	2.76	3.10	1.18	2.14	0.69	0.24	0.09
Unused Area	19	16.63	2.56	13.58	2.56	0.79	0.29	1.63	0.86	0.63	0.42
			P = 0.49		*P* = 0.74		*P* = 0.22		*P* = 0.14		*P* = 0.63
Reference, Ocean Backshore											
Nesting Area	75	9.68	1.30	8.07	1.07	0.83	0.29	0.00	0.00	0.79	0.42
Unused Area	59	11.19	2.24	10.00	2.17	0.37	0.12	0.00	0.00	0.81	0.27
			P = 0.93		*P* = 0.93		*P* = 0.20		*P* = 1.00		*P* = 0.29
Reference, Ocean Old Wrack											
Nesting Area	19	16.00	5.82	11.95	4.06	3.58	1.83	0.21	0.12	0.26	0.13
Unused Area	17	20.29	7.32	18.82	7.23	0.53	0.19	0.06	0.19	0.88	0.47
			P = 0.65		*P* = 0.57		*P* = 0.16		*P* = 0.34		*P* = 0.19
Reference, Ocean Open Vegetation											
Nesting Area	69	13.97	1.90	11.43	1.66	0.88	0.31	0.03	0.03	1.62	0.31
Unused Area	45	11.09	1.35	9.07	1.23	0.49	0.23	0.00	0.00	1.53	0.42
			P = 0.70		*P* = 0.81		*P* = 0.16		*P* = 0.42		*P* = 0.64

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Reference, Sound Intertidal Zone											
Nesting Area	45	31.73	5.13	6.80	1.19	4.31	2.07	20.20	4.95	0.42	0.17
Unused Area	41	36.37	6.59	11.83	3.75	7.10	2.34	17.29	4.16	0.15	0.08
			$P = 0.95$		$P = 0.65$		$P = 0.08$		$P = 0.97$		$P = 0.12$
Reference, Sound Fresh Wrack											
Nesting Area	47	42.98	9.80	25.03	8.44	8.70	4.13	9.07	2.94	0.17	0.09
Unused Area	48	95.35	42.18	61.13	37.43	27.88	15.99	5.90	1.64	0.46	0.32
			$P = 0.99$		$P = 0.68$		$P = 0.65$		$P = 0.77$		$P = 0.74$
Reference, Sound Backshore											
Nesting Area	66	9.58	2.15	5.60	1.18	3.51	1.37	0.19	0.07	0.28	0.08
Unused Area	67	73.12	45.24	48.16	37.97	24.27	16.02	0.39	0.11	0.30	0.07
			$P = 0.02$		$P = 0.006$		$P = 0.34$		$P = 0.21$		$P = 0.82$
Reference, Sound Old Wrack											
Nesting Area	62	14.73	3.37	12.06	3.19	2.00	0.64	0.56	0.21	0.10	0.05
Unused Area	69	47.33	19.44	26.09	11.54	19.90	12.05	0.80	0.24	0.55	0.16
			$P = 0.01$		$P = 0.02$		$P = 0.02$		$P = 0.30$		$P = 0.0002$
Reference, Sound Open Vegetation											
Nesting Area	56	12.34	2.14	10.64	2.12	0.80	0.18	0.01	0.01	0.88	0.18
Unused Area	32	12.75	1.68	10.34	1.50	1.09	0.39	0.03	0.03	1.28	0.34
			$P = 0.11$		$P = 0.09$		$P = 0.77$		$P = 0.67$		$P = 0.62$
Reference, Tidal Pond Intertidal Zone											
Nesting Area	28	18.96	4.96	16.79	4.87	1.25	0.45	0.36	0.27	0.57	0.19
Unused Area	0	-	-	-	-	-	-	-	-	-	-

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
South Monomoy,[b] Ocean Intertidal Zone											
Nesting Area	82	14.78	1.92	9.85	0.31	1.18	0.31	3.57	1.08	0.17	0.05
Unused Area	43	12.88	2.38	6.02	1.02	1.05	0.56	5.58	1.92	0.23	0.08
			$P = 0.53$		$P = 0.17$		$P = 0.48$		$P = 0.91$		$P = 0.55$
South Monomoy,[b] Ocean Fresh Wrack											
Nesting Area	44	27.43	3.30	18.66	2.09	6.02	2.07	2.20	0.54	0.55	0.15
Unused Area	21	16.76	2.32	13.81	2.34	0.76	0.27	1.62	0.78	0.57	0.38
			$P = 0.07$		$P = 0.18$		$P = 0.05$		$P = 0.09$		$P = 0.46$
South Monomoy,[b] Ocean Backshore											
Nesting Area	94	11.63	1.41	9.07	1.04	1.74	0.74	0.04	0.03	0.77	0.34
Unused Area	62	11.37	2.16	10.19	2.10	0.40	0.12	0.00	0.00	0.77	0.26
			$P = 0.68$		$P = 0.83$		$P = 0.11$		$P = 0.25$		$P = 0.30$
South Monomoy,[b] Ocean Old Wrack											
Nesting Area	34	24.03	4.35	18.91	3.50	3.59	1.26	0.79	0.39	0.74	0.19
Unused Area	18	21.00	6.94	19.22	6.83	0.72	0.27	0.06	0.06	1.00	0.46
			$P = 0.36$		$P = 0.57$		$P = 0.33$		$P = 0.09$		$P = 0.85$
South Monomoy,[b] Ocean Open Vegetation											
Nesting Area	92	14.26	1.59	11.58	1.40	1.13	0.31	0.03	0.02	1.52	0.20
Unused Area	47	10.96	1.33	9.00	1.21	0.47	0.23	0.00	0.00	1.49	0.41
			$P = 0.49$		$P = 0.64$		$P = 0.06$		$P = 0.31$		$P = 0.19$

Continued.

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.

[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table 26, Continued. Mean counts of arthropods trapped during 3-hour trapping periods in habitats along random transects, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects that included the habitat. *P*-values were obtained from Wilcoxon Rank-sum tests. Nesting area is defined as all beach area within 500 m of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Management Area and Habitat		Total Arthropods		Diptera		Coleoptera		Amphipoda		Other [a]	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
South Monomoy,[b] Sound Intertidal Zone											
Nesting Area	53	32.94	4.66	11.42	2.29	4.57	1.87	16.43	4.28	0.53	0.20
Unused Area	45	37.89	6.13	15.02	3.85	7.13	2.19	15.51	3.87	0.22	0.09
			P = 077		*P* = 0.88		*P* = 0.12		*P* = 0.70		*P* = 0.46
South Monomoy,[b] Sound Fresh Wrack											
Nesting Area	48	53.40	10.75	32.86	9.59	10.29	4.26	9.61	3.06	0.63	0.21
Unused Area	53	97.87	38.42	62.92	34.04	26.60	14.49	6.85	1.96	1.49	1.09
			P = 0.81		*P* = 0.79		*P* = 0.57		*P* = 0.85		*P* = 0.16
South Monomoy,[b] Sound Backshore											
Nesting Area	69	25.96	7.39	16.86	5.82	8.36	3.41	0.33	0.12	0.42	0.12
Unused Area	71	71.62	42.71	47.59	35.84	23.21	15.12	0.38	0.10	0.44	0.10
			P = 0.21		*P* = 0.13		*P* = 0.62		*P* = 0.62		*P* = 0.68
South Monomoy,[b] Sound Old Wrack											
Nesting Area	65	22.37	5.47	17.31	4.30	4.18	1.68	0.68	0.21	0.20	0.11
Unused Area	75	48.88	17.94	26.59	10.62	18.47	11.09	1.80	0.90	2.03	0.81
			P = 0.02		*P* = 0.04		*P* = 0.19		*P* = 0.28		*P* = 0.0004
South Monomoy,[b] Sound Open Vegetation											
Nesting Area	49	13.55	2.35	11.34	2.24	1.10	0.27	0.02	0.02	1.09	0.21
Unused Area	32	19.00	4.34	15.63	3.95	1.06	0.39	0.31	0.03	2.28	0.61
			P = 0.06		*P* = 0.06		*P* = 0.92		*P* = 0.76		*P* = 0.33
South Monomoy,[b] Tidal Pond Intertidal Zone											
Nesting Area	24	16.08	4.58	13.92	4.49	1.54	0.62	0.13	0.13	0.50	0.19
Unused Area	0	-	-	-	-	-	-	-	-	-	-

[a] Other arthropods (< 5%) includes Arachnida, Homoptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonoptera, and Zoraptera.
[b] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island..

Table 27. Candidate variables measured along random transects used to construct logistic regression models to predict Piping Plover nesting areas vs. unused areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Candidate Variable	n	$\bar{x}$	SE	Minimum	Median	Maximum
South Monomoy Island Model [a]						
*Distance to Moist Substrate (m)	219	718.8	42.35	5.0	600.0	1930.0
Access to Sound	219	0.5	0.03	0.0	1.0	1.0
Intertidal Zone (m)	219	34.8	5.21	0.0	15.8	774.8
Fresh Wrack (m)	219	1.4	0.19	0.0	0.5	24.1
*Backshore (m)	219	19.9	1.41	0.0	11.9	98.0
Old Wrack (m)	219	1.7	0.16	0.0	1.1	14.2
*Open Vegetation (m)	219	10.0	0.81	0.0	5.2	53.6
Reference Area Model [a]						
Distance to Moist Substrate (m)	164	916.6	47.02	5.0	1125.0	1930.0
Access to Sound	164	0.5	0.04	0.0	1.0	1.0
Intertidal Zone (m)	164	20.6	2.30	0.0	13.0	246.4
Fresh Wrack (m)	164	1.5	0.24	0.0	0.6	24.1
*Backshore (m)	164	19.9	1.41	0.0	13.3	80.7
Old Wrack (m)	164	1.9	0.19	0.0	1.3	14.2
*Open Vegetation (m)	164	9.9	0.92	0.0	4.8	53.6
*Number of Great Black-backed Gulls	164	24.7	2.15	0.0	17.0	196.0

* Variables that were significant ($P \leq 0.05$) in the logistic regression models.

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

Table 28. Logistic regression parameter estimates based on transect data for predicting Piping Plover nesting areas vs. unused areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Model	Variable	β	SE	Wald χ^2	*P*
South Monomoy Island Model (n = 219) [a]					
500-m Nesting Area					
	Intercept	-0.2650	0.2639	1.0082	0.3153
	Backshore (m)	0.0307	0.0103	8.9715	0.0027
	Distance to Moist Substrate (m)	-0.0006	0.0002	6.7635	0.0093
	Open Vegetation (m)	0.0348	0.0157	4.9128	0.0267
100-m Nesting Area					
	Intercept	-2.4639	0.4020	37.5724	< 0.0001
	Backshore (m)	0.0601	0.0121	24.7665	< 0.0001
	Distance to Moist Substrate (m)	-0.0011	0.0004	8.9153	0.0028
	Open Vegetation (m)	0.0444	0.0175	6.4400	0.0112
Reference Area Model (n = 164) [a]					
500-m Nesting Area					
	Intercept	-0.7463	0.3311	5.0808	0.0242
	Backshore (m)	0.0506	0.0138	13.5052	0.0002
	Number of Great Black-backed Gulls	-0.0325	0.0092	12.5965	0.0004
	Open Vegetation (m)	0.0436	0.0195	4.9778	0.0257
100-m Nesting Area					
	Intercept	-2.7996	0.5226	28.7024	< 0.0001
	Backshore (m)	0.0740	0.0170	18.9683	< 0.0001
	Number of Great Black-backed Gulls	-0.0439	0.0134	10.7240	0.0011
	Open Vegetation (m)	0.0439	0.0213	4.2322	0.0397

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

Table 29. Percent of transects predicted correctly and incorrectly as nesting area or unused area by logistic regression models, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Model	Probability Level [a]		Observed	Predicted			
				Correct		Incorrect	
			n	n	%	n	%
South Monomoy Island Model							
500-m Nesting Area	0.55						
		Nesting Area	118	68	57.6	50	42.4
		Unused Area	101	78	77.2	23	22.7
		Total	219	146	66.7	73	33.3
100-m Nesting Area	0.44						
		Nesting Area	51	29	56.9	22	43.1
		Unused Area	168	159	94.6	9	5.4
		Total	219	188	85.8	31	14.2
Reference Area Model							
500-m Nesting Area	0.51						
		Nesting Area	77	51	66.2	26	33.8
		Unused Area	87	74	85.1	13	14.9
		Total	164	125	76.2	39	23.8
100-m Nesting Area	0.43						
		Nesting Area	36	24	66.7	12	33.3
		Unused Area	128	118	92.2	10	7.8
		Total	164	142	86.6	22	13.4

[a] Probability level corresponding to the greatest value of "percent correct" listed in the classification table (an option of PROC LOGISTIC, SAS). The probability level is used as a cut-off point for determining the percent correctly and incorrectly classified based on the predicted values.

Table 30. Mean percent time incubating Piping Plovers were disturbed by various sources during 5-minute behavioral observations, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of 5-minute observations because individuals were not marked. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Great Black-backed Gull		Herring Gull		Immature Gull		American Oystercatcher		Tern Spp.		Piping Plover		Other [a]		Unknown	
			$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE
1999																		
	Gull-removal	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	2.08
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	2.22	-
	Reference	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.13
				-		-		-		-		-		-		-		$T = 0.93$
																		$P = 1.00$
2000																		
	Gull-removal	7	0.13	0.13	0.03	0.03	0.00	0.00	0.16	0.16	0.16	0.16	0.00	0.00	0.19	0.16	0.58	0.30
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	23	0.30	0.20	0.07	0.04	0.00	0.00	0.24	0.18	0.09	0.09	0.006	0.006	0.00	0.00	1.58	1.17
				$T = 0.75$		$T = 0.17$		-		$T = 0.72$		$T = 0.94$		$T < 0.0001$		$T = -3.59$		$T = -0.47$
				$P = 0.80$		$P = 0.43$				$P = 0.76$		$P = 0.93$		$P < 0.0001$		$P = 0.01$		$P = 0.23$
1999-2000																		
	Gull-removal	10	0.09	0.09	0.02	0.02	0.00	0.00	0.11	0.11	0.11	0.11	0.00	0.00	0.13	0.11	1.03	0.62
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	2.22	-
	Reference	40	0.17	0.12	0.04	0.02	0.00	0.00	0.14	0.10	0.05	0.05	0.003	0.003	0.00	0.00	0.99	0.68
				$T = 0.84$		$T = 0.26$		-		$T = 0.76$		$T = 0.96$		$T = 0.00$		$T = -4.25$		$T = -0.22$
				$P = 1.00$		$P = 0.45$				$P = 0.88$		$P = 1.00$		$P < 0.0001$		$P = 0.007$		$P = 0.28$

[a] Other disturbances in the gull-removal area in 2000 include a Willet (57.1%), a Northern Harrier (14.3%), and a pedestrian (14.3%).

Table 31. Mayfield daily and interval survival rate estimates (Mayfield 1975) for Piping Plover nests on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. Chi-square tests were used to test for differences in survival among the years. Survival rates with the same letters were not significantly different (z-tests, $P < 0.05$).

Year	Number of Nests	Daily Survival	Variance	Bias Adjusted Interval Survival [a]
1998	38	0.9681 B	4.4735E-05	0.3234
1999	31	0.9813 A	2.6260E-05	0.5192
2000	39	0.9805 A	2.1946E-05	0.5053
			df = 2	
			$\chi^2 = 109.95$	
			$P < 0.0001$	
1998-2000	108	0.9770	9.9597E-06	0.4503

[a] The probability that a nest initiated will survive to hatching, bias adjusted (Heisey and Fuller 1985).

Table 32. Mayfield daily and interval survival rate estimates (Mayfield 1975) for exclosed and unexclosed Piping Plover nests on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. *Z*-tests were used to test for differences in survival between exclosed and unexclosed nests.

Year		Number of Nests	Daily Survival	Variance	Bias Adjusted Interval Survival [a]
1998					
	Exclosed	20	0.9874	2.5930E-05	0.6411
	Unexclosed	18	0.9245	3.2913E-04	0.0544
				$z = 14.21$	
				$P < 0.0001$	
1999					
	Exclosed	17	0.9827	4.2145E-05	0.5384
	Unexclosed	14	0.9795	6.8459E-05	0.4751
				$z = 1.18$	
				$P = 0.12$	
2000					
	Exclosed	17	0.9981	3.6212E-06	0.9353
	Unexclosed	22	0.9538	1.2711E-04	0.1847
				$z = 18.10$	
				$P < 0.0001$	
1998-2000					
	Exclosed	54	0.9900	7.0016E-06	0.7089
	Unexclosed	54	0.9554	5.0071E-05	0.2053
				$z = 33.65$	
				$P < 0.0001$	

[a] The probability that a nest initiated will survive to hatching, bias adjusted (Heisey and Fuller 1985).

Table 33. Mayfield daily and interval survival rate estimates (Mayfield 1975) for Piping Plover nests, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of nests. Chi-square tests were used to test for differences in survival among the management areas. *Z*-tests were used to test for differences in survival between the gull-removal area and the reference area.

		All Nests				Exclosed Nests				Unexclosed Nests			
Year	Management Area	n	Daily Survival	Variance	Bias Adjusted Interval Survival [a]	n	Daily Survival	Variance	Bias Adjusted Interval Survival [a]	n	Daily Survival	Variance	Bias Adjusted Interval Survival [a]
1998													
	Gull-removal	12	0.9600	2.1943E-04	0.2162	8	0.9825	1.0080E-04	0.5158	4	0.0000	-	-
	Buffer	2	0.7500	2.3438E-02	-0.0013	1	0.8571	1.7493E-02	-0.0053	1	0.0000	-	-
	Reference	24	0.9744	4.9277E-05	0.4014	11	0.9933	2.2074E-05	0.7866	13	0.9469	2.4307E-04	0.1325
			df = 2, χ^2 = 22.09, $P < 0.001$				df = 2, χ^2 = 15.42, $P < 0.001$					-	
			z = -3.19, $P < 0.001$				z = -2.83, $P = 0.002$						
1999													
	Gull-removal	10	0.9753	1.1892E-04	0.3974	4	0.9773	2.5239E-04	0.3898	6	0.9738	2.2283E-04	0.3520
	Buffer	1	1.0000	-	1.0000	1	1.0000	-	1.0000	0	-	-	-
	Reference	20	0.9830	3.5674E-05	0.5459	12	0.9828	5.8031E-05	0.5360	8	0.9832	9.2573E-05	0.5318
			z = -2.08, $P = 0.02$				z = -0.67, $P = 0.25$				z = -1.35, $P = 0.09$		
2000													
	Gull-removal	11	0.9730	1.1793E-04	0.3672	3	1.0000	0.0000E-00	1.0000	8	0.9547	3.2628E-04	0.1653
	Buffer	0	-	-	-	0	-	-	-	0	-	-	-
	Reference	28	0.9831	2.5673E-05	0.5509	14	0.9977	5.2726E-06	0.9220	14	0.9533	2.0816E-04	0.1712
			z = -2.96, $P = 0.002$				z = 3.75, $P < 0.0002$				z = 0.19, $P = 0.42$		
1998-2000													
	Gull-removal	33	0.9700	4.8500E-05	0.3447	15	0.9857	4.0462E-05	0.5979	18	0.9482	1.9588E-04	0.1439
	Buffer	3	0.9394	1.7252E-03	-0.0116	2	0.9688	9.4604E-04	0.1476	1	0.0000	-	-
	Reference	72	0.9803	1.1872E-05	0.5051	37	0.9922	7.5404E-06	0.7630	35	0.9600	6.4105E-05	0.2396
			df = 2, χ^2 = 88.75, $P < 0.001$				df = 2, χ^2 = 25.13, $P < 0.001$				z = -3.31, $P < 0.001$		
			z = -8.06, $P < 0.0001$				z = -3.82, $P < 0.0002$						

[a] The probability that a nest initiated will survive to hatching, bias adjusted (Heisey and Fuller 1985).

Table 34. Fate of Piping Plover nests, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area	Hatched		Depredated		Storm Tide/ Flood		Abandoned/ Covered w/sand		Unknown		Total Nests	
		n	%	n	%	n	%	n	%	n	%	n	%
1998													
All Nests													
	Gull-removal	5	41.7%	2	16.7%	2	16.7%	3	25.0%	0	0.0%	12	100%
	Buffer	0	0.0%	0	0.0%	0	0.0%	1	50.0%	1	50.0%	2	100%
	Reference	11	45.8%	4	16.7%	1	4.2%	1	4.2%	7	29.2%	24	100%
Exclosed Nests													
	Gull-removal	5	62.5%	0	0.0%	1	12.5%	2	25.0%	0	0.0%	8	100%
	Buffer	0	0.0%	0	0.0%	0	0.0%	1	100.0%	0	0.0%	1	100%
	Reference	9	81.8%	0	0.0%	1	9.1%	1	9.1%	0	0.0%	11	100%
Unexclosed Nests													
	Gull-removal	0	0.0%	2	50.0%	1	25.0%	1	25.0%	0	0.0%	4	100%
	Buffer	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%	1	100%
	Reference	2	15.4%	4	30.8%	0	0.0%	0	0.0%	7	53.8%	13	100%

Continued.

[a] 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

[b] Abandoned after adult female was found dead in the exclosure.

Table 34, Continued. Fate of Piping Plover nests by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area	Hatched		Depredated		Storm Tide/ Flood		Abandoned/ Covered w/sand		Unknown		Total Nests	
		n	%	n	%	n	%	n	%	n	%	n	%
1999													
All Nests													
	Gull-removal	5	50.0%	2	20.0%	0	0.0%	3	30.0%	0	0.0%	10	100%
	Buffer	1	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100%
	Reference	12	60.0%	0	0.0%	1	5.0%	4 [b]	20.0%	3	15.0%	20	100%
Exclosed Nests													
	Gull-removal	2	50.0%	0	0.0%	0	0.0%	2	50.0%	0	0.0%	4	100%
	Buffer	1	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100%
	Reference	7	58.3%	0	0.0%	1	8.3%	4 [b]	33.3%	0	0.0%	12	100%
Unexclosed Nests													
	Gull-removal	3	50.0%	2	33.3%	0	0.0%	1	16.7%	0	0.0%	6	100%
	Buffer		-		-		-		-		-		-
	Reference	5	62.5%	0	0.0%	0	0.0%	0	0.0%	3	37.5%	8	100%

Continued.

[a] 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

[b] Abandoned after adult female was found dead in the exclosure.

Table 34, Continued. Fate of Piping Plover nests by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area	Hatched		Depredated		Storm Tide/ Flood		Abandoned/ Covered w/sand		Unknown		Total Nests	
		n	%	n	%	n	%	n	%	n	%	n	%
2000													
All Nests													
	Gull-removal	5	45.5%	3	27.3%	1	9.1%	1	9.1%	1	9.1%	11	100%
	Buffer		-		-		-		-		-		-
	Reference	17	60.7%	3	10.7%	2	7.1%	3	10.7%	3	10.7%	28	100%
Exclosed Nests													
	Gull-removal	3	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3	100%
	Buffer		-		-		-		-		-		-
	Reference	13	92.9%	0	0.0%	0	0.0%	1	7.1%	0	0.0%	14	100%
Unexclosed Nests													
	Gull-removal	2	25.0%	3	37.5%	1	12.5%	1	12.5%	1	12.5%	8	100%
	Buffer		-		-		-		-		-		-
	Reference	4	28.6%	3	21.4%	2	14.3%	2	14.3%	3	21.4%	14	100%

Continued.

[a] 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

[b] Abandoned after adult female was found dead in the exclosure.

Table 34, Continued. Fate of Piping Plover nests by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area	Hatched		Depredated		Storm Tide/ Flood		Abandoned/ Covered w/sand		Unknown		Total Nests	
		n	%	n	%	n	%	n	%	n	%	n	%
1998-2000													
All Nests													
	Gull-removal	15	45.5%	7	21.2%	3	9.1%	7	21.2%	1	3.0%	33	100%
	Buffer	1	33.3%	0	0.0%	0	0.0%	1	33.3%	1	33.3%	3	100%
	Reference	40	55.6%	7	9.7%	4	5.6%	8 [b]	11.1%	13	18.1%	72	100%
	Nest Success, Gull-removal vs. Reference Area: df = 1, χ^2 = 0.93, *P* = 0.34												
Exclosed Nests													
	Gull-removal	10	66.7%	0	0.0%	1	6.7%	4	26.7%	0	0.0%	15	100%
	Buffer	1	50.0%	0	0.0%	0	0.0%	1	50.0%	0	0.0%	2	100%
	Reference	29	78.4%	0	0.0%	2	5.4%	6 [b]	16.2%	0	0.0%	37	100%
	(Nest Success, Gull-removal vs. Reference Area: df = 1, χ^2 = 0.78, *P* = 0.38) [a]												
Unexclosed Nests													
	Gull-removal	5	27.8%	7	38.9%	2	11.1%	3	16.7%	1	5.6%	18	100%
	Buffer	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%	1	100%
	Reference	11	31.4%	7	20.0%	2	5.7%	2	5.7%	13	37.1%	35	100%
	Nest Success, Gull-removal vs. Reference Area: df = 1, χ^2 = 0.08, *P* = 0.78												

[a] 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.
[b] Abandoned after adult female was found dead in the exclosure.

Table 35. Number of Piping Plover nests abandoned or lost to known causes, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area (n = number of nests lost to known causes or abandoned)	Depredated by Gull		Depredated by Coyote		Depredated by American Oystercatcher		Depredated by Unidentified Avian Predator		Storm Tide/ Flood		Abandoned/ Covered w/sand	
		n	%	n	%	n	%	n	%	n	%	n	%
1998													
All Nests													
	Gull-removal (n = 7)	1	14.3%	0	0.0%	0	0.0%	1	14.3%	2	28.6%	3	42.9%
	Buffer (n = 1)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
	Reference (n = 6)	1	16.7%	2	33.3%	0	0.0%	1	16.7%	1	16.7%	1	16.7%
Exclosed Nests													
	Gull-removal (n = 3)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	33.3%	2	66.7%
	Buffer (n = 1)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
	Reference (n = 2)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	50.0%	1	50.0%
Unexclosed Nests													
	Gull-removal (n = 4)	1	25.0%	0	0.0%	0	0.0%	1	25.0%	1	25.0%	1	25.0%
	Buffer (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Reference (n = 4)	1	25.0%	2	50.0%	0	0.0%	1	25.0%	0	0.0%	0	0.0%

Continued.

[a] Abandoned after adult female was found dead in the exclosure.

Table 35, Continued. Number of Piping Plover nests abandoned or lost to known causes, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area (n = number of nests lost to known causes or abandoned)	Depredated by Gull		Depredated by Coyote		Depredated by American Oystercatcher		Depredated by Unidentified Avian Predator		Storm Tide/ Flood		Abandoned/ Covered w/sand	
		n	%	n	%	n	%	n	%	n	%	n	%
1999													
All Nests													
	Gull-removal (n = 5)	2	40.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3	60.0%
	Buffer (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Reference (n = 5)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	20.0%	4 [a]	80.0%
Exclosed Nests													
	Gull-removal (n = 2)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2	100.0%
	Buffer (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Reference (n = 5)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	20.0%	4 [a]	80.0%
Unexclosed Nests													
	Gull-removal (n = 3)	2	66.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	33.3%
	Buffer		-		-		-		-		-		-
	Reference (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Continued.

[a] Abandoned after adult female was found dead in the exclosure.

Table 35, Continued. Number of Piping Plover nests abandoned or lost to known causes, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area (n = number of nests lost to known causes or abandoned)	Depredated by Gull		Depredated by Coyote		Depredated by American Oystercatcher		Depredated by Unidentified Avian Predator		Storm Tide/ Flood		Abandoned/ Covered w/sand	
		n	%	n	%	n	%	n	%	n	%	n	%
2000													
All Nests													
	Gull-removal (n = 5)	0	0.0%	0	0.0%	1	20.0%	2	40.0%	1	20.0%	1	20.0%
	Buffer		-		-		-		-		-		-
	Reference (n = 8)	0	0.0%	0	0.0%	1	12.5%	2	25.0%	2	25.0%	3	37.5%
Exclosed Nests													
	Gull-removal (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Buffer		-		-		-		-		-		-
	Reference (n = 1)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
Unexclosed Nests													
	Gull-removal (n = 5)	0	0.0%	0	0.0%	1	20.0%	2	40.0%	1	20.0%	1	20.0%
	Buffer		-		-		-		-		-		-
	Reference (n = 7)	0	0.0%	0	0.0%	1	14.3%	2	28.6%	2	28.6%	2	28.6%

Continued.

[a] Abandoned after adult female was found dead in the exclosure.

Table 35, Continued. Number of Piping Plover nests abandoned or lost to known causes, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year	Management Area (n = number of nests lost to known causes or abandoned)	Depredated by Gull		Depredated by Coyote		Depredated by American Oystercatcher		Depredated by Unidentified Avian Predator		Storm Tide/ Flood		Abandoned/ Covered w/sand	
		n	%	n	%	n	%	n	%	n	%	n	%
1998-2000													
All Nests													
	Gull-removal (n = 17)	3	17.6%	0	0.0%	1	5.9%	3	17.6%	3	17.6%	7	41.2%
	Buffer (n = 1)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
	Reference (n = 19)	1	5.3%	2	10.5%	1	5.3%	3	15.8%	4	21.1%	8 [a]	42.1%
Exclosed Nests													
	Gull-removal (n = 5)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	20.0%	4	80.0%
	Buffer (n = 1)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
	Reference (n = 8)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2	25.0%	6 [a]	75.0%
Unexclosed Nests													
	Gull-removal (n = 12)	3	25.0%	0	0.0%	1	8.3%	3	25.0%	2	16.7%	3	25.0%
	Buffer (n = 0)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Reference (n = 11)	1	9.1%	2	18.2%	1	9.1%	3	27.3%	2	18.2%	2	18.2%

[a] Abandoned after adult female was found dead in the exclosure.

Table 36. Mean counts of large gulls within 100 m of successful vs. unsuccessful nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal									
		Successful	5	1.34	0.71	0.58	0.25	0.55	0.40	0.21	0.08
		Unsuccessful	5	1.36	0.13	0.82	0.15	0.52	0.21	0.02	0.02
				T = -0.92, P = 0.15		T = -0.21, P = 0.30		T = 0.49, P = 0.59		T = -2.05, P = 0.05	
	Buffer										
		Successful	1	15.42	-	11.21	-	1.71	-	2.50	-
		Unsuccessful	0	-	-	-	-	-	-	-	-
					-		-		-		-
	Reference										
		Successful	12	9.21	2.65	6.27	1.98	1.23	0.17	1.71	0.69
		Unsuccessful	8	10.33	3.70	7.21	2.44	1.78	0.97	1.34	0.79
				T = 0.57, P = 0.65		T = 0.36, P = 0.50		T = 0.08, P = 0.39		T = 0.88, P = 0.89	
	South Monomoy										
		Successful	18	7.37	2.00	4.96	1.49	1.07	0.17	1.34	0.49
		Unsuccessful	13	6.88	2.55	4.75	1.71	1.29	0.61	0.83	0.51
				T = 0.47, P = 0.58		T = 0.56, P = 0.64		T = -0.16, P = 0.30		T = 0.37, P = 0.53	
2000										
	Gull-removal									
		Successful	5	2.03	1.10	0.76	0.29	0.48	0.23	0.80	0.60
		Unsuccessful	6	3.14	1.85	0.55	0.24	0.58	0.26	2.01	1.39
				T = 0.61, P = 0.69		T = 0.38, P = 0.57		T = 1.01, P = 0.89		T = 0.64, P = 0.70	
	Buffer										
		Successful	0	-	-	-	-	-	-	-	-
		Unsuccessful	0	-	-	-	-	-	-	-	-
					-		-		-		-
	Reference										
		Successful	17	7.13	1.94	4.67	1.30	1.23	0.51	1.23	0.32
		Unsuccessful	11	6.79	1.12	4.07	1.01	0.59	0.15	2.14	0.71
				T = 0.25, P = 0.45		T = 0.50, P = 0.60		T = 0.21, P = 0.52		T = -0.16, P = 0.32	

Continued.

Table 36, Continued. Mean counts of large gulls within 100 m of successful vs. unsuccessful nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2000										
	South Monomoy									
	Successful	22	5.97	1.58	3.78	1.06	1.06	0.40	1.13	0.28
	Unsuccessful	17	5.51	1.04	2.82	0.77	0.59	0.13	2.10	0.65
			T = 0.61, P = 0.68		T = 0.44, P = 0.56		T = 0.41, P = 0.58		T = -0.35, P = 0.25	
1999-2000										
	Gull-removal									
	Successful	10	1.69	0.63	0.67	0.18	0.51	0.22	0.50	0.30
	Unsuccessful	11	2.33	1.01	0.67	0.15	0.55	0.16	1.11	0.79
			T = 0.87, P = 0.83		T = 0.66, P = 0.72		T = 0.63, P = 0.69		T = 0.32, P = 0.54	
	Buffer									
	Successful	1	15.42	-	11.21	-	1.71	-	2.50	-
	Unsuccessful	0	-	-	-	-	-	-	-	-
				-		-		-		-
	Reference									
	Successful	29	7.99	1.56	5.33	1.11	1.23	0.30	1.43	0.34
	Unsuccessful	19	8.28	1.68	5.39	1.20	1.09	0.43	1.80	0.52
			T = 0.67, P = 0.73		T = 0.40, P = 0.53		T = 0.85, P = 0.81		T = 0.60, P = 0.67	
	South Monomoy									
	Successful	40	6.60	1.24	4.31	0.88	1.06	0.23	1.23	0.26
	Unsuccessful	30	6.10	1.23	3.66	0.86	0.89	0.28	1.55	0.44
			T = 0.81, P = 0.88		T = 0.43, P = 0.55		T = 0.67, P = 0.72		T = 0.50, P = 0.59	

Table 37. Mean counts of large gulls within 100 m of Piping Plover broods, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal	5	0.84	0.23	0.48	0.17	0.28	0.11	0.09	0.05
	Buffer	1	0.25	-	0.25	-	0.00	-	0.00	-
	Reference	12	5.68	1.73	4.15	1.38	1.24	0.44	0.28	0.15
			T = -1.82, P = 0.06		T = -1.81, P = 0.06		T = -1.42, P = 0.09		T = -0.09, P = 0.36	
2000										
	Gull-removal	5	4.37	0.88	1.22	0.28	0.80	0.28	2.44	0.47
	Buffer	0	-	-	-	-	-	-	-	-
	Reference	17	5.07	1.28	3.57	0.90	1.08	0.41	0.42	0.23
			T = -0.44, P = 0.24		T = -1.10, P = 0.12		T = 0.03, P = 0.38		T = -7.33, P = 0.0003	
1999-2000										
	Gull-removal	10	2.60	0.73	0.80	0.19	0.54	0.17	1.26	0.45
	Buffer	1	0.25	-	0.25	-	0.00	-	0.00	-
	Reference	29	5.33	1.02	3.81	0.76	1.15	0.30	0.36	0.15
			T = -1.01, P = 0.13		T = -3.21, P = 0.02		T = -0.30, P = 0.27		T = -2.97, P = 0.02	

Table 38. Mean counts of large gulls within 100 m of Piping Plover broods vs. random points, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal									
		Broods	5	0.84	0.23	0.48	0.17	0.28	0.11	0.09	0.05
		Random Points	106	2.86	0.66	1.28	0.23	1.10	0.23	0.47	0.33
				T = -1.06, P = 0.11		T = -0.80, P = 0.15		T = -0.93, P = 0.13		T = -0.37, P = 0.11	
	Buffer										
		Broods	1	0.25	-	0.25	-	0.00	-	0.00	-
		Random Points	104	17.54	1.78	12.62	1.26	4.37	0.80	0.56	0.17
					-		-		-		-
	Reference										
		Broods	12	5.68	1.73	4.15	1.38	1.24	0.44	0.28	0.15
		Random Points	210	31.84	2.04	26.19	1.81	3.79	0.70	1.86	0.38
				T = -8.18, P = 0.0002		T = -7.92, P = 0.0002		T = -0.96, P = 0.12		T = -1.14, P = 0.11	
2000										
	Gull-removal									
		Broods	5	4.37	0.89	1.12	0.28	0.80	0.28	2.44	0.47
		Random Points	105	4.65	0.94	1.80	0.38	0.99	0.29	1.86	0.62
				T = -1.23, P = 0.09		T = -0.65, P = 0.14		T = -0.79, P = 0.13		T = -3.33, P = 0.02	
	Buffer										
		Broods	0	-	-	-	-	-	-	-	-
		Random Points	107	30.28	3.19	17.21	1.51	9.73	1.72	3.34	0.71
					-		-		-		-
	Reference										
		Broods	17	5.07	1.28	3.57	0.90	1.08	0.41	0.42	0.23
		Random Points	216	33.86	2.94	25.01	2.38	6.72	1.15	2.13	0.45
				T = -10.63, P < 0.0001		T = -10.27, P < 0.0001		T = -1.88, P = 0.06		T = -0.91, P = 0.13	

Continued.

Table 38, Continued. Mean counts of large gulls within 100 m of Piping Plover broods vs. random points, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods or the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999-2000										
	Gull-removal									
	Broods	10	2.60	0.73	0.80	0.19	0.54	0.17	1.26	0.45
	Random Points	211	3.75	0.58	1.54	0.22	1.05	0.18	1.16	0.35
			T = -0.32, P = 0.21		T = -1.17, P = 0.10		T = -1.01, P = 0.12		T = -2.28, P = 0.04	
	Buffer									
	Broods	1	0.25	-	0.25	-	0.00	-	0.00	-
	Random Points	211	24.00	1.89	14.95	1.00	7.09	0.97	1.97	0.38
				-		-		-		-
	Reference									
	Broods	29	5.33	1.02	3.81	0.76	1.15	0.30	0.36	0.15
	Random Points	426	32.86	1.80	25.59	1.50	5.27	0.68	2.00	0.29
			T = -19.56, P < 0.0001		T = -18.81, P < 0.0001		T = -2.86, P = 0.02		T = -2.16, P = 0.04	

Table 39. Percent time Piping Plover broods spent in different behaviors during 5-minute behavioral observations , by age group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Means with the same letters were not significantly different ($P < 0.05$).

Management Area / Age Group	n	Foraging $\bar{x}$ %	SE	Disturbed $\bar{x}$ %	SE	Resting $\bar{x}$ %	SE	Alert $\bar{x}$ %	SE	Moving $\bar{x}$ %	SE	Brooding $\bar{x}$ %	SE
Gull-removal													
0 – 2 Days	10	46.15 A	14.10	2.69	1.30	7.35 A	3.52	6.93 A	3.41	1.93 B	1.09	34.96 A	11.11
3 – 10 Days	9	56.53 A	11.57	1.98	1.75	13.03 A	5.57	10.53 A	3.03	6.29 A	1.69	11.62 A	4.62
11 – 25 Days	9	58.07 A	9.12	2.90	1.84	12.39 A	3.29	19.91 A	6.41	5.43 A	1.23	1.29 B	1.29
		$T = -5.55$, $P = 0.0005$		$T = -1.09$, $P = 0.13$		$T = -2.32$, $P = 0.03$		$T = -3.65$, $P = 0.006$		$T = -5.06$, $P = 0.0009$		$T = -5.22$, $P = 0.0007$	
Buffer													
0 – 2 Days	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	100.00	-
3 – 10 Days	1	100.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
11 – 25 Days	0	-	-	-	-	-	-	-	-	-	-	-	-
Reference													
0 – 2 Days	34	36.82 B	5.66	2.61 A	0.70	8.27	1.95	10.64	2.47	5.08	1.14	36.58 A	5.10
3 – 10 Days	31	75.23 A	4.15	3.95 A	1.62	4.83	1.57	7.11	1.72	3.02	0.58	5.87 B	1.74
11 – 25 Days	29	70.60 A	4.07	0.86 B	0.18	8.09	1.57	12.84	2.71	6.00	1.08	1.61 C	0.72
		$T = -14.64$, $P < 0.0001$		T - -2.12, $P = 0.04$		$T = -0.86$, $P = 0.16$		$T = -0.18$, $P = 0.33$		$T = -1.14$, $P = 0.12$		$T = -19.63$, $P < 0.0001$	
South Monomoy Island													
0 – 2 Days	45	38.07 B	5.32	2.57	0.60	7.88	1.66	9.58	2.02	4.27	0.92	37.62 A	4.73
3 – 10 Days	41	71.73 A	4.20	3.42	1.28	6.51	1.75	7.69	1.47	3.67	0.61	6.99 B	1.68
11 – 25 Days	38	67.64 A	3.82	1.34	0.46	9.11	1.44	14.51	2.57	5.87	0.87	1.53 C	0.62
		$T = -13.77$, $P < 0.0001$		$T = -1.55$, $P = 0.08$		$T = -1.15$, $P = 0.12$		$T = -1.42$, $P = 0.09$		$T = -1.39$, $P = 0.09$		$T = -24.82$, $P < 0.0001$	

Table 40. Percent time Piping Plover broods spent in different behaviors during 5-minute behavioral observations, by age group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods.

Age Group	Behavior	n	$\bar{x}$ %	SE
0-2 Days				
	Foraging	45	38.07	5.32
	Disturbed	45	2.57	0.60
	Resting	45	7.88	1.66
	Alert	45	9.58	2.02
	Moving	45	4.27	0.92
	Brooding	45	37.62	4.73
3-10 Days				
	Foraging	41	71.73	4.20
	Disturbed	41	3.42	1.28
	Resting	41	6.51	1.75
	Alert	41	7.69	1.47
	Moving	41	3.67	0.61
	Brooding	41	6.99	1.68
11-25 Days				
	Foraging	38	67.64	3.82
	Disturbed	38	1.34	0.46
	Resting	38	9.11	1.44
	Alert	38	14.51	2.57
	Moving	38	5.87	0.87
	Brooding	38	1.53	0.62
3-25 Days				
	Foraging	44	71.67	3.37
	Disturbed	44	2.06	0.56
	Resting	44	7.22	1.17
	Alert	44	10.87	1.80
	Moving	44	4.41	0.56
	Brooding	44	3.79	0.88
0-25 Days				
	Foraging	50	61.08	3.70
	Disturbed	50	2.53	0.50
	Resting	50	7.65	1.01
	Alert	50	11.17	1.72
	Moving	50	4.78	0.72
	Brooding	50	12.80	2.43

Table 41. Percent time Piping Plover broods spent in different behaviors during 5-minute behavioral observations, by age group and management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Age Group	Management Area		Foraging		Disturbed		Resting		Alert		Moving		Brooding	
		n	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE
0 – 2 Days														
	Gull-removal	10	46.15	14.10	2.69	1.30	7.35	3.52	6.93	3.41	1.93	1.09	34.96	11.11
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	100.00	-
	Reference	34	36.82	5.66	2.61	0.70	8.27	1.95	10.64	2.47	5.08	1.14	36.58	5.10
			T = 0.39, P = 0.53		T = 0.71, P = 0.76		T = 0.89, P = 1.00		T = 0.35, P = 0.51		T = -1.03, P = 0.13		T = 0.91, P = 1.00	
3 – 10 Days														
	Gull-removal	9	56.53	11.57	1.98	1.75	13.03	5.57	10.53	3.03	6.29	1.69	11.62	4.62
	Buffer	1	100.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	31	75.23	4.15	3.95	1.62	4.83	1.57	7.11	1.72	3.02	0.58	5.87	1.74
			T = -2.07, P = 0.05		T = 0.04, P = 0.38		T = -1.07, P = 0.12		T = -0.10, P = 0.32		T = -1.56, P = 0.08		T = -0.13, P = 0.30	
11 – 25 Days														
	Gull-removal	9	58.07	9.12	2.90	1.84	12.39	3.29	19.91	6.41	5.43	1.23	1.29	1.29
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	29	70.60	4.07	0.86	0.18	8.09	1.57	12.84	2.71	6.00	1.08	1.61	0.72
			T = -1.44, P = 0.09		T = -0.11, P = 0.31		T = 0.02, P = 0.36		T = 0.22, P = 0.45		T = 0.55, P = 0.63		T = 0.69, P = 0.75	

Continued.

Table 41, Continued. Percent time Piping Plover broods spent in different behaviors during 5-minute behavioral observations, by age group and management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Age Group	Management Area	n	Foraging $\bar{x}$ %	Foraging SE	Disturbed $\bar{x}$ %	Disturbed SE	Resting $\bar{x}$ %	Resting SE	Alert $\bar{x}$ %	Alert SE	Moving $\bar{x}$ %	Moving SE	Brooding $\bar{x}$ %	Brooding SE
3 – 25 Days														
	Gull-removal	10	61.65	9.34	2.06	1.00	10.55	2.86	15.55	4.62	5.25	1.18	4.83	2.16
	Buffer	1	100.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	33	73.84	3.33	2.12	0.69	6.39	1.25	9.78	1.91	4.29	0.65	3.59	0.98
			T = -1.41, P = 0.09		T = 0.54, P = 0.63		T = -0.53, P = 0.21		T = -0.43, P = 0.23		T = 0.36, P = 0.52		T = 0.71, P = 0.77	
0 – 25 Days														
	Gull-removal	12	61.57	8.60	2.99	1.20	8.91	2.49	12.63	3.31	4.11	0.96	9.78	3.12
	Buffer	1	50.00	-	0.00	-	0.00	-	0.00	-	0.00	-	50.00	-
	Reference	37	61.22	4.22	2.44	0.55	7.44	1.10	10.99	2.06	5.13	0.92	12.77	2.97
			T = -0.63, P = 0.19		T = 0.59, P = 0.66		T = 0.83, P = 0.92		T = 0.15, P = 0.41		T = 0.70, P = 0.75		T = -0.22, P = 0.29	

Table 42. Percent time Piping Plover broods were disturbed by gulls and unknown sources during 5-minute behavioral observations, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Year	Management Area	n	Great Black-backed Gulls		Herring Gulls		Immature Gulls		Laughing Gulls		Unknown [a]		Total Disturbance [b]	
			$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE
1999														
	Gull-removal	5	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.41	2.30	1.29
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	12	0.18	0.08	0.11	0.06	0.00	0.00	0.00	0.00	0.34	0.15	2.35	1.18
			T = 0.75, P = 0.77		T = -1.18, P = 0.11			-		-	T = 0.54, P = 0.63		T = 1.24, P = 0.98	
2000														
	Gull-removal	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.23	4.75	2.40
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	17	0.10	0.08	0.12	0.09	0.02	0.01	0.00	0.00	0.28	0.10	2.80	0.84
			T = -0.52, P = 0.21		T = -0.47, P = 0.22		T = -0.28, P = 0.26			-	T = 1.03, P = 1.00		T = 0.53, P = 0.63	
1999-2000														
	Gull-removal	10	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.23	3.53	1.35
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	29	0.13	0.06	0.11	0.06	0.01	0.01	0.00	0.00	0.31	0.08	2.62	0.68
			T = 0.52, P = 0.62		T = -1.57, P = 0.08		T = -0.34, P = 0.29			-	T = 0.56, P = 0.64		T = 0.46, P = 0.58	

[a] Unknown is not limited to gull species.
[b] Total Disturbance includes disturbance by gulls and other species.

Table 43. Percent time Piping Plover broods were disturbed by various sources other than gulls and unknown sources during 5-minute behavioral observations, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Year	Management Area	n	Piping Plovers		American Oystercatchers		Common Terns		Least Terns		Pedestrians		Other [a]	
			$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE	$\bar{x}$ %	SE
1999														
	Gull-removal	5	1.03	0.89	0.00	0.00	0.33	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	12	0.05	0.03	0.22	0.20	0.02	0.02	1.22	1.22	0.13	0.13	0.08	0.05
			T = -1.07, P = 0.13		T = -0.41, P = 0.28		T = -2.00, P = 0.05			-		-	T = -0.77, P = 0.18	
2000														
	Gull-removal	5	1.31	0.95	0.05	0.05	2.95	2.60	0.00	0.00	0.11	0.11	0.00	0.00
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	17	1.30	0.87	0.36	0.16	0.10	0.10	0.41	0.41	0.04	0.04	0.08	0.05
			T = 1.02, P = 1.00		T = -0.56, P = 0.21		T = -2.24, P = 0.04			-	T = 0.91, P = 1.00		T = -0.50, P = 0.22	
1999-2000														
	Gull-removal	10	1.17	0.62	0.02	0.02	1.64	1.30	0.00	0.00	0.05	0.05	0.00	0.00
	Buffer	1	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
	Reference	29	0.78	0.52	0.30	0.12	0.07	0.06	0.74	0.55	0.08	0.06	0.08	0.04
			T = 0.19, P = 0.30		T = -1.06, P = 0.13		T = -5.52, P = 0.002		T = -0.34, P = 0.29		T = 0.84, P = 0.84		T = -1.29, P = 0.10	

[a] Other disturbances in the reference area in 1999 include a Horned Lark (60%), a Red-winged Blackbird (20%), and an airplane (20%). Other disturbances in the reference area in 2000 include a helicopter on two occasions (87.5%) and a Semipalmated Plover (12.5%).

Table 44. Percent time Piping Plover broods of ages 0-25 days spent in different habitats during 5-minute behavioral observations) by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. ANOVAs were conducted on ranked values of brood use. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Access Group	Habitat	n	$\bar{x}$ %		SE
Access to Ocean Only					
	Ocean Backshore	13	45.99	A	7.81
	Ocean Open Vegetation	13	24.32	B	7.22
	Ocean Old Wrack	13	19.64	BC	7.98
	Ocean Intertidal Zone	13	5.92	CD	3.16
	Ocean Fresh Wrack	13	4.12	D	1.83
					$F = 8.07$, $P < 0.0001$
Access to Ocean and Sound					
	Sound Intertidal Zone	5	30.28		18.13
	Sound Backshore	5	14.28		7.75
	Sound Old Wrack	5	14.25		7.43
	Ocean Open Vegetation	5	11.48		7.38
	Sound Open Vegetation	5	10.32		6.12
	Ocean Fresh Wrack	5	7.35		5.60
	Ocean Backshore	5	6.48		6.01
	Ocean Old Wrack	5	3.30		3.30
	Ocean Intertidal Zone	5	1.24		0.87
	Sound Fresh Wrack	5	1.02		1.02
					$F = 0.91$, $P = 0.53$
Access to Ocean and Seal Carcass					
	Ocean Backshore	4	53.69	A	6.78
	Seal Carcass	4	16.08	B	2.30
	Ocean Open Vegetation	4	13.52	BC	3.96
	Ocean Intertidal Zone	4	13.12	BCD	7.58
	Ocean Old Wrack	4	1.71	CD	1.12
	Ocean Fresh Wrack	4	1.89	D	1.89
					$F = 7.10$, $P = 0.0008$

Continued.

Table 44, Continued. Percent time Piping Plover broods of ages 0-25 days spent in different habitats during 5-minute behavioral observations) by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. ANOVAs were conducted on ranked values of brood use. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Access Group	Habitat	n	$\bar{x}$ %	SE
Access to Sound and Tidal Pond Intertidal Zone				
	Tidal Pond Intertidal Zone	25	40.40 A	5.19
	Sound Backshore	25	30.78 A	4.87
	Sound Open Vegetation	25	8.51 B	2.03
	Sound Old Wrack	25	9.23 B	1.93
	Sound Fresh Wrack	25	8.23 B	2.07
	Sound Intertidal Zone	25	2.77 C	0.82
				$F = 20.99$, $P < 0.0001$
Access to Sound, Tidal Pond Intertidal Zone, and Seal Carcass				
	Seal Carcass	3	26.05	12.85
	Sound Old Wrack	3	24.24	12.58
	Sound Backshore	3	24.20	5.84
	Tidal Pond Intertidal Zone	3	14.01	3.72
	Sound Fresh Wrack	3	5.27	3.03
	Sound Open Vegetation	3	5.00	4.18
	Sound Intertidal Zone	3	1.23	0.62
				$F = 2.54$, $P = 0.07$

Table 45. Percent time Piping Plover broods of ages 3-25 days spent in different habitats during 5-minute behavioral observations, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. ANOVAs were conducted on ranked values of brood use. Means are listed in order of ranks. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Access Group	Habitat	n	$\bar{x}$ %		SE
Access to Ocean Only					
	Ocean Backshore	10	45.91	A	7.50
	Ocean Open Vegetation	10	23.00	B	5.47
	Ocean Old Wrack	10	15.06	BC	5.83
	Ocean Intertidal Zone	10	9.72	BC	4.75
	Ocean Fresh Wrack	10	6.31	C	3.45
					$F = 7.60$, $P < 0.0001$
Access to Ocean and Sound					
	Ocean Intertidal Zone	5	29.73		18.45
	Sound Fresh Wrack	5	19.19		16.96
	Ocean Old Wrack	5	14.86		7.53
	Sound Open Vegetation	5	8.61		5.34
	Ocean Backshore	5	8.57		7.16
	Sound Backshore	5	7.19		7.19
	Sound Old Wrack	5	3.89		3.89
	Ocean Open Vegetation	5	3.78		2.39
	Sound Intertidal Zone	5	3.09		2.59
	Ocean Fresh Wrack	5	1.09		1.09
					$F = 0.57$, $P = 0.81$
Access to Ocean and Seal Carcass					
	Ocean Backshore	4	51.22	A	7.03
	Seal Carcass	4	17.38	B	2.42
	Ocean Open Vegetation	4	12.39	BC	4.66
	Ocean Intertidal Zone	4	15.10	BC	8.72
	Ocean Old Wrack	4	1.85	C	1.21
	Ocean Fresh Wrack	4	2.05	C	2.05
					$F = 6.11$, $P = 0.002$

Continued.

Table 45, Continued. Percent time Piping Plover broods of ages 3-25 days spent in different habitats during 5-minute behavioral observations, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. ANOVAs were conducted on ranked values of brood use. Means are listed in order of rank. Ranks with the same letters were not significantly different ($P < 0.05$, Fischer's LSD).

Access Group	Habitat	n	$\bar{x}$ %		SE
Access to Sound and Tidal Pond Intertidal Zone					
	Tidal Pond Intertidal Zone	22	40.49	A	5.93
	Sound Backshore	22	27.94	A	5.18
	Sound Old Wrack	22	10.42	B	2.22
	Sound Fresh Wrack	22	9.69	B	2.34
	Sound Open Vegetation	22	7.84	BC	2.03
	Sound Intertidal Zone	22	3.54	C	1.00
				$F = 14.87$, $P < 0.0001$	
Access to Sound, Tidal Pond Intertidal Zone, and Seal Carcass					
	Sound Backshore	3	24.69	A	3.53
	Sound Old Wrack	3	23.02	AB	11.23
	Seal Carcass	3	29.47	ABC	14.51
	Tidal Pond Intertidal Zone	3	11.64	ABCD	3.64
	Sound Fresh Wrack	3	6.10	BCD	3.43
	Sound Open Vegetation	3	3.65	CD	2.73
	Sound Intertidal Zone	3	1.44	D	0.72
				$F = 2.88$, $P = 0.05$	

Table 46. Brood habitat use in proportion to availability (Compositional Analysis, Aebischer 1993) for broods of ages 0-25 days, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects or the number of broods.

Access Group	Habitat	Availability [a] n	$\bar{x}$ %	SE	Use [b] n	$\bar{x}$ %	SE	Rank [c]
Access to Ocean Only								
	Ocean Old Wrack	47	0.88	0.29	13	19.64	7.98	1 A
	Ocean Backshore	47	41.69	3.03	13	45.99	7.81	2 A
	Ocean Open Vegetation	47	26.75	1.93	13	24.32	7.22	3 AB
	Ocean Fresh Wrack	47	1.39	0.58	13	4.12	1.83	4 BC
	Ocean Intertidal Zone	47	29.29	3.19	13	5.94	3.16	5 C
						Wilks' $\lambda = 0.317$, $F = 4.86$, $P = 0.02$		
Access to Ocean and Sound								
	Sound Old Wrack	41	1.30	0.49	5	14.25	7.43	1
	Sound Intertidal Zone	41	24.05	5.98	5	30.28	18.13	2
	Sound Open Vegetation	41	2.60	1.77	5	10.32	6.12	3
	Sound Backshore	41	7.84	2.97	5	14.28	7.75	4
	Ocean Fresh Wrack	41	1.25	0.65	5	7.35	5.60	5
	Ocean Old Wrack	41	0.81	0.31	5	3.30	3.30	6
	Sound Fresh Wrack	41	0.80	0.30	5	1.02	1.02	7
	Ocean Open Vegetation	41	16.76	2.65	5	11.48	7.38	8
	Ocean Intertidal Zone	41	17.66	4.04	5	1.24	0.87	9
	Ocean Backshore	41	26.94	4.51	5	6.48	6.01	10
			No multivariate tests performed for Intercept due to insufficient error degrees of freedom.					
Access to Ocean and Seal Carcass								
	Seal Carcass	26	0.01	0.00	4	16.08	2.30	1
	Ocean Backshore	26	46.75	4.56	4	53.69	6.78	2
	Ocean Open Vegetation	26	25.18	1.92	4	13.52	3.96	3
	Ocean Old Wrack	26	0.95	0.43	4	1.71	1.12	4
	Ocean Fresh Wrack	26	0.75	0.22	4	1.89	1.89	5
	Ocean Intertidal Zone	26	26.36	4.72	4	13.12	7.58	6
			No multivariate tests performed for Intercept due to insufficient error degrees of freedom.					

Continued.

[a] Availability is based on measurements of habitats on random transects.
[b] Use is based on 5-minute behavioral observations of broods.
[c] A habitat rank of 1 = the most preferred habitat based on use and availability.

Table 46, Continued. Brood habitat use in proportion to availability (Compositional Analysis, Aebischer 1993) for broods of ages 0-25 days, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects or the number of broods.

Access Group	Habitat	Availability [a] n	$\bar{x}$ %	SE	Use [b] n	$\bar{x}$ %	SE	Rank [c]
Access to Sound and Tidal Pond Intertidal Zone								
	Tidal Pond Intertidal Zone	31	20.70	4.09	25	40.40	5.19	1 A
	Sound Backshore	31	38.94	3.72	25	30.78	4.87	2 AB
	Sound Fresh Wrack	31	2.18	0.81	25	8.23	2.07	3 B
	Sound Open Vegetation	31	15.77	2.56	25	8.51	2.03	4 B
	Sound Old Wrack	31	5.65	1.11	25	9.23	1.93	5 B
	Sound Intertidal Zone	31	16.77	3.88	25	2.77	0.82	6 C
						Wilks' $\lambda = 0.369$, $F = 6.83$, $P = 0.0007$		
Access to Sound, Tidal Pond Intertidal Zone and Seal Carcass								
	Seal Carcass	30	0.01	0.00	3	26.05	12.85	1
	Sound Old Wrack	30	9.55	1.77	3	24.24	12.58	2
	Tidal Pond Intertidal Zone	30	14.34	3.48	3	14.01	3.72	3
	Sound Backshore	30	32.36	3.15	3	24.20	5.84	4
	Sound Open Vegetation	30	28.56	4.40	3	5.00	4.18	5
	Sound Fresh Wrack	30	4.74	1.20	3	5.27	3.03	6
	Sound Intertidal Zone	30	10.45	1.66	3	1.23	0.62	7
						No multivariate tests performed for Intercept due to insufficient error degrees of freedom.		

[a] Availability is based on measurements of habitats on random transects.
[b] Use is based on 5-minute behavioral observations of broods.
[c] A habitat rank of 1 = the most preferred habitat based on use and availability.

Table 47. Brood habitat use in proportion to availability (Compositional Analysis, Aebischer 1993) for broods of ages 3-25 days, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects or the number of broods for which 5-minute behavioral observations were conducted.

Access Group	Habitat	Availability [a] n	$\bar{x}$ %	SE	Use [b] n	$\bar{x}$ %	SE	Rank [c]
Access to Ocean Only								
	Ocean Backshore	47	41.69	3.03	10	46.34	7.54	1
	Ocean Old Wrack	47	0.88	0.29	10	14.49	5.94	2
	Ocean Open Vegetation	47	26.75	1.93	10	23.06	5.49	3
	Ocean Fresh Wrack	47	1.39	0.58	10	6.38	3.45	4
	Ocean Intertidal Zone	47	29.29	3.19	10	9.72	4.75	5
						Wilks' $\lambda = 0.476$, $F = 1.65$, $P = 0.28$		
Access to Ocean and Sound								
	Sound Old Wrack	41	1.30	0.49	5	14.86	7.53	1
	Ocean Fresh Wrack	41	1.25	0.65	5	19.19	16.96	2
	Sound Intertidal Zone	41	24.05	5.98	5	29.73	18.45	3
	Sound Open Vegetation	41	2.60	1.77	5	3.78	2.39	4
	Sound Backshore	41	7.84	2.97	5	8.57	7.16	5
	Ocean Old Wrack	41	0.81	0.31	5	3.89	3.89	6
	Sound Fresh Wrack	41	0.80	0.30	5	1.09	1.09	7
	Ocean Open Vegetation	41	16.76	2.65	5	8.61	5.34	8
	Ocean Intertidal Zone	41	17.66	4.04	5	3.09	2.59	9
	Ocean Backshore	41	26.94	4.51	5	7.19	7.19	10
			No multivariate tests performed for Intercept due to insufficient error degrees of freedom.					
Access to Ocean and Seal Carcass								
	Seal Carcass	26	0.01	0.00	4	17.63	2.37	1
	Ocean Backshore	26	46.75	4.56	4	51.75	6.58	2
	Ocean Old Wrack	26	0.95	0.43	4	1.85	1.21	3
	Ocean Open Vegetation	26	25.18	1.92	4	12.75	4.91	4
	Ocean Fresh Wrack	26	0.75	0.22	4	2.05	2.05	5
	Ocean Intertidal Zone	26	26.36	4.72	4	13.97	8.14	6
			No multivariate tests performed for Intercept due to insufficient error degrees of freedom.					

Continued.

[a] Availability is based on measurements of habitats on random transects.
[b] Use is based on 5-minute behavioral observations of broods.
[c] A habitat rank of 1 = the most preferred habitat based on use and availability.

Table 47, Continued. Brood habitat use in proportion to availability (Compositional Analysis, Aebischer 1993) for broods of ages 3-25 days, by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of transects or the number of broods for which 5-minute behavioral observations were conducted.

Access Group	Habitat	Availability [a] n	$\bar{x}$ %	SE	Use [b] n	$\bar{x}$ %	SE	Rank [c]
Access to Sound and Tidal Pond Intertidal Zone								
	Tidal Pond Intertidal Zone	31	20.70	4.09	22	40.54	5.93	1 A
	Sound Backshore	31	38.94	3.72	22	27.77	5.18	2 AB
	Sound Fresh Wrack	31	2.18	0.81	22	9.75	2.35	3 AB
	Sound Old Wrack	31	5.65	1.11	22	10.44	2.22	4 B
	Sound Open Vegetation	31	15.77	2.56	22	7.86	2.03	5 B
	Sound Intertidal Zone	31	16.77	3.88	22	3.56	1.00	6 C
						Wilks' $\lambda = 0.424$, $F = 4.62$, $P = 0.008$		
Access to Sound, Tidal Pond Intertidal Zone and Seal Carcass								
	Seal Carcass	30	0.01	0.00	3	29.47	14.51	1
	Sound Old Wrack	30	9.55	1.77	3	23.02	11.23	2
	Sound Backshore	30	32.36	3.15	3	24.69	3.53	3
	Tidal Pond Intertidal Zone	30	14.34	3.48	3	11.64	3.64	4
	Sound Open Vegetation	30	28.56	4.40	3	3.65	2.73	5
	Sound Fresh Wrack	30	4.74	1.20	3	6.10	3.43	6
	Sound Intertidal Zone	30	10.45	1.66	3	1.44	0.72	7
						No multivariate tests performed for Intercept due to insufficient error degrees of freedom.		

[a] Availability is based on measurements of habitats on random transects.
[b] Use is based on 5-minute behavioral observations of broods.
[c] A habitat rank of 1 = the most preferred habitat based on use and availability.

Table 48. Mean foraging rates (attempts per minute) of Piping Plover broods in different habitats during 5-minute behavioral observations, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Habitats were included in analyses only if n > 2. Means with the same letters were not significantly different.

Age Group	Habitat	n	$\bar{x}$ %		SE
0-2 Days					
	Seal Carcass	1	19.00	-	-
	Tidal Pond Intertidal Zone	14	5.46	A	0.93
	Ocean Old Wrack	5	4.39	A	0.87
	Sound Intertidal Zone	2	4.38	-	1.38
	Ocean Intertidal Zone	2	3.72	-	0.72
	Sound Fresh Wrack	4	3.59	AB	1.49
	Sound Old Wrack	7	1.66	B	0.59
	Ocean Open Vegetation	10	1.46	B	0.82
	Ocean Backshore	15	1.45	B	0.48
	Sound Open Vegetation	10	1.30	B	0.88
	Ocean Fresh Wrack	1	1.03	-	-
	Sound Backshore	18	0.96	B	0.29
					T = -6.27
					P < 0.0001
3-10 Days					
	Tidal Pond Intertidal Zone	20	12.56	A	2.20
	Seal Carcass	6	6.61	AB	1.08
	Ocean Fresh Wrack	7	6.56	ABC EF	2.78
	Sound Intertidal Zone	12	6.70	BCD	1.14
	Ocean Intertidal Zone	8	5.84	BCD	1.09
	Sound Fresh Wrack	9	4.75	BCD	0.79
	Ocean Old Wrack	7	4.43	CD FGH	2.87
	Sound Old Wrack	19	3.72	DEFG	0.58
	Sound Open Vegetation	17	3.43	DEF H	0.83
	Sound Backshore	21	2.94	FGH	0.61
	Ocean Backshore	14	1.59	GH	0.46
	Ocean Open Vegetation	10	1.53	H	0.36
					T = -11.31
					P < 0.0001

Continued.

Table 48, Continued. Mean foraging rates (attempts per minute) of Piping Plover broods in different habitats during 5-minute behavioral observations, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Habitats were included in analyses only if n > 2. Means with the same letters were not significantly different.

Age Group	Habitat	n	$\bar{x}$ %		SE
11-25 Days					
	Sound Fresh Wrack	16	11.89	A	1.20
	Tidal Pond Intertidal Zone	17	11.01	A	1.35
	Seal Carcass	6	8.93	AB	0.93
	Ocean Intertidal Zone	6	6.71	BCDE	1.26
	Sound Intertidal Zone	16	6.13	BC E	0.97
	Sound Old Wrack	19	4.97	CDE	0.52
	Sound Backshore	22	3.89	DEF	0.59
	Ocean Old Wrack	9	3.83	EF	1.00
	Ocean Fresh Wrack	4	2.47	EFG	1.16
	Sound Open Vegetation	16	2.31	FG	0.67
	Ocean Open Vegetation	12	2.15	FG	0.54
	Ocean Backshore	15	1.80	G	0.34
					T = -16.81
					P < 0.0001
3-25 Days					
	Tidal Pond Intertidal Zone	24	11.57	A	1.16
	Sound Fresh Wrack	18	10.36	A	1.07
	Seal Carcass	7	8.06	AB	0.95
	Sound Intertidal Zone	19	6.47	BC	0.71
	Ocean Intertidal Zone	9	5.70	BCD	1.06
	Ocean Old Wrack	11	5.06	CD FG	1.81
	Sound Old Wrack	22	4.77	DE	0.48
	Ocean Fresh Wrack	8	3.61	DEF	0.73
	Sound Backshore	25	3.54	EF	0.47
	Sound Open Vegetation	24	2.85	FG	0.62
	Ocean Open Vegetation	14	2.18	FG	0.38
	Ocean Backshore	17	1.61	G	0.30
					T = -21.27
					P < 0.0001

Continued.

Table 48, Continued. Mean foraging rates (attempts per minute) of Piping Plover broods in different habitats during 5-minute behavioral observations, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances. Habitats were included in analyses only if n > 2. Means with the same letters were not significantly different.

Age Group	Habitat	n	$\bar{x}$ %		SE
0-25 Days					
	Sound Fresh Wrack	19	10.07	A	1.06
	Tidal Pond Intertidal Zone	27	9.87	A	0.93
	Seal Carcass	7	8.19	AB	0.90
	Sound Intertidal Zone	21	6.28	B	0.67
	Ocean Intertidal Zone	9	5.60	BC	1.02
	Sound Old Wrack	23	4.50	C	0.48
	Ocean Old Wrack	13	4.99	CD	1.51
	Ocean Fresh Wrack	8	3.52	CDE	0.76
	Sound Backshore	29	2.86	DE	0.43
	Sound Open Vegetation	26	2.06	EF	0.44
	Ocean Open Vegetation	16	2.06	EF	0.49
	Ocean Backshore	19	1.59	F	0.27
					T = -23.10
					P < 0.0001

Table 49. Mean foraging rates (attempts per minute) of Piping Plover broods of all ages in different habitats during 5-minute behavioral observations in the gull-removal area vs. the reference area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Habitat	Gull-removal Area			Reference Area			
	n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	MRPP *T* Statistic and *P*-values
Ocean Intertidal Zone	2	7.50	1.50	7	5.06	1.21	$T = 0.25$, $P = 0.41$
Ocean Fresh Wrack	4	3.46	1.34	4	3.57	0.95	$T = 1.11$, $P = 0.89$
Ocean Backshore	8	1.58	0.45	10	1.71	0.38	$T = 1.01$, $P = 1.00$
Ocean Old Wrack	7	5.53	2.70	6	4.35	1.23	$T = 0.95$, $P = 0.91$
Ocean Open Vegetation	8	2.80	0.82	8	1.32	0.44	$T = -0.98$, $P = 0.14$
Sound Intertidal Zone	4	7.70	1.79	17	5.94	0.71	$T = 0.40$, $P = 0.56$
Sound Fresh Wrack	1	7.85	-	18	10.20	1.11	-
Sound Backshore	3	3.07	1.24	26	2.84	0.47	$T = 0.97$, $P = 0.96$
Sound Old Wrack	2	5.83	1.15	21	4.38	0.51	$T = 0.13$, $P = 0.47$
Sound Open Vegetation	4	2.30	1.96	22	2.01	0.41	$T = 0.78$, $P = 0.79$
Tidal Pond Intertidal Zone	0	-	-	27	9.87	0.93	-
Seal Carcass	2	9.47	1.27	5	7.68	1.14	$T = -0.09$, $P = 0.36$

Table 50. Mean counts of large gulls within 100 m of successful vs. unsuccessful broods, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Total Large Gulls $\bar{x}$	SE	Great Black-backed Gulls $\bar{x}$	SE	Herring Gulls $\bar{x}$	SE	Immature Gulls $\bar{x}$	SE
1999										
	Gull-removal									
	Successful	3	0.84	0.33	0.54	0.29	0.25	0.19	0.05	0.03
	Unsuccessful	2	0.84	0.44	0.39	0.19	0.31	0.11	0.14	0.14
				-		-		-		-
	Buffer									
	Successful	0	-	-	-	-	-	-	-	-
	Unsuccessful	1	0.25	-	0.25	-	0.00	-	0.00	-
				-		-		-		-
	Reference									
	Successful	10	5.50	1.94	4.25	1.63	0.94	0.27	0.31	0.18
	Unsuccessful	2	6.58	5.15	3.70	2.41	2.74	2.60	0.14	0.14
			$T = 0.90$, $P = 0.83$		$T = 0.49$, $P = 0.60$		$T = 1.19$, $P = 1.00$		$T = 0.27$, $P = 0.45$	
	South Monomoy Island									
	Successful	13	4.43	1.58	3.39	1.32	0.78	0.22	0.25	0.14
	Unsuccessful	5	3.02	2.19	1.68	1.12	1.22	1.03	0.11	0.07
			$T = 0.60$, $P = 0.67$		$T = 0.26$, $P = 0.49$		$T = 0.69$, $P = 0.73$		$T = 0.05$, $P = 0.41$	
2000										
	Gull-removal									
	Successful	4	4.71	1.04	1.15	0.36	1.01	0.25	2.55	0.58
	Unsuccessful	1	3.00	-	1.00	-	0.00	-	2.00	-
				-		-		-		-
	Reference									
	Successful	11	5.26	1.84	3.74	1.24	0.96	0.49	0.56	0.35
	Unsuccessful	6	4.74	1.55	3.27	1.25	1.31	0.80	0.17	0.11
			$T = 0.40$, $P = 0.55$		$T = 0.62$, $P = 0.69$		$T = 0.52$, $P = 0.63$		$T = 0.02$, $P = 0.43$	
	South Monomoy Island									
	Successful	15	5.11	1.36	3.05	0.96	0.97	0.36	1.09	0.37
	Unsuccessful	7	4.49	1.34	2.94	1.10	1.12	0.70	0.43	0.28
			$T = 0.52$, $P = 0.62$		$T = 0.71$, $P = 0.75$		$T = 0.10$, $P = 0.43$		$T = -0.23$, $P = 0.29$	

Continued.

Table 50, Continued. Mean counts of large gulls within 100 m of successful vs. unsuccessful broods, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999-2000										
	Gull-removal									
		Successful	7	3.05	0.97	0.89	0.25	0.68	0.21	1.48	0.59
		Unsuccessful	3	1.56	0.76	0.59	0.23	0.21	0.12	0.76	0.64
				T = 0.02, P = 0.40		T = 0.22, P = 0.48		T = -0.63, P = 0.21		T = 0.46, P = 0.60	
	Buffer										
		Successful	0	-	-	-	-	-	-	-	-
		Unsuccessful	1	0.25	-	0.25	-	0.00	-	0.00	-
					-		-		-		
	Reference										
		Successful	21	5.38	1.30	3.98	0.99	0.95	0.28	0.44	0.20
		Unsuccessful	8	5.20	1.53	3.37	1.02	1.66	0.80	0.16	0.08
				T = 0.37, P = 0.52		T = 0.33, P = 0.50		T = -0.48, P = 0.23		T = -0.08, P = 0.34	
	South Monomoy Island										
		Successful	28	4.79	1.02	3.21	0.78	0.89	0.22	0.70	0.22
		Unsuccessful	12	3.88	1.16	2.42	0.78	1.16	0.56	0.30	0.17
				T = 0.54, P = 0.62		T = 0.49, P = 0.59		T = -0.70, P = 0.18		T = -0.27, P = 0.27	

Table 51. Prefledging daily and interval survival rate estimates (Flint et al. 1995) and chicks fledged/pair, by year, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. Chi-square tests were used to test for differences in survival among the years (Sauer and Williams 1989).

Year	Breeding Pairs	Broods	Chicks Hatched	Chicks Fledged		Daily Survival	SE	Interval Survival [a]	Chicks Fledged per Breeding Pair
1998	27	16	53	19	35.8%	0.9459	0.0176	0.2490	0.70
1999	26	18	63	35	55.6%	0.9726	0.0094	0.4999	1.35
2000	28	22	79	37	46.8%	0.9630	0.0115	0.3901	1.32
								df = 2	
								$\chi^2 = 1.86$	
								$P = 0.39$	
1998-2000	81	56	195	91	46.7%	0.9627	0.0070	0.3867	1.12

[a] The probability that a chick will survive to fledge.

Table 52. Prefledging daily and interval survival rate estimates (Flint et al. 1995) and chicks fledged/pair, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. *Z*-tests were used to test for differences in survival between the gull-removal area and the reference area (Sauer and Williams 1989).

Year	Area	Breeding Pairs	Broods	Chicks Hatched	Chicks Fledged		Daily Survival	SE	Interval Survival [a]	Chicks Fledged per Breeding Pair
1998										
	Gull-Removal	9	5	19	4	21.1%	0.8900	0.0736	0.0543	0.44
	Reference	17	11	34	15	44.1%	0.9614	0.0151	0.3737	0.88
									z = -0.95	
									P = 0.17	
1999										
	Gull-Removal	9	5	16	5	31.3%	0.9468	0.0152	0.2547	0.56
	Reference	16	12	43	30	69.8%	0.9840	0.0083	0.6675	1.88
									z = -2.14	
									P = 0.02	
2000										
	Gull-Removal	7	5	17	9	52.9%	0.9711	0.0207	0.4804	1.29
	Reference	21	17	62	28	45.2%	0.9604	0.0141	0.3646	1.33
									z = 0.43	
									P = 0.33	
1998-2000										
	Gull-Removal	25	15	52	18	34.6%	0.9451	0.0178	0.2440	0.72
	Reference	54	40	139	73	52.5%	0.9695	0.0071	0.4607	1.35
									z = -1.27	
									P = 0.10	

[a] The probability that a chick will survive to fledge.

Table 53. Prefledging daily and interval survival rate estimates (Flint et al. 1995), by access group, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. The sample size (n) equals the number of broods. Chi-square tests were used to test for differences in survival among the access groups (Sauer and Williams 1989).

Access Group	n [a]	Daily Survival	SE	Interval Survival
Access to Ocean Only	13	0.9502	0.0205	0.2788
Access to Ocean and Sound	5	0.9392	0.0201	0.2086
Access to Ocean and Seal Carcass	4	0.9765	0.0108	0.5515
Access to Sound and Tidal Pond Intertidal Zone	25	0.9682	0.0095	0.4456
Access to Sound, Tidal Pond Intertidal Zone, and Seal Carcass	3	0.9706	0.0239	0.4741
				df = 4
				$\chi^2 = 3.38$
				$P = 0.50$
Access to Seal Carcass	7	0.9741	0.0103	0.5187
Access to Tidal Pond Intertidal Zone	28	0.9682	0.0095	0.4456
All other Broods	18	0.9473	0.0161	0.2583
				df = 2
				$\chi^2 = 1.99$
				$P = 0.37$

[a] Sample sizes do not include 3 broods from the gull-removal area and 3 broods from the reference area in 1998, because the access group could not be determined..

Table 54. Mean foraging rates (attempts per minute) of Piping Plover broods of ages 3-10 days in different habitats during behavioral observations from other Piping Plover studies on the Atlantic Coast. The sample size (n) equals the number of broods)

		This Study			Loegering			Elias-Gerken			Kuklinski			Houghton		
		South Monomoy Island, MA			Assateague Island, MD			Long Island, NY			Cape Hatteras, NC			West Hampton Dunes, NY		
		1998-2000			1988-1990			1992-1993			1996			1993-2000		
		n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE	n	$\bar{x}$ %	SE
Ocean		-	-	-	21	5.9	1.3	-	-	-	-	-	-	57	4.5	0.450
	Intertidal Zone	8	5.84	1.09	-	-	-	13	7	1.2	-	-	-	41	5.4	0.660
	Fresh Wrack	7	6.56	2.78	-	-	-	17	6	0.9	-	-	-	41	5.6	0.542
	Backshore	14	1.59	0.46	-	-	-	24	4	0.6	2	5.2	3.0	41	2.8	0.762
	Old Wrack	7	4.43	2.87	-	-	-	27	4	0.6	-	-	-	42	4.7	0.785
	Open Vegetation	10	1.53	0.36				49	5	0.6	8	3.8	1.3	13	1.1	0.615
Sound/Bay		-	-	-	9	13.3	1.1	-	-	-	-	-	-	84	7.6	0.575
	Intertidal Zone	12	6.7	1.14	-	-	-	4	9	1.7	-	-	-	77	9.6	0.686
	Fresh Wrack	9	4.75	0.79	-	-	-	3	6	1.4	-	-	-	54	8.4	0.939
	Backshore	21	2.94	0.61	-	-	-	3	5	0.3	-	-	-	28	2.2	0.576
	Old Wrack	19	3.72	0.58	-	-	-	3	5	1.2	-	-	-	38	4.8	0.594
	Open Vegetation	17	3.43	0.83	-	-	-	2	4	2.5	-	-	-	52	4.1	0.664
	Wet Sand Flat	-	-	-	-	-	-	-	-	-	7	14.6	2.0	-	-	-
Ephemeral Pool		-	-	-	-	-	-	44	13	0.9	1	6.2	-	10	14.1	4.398
Tidal Pond Intertidal Zone		20	12.56	2.20	-	-	-	-	-	-	-	-	-	-	-	-
Seal Carcass		6	6.61	1.08	-	-	-	-	-	-	-	-	-	-	-	-
Interior		-	-	-	11	10.8	1.6	-	-	-	-	-	-	-	-	-
	Interdune/overwash	-	-	-	-	-	-	6	7	2.2	7	8.6	1.6	-	-	-

Table 55. Number of breeding pairs and overall productivity (chicks fledged/breeding pair) of Piping Plovers at Monomoy National Wildlife Refuge, Chatham, Massachusetts, 1991-2000. Data prior to 1998 were obtained from census forms and maps prepared by USFWS for Massachusetts Division of Fish and Wildlife.

Year	Gull-removal Area	Buffer Area	Reference Area				Monomoy NWR		
			Powder Hole	Ocean/ South Tip	Overwash Area	Reference Area Total	South Monomoy Island	North Monomoy Island	Monomoy NWR Total
Breeding Pairs									
1991	0	0	2	0	0	2	2	0	2
1992	0	0	3	0	0	3	3	0	3
1993	2	0	2	0	0	2	4	0	4
1994	3	0	4	0	0	4	7	0	7
1995	3	1	6	3	1	10	14	0	14
1996	5	1	8	5	0	13	19	1	20
1997	8	1	10	5	1	16	25	1	26
1998	9	1	10	5	2	17	27	1	28
1999	9	1	11	4	1	16	26	1	27
2000	7	0	14	6	1	21	28	2	30
Chicks fledged/Pair									
1991	-	-	0/2 (0.00)	-	-	0/2 (0.00)	0/2 (0.00)	-	0/2 (0.00)
1992	-	-	4/3 (1.33)	-	-	4/3 (1.33)	4/3 (1.33)	-	4/3 (1.33)
1993	4/2 (2.00)	-	4/2 (2.00)	-	-	4/2 (2.00)	8/4 (2.00)	-	8/4 (2.00)
1994	3/3 (1.00)	-	7/4 (1.75)	-	-	7/4 (1.75)	11/7 (1.57)	-	11/7 (1.57)
1995	3/3 (1.00)	0/1 (0.00)	5/6 (0.83)	5/3 (1.67)	0/1 (0.00)	10/10 (1.00)	13/14 (0.93)	-	13/14 (0.93)
1996	10/5 (2.00)	0/1 (0.00)	19/8 (2.38)	13/5 (2.60)	-	32/13 (2.46)	42/19 (2.21)	0/1 (0.00)	42/20 (2.10)
1997	16/8 (2.00)	2/1 (2.00)	19/10 (1.90)	7/5 (1.40)	0/1 (0.00)	26/16 (1.63)	44/25 (1.76)	2/1 (2.00)	46/26 (1.77)
1998	4/9 (0.44)	0/0 (0.00)	11/10 (1.10)	4/5 (0.80)	0/2 (0.00)	15/17 (0.88)	19/27 (0.70)	4/1 (4.00)	23/28 (0.82)
1999	5/9 (0.55)	0/0 (0.00)	20/11 (1.82)	10/4 (2.50)	0/1 (0.00)	30/16 (1.88)	35/26 (1.35)	3/1 (3.00)	38/27 (1.41)
2000	9/7 (1.29)	-	23/14 (1.64)	5/6 (0.83)	0/1 (0.00)	28/21 (1.33)	37/28 (1.32)	3/2 (1.50)	40/30 (1.33

Table 56. Number of breeding pairs and overall productivity (chicks fledged/breeding pair) of Piping Plovers at Monomoy National Wildlife Refuge, Chatham, Massachusetts, South Beach, Chatham, Massachusetts, the state of Massachusetts, and New England, 1991-2000. Data from Monomoy National Wildlife Refuge prior to 1998 were obtained from census forms and maps prepared by USFWS for Massachusetts Division of Fisheries and Wildlife. Data from South Beach were obtained from Massachusetts Division of Fisheries and Wildlife. Data from Massachusetts and New England were obtained from USFWS (Status Update, USFWS 2002).

Year	Monomoy NWR			South Beach, Chatham, MA	Massachusetts	New England
	South Monomoy Island	North Monomoy Island	Total			
Breeding Pairs						
1991	2	0	2	5	160	240
1992	3	0	3	8	213	297
1993	4	0	4	13	289	376
1994	7	0	7	15	352	449
1995	14	0	14	30	441	552
1996	19	1	20	32	454	590
1997	25	1	26	35	483	619
1998	27	1	28	40	495	627
1999	26	1	27	41	501	624
2000	28	2	30	34	496	623
Chicks Fledged/Pair						
1991	0/2 (0.00)	-	0/2 (0.00)	12/5 (2.40)	.	.
1992	4/3 (1.33)	-	4/3 (1.33)	13/8 (1.63)	2.03	1.91
1993	8/4 (2.00)	-	8/4 (2.00)	28/13 (2.15)	1.92	1.85
1994	11/7 (1.57)	-	11/7 (1.57)	24/15 (1.60)	1.80	1.81
1995	13/14 (0.93)	-	13/14 (0.93)	37/30 (1.23)	1.62	1.67
1996	42/19 (2.21)	0/1 (0.00)	42/20 (2.10)	43/32 (1.34)	1.35	1.40
1997	44/25 (1.76)	2/1 (2.00)	46/26 (1.77)	31/35 (0.89)	1.33	1.39
1998	19/27 (0.70)	4/1 (4.00)	23/28 (0.82)	30/40 (0.75)	1.50	1.46
1999	35/26 (1.35)	3/1 (3.00)	38/27 (1.41)	27/41 (0.66)	1.60	1.62
2000	37/28 (1.32)	3/2 (1.50)	40/30 (1.33	17/34 (0.50)	1.09	1.18

FIGURES

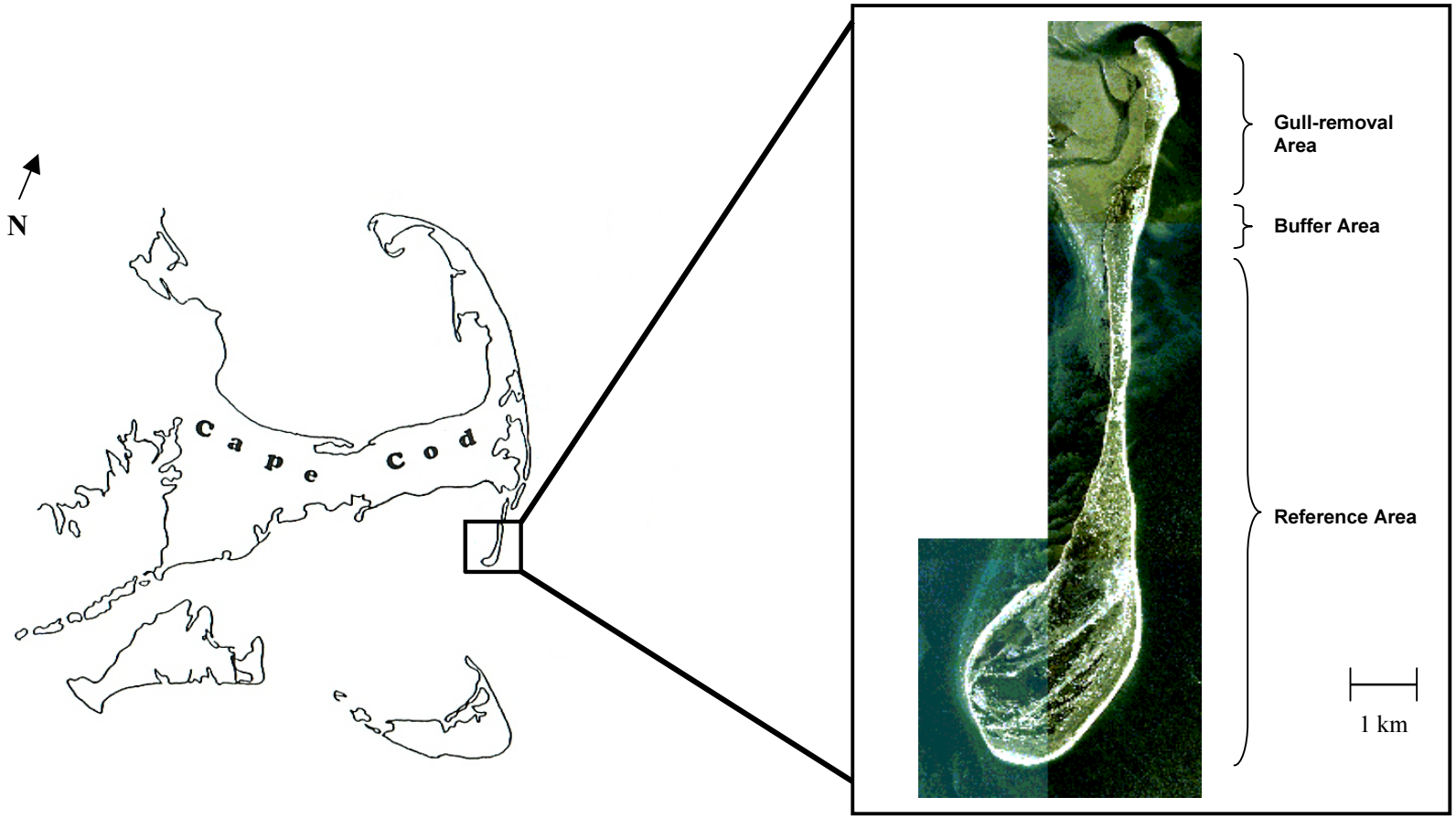


Figure 1. Location of South Monomoy Island on Cape Cod, Massachusetts, and management areas used in this study based on the 1996 USFWS Restoration of Avian Diversity project. (Orthophotographs taken 1 September 1994, Coastal Color Orthophotos index numbers 325810, 329810, 329814, and 329818, MassGIS, Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.)

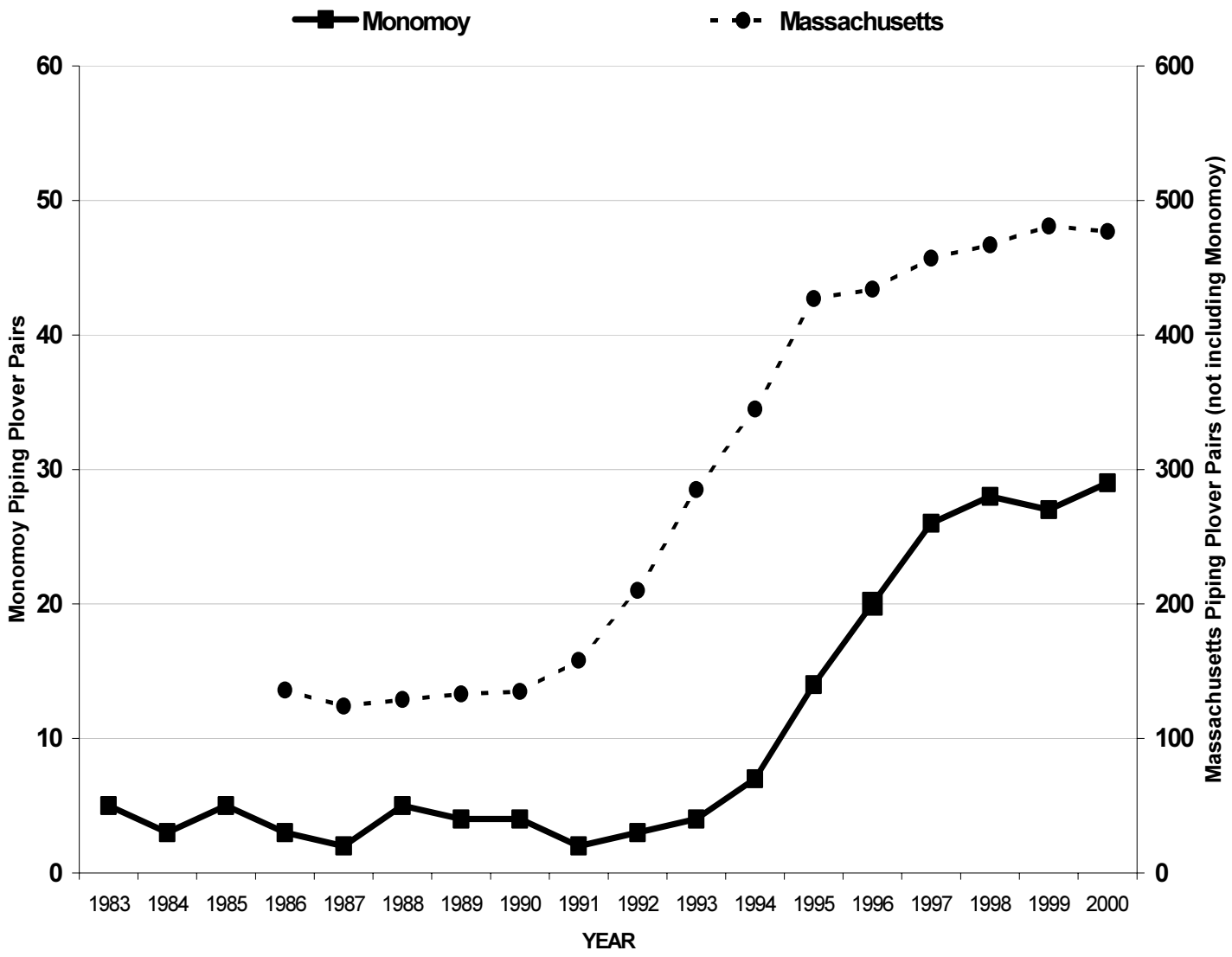


Figure 2. Number of Piping Plover pairs at Monomoy National Wildlife Refuge (includes both North and South Monomoy Islands) from 1983 to 2000 (with larger square marking the year of gull removal, and number of Piping Plover pairs in Massachusetts (not including the Monomoy Islands) from 1986 to 2000 (USFWS 2002).

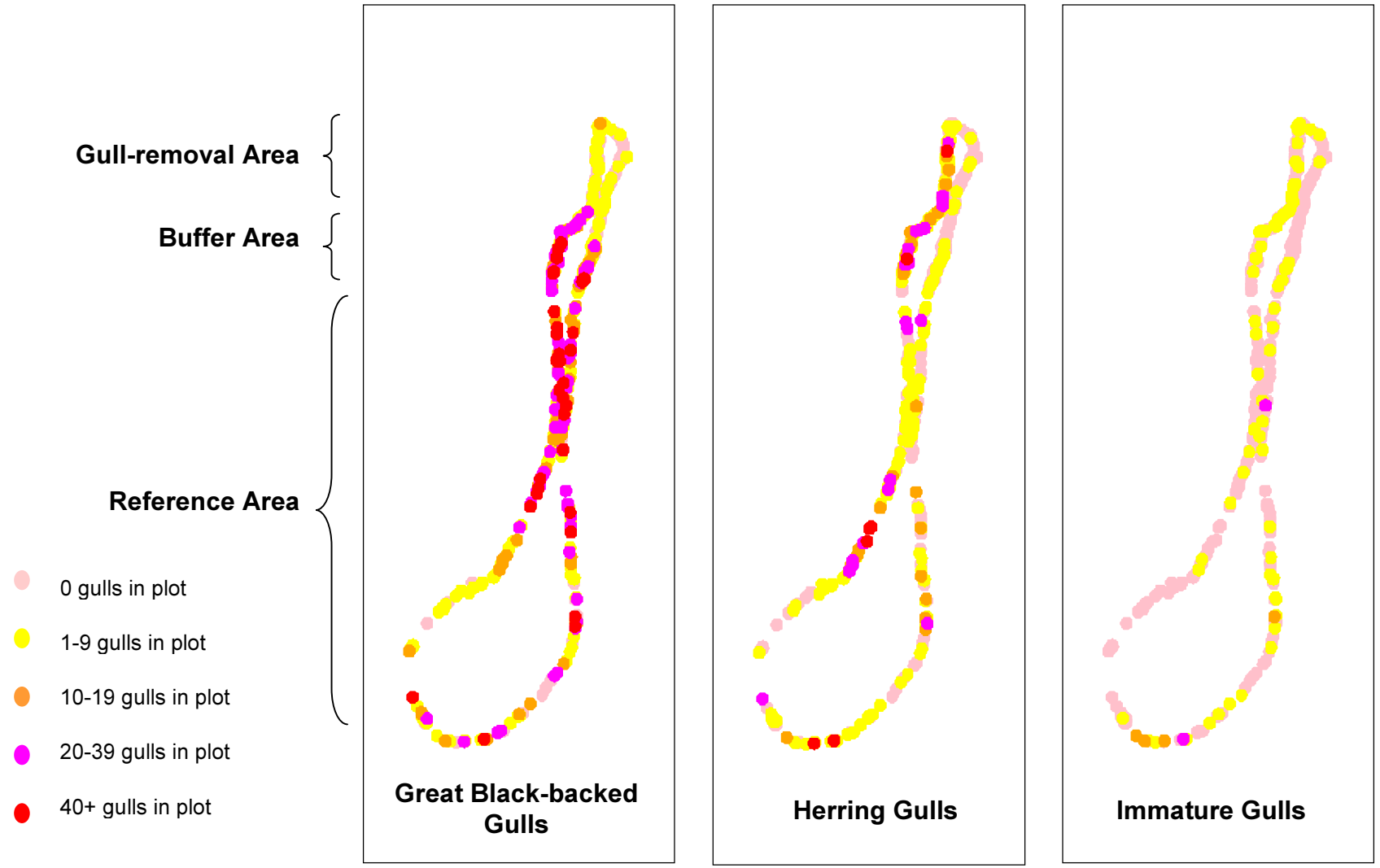


Figure 3. Relative gull abundance and distribution based on counts of gulls in random 100 m-radius plots, during the Piping Plover prenesting period, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000.

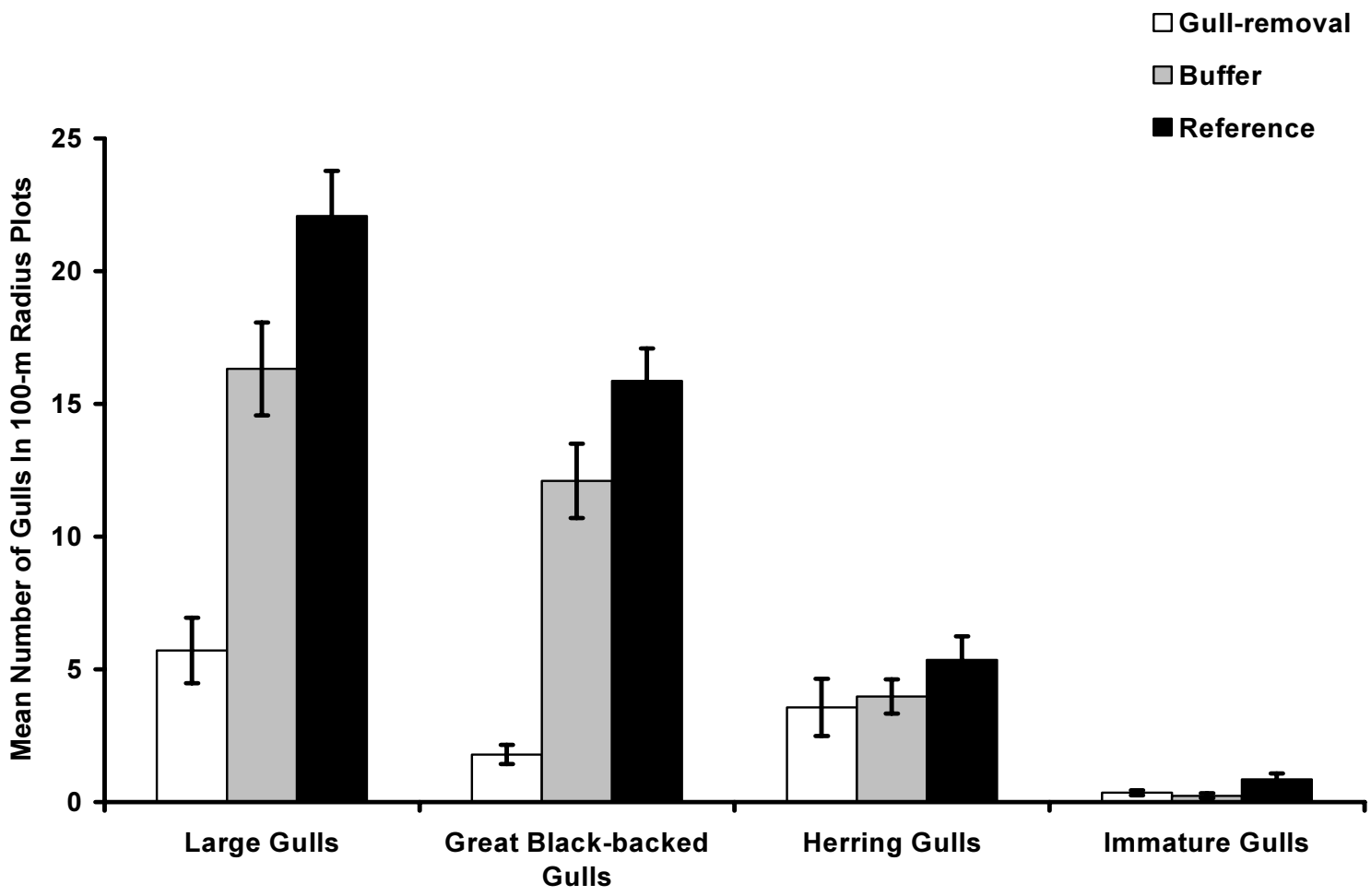


Figure 4. Relative gull abundance among the management areas based on mean counts of gulls in random 100 m-radius plots, during the Piping Plover prenesting period, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean.

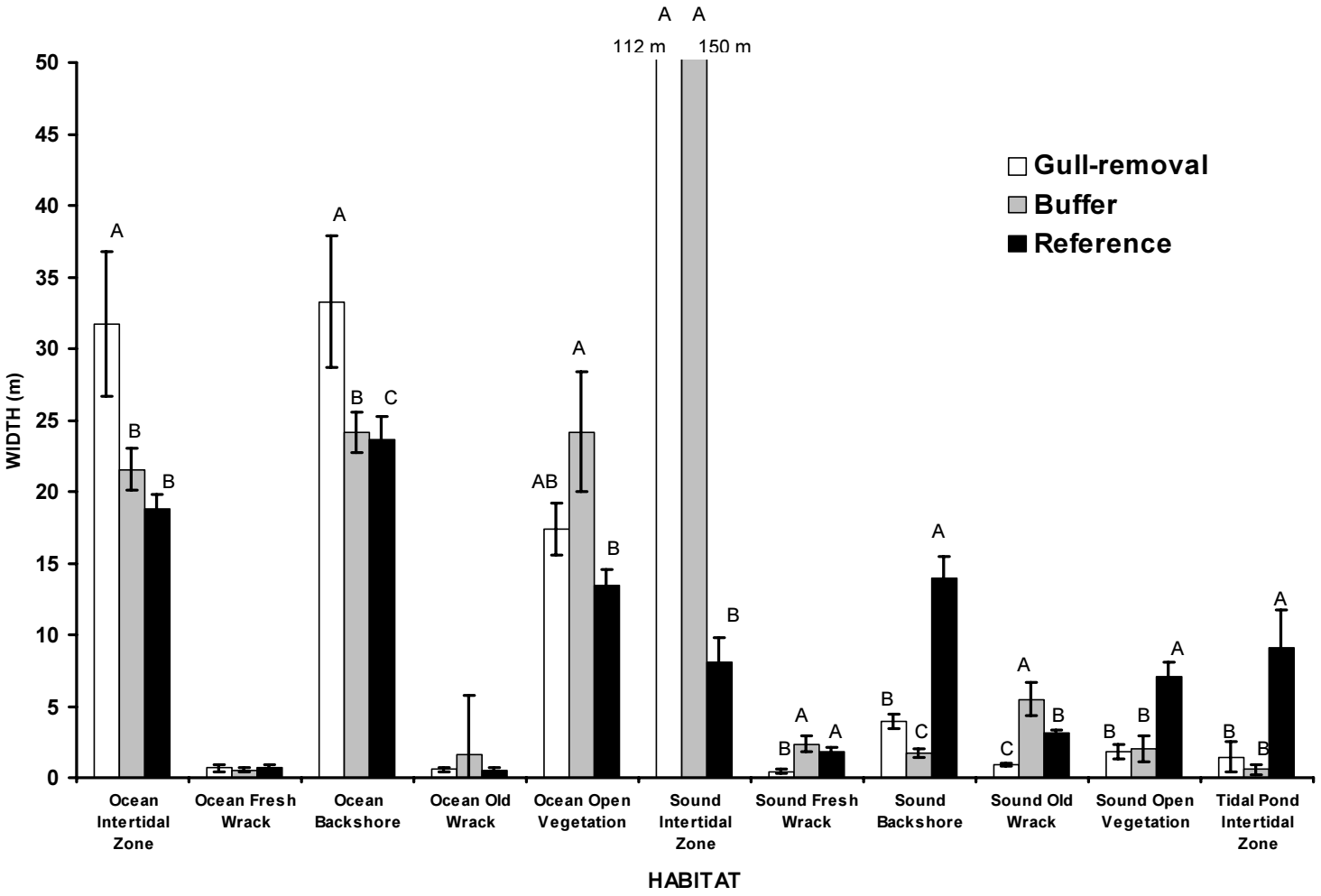
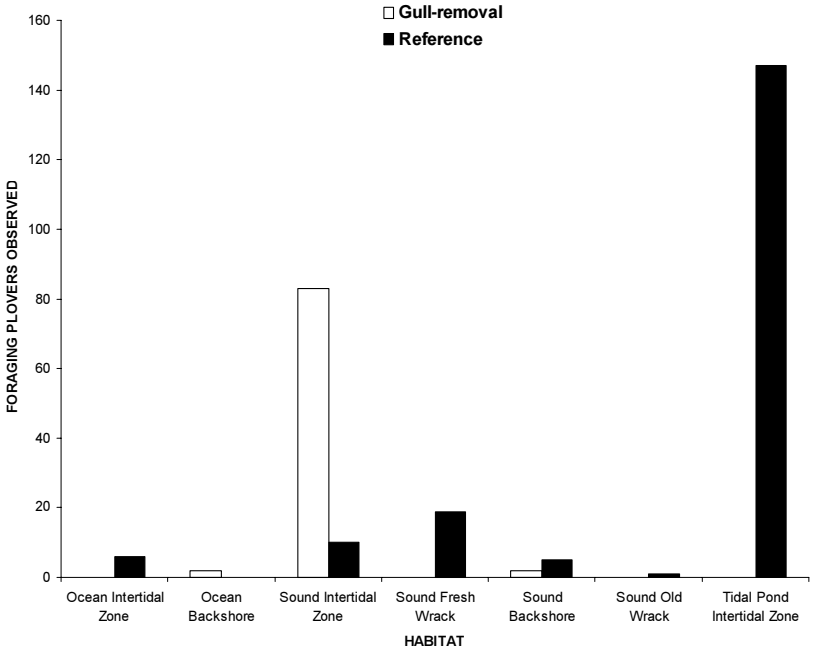


Figure 5. Mean width of habitats (m) measured along random transects, among the management areas (gull-removal: n = 50, buffer: n = 62, reference: n = 116), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean. For each habitat where a difference was found among the management areas (MRPP, $P \leq 0.05$), pairwise comparisons were conducted. Bars labeled with the same letters within the same habitat were not significantly different (MRPP, $P > 0.5$).

a)



b)

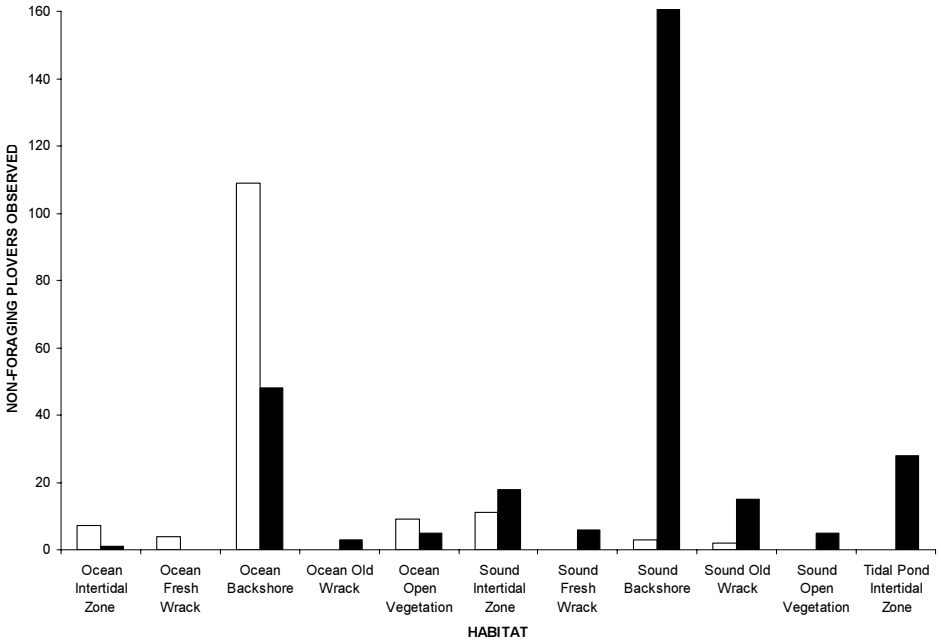


Figure 6. Habitat use between the management areas by foraging (a), and nonforaging (b) Piping Plovers during the prenesting period, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Both foraging and nonforaging plovers did not use habitat in equal proportions between the management areas (foraging: $n = 275$, $df = 6$, $= 227.13$, $P < 0.0001$ with the largest partial chi-square statistics for sound intertidal zone and tidal pond intertidal zone habitats; nonforaging: $n = 556$, $df = 6$, $= 301.95$, $P < 0.0001$ with the largest partial chi-square statistics for ocean and sound backshore habitats). Missing columns represent zero plovers observed in the habitat.

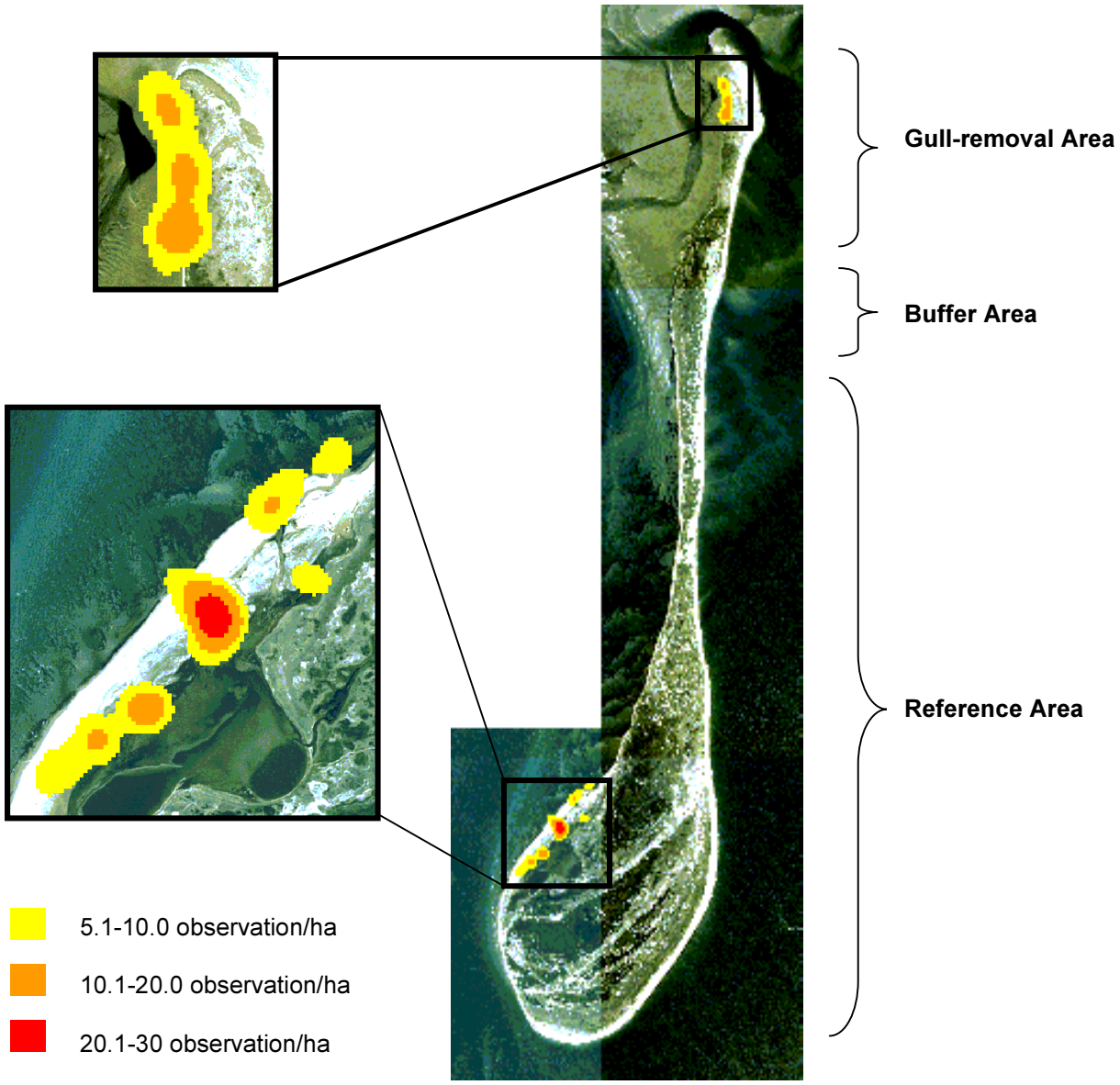


Figure 7. Approximate locations and frequency of observations of foraging Piping Plovers observed throughout the prenesting period, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. ArcView 3.1 was used to generate Kernal density estimates of observations per ha (search radius = 100 m, cell size = 10, rows = 1200, columns = 800). Locations of observations were obtained using Garmin 12 hand-held GPS units. Upper left shows observations of plovers in the gull-removal area mostly in the sound-side intertidal zone or sand flat habitat. Lower left shows observations of plovers in the reference area mostly in the tidal pond intertidal zone habitat. (Orthophotographs taken 1 September 1994, Coastal Color Orthophotos index numbers 325810, 329810, 329814, and 329818, MassGIS, Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.)

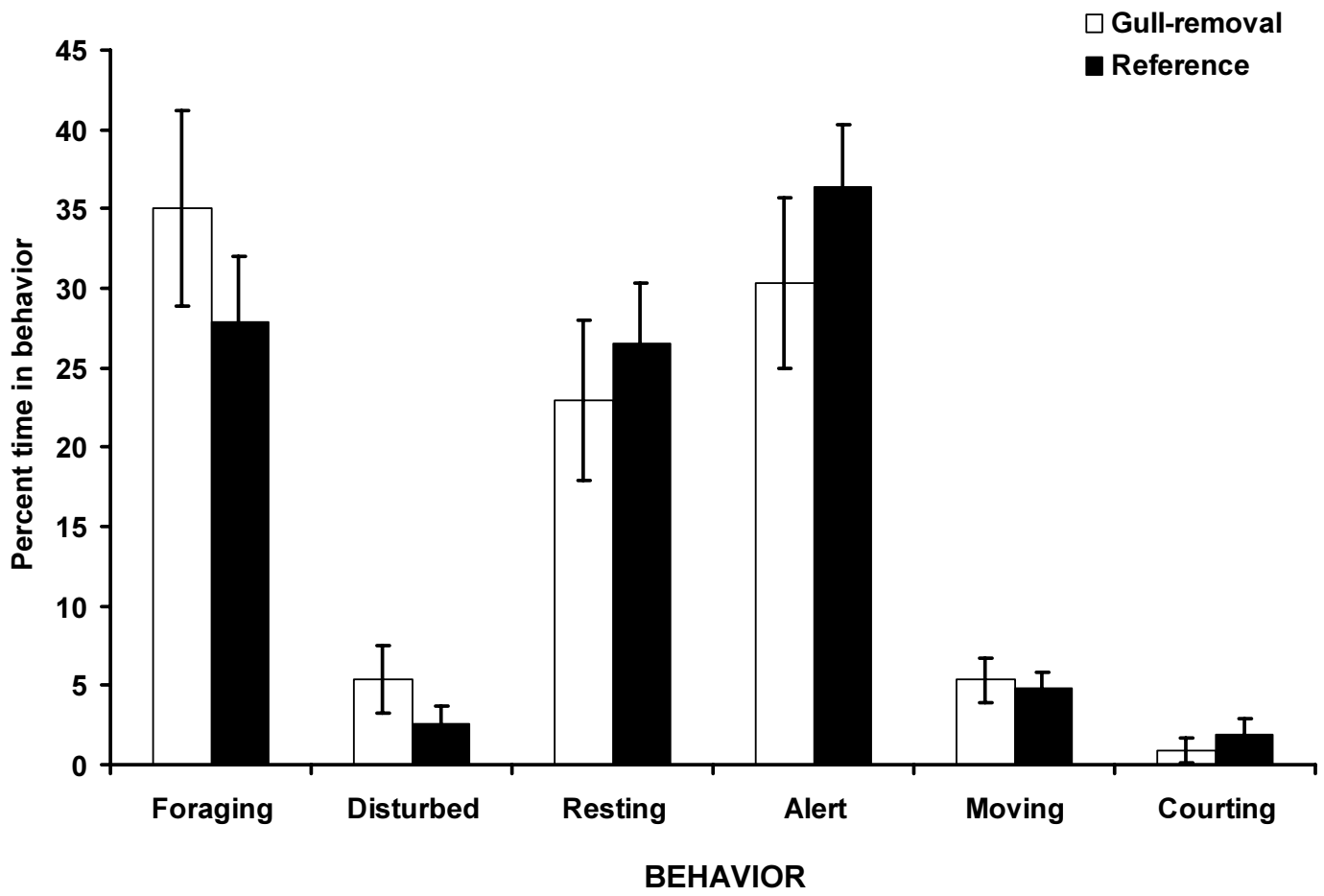


Figure 8. Mean percent time Piping Plovers were observed in different behaviors during 5-minute observations during the prenesting period, between the gull-removal area (n = 53) and the reference area (n = 93), South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean. There were no differences between the management areas in percent time in behaviors (MRPP, $P > 0.05$).

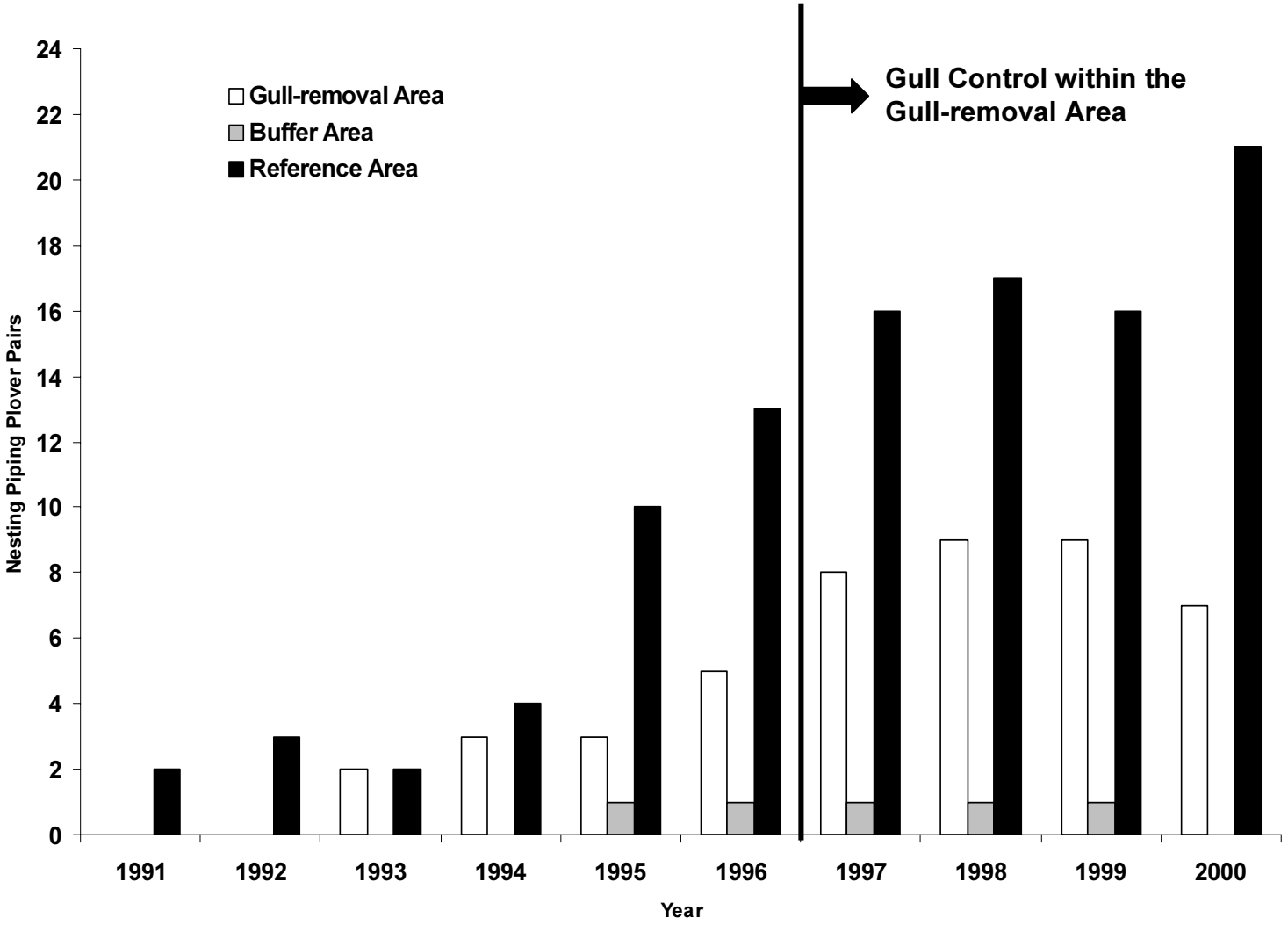


Figure 9. Number of nesting Piping Plover pairs, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1991-2000 (USFWS census data 1991-1997). Missing columns represent zero nesting Piping Plovers in the management area that year.

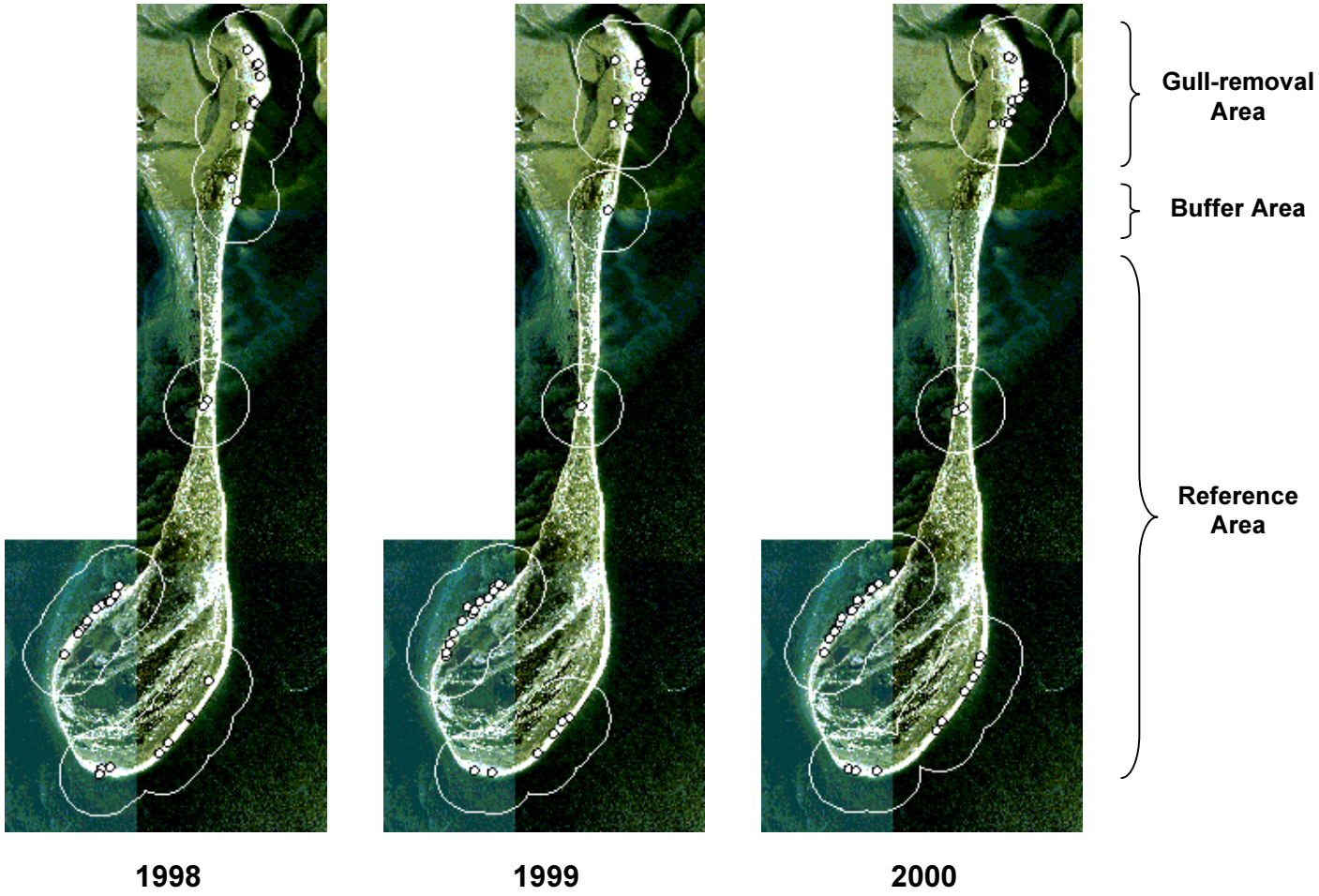


Figure 10. Approximate locations of Piping Plover nests with the boundary between the nesting ($\geq$ 500 m from all nest locations) and unused areas delineated, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. Locations were obtained using Garmin 12 hand-held GPS units. (Orthophotographs taken 1 September 1994, Coastal Color Orthophotos index numbers 325810, 329810, 329814, and 329818, MassGIS, Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.)

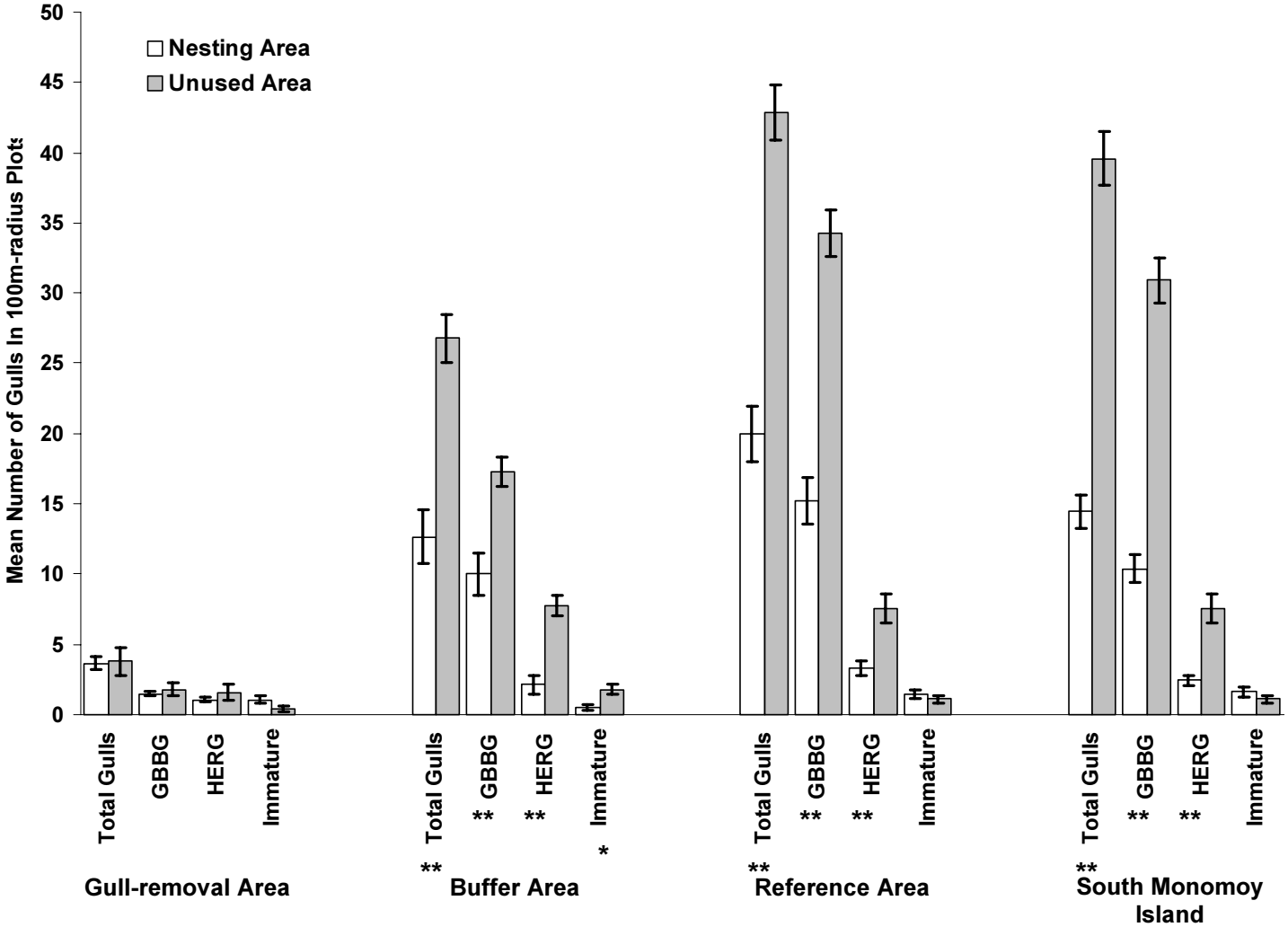


Figure 11. Relative gull abundance in nesting and unused areas based on mean counts of gulls in random 100 m-radius plots, by the management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. (GBBG = Great Black-backed Gulls, HERG = Herring Gulls, Immature = immature large gulls. Error bars represent the standard error of the mean. Where significant differences were found between management areas using MRPP, ** = $P < 0.0001$, and * = $P < 0.05$.

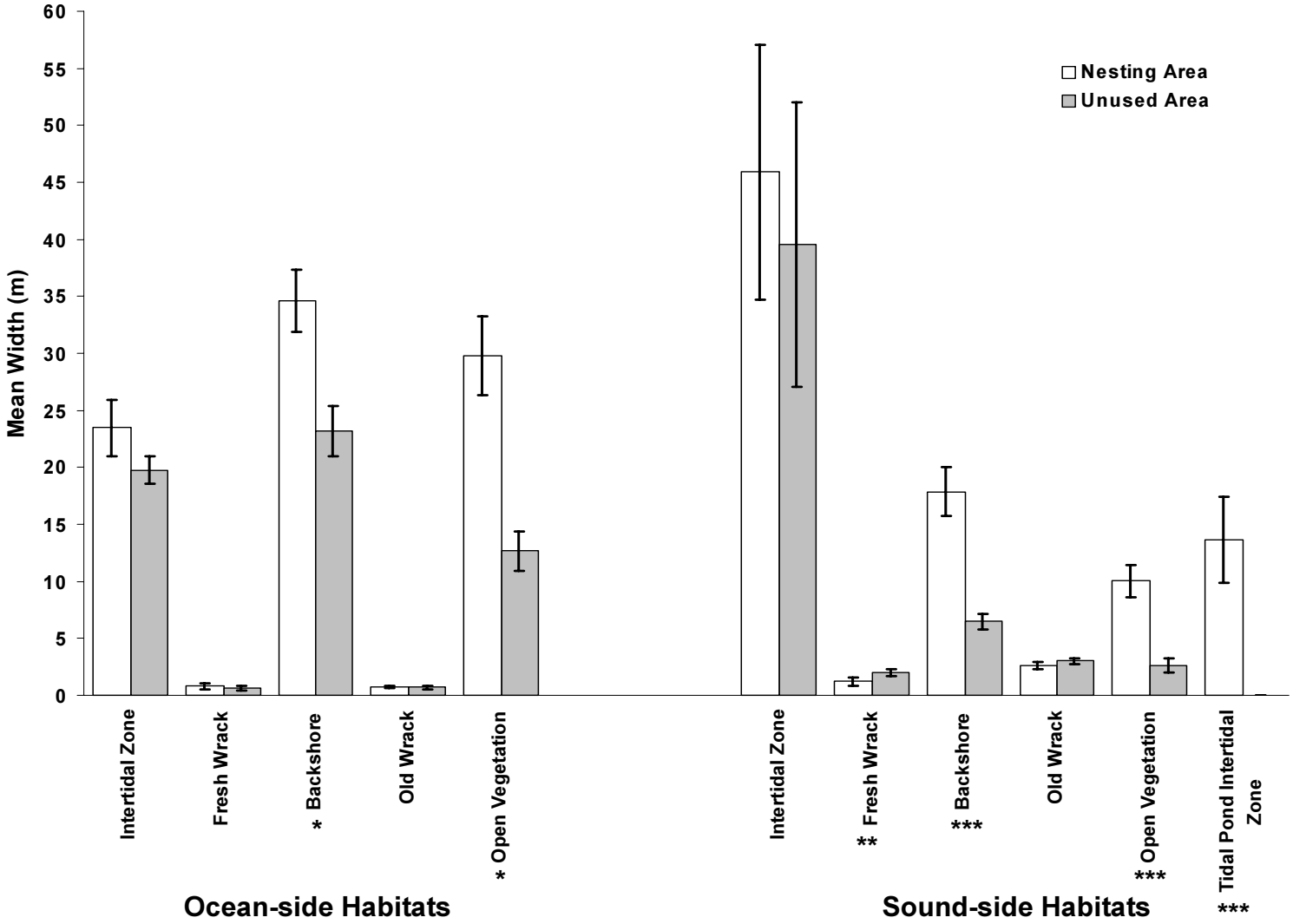


Figure 12. Mean width of habitats (m) measured along random transects, in nesting and unused areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean. Where significant differences were found between management areas using MRPP, *** = $P < 0.0001$, ** = $P < 0.001$, and * = $P < 0.01$. There was no tidal pond intertidal zone habitat in the unused area.

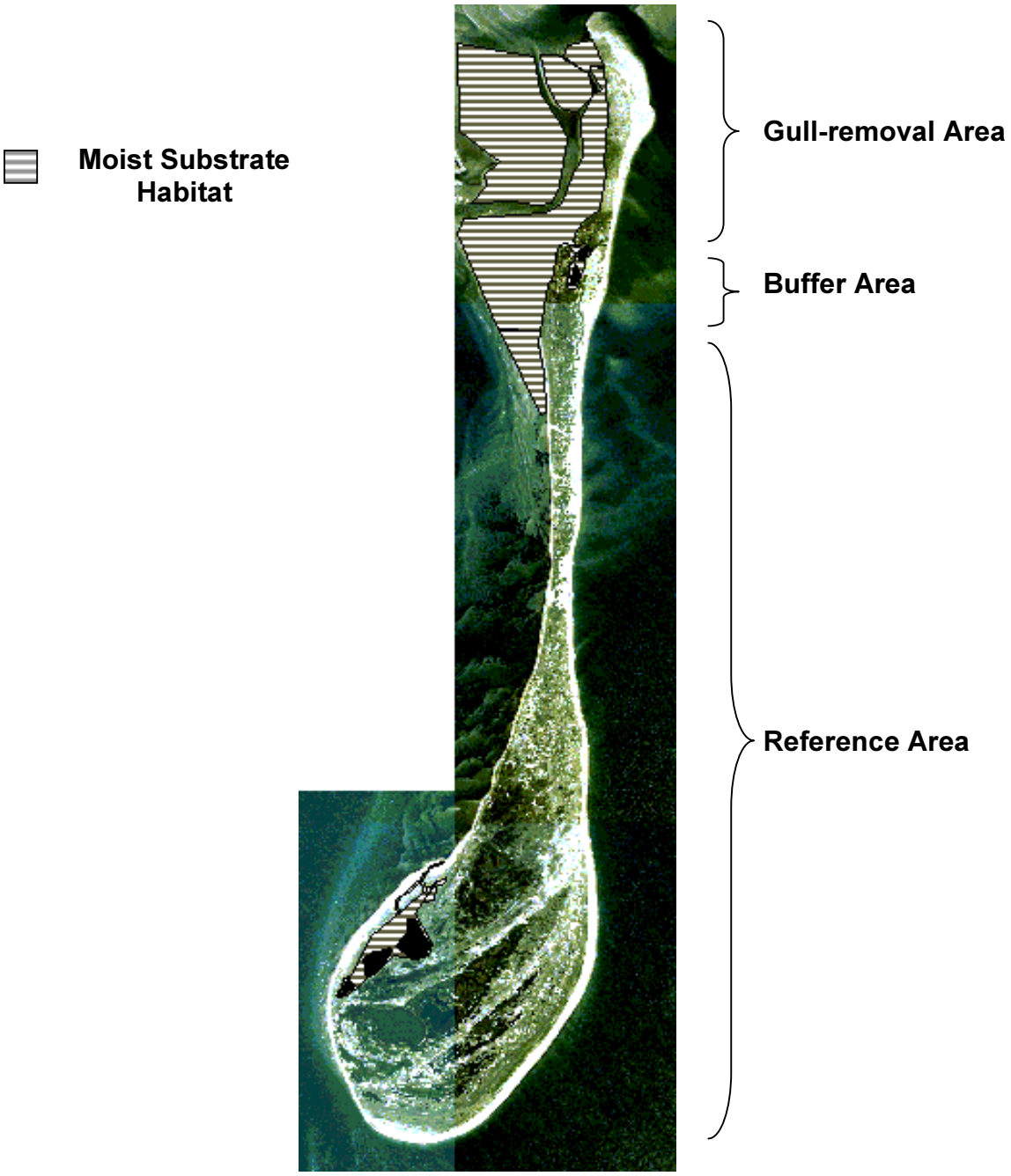


Figure 13. Moist substrate habitat on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000. Polygons layered over orthophotographs were delineated using ArcView Version 3.1 (ESRI). (Orthophotographs taken 1 September 1994, Coastal Color Orthophotos index numbers 325810, 329810, 329814, and 329818, MassGIS, Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.)

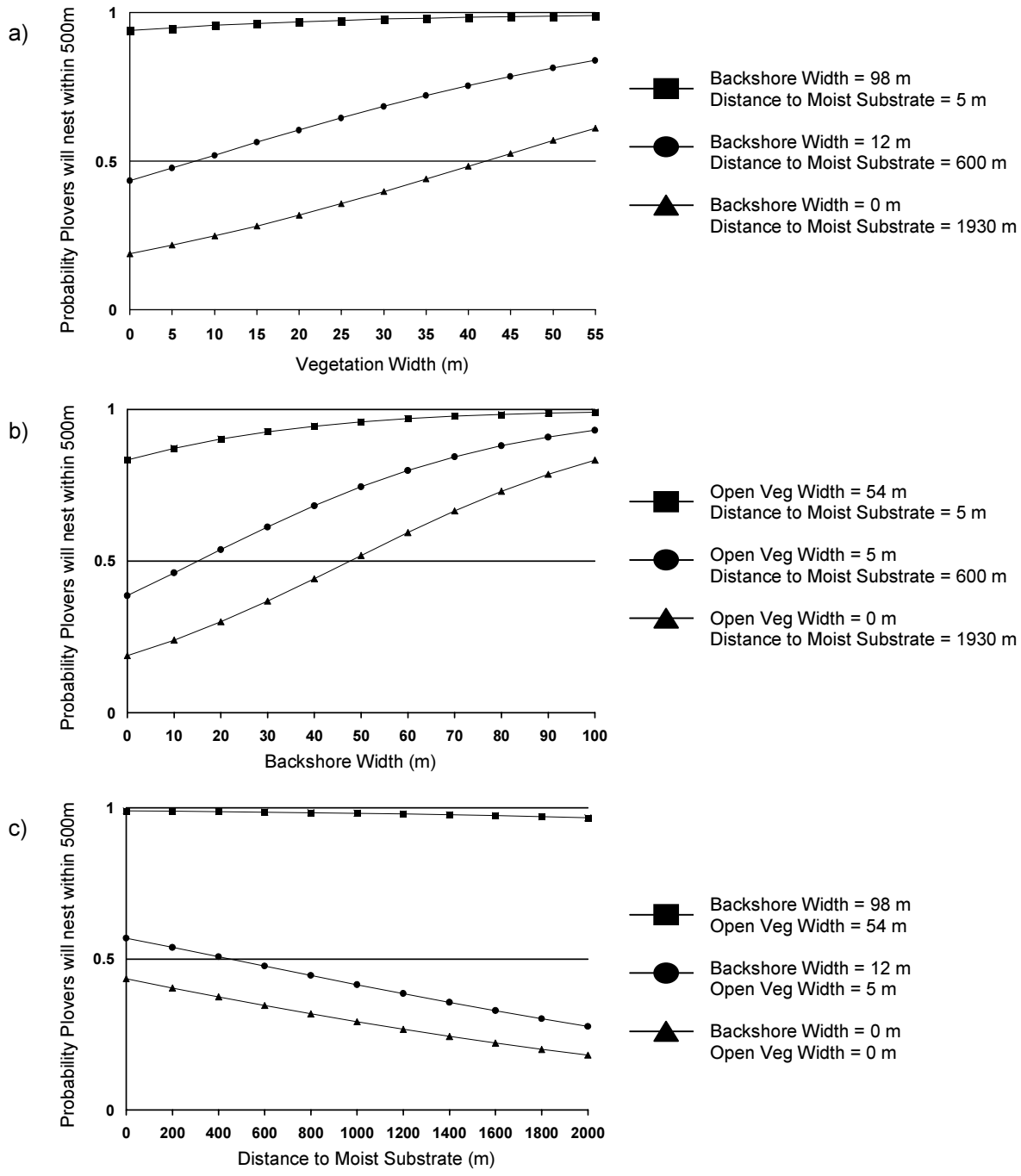


Figure 14. Curves depicting the probability that Piping Plovers will nest within 500 of areas on South Monomoy Island given different backshore widths (m), open vegetation widths (m) and distances (m) to moist substrate habitats.

Logistic Regression Equation:

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

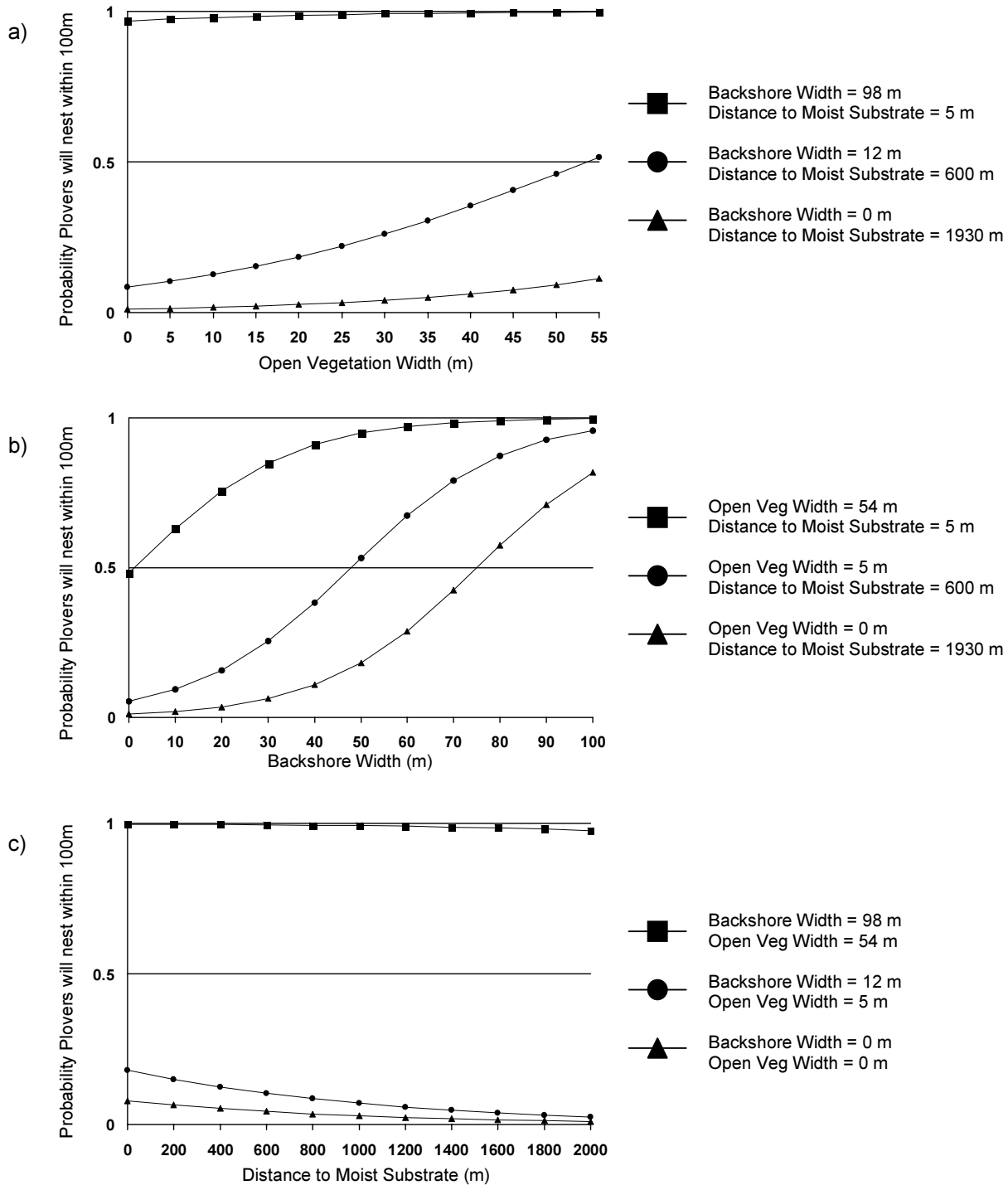


Figure 15. Curves depicting the probability that Piping Plovers will nest within 100 of areas on South Monomoy Island given different backshore widths (m), open vegetation widths (m) and distances (m) to moist substrate habitats.

Logistic Regression Equation:

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

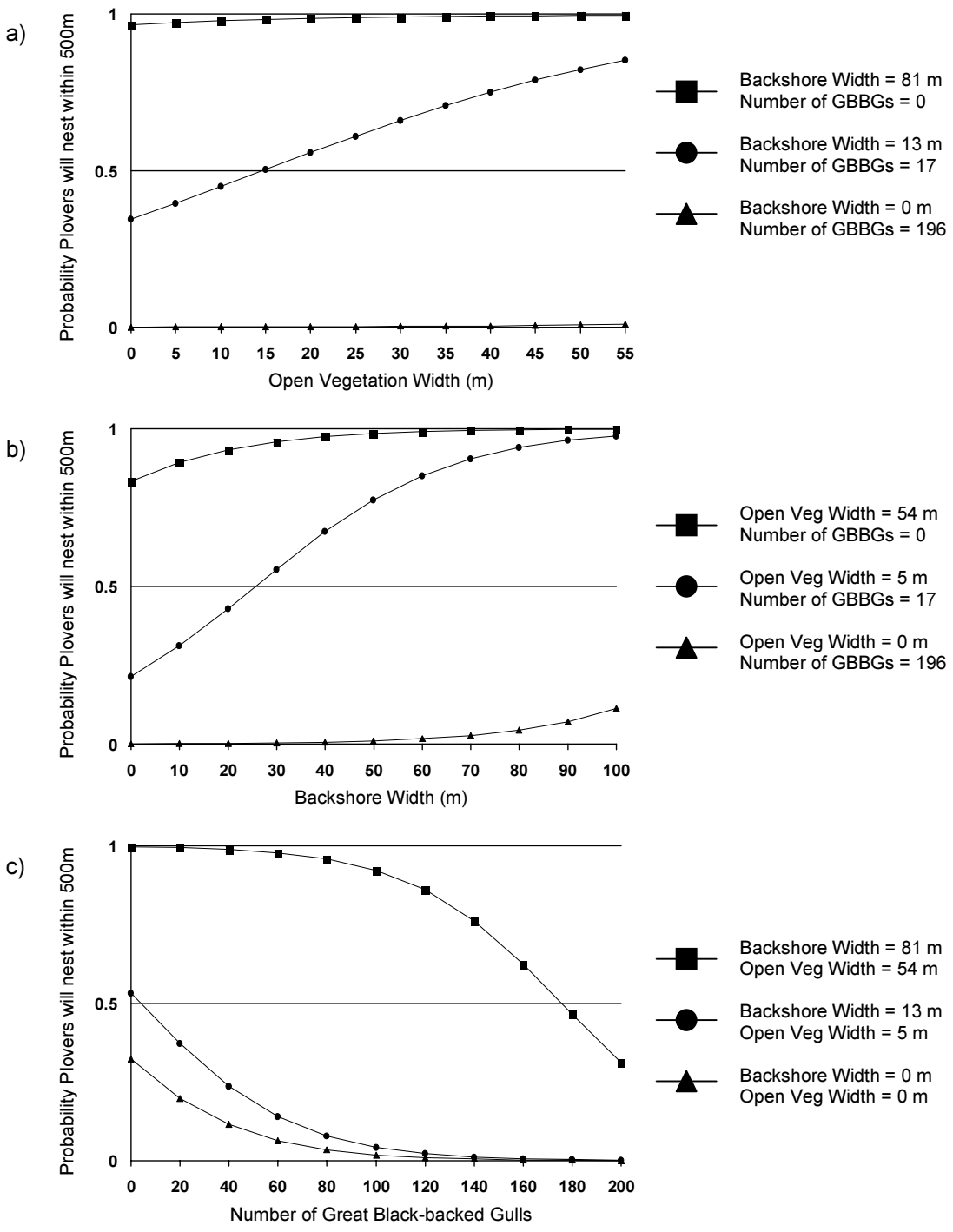


Figure 16. Curves depicting the probability that Piping Plovers will nest within 500 of areas in the reference area, South Monomoy Island, given different backshore widths (m), open vegetation widths (m) and numbers of Great Black-backed Gulls.

Logistic Regression Equation:

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

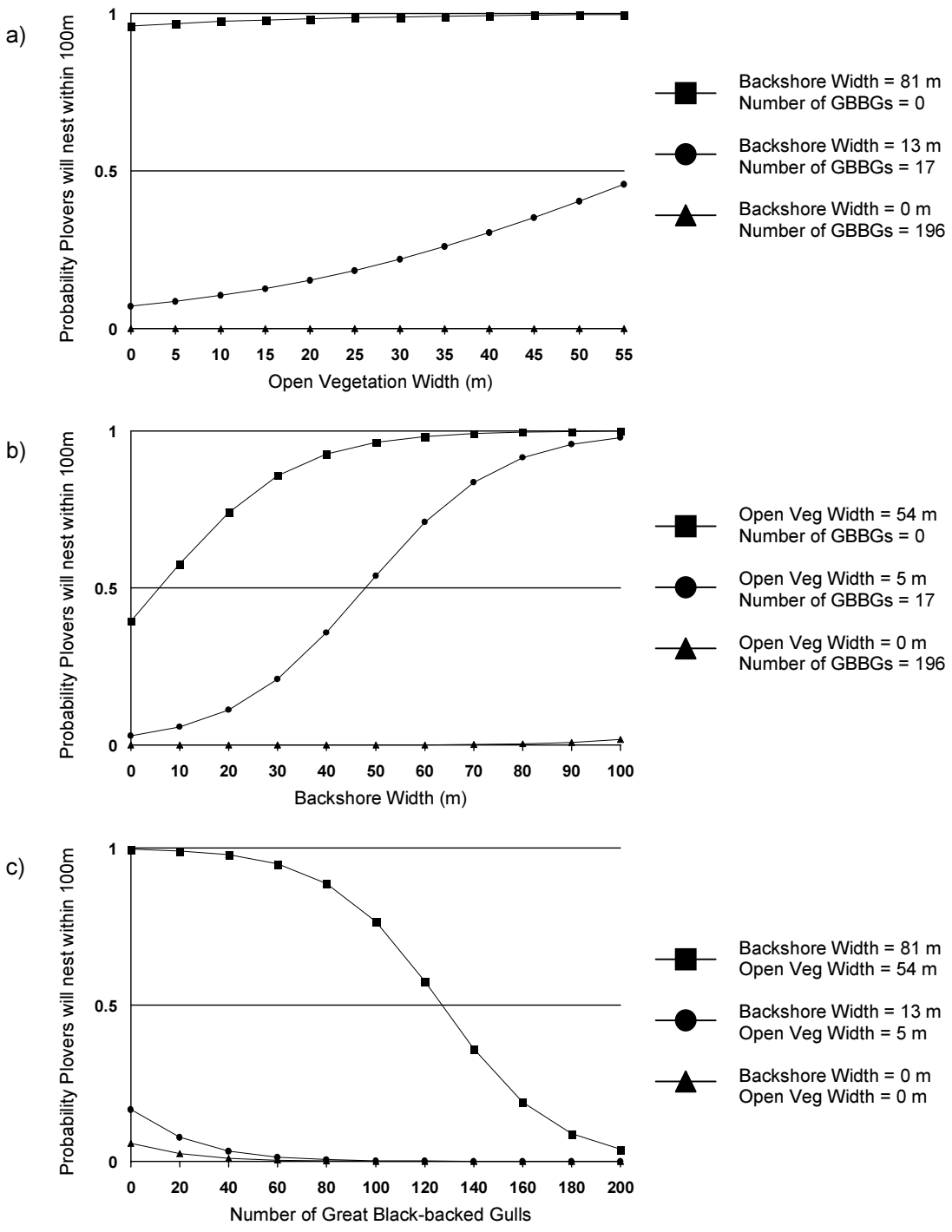


Figure 17. Curves depicting the probability that Piping Plovers will nest within 500 of areas in the reference area, South Monomoy Island given different backshore widths (m), open vegetation widths (m) and numbers of Great Black-backed Gulls.

Logistic Regression Equation:

[a] $\theta = 1 / (1 + \exp [- (\beta_0 + \sum_{j=1} \beta_j X_{ij})])$ $\quad i = 1,2,\ldots,n$

θ = Probability that plover(s) will nest in the area (nesting area), β_0 = beta value of the intercept, β_j = beta value of the j dependent variables, and X_{ij} = data values for the k independent variables.

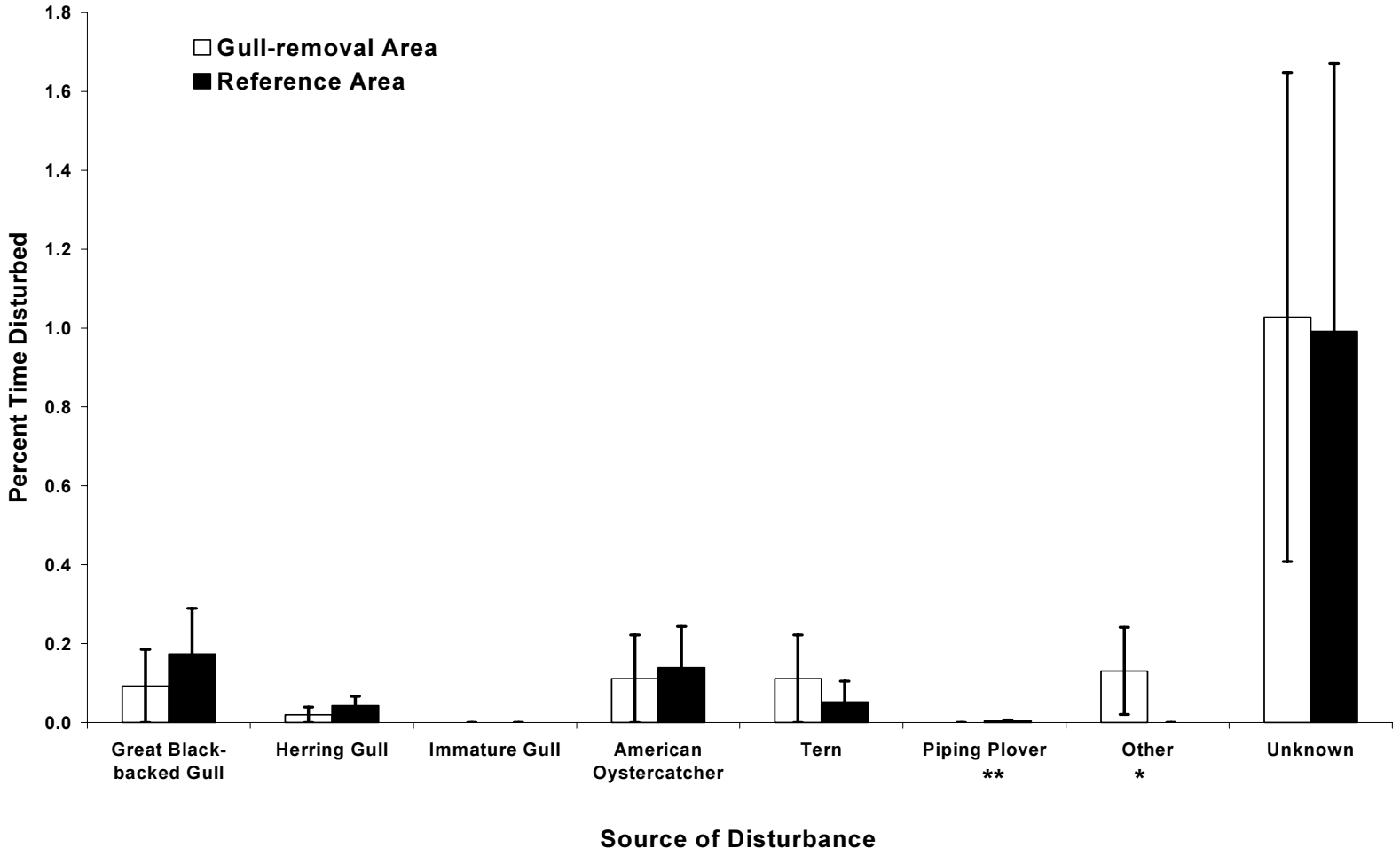


Figure 18. Mean percent time incubating Piping Plovers were observed disturbed by various sources during 5-minute observations, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean. Where significant differences were found between the management areas using MRPP, ** = $P < 0.0001$, and * = $P < 0.01$. Missing columns represent zero percent time disturbed.

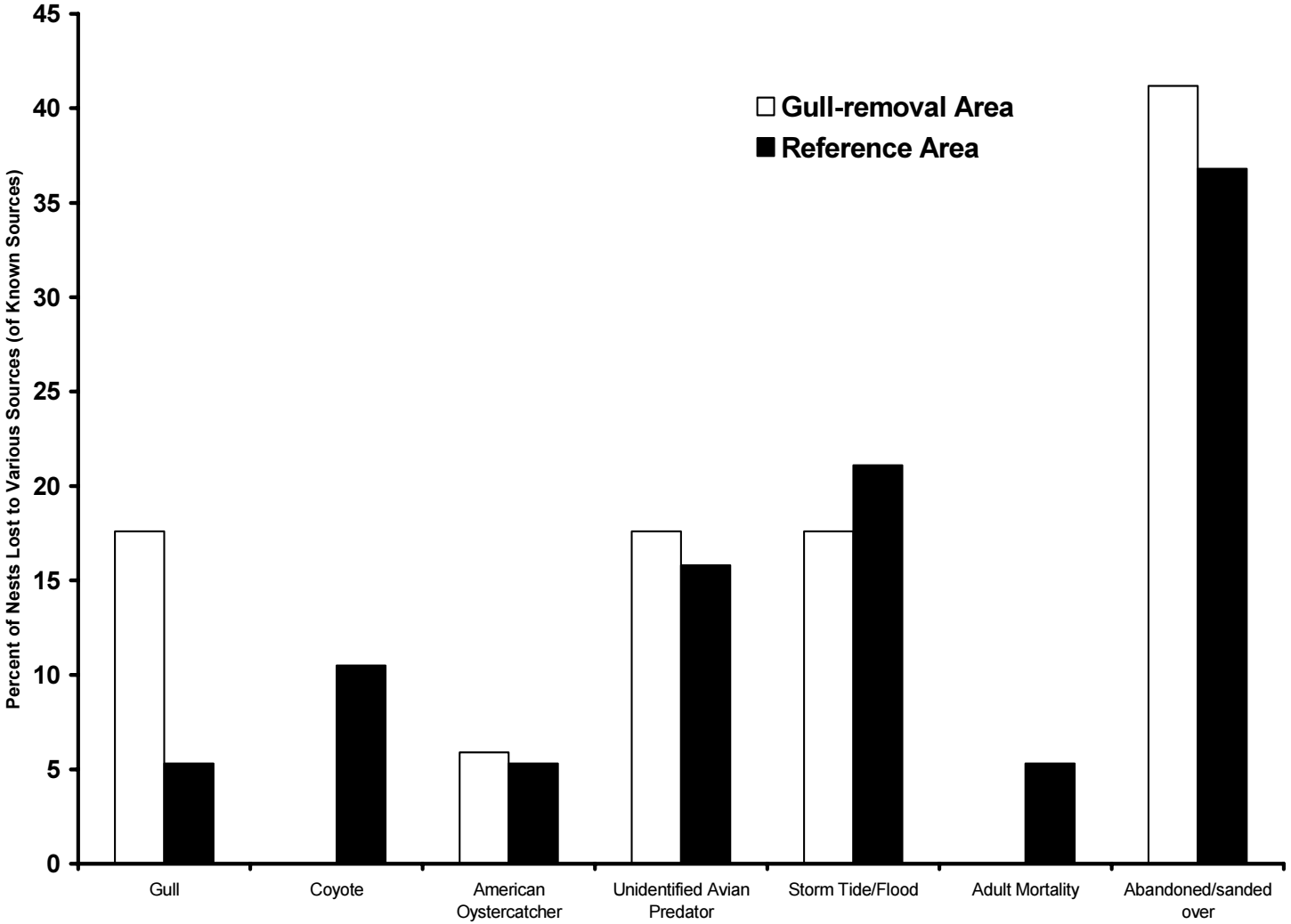


Figure 19. Percent of Piping Plover nest loss to various sources of nests lost when cause was known, South Monomoy Island, by management area, Cape Cod, Massachusetts, 1998-2000. Missing columns represent zero nests lost to the specific source.

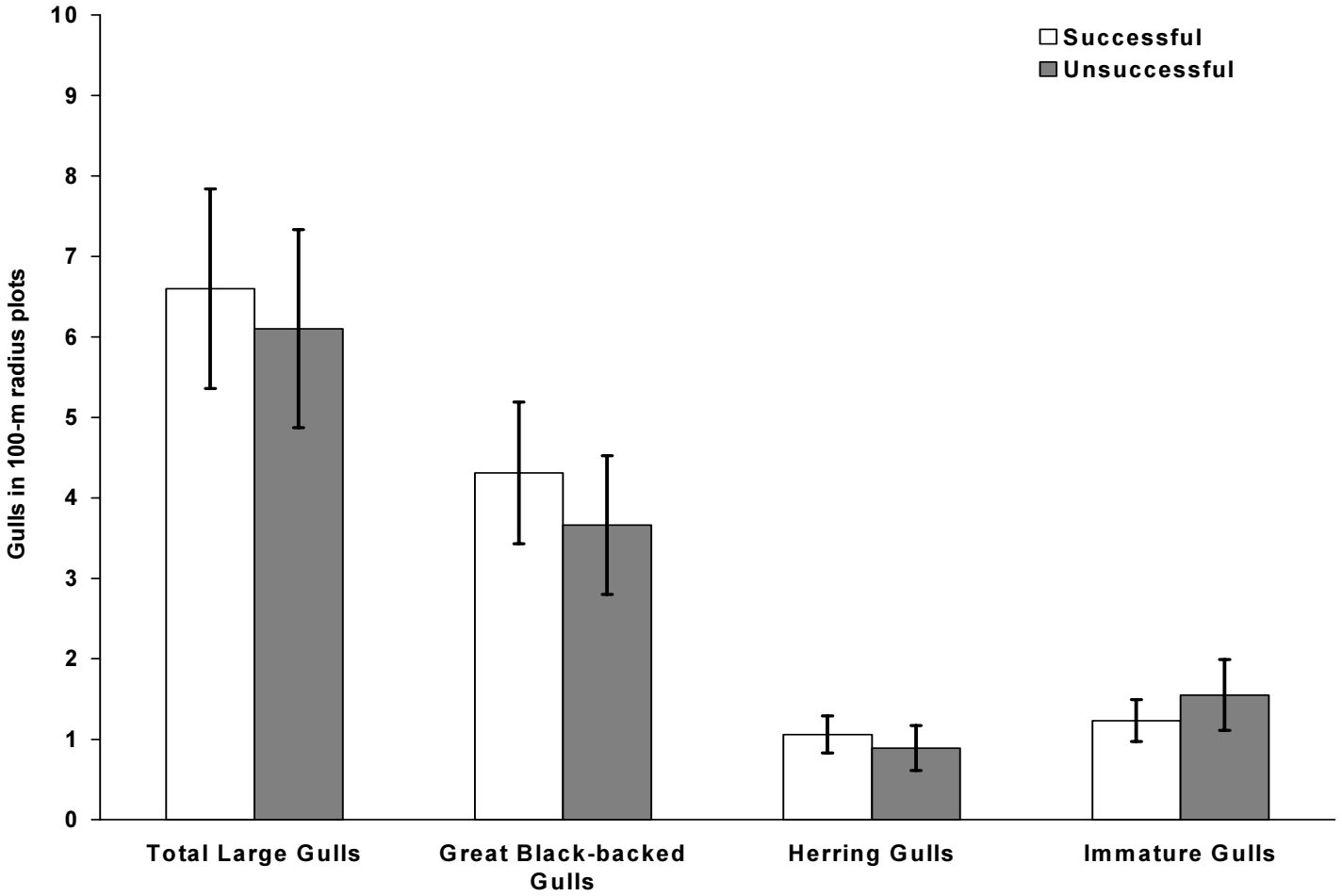


Figure 20. Mean number of gulls within 100 m of successful and unsuccessful nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. Error bars represent the standard error of the mean. There was no difference in the number of large gulls within 100 m of successful and unsuccessful nests.

APPENDICES

Appendix A. Individual Piping Plover nest and brood chronology, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Table A-1. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
1998, Gull-removal Area														
N02A	NO	OB	5/08	5/08	-	1	-	1	5/10	STRM	-	0	-	-
N02B	NO	OB	5/16	5/15	-	1	-	1	5/18	ABAN	-	0	-	-
N02C	NO	OV	6/18	-	-	4	-	4	6/20	GULL	-	0	-	-
N03A	NT	OB	5/16	-	-	3	5/20	3	5/29	ABAN	-	0	-	-
N04A	NS	SV	5/18	5/13	5/19	4	5/20	4	5/23	STRM	-	0	-	-
N05A	NT	OV	5/23	5/20	5/26	4	5/26	0	-	-	6/20	4	0	2
N06A	NO	OV	5/26	5/18	5/24	4	5/26	0	-	-	6/19	4	0	0
N08A	NT	OV	5/26	-	-	-	-	-	5/26	AVPR	-	0	-	-
N08B	NT	OV	5/31	5/30	6/07	4	6/10	4	6/28	ABAN	-	0	-	-
N09A	NO	OB	6/01	5/27	6/03	4	6/11	0	-	-	6/28	4	0	0
N10A	NO	OB	6/07	5/23	5/29	4	6/11	0	-	-	6/27	4	0	0
N12A	NO	OV	6/27	6/26	6/30	3	7/04	0	-	-	7/26	3	0	2

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
1998, Buffer Area														
N01A	BA	OV[e]	5/08	5/04	-	3	-	3	5/10	UNKN	-	0	-	-
N01B	BA	OB	5/26	-	-	4	5/30	4	6/04	ABAN	-	0	-	-
1998, Reference Area														
S01A	PH	SB	5/14	5/08	5/14	4	5/23	0	-	-	6/11	4	0	1
S02A	PH	SV	5/14	5/10	5/16	4	-	4	5/25	UNKN	-	0	-	-
S02B	PH	SB	6/07	-	-	4	-	4	6/13	UNKN	-	0	-	-
S02C	PH	SB	2/23	6/20	6/24	3	6/27	0	-	-	7/19	2	1	1
S03A	ST	OV	5/15	5/14	5/21	4	-	4	6/12	AVPR	-	0	-	-
S04A	ST	OB	5/15	-	-	4	-	4	5/21	COYO	-	0	-	-
S04B	ST	OB	6/07	5/26	5/31	4	-	2[f]	-	-	6/28	2	0	2
S05A	PH	SB	5/15	5/05	5/11	4	5/23	0	-	-	6/07	3	1	1
S06A	PH	SB	5/15	5/15	5/24	4	5/28	0	-	-	6/16	4	0	0
S07A	PH	SB	5/15	5/13	5/19	4	5/23	0	-	-	6/12	4	0	4
S08A	PH	SV	5/17	-	-	3	-	3	6/04	UNKN	-	0	-	-
S08B	PH	SV	6/17	6/14	6/20	4	6/27	3[f]	-	-	7/19	1	0	1
S09A	EO	OV	5/18	-	-	4	-	4	5/26	COYO	-	0	-	-
S09B	EO	OB	6/07	-	-	3	-	3	6/12	UNKN	-	0	-	-

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
1998, Reference Area, Continued.														
S10A	EO	OV	5/23	5/20	5/26	4	-	4	6/12	UNKN	-	0	-	-
S10B	EO	OB	6/23	6/22	-	3	-	3	6/27	GULL	-	0	-	-
S11A	PH	SV	5/25	-	-	3	-	3	6/13	UNKN	-	0	-	-
S12A	PH	SB	5/27	5/26	6/01	4	6/22	0	-	-	6/26	3	1	0
S13A	EO	OV	5/30	5/27	6/03	4	-	4	6/12	UNKN	-	0	-	-
S13B	EO	OV	6/21	6/20	6/26	4	-	0	-	-	7/21	4	0	2
S14A	PH	TB	6/08	-	-	3	6/21	3	6/29	STRM	-	0	-	-
S15A	PH	SB	6/17	6/08	6/14	4	6/21	0	-	-	7/11	3	1	3
N07A	WA	OB	5/29	6/20	6/26	4	5/30	0	-	-	6/22	4	0	0
N11A	WA	OV	6/22	-	-	4	6/27	4	7/15	ABAN	-	0	-	-

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
1999, Gull-removal Area														
06A	NO	OV	5/07	5/07	5/12	4	5/14	4	5/16	ABAN	-	0	-	-
06B	NO	OV	5/29	5/29	6/05	3	-	3	6/09	GULL	-	0	-	-
08A	NO	OB	5/11	5/11	5/17	4	5/17	0	-	-	6/12	4	0	1
10A	NT	OV	5/13	5/08	5/13	4	5/14	0	-	-	6/12	4	0	2
22A	NO	OV	5/31	5/28	6/03	4	-	0	-	-	6/29	4	0	2
24A	NO	OB	6/01	6/01	6/06	4	-	4	6/10	GULL	-	0	-	-
25A	NT	OV	6/02	5/26	5/31	4	-	0	-	-	6/27	2	2	0
27A	NS	SV	6/18	6/18	6/23	4	6/30	4	7/04	ABAN	-	0	-	-
28A	NS	SV	6/19	6/19	6/24	3	-	3	7/03	ABAN	-	0	-	-
29A	NT	SV	6/25	6/19	6/25	3	-	0	-	-	7/22	2	1	0
1999, Buffer Area														
26A	BA	OB	6/02	5/28	6/03	4	6/06	0	-	-	6/27	4	0	0

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
1999, Reference Area														
01A	ST	OB	5/01	5/01	5/10	4	-	4	5/11	UNKN	-	0	-	-
01B	ST	OV	5/19	5/19	5/26	4	-	0	-	-	6/19	4	0	4
02A	PH	SB	5/04	5/01	5/06	4	5/11	4	5/20	ADMO	-	0	-	-
03A	PH	SB	5/05	5/05	5/12	4	5/13	0	-	-	6/07	4	0	4
04A	PH	SV	5/06	5/06	5/11	4	5/13	4	5/20	ABAN	-	0	-	-
04B	PH	SB	5/30	5/30	6/03	4	-	4	6/17	UNKN	-	0	-	-
05A	EO	OB	5/06	5/06	5/13	4	5/17	4	5/21	ABAN	-	0	-	-
05B	EO	OB	6/02	6/02	6/08	4	-	0	-	-	7/02	4	0	2
07A	PH	SB	5/08	5/08	5/14	4	5/17	0	-	-	6/09	4	0	4
09A	EO	OV	5/12	-	-	3	-	3	5/14	UNKN	-	0	-	-
11A	PH	SB	5/15	5/11	5/17	4	5/28	1[f]	-	-	6/12	1	2	1
12A	PH	SV	5/16	-	-	4	5/17	4	5/18	ABAN	-	0	-	-
12B	PH	SB	5/29	5/29	6/04	4	-	0	-	-	6/29	4	0	0
13A	EO	SB	5/16	5/16	5/24	4	5/28	0	-	-	6/18	4	0	4
14A	PH	SV	5/19	5/11	5/17	2	-	0	-	-	6/13	2	0	1
15A	PH	SB	5/19	5/19	5/25	4	-	0	-	-	6/20	4	0	3
16A	PH	SB	5/26	5/26	5/31	4	6/05	0	-	-	6/23	4	0	3
17A	PH	SB	5/26	5/23	5/29	4	5/31	0	-	-	6/22	4	0	4
18A	PH	TB	5/26	-	-	4	5/28	4	6/15	STRM	-	0	-	-
23A	WA	SB	5/31	5/31	6/07	4	6/11	0	-	-	7/10	4	0	0

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
2000, Gull-removal Area														
09A	NO	OV	05/08	05/08	05/14	4	-	4	05/24	AMOY	-	0	-	-
09B	NO	OB	06/05	05/31	06/06	4	06/13	0	-	-	07/01	4	0	4
14A	NT	OV	05/13	05/13	-	1	-	1	05/20	ABAN	-	0	-	-
14B[g]	NT	OV	06/02	06/02	06/08	4	-	1	-	-	07/06	3	0	1
15A	NO	OV	05/15	05/15	05/22	4	-	4	05/23	AVPR	-	0	-	-
15B	NO	OB	06/03	05/30	06/05	4	-	4	06/07	STRM	-	0	-	-
17A	NO	OV	05/23	-	-	4	-	4	05/30	AVPR	-	0	-	-
17B	NO	OV	06/07	06/06	06/12	4	-	0	-	-	07/08	4	0	0
22A	NO	OB	06/01	06/01	06/05	3	06/13	0	-	-	07/03	3	0	2
24A	NO	OB	06/01	06/01	06/07	4	06/13	0	-	-	07/01	3	1	2
29A	NS	SV	06/21	06/20	06/24	3	-	3	07/15	UNKN	-	0	-	-

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
2000, Reference Area														
01A	PH	SB	05/06	05/06	05/12	4	05/27	0	-	-	06/07	4	0	2
02A	EO	OB	05/06	05/06	05/13	3	05/31	0	-	-	06/08	3	0	0
03A	PH	SB	05/06	05/04	05/10	4	05/15	0	-	-	06/05	4	0	0
04A	PH	SB	05/07	05/07	05/14	4	05/27	0	-	-	06/09	4	0	0
05A	PH	SB	05/07	05/05	05/12	4	05/15	0	-	-	06/07	4	0	0
06A	PH	SV	05/07	05/05	-	3	-	3	05/12	ABAN	-	0	-	-
06B	PH	SB	05/23	05/22	05/30	4	06/02	0	-	-	06/24	4	0	4
07A	EO	OB	05/08	05/08	05/14	4	05/27	4	05/31	ABAN	-	0	-	-
08A	ST	OB	05/08	05/06	05/13	4	-	4	05/30	AVPR	-	0	-	-
08B	ST	OV	06/10	06/06	06/12	4	-	0	-	-	07/07	4	0	1
10A	PH	SB	05/10	05/10	05/17	4	05/31	0	-	-	06/14	4	0	3
11A	PH	SB	05/10	05/10	05/15	4	-	4	05/18	UNKN	-	0	-	-
11B	PH	SB	05/27	05/27	06/02	4	06/08	0	-	-	06/27	4	0	4
12A	PH	SV	05/13	05/10	05/16	4	-	0	-	-	06/12	4	0	4
13A	PH	SB	05/13	05/13	05/20	4	-	4	06/01	UNKN	-	0	-	-
13B	PH	SV	06/14	06/14	06/20	4	-	4	06/28	AMOY	-	0	-	-
16A	PH	SB	05/22	05/22	05/29	4	06/02	0	-	-	06/24	4	0	1
18A	PH	TB	05/25	06/22	06/28	4	06/08	0	-	-	06/23	4	0	3
19A	PH	SB	05/27	05/26	06/01	4	06/08	0	-	-	06/28	4	0	0

Continued.

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-1, Continued. Individual nest chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Nest Number[a]	Location[b]	Habitat[c]	Date Nest Found	Estimated Date of Nest Initiation	Estimated Date of Nest Completion	Clutch Size	Date Nest Exclosed	Number of Eggs Lost	Estimated Date of Nest Loss	Cause of Nest Loss[d]	Estimated Date of Hatch	Number of Eggs Hatched	Number of Eggs Left in Scrape After Hatch	Number of Chicks Fledged
2000, Reference Area, Continued.														
21A	WA	SV	05/29	-	-	2	-	2	-	ABAN	-	0	-	-
21B	WA	OB	05/29	-	-	2	-	2	06/07	STRM	-	0	-	-
23A	EO	OB	06/01	-	-	1	-	1	06/03	UNKN	-	0	-	-
23B	EO	OB	06/08	06/08	06/12	3	06/20	0	-	-	07/08	3	0	3
25A	EO	OB	06/05	-	-	2	-	2	06/06	STRM	-	0	-	-
25B	EO	OB	06/16	-	-	3	-	3	06/25	AVPR	-	0	-	-
26A	PH	SV	06/08	06/08	06/15	4	-	0	-	-	07/13	3	1	0
27A	ST	OV	06/13	06/11	06/17	4	-	0	-	-	07/15	2	2	1
28A	PH	SB	06/14	06/13	06/19	4	06/28	0	-	-	07/13	3	1	2

[a] Nest numbers in 1998 were labeled N for the north half and S for the south half of the island. First nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.
[b] BA = Buffer Area, EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[c] OB = Ocean Backshore, OV = Ocean Open Vegetation, SB = Sound Backshore, SV = Sound Open Vegetation, TB = Tidal Pond Backshore.
[d] ABAN = Abandoned, ADMO = Adult Mortality, AMOY = American Oystercatcher, AVPR = Unidentified Avian Predator, COYO = Coyote, GULL = Gull, STRM = Storm/Flood Tide, UNKN = Unknown.
[e] Nest was located in vegetation between ocean side and Hospital Pond.
[f] Cause of egg loss was unknown.
[g] One egg was laid 1m from clutch and was eventually abandoned.

Table A-2. Individual brood chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year, Management Area	Nest Area [a]	Primary Foraging Habitat [b]	Brood/ Nest Number [c]	Hatch Date	Number of Chicks Hatched	Number of Chicks Fledged	Number of Chicks Observed By Age (days; D00 = Day 0, hatch day; D25 = Day 25, fledge day)																											
							D00	D01	D02	D03	D04	D05	D06	D07	D08	D09	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25
1998, Gull-removal Area																																
	NT	Sound	N05A	06/20	4	2	2	3	.	.	.	.	1	3	.	.	.	.	.	3	2	1	.	.	1	.	2	2	.	2	.	2
	NO	Ocean	N06A	06/20	4	0	3	2	.	.	.	.	.	1	.	.	.	1	1	0	.	.	.	.	.	.	.	.	.	.	.	.
	NO	Ocean	N09A	06/28	4	0	4	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	NO	Ocean	N10A	06/27	4	0	1	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	NO	Sound	N12A	07/26	3	2	2	3	3	1	.	.	2	2	.	2	2	2	2	2	2	2	.	2	.	2	2	.	.	2	.	2
1998, Reference Area																																
	WA	Sound	N07A	06/24	4	0	4	.	.	.	.	.	.	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	0	.	.
	PH	Sound	S01A	06/16	4	1	3	2	4	.	2	4	2	2	.	2	2	.	.	.	.	.	1	1	1	1	1	1	1	1	.	1
	PH	Sound	S02C	07/19	2	1	1	2	2	2	2	2	1	.	.	2	1	1	.	1	1	.	1	1	.	1	.	1	.	.	.	1
	ST	Ocean	S04B	07/02	2	2	2	1	2	1	.	.	2	.	.	.	2	1	.	1	2	.	.	.	.	2	2	.	.	.	.	2
	PH	Sound	S05A	06/07	3	1	3	.	.	.	.	.	.	.	.	.	1	1	.	1	.	1	1	1	1	1	.	.	.	.	.	1
	PH	Sound	S06A	06/16	4	0	2	.	4	.	4	.	.	3	3	3	3	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.
	PH	Sound	S07A	06/16	4	4	.	.	4	.	4	2	.	4	4	4	4	.	.	.	.	.	4	4	4	4	3	.	4	4	4	4
	PH	Sound	S08B	07/19	1	1	1	.	1	1	1	1	1	.	.	1	1	1	.	1	1	.	1	1	.	1	.	.	.	.	.	1
	PH	Sound	S12A	06/26	3	0	3	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	EO	Ocean	S13B	07/21	4	2	4	3	3	3	.	.	.	3	.	3	.	1	2	.	.	.	2	.	.	.	.	.	.	.	.	2
	PH	Sound	S15A	07/11	3	3	2	3	3	3	2	3	3	3	3	2	3	3	3	2	3	.	.	3	3	3	.	3	3	.	3	3

Continued.

[a] EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.

[b] Ocean = ocean side was the primary foraging area, Sound = sound side or tidal pond intertidal zone was the primary foraging area. Only if nest area = PH does the primary foraging area included tidal pond intertidal zone.

[c] Brood/nest numbers in 1998 were labeled N for the north half, and S for the south half of the island. Broods from first nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.

Table A-2, Continued. Individual brood chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year, Management Area	Nest Area [a]	Primary Foraging Habitat [b]	Brood/ Nest Number [c]	Hatch Date	Number of Chicks Hatched	Number of Chicks Fledged	Number of Chicks Observed By Age (days; D00 = Day 0, hatch day; D25 = Day 25, fledge day)																										
							D00	D01	D02	D03	D04	D05	D06	D07	D08	D09	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25
1999, Gull-removal Area																															
	NO	Seal	08A	06/12	4	1	4	.	4	4	.	4	4	4	2	2	.	2	2	3	2	2	.	.	3	.	.	.	.	1	1	1
	NT	Ocean	10A	06/12	4	2	4	.	3	3	.	2	1	2	2	2	1	2	2	2	2	2	.	.	2	.	.	1	1	1	.	2
	NO	Seal	22A	06/29	4	2	.	4	.	.	3	1	3	.	3	3	3	2	3	3	.	2	2	1	2	.	.	.	.	2	.	2
	NT	Ocean	25A	06/27	2	0	2	.	.	2	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	NT	Sound	29A	07/22	2	0	2	2	2	2	.	1	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1999, Buffer Area																															
	EO	Ocean	26A	06/27	4	0	1	.	.	1	.	.	1	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1999, Reference Area																															
	ST	Ocean	01B	06/19	4	4	2	3	3	4	3	3	3	4	3	.	4	.	3	.	4	1	3	3	4	3	3	.	.	4	.	4
	PH	Sound	03A	06/07	4	4	3	3	3	4	4	3	4	4	2	4	4	4	3	3	3	3	3	4	2	3	4	.	2	4	4	4
	EO	Seal	05B	07/02	4	2	.	1	2	.	4	4	4	3	1	.	3	.	2	2	2	2	.	.	2	2	1	.	2	2	2	2
	PH	Sound	07A	06/09	4	4	1	2	4	4	3	4	3	3	4	3	4	4	3	2	2	2	2	1	3	.	2	.	4	.	4	4
	PH	Sound	11A	06/12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	1	1	.	1	.	1	.	1	1	1	1	1
	PH	Sound	12B	06/29	4	0	1	3	2	.	2	.	1	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	PH	Seal	13A	06/18	4	4	3	4	4	4	4	.	4	3	4	4	.	2	3	4	.	4	4	4	4	4	4	4	4	.	4	4
	PH	Sound	14A	06/13	2	1	2	1	1	1	1	1	1	1	1	1	1	1	.	.	1	.	1	.	1	.	.	1	1	1	1	1
	PH	Seal	15A	06/20	4	3	3	.	4	4	3	3	3	3	.	3	.	3	.	2	3	3	3	3	3	3	3	3	.	.	3	3
	PH	Sound	16A	06/23	4	3	2	.	3	3	4	.	3	.	2	.	3	3	3	3	3	3	3	3	3	.	.	3	2	2	3	3
	PH	Sound	17A	06/22	4	4	3	4	2	2	3	2	.	3	.	4	.	4	4	4	4	4	4	4	4	4	.	.	4	4	4	4
	WA	Sound	23A	07/10	4	0	3	3	1	.	2	1	1	.	1	1	1	1	.	1	1	1	1	.	1	1	1	0	.	.	.	.

Continued.

[a] EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.

[b] Ocean = ocean side was the primary foraging area, Sound = sound side or tidal pond intertidal zone was the primary foraging area. Only if nest area = PH does the primary foraging area included tidal pond intertidal zone.

[c] Brood/nest numbers in 1998 were labeled N for the north half, and S for the south half of the island. Broods from first nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.

Table A-2, Continued. Individual brood chronology, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Year, Management Area	Nest Area [a]	Primary Foraging Habitat [b]	Brood/ Nest Number [c]	Hatch Date	Number of Chicks Hatched	Number of Chicks Fledged	Number of Chicks Observed By Age (days; D00 = Day 0, hatch day; D25 = Day 25, fledge day)																											
							D00	D01	D02	D03	D04	D05	D06	D07	D08	D09	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25
2000, Gull-removal Area																																
	NO	Ocean	09B	07/01	4	4	2	2	3	.	4	4	4	4	4	.	4	2	4	4	4	4	4	4	4	3	4	.	4	4	4	4
	NT	Sound	14B	07/06	3	1	3	.	2	3	.	3	.	3	2	2	2	2	2	2	1	1	.	1	1	1	.	.	1	1	1	1
	NO	Ocean	17B	07/08	4	0	2	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	NO	Ocean	22A	07/03	3	2	2	3	3	3	.	2	3	.	3	1	3	3	3	3	3	3	3	3	3	.	2	3	2	2	.	2
	NO	Ocean	24A	07/01	3	2	2	2	3	2	3	3	3	3	3	.	2	2	2	2	2	2	2	2	2	1	2	.	2	1	1	2
2000, Reference Area																																
	PH	Sound	01A	06/07	4	2	4	.	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	.	2	2	1	2	2	2
	EO	Ocean	02A	06/08	3	0	3	.	1	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	PH	Sound	03A	06/05	4	0	4	1	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	PH	Sound	04A	06/09	4	0	2	4	4	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	PH	Sound	05A	06/07	4	0	4	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	PH	Sound	06B	06/24	4	4	3	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4
	ST	Ocean	08B	07/07	4	1	1	1	.	3	3	2	1	1	1	1	1	1	1	.	1	1	1	1	1	.	.	1	1	1	1	1
	PH	Seal	10A	06/14	4	3	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	3	4	4	4	4	3	4	4	3
	PH	Sound	11B	06/27	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	4	4	4
	PH	Sound	12A	06/12	4	4	3	3	4	4	4	4	4	3	4	4	4	4	4	4	2	4	4	3	4	3	4	4	4	4	4	4
	PH	Sound	16A	06/24	4	1	4	4	4	3	2	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	1
	PH	Sound	18A	06/23	4	3	4	4	3	.	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3
	PH	Sound	19A	06/28	4	0	4	4	4	4	4	4	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	EO	Ocean	23B	07/08	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	1	3	3	3	.	.	3	2	3	3	.	3
	PH	Sound	26A	07/13	3	0	3	3	3	3	3	3	.	3	3	1	3	3	3	.	.	.	1	0	.	.	.	.	.	.	.	.
	ST	Ocean	27A	07/15	2	1	1	2	2	1	.	2	2	.	.	1	1	.	.	.	.	1	1	.	.	.	1	1	1	.	1	1
	PH	Sound	28A	07/13	3	2	3	3	3	3	3	3	2	3	3	3	3	2	2	.	.	2	2	2	2	.	2	.	1	2	2	2

[a] EO = East Ocean, NO = North Ocean, NS = North Sound, NT = North Tip, PH = Powder Hole Area, ST = South Tip, WA = Overwash.
[b] Ocean = ocean side was the primary foraging area, Sound = sound side or tidal pond intertidal zone was the primary foraging area. Only if nest area = PH does the primary foraging area included tidal pond intertidal zone.
[c] Brood/nest numbers in 1998 were labeled N for the north half, and S for the south half of the island. Broods from first nest attempts are labeled with the letter A, second nest attempts are labeled with the letter B, etc.

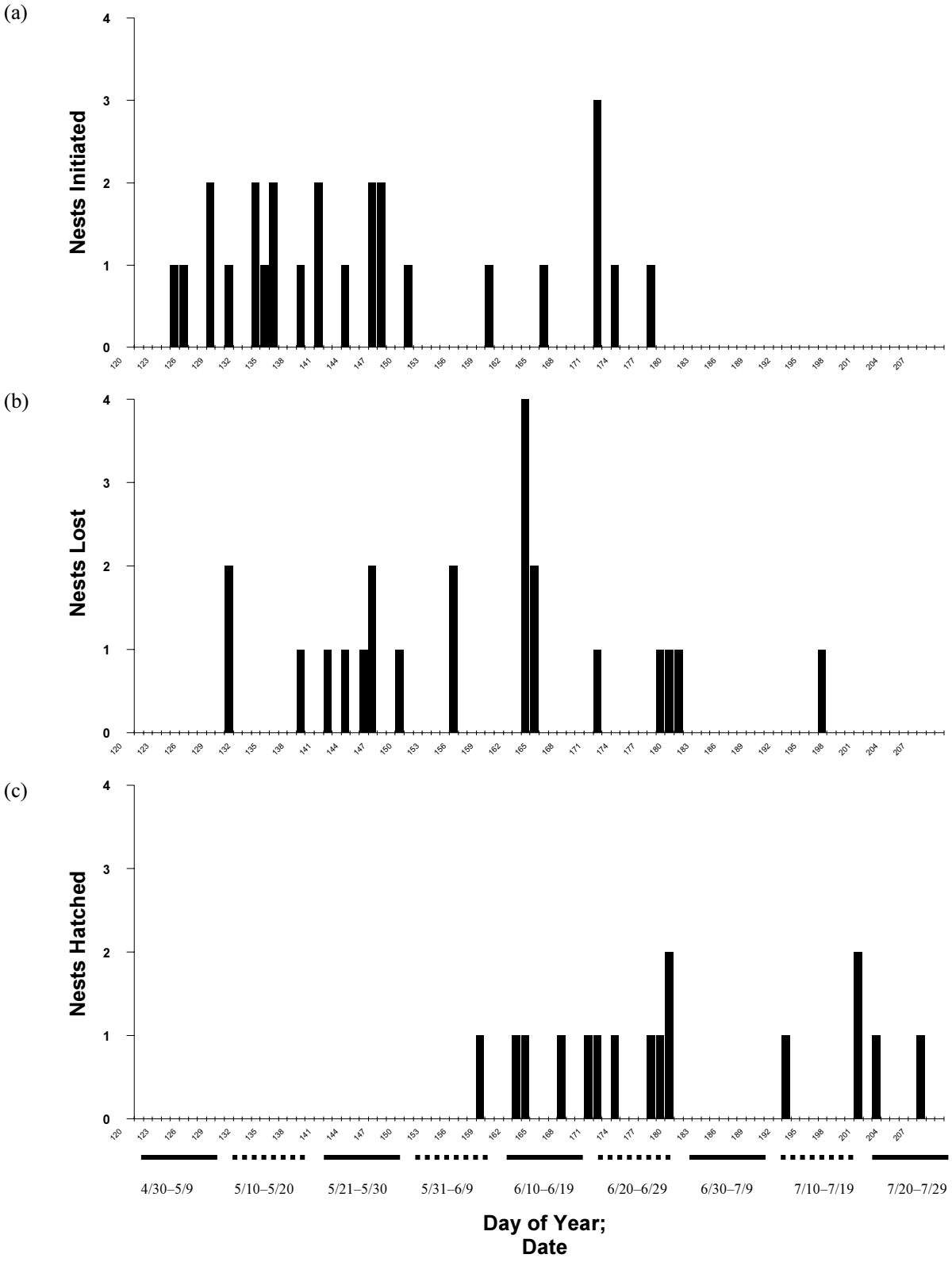


Figure A-1. Number of nests initiated, lost, and hatched, by date, South Monomoy Island, Cape Cod, Massachusetts, 1998.

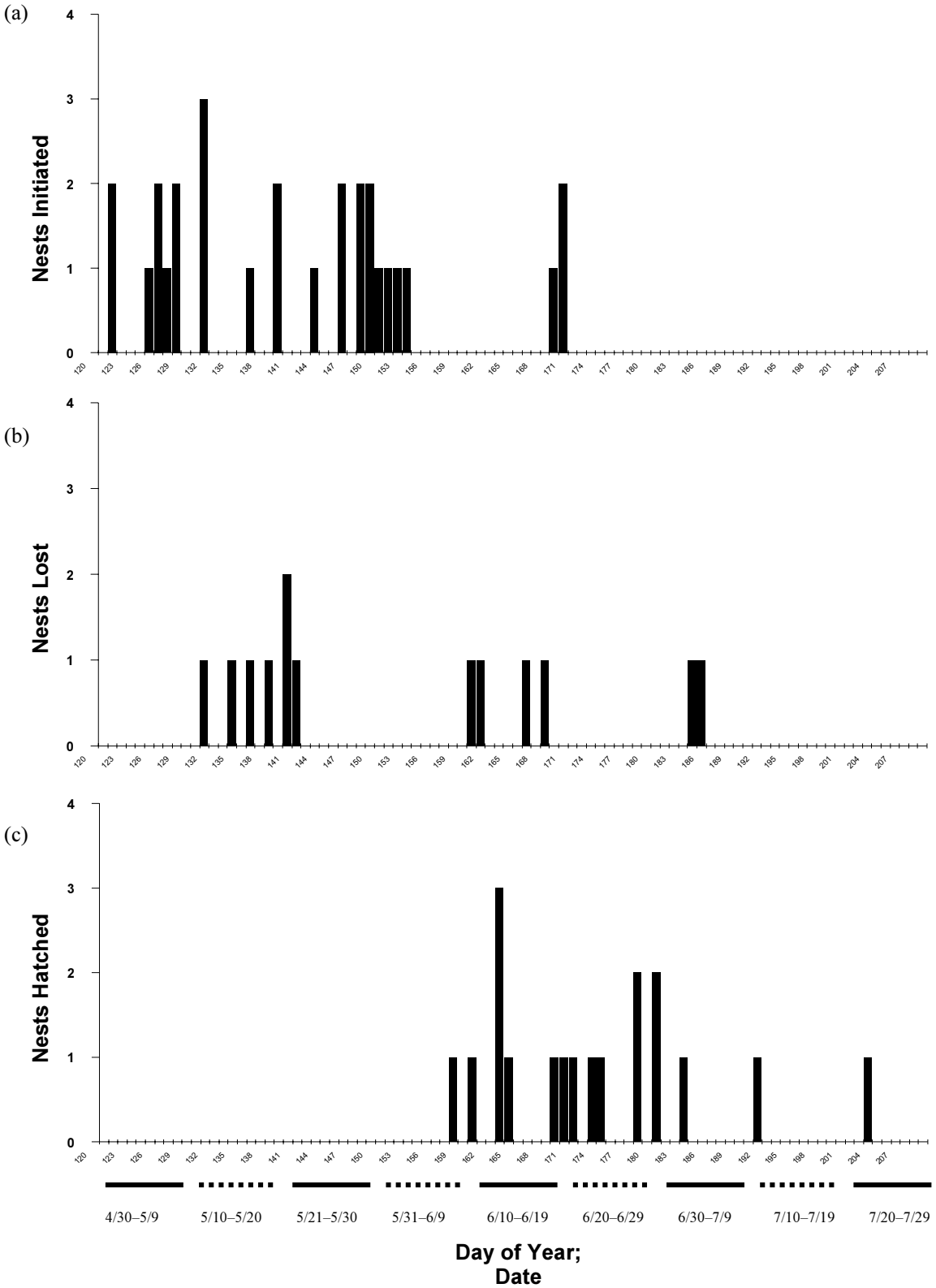


Figure A-2. Number of nests initiated, lost, and hatched, by date, South Monomoy Island, Cape Cod, Massachusetts, 1999.

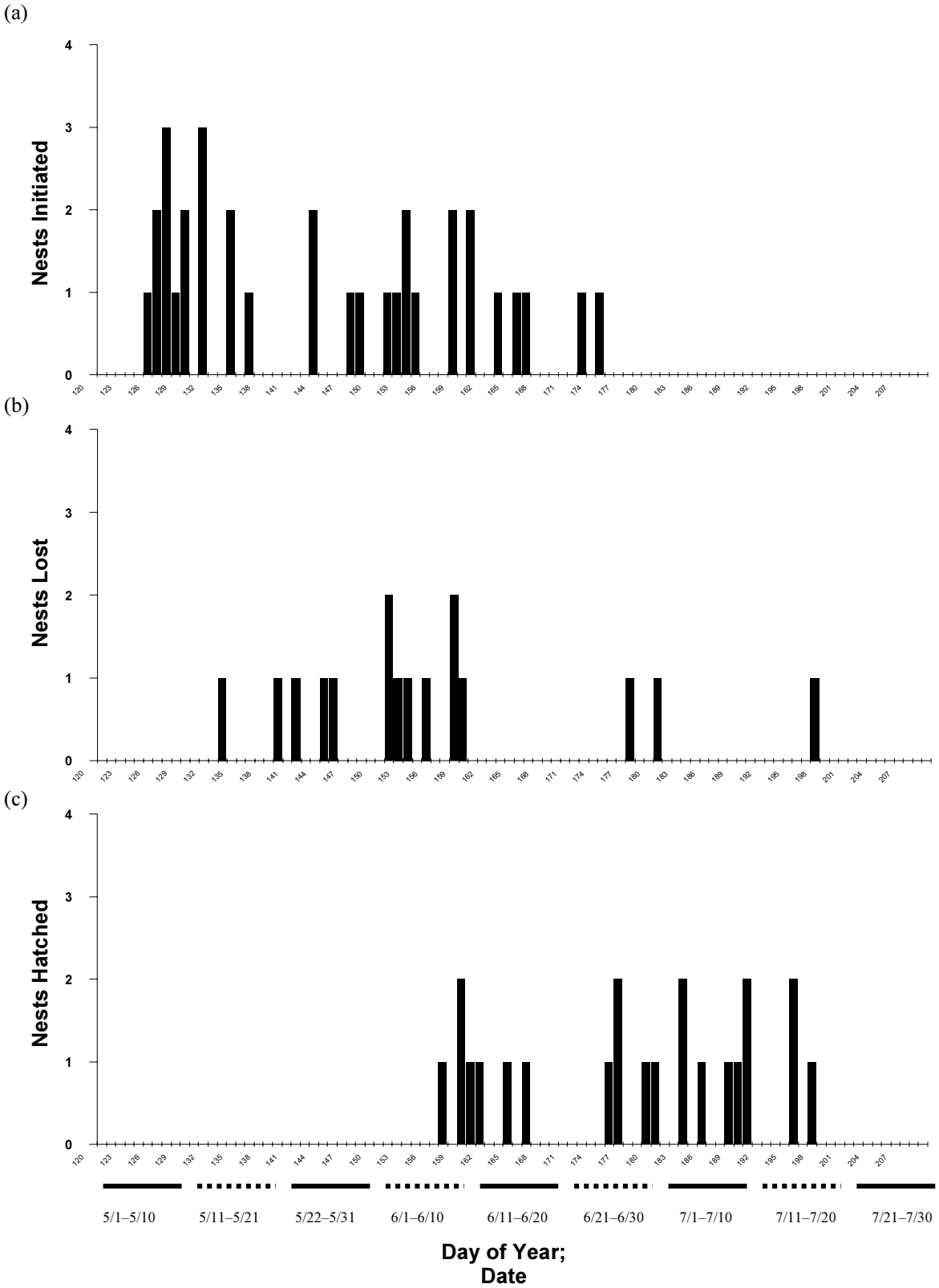


Figure A-3. Number of nests initiated, lost, and hatched, by date, South Monomoy Island, Cape Cod, Massachusetts, 2000.

Appendix B. Distribution of Potential Predators, Competitors, and Disturbances Other Than Large Gulls

Methods--We recorded the number of potential predators, competitors and disturbances, within 100 m of prenesting Piping Plovers, nests, and broods during daily surveys. Table B-1 lists all species seen within 100 m of prenesting plovers, plover nests, and broods. We standardized counts by always counting species in a predetermined order. To standardize the level of observer disturbance to plovers and other species during counts, we conducted counts from where we first observed the prenesting plover or plover brood, then recorded our distance (m) from the focal bird. For plover nests, we conducted counts of species from an observation point on the backshore located approximately 100 m from nests. Our distance and position relative to nests were determined using hand-held Garmin12 GPS units with the nest locations loaded in the memory. We used MRPP to examine differences in species' abundance within 100 m of prenesting plovers, plover nests and plover broods among the management areas. We compared species' abundance within 100 m of successful and unsuccessful nests and broods using MRPP.

We recorded the number of potential predators, competitors and disturbances within 100 m of random points in the nesting and unused areas. We approached random points as we did plover nests (see above). Nesting areas were defined as all beach area within 500 m of a plover nest. We used MRPP to compare species' abundance in the Piping Plover nesting areas to species' abundance in the unused areas, within each management area, and island-wide.

Results and Conclusions--We counted more Laughing Gulls, shorebirds, and pedestrians near prenesting plovers in the gull-removal area than near prenesting plovers in the reference area (Table B-2). Laughing Gulls, shorebirds, and commercial shell-fishermen gathered on the sound-side intertidal zone sand flat in the gull-removal area to forage and harvest soft-shell clams. Foraging prenesting plovers preferred this habitat, and were concentrated there. Laughing Gulls might have used the sand flat because it was a good foraging area close to their colony site located in the gull-removal area. Laughing Gulls were not observed nesting in the reference area.

In 1999, shorebirds were more abundant near nests in the gull-removal area than near nests in the reference area (Table B-3). This was a function of the greater number of plover nests

in that year found on the sound side adjacent to the sand flat where shorebirds foraged. Plover nests on the sound side of the gull-removal area were found late in the season. These pairs probably failed elsewhere and were renesting on South Monomoy. They might have nested on the sound side in marginal nesting habitat because optimal nesting habitat was occupied. They might have renested in marginal habitat to take advantage of the moist substrate habitat of the sand flat, which would provide chicks with abundant prey if the nest were successful. In 2000, Least Terns were more abundant near nests and broods in the reference area than near nests and broods in the gull-removal area (Table B-3 and B-4). This was a function of the greater number of plover nests within the Least Tern colony in the reference area and the lack of a substantial Least Tern colony in the gull-removal area in 2000. Laughing Gulls and Common Terns were consistently more abundant near nests and broods in the gull-removal area than near nests and broods in the reference area. This was a function of the colonial nesting behavior of these species. Both the Laughing Gull and Common Tern colonies were located in the gull-removal area, adjacent to the plover nesting area. Pedestrians were more abundant near broods in the reference area than near broods in the gull removal area (Table B-4). We observed plover broods foraging near where beach-goers were able to land boats.

Island-wide and throughout the study, we found no difference between the abundance of species near successful nests and unsuccessful nests (Table B-5). We counted more American Oystercatchers near successful broods than near unsuccessful broods in the gull-removal area, and more pedestrians near successful broods than near unsuccessful broods island wide (Table B-6).

We consistently counted more Laughing Gulls, Common Terns, and Least Terns in the Piping Plover nesting areas than in the unused areas island-wide (Table B-7). Our results were influenced by the Laughing Gull and the Common Tern colony located adjacent to Piping Plover nesting areas in the gull-removal area. Laughing Gulls and Common Terns increased rapidly in the gull-removal area during our study, most likely as a result of the gull-removal program. Least terns used similar habitat to Piping Plovers for nesting, as they may prefer to nest where the beaches are wide and the wave energy is low to prevent flooding. Least Terns may require wide beaches to provide enough space for the colony.

Table B-1. List of positively identified species observed within 100 m of prenesting plovers, plover nests, plover broods, or random points during sampling on South Monomoy Island, Cape Cod, Massachusetts, 1998-2000.

Shorebirds	
Black-bellied Plover	*Pluvialis squatarola*
Ruddy Turnstone	*Arenaria interpres*
Semipalmated Plover	*Charadrius semipalmatus*
Short-billed Dowitcher	*Limnodromus griseus*
Red Knot	*Calidris canutus*
Willet	*Catoptrophorus semipalmatus*
Greater Yellowlegs	*Tringa melanoleuca*
Sanderling	*Calidris alba*
Dunlin	*Calidris alpina*
Least Sandpiper	*Calidris minutilla*
Semipalmated Sandpiper	*Calidris pusilla*

Other Birds	
Common Loon	*Gavia immer*
Double-crested Cormorant	*Phalacrocorax auritus*
Canada Goose	*Branta canadensis*
Brant	*Branta bernicla*
Red-breasted Merganser	*Mergus serrator*
Northern Gannet	*Morus bassanus*
Bonaparte's Gull	*Larus philadelphia*
Black Skimmer	*Rynchops niger*
Great Blue Heron	*Ardea herodias*
Snowy Egret	*Egretta thula*
Northern Harrier	*Circus cyaneus*
Bald Eagle	*Haliaeetus leucocephalus*
Merlin	*Falco columbarius*
Horned Lark	*Eremophila alpestris*
Tree Swallow	*Iridoprocne bicolor*
Red-winged Blackbird	*Agelaius phoeniceus*
Common Grackle	*Quiscalus quiscula*
European Starling	*Sturnus vulgaris*
Song Sparrow	*Melospiza melodia*
Savannah Sparrow	*Passerculus sandwichensis*

Table B-2. Mean counts of individuals of species within 100 m of Piping Plovers during the prenesting period, between the gull-removal and reference areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number plovers observed. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Laughing Gulls		American Oystercatchers		Shorebirds		Pedestrians	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999										
	Gull-removal	22	0.00	0.00	0.64	0.20	57.27	30.56	0.23	0.23
	Reference	81	0.00	0.00	0.21	0.07	0.73	0.41	0.01	0.01
				-		T = -3.46		T = -7.25		T = 0.98
						P = 0.01		P = 0.0004		P = 1.00
2000										
	Gull-removal	78	0.65	0.38	0.19	0.08	11.50	6.30	0.33	0.12
	Reference	176	0.00	0.00	0.22	0.05	4.23	2.87	0.02	0.01
				T = -8.23		T = 0.49		T = -0.86		T = -11.13
				P = 0.0001		P = 0.58		P = 0.16		P < 0.0001
1999-2000										
	Gull-removal	100	0.51	0.30	0.29	0.08	21.57	8.44	0.31	0.10
	Reference	257	0.00	0.00	0.21	0.04	3.13	1.97	0.02	0.01
				T = -9.32		T = 0.31		T = -6.20		T = -13.58
				P < 0.0001		P = 0.46		P = 0.001		P < 0.0001

Table B-3. Mean counts of individuals of species within 100 m of Piping Plover nests, among the management areas, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area		Laughing Gulls		American Oystercatchers		Common Terns		Least Terns		Shorebirds		Pedestrians	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999														
	Gull-removal	10	1.05	0.40	0.75	0.21	102.62	41.98	0.14	0.14	1.84	1.05	0.24	0.11
	Buffer	1	0.00	-	0.63	-	0.17	-	0.04	-	0.00	-	0.17	-
	Reference	21	0.02	0.02	0.56	0.12	0.44	0.35	2.48	2.36	0.16	0.06	0.14	0.05
			T = -11.05		T = 0.63		T = -7.02		T = -0.92		T = -2.61		T = -0.02	
			P < 0.0001		P = 0.69		P = 0.0003		P = 0.16		P = 0.02		P = 0.36	
2000														
	Gull-removal	11	14.81	6.96	0.58	0.16	99.18	36.70	0.02	0.01	0.52	0.25	0.08	0.05
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	28	0.01	0.01	0.52	0.10	0.33	0.14	6.14	3.33	0.19	0.07	0.03	0.01
			T = -7.37		T = 0.74		T = -9.92		T = -2.54		T = -0.50		T = 0.27	
			P < 0.0001		P = 0.81		P < 0.0001		P = 0.03		P = 0.23		P = 0.46	
1999-2000														
	Gull-removal	21	8.26	3.88	0.66	0.13	100.82	27.03	0.08	0.07	1.15	0.52	0.15	0.06
	Buffer	1	0.00	-	0.63	-	0.17	-	0.04	-	0.00	-	0.17	-
	Reference	49	0.01	0.01	0.54	0.08	0.38	0.17	4.57	2.15	0.17	0.05	0.07	0.02
			T = -9.62		T = 0.44		T = -17.56		T = -2.34		T = -4.38		T = -0.84	
			P < 0.0001		P = 0.55		P < 0.0001		P = 0.03		P = 0.003		P = 0.16	

Table B-4. Mean counts of individuals of species within 100 m of Piping Plover broods, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances comparing the gull-removal area to the reference area.

Year	Management Area		Laughing Gulls		American Oystercatchers		Common Terns		Least Terns		Shorebirds		Pedestrians	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999														
	Gull-removal	5	2.65	0.79	0.29	0.17	217.34	106.53	3.07	1.69	5.15	4.14	0.00	0.00
	Buffer	1	0.00	-	0.75	-	7.00	-	0.00	-	0.00	-	0.00	-
	Reference	12	0.00	0.00	0.84	0.18	1.17	0.68	4.34	4.17	0.78	0.30	0.25	0.10
			T = -8.75		T = -1.15		T = -9.51		T = -0.53		T = 0.14		T = -3.03	
			P < 0.0001		P = 0.12		P < 0.0001		P = 0.23		P = 0.42		P = 0.02	
2000														
	Gull-removal	5	20.55	11.82	0.64	0.28	94.11	57.86	0.05	0.05	7.48	7.32	0.00	0.00
	Buffer	0	-	-	-	-	-	-	-	-	-	-	-	-
	Reference	17	0.02	0.01	0.73	0.15	1.08	0.49	2.67	1.12	2.02	0.89	0.05	0.03
			T = -8.60		T = 0.87		T = -8.66		T = -4.32		T = 1.04		T = -0.72	
			P < 0.0001		P = 0.88		P < 0.0001		P = 0.005		P = 1.00		P = 0.18	
1999-2000														
	Gull-removal	10	11.60	6.33	0.47	0.16	155.73	60.73	1.56	0.94	6.32	3.98	0.00	0.00
	Buffer	1	0.00	-	0.75	-	7.00	-	0.00	-	0.00	-	0.00	-
	Reference	29	0.01	0.01	0.78	0.11	1.11	0.39	3.36	1.81	1.51	0.54	0.13	0.05
			T = -14.22		T = -0.41		T = -16.29		T = 0.24		T = -0.55		T = -3.14	
			P < 0.0001		P = 0.23		P < 0.0001		P = 0.49		P = 0.21		P = 0.02	

Table B-5. Mean counts of individuals of species within 100 m of successful vs. unsuccessful Piping Plover nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls		American Oystercatchers		Common Terns		Least Terns		Shorebirds		Pedestrians		Other	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1999																
	Gull-removal															
	Successful	5	1.82	0.61	0.53	0.21	201.43	55.19	0.27	0.27	1.69	1.27	0.26	0.14	1.45	0.85
	Unsuccessful	5	0.28	0.19	0.98	0.35	3.80	1.66	0.00	0.00	1.98	1.82	0.21	0.17	0.09	0.03
			T = -4.32		T = 0.40		T = -4.21		T = 0.00		T = 0.89		T = 0.62		T = 2.71	
			P = 0.005		P = 0.57		P = 0.006		P < 0.0001		P = 0.81		P = 0.68		P = 0.02	
	Buffer															
	Successful	1	0.00	-	0.63	-	0.17	-	0.04	-	0.00	-	0.17	-	0.04	-
	Unsuccessful	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-		-		-		-		-		-		-
	Reference															
	Successful	12	0.00	0.00	0.66	0.20	0.67	0.61	4.24	4.13	0.19	0.09	0.10	0.03	1.06	0.34
	Unsuccessful	8	0.04	0.04	0.46	0.13	0.08	0.08	0.14	0.06	0.10	0.07	0.12	0.07	3.07	2.44
			T < 0.0001		T = 0.14		T = 0.46		T = 0.47		T = 0.49		T = 0.93		T = 0.79	
			P < 0.0001		P = 0.42		P = 0.62		P = 0.58		P = 0.59		P = 0.96		P = 0.84	
	South Monomoy															
	Successful	18	0.51	0.25	0.62	0.14	56.41	25.98	2.91	2.75	0.60	0.37	0.15	0.05	1.11	0.48
	Unsuccessful	13	0.13	0.08	0.66	0.16	1.51	0.79	0.08	0.04	0.82	0.70	0.15	0.07	1.92	1.52
			T = -0.51		T = 0.87		T = -2.04		T = -0.32		T = 0.99		T = 0.88		T = 0.20	
			P = 0.21		P = 0.91		P = 0.05		P = 0.31		P = 0.84		P = 0.89		P = 0.44	

Continued.

Table B-5, Continued. Mean counts of individuals of species within 100 m of successful vs. unsuccessful Piping Plover nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls $\bar{x}$	Laughing Gulls SE	American Oystercatchers $\bar{x}$	American Oystercatchers SE	Common Terns $\bar{x}$	Common Terns SE	Least Terns $\bar{x}$	Least Terns SE	Shorebirds $\bar{x}$	Shorebirds SE	Pedestrians $\bar{x}$	Pedestrians SE	Other $\bar{x}$	Other SE
2000																
	Gull-removal															
	Successful	5	19.26	11.21	0.52	0.15	115.47	59.06	0.04	0.03	0.67	0.43	0.02	0.02	0.59	0.15
	Unsuccessful	6	11.09	9.37	0.63	0.27	85.61	50.31	0.00	0.00	0.39	0.32	0.12	0.08	1.67	1.50
			T = 0.61		T = 0.36		T = 0.73		T = -1.35		T = 0.60		T = -0.24		T = -0.21	
			P = 0.69		P = 0.54		P = 0.76		P = 0.09		P = 0.71		P = 0.35		P = 0.32	
	Buffer															
	Successful	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Unsuccessful	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-		-		-		-		-		-		-
	Reference															
	Successful	17	0.002	0.002	0.68	0.12	0.41	0.22	8.47	5.33	0.31	0.11	0.05	0.01	0.87	0.17
	Unsuccessful	11	0.01	0.01	0.26	0.14	0.21	0.11	2.53	2.00	0.01	0.01	0.00	0.00	1.00	0.47
			T = 0.96		T = -2.81		T = 0.38		T = 0.19		T = -5.15		T = -3.52		T = 0.09	
			P = 0.83		P = 0.02		P = 0.59		P = 0.34		P = 0.001		P = 0.01		P = 0.38	
	South Monomoy															
	Successful	22	4.38	2.92	0.65	0.10	26.56	16.18	6.55	4.16	0.39	0.13	0.04	0.01	0.81	0.13
	Unsuccessful	17	3.92	3.38	0.39	0.13	30.35	19.58	1.64	1.30	0.14	0.11	0.04	0.03	1.24	0.58
			T = 0.95		T = -1.75		T = 0.89		T = -0.61		T = -2.57		T = -1.45		T = -1.16	
			P = 0.84		P = 0.06		P = 0.86		P = 0.23		P = 0.03		P = 0.08		P = 0.12	

Continued.

Table B-5, Continued. Mean counts of individuals of species within 100 m of successful vs. unsuccessful Piping Plover nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of nests. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls $\bar{x}$	Laughing Gulls SE	American Oystercatchers $\bar{x}$	American Oystercatchers SE	Common Terns $\bar{x}$	Common Terns SE	Least Terns $\bar{x}$	Least Terns SE	Shorebirds $\bar{x}$	Shorebirds SE	Pedestrians $\bar{x}$	Pedestrians SE	Other $\bar{x}$	Other SE
1999-2000																
	Gull-removal															
	Successful	10	10.54	6.04	0.53	0.12	158.45	40.71	0.16	0.14	1.18	0.65	0.14	0.08	1.02	0.43
	Unsuccessful	11	6.18	5.18	0.79	0.21	48.42	29.27	0.00	0.00	1.12	0.83	0.16	0.09	0.67	0.15
			T = 0.52		T = 0.04		T = -2.42		T = -2.03		T = 0.74		T = 0.75		T = -0.85	
			P = 0.65		P = 0.37		P = 0.03		P = 0.04		P = 0.75		P = 0.78		P = 0.19	
	Buffer															
	Successful	1	0.00	-	0.63	-	0.17	-	0.04	-	0.00	-	0.17	-	0.04	-
	Unsuccessful	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				-		-		-		-		-		-		-
	Reference															
	Successful	29	0.001	0.001	0.67	0.11	0.52	0.28	6.72	3.53	0.26	0.07	0.07	0.02	0.95	0.17
	Unsuccessful	19	0.03	0.02	0.35	0.10	0.15	0.07	1.52	1.17	0.04	0.03	0.05	0.03	1.87	1.05
			T = -1.18		T = -2.11		T = -0.23		T = -0.64		T = -4.13		T = -0.74		T = 0.07	
			P = 0.12		P = 0.05		P = 0.32		P = 0.21		P = 0.006		P = 0.16		P = 0.38	
	South Monomoy															
	Successful	40	2.64	1.62	0.64	0.08	39.99	14.68	4.91	2.59	0.48	0.18	0.09	0.02	0.95	0.16
	Unsuccessful	30	2.28	1.92	0.51	0.11	17.85	11.27	0.96	0.74	0.44	0.31	0.09	0.04	1.54	0.72
			T = 0.98		T = -0.30		T = -0.20		T = -1.09		T = -0.95		T = -0.02		T = -1.30	
			P = 0.85		P = 0.25		P = 0.29		P = 0.13		P = 0.15		P = 0.35		P = 0.10	

Table B-6. Mean counts of individuals of species within 100 m of successful vs. unsuccessful Piping Plover broods, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of broods. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Management Area			Laughing Gulls		American Oystercatchers		Common Terns		Least Terns		Shorebirds		Pedestrians	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Gull-removal														
	Successful	7	6.99	3.03	0.67	0.19	96.85	41.48	2.22	1.29	5.55	5.20	0.00	0.00
	Unsuccessful	3	22.36	21.32	0.00	0.00	293.10	172.61	0.00	0.00	8.10	6.79	0.00	0.00
				T = 0.81		*T* = -2.54		*T* = 0.03		*T* = -0.75		*T* = 0.67		-
				P = 0.79		*P* = 0.03		*P* = 0.42		*P* = 0.19		*P* = 0.72		*P* = 1.00
Buffer														
	Successful	0	-	-	-	-	-	-	-	-	-	-	-	-
	Unsuccessful	1	0.00	-	0.75	-	7.00	-	0.00	-	0.00	-	0.00	-
Reference														
	Successful	21	0.01	0.01	0.65	0.13	1.25	0.51	3.36	2.35	1.25	0.63	0.18	0.06
	Unsuccessful	8	0.00	0.00	1.11	0.21	0.75	0.50	3.35	2.40	2.19	1.08	0.01	0.01
				T = -0.38		*T* = -1.14		*T* = 0.36		*T* = 1.09		*T* = 0.20		*T* = -2.47
				P = 0.29		*P* = 0.12		*P* = 0.54		*P* = 0.91		*P* = 0.45		*P* = 0.03
South Monomoy Island														
	Successful	28	1.76	0.92	0.66	0.11	25.15	12.62	3.08	1.78	2.32	1.36	0.13	0.05
	Unsuccessful	12	5.59	5.40	0.80	0.20	74.36	52.96	2.23	1.64	3.49	1.81	0.01	0.01
				T = 0.89		*T* = 0.75		*T* = 0.74		*T* = 0.97		*T* = 0.10		*T* = -2.59
				P = 0.83		*P* = 0.81		*P* = 0.76		*P* = 0.88		*P* = 0.42		*P* = 0.03

Table B-7. Mean counts of individuals of species within 100 m of random points, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls $\bar{x}$	Laughing Gulls SE	American Oystercatchers $\bar{x}$	American Oystercatchers SE	Common Terns $\bar{x}$	Common Terns SE	Least Terns $\bar{x}$	Least Terns SE	Shorebirds $\bar{x}$	Shorebirds SE	Pedestrians $\bar{x}$	Pedestrians SE
1999														
	Gull-removal													
	Nesting Area	131	0.81	0.27	0.64	0.11	98.19	21.83	0.08	0.05	13.54	4.03	0.44	0.12
	Unused Area	3	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00	0.67	0.67
				T = -0.31		*T* = 1.15		*T* = -0.59		*T* = -0.03		*T* = -0.14		*T* = 0.74
				P = 0.15		*P* = 1.00		*P* = 0.14		*P* = 0.02		*P* = 0.13		*P* = 1.00
	Buffer													
	Nesting Area	70	0.03	0.03	0.29	0.08	2.69	0.90	0.00	0.00	0.00	0.00	0.00	0.00
	Unused Area	62	0.02	0.02	0.92	0.15	0.39	0.17	0.00	0.00	11.74	5.24	0.02	0.02
				T = 0.99		*T* = -8.67		*T* = -4.75		-		*T* = 9.36		-
				P = 0.84		*P* = 0.0002		*P* = 0.003		*P* = 1.00		*P* < 0.0001		*P* = 1.00
	Reference													
	Nesting Area	143	0.00	0.00	0.28	0.06	0.64	0.42	1.99	0.97	0.16	0.10	0.20	0.09
	Unused Area	120	0.00	0.00	0.31	0.07	0.09	0.04	0.03	0.03	0.37	0.30	0.07	0.19
				-		*T* = 0.71		*T* = -1.35		*T* = -4.91		*T* = 0.79		*T* = -0.35
				P = 1.00		*P* = 0.84		*P* = 0.09		*P* = 0.003		*P* = 0.78		0.26
	South Monomoy [a]													
	Nesting Area	134	0.04	0.24	0.32	0.06	47.60	18.63	2.11	1.03	3.35	2.99	0.31	0.12
	Unused Area	109	0.00	0.00	0.18	0.05	0.07	0.03	0.03	0.03	0.42	0.32	0.08	0.06
				T = -3.99		*T* = -0.78		*T* = -8.17		*T* = -4.54		*T* = -0.43		*T* = -1.02
				P = 0.007		*P* = 0.15		*P* = 0.0001		*P* = 0.004		*P* = 0.28		*P* = 0.13

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table B-7, Continued. Mean counts of individuals of species within 100 m of random points, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls $\bar{x}$	Laughing Gulls SE	American Oystercatchers $\bar{x}$	American Oystercatchers SE	Common Terns $\bar{x}$	Common Terns SE	Least Terns $\bar{x}$	Least Terns SE	Shorebirds $\bar{x}$	Shorebirds SE	Pedestrians $\bar{x}$	Pedestrians SE
2000														
	Gull-removal													
	Nesting Area	132	4.21	1.13	0.36	0.06	147.52	24.22	0.08	0.05	11.31	3.96	0.10	0.05
	Unused Area	7	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.71	0.57	0.00	0.00
				T = -0.99		*T* = -1.26		*T* = -1.61		*T* = -0.07		*T* = -0.28		*T* = -0.18
				P = 0.11		*P* = 0.10		*P* = 0.07		*P* = 0.05		*P* = 0.13		*P* = 0.11
	Buffer													
	Nesting Area	0	-	-	-	-	-	-	-	-	-	-	-	-
	Unused Area	141	0.13	0.09	0.96	0.11	0.35	0.11	0.00	0.00	4.96	1.56	0.01	0.01
	Reference													
	Nesting Area	150	0.01	0.01	0.33	0.07	1.01	0.69	4.97	1.49	0.39	0.17	0.03	0.03
	Unused Area	126	0.01	0.01	0.21	0.06	0.06	0.03	0.02	0.02	0.29	0.21	0.00	0.00
				T = 1.00		*T* = -0.07		*T* = -1.58		*T* = -7.70		*T* = -7.60		-
				P = 0.84		*P* = 0.30		*P* = 0.07		*P* = 0.0003		*P* = 0.0003		*P* = 1.00
	South Monomoy [a]													
	Nesting Area	171	1.80	0.76	0.32	0.06	38.73	11.92	3.06	1.09	1.51	0.92	0.05	0.04
	Unused Area	157	0.01	0.01	0.36	0.06	0.13	0.08	0.01	0.01	1.06	0.43	0.01	0.01
				T = -7.69		*T* = 0.70		*T* = -7.82		*T* = -5.70		*T* = 0.85		*T* = -0.40
				P = 0.0001		*P* = 0.83		*P* = 0.0002		*P* = 0.001		*P* = 0.85		*P* = 0.33

Continued.

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Table B-7, Continued. Mean counts of individuals of species within 100 m of random points, during the nesting period, between the nesting and unused areas, by management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Year	Management Area	n	Laughing Gulls $\bar{x}$	Laughing Gulls SE	American Oystercatchers $\bar{x}$	American Oystercatchers SE	Common Terns $\bar{x}$	Common Terns SE	Least Terns $\bar{x}$	Least Terns SE	Shorebirds $\bar{x}$	Shorebirds SE	Pedestrians $\bar{x}$	Pedestrians SE
1999-2000														
	Gull-removal													
	Nesting Area	263	2.52	0.59	0.51	0.06	122.95	16.35	0.08	0.04	12.42	2.82	0.27	0.06
	Unused Area	10	0.00	0.00	0.30	0.30	0.10	0.10	0.00	0.00	0.80	0.47	0.20	0.20
				T = -1.12		T = -0.08		T = -2.19		T = -0.13		T = -0.59		T = 0.60
				P = 0.09		P = 0.31		P = 0.04		P = 0.08		P = 0.13		P = 1.00
	Buffer													
	Nesting Area	70	0.03	0.03	0.29	0.08	2.69	0.90	0.00	0.00	0.00	0.00	0.00	0.00
	Unused Area	203	0.10	0.06	0.95	0.09	0.36	0.09	0.00	0.00	7.03	1.94	0.01	0.01
				T = -0.01		T = -12.28		T = -13.12		-		T = -8.38		T = -0.34
				P = 0.34		P < 0.0001		P < 0.0001		P = 1.00		P = 0.0001		P = 0.30
	Reference													
	Nesting Area	293	0.003	0.003	0.30	0.05	0.83	0.41	3.52	0.90	0.28	0.10	0.11	0.05
	Unused Area	246	0.004	0.004	0.26	0.05	0.07	0.03	0.02	0.01	0.33	0.18	0.03	0.03
				T = 1.00		T = 0.64		T = -3.01		T = -11.75		T = 0.29		T = -0.85
				P = 0.84		P = 0.73		P = 0.01		P < 0.0001		P = 0.49		P = 0.16
	South Monomoy [a]													
	Nesting Area	305	1.16	0.44	0.32	0.04	42.66	10.55	2.64	0.76	2.32	1.41	0.17	0.06
	Unused Area	266	0.004	0.004	0.29	0.04	0.11	0.05	0.02	0.01	0.80	0.29	0.04	0.02
				T = -9.39		T = 0.59		T = -15.78		T = -9.76		T = -0.18		T = -2.00
				P < 0.0001		P = 0.68		P < 0.0001		P < 0.0001		P = 0.34		P = 0.05

[a] A random subset of all random points was used when combining all management areas so that sampling intensity was equal throughout the island.

Appendix C. Sensitivity Analysis of the Nesting Area Size

In order to quantify characteristics of Piping Plover nesting habitat, we subjectively chose all beach area within 500 m of Piping Plover nests to be Piping Plover "nesting area" and all area beyond 500 m to be "unused area" (see page 18). We then sampled within the nesting and unused areas and made inferences about Piping Plover nesting habitat. Here we examine the sensitivity of the 500-m boundary between nesting and unused area to make inferences about nesting habitat by altering the distance from nests for which we used to determine the nesting area. We pooled 1999 and 2000 data for these analyses.

Univariate Analyses

To examine the sensitivity of analyses comparing nesting vs. unused areas in number of gulls and habitat width based on the subjective 500-m boundary defining the nesting area, we reclassified all random points and transects based on a 100-m boundary distance from Piping Plover nests. All random points and transects within 100 m of a nest were reclassified as "nesting" while all random points and transects beyond 100 m of a nest were reclassified as "unused." We used MRPP to examine differences in gull abundance and habitat widths in nesting vs. unused areas based on the 100-m boundary. We then examined the inferences we made using the 500-m boundary analyses vs. the 100-m boundary analyses.

Gull numbers—Based on the 100-m boundary defining the nesting area, we classified 98 random points as "nesting" and 175 random points as "unused" in the gull-removal area, and 118 random points as "nesting" and 421 random points as "unused" in the reference area. For island-wide comparisons (management areas pooled), we randomly selected a set of 119 points classified as "nesting" and 452 points classified as "unused" for analyses so that sampling intensity equal throughout the island.

Inferences made when comparing the number of gulls in nesting and unused areas were the same with both the 500-m boundary and the 100-m boundary between nesting and unused areas. Island wide, when basing analyses on the 100-m boundary, we counted fewer gulls in random plots in Piping Plover nesting areas than in random plots in the unused areas as we did when basing analyses on the 500-m boundary. The mean number of gulls within 100 m of

random points in both the nesting and unused areas increased with the increase in nesting area size (Table C-1).

Habitat Width--Based on the 100-m boundary defining the nesting area, we classified 23 random ocean side transects as "nesting" and 27 random transects as "unused" in the gull-removal area, and 24 random transects as "nesting" and 92 random transects as "unused" in the reference area. For island-wide comparisons (management areas pooled), we randomly selected a set of 34 transects classified as "nesting" and 92 transects classified as "unused" for analyses.

Inferences made when comparing habitat widths in nesting and unused areas island-wide were the same with both the 500-m boundary and the 100-m boundary analyses. When basing analyses on the 100-m boundary, the ocean- and sound-side backshore and open vegetation habitats and the tidal pond intertidal zone habitat were wider in the nesting areas than in the unused areas (Table C-2). However, within the gull-removal area, we found that the 100-m boundary analyses were more sensitive in detecting differences in habitat width between the nesting and unused area. This can be explained by the more equal sample sizes between the areas in the 100-m boundary analyses compared to the 500-m boundary analyses.

Mean habitat widths in Piping Plover nesting areas increased with decreasing boundary size. When the sampling area for the nesting area was large, we included more transects in areas unsuitable for Piping Plover nesting (where the width of the backshore and/or open vegetation was minimal). Therefore, by reducing the size of the sampling area, more precise estimates of the mean habitat widths were obtained, despite the fact that inferences made with the differing sampling area sizes were the same.

Logistic Regression

We reclassified all random points and transects based on a 100-, 200-, 300-, and 400-m boundary distance from Piping Plover nests (see page 18, Figure C-1). We constructed logistic regression models to examine variables that were influential in Piping Plover nesting area selection on South Monomoy Island (see pages 21 and 22). We then examined Akaike's Information Criterion (AIC) and the percent of concordant transects to determine the best fitting model.

Inferences made were the same for all models despite different nesting area size. For the South Monomoy Island models, based on the lowest value AIC and the highest percent concordant, the 100-m boundary model was the best fitting model. For the Reference Area models, the 100-m boundary model was the best fitting model based on AIC, and the 200-m boundary model was the best fitting model based on percent concordant (Table C-3).

We recommend classifying nesting area as all beach area within 100 m of Piping Plover nests to make inferences about nesting vs. unused areas. However, if sample sizes are insufficient using a 100m boundary, similar inferences can be made using a larger sampling area.

Table C-1. Mean counts of large gulls within 100 m of random points in nesting areas compared to mean counts of large gulls within 100 m of random points in unused areas, by nesting area size and management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of random points. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Management Area, Nesting Area Size [a]			Total Large Gulls		Great Black-backed Gulls		Herring Gulls		Immature Gulls	
		n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Gull-removal Area										
100m	Nesting Area [a]	98	3.58	0.84	1.34	0.31	1.13	0.27	1.11	0.46
	Unused Area	175	3.67	0.51	1.61	0.20	1.05	0.17	1.01	0.36
			T = -0.11, P = 0.32		T = -1.28, P = 0.10		T = 0.47, P = 0.57		T = 0.87, P = 0.89	
500m	Nesting Area	263	3.63	0.46	1.50	0.18	1.06	0.15	1.07	0.29
	Unused Area	10	3.80	0.98	1.80	0.47	1.60	0.60	0.40	0.22
			T = -0.86, P = 0.14		T = -1.01, P = 0.13		T = -0.61, P = 0.18		T = -0.07, P = 0.17	
Reference Area										
100m	Nesting Area	118	10.70	1.51	6.82	0.94	2.72	0.83	1.16	0.44
	Unused Area	421	35.97	1.77	28.70	1.49	5.93	0.69	1.34	0.24
			T = -56.33, P < 0.0001		T = -61.60, P < 0.0001		T = -6.58, P = 0.0009		T = 0.63, P = 0.70	
500m	Nesting Area	293	19.98	2.01	15.25	1.65	3.28	0.52	1.46	0.33
	Unused Area	246	42.89	1.95	34.23	1.66	7.55	1.07	1.11	0.25
			T = -73.69, P < 0.0001		T = -72.85, P < 0.0001		T = -12.62, P < 0.0001		T = 0.40, P = 0.54	
South Monomoy Island										
100m	Nesting Area	119	8.62	1.35	5.16	0.87	1.76	0.35	1.70	0.56
	Unused Area	452	30.77	1.43	23.85	1.18	5.63	0.63	1.30	0.24
			T = -46.91, P < 0.0001		T = -50.86, P < 0.0001		T = -9.28, P < 0.0001		T = 0.80, P = 0.87	
500m	Nesting Area	305	14.45	1.23	10.40	0.96	2.44	0.34	1.61	0.35
	Unused Area	266	39.58	1.90	30.91	1.61	7.55	1.00	1.12	0.25
			T = -88.21, P < 0.0001		T = -87.68, P < 0.0001		T = -22.49, P < 0.0001		T = 0.23, P = 0.45	

[a] Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. In this table, nesting area size is area either 100 m or 500 m from plover nests. Area beyond the nesting area is unused area.

Table C-2. Mean width (m) of foraging habitats on random transects, between the nesting and unused areas, by nesting area size and management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Habitat, Nesting Area Size [a]		Gull-removal Area			Reference Area			South Monomoy Island [a]		
		n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Ocean Intertidal Zone										
100m	Nesting Area [a]	23	35.15	8.52	24	17.39	1.60	34	19.53	4.12
	Unused Area	27	28.80	6.12	92	19.20	1.10	92	21.65	1.76
			T = 0.46, P = 0.58			T = -0.69, P = 0.17			T = -1.17, P = 0.11	
500m	Nesting Area	48	32.06	5.29	64	17.88	1.23	72	21.78	2.78
	Unused Area	2	23.72	10.35	52	19.98	1.41	54	20.15	1.39
			T = 0.26, *P* = 0.37			*T* = 0.23, *P* = 0.44			*T* = -0.04, *P* = 0.35	
Ocean Fresh Wrack										
100m	Nesting Area	23	0.78	0.44	24	1.08	0.83	34	1.01	0.60
	Unused Area	27	0.57	0.22	92	0.59	0.16	92	0.68	0.16
			T = 0.88, P = 0.91			T = 0.93, P = 1.00			T = 0.96, P = 1.00	
500m	Nesting Area	48	0.69	0.24	64	0.84	0.34	72	0.88	0.31
	Unused Area	2	0.00	0.00	52	0.51	0.22	54	0.61	0.22
			T = -0.29, *P* = 0.16			*T* = 0.08, *P* = 0.39			*T* = 0.06, *P* = 0.37	
Ocean Backshore										
100m	Nesting Area	23	52.38	6.72	24	31.09	3.73	34	40.40	4.87
	Unused Area	27	16.98	4.36	92	21.71	1.73	92	20.64	1.57
			T = -13.18, P < 0.0001			T = -4.13, P = 0.007			T = -12.52, P < 0.0001	
500m	Nesting Area	48	34.11	4.75	64	26.40	2.11	72	30.10	2.80
	Unused Area	2	13.04	0.30	52	20.26	2.40	54	20.47	2.20
			T = -0.75, *P* = 0.20			*T* = -3.21, *P* = 0.02			*T* = -3.99, *P* = 0.008	
Ocean Old Wrack										
100m	Nesting Area	23	0.69	0.23	24	0.39	0.22	34	0.56	0.20
	Unused Area	27	0.45	0.17	92	0.60	0.13	92	0.58	0.13
			T = 0.37, P = 0.51			T = 0.15, P = 0.39			T = 0.94, P = 1.00	
500m	Nesting Area	48	0.54	0.14	64	0.63	0.17	72	0.66	0.16
	Unused Area	2	1.00	1.00	52	0.45	0.13	54	0.46	0.13
			T = 1.06, *P* = 0.97			*T* = 0.51, *P* = 0.60			*T* = 0.36, *P* = 0.50	

Continued.

[a] Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. In this table, nesting area size is area either 100 m or 500 m from plover nests. Area beyond the nesting area is unused area.

Table C-2, Continued. Mean width (m) of foraging habitats on random transects, between the nesting and unused areas, by nesting area size and management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Habitat / Nesting Area Size [a]		Gull-removal Area			Reference Area			South Monomoy Island [a]		
		n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Ocean Open Vegetation										
100m	Nesting Area [a]	23	23.03	2.68	24	18.09	2.40	34	21.23	2.28
	Unused Area	27	12.63	2.10	92	12.56	1.17	92	11.78	1.13
			T = -4.42, P = 0.006			T = -2.27, P = 0.04			T = -7.35, P = 0.0005	
500m	Nesting Area	48	17.24	1.88	64	16.07	1.49	72	17.20	1.53
	Unused Area	2	21.63	3.85	52	10.26	1.43	54	10.50	1.39
			T = -0.15, *P* = 0.41			*T* = -3.62, *P* = 0.01			*T* = -4.56, *P* = 0.005	
Sound Intertidal Zone										
100m	Nesting Area	12	76.72	22.71	33	6.64	0.87	30	10.00	2.13
	Unused Area	52	120.02	22.77	88	8.64	2.29	97	45.08	11.38
			T = 0.19, P = 0.43			T = 0.25, P = 0.46			T = -2.44, P = 0.03	
500m	Nesting Area	62	99.72	16.75	65	6.35	0.63	67	39.88	13.49
	Unused Area	2	489.36	230.91	56	10.12	3.56	60	33.35	11.05
			T = -2.75, *P* = 0.03			*T* = 0.52, *P* = 0.62			*T* = 0.62, *P* = 0.69	
Sound Fresh Wrack										
100m	Nesting Area	12	0.36	0.13	33	2.46	0.87	30	2.20	0.92
	Unused Area	52	0.47	0.15	88	1.60	0.19	97	1.61	0.18
			T = -0.21, P = 0.28			T = 0.15, P = 0.13			T = -0.82, P = 0.16	
500m	Nesting Area	62	0.46	0.13	65	1.85	0.47	67	1.43	0.43
	Unused Area	2	0.00	0.00	56	1.82	0.25	60	2.11	0.26
			T = -0.35, *P* = 0.11			*T* = -1.32, *P* = 0.10			*T* = -8.07, *P* = 0.0002	
Sound Backshore										
100m	Nesting Area	12	4.65	1.66	33	30.11	3.79	30	31.05	4.14
	Unused Area	52	3.79	0.45	88	7.83	0.98	97	6.37	0.70
			T = 1.19, P = 1.00			T = -32.38, P < 0.0001			T = -39.14, P < 0.0001	
500m	Nesting Area	62	3.89	0.49	65	20.48	2.55	67	18.01	2.49
	Unused Area	2	5.68	2.16	56	6.27	0.64	60	5.71	0.60
			T = 0.32, *P* = 0.55			*T* = -16.50, *P* < 0.0001			*T* = -14.18, *P* < 0.0001	

Continued.

[a] Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. In this table, nesting area size is area either 100 m or 500 m from plover nests. Area beyond the nesting area is unused area.

Table C-2, Continued. Mean width (m) of foraging habitats on random transects, between the nesting and unused areas, by nesting area size and management area, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000. The sample size (n) equals the number of transects. Test statistics (*T*) and p-values were obtained from BLOSSOM Multi-response Permutation Procedure (MRPP), a nonparametric randomization test based on Euclidean distances.

Habitat	Nesting Area Size [a]	Gull-removal Area			Reference Area			South Monomoy Island [a]		
		n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Sound Old Wrack										
100m	Nesting Area [a]	12	0.78	0.24	33	3.58	0.54	30	3.20	0.58
	Unused Area	52	0.93	0.15	88	2.94	0.26	97	2.58	0.24
			T = 0.49, P = 0.59			T = -0.68, P = 0.18			T = 0.14, P = 0.31	
500m	Nesting Area	62	0.92	0.13	65	3.41	0.38	67	2.57	0.36
	Unused Area	2	0.35	0.35	56	2.77	0.27	60	2.90	0.29
			T = 0.13, P = 0.48			T = -0.77, P = 0.16			T = -1.46, P = 0.08	
Sound Open Vegetation										
100m	Nesting Area	12	2.63	0.90	33	17.37	2.53	30	16.49	2.75
	Unused Area	52	1.64	0.62	88	3.24	0.53	97	2.85	0.66
			T = -1.69, P = 0.07			T = -30.47, P < 0.0001			T = -27.58, P < 0.0001	
500m	Nesting Area	62	1.54	0.45	65	11.74	1.58	67	9.45	1.58
	Unused Area	2	10.46	10.46	56	1.70	0.30	60	2.30	0.80
			T = 1.36, P = 1.00			T = -22.34, P < 0.0001			T = -11.53, P < 0.0001	
Tidal Pond Intertidal Zone										
100m	Nesting Area	12	0.00	0.00	33	27.59	8.44	30	28.78	9.21
	Unused Area	52	1.79	1.31	88	2.18	1.09	97	0.95	0.66
			T = -0.23, P = 0.25			T = -19.24, P < 0.0001			T = -25.72, P < 0.0001	
500m	Nesting Area	62	0.00	0.00	65	16.96	4.68	67	14.26	4.49
	Unused Area	2	46.60	13.26	56	0.00	0.00	60	0.00	0.00
			T = -44.18, P < 0.0001			T = -13.16, P < 0.0001			T = -10.45, P < 0.0001	

[a] Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. In this table, nesting area size is area either 100 m or 500 m from plover nests. Area beyond the nesting area is unused area.

Table C-3. Akaike's Information Criterion (AIC) and percent of concordant transects for logistic regression models when the nesting area is defined as all beach area within differing distances from Piping Plover nests, South Monomoy Island, Cape Cod, Massachusetts, 1999-2000.

Model	Nesting Area Size [a]	Nesting Area Transects (n)	Unused Area Transects (n)	Akaike's Information Criterion (AIC, intercept and covariates)	Percent Concordant
South Monomoy Island Model					
Significant Variables: Backshore Width (m), Distance to Moist Substrate Habitat (m), Open Vegetation Width (m)					
	100m	51	168	168.605	85.1%
	200m	70	149	211.247	81.4%
	300m	91	128	246.248	78.5%
	400m	109	110	270.079	73.6%
	500m	118	101	273.983	72.4%
Reference Area Model					
Significant Variables: Backshore Width (m), Number of Great Black-backed Gulls, Open Vegetation Width (m)					
	100m	36	128	119.246	88.7%
	200m	45	119	126.982	90.2%
	300m	58	106	149.103	87.3%
	400m	71	93	169.530	84.4%
	500m	77	87	181.656	81.5%

[a] Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. In this table, nesting area size is area either 100, 200, 300, 400 or 500 m from plover nests. Area beyond the nesting area is unused area.

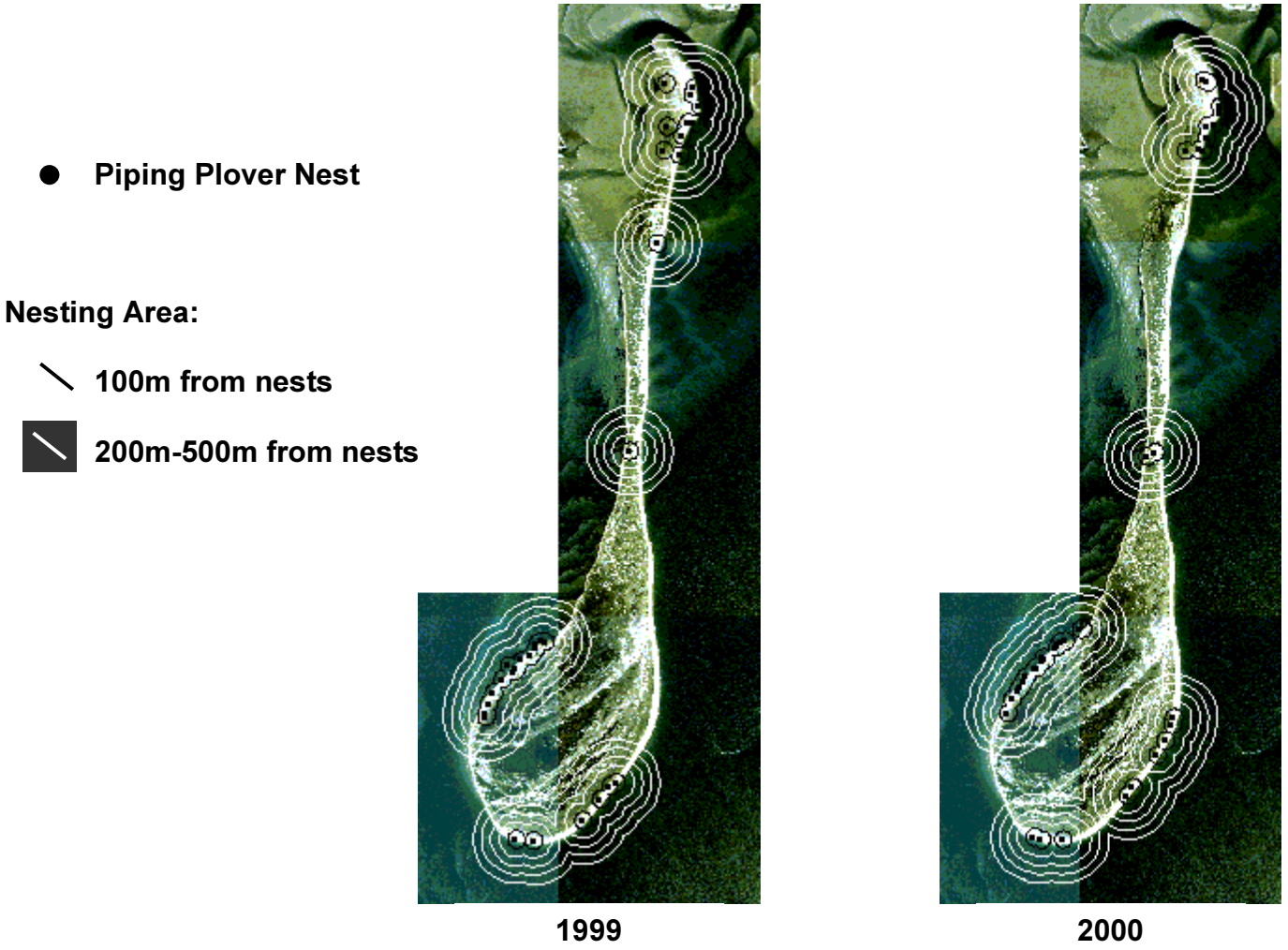


Figure C-1. Piping Plover nesting area boundaries used for logistic regression models. Nesting area is defined as all beach area within a certain distance of all Piping Plover nests. Area beyond the nesting area is defined as unused area.

Appendix D. Intertidal Zone Infauna Samples: A Pilot Study

To better comprehend the labor intensity and logistics of sampling for benthic organisms that may be Piping Plover prey, we sampled for substrate organisms during the Piping Plover brood-rearing period following Loegering and Fraser (1995). We took core samples from in (saturated sample) and above (wet sample) the swash zone of the intertidal habitat in brood foraging areas and along transects at random locations (Figure D-1). Samples were taken from ocean-side, sound-side, and tidal pond intertidal zone types, and from both the gull-removal and reference area. We used 10.2 cm diameter PVC pipe to extract a 5 cm deep core. We immediately saturated substrate cores with 80% ethanol with approximately 1 gm/500 ml Rose Bengal protein stain (Mason and Yevich 1967). We extracted all invertebrates >1 mm from each sample within 5 days of collection, and stored them in 70% ethanol (Tables D-1 and D-2). For one sampling period, we took both 5 cm and 10 cm deep core samples in the same location to examine differences in infauna abundance and diversity between the core depths (Table D-1). Sample sizes were not large for statistical comparisons between management areas, between brood-rearing and nonbrood-rearing areas, between core depths, and among intertidal zone types. Substrate particle size varied among the samples which might have lead core depth inaccuracy and bias. We found that we were logistically burdened by infauna sampling, and therefore did not continue these methods in 2000.

Literature Cited

Loegering, J. P. and J. D. Fraser. 1995. Factors affecting piping plover chick survival in different brood-rearing habitats. J. Wildl. Manage. 59(4): 646-655.

Mason, W. T. and P. P. Yevich. 1967. The use of phloxine B and rose bengal stains to facilitate sorting benthic samples. Trans. Amer. Microsc. Soc. 86(2): 221-223.

Table D-1. Summary of organisms found within substrate core samples taken from the intertidal zone in brood-rearing habitats and at random locations, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Core Depth (cm)	Date Collected	Time Collected	Number	Brood Core (B) or Random Point Core (R)	Area (Gull-removal = GRA, Reference = REF)	Intertidal Zone Type (O = Ocean, S = Sound, T = Tidal Pond)	Wet (W) or Saturated (S) Sand	Nematodes (width <1mm)	Polychaetes (pieces, length 1-2 cm, width >1mm)	Amphipods	Pelecypod Molluscks (bivalves)	Gastropod Molusks	Insect Larva	Horseshoe Crabs	Iso/copopods	Mole Crabs	Seeds	Eggs/Egg Sacs	Other	Collector	Date Sorted	Sorter
05	061999	0930	10A	B	GRA	O	W	0000	0000	000	000	000	000	000	000	000	000	000	000	SK	061999	SK
05	061999	0930	10A	B	GRA	O	S	0001	0000	000	000	000	000	000	000	000	000	000	000	SK	062099	PK
05	061999	0825	143	R	GRA	S	W	0007	0000	000	001	000	000	000	000	000	000	000	000	SK	062099	PK
05	061999	0825	143	R	GRA	S	S	0006	0000	000	000	000	000	000	000	000	000	000	000	SK	062099	PK
05	061999	1215	07A	B	REF	T	W	0000	0000	000	000	000	000	000	000	000	000	000	000	PK	061999	SK
05	061999	1215	07A	B	REF	T	S	0002	0000	000	008	000	000	000	000	000	000	000	000	VS	062099	SK
05	061999	1155	683	R	REF	S	W	0000	0000	000	000	000	000	000	000	000	000	000	000	SK	061999	SK
05	061999	1155	683	R	REF	S	S	0001	0000	000	002	000	000	000	000	000	000	000	000	SK	062099	SK
05	062499	1310	08A	B	GRA	O	W	0002	0000	023	000	000	000	000	000	000	000	000	000	PK	062699	VS
05	062499	1310	08A	B	GRA	O	S	0000	0000	001	000	000	000	000	000	000	000	000	000	PK	062699	SK
05	062499	1050	146	R	GRA	S	W	0158	0000	001	000	000	008	000	000	000	000	000	000	PK	062699	SK
05	062499	1050	146	R	GRA	S	S	0007	0000	000	000	000	007	000	000	000	000	000	000	PK	062599	VS
05	062499	1430	03A	B	REF	S	W	0653	0000	000	000	000	000	000	000	001	001	000	000	AV	062699	VS
05	062499	1430	03A	B	REF	S	S	1976	0000	001	000	000	000	000	000	000	000	000	000	VS	062699	SK
05	062499	1250	685	R	REF	S	W	0888	0000	000	000	000	000	000	000	000	000	000	000	SK	062699	VS
05	062499	1250	685	R	REF	S	S	2814	0000	000	000	000	000	000	000	000	000	000	000	SK	062999	AV,VS

Continued.

Table D-1, Continued. Summary of organisms found within substrate core samples taken from the intertidal zone in brood-rearing habitats and at random locations, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Core Depth (cm)	Date Collected	Time Collected	Number	Brood Core (B) or Random Point Core (R)	Area (Gull-removal = GRA, Reference = REF)	Intertidal Zone Type (O = Ocean, S = Sound, T = Tidal Pond)	Wet (W) or Saturated (S) Sand	Nematodes (width <1mm)	Polychaetes (pieces, length 1-2 cm, width >1mm)	Amphipods	Pelecypod Molluscks (bivalves)	Gastropod Molusks	Insect Larva	Horseshoe Crabs	Iso/copopods	Mole Crabs	Seeds	Eggs/Egg Sacs	Other	Collector	Date Sorted	Sorter
05	070699	1520	22A	B	GRA	O	W	0000	0000	000	000	000	000	000	000	000	000	000	000	AV	071299	VS
05	070699	1520	22A	B	GRA	O	S	0000	0000	000	000	000	000	000	000	000	000	000	002	AV	071199	VS,PK
05	070699	1055	152	R	GRA	S	W	0209	0000	006	059	000	000	000	000	000	000	070	000	AV	071299	VS
05	070699	1055	152	R	GRA	S	S	0150	0006	000	035	049	000	002	002	000	000	000	000	AV	071799	SK
05	070699	1210	13A	B	REF	O	W	0252	0000	001	000	000	000	000	000	000	000	000	002	SK	071199	SK,JF
05	070699	1210	13A	B	REF	O	S	0040	0000	021	000	000	000	000	000	000	000	000	000	SK	071299	SK
05	070699	1045	692	R	REF	S	W	0004	0000	000	000	000	000	000	000	003	000	000	000	PK	071299	PK
05	070699	1045	692	R	REF	S	S	0000	0015	000	001	000	000	000	000	008	001	000	000	PK	071799	AV,VS
05	071899	1335	08A	B	GRA	O	W	0000	0000	000	000	000	000	000	000	000	000	000	000	SK	072199	SK
05	071899	1335	08A	B	GRA	O	S	0000	0000	001	000	000	000	000	000	000	000	000	000	SK	072299	SK
05	071899	1030	160	R	GRA	S	W	0344	0031	000	000	071	000	001	000	000	000	000	000	SK	072199	VS
05	071899	1030	160	R	GRA	S	S	0098	0010	000	014	003	000	000	000	000	000	000	000	SK	072399	SK,PK
05	071899	1100	16A	B	REF	T	W	0202	0003	010	019	000	000	000	000	000	000	000	004	PK	072099	AV
05	071899	1100	16A	B	REF	T	S	0349	0057	009	010	000	000	000	000	000	000	001	008	PK	072199	SK
05	071899	1215	700	R	REF	S	W	0314	0000	000	000	000	000	000	000	000	000	000	000	VS	072099	VS
05	071899	1215	700	R	REF	S	S	0059	0000	000	000	000	000	000	000	000	000	000	000	VS	072199	AV

Continued.

Table D-1, Continued. Summary of organisms found within substrate core samples taken from the intertidal zone in brood-rearing habitats and at random locations, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Core Depth (cm)	Date Collected	Time Collected	Number	Brood Core (B) or Random Point Core (R)	Area (Gull-removal = GRA, Reference = REF)	Intertidal Zone Type (O = Ocean, S = Sound, T = Tidal Pond)	Wet (W) or Saturated (S) Sand	Nematodes (width <1mm)	Polychaetes (pieces, length 1-2 cm, width >1mm)	Amphipods	Pelecypod Molluscks (bivalves)	Gastropod Molusks	Insect Larva	Horseshoe Crabs	Iso/copopods	Mole Crabs	Seeds	Eggs/Egg Sacs	Other	Collector	Date Sorted	Sorter
05	072499	1035	25A	B	GRA	O	W	0150	0000	001	000	000	000	000	000	000	000	000	000	PK	072599	PK
05	072499	1035	25A	B	GRA	O	S	0676	0000	000	000	000	000	000	000	000	000	000	001	PK	072699	AV
05	072499	1000	164	R	GRA	S	W	0207	0000	000	121	023	000	083	000	000	000	002	000	PK	072899	SK
05	072499	1000	164	R	GRA	S	S	0282	0000	091	000	005	000	000	001	000	000	001	000	PK	072899	AV
05	072499	1125	12B	B	REF	T	W	0003	0000	000	000	000	000	000	000	000	000	000	001	AV	072699	AV
05	072499	1125	12B	B	REF	T	S	1500	0005	000	047	001	000	000	001	000	000	000	000	AV	072599	PK
05	072499	1055	704	R	REF	O	W	4000	0000	000	000	000	000	000	000	000	000	000	000	SK	072699	SK
05	072499	1055	704	R	REF	O	S	1000	0000	000	000	000	000	000	000	000	000	000	000	SK	073099	PK
05	080299	1050	22A	B	GRA	O	W	0100	0005	000	000	000	000	000	000	000	000	000	000	VS	080499	PK
05	080299	1050	22A	B	GRA	O	S	0175	0000	002	000	000	000	000	000	000	000	000	000	VS	080399	VS
05	080299	1220	169	R	GRA	S	W	0040	0000	036	031	000	000	000	000	000	000	000	001	VS	080599	AV
05	080299	1220	169	R	GRA	S	S	0030	0000	000	014	008	000	001	000	000	000	000	000	VS	080599	SK
05	080299	1215	13A	B	REF	O	W	0327	0000	000	000	000	000	000	000	000	000	000	000	SK	080399	VS
05	080299	1215	13A	B	REF	O	S	0210	0000	000	000	000	000	000	000	000	000	000	000	SK	080599	PK
05	080299	1030	709	R	REF	S	W	0032	0000	000	000	000	000	000	000	000	000	000	000	PK	080599	PK
05	080299	1030	709	R	REF	S	S	0084	0002	000	000	000	000	000	000	000	000	000	000	PK	080499	AV

Continued.

Table D-1, Continued. Summary of organisms found within substrate core samples taken from the intertidal zone in brood-rearing habitats and at random locations, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Core Depth (cm)	Date Collected	Time Collected	Number	Brood Core (B) or Random Point Core (R)	Area (Gull-removal = GRA, Reference = REF)	Intertidal Zone Type (O = Ocean, S = Sound, T = Tidal Pond)	Wet (W) or Saturated (S) Sand	Nematodes (width <1mm)	Polychaetes (pieces, length 1-2 cm, width >1mm)	Amphipods	Pelecypod Molluscks (bivalves)	Gastropod Molusks	Insect Larva	Horseshoe Crabs	Iso/copopods	Mole Crabs	Seeds	Eggs/Egg Sacs	Other	Collector	Date Sorted	Sorter
05	080799	1025	25A	B	GRA	O	W	0000	0000	000	000	000	000	000	000	000	000	000	000	SK	081199	VS
05	080799	1025	25A	B	GRA	O	S	0008	0000	000	000	000	000	000	000	000	000	000	013	SK	081199	AV
05	080799	1145	172	R	GRA	S	W	0001	0041	000	105	060	000	000	000	000	000	000	000	SK	081099	AV
05	080799	1145	172	R	GRA	S	S	0043	0003	000	207	104	000	000	000	000	000	000	000	SK	081099	SK
05	080799	1130	07A	B	REF	T	W	0113	0000	000	000	000	001	000	000	000	000	000	000	PK	080899	PK
05	080799	1130	07A	B	REF	T	S	0003	0000	000	000	000	000	000	000	000	000	000	000	PK	080899	VS
05	080799	1245	715	R	REF	O	W	0250	0000	000	000	000	000	000	000	000	000	000	000	VS	080899	VS
05	080799	1245	715	R	REF	O	S	0002	0000	000	000	000	000	000	000	000	000	000	000	VS	080899	AV
05	081399	1440	173	R	GRA	S	W	0698	0000	000	566	000	000	000	000	000	000	000	000	AV	081499	AV,PK,VS
05	081399	1440	173	R	GRA	S	S	0150	0000	000	000	000	000	000	000	000	000	000	000	AV	081499	PK
05	081399	1320	10A	B	GRA	O	W	0000	0000	001	000	000	000	000	000	000	000	000	002	AV	081499	AV
05	081399	1320	10A	B	GRA	O	S	0007	0000	000	000	000	000	000	000	000	000	000	000	AV	081499	VS
05	081399	1545	712	R	REF	S	W	0642	0000	001	000	000	000	000	000	000	000	000	000	SK	081499	PK
05	081399	1545	712	R	REF	S	S	0160	0000	007	000	000	000	000	000	000	000	000	000	SK	081599	VS
05	081399	1420	01B	B	REF	O	W	0121	0000	000	000	000	000	000	000	000	000	000	000	VS	081599	PK
05	081399	1420	01B	B	REF	O	S	0021	0000	000	000	000	000	000	000	000	000	000	000	VS	081599	VS

Continued.

Table D-1, Continued. Summary of organisms found within substrate core samples taken from the intertidal zone in brood-rearing habitats and at random locations, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Core Depth (cm)	Date Collected	Time Collected	Number	Brood Core (B) or Random Point Core (R)	Area (Gull-removal = GRA, Reference = REF)	Intertidal Zone Type (O = Ocean, S = Sound, T = Tidal Pond)	Wet (W) or Saturated (S) Sand	Nematodes (width <1mm)	Polychaetes (pieces, length 1-2 cm, width >1mm)	Amphipods	Pelecypod Molluscks (bivalves)	Gastropod Molusks	Insect Larva	Horseshoe Crabs	Iso/copopods	Mole Crabs	Seeds	Eggs/Egg Sacs	Other	Collector	Date Sorted	Sorter
10	080799	1025	25A	B	GRA	O	W	0003	0000	000	000	000	000	000	000	000	000	000	009	SK	081199	AV
10	080799	1025	25A	B	GRA	O	S	0500	0003	009	000	000	000	000	000	000	000	000	016	SK	081199	PK,SK
10	080799	1145	172	R	GRA	S	W	0026	0006	000	492	021	000	000	000	000	000	000	000	SK	081099	PK,VS
10	080799	1145	172	R	GRA	S	S	0128	0006	000	143	064	000	000	000	000	000	000	000	SK	081199	PK,VS
10	080799	1130	07A	B	REF	T	W	0099	0000	000	000	000	000	000	000	000	000	000	000	PK	080899	AV,VS
10	080799	1130	07A	B	REF	T	S	0012	0000	000	002	000	000	000	000	000	000	000	000	PK	080899	SK
10	080799	1245	715	R	REF	O	W	0256	0000	000	000	000	000	000	000	000	000	000	000	VS	080899	PK,AV
10	080799	1245	715	R	REF	O	S	0402	0000	000	000	000	000	000	000	000	000	000	000	VS	080899	SK,PK

Table D-2. Mean number of organisms found within substrate core samples taken from the intertidal zone, by management area and intertidal zone type, South Monomoy Island, Cape Cod, Massachusetts, 1999.

Area	Organism	Ocean Intertidal Zone			Sound Intertidal Zone			Tidal Pond Intertidal Zone		
		n	Mean	SE	n	Mean	SE	n	Mean	SE
Gull-removal										
	Nematodes	8	140	103.6	8	304	101.6			-
	Polychaetes	8	1	0.6	8	11	6.8			-
	Amphipods	8	4	2.9	8	17	11.5			-
	Pelecypod Mollusks	8	0	0.0	8	144	70.4			-
	Gastropod Mollusks	8	0	0.0	8	40	20.1			-
	Insect Larva	8	0	0.0	8	2	1.9			-
	Horseshoe Crabs	8	0	0.0	8	11	10.3			-
	Iso/Copopods	8	0	0.0	8	0	0.3			-
	Mole Crabs	8	0	0.0	8	0	0.0			-
	Seeds	8	0	0.0	8	0	0.0			-
	Eggs/Egg Sacs	8	0	0.0	8	9	8.7			-
	Other	8	2	1.6	8	0	0.1			-
Reference										
	Nematodes	5	1245	941.1	7	1090	558.5	4	543	341.2
	Polychaetes	5	0	0.0	7	2	2.1	4	16	14.6
	Amphipods	5	4	4.4	7	1	1.1	4	5	4.8
	Pelecypod Mollusks	5	0	0.0	7	0	0.3	4	21	10.6
	Gastropod Mollusks	5	0	0.0	7	0	0.0	4	0	0.3
	Insect Larva	5	0	0.0	7	0	0.0	4	0	0.3
	Horseshoe Crabs	5	0	0.0	7	0	0.0	4	0	0.0
	Iso/Copopods	5	0	0.0	7	0	0.0	4	0	0.3
	Mole Crabs	5	0	0.0	7	2	1.6	4	0	0.0
	Seeds	5	0	0.0	7	0	0.2	4	0	0.0
	Eggs/Egg Sacs	5	0	0.0	7	0	0.0	4	0	0.3
	Other	5	0	0.4	7	0	0.0	4	3	2.9

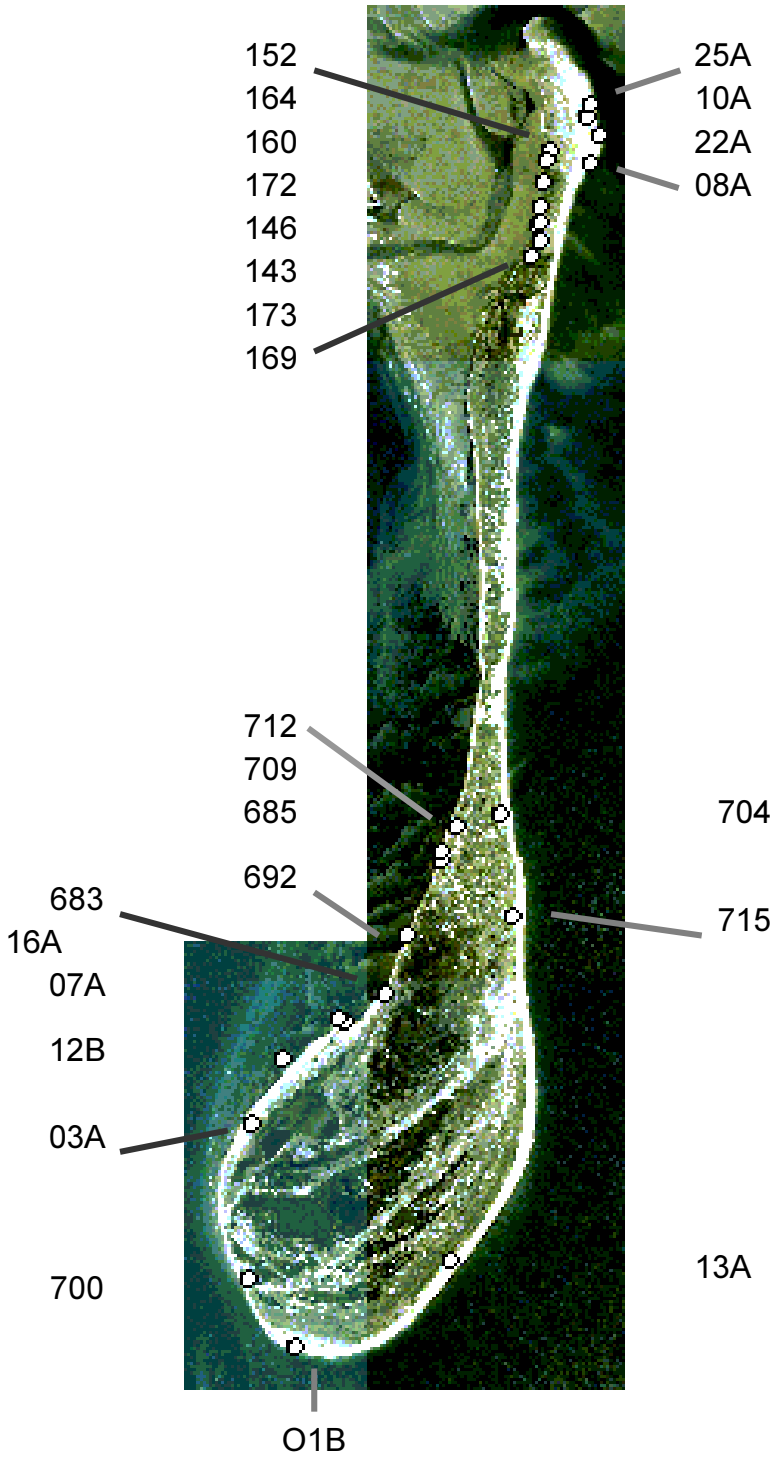


Figure D-1. Locations substrate core samples taken from the intertidal zone in brood-rearing habitats (two-digit number with a letter) and at random locations (three-digit number), South Monomoy Island, Cape Cod, Massachusetts, 1999. Core locations were plotted using ArcView Version 3.1 (ESRI). (Orthophotographs taken 1 September 1994, Coastal Color Orthophotos index numbers 325810, 329810, 329814, and 329818, MassGIS, Commonwealth of Massachusetts Executive office of Environmental Affairs; http://www.state.ma.us/mgis/massgis.htm.)

VITA

Shannon Elizabeth Keane was born in Boston, Massachusetts in 1972. She graduated from Lincoln-Sudbury Regional High School in 1991. She attended the University of Massachusetts at Amherst, and received a Bachelor of Science degree in both Wildlife Biology and Natural Resources Management in 1997. For the 1994-1995 acedemic year, Shannon attended the University of Alaska, Fairbanks. She then spent the summer of 1995 as a field technician for the Institute of Arctic Biology studying Pacific Black Brant ecology on the Yukon-Kuskakwim Delta in Alaska. In the summer of 1996, she was a field technicinan for Connecticut Audubon Society, assisting in a study of Common Terns and endangered Roseate Terns on Falkner Island in Long Island Sound, Connecticut. In 1997, Shannon monitored Piping Plover reproductive success for Massachusetts Audubon Society at various locations on Cape Cod, Massachusetts. She began working on the Monomoy National Wildlife Refuge Piping Plover and Gull project through Virginia Polytechnic Institute and State University in April 1998. Shannon was granted an assistantship at Virginia Polytechnic Institute and State University in August 1998.