Section 6 Performance Report Review

Attachment to letter dated: March 5, 1998

Project: Characterization of Key Information Gaps Associated with Ecology of Piping and Snowy Plovers along the Texas Gulf Coast

Final or Interim report? Final

Job # : 82

Report: X is acceptable as is

___ is acceptable as is for interim report, but the following comments are made for future reference

___ needs some minor revision

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. E-1-9

ENDANGERED AND THREATENED SPECIES CONSERVATION

Project No. 82: Characterization of Key Information Gaps Associated with the Ecology of Piping Plovers and Snowy Plovers along the Texas Gulf Coast

Project Coordinator: Lee F. Elliot

Principle Investigator: Curtis Zonick

Gary L. Graham
Program Director, Endangered Species

Andrew Sansom
Executive Director

January 30, 1998

FINAL REPORT

State: Texas **Grant Number:** E-1-9

Grant Title: Endangered and Threatened Species Conservation

Project Title: Characterization of Key Information Gaps Associated with the Ecology of Piping Plovers and Snowy Plovers along the Texas Gulf Coast

Contract Period: September 1, 1996 through August 30, 1997.

Project Number: 82

Objective: To characterize the nocturnal ecology of Piping Plovers and Snowy Plovers along the Texas Gulf Coast on selected public lands, and on selected privately held lands where landowners permission can be arranged; to characterize the historical and current breeding distribution of Snowy Plovers along the Texas Gulf Coast; to characterize washover passes as a habitat type for Piping Plovers and Snowy Plovers; to seek cooperative agreement with private landowners leading to the conservation of Piping and Snowy Plover habitat.

PREFACE

Attachments A (Snowy Plover Breeding Ecology Along the Texas Gulf Coast) and B (The use of Texas Barrier island Washover Pass Habitat by Piping Plovers and Other Coast Waterbirds) are submitted to meet the Federal Aid Report requirements for this study.

Submitted by: Lee Elliott **Date:** November 1, 1997

Approved by: Neil E. Carter **Date:** January 31, 1998
Neil (Nick) E. Carter

Attachment A

SNOWY PLOVER BREEDING ECOLOGY ALONG THE TEXAS GULF COAST

A Report to the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service

Curt Zonick
National Audubon Society

September 1997

SNOWY PLOVER BREEDING ECOLOGY ALONG THE TEXAS GULF COAST

INTRODUCTION

A better understanding of the current breeding biology of Snowy Plovers along the Texas Gulf Coast is needed to appraise the current health of the species in Texas, and to provide a baseline from which to assess future population trends. Until recently, the breeding distribution of Snowy Plovers in Texas and Northern Mexico was poorly understood. Snowy Plovers are not detectable by most organized breeding bird surveys and few independent efforts have been made in Texas to document their breeding activity, or the breeding activity of other shorebird and waterbird species sharing tidal flat habitat with Snowy Plovers during the summer period. The habitat requirements of breeding Snowy Plovers along the central and upper Texas coast, and the factors that may threaten current breeding populations in these regions (e.g. predation, human disturbance) have also only just recently been investigated. This study expands on other recent work investigating the breeding ecology of Snowy Plovers along the Texas Coast (Rupert 1996, Zonick 1996).

METHODS

To identify new nesting sites and characterize the ecology of nesting Snowy Plovers, I expanded upon research that I began in 1993. Aerial photographs and maps delineating habitat features were studied to identify locations within Texas' Gulf Coastal counties that appeared to exhibit suitable breeding habitat for Snowy Plovers as defined in Zonick (1996) and delimited by the Bureau of Economic Geology Submerged Lands of Texas Maps. I visited the areas that 1) appeared to offer the most promise for supporting breeding Snowy Plovers, 2) that were accessible, and 3) where permission could be obtained to enter the property, and censused these sites for the presence of Snowy Plovers and evidence of breeding activity (territorial behavior, nests, chicks, etc.).

Ten sites were monitored approximately weekly throughout the early part of the breeding season. With the assistance of Jeff Rupert (National Audubon Society) I mapped and revisited nests in order to describe macrohabitat and microhabitat features of nesting sites, determine nest fates, determine causes of nest loss, and develop a rough estimate of nesting success for Snowy Plovers along the Texas coast. Care was take to avoid attracting predators to nests by maintaining a distance of 5-10 meters from the nests and collecting nest site data with the aid of binoculars. Nests were marked for relocation by sinking numbered tongue depressors 2/3 into the ground no closer than 10 m from the nests.

Nest fate was estimated based on egg shell evidence in and within a 10 m radius around the nests, presence of predator tracks around nests, and the presence of broods nearby nest location. Nests with no eggs and numerous predator tracks were scored as failed nests. Nests with no eggs, but broods nearby and an absence of predator tracks were scored as successful. When possible, nest bowls were carefully examined for eggshell evidence to support nest fate as described by Mabee (1997).

RESULTS

Breeding Distribution

Several of the locations that I identified as potential breeding sites prior to my surveys this summer were found to support breeding Snowy Plovers. Many man-made structures that mimic natural saline lagoon habitat found along the Texas Coast supported Snowy Plover colonies. Two additional habitat type delimited on the BEG maps that were used by Snowy Plovers but were not listed in Zonick 1996 were the berm (BB) and beach (B) habitat types. Several privately-owned sites were monitored during this study, with land-owner consent. However, some of the landowners requested that the information I collected on their property remain confidential, therefore, the locations of these sites and the data collected at these sites have been withheld from this report.

Breeding Snowy Plover were not detected on private or public property sites along the upper Texas Coast with suitable habitat (e.g. Bolivar Flats, Big Reef, San Luis Pass). However, the amount of nesting habitat as defined in Zonick 1996 is greatly diminished along the upper Texas coast relative to the Laguna Madre.

Accompanied by Jeff Rupert, I conducted 3 censuses at a total of 6 locations in Mexico on beach and barrier island habitat between the Rio Grande and Mezquital. These censuses revealed populations of Snowy Plovers, and other flat-nesting birds nesting primarily within the wide band coppice dunes bordering the Gulf shoreline. We recorded a total of 36 nests from Snowy Plovers (17), Least Terns (12) and Wilson's Plovers (7). I also observed a small colony of American Avocets (estimated 20 pairs with several nests found) just bayward of a large tidal pool running up the spine of the peninsula enclosing the northern extent of the Tamaulipan Laguna Madre.

Therefore, it appears that the large majority of the current Snowy Plover Texas Coastal breeding population occupies the high flat habitat and washover pass habitat along the Texas Laguna Madre and at least the beach and barrier island habitat along the upper coast of Mexico.

Nesting Success

A total of 175 nests from 7 different species were mapped at 10 Texas sites visited approximately weekly throughout the early part of the breeding season (Table 1).

Species	# nests	# eggs	Distance to water		Distance to vegetation	
Snowy Plover	78	2.53 (3)	119.4	(6-450)	21.3	(0-175)
Least Tern	71	1.72 (3)	147.9	(3-650)	7.8	(0-120)
Wilson's Plover	15	2.87 (4)	72.9	(11-200)	1.8	(0-8)
Black-necked Stilt	5	4.00 (4)	38.4	(2-75)	5.5	(0-16)
Common Nighthawk	3	1.67 (2)	131.0	(18-225)	0.1	(0-0)
Killdeer	2	2.50 (4)	15.0	(10-20)	1.0	(0-2)
Willet	1	3.00 (3)	35.0	--	0.0	--

Table 1. Data collected in associated with nests mapped at 10 coastal breeding sites. Because Snowy Plover nests were targeted, the number of nests do not reflect the relative abundance of each species. The mean number of eggs /nest are reported for each species, with the maximum clutch size observed in parentheses. Because some nests were observed only once, the numbers reported in this table probably underestimate average clutch sizes. The average distance of nests to the nearest body of standing water and vegetation are reported in meters. Minimum and maximum distances are reported in parentheses.

A total of 70 Snowy Plover nests were monitored approximately weekly at 10 locations. We were able to deduce nest fates for 48 of the 70 nests, and estimated hatching success for these nests using the Mayfield method (Mayfield 1975). Hatching success was high at one of the sites but low at the other sites (Table 2). The site with high hatch success (Sunset Lake) was located along a major highway but generally received low levels of human disturbance. Few predator tracks were observed at this site. The other sites (washover passes and CPL) also experienced very low levels of human disturbance, but nest predators such as coyotes and raccoons appeared to be much more common based upon the presence of tracks at the sites.

Location	# nests	Fate	Hatching success
Washover Passes	26	3/17/6	19.8 %
CPL	14	2/4/8	17.4 %
Sunset Lake	8	5/1/2	78.1 %
Total	48	10/22/16	25.1 %

Table 2. Hatching success is estimated for 48 nests monitored approximately weekly at 10 sites along the Texas Coast. Eight of the sites were washover passes, and the data from these sites have been pooled for a cumulative "washover pass" estimate. Hatching success estimates only the likelihood a nest will survive to hatching according to the Mayfield Method (Mayfield), and does not indicate anything about the likelihood that chicks will survive to fledge. Estimates are based upon a 26 day incubation period.

Another major difference between the 3 sites was the spatial distribution of shell and gravel banks. Snowy Plovers and Least Terns exhibited an apparent preference for shell covered microhabitat when placing their nests (Table 3). Snowy Plovers, in particular, not only nests within shell covered areas, but lined their nests with shell fragments.

	Snowy Plovers		Least Terns	
Shell/gravel cover				
none	20.8	(10)	17.3	(9)
low	4.2	(2)	53.8	(28)
moderate	22.9	(11)	7.7	(4)
high	52.1	(25)	21.2	11
Nest Lining				
none	4.2	(2)	71.1	(37)
shell/gravel	91.6	(44)	29.9	(15)
other	4.2	(2)	0.0	0

Table 3. Association of shell and gravel to Snowy Plover and Least Tern nests. Nest macrohabitat features are described with regard to shell/gravel cover surrounding nests, and nest lining material. Data are summarized as the % of the total nests followed by the # of nests in parentheses.

Shell banks may offer some measure of camouflage. Microshadows cast by the shell fragments closely resemble the dark flecks on the plovers eggs, and nests on this microhabitat can be very difficult to visually distinguish. Most likely, however, shell banks are preferred because they offered an elevated, well draining microsite that reduces the likelihood of nest loss from flooding during unseasonal high tides or summer rainstorms.

At the Sunset Lake site - a man-made berm along Highway 181/35 north of Corpus Christi - shell and gravel banks were distributed relatively homogeneously, and created the matrix habitat at the site. In contrast, at most of the washover passes and the CPL site, shell and gravel banks were distributed in a highly clumped fashion within a matrix of unvegetated sand flats. As a result, predator populations were probably able to locate plover nests much easier at the washovers and at the CPL site by systematically checking the patchy shell banks. At heavily depredated washover passes we observed tracks that indicating that coyotes were targetting shell banks (Figure 1).

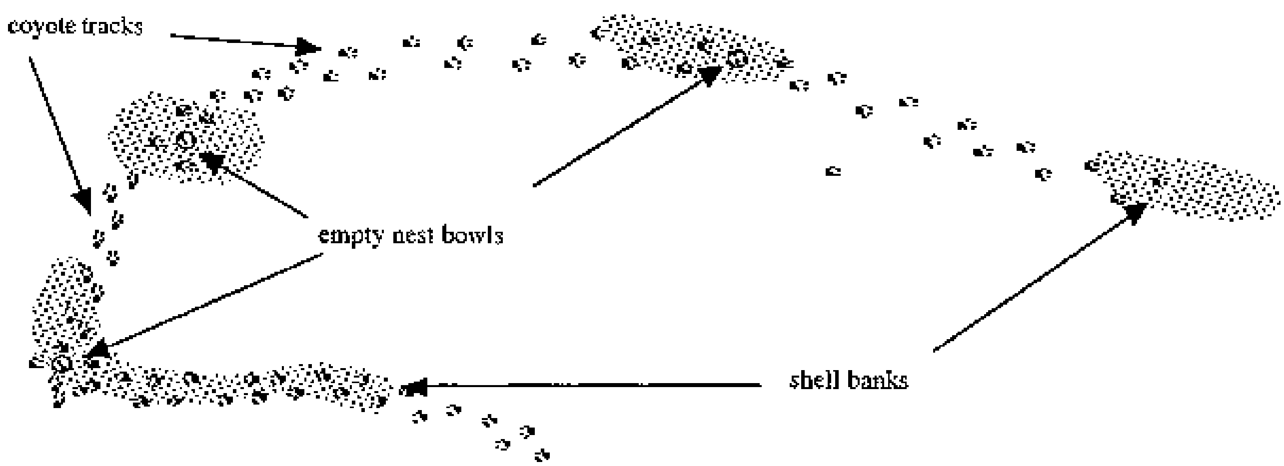

Figure 1. Tracks left by coyotes indicated that they, and perhaps other nest predators, were able to efficiently detect Snowy Plovers nests by targeting shell bank microhabitat.

Coyote depredation was the greatest determinable cause of nest failure followed by crushing from vehicles (Table 4). All coyote depredations were recorded on barrier island washover pass habitat.

Cause of nest failure	# Nests
coyote	19
vehicle running over nest	7
eggs washed out of nest by rain/wind	2
coyote/dog	1
raccoon	1
raven	1
abandoned	1

Table 4. Causes of nest failure from 32 nests where outcomes were determinable.

The association between Snowy Plovers and Least Terns

Snowy Plovers and Least Terns often nested together in loose colonies. We searched 9 Snowy Plover nesting sites for confirmed nesting evidence of Least Tern nesting activity (e.g. nests with eggs or broods), and confirmed that Least Terns were nesting in at least 8 of the sites and attempting to nest in the other site. Both species preferred to nest in areas with sandy substrate covered by small stones, shell fragments or other types of surface materials. Snowy Plovers and Least Terns did not differ with regard to the distance they located their nests from bodies of standing water ($p = 0.3664$; Table 1), however, Least Terns were more likely to nest near vegetation ($p = 0.0317$; Table 1) and Snowy Plovers were more likely to nest near debris (e,g, jetsam, human refuse, driftwood; $p = 0.0003$).

Snowy Plovers may benefit by nesting in association with Least Terns by experience lower levels of nest loss from depredation due to the aggressive mobbing behavior of Least Terns. However, Snowy Plovers begin nesting earlier than Least Terns along the Texas Coast, and many plover nests are established before terns arrive. We detected the first Snowy Plover nest at our sites on 20 March 1997, whereas the first Least Tern was not recorded until 28 March 1997, and the first Least Tern nest was not detected until 1 May 1997. Least Terns also do not appear to exhibit the level of site fidelity along the Texas Coast that would allow Snowy Plovers to predict where terns will be nesting until well after many Snowy Plover nests have been established.

Snowy Plovers do not always benefit from the presence of Least Terns. At one site (CPL), I marked nest bowls made and maintained by territorial male Snowy Plovers as I discovered them - including those that did not contain eggs. Many of these unfilled nest bowls, or "scrapes", were maintained by male plovers for over a month even though I never found the nests to contain Snowy Plover eggs. Presumably these males were unable to attract a mate but continued to defend breeding territories. At least 3 such nest bowls were "pirated" by arriving Least Terns that laid clutches in the plover-made nests. However, whereas some interspecific aggression was observed between terns and plovers, such displays were infrequent given their close nesting associations.

DISCUSSION

Snowy Plovers were predictably associated with the 4 habitat type described in Zonick 1996 (washover passes [WA], shallow lagoons [W], low flats [LF] and high flats [HF]. Additionally, Snowy Plovers were found in association with berms [BB] and beaches [B]. Snowy Plovers and, to a lesser extent Least Terns, appeared to preferentially nest within shell-covered microhabitats, and this bias appeared to increase their susceptibility to depredation by coyotes and probably other nest predators. Hatching success was very low at two of the 3 site groupings where nest fates were monitored. Mammalian depredation and vehicular crushing were the 2 highest causes of nest loss. Censuses of coastal habitat in northern Mexico revealed apparently healthy nesting populations, primarily within coppice dunefields and backbeach habitat.

Hill (1985) reported higher Least Tern nest loss from depredation when nests were placed within stone covered microhabitat at Salt Plains National Wildlife Refuge (SPNWR). However, Snowy Plovers nesting at the refuge were less less likely to place their nests on shell covered habitat (20.2% placement at SPNWR vs. almost 80 % at sites monitored for this study). Snowy Plover nest success at SPNWR averaged 19.0 %, 17.1%, and 64.9 % over a three year period (Hill 1985). Mammalian predators were the primary cause of nest loss during all three years.

Measures that 1) limit or prevent vehicular entry into washover passes and 2) minimize anthropogenically enhanced predator populations would be expected to enhance Snowy Plover and Least Tern productivity on barrier island habitats. Within man-made sites and other easily managed areas, steps that can be taken to protect predator intrusion (e.g deployment of electric fencing around known nesting colonies) or greatly expand the presence of shell banks (to reduce the predictability of nest location) should increase local productivity of these two species.

ACKNOWLEDGMENT

On behalf of the National Audubon Society I would like to acknowledge the support of the Texas Parks and Wildlife Department, the U.S. Fish and Wildlife Service, the Central Power and Light Company, the Texas Department of Transportation and the dedicated staff at the Laguna Atascosa National Wildlife Refuge for their role in making this research possible. Laguna Atascosa, in particular, has a long history of supporting Piping Plover recovery and shorebird conservation, and is still among the best places in Texas from which to conduct research. I would also like to personally express my appreciation to Jeff Rupert and Scott Hedges (National Audubon Society), Gene Blacklock (EcoServices, inc.), Lee Elliott (Texas Parks and Wildlife Department), Ted Eubanks (Fermata, Inc.), and Tim Cooper and Steve Labuda (Laguna Atascosa NWR) for their assistance in the field, for their valuable advise, and for their admirable dedication to the conservation of Texas' native bird communities.

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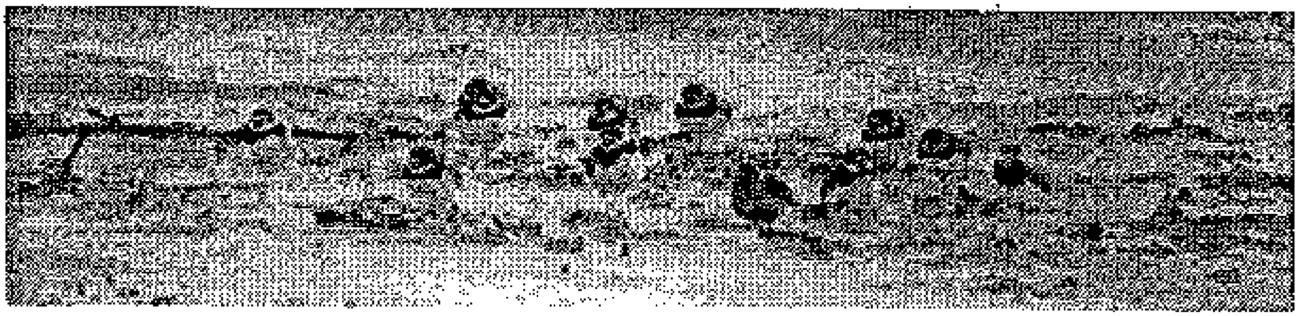
Zonick, 1996. Key residual questions associated with the ecology of Piping Plovers and Snowy Plovers along the Texas Gulf Coast. Report to Texas Parks and Wildlife Department. 11 pp.

Attachment B

THE USE OF TEXAS BARRIER ISLAND WASHOVER PASS HABITAT BY PIPING PLOVERS AND OTHER COASTAL WATERBIRDS



A Report to the Texas Parks and Wildlife Department
and the U.S. Fish and Wildlife Service

Curt Zonick
National Audubon Society

September 1997

THE USE OF TEXAS BARRIER ISLAND WASHOVER PASS HABITAT BY PIPING PLOVERS AND OTHER COASTAL WATERBIRDS

INTRODUCTION

This study addresses the lack of standardized information associated with the use of washover pass habitat by coastal waterbirds, particularly the federally-threatened Piping Plover (*Charadrius melodus*) and its close relative the Snowy Plover (*C. alexandrinus*). Recent censuses have established that the majority of the world's Piping Plovers and southeastern Snowy Plovers (*C. a. tenuirostris*) winter along the western Gulf Coast, especially the Texas Coast (Haig and Plissner 1993, Eubanks 1994, Elliott 1996). Whereas a great deal is now known about the general distribution and habitat associations (Nicholls and Baldassarre 1990a, b, Haig and Plissner 1993, Eubanks 1994, Brush 1995, Lee 1995, Elliott 1996, Zonick and Ryan 1996, Garza 1997), behavior (Johnson and Baldassarre 1988, Elliott and Teas 1996, Zonick and Ryan 1996), and foraging ecology (Withers 1994, Elliott and Teas 1996, Zonick and Ryan 1996) of these 2 species during the winter period, relatively little is known about their roosting ecology or their use of washover habitat.

Both plover species have been observed to congregate in large diurnal roosts in washover passes. Zonick and Ryan (1996) described washover passes as an important, and perhaps critical, winter habitat for both Piping Plovers and Snowy Plovers (Zonick and Ryan 1994). Washover passes exhibit sparsely vegetated coastal wetland habitat Figure 1) - features preferred by Piping Plovers and Snowy Plovers - and are only rarely inundated by high tides. Therefore, passes may provide essential roosting habitat for plovers and other waterbird species.

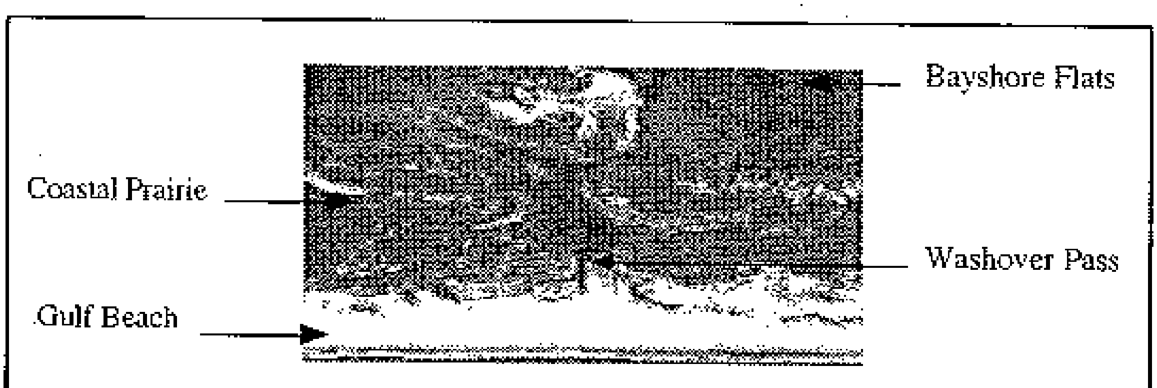


Figure 1. Aerial photograph of a washover pass. The view is from the Gulf of Mexico looking westward through the pass to the bayshore habitat bordering the Laguna Madre. Coastal prairie habitat borders the washover pass to the north and south, and a patch of prairie lies between 2 forks in the west side of the pass. The pass itself, however, is nearly unvegetated, and exhibits many microhabitats used by foraging and roosting plovers (e.g. saturated sand and algal flat and dry patches of sand).

Zonick (1996) proposed that washover passes may serve as essential winter refugia for these species because diurnal roosting was often associated with harsh weather conditions (e.g. periods of high bayshore tides often accompanying winter north fronts), when Piping Plovers and Snowy Plovers may have difficulty foraging due to the inaccessibility of suitable foraging habitat. Under such conditions, washover passes may provide the most optimal available habitat.

A large portion of the Snowy Plover breeding population on Texas barrier islands appeared to be concentrated in washover passes, suggesting this habitat may also provide important habitat for the Snowy Plover during the breeding season (Zonick and Ryan 1996). This is the first standardized to focus on the use of Texas washover pass habitat by plovers and other coastal waterbirds.

Washover Pass Habitat

Lonard and Judd (1993) describe barrier islands as "paradigms of disturbance dominated ecosystems" and nowhere is this more evident on barrier islands than within washover pass habitat. Washover passes are a dynamic barrier island habitats created and maintained by hurricanes and tropical storm events. Tropical storms and hurricanes regularly bring great forces to bear on the barrier islands along the Texas Gulf Coast. When these storms strike, weak spots in the islands (e.g. low areas or areas without a substantial dune line) quickly erode, sometimes creating temporary tidal channels connecting the Gulf and bayshore waters. These temporary channels are often referred to as "washover channels". Most washover channels quickly shoal in to form "washover passes"a seral stage in the succession of these disturbed landscapes. Even though washover passes (also called washover areas) are generally above the mean high tide line, they remain relatively free of vegetation for extended periods due to the harsh coastal climate. If undisturbed, washover passes eventually "heal", and coastal prairie and foredunes become reestablished. However, often another tropical storm event strikes the area before the pass can completely recover. Until they heal, washover passes are lower in elevation than the surrounding coastal prairie tracts, and lack protective dune lines. For these reasons, storm surges become funneled into the washover passes and continually scour away pioneer vegetation and dunes. As a result, most washover passes persist as semi-permanent features that are maintained by a regular regime of storm surge disturbance much as prairie habitat is maintained by a recurring regime of fire and grazing disturbance, or as bottomland hardwood forests are maintained by a recurring flood disturbance regime.

METHODS AND STUDY AREA

Diurnal avian censuses were conducted at 25 washover passes located on Mustang Island, South Padre Island, and Brazos Island (Figure 2; Appendix I).

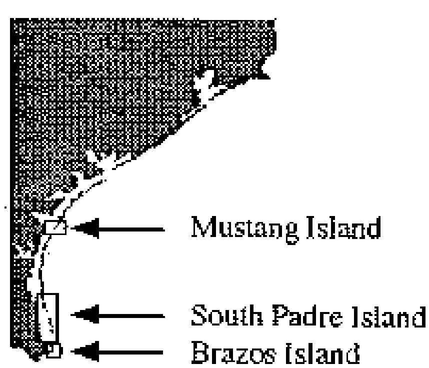


Figure 2. Locations of the 3 barrier islands monitored during this study.

The passes on South Padre Island were divided into 3 separate regions - a 9.2 km southern region located proximal to the City of South Padre along Highway 100, a 19.6 km northern region located distal to the development and extending to the Mansfield Channel, and a 13.5 km central portion located between these 2 regions. Natural boundaries were used to delineate the washover passes (Zonick 1996). Censuses began July 1996 and ended July 1997. Censuses were conducted approximately twice each month during the nonbreeding season (July - March). During the breeding season (April - August) the frequency of site visitation was reduced to minimize disturbing resident breeding colonies. Jeff Rupert (National Audubon Society) assisted with the censuses conducted during the breeding season.

Separate censuses were conducted within each washover pass, within beach habitat directly adjacent to each washover pass, and within sections of beach lying between the washover passes. The abundance of all waterbird species was recorded during each census. Foraging terns, swallows, and other birds in flight during the census were not included in the counts. However, with the exception of individuals in flight during the census, and a small number of passerines occupying backbeach habitat and the washover margins, the censuses should be considered complete and accurate counts of the entire bird community using the beach and washover habitats.

Parameters describing the local environmental conditions within the census area were recorded during the censuses. These parameters included air temperature, wind speed, wind direction, precipitation, bayshore tidal inundation, and 3 estimates of direct human-related disturbance (# vehicles, # pedestrians, and # dogs). The year was partitioned into summer (May 16 - July 10), winter (1 November - February 20) spring (February 21 - May 15) and fall (July 11 - October 31) periods for seasonal comparisons of washover pass use. The seasons are largely defined by the temporal boundaries of Piping Plover and Snowy Plover life cycle stages (breeding season, migratory pulses). For washover pass censuses, data were also collected describing the number and size of standing pools of water (referred to as "lakes" in this report) within the passes.

Plover and waterbird densities are reported for pass habitat (# birds/ha) and beach habitat (# birds/km). The area of each pass was measured by digitizing pass boundaries from recent aerial photographs (1994; 1:45,000) into the GIS application ATLAS (version 2.1, Strategic Mapping Inc., Santa Clara, CA). Data were statistically analyzed using JMP (version 3.1.5., SAS Institute, Inc. Cary, N.C.). Most parameters were compared using Wilcoxon/Kruskal-Wallis nonparametric analyses of variance (ANOVA). Relationships between bird population estimates and environmental conditions (e.g. lake #, human disturbance) were evaluated by linear regression.

RESULTS

Results are presented separately for washover pass habitat and for the beach habitat located adjacent to the 23 passes monitored during this study. Results are summarized independently for each of the washover passes in Appendix I. The results presented below summarize findings for all passes, or grouped sets of passes.

Washover Pass Habitat

Area

The washover passes monitored during this study ranged in size from 11 ha to 115 ha, with a mean area of 39 ha. Collectively, they comprised 895 ha of habitat.

Lakes

Many of the washover passes contained small lakes of standing water, some of which were deep enough to retain water throughout the study. The number of lakes/washover pass ranged from 0 to 3. The average number of lakes/washover throughout the study ranged from 0.06 - 1.11, with a mean of 0.58 lakes/washover.

Human Disturbance

Human disturbance within the washover passes varied somewhat along the coast, but was generally infrequent (Table 1). No disturbances were observed during 86% of the censuses (285/333). The islands did not differ significantly with regard to vehicle density ($p = 0.2559$) pedestrian density ($p = 0.7829$) or dog density ($p = 0.5506$).

Island	N	Vehicles	Pedestrians	Dogs
Mustang	42	0.004	0.004	0.000
South Padre	257	0.027	0.019	0.002
Brazos	36	0.019	0.006	0.000

Table 1. Mean densities (#/ha/census) of human-related disturbances recorded within the washover passes on each barrier island.

The 3 geographic regions of South Padre Island (see Methods and Study Area) varied significantly with regard to human disturbance (Table 2). The regions differed with regard to vehicle density ($p < 0.0001$), pedestrian density ($p = 0.0017$) and dog density ($p = 0.0088$). The South Region, nearest the City of South Padre Island, exhibited the highest levels of human disturbance. Human disturbance was much lower north of Highway 100 (i.e. the Central and North Regions for this study; Table 2).

Region	N	Vehicles	Pedestrians	Dogs
South	77	0.089 [North, Central]	0.062 [North, Central]	0.006 [Central]
Central	128	0.002	0.001	0.000
North	52	0.000	0.000	0.000

Table 2. Mean densities (#/ha/census) of human-related disturbances recorded within the washover passes within each of the 3 geographic regions of South Padre Island. The results of pairwise comparisons between the regions are summarized in brackets []. Regions with significantly lower levels of disturbance are enclosed in brackets after the data from the region in question. For example, both the North and Central Regions had significantly lower densities of vehicles during the censuses than the South Region, and are enclosed in brackets under "Vehicles" on the row summarizing data from the South Region.

Piping Plovers

Piping Plovers were recorded at least once in all but 1(pass SPI C3; see Appendix I) of the 23 washover passes monitored. The maximum number of Piping Plovers observed in a single pass was 158 at pass SPI C8 (Appendix I). The mean number of Piping Plovers per pass ranged from 0 - 17.4, with a mean of 3.2 (Table 3). When all of the passes were considered together, the cumulative maximum and mean populations of Piping Plovers were 548 and 72.7 respectively.

	Piping Plovers	Snowy Plovers
Abundance		
Maximum	23.8 (36.9)	17.0 (17.8)
Mean	3.2 (3.2)	3.8 (3.8)
Density		
Maximum	0.65 (1.0)	0.44 (0.26)
Mean	0.08 (0.13)	0.09 (0.07)

Table 3. Total population data are summarized for Piping Plovers and Snowy Plovers as they were recorded during the washover pass censuses. The numbers in the table represent the average of all 23 passes. Abundance (number of birds/pass) and density (number of birds/ha/pass) summaries are presented. Standard deviations are reported in parentheses.

Most of the Piping Plovers observed during the censuses were foraging (Table 4). Piping Plover foraging flocks ranged from 1 - 107 birds, with an average of 15.2 birds/flock. Piping Plover roosting flocks ranged from 1 - 51 birds, with an average of 8.3 birds/flock. More Piping Plovers were involved in foraging than roosting (i.e. the foraging proportion was > 50%) in 18 of the 22 washover passes where Piping Plovers were detected.

	Foraging	Roosting	Foraging Proportion
Piping Plovers	944	233	76.0
Snowy Plovers	756	334	67.7

Table 4. The general behavior (foraging vs. roosting) of Piping and Snowy Plovers is summarized. The foraging and roosting summaries represent the total number of birds from all censuses. Foraging proportion represents the average percentage of plovers engaged in foraging behavior. This statistic was calculated for each census where a Piping Plover or Snowy Plover was recorded, and then averaged over all such censuses. It is an estimate of the average behavior of each species within a typical sample of the 23 washover passes during the 1996-1997 study period.

Piping Plover roosting flocks were detected at 15 of the 23 washover passes monitored during this study. Roosting Piping Plovers were most frequently detected at the four passes monitored on Mustang Island and Brazos Island. Roosting flocks were observed on 4 separate occasions at each of the Mustang Island passes (MI S1 and MI S2; Appendix I), on 5 occasions at the South Washover on Brazos Island (MI N2; Appendix I), and on 3 occasions at the North Washover pass on Brazos Island (MI N1; Appendix I). The washover pass with the highest mean roost flock size for Piping Plovers was SPI C8 (Appendix 1) on South Padre Island with 3.5 roosting Piping Plovers/census. Pass MI S2 (Newport Pass), ranked second among passes with an average of 3.1 roosting Piping Plovers/census (Figure 3).

Figure 3. A small flock of 11 Piping Plovers and 1 Dunlin roost within Sargassum wrack material along the eastern margin of pass MI S2 on Mustang Island (Newport Pass, April 14, 1997). This pass supported the 2nd largest average roosting flock of Piping Plovers.

Snowy Plovers

Snowy Plovers were detected at least once in all of the washover passes. The number of Snowy Plovers per pass ranged from 0 - 158, with a mean of 23.8. The mean number of Snowy Plovers per pass ranged from 0 - 17.4, with a mean of 3.2. When all of the passes were considered together, the cumulative maximum and mean populations of Snowy Plovers were 391 and 75.5 respectively.

Most of the Snowy Plovers observed during the censuses were foraging (Table 4). Snowy Plover foraging flocks ranged from 1 - 80 birds, with an average of 7.3 birds/flock. Snowy Plover roosting flocks ranged from 1 - 38 birds, with an average of 5.6 birds/flock. More Snowy Plovers were involved in foraging than roosting (i.e. the foraging proportion was > 50%) in 17 of the 23 washover passes where Snowy Plovers were detected. Snowy Plover roosting flocks were detected at 22 of the 23 washover passes monitored during this study.

Factors affecting plover populations

Area. The area of habitat within the individual washover passes was positively correlated with the number of Piping Plovers ($p = 0.0116$) and Snowy Plovers ($p < 0.0001$) present during the censuses. Therefore, plover densities (# plovers/ha) were used to compare the effects of environmental parameters on plover populations.

Lakes. Whereas Piping Plover density was not affected by the presence of lakes within the washover passes ($p = 0.1155$), the density of Snowy Plover populations increased with the number of lakes within the washovers ($p = 0.0003$).

Human Disturbance. Neither Piping Plover density ($p = 0.8025$, 0.8973, and 0.6382 respectively) nor Snowy Plover density ($p = 0.4141$, 0.4404, and 0.2445 respectively) was significantly affected by human disturbance as measured by vehicle density, pedestrian density and dog density.

Bayshore Tidal Inundation. Bayshore tidal conditions significantly affected the density of Piping Plovers ($p < 0.0001$; Figure 4) and Snowy Plovers ($p < 0.0001$; Figure 5) within the passes. Both species were present in washover passes at greater densities during high and very high tides.

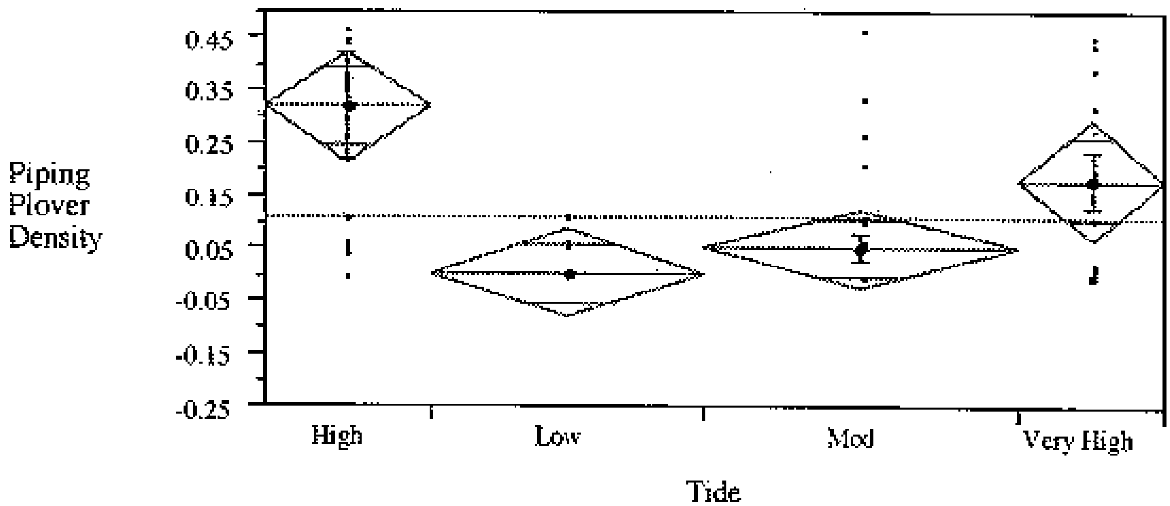


Figure 4. A pictogram illustrating the variation of average Piping Plover density within the 23 washover passes during different levels of bayshore tidal inundation. The passes were used preferentially during the high and very high bayshore tides.

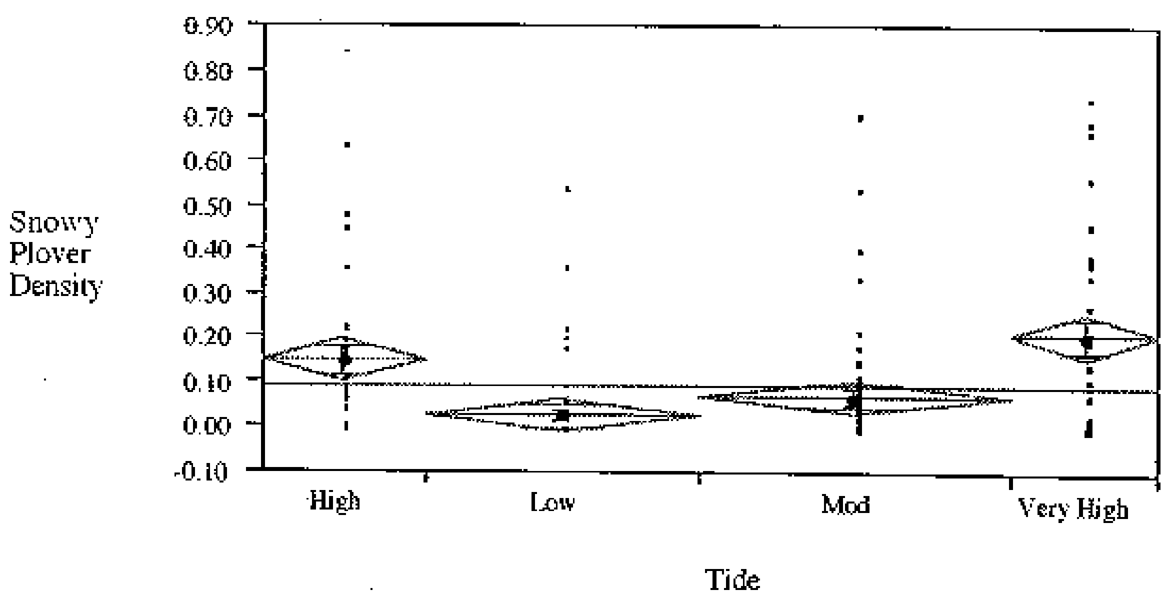


Figure 5. A pictogram illustrating the variation of average Snowy Plover density within the 23 washover passes during different levels of bayshore tidal inundation. The passes were used preferentially during the high and very high bayshore tides.

Location. Piping Plover densities were significantly higher in washover passes on Brazos Island than on Mustang Island or South Padre Island (Table 5). There was no difference between Piping Plover density in washovers on South Padre Island and Mustang Island.

Snowy Plover densities were significantly higher in washovers on Brazos Island than on Mustang or South Padre (Table 5). However, Snowy Plover densities on Mustang Island were significantly higher than were those on South Padre Island (Table 5).

Island	N	Piping Plovers	Snowy Plovers
Mustang	42	0.06	0.07 [South Padre]
South Padre	257	0.06	0.09
Brazos	36	0.37 [Mustang, South Padre]	0.13 [Mustang, South Padre]

Table 5. Mean densities of Piping Plover and Snowy Plover populations within washover passes among the 3 islands. The results of pairwise comparisons between the islands are summarized in brackets []. Islands with significantly lower plover densities ($p < 0.05$) are enclosed in brackets after the data from the island in question. For example, both Mustang Island and South Padre Island had significantly lower densities of Piping Plovers and Snowy Plovers during the censuses than did Brazos Island, and are enclosed in brackets on the row summarizing data from the Brazos Island.

The density of Piping Plovers was significantly lower among passes within the South Region than within the North Region (Table 6). Piping Plover densities did not differ among the North and Central Regions. Snowy Plover densities did not differ significantly among any of the geographic regions of South Padre Island.

Region	N	Piping Plovers	Snowy Plovers
South	77	0.02	0.06
Central	128	0.10 [South]	0.11
North	52	0.09	0.09

Table 6. Mean densities of Piping Plover and Snowy Plover populations within washover passes among the 3 geographic regions on South Padre Island. The results of pairwise comparisons between the regions are summarized in brackets []. Regions with significantly lower plover densities ($p < 0.05$) are enclosed in brackets after the data from the region in question. In this case, only the Central and South regions differed significantly with regard to Piping Plover density, with the Central region supporting more than the South region.

Season. Both Piping Plovers ($p = 0.0002$) and Snowy Plovers ($p < 0.0001$) showed seasonal preferences for their use of washovers passes. However, the season of preferential use varied somewhat. Piping Plovers used the passes most frequently during the migratory periods, particularly during spring migration (Figure 4).

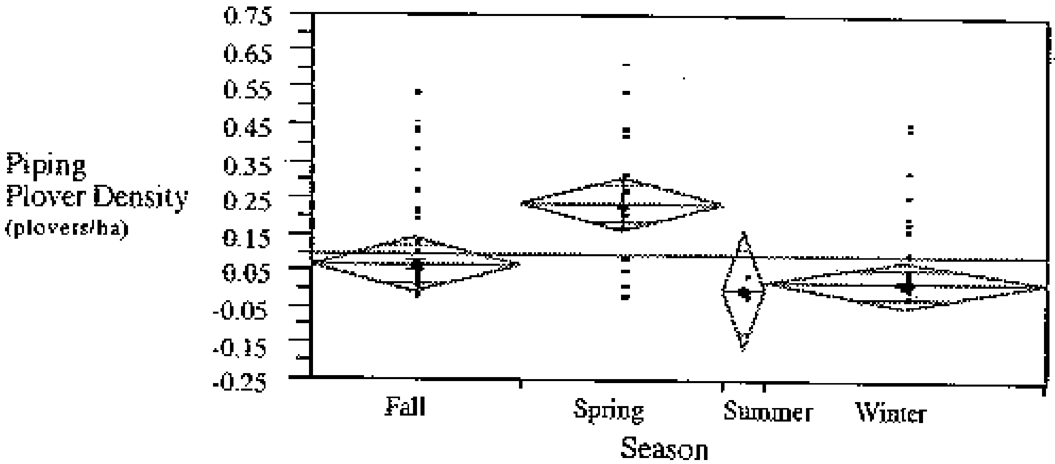


Figure 4. A pictogram illustrating the seasonal variation of average Piping Plover density within the 23 washover passes. The passes were used preferentially during the fall and spring migration periods, and plover densities were highest during the spring migration and lowest during the summer period.

Snowy Plovers, many of which bred within the washover being monitored (see "Snowy Plover Breeding Activity" below), used the passes preferentially during the spring and summer breeding period (Figure 5).

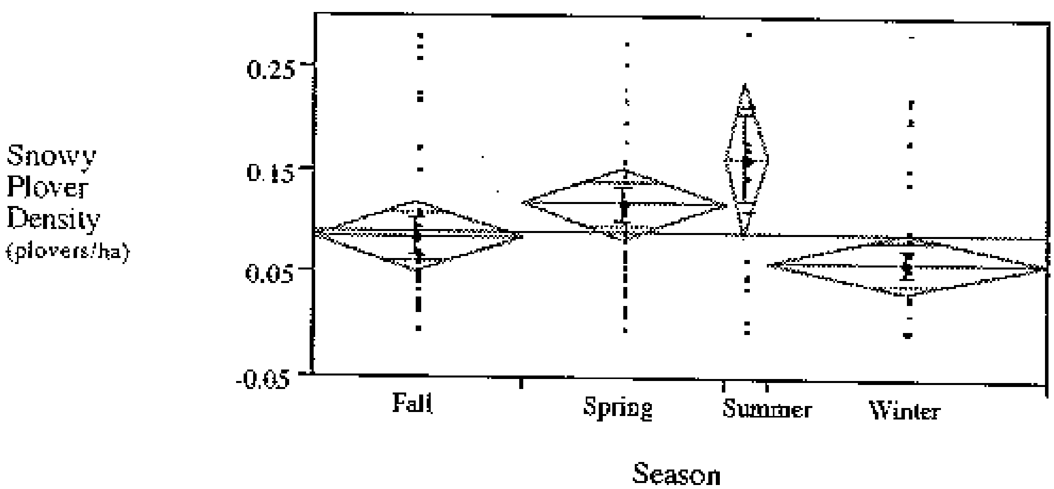


Figure 5. A pictogram illustrating the seasonal variation of average Snowy Plover density within the 23 washover passes. The passes were used preferentially during the spring and summer breeding periods, and plover densities were highest during the spring migration and lowest during the winter period.

Climatic Factors. Temperature, wind direction and wind speed, had no effect on the use of washovers by Piping Plovers ($p = 0.5923$, 0.6081 and 0.3995 respectively) or Snowy Plovers ($p = 0.3578$, 0.3075, and 0.3428 respectively).

Snowy Plover Breeding Activity

Snowy Plover populations were recorded in 20 of the 23 washover passes monitored during the breeding season (April - July). Nesting was confirmed to have occurred in at least 13 washover passes and was suspected in several other passes where territorial males were detected but nests or broods were not found. Whereas detailed nesting density and distribution measures were not measured in order to minimize disturbances to nesting colonies, some washover passes clearly supported large Snowy Plover nesting populations. For example, 8 nests were detected at washover pass SPI C8 during a partial census on 11 April 1997, yielding a minimum density estimate of about one nest every 4 hectares. Snowy Plovers nested in passes with and without lakes.

Least Terns, Wilson's Plovers and Common Nighthawks were also confirmed to have nested in the washover passes. Least Terns in particular nested in some washover passes in great number and were confirmed to have nested in 17 of the 23 washover passes. For example, a minimum of 38 tern nests were estimated in washover SPI C8 on 22 May 1997 based upon a count of the number of birds seen in incubating posture.

Both Least Terns and Snowy Plovers preferred to nest in shell fields, a microhabitat that was concentrated within washover passes relative to other barrier island habitats. Shell fields were particularly well defined along the north and south margins of many washovers and formed large, arc-shaped fans covering the western margin of most washover passes. Due to their close nesting association and high nesting density, Snowy Plover/Least Tern nesting groups existed as colonial nesting sites generally concentrated near the western margin of the washover passes. More information on Snowy Plover breeding ecology is presented in Zonick (1997)

Waterbird Guilds

All washover passes supported populations of shorebirds, seabirds and waders - the three major guilds of waterbirds using barrier island habitat. Tallies of waterbird species recorded during washover pass censuses are presented in Appendix II. Total population data for each of the dominant waterbird guilds are summarized in Table 7.

	Shorebirds	**Seabirds**	**Waders**
Abundance			
Maximum	169.2	212.7	9.0
Mean	28.7	28.5	1.0
Density			
Maximum	22.4	24.0	6.9
Mean	0.83	0.79	0.05

Table 7. Population data are summarized for shorebirds, seabirds and waders as they were recorded during the washover pass censuses. The numbers in the table represent the average of all 23 passes. Abundance (number of birds/pass) and density (number of birds/ha/pass) summaries are presented.

Factors affecting waterbird populations

Area. The area of habitat within the individual washover passes was positively correlated with the number of shorebirds ($p = 0.0344$) and total waterbird ($p = 0.0387$), but not waders ($p = 0.3095$) or seabirds ($9 = 0.2035$) present in washover passes during the censuses.

Lakes. The total number of waterbirds was positively correlated with the number of lakes/washover pass ($p = 0.0111$).

Human Disturbance. Total waterbird density was not significantly affected by human disturbance as measured by vehicle density ($p = 0.8025$), pedestrian density ($p = 0.8973$) and dog density ($p = 0.6382$).

Bayshore Tidal Inundation. Bayshore tidal conditions significantly affected the density of shorebirds ($p < 0.0001$), seabirds ($p = 0.0086$), and total waterbirds ($p < 0.0001$) but not waders ($p = 0.0686$) within the passes. Waterbirds were present at greater densities during high and very high tides (Figure 6).

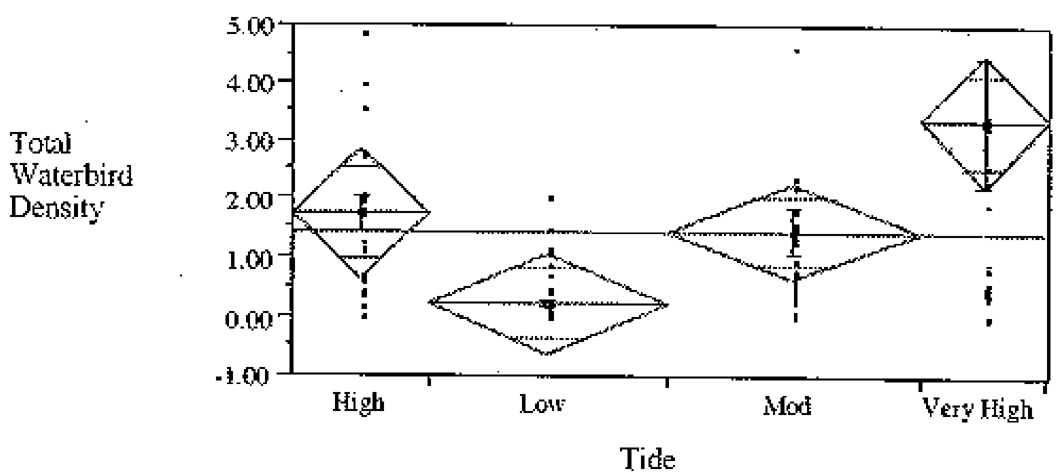


Figure 6. A pictogram illustrating the variation of average waterbird density within the 23 washover passes during different levels of bayshore tidal inundation. The passes were used preferentially during the high and very high bayshore tides.

Beach Habitat

Beach Length

For census purposes, beach habitat was partitioned into the regions directly Gulfward of the washover passes (washover beaches) and the regions between the passes (inter-pass beaches). Taken together, a total of 7.6 km of washover beach and 42.6 km of interpass beach were monitored.

Human Disturbance

Human disturbance was considerably higher within both types of beach habitat than was observed within the washover passes (Table 8; compare to Table 1). Whereas the density measures are not directly comparable (due to the different units of measurement), for an approximate comparison, one might estimate the area of beach present assuming 100 m wide beaches. The areas from 100 m wide beaches would result in density estimates of 0.28 vehicles/ha, 0.33 pedestrians/ha, and 0.04 dogs/ha for washover beach habitat and 0.27 vehicles/ha, 0.37 pedestrians/ha and 0.01 dogs/ha for inter-pass beach habitat. These density estimates are many times greater than those for washover pass habitat (see Table 1).

There was no difference between the 2 types of beach habitat with regard to vehicular density ($p = 0.5490$), pedestrian density ($p = 0.3107$) or dog density ($p = 0.7879$).

Beach Type	N	Vehicles	Pedestrians	Dogs
Washover	55	2.71	3.50	0.28
Interpass	102	2.66	3.71	0.13

Table 8. Mean densities (#/km/census) of human-related disturbances recorded within the 2 beach types.

Mustang Island beaches experienced much higher levels of human disturbance during the study period than did beaches on either South Padre Island or Brazos Island (Table 9). The difference was significant for both washover beach and inter-pass beach habitats.

Beach Type	N	Vehicles	Pedestrians	Dogs
Washover				
Mustang	14	6.31 [BI, SPI]	7.86 [BI, SPI]	1.31 [BI, SPI]
South Padre	20	1.51	1.69	0.07
Brazos	13	0.90	0.71	0.06
Inter-pass				
Mustang	14	6.30 [BI, SPI]	7.86 [BI, SPI]	0.37 [BI, SPI]
South Padre	28	1.74	2.08	0.09
Brazos	13	0.72	0.77	0.00

Table 9. Mean densities (#/km/census) of human-related disturbances recorded within the 2 beach types. The results of pairwise comparisons between the islands are summarized in brackets []. Islands with significantly lower levels of disturbance ($p < 0.05$) are enclosed in brackets after the data from the island in question. Mustang Island beaches (washover and inter-pass) exhibited higher levels of disturbance than South Padre Island and Brazos Island for all three measures of disturbance.

Piping Plovers

Piping Plovers were recorded at least once on all beach segments monitored during this study. Average Piping Plover beach densities varied from about 1 plovers every 2 kilometers (South Padre Island inter-pass beaches; Table 10) to just over 2 plovers per kilometer of beach (Mustang Island washover beach habitat; Table 10). Piping Plovers demonstrated no preference for washover or inter-pass beaches ($p = 0.6541$). There was no difference in beach density among the 3 islands ($p = 0.7632$).

	Washover Beaches		Inter-Pass Beaches	
Mustang	2.14	[12.50]	1.21	[7.39]
South Padre	0.68	[4.74]	0.40	[2.77]
Brazos	0.90	[8.33]	0.82	[4.90]
Total	1.17	[12.50]	0.71	[7.39]

Table 10. Piping Plover beach population data are summarized as mean and maximum [maximum in brackets] density estimates as they were recorded during the beach censuses. Densities are reported as the number of plovers/km. The numbers in the table represent the average of all washover beach segments and inter-pass beach segments by island.

Most of the Piping Plovers observed during the censuses were foraging. On average, 91.1% and 78.3% of the Piping Plovers recorded in inter-pass and washover beaches respectively were foraging. There was no difference between the 2 beach types (washover and inter-pass) with regard to the behavior of Piping Plovers ($p = 0.1709$). Similarly, there was no difference among islands with regard to the behavior of Piping Plovers found on beach habitat ($p = 0.1916$).

Piping Plover beach densities were not affected by vehicle density ($p = 0.1650$) or pedestrian density ($p = 0.1500$). Piping Plover beach densities were affected by bayshore tidal inundation, however ($p = 0.0497$), with plovers using beaches at higher densities during very high bayshore tides (Figure 7).

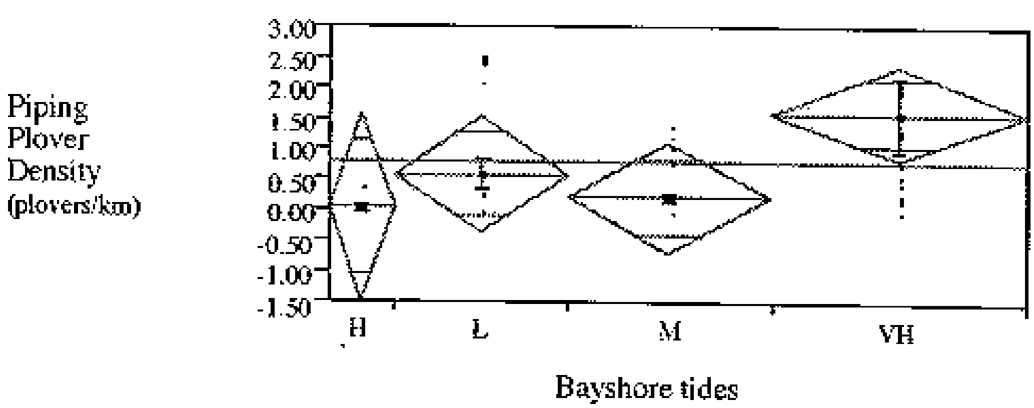


Figure 6. A pictogram illustrating the variation of average Piping Plover density on beach habitat during different levels of bayshore tidal inundation. Beaches were used preferentially during very high bayshore tides.

Snowy Plovers

Snowy Plovers were recorded at least once on all beach segments monitored during this study. Average Snowy Plover beach densities varied from about 1 plovers every 33 kilometers (Mustang Island inter-pass beaches; Table 11) to just under 2 plovers per kilometer of beach (Brazos Island washover beach habitat; Table 11). In contrast to Piping Plovers, Snowy Plovers demonstrated a significant preference for washover beaches over inter-pass beaches (p = 0.0292). However, there was no difference in Snowy Plover beach density among the 3 islands (p = 0.0730).

	Washover Beaches		Inter-Pass Beaches	
Mustang	0.48	[5.00]	0.03	[0.43]
South Padre	0.32	[2.11]	0.07	[1.30]
Brazos	1.99	[9.17]	0.14	[1.02]
Total	0.83	[9.17]	0.08	[1.30]

Table 10. Snowy Plover beach population data are summarized as mean and maximum [maximum in brackets] density estimates for Snowy Plovers as they were recorded during the beach censuses. Densities are reported as the number of plovers/km. The numbers in the table represent the average of all washover beach segments and inter-pass beach segments by island.

The majority of the Snowy Plovers observed during the censuses were foraging, although more Snowy Plovers were found roosting on beaches compared to Piping Plovers. On average, 80.6% and 52.4 of the Snowy Plovers recorded in inter-pass and washover beaches respectively were foraging. Whereas Snowy Plovers preferred washover beaches, there was no difference between the 2 beach types (washover and inter-pass) with regard to the behavior of Snowy Plovers (p = 0.1176). Similarly, there was no difference among islands with regard to the behavior of Snowy Plovers found on beach habitat (p = 0.2667). Snowy Plover beach density was not affected by bayshore tide levels (p = 0.9246).

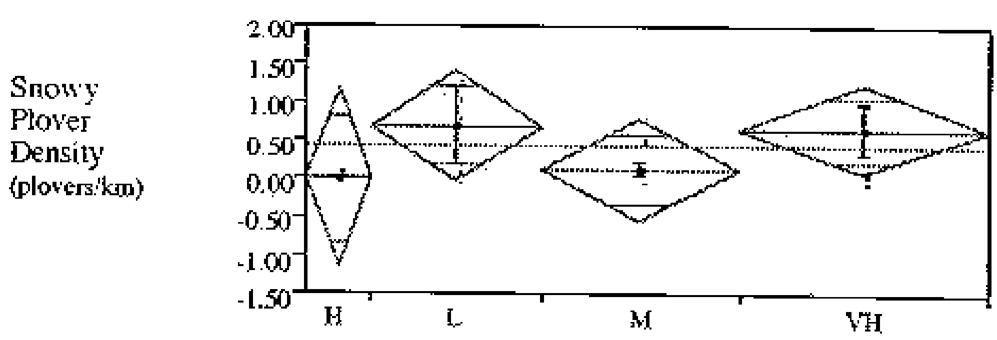


Figure 7. A pictogram illustrating the use of beach habitat by Snowy Plovers during different levels of bayshore tidal inundation. Beaches were used equally during all tide levels.

Waterbird Guilds

All beaches monitored during this study supported populations of shorebirds, seabirds and waders, the 3 major guilds of waterbirds using barrier island habitat. Population data are summarized for these guilds in Table 11.

	Shorebirds	Seabirds	Waders
Washover	38.2 [229.3]	19.9 [281.7]	0.7 [8.6]
Inter-Pass	27.3 [103.1]	60.5 [111.3]	0.2 [3.5]

Table 11. Beach population data are summarized as mean and maximum [maximum in brackets] density estimates for shorebirds, seabirds and waders as they were recorded during the beach censuses. Densities are reported as the number of birds/km. The numbers in the table represent the average of all washover beach segments and inter-pass beach segments by island.

Seabirds were much more likely to use washover beach habitat than inter-pass beach habitat ($p = 0.0003$). No such preference was evident for shorebird ($p = 0.2753$) or wader ($p = 0.9413$) populations, which used the washover and inter-pass beach types equally.

Nocturnal Ecology

Unfortunately, little remains known about the nocturnal ecology of Piping and Snowy Plovers. Despite initial optimism, the nightscope used during this work (Noctron V light-intensifying spotting scope fitted with a 135 mm lens) proved to be an inefficient tool for monitoring plovers at night. Efforts to use the scope to scan passes for the presence/absence of plovers were particularly fruitless, as plovers and other shorebirds were not distinguishable beyond a range of 20-25 meters from the observation point. The only technique that proved useful was to approach plovers just before nightfall, and continue to monitor these flocks with the aid of the nightscope after nightfall. This technique facilitated the tracking of small group of plovers. However, if the flock moved more than 100-200 meters away from the observer the birds became undetectable, and it was not possible to reacquire the group using the nightscope.

Plovers were monitored after nightfall with the nightscope on three occasions (3 September 1996, 9 October 1996, 25 November 1996,) by locating these flocks near sunset and setting up the nightscope to monitor the flocks as sunlight faded. Plovers were monitored at 10' intervals for a period of two hours on all three occasions. During 11 other efforts to monitor plovers with the nightscope, flocks either were never acquired with the scope after nightfall or quickly moved out of ranged and were never reacquired.

On two occasions (3 September 1996, 25 November 1996), roosting flocks of plovers were detected before nightfall and, using the nightscope, were confirmed to continue roosting for 2 hours after nightfall. On 9 October 1996, a flock 22 Piping Plovers and 14 Snowy Plovers was observed to forage before and 2 hours after nightfall despite the lack of moonlight establishing that plovers are able to forage at night under almost total darkness.

I am directing an ongoing radiotelemetry study supported by the U.S. Army Corps of Engineers investigating the movements of Piping Plovers and Snowy Plovers in the Laguna Madre. This study is expected to provide much greater information of the roosting and nocturnal behaviors of Piping Plovers and Snowy Plovers. I will make our findings available to the Texas Parks and Wildlife Department, the U.S. Fish and Wildlife Service and other groups involved in the conservation of Piping Plovers and coastal ecosystems.

DISCUSSION

Washover Passes were used regularly by Piping Plovers, Snowy Plovers and other waterbird species. Passes were most commonly used during periods of high bayshore tides and during the spring migration period by Piping Plovers, and the spring migration and summer breeding periods by Snowy Plovers. Washover passes supported many large breeding colonies of Snowy Plovers and other species of concern (e.g. Least Terns, Wilson's Plover). Whereas human disturbance was generally very low within the washover passes, it was much higher on neighboring beaches. Because human use is increasing steadily on many Texas beaches, and beach traffic often "spills" into the washover passes during peak beach use periods, human disturbance is a potential future threat to waterbirds using barrier islands and washover pass habitat in particular. It should be noted that periods of high human beach visitation in the spring and summer coincide with the preferential use of washover passes by plovers and other waterbirds.

Whereas large passes supported more Piping Plovers, Snowy Plovers and waterbirds in general, bird density was just as high in small passes as large passes, therefore preferential attention to large passes over small passes is not justified. Passes with lakes were preferred by Snowy Plovers and some waterbird species. However, the lakes are ephemeral features that varied greatly during the year. Furthermore, the presence and size of washover lakes were be greatly affected by local storm influences. Therefore predicting which passes will have lakes, and therefore may be more important to waterbirds, is at best a crude science.

Whereas most plovers recorded during the washover censuses were engaged in foraging activity, a few observations from this study support the value of washover passes as diurnal plover roosts. Diurnal roosting flocks of Piping Plovers were found during at least 2 censuses at both Mustang Island washover passes (MI SI, MI S2; see appendix), one South Padre Island washover pass (SPI C8; see appendix), and both Brazos Island passes (BI N1, and BI C2 see appendix).

Because Snowy Plovers and birds from the seabird guild preferred to use washover beaches, measures that reduced the amount of disturbance in these beach zones would likely benefit these and other waterbirds.

Disturbance within washover passes was most evident along the north and south margins of the passes, and habitat alterations caused by human incursions were generally concentrated in these margins within washover habitat. These areas are often used by people with 4-wheel drive vehicles as paths to bayshore windsurfing, crabbing, or fishing spots. Because these margins often contain patches of shell, they are often contain Snowy Plovers and Least Tern nesting colonies in the spring and summer. Measures that prevent vehicular entry into washover pass habitat should boost the productivity of Snowy Plovers and other waterbirds by reducing the disturbance to these populations and the loss of nests crushed by vehicles.

ACKNOWLEDGMENT

On behalf of the National Audubon Society I would like to acknowledge the support of the U.S. Fish and Wildlife Service and the dedicated staff at the Laguna Atascosa National Wildlife Refuge for their role in making this research possible. Laguna Atascosa, in particular, has a long history of supporting Piping Plover recovery and shorebird conservation, and is still among the best places in Texas from which to conduct research. I would also like to personally express my appreciation to Jeff Rupert and Scott Hedges (National Audubon Society), Gene Blacklock (EcoServices, inc.), Lee Elliott (Texas Parks and Wildlife Department), Ted Eubanks (Fermata, Inc.), and Tim Cooper and Steve Labuda (Laguna Atascosa NWR) for their assistance in the field, for their valuable advise, and for their admirable dedication to the conservation of Texas' native bird communities.

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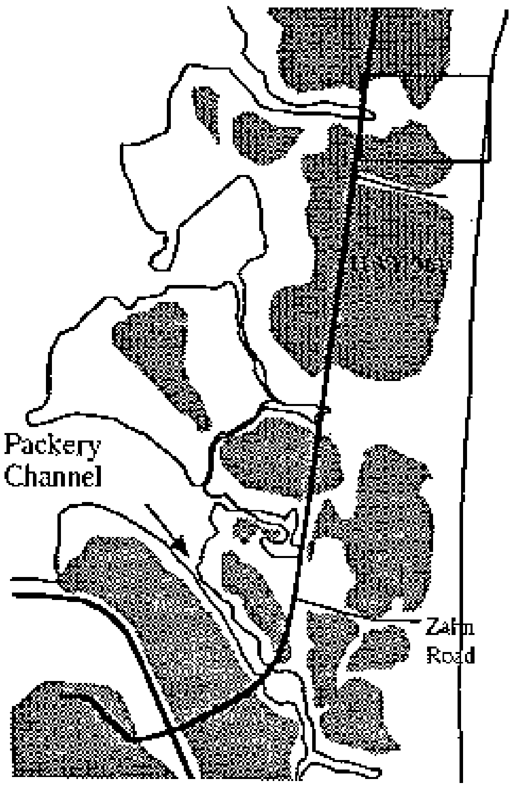
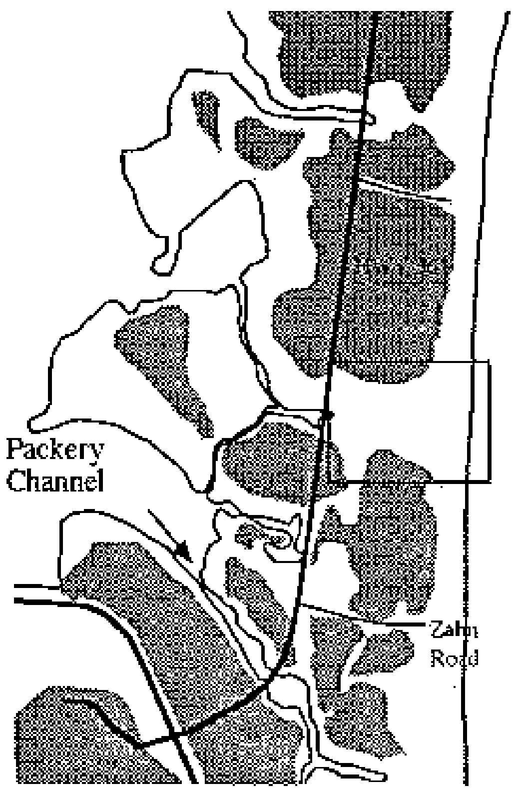
APPENDIX I

Location Information	
Washover Pass #	MI S1
Island	Mustang
Region	South
Latitude	27°40'0"

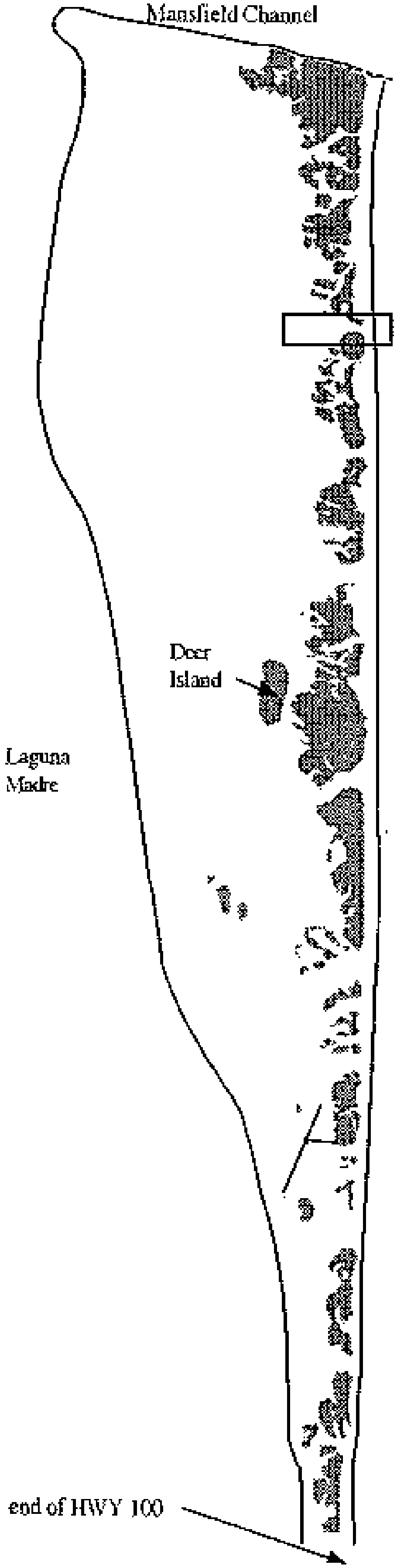


Parameter	Mean	Max
Area	26.21	26.21
# Lakes	0.11	1
Vehicles	0.11	1
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	1.42	12
# Snowy Plovers	1	9
# Piping and Snowy Plovers	2.42	21
Piping Plover Density	0.05	0.46
Snowy Plover Density	0.04	0.34
Other Waterbirds		
Total Shorebird Population	8.68	65
Total Seabird Population	60.42	629
Total Wader Population	0.11	1
Total Waterbird Population	69.21	636
Shorebird Density	0.33	2.48
Seabird Density	2.31	24
Wader Density	0	0.04

Location Information	
Washover Pass #	MI S2
Island	Mustang
Region	South
Latitude	27°38'0"

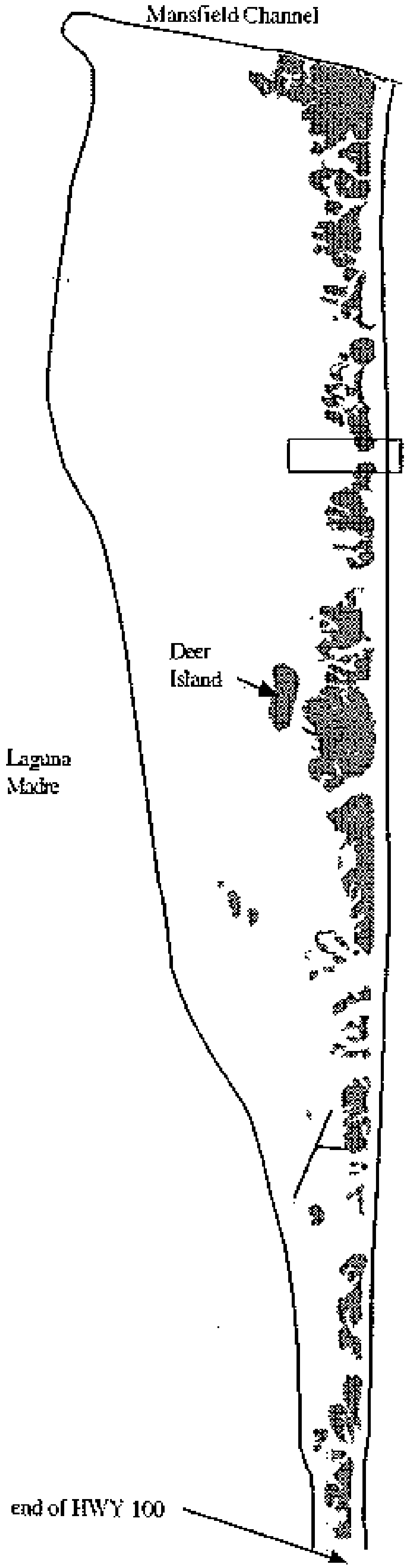


Parameter	Mean	Max
Area	54.62	54.62
# Lakes	0.17	2
Vehicles	0.22	2
Pedestrians	0.39	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	3.74	30
# Snowy Plovers	4.78	38
# Piping and Snowy Plovers	8.52	68
Piping Plover Density	0.07	0.55
Snowy Plover Density	0.09	0.7
Other Waterbirds		
Total Shorebird Population	14.78	123
Total Seabird Population	97.13	1237
Total Wader Population	0.3	5
Total Waterbird Population	112.3	1238
Shorebird Density	0.27	2.25
Seabird Density	1.78	22.65
Wader Density	0.01	0.09



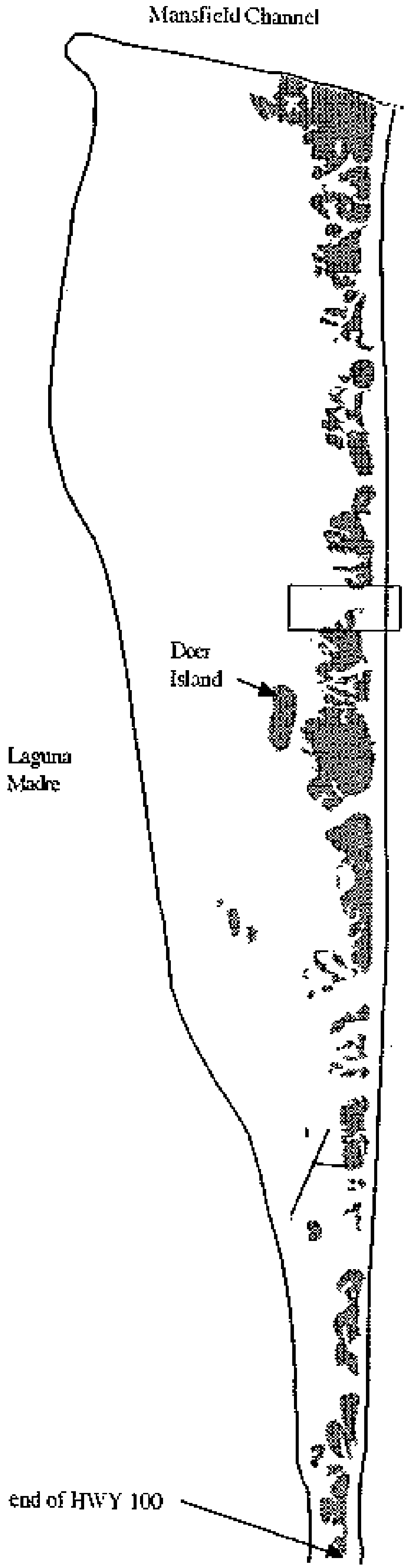
Location Information	
Washover Pass #	SPI N1
Island	South Padre
Region	North
Latitude	26°32'2.2"

Parameter	Mean	Max
Area	17.13	17.13
# Lakes	1.11	2
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.22	2
# Snowy Plovers	1	4
# Piping and Snowy Plovers	1.22	6
Piping Plover Density	0.12	0.01
Snowy Plover Density	0.23	0.06
Other Waterbirds		
Total Shorebird Population	9.25	31
Total Seabird Population	0.88	7
Total Wader Population	0.56	2
Total Waterbird Population	11.25	35
Shorebird Density	0.54	1.81
Seabird Density	0.05	0.41
Wader Density	0.03	0.18



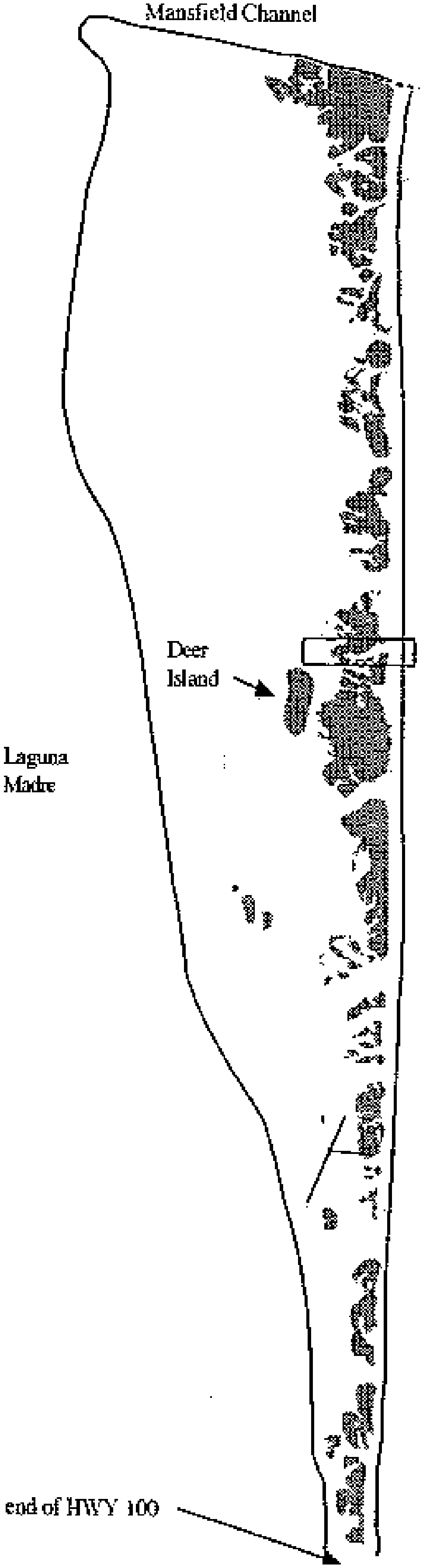
Location Information	
Washover Pass #	SPI N2
Island	South Padre
Region	North
Latitude	26°30'24.6"

Parameter	Mean	Max
Area	44.74	44.74
# Lakes	0.9	1
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	1.1	5
# Snowy Plovers	1.1	7
# Piping and Snowy Plovers	2.2	12
Piping Plover Density	0.02	0.02
Snowy Plover Density	0.11	0.16
Other Waterbirds		
Total Shorebird Population	19.1	68
Total Seabird Population	13.22	48
Total Wader Population	0.7	2
Total Waterbird Population	38.67	116
Shorebird Density	0.43	1.52
Seabird Density	0.3	1.07
Wader Density	0.02	0.04



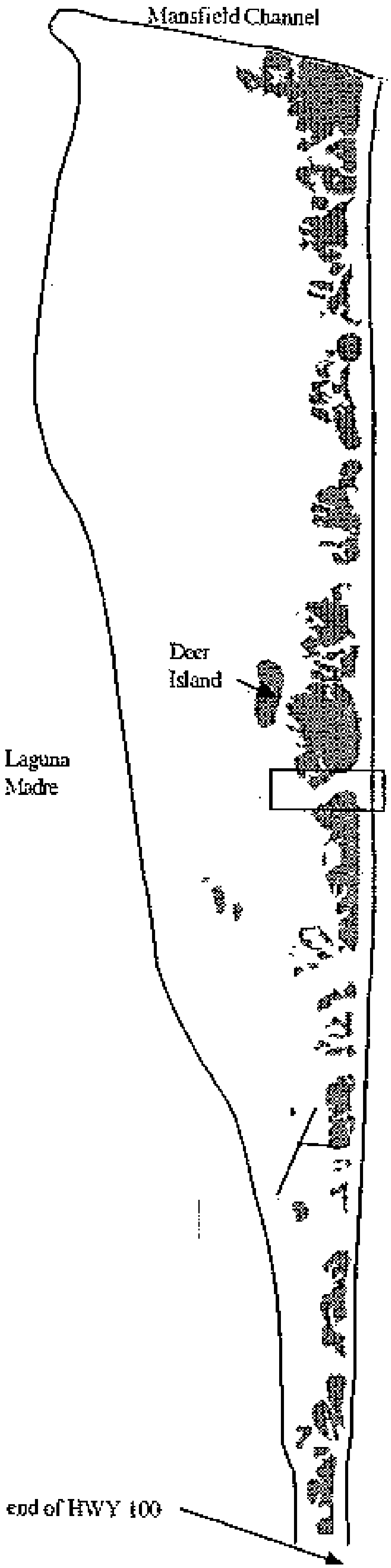
Location Information	
Washover Pass #	SPI N3
Island	South Padre
Region	North
Latitude	26°28'43.7"

Parameter	Mean	Max
Area	59.21	59.21
# Lakes	1	2
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	2	14
# Snowy Plovers	1.27	4
# Piping and Snowy Plovers	3.27	18
Piping Plover Density	0.03	0.24
Snowy Plover Density	0.02	0.07
Other Waterbirds		
Total Shorebird Population	39.9	68
Total Seabird Population	54.8	48
Total Wader Population	0.73	2
Total Waterbird Population	98.9	116
Shorebird Density	0.67	4.14
Seabird Density	0.93	7.08
Wader Density	0.01	0.03



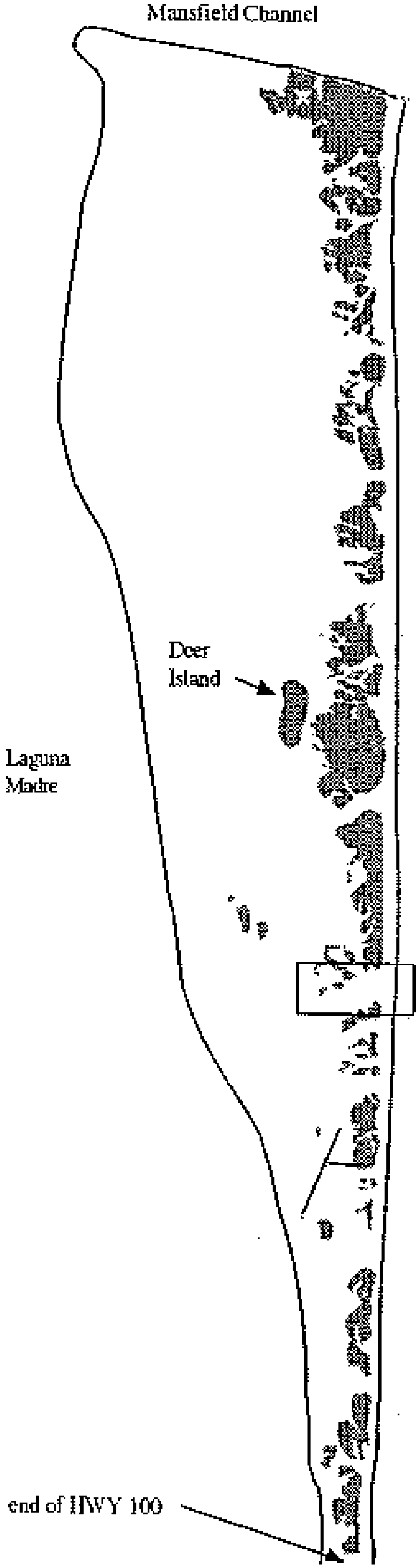
Location Information	
Washover Pass #	SPI N4
Island	South Padre
Region	North
Latitude	26°27'8.6"

Parameter	Mean	Max
Area	21.16	21.16
# Lakes	0.18	1
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.09	1
# Snowy Plovers	2	18
# Piping and Snowy Plovers	2.09	19
Piping Plover Density	0	0.05
Snowy Plover Density	0.09	0.85
Other Waterbirds		
Total Shorebird Population	6.36	57
Total Seabird Population	0.4	4
Total Wader Population	0.27	2
Total Waterbird Population	7.1	57
Shorebird Density	0.67	2.69
Seabird Density	0.93	0.19
Wader Density	0.01	0.09



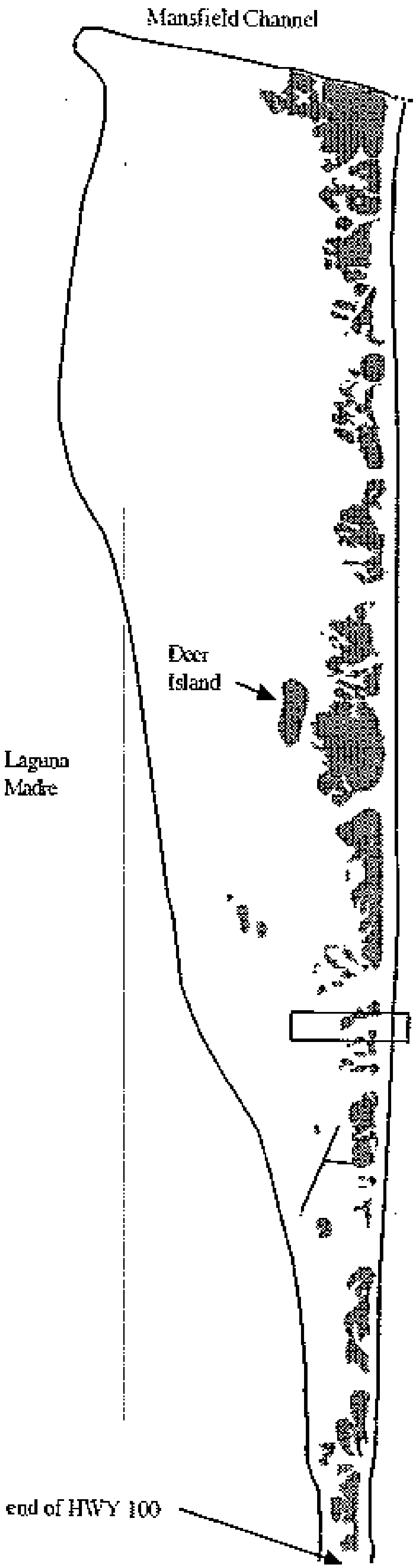
Location Information	
Washover Pass #	SPI N5
Island	South Padre
Region	North
Latitude	26°24'7.1"

Parameter	Mean	Max
Area	79.05	79.05
# Lakes	1.09	2
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	5	17
# Snowy Plovers	17.18	80
# Piping and Snowy Plovers	22.18	97
Piping Plover Density	0.06	0.22
Snowy Plover Density	0.22	1.01
Other Waterbirds		
Total Shorebird Population	64.55	135
Total Seabird Population	137.6	506
Total Wader Population	1.91	4
Total Waterbird Population	204.7	613
Shorebird Density	0.82	1.71
Seabird Density	1.74	6.4
Wader Density	0.02	0.05



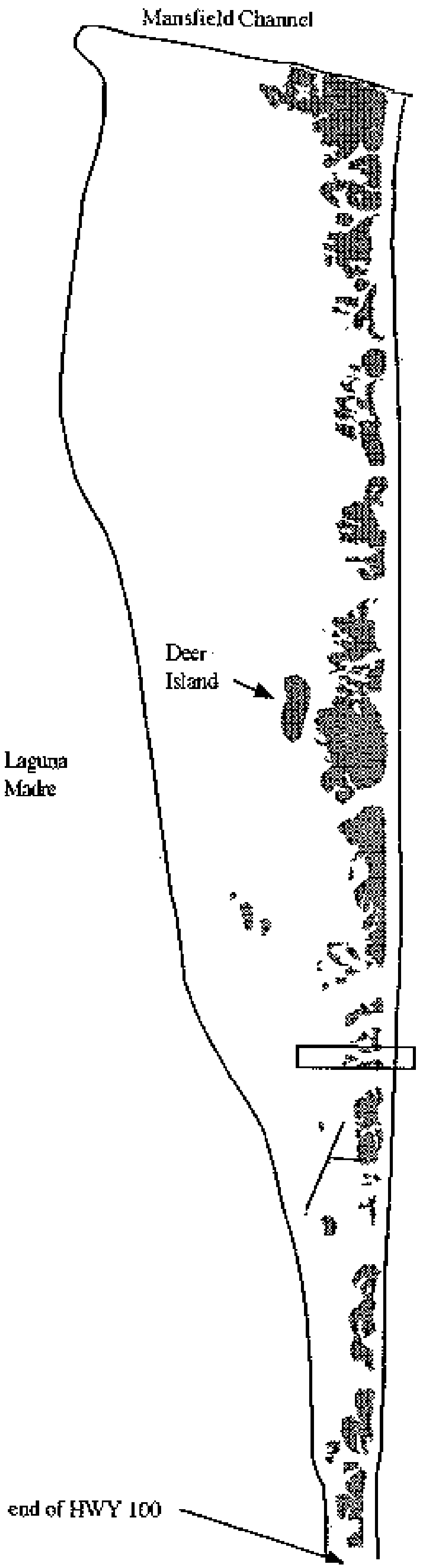
Location Information	
Washover Pass #	SPI C1
Island	South Padre
Region	Central
Latitude	26°21'48.9"

Parameter	**Mean**	**Max**
Area	115.48	115.48
# Lakes	0.31	2
Vehicles	0	0
Pedestrians	0.08	1
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	2.85	26
# Snowy Plovers	5.69	44
# Piping and Snowy Plovers	8.54	70
Piping Plover Density	0.02	0.23
Snowy Plover Density	0.05	0.38
Other Waterbirds		
Total Shorebird Population	33.54	366
Total Seabird Population	3.46	106
Total Wader Population	0.85	10
Total Waterbird Population	37.85	376
Shorebird Density	0.29	3.17
Seabird Density	0.03	0.23
Wader Density	0.01	0.09



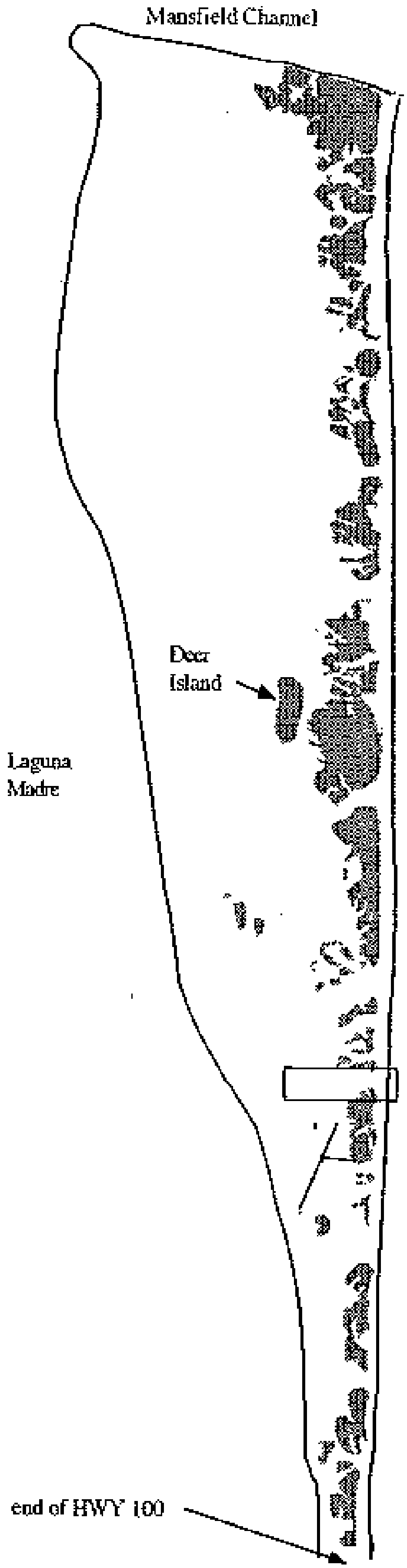
Location Information	
Washover Pass #	SPI C2
Island	South Padre
Region	Central
Latitude	26°21'21.5"

Parameter	Mean	Max
Area	33.94	33.94
# Lakes	0.85	1
Vehicles	0	0
Pedestrians	0.08	1
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	2.15	16
# Snowy Plovers	4.08	24
# Piping and Snowy Plovers	6.23	40
Piping Plover Density	0.06	0.47
Snowy Plover Density	0.12	0.71
Other Waterbirds		
Total Shorebird Population	29.46	184
Total Seabird Population	2.85	26
Total Wader Population	0.31	1
Total Waterbird Population	32.77	185
Shorebird Density	0.87	5.42
Seabird Density	0.08	0.77
Wader Density	0.01	0.03



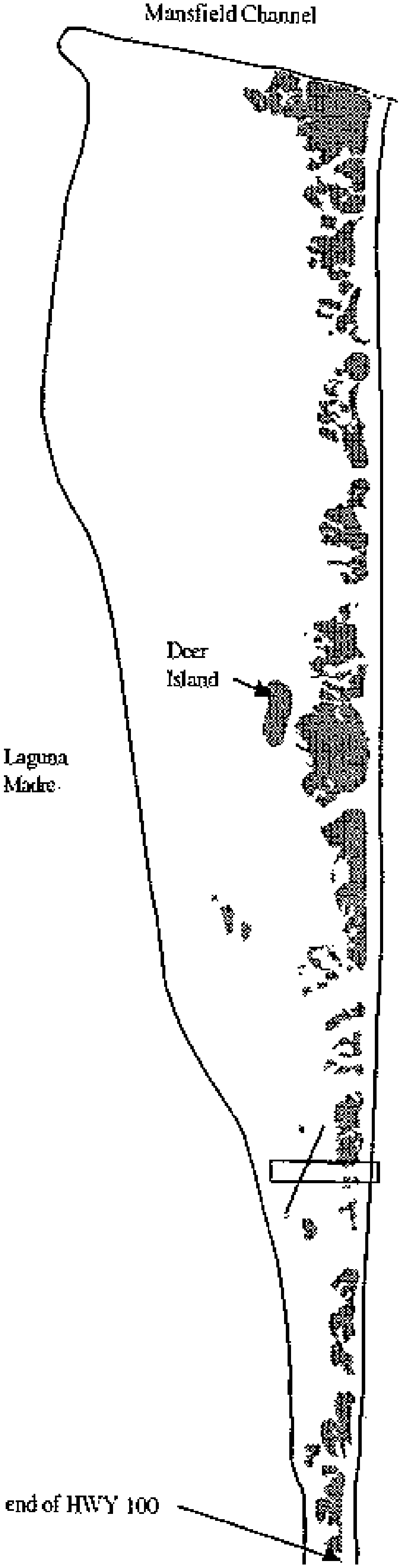
Location Information	
Washover Pass #	SPI C3
Island	South Padre
Region	Central
Latitude	26°20'53.8"

Parameter	Mean	Max
Area	28.88	28.88
# Lakes	0.14	1
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0	0
# Snowy Plovers	0.5	3
# Piping and Snowy Plovers	0.5	3
Piping Plover Density	0	0
Snowy Plover Density	0.02	0.1
Other Waterbirds		
Total Shorebird Population	2.43	27
Total Seabird Population	1.21	10
Total Wader Population	0	0
Total Waterbird Population	3.64	37
Shorebird Density	0.08	0.93
Seabird Density	0.04	0.35
Wader Density	0	0



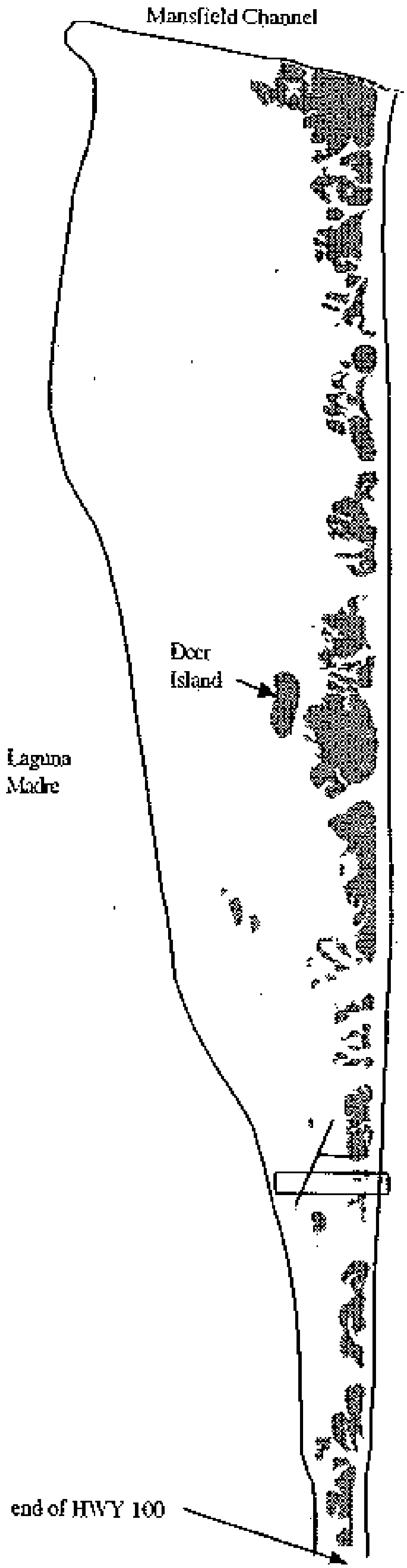
Location Information	
Washover Pass #	SPI C4
Island	South Padre
Region	Central
Latitude	26°20'34.5"

Parameter	Mean	Max
Area	38.27	38.27
# Lakes	0.67	2
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	1.25	13
# Snowy Plovers	3.83	15
# Piping and Snowy Plovers	5.08	28
Piping Plover Density	0.03	0.34
Snowy Plover Density	0.1	0.39
Other Waterbirds		
Total Shorebird Population	53.17	516
Total Seabird Population	27.42	184
Total Wader Population	1.25	13
Total Waterbird Population	81.83	529
Shorebird Density	1.39	13.48
Seabird Density	0.72	4.81
Wader Density	0.03	0.34



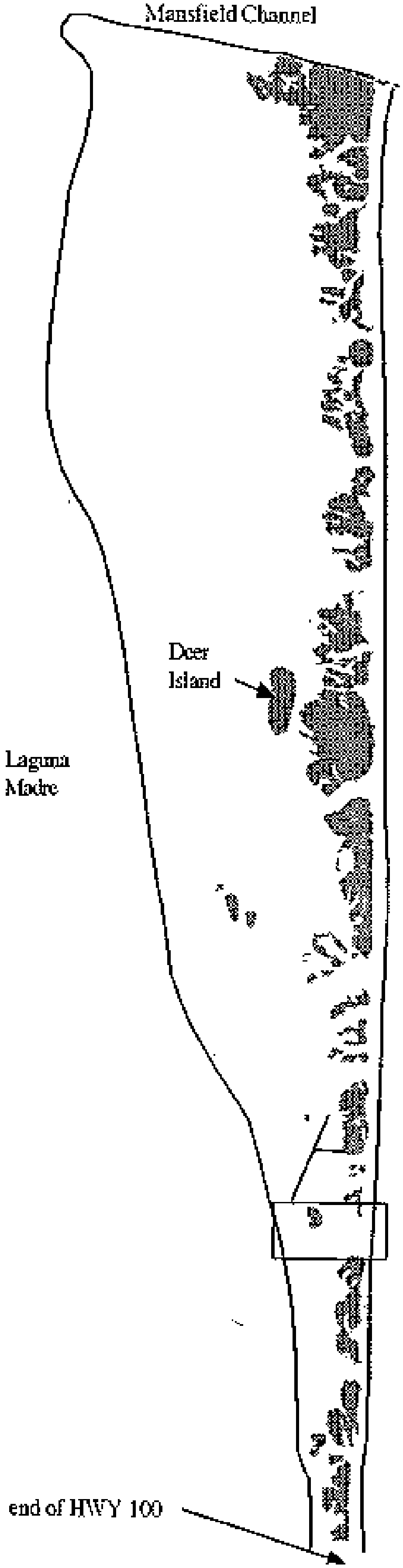
Location Information	
Washover Pass #	SPI C5
Island	South Padre
Region	Central
Latitude	26°19'21.4"

Parameter	Mean	Max
Area	11	11
# Lakes	1	2
Vehicles	0.06	1
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	2.56	21
# Snowy Plovers	2.22	7
# Piping and Snowy Plovers	4.78	28
Piping Plover Density	0.4	1.91
Snowy Plover Density	0.28	0.64
Other Waterbirds		
Total Shorebird Population	17.72	105
Total Seabird Population	5.5	42
Total Wader Population	0.28	1
Total Waterbird Population	23.5	112
Shorebird Density	1.61	9.55
Seabird Density	0.5	3.82
Wader Density	0.03	0.09



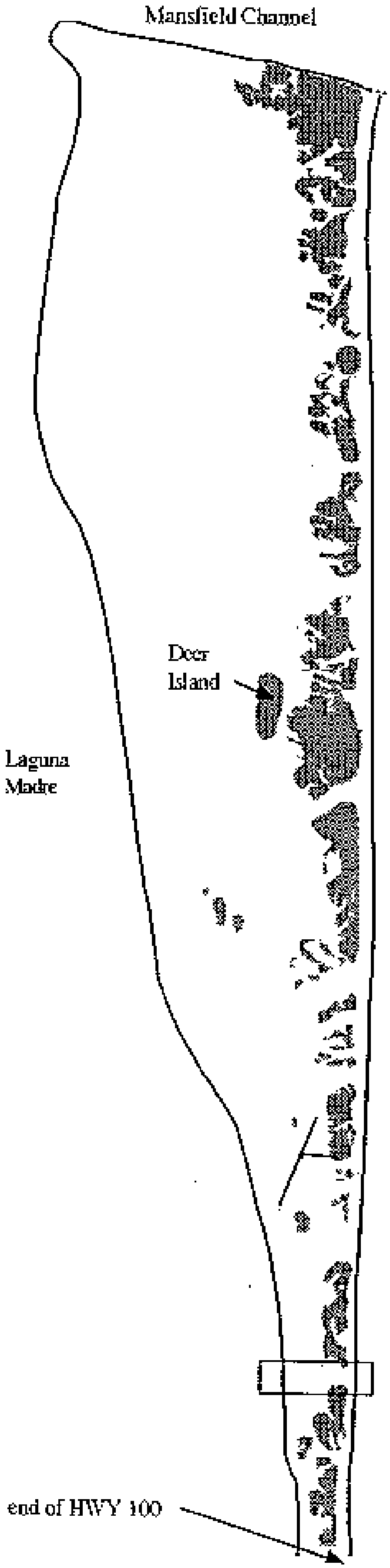
Location Information	
Washover Pass #	SPI C6
Island	South Padre
Region	Central
Latitude	26°19'4.6"

Parameter	Mean	Max
Area	13.45	13.45
# Lakes	0.36	2
Vehicles	0	0
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.07	1
# Snowy Plovers	1.64	9
# Piping and Snowy Plovers	1.71	10
Piping Plover Density	0.01	0.07
Snowy Plover Density	0.12	0.67
Other Waterbirds		
Total Shorebird Population	6.64	29
Total Seabird Population	3.71	49
Total Wader Population	2.14	23
Total Waterbird Population	12.71	79
Shorebird Density	0.49	2.16
Seabird Density	0.28	3.64
Wader Density	0.16	1.71



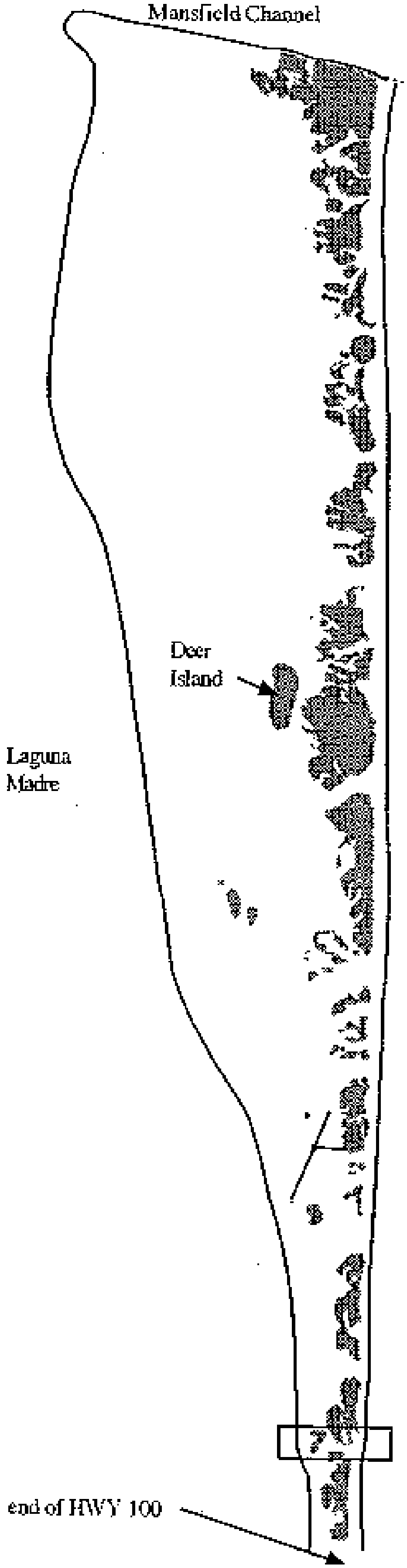
Location Information	
Washover Pass #	SPI C7
Island	South Padre
Region	Central
Latitude	26°18'19.6"

Parameter	Mean	Max
Area	108.14	108.14
# Lakes	0.07	1
Vehicles	0.07	1
Pedestrians	0.2	3
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	3.27	31
# Snowy Plovers	2.6	24
# Piping and Snowy Plovers	5.87	55
Piping Plover Density	0.03	0.29
Snowy Plover Density	0.02	0.22
Other Waterbirds		
Total Shorebird Population	20.27	83
Total Seabird Population	8.47	120
Total Wader Population	0	0
Total Waterbird Population	28.8	121
Shorebird Density	0.19	0.77
Seabird Density	0.08	1.11
Wader Density	0	0



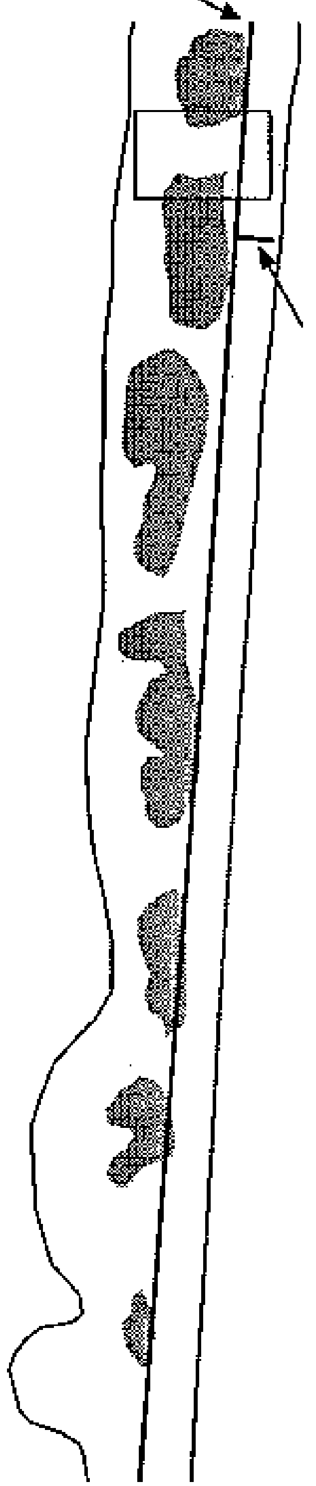
Location Information	
Washover Pass #	SPI C8
Island	South Padre
Region	Central
Latitude	26°16'26.9"

Parameter	Mean	Max
Area	34.32	34.32
# Lakes	1	1
Vehicles	0.13	2
Pedestrians	0.27	4
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	13.8	158
# Snowy Plovers	9.47	24
# Piping and Snowy Plovers	23.27	182
Piping Plover Density	0.4	4.6
Snowy Plover Density	0.28	0.7
Other Waterbirds		
Total Shorebird Population	153	770
Total Seabird Population	128.53	391
Total Wader Population	2	9
Total Waterbird Population	286.4	1159
Shorebird Density	4.46	22.44
Seabird Density	3.75	11.39
Wader Density	0.06	0.26



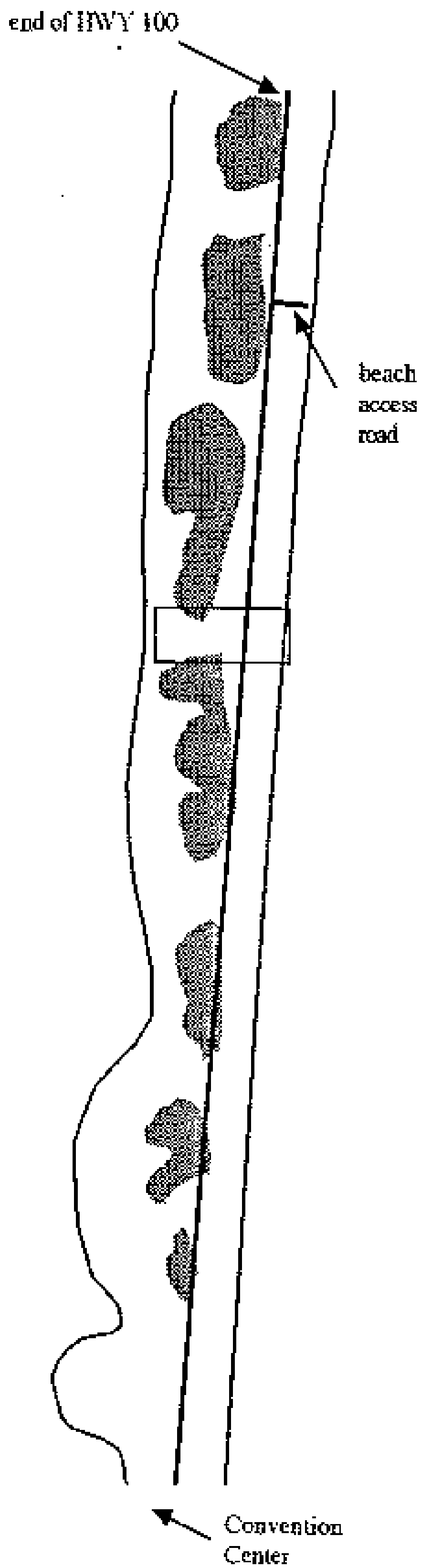
Location Information	
Washover Pass #	SPI C9
Island	South Padre
Region	Central
Latitude	26°15'28.0"

Parameter	Mean	Max
Area	26.61	26.61
# Lakes	0.93	1
Vehicles	0.07	1
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.86	12
# Snowy Plovers	0.93	0.6
# Piping and Snowy Plovers	1.79	12.6
Piping Plover Density	0.03	0.45
Snowy Plover Density	0.03	0.23
Other Waterbirds		
Total Shorebird Population	13.36	72
Total Seabird Population	8.5	71
Total Wader Population	0.57	2
Total Waterbird Population	24.14	143
Shorebird Density	0.5	2.71
Seabird Density	0.32	2.67
Wader Density	0.02	0.08



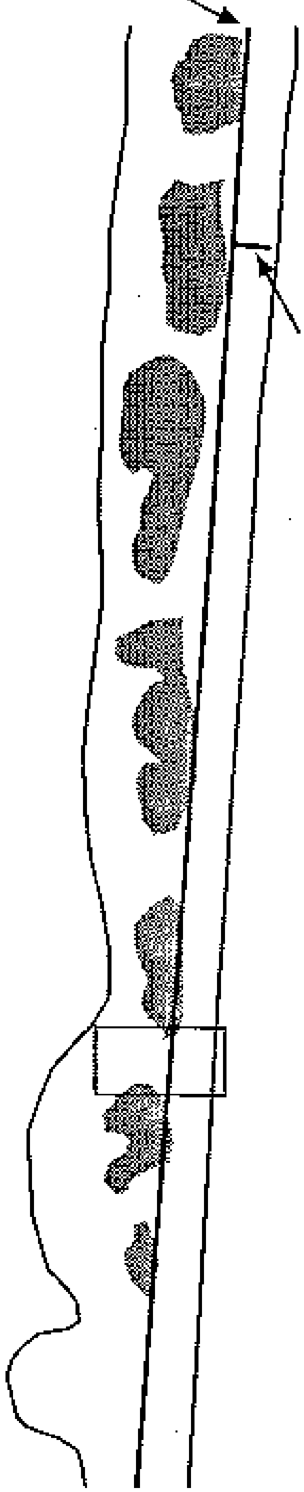
Location Information	
Washover Pass #	SPI S1
Island	South Padre
Region	South
Latitude	26°13'54.6"

Parameter	Mean	Max
Area	13.63	13.63
# Lakes	0.87	1
Vehicles	0.33	1
Pedestrians	0.27	3
Dogs (leashed)	0	0
Dogs (unleashed)	0.2	3
Piping & Snowy Plovers		
# Piping Plovers	0.2	2
# Snowy Plovers	1.47	7
# Piping and Snowy Plovers	1.67	9
Piping Plover Density	0.01	0.15
Snowy Plover Density	0.11	0.51
Other Waterbirds		
Total Shorebird Population	10.93	71
Total Seabird Population	11.33	84
Total Wader Population	7.4	94
Total Waterbird Population	30.6	142
Shorebird Density	0.8	5.21
Seabird Density	0.83	6.16
Wader Density	0.54	6.9



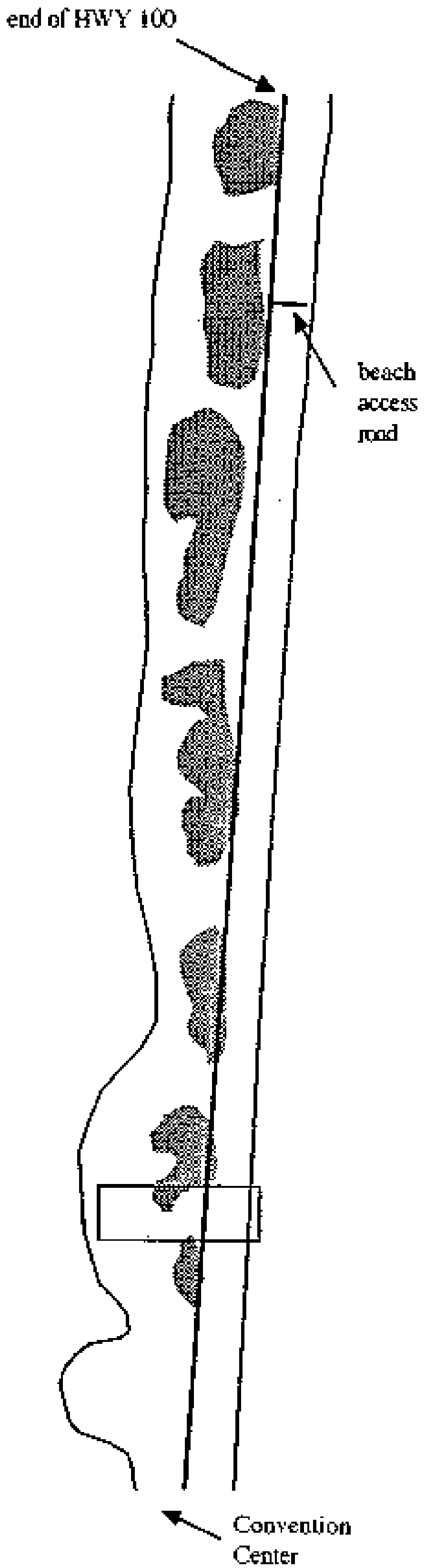
Location Information	
Washover Pass #	SPI S2
Island	South Padre
Region	South
Latitude	26°11'55.0"

Parameter	Mean	Max
Area	17.97	17.97
# Lakes	1	2
Vehicles	0.57	4
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.07	1
# Snowy Plovers	0.71	5
# Piping and Snowy Plovers	0.78	6
Piping Plover Density	0	0.06
Snowy Plover Density	0.04	0.28
Other Waterbirds		
Total Shorebird Population	10.5	84
Total Seabird Population	7.71	40
Total Wader Population	0.71	4
Total Waterbird Population	30.6	106
Shorebird Density	0.58	4.67
Seabird Density	0.43	2.23
Wader Density	0.04	0.22



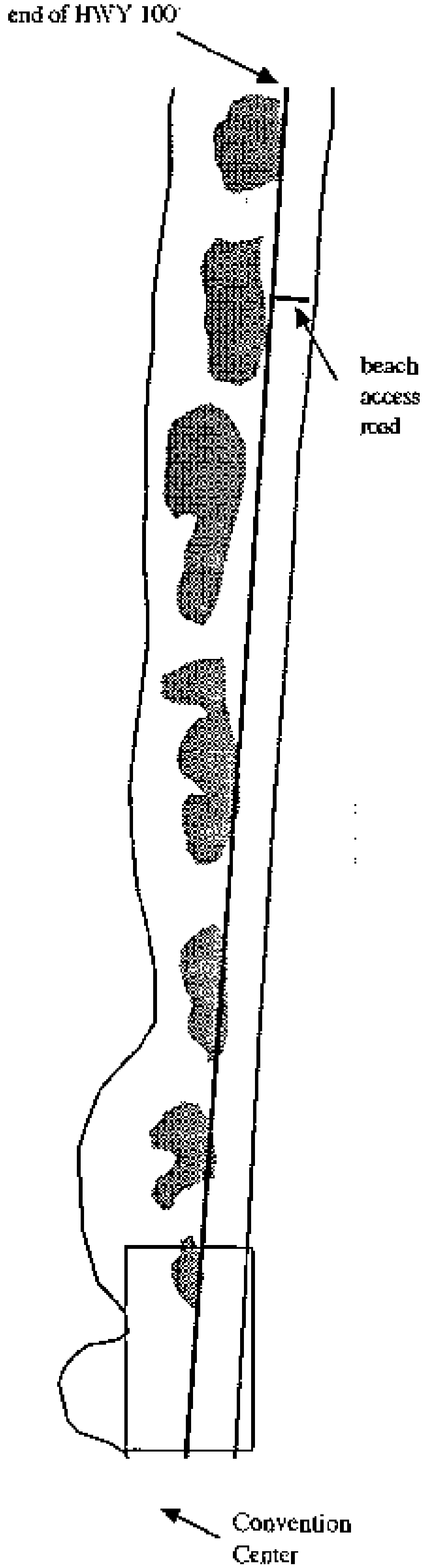
Location Information	
Washover Pass #	SPI S3
Island	South Padre
Region	South
Latitude	26°9'51.3"

Parameter	Mean	Max
Area	13.53	13.53
# Lakes	0.47	3
Vehicles	4.67	51
Pedestrians	3.93	53
Dogs (leashed)	0	0
Dogs (unleashed)	0.13	2
Piping & Snowy Plovers		
# Piping Plovers	0.27	3
# Snowy Plovers	0.4	3
# Piping and Snowy Plovers	0.67	6
Piping Plover Density	0.02	0.22
Snowy Plover Density	0.03	0.22
Other Waterbirds		
Total Shorebird Population	6.4	37
Total Seabird Population	7.87	64
Total Wader Population	0.13	1
Total Waterbird Population	14.47	69
Shorebird Density	0.47	2.73
Seabird Density	0.58	4.73
Wader Density	0.01	0.07



Location Information	
Washover Pass #	SPI S4
Island	South Padre
Region	South
Latitude	26°9'22.7"

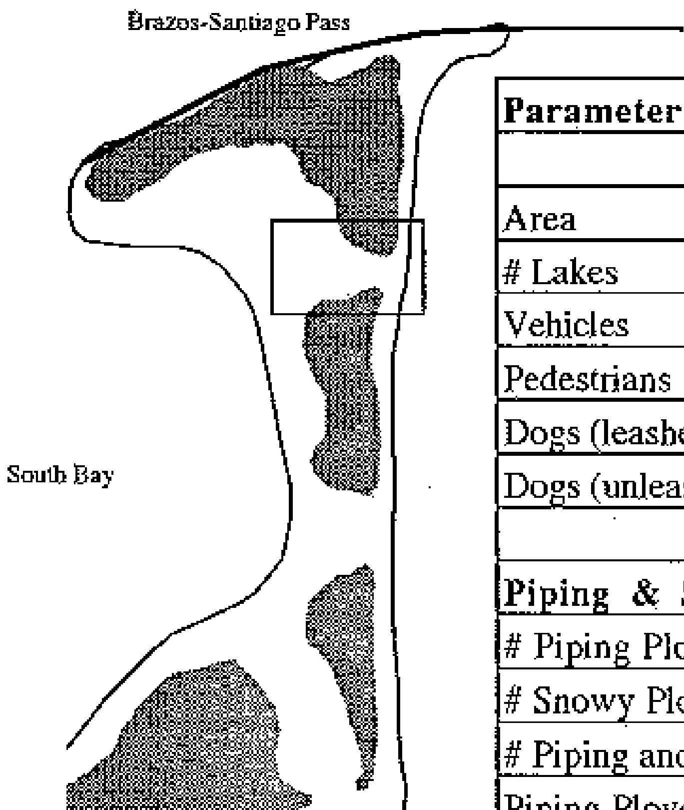
Parameter	**Mean**	**Max**
Area	13.91	13.91
# Lakes	0.75	1
Vehicles	0.12	1
Pedestrians	0	0
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	0.06	1
# Snowy Plovers	0.56	4
# Piping and Snowy Plovers	0.62	5
Piping Plover Density	0	0.07
Snowy Plover Density	0.04	0.29
Other Waterbirds		
Total Shorebird Population	3.69	17
Total Seabird Population	0.5	4
Total Wader Population	0.56	2
Total Waterbird Population	4.88	19
Shorebird Density	0.27	1.22
Seabird Density	0.04	0.29
Wader Density	0.04	0.14



Location Information	
Washover Pass #	SPI S5
Island	South Padre
Region	South
Latitude	26°9'5.0"

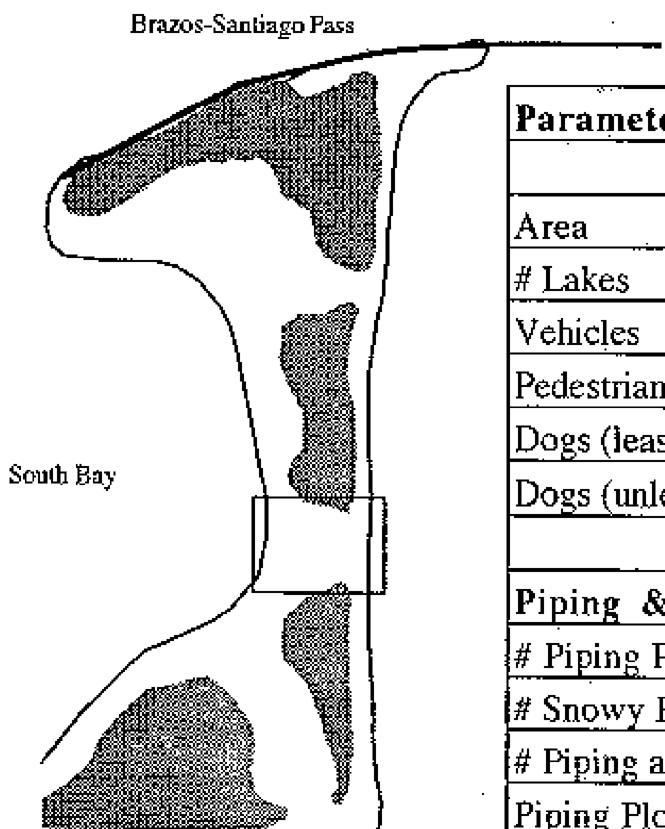
Parameter	Mean	Max
Area	40.24	40.24
# Lakes	0.06	1
Vehicles	1.71	5
Pedestrians	0.35	3
Dogs (leashed)	0	0
Dogs (unleashed)	0.18	2
Piping & Snowy Plovers		
# Piping Plovers	2.12	19
# Snowy Plovers	2.94	16
# Piping and Snowy Plovers	5.06	35
Piping Plover Density	0.05	0.47
Snowy Plover Density	0.07	0.4
Other Waterbirds		
Total Shorebird Population	20.35	95
Total Seabird Population	7.35	106
Total Wader Population	0.06	1
Total Waterbird Population	27.94	131
Shorebird Density	0.51	2.36
Seabird Density	0.18	2.63
Wader Density	0	0.02

Location Information	
Washover Pass #	BI Ni
Island	Brazos
Region	North
Latitude	26°3'0"



Parameter	Mean	Max
Area	34.95	34.95
# Lakes	0.35	1
Vehicles	1.29	12
Pedestrians	0.24	4
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	17.39	91
# Snowy Plovers	6.78	26
# Piping and Snowy Plovers	24.17	117
Piping Plover Density	0.5	2.6
Snowy Plover Density	0.19	0.74
Other Waterbirds		
Total Shorebird Population	53.78	237
Total Seabird Population	34.35	537
Total Wader Population	1.28	20
Total Waterbird Population	79.35	550
Shorebird Density	1.54	6.78
Seabird Density	0.98	15.36
Wader Density	0.04	0.57

Location Information	
Washover Pass #	BI N2
Island	Brazos
Region	North
Latitude	26°1'0"



Parameter	Mean	Max
Area	49.39	49.39
# Lakes	0.11	1
Vehicles	0.11	2
Pedestrians	0.22	4
Dogs (leashed)	0	0
Dogs (unleashed)	0	0
Piping & Snowy Plovers		
# Piping Plovers	12.22	72
# Snowy Plovers	3.33	14
# Piping and Snowy Plovers	15.55	86
Piping Plover Density	0.25	1.46
Snowy Plover Density	0.07	0.28
Other Waterbirds		
Total Shorebird Population	62.44	474
Total Seabird Population	33.06	288
Total Wader Population	0.67	8
Total Waterbird Population	93.18	498
Shorebird Density	1.26	9.6
Seabird Density	0.67	5.83
Wader Density	0.01	0.16

APPENDIX II

Total Waterbird Abundance in all Washover Passes

SHOREBIRDS

Species		Total # observed
Piping Plover	Charadrius melodus	1177
Snowy Plover	Charadrius alexandrinus	1090
Semipalmated Plover	Charadrius semipalmatus	107
Wilson's Plover	Charadrius wilsonia	134
Killdeer	Charadrius vociferus	27
Black-bellied Plover	Pluvialis squatarola	458
Lesser Golden Plover	Pluvialis dominica	46
Ruddy Turnstone	Arenaria interpres	180
Sanderling	Calidris alba	1800
Red Knot	Calidris canutus	48
Dunlin	Calidris alpina	565
Semipalmated Sandpiper	Calidris pusilla	3
Western Sandpiper	Calidris mauri	378
Least Sandpiper	Calidris minutilla	306
White-rumped Sandpiper	Calidris fuscicollis	9
Baird's Sandpiper	Calidris bairdii	21
peeps	Small Calidris spp.	2790
Wilson's Phalarope	Phalaropus tricolor	6
Red-necked Phalarope	Phalaropus lobatus	3
Lesser Yellowlegs	Tringa flavipes	30
Greater Yellowlegs	Tringa melanoleuca	283
Spotted Sandpiper	Actitis macularia	3
Willet	Catotrophorus semipalmatus	45
Black-necked Stilt	Himantopus mexicanus	11
American Avocet	Recurvirostrus americanus	18
American Oystercatcher	Haematopus palliatus	1
Short-billed Dowitcher	Limnodromus griseus	6
Common Snipe	Gallinago gallinago	1
Long-billed Curlew	Numenius americanus	1
Pectoral Sandpiper	Calidris melantos	1
Stilt Sandpiper	Calidris himantopus	3
Total		**9542**

WADERS

Species		Total # observed
Great Blue Heron	*Ardea herodias*	103
Reddish Egret	*Egretta rufescens*	88
Great Egret	*Casmerodius albus*	10
Snowy Egret	*Egretta thula*	22
Tricolored Heron	*Egretta tricolor*	26
Little Blue Heron	*Egretta caerulea*	3
Cattle Egret	*Bubulcus ibis*	60
Green Heron	*Butorides striatus*	6
White Ibis	*Eudocimus albus*	6
Total		**324**

SEABIRDS

Species		Total # observed
Least Tern	*Sterna antillarum*	3905
Forster's Tern	*Sterna forsteri*	316
Common Tern	*Sterna hirundo*	7
Sandwich Tern	*Sterna sandvicensis*	219
Royal Tern	*Sterna maxima*	762
Caspian Tern	*Sterna caspia*	87
Black Tern	*Chidonias niger*	1316
Gull-billed Tern	*Sterna nilotica*	31
Herring Gull	*Larus argentatus*	28
Laughing Gull	*Larus atricilla*	1662
Ring-billed Gull	*Larus delawarensis*	262
Brown Pelican	*Pelicanus occidentalis*	44
Cormorant spp.	*Phalacrocorax* spp.	1451
Total		**9864**

OTHER WATERBIRDS

Species		Total # observed
American Wigeon	*Anas americana*	7
Mottled Duck	*Anus fulvigula*	8
Blue-winged Teal	*Anas discors*	3
Bufflehead	*Bucephala albeola*	14
Lesser Scaup	*Aythya affinis*	21
Common Goldeneye	*Bucephala clangula*	1
Red-breasted Merganser	*Mergus serrator*	145
Eared Grebe	*Podyceps nigricollis*	40
Pied-billed Grebe	*Podilymbus podiceps*	1
Common Loon	*Gavia adamsii*	1
Total		**241**