5-1997

Habitat use and activities of the piping plover, Charadrius melodus, wintering on South Padre Island, Texas

Humberto Garza Jr.

HABITAT USE AND ACTIVITIES OF THE PIPING PLOVER, *CHARADRIUS MELODUS*, WINTERING ON SOUTH PADRE ISLAND, TEXAS

A Thesis

by

HUMBERTO GARZA, JR.

Submitted to The University of Texas-Pan American
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 1997

Major Subject: Biology

HABITAT USE AND ACTIVITIES OF THE PIPING PLOVER, *CHARADRIUS MELODUS*, WINTERING ON SOUTH PADRE ISLAND, TEXAS

A Thesis
by
HUMBERTO GARZA, JR.

Approved as to style and content by:

Dr. Timothy Brush
(Chair of Committee)

Dr. Robert I. Lonard
(Committee Member)

Dr. Frank W. Judd
(Committee Member)

MAY 1997

Garza, Humberto Jr., Habitat Use and Activities of The Piping Plover, Charadrius melodus, Wintering On South Padre Island, Texas. Master of Science (MS), May, 1997, 49 pp., 14 tables, 11 figures, 20 titles.

The Piping Plover, *Charadrius melodus*, is endangered in its breeding sites and threatened in its wintering sites. This migratory shorebird spends 3 to 4 months on northern U.S. and southern Canadian breeding sites and the remainder of the year in Gulf of Mexico, Caribbean, and southern U.S. wintering sites. Up to 2.4% of the estimated Piping Plover population remains for the 9 to 10 month non-breeding season on South Padre Island (S.P.I.). During the non-breeding season, I conducted censuses at 15 sites in the southern portion of South Padre Island to determine Piping Plover habitat preferences. Piping Plovers prefer bay side flats as opposed to beach areas on South Padre Island, and habitat use is determined by conditions such as exposure and wetness of bay side habitats. Piping Plovers tend to forage in habitats close to the Laguna Madre, such as mud flats and roost farther away on the sand flats.

ACKNOWLEDGMENTS

Funds to support this study were provided by grant # 531730 from Franke Brothers Realtors, Inc., South Padre Island, Texas, which is gratefully acknowledged. I thank my M.S. thesis committee members, Drs. Timothy Brush (Chairman), Frank W. Judd and Robert I. Lonard for their advice and guidance. Thanks go to Roy Perez, Arthur Coykendall, and Christopher Perez for their support. I am grateful to Nancy Ochoa, Jeff Rupert and members of my family for proof-reading and editorial assistance. I thank Louis J. duBois, Jr. for his help with AutoCad and map making.

TABLE OF CONTENTS

LIST OF TABLES

List of tables continued.

LIST OF FIGURES

HABITAT USE AND ACTIVITIES OF THE PIPING PLOVER, *CHARADRIUS MELODUS*, WINTERING ON SOUTH PADRE ISLAND, TEXAS

INTRODUCTION

The Piping Plover *(Charadrius melodus)* is a small, stocky, migratory shorebird up to 17 cm long with a wingspan of 11.0-12.7 cm. Both sexes have pale brownish upper parts and underparts (Palmer 1967, Haig 1986). A dark band encircling the body below the neck, a dark stripe across the forecrown, and bright orange legs are distinguishing marks in summer adults (Palmer 1967, Federal Register 1985, Haig 1986). Wintering Piping Plovers lose their breeding markings, such as forecrown and neck bands and orange bill, but are distinguished from Snowy Plovers (*C. alexandrinus*) and Collared Plovers (*C. collaris*) by their slightly larger size, shorter bill, and yellow-orange legs (Haig and Oring 1987).

Early 20th century accounts report that shorebird hunting caused the first known major decline of the species (Bent 1929). Federal protection provided by the Migratory Bird Treaty Act of 1918, allowed the species to recover by the 1920's when it was considered common (Bent 1929). Since then the population has decreased in most of its range

(Federal Register 1985). Population declines have been noted by Cairns and McLaren (1980), Haig and Oring (1985), and Haig (1986). In 1985, the Piping Plover was listed as endangered in the Great Lakes and Northern Great Plains (breeding sites), and threatened in all other areas (wintering sites) according to the U.S. Federal Register (Federal Register 1985; effective date January 10, 1986).

Charadrius melodus spends about three to four months of the year in the northern U.S. and southern Canadian breeding sites (Haig and Oring 1985)(Fig. 1). Birds may be found at these breeding sites from late March to August, although most individuals remain for shorter periods (Wilcox 1959, Cairns 1982, Federal Register 1985). Throughout the rest of the year (non-breeding season), Piping Plovers use beaches, sand flats, and dunes along the southern Atlantic Coast, Gulf of Mexico-Coast, and off-shore islands (Haig and Oring 1985, Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990a)(Fig. 1). Piping Plovers are rarely found using dunes. They may also be found in the Caribbean on beaches and sand flats (Haig and Oring 1985). Haig and Oring (1985) indicate that Piping Plovers from the Great Lakes and Northern Great Plains winter primarily along the Gulf of Mexico. According to Haig and Plissner (1993), censuses conducted in 1991 showed that the population of Piping Plovers at South Padre Island comprises approximately 2.4%

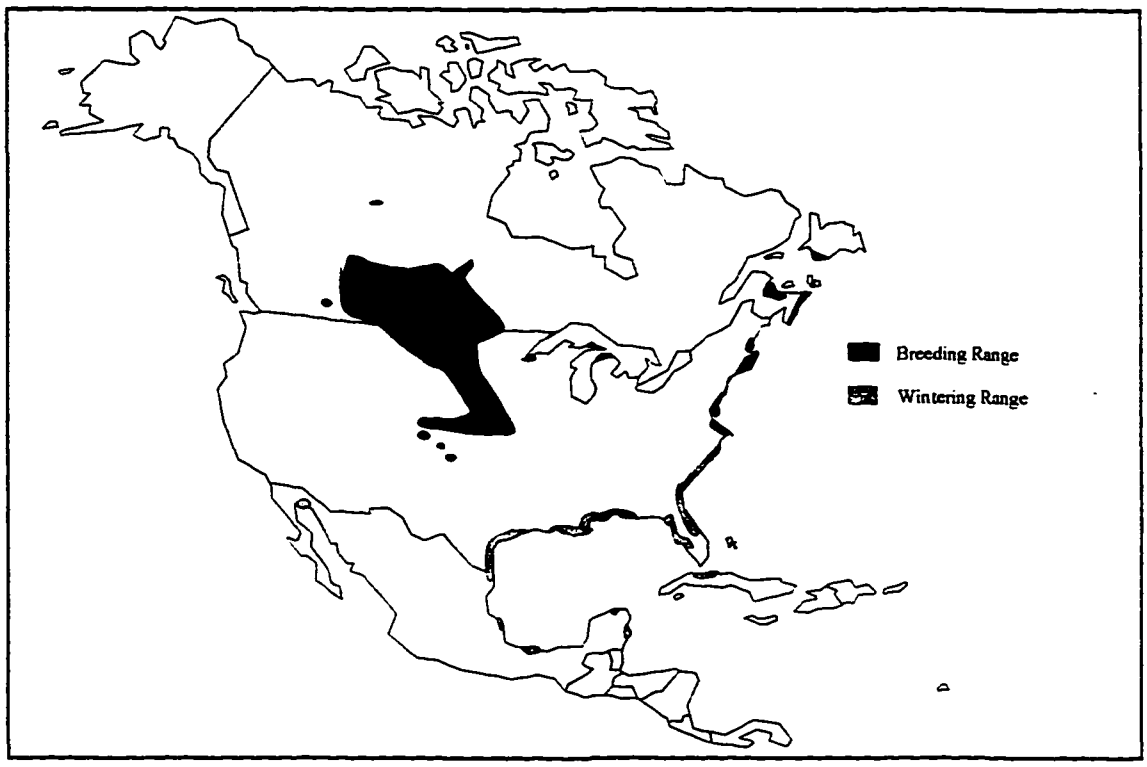

Fig. 1. Distribution of Piping Plovers in North America (modified from Haig 1992).

of all Piping Plovers censused in the International Piping Plover surveys. Haig and Plissner (1993) also indicated that the area inhabited by the largest number of Piping Plovers comprised 8.1% of the censused population in 1991, so South Padre Island, Texas, is a significant wintering site for the species.

The non-breeding season for the Piping Plover extends from early July for a few early-arriving birds to the middle of May for late breeding migrants. Most Piping Plovers return to their wintering sites in August or September; however, some unaccompanied juveniles and males return to their wintering grounds in late October or early November (Haig 1992). Censusing Piping Plovers on South Padre Island is important because *C. melodus* may be found on the island throughout most of the year. Information about wintering Piping Plovers is limited, and more needs to be known about habitat use to protect the species.

Research on wintering Piping Plovers has focused on habitat associations and distribution (Nicholls and Baldassarre 1990a, 1990b, and Mitchell, 1993), wintering ecology in coastal Alabama (Johnson and Baldassarre 1988), and seasonal abundance in Texas (Eubanks 1994). Research has been done on the distribution and status of the Piping Plover throughout the annual cycle (Haig and Oring 1985). Information from Christmas bird counts and an International

census in 1991 (Haig and Plissner 1993) have contributed to knowledge of wintering Piping Plovers; but more research is needed to determine which wintering habitat conditions are most favorable to the wintering Piping Plovers on South Padre Island, Texas.

Piping Plovers use mud flats, algal flats, and sand flats in Texas (Eubanks 1994), but the conditions of the habitat when used and when not used may be important to determine the habitat conditions that Piping Plovers prefer. A study on effects of tidal cycles on habitat selection and habitat partitioning by migrating shorebirds (Burger et al. 1977) indicates that changes in tide levels affect prey availability and foraging space, i.e. tide changes cause foraging birds to move from one area to another. This may be a factor determining if a particular site or habitat is favorable to Piping Plovers. Also, no study has examined seasonal changes in numbers and habitat use on the wintering grounds.

Recreational development and construction on South Padre Island is rapidly increasing. This development and northward expansion of the city limits adversely affects Piping Plover habitat and it is a major threat to the species on South Padre Island because it may limit the area that can be utilized by wintering Piping Plovers.

The purposes of this study were to examine, describe,

and quantify the activities and patterns of habitat use by wintering Piping Plovers on South Padre Island, Texas. This study assesses the importance of tide levels, temperatures, time of year, and size and disturbance of sites on Piping Plovers wintering along South Padre Island, Texas. Disturbance includes direct human disturbance and habitat destruction due to development of recreational facilities.

STUDY AREAS

Study areas were located in the southern portion of South Padre Island, Cameron County, Texas (Fig. 2). Sites included partially altered habitats on the bay side of South Padre Island from within the city limits to the northern end of Park Road 100, and along the beach side from public access point number 3 to the northern end of Park Road 100. These sites were chosen for censusing because they represented a sampling of habitats most likely to be affected by recreational development in the near future. The 15 sites censused for Piping Plovers during this study are described in Table 1. The amount of habitat present was estimated by field surveys, aerial photo analysis, and topographic map analysis.

Table 1. Description of study areas and habitat on South Padre Island, Texas.

Site No.	Description of Location	Amount of Habitat
Site 1	Bay side flats North of old Causeway and public boat ramps (Fig. 3).	1.02 ha. mud flats 0.97 ha. algal flats 0.67 ha. sand flats
Site 2	Bay side flats adjacent to South side of the Causeway (Fig. 3).	1.13 ha. mud flats
Site 3	Bay side flats adjacent to North side of the Causeway (Fig. 3).	3.08 ha. mud flats
Site 4	Seasonally exposed Bay side flats, behind the 1st Nat'l. Bank between two apartments (Fig. 3).	1.45 ha. mud flats 1.05 ha. algal flats 2.91 ha. sand flats

Table 1. Continued.

Site No.	Description of Location	Amount of Habitat
Site 5	Small sand flat, South of Hibiscus Street (Fig. 3).	0.22 ha. sand flats
Site 6	Flats South of Landfill Towers condominiums (Fig. 3).	1.85 ha. sand flats
Site 7	Bay side flats North of the Landfill Towers condominiums and South of S.P.I. Convention Center (Fig. 4).	0.89 ha. mud flats 2.26 ha. algal flats 6.21 ha. sand flats
Site 8	Bay side flats Southeast of S.P.I. Convention Center (Fig. 4).	1.71 ha. sand flats
Site 9	Bay side flats on the West side of S.P.I. Convention Center (Fig. 4).	0.73 ha. mud flats 0.95 ha. algal flats 1.35 ha. sand flats
Site 10	Bay side flats North of S.P.I. Convention Center to southern border of Franke Brothers property line (Fig. 4).	2.84 ha. mud flats 42.77 ha. sand flats
Site 11	Bay side fill area, Franke Brothers property (Fig. 4).	80.49 ha. fill
Site 12	Bay side flats North of Franke Brothers property up to about 2.3 km North of S.P.I. Convention Center (Fig. 4).	5.33 ha. mud flats 11.13 ha. algal flats 58.71 ha. sand flats
Site 13	Bay side flats about 5.1 km North of S.P.I. Convention Center (Fig. 4).	4.78 ha. mud flats 13.01 ha. algal flats 32.33 ha. sand flats
Site 14	Bay side flats about 10.6 km North of S.P.I. Convention Center (Fig. 5).	5.44 has. mud flats 19.82 ha. algal flats 56.66 ha. sand flats
Site 15	Beach side from public access # 3 to the northern end of Highway 100 (Figs. 4 and 5).	62.36 ha. surf zone 67.52 ha. upper beach

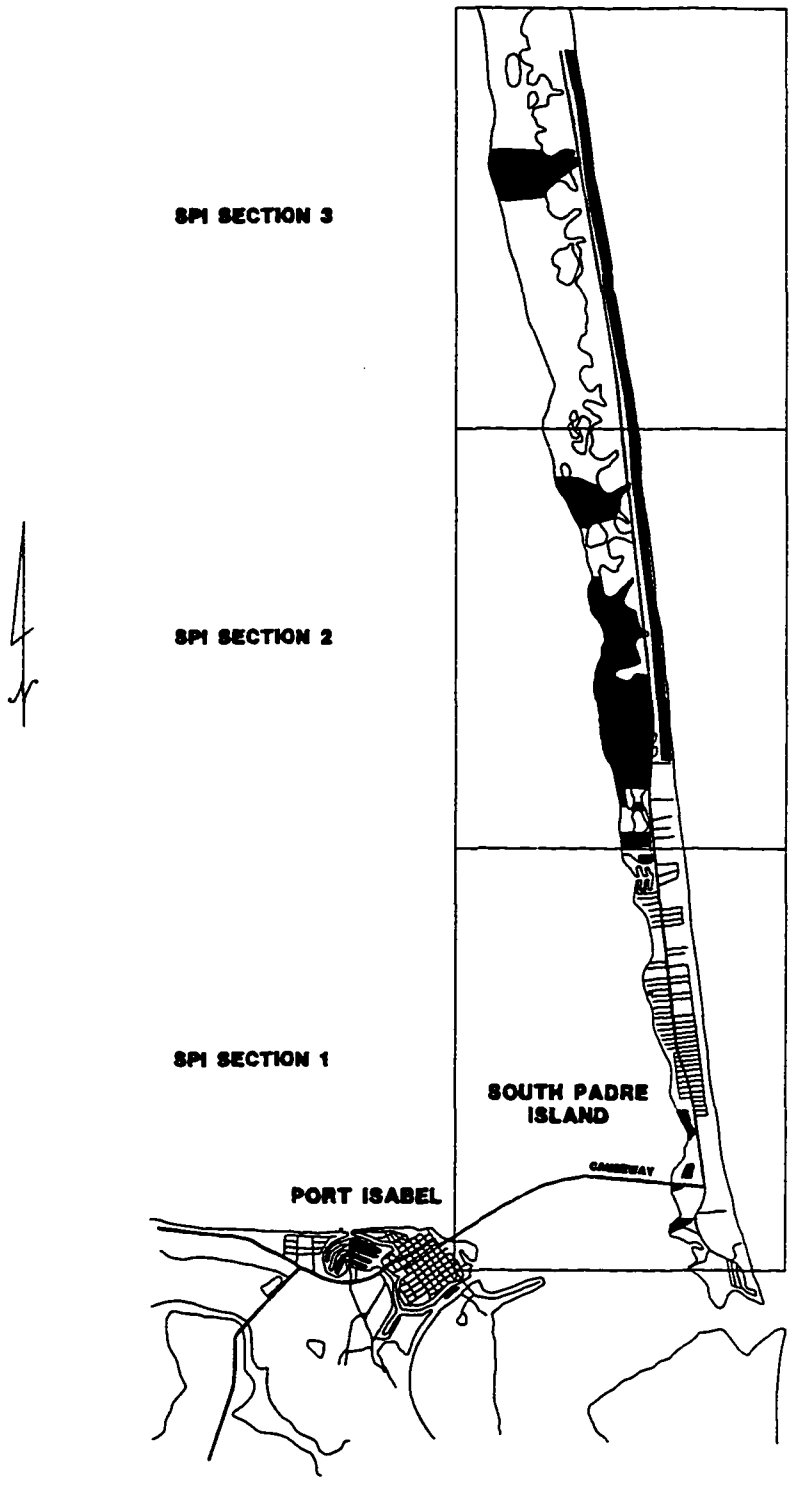

Fig. 2. Vicinity map for Piping Plover surveys, South Padre Island, Texas.

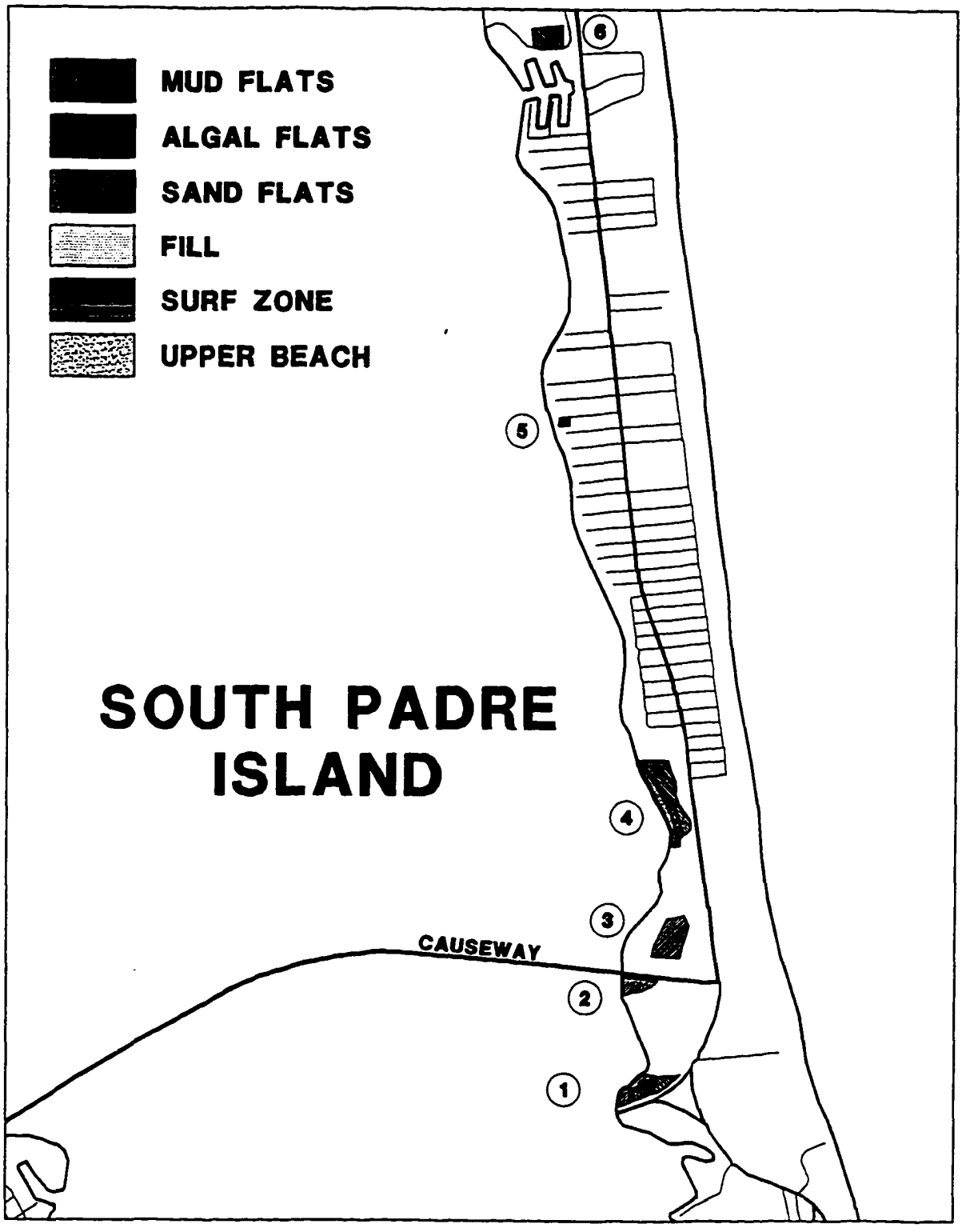

Fig. 3. S.P.I. section 1, Study Sites 1 - 6, in the southernmost portion of South Padre Island, Texas.

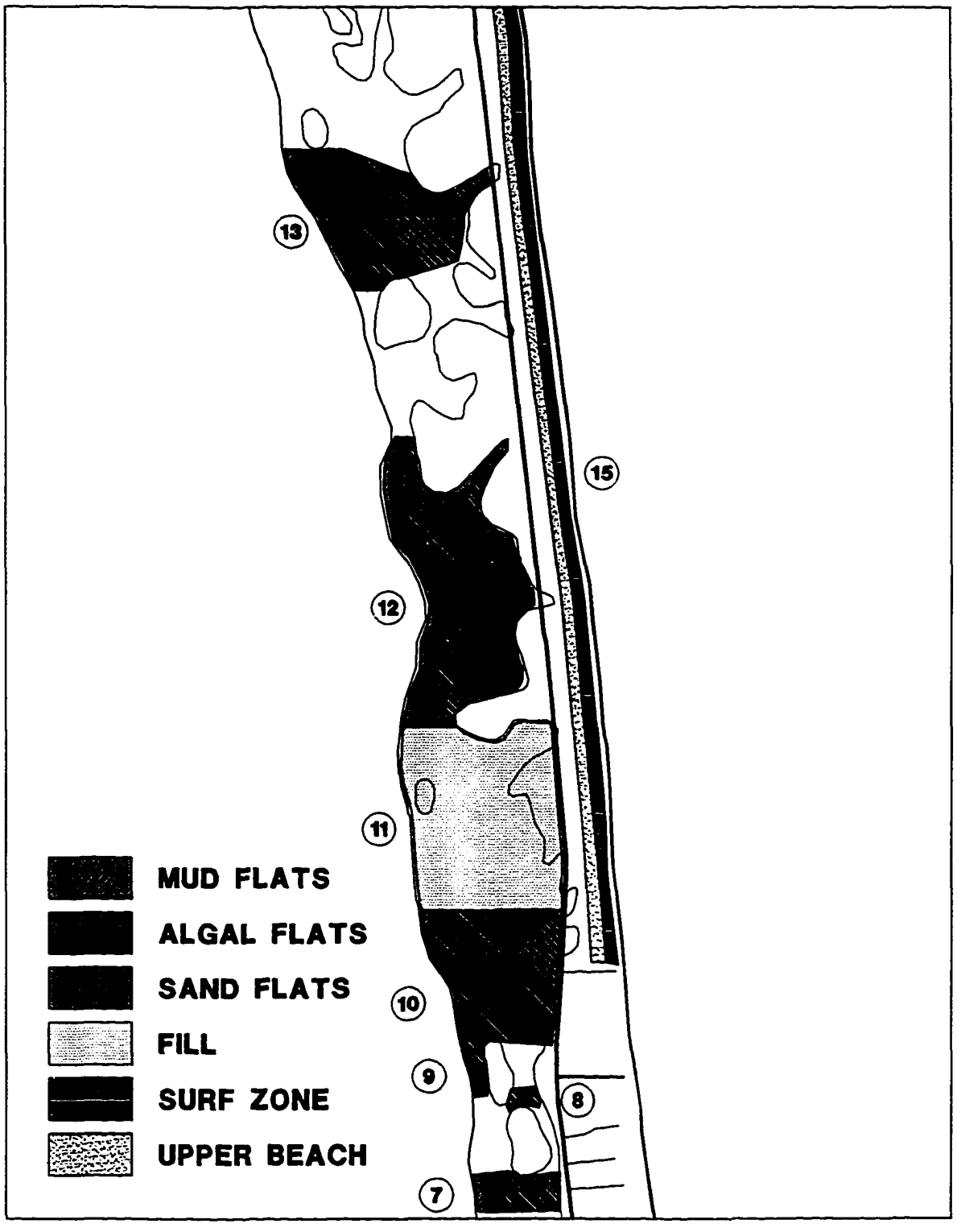

Fig. 4. S.P.I. section 2, Study Sites 7 - 13 and 15, in the northern portion of the City of South Padre Island and adjoining unincorporated land.

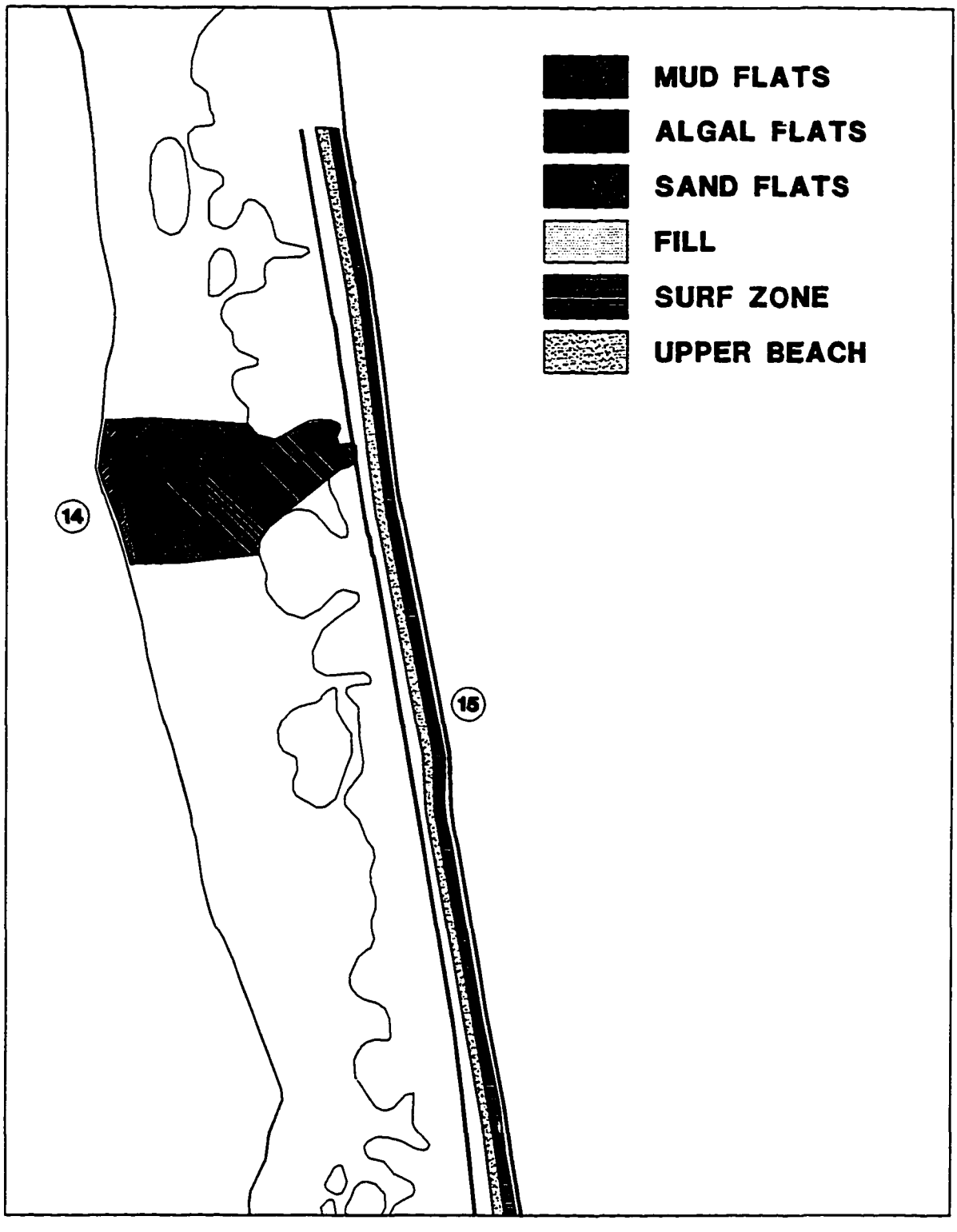

Fig. 5. S.P.I. section 3, Study Sites 14 and 15, North of the City of South Padre Island, Texas.

Each site has specific amounts of habitat. These are given in Table 1. Site 11 is unique because it has been filled in with sand for future development. However, during extremely low tides some flats are exposed. Site 11 was listed as fill; but, most of the Piping Plovers at this site were found during times when the flats were exposed. That is, Piping Plovers were found mainly on flats rather than on the fill. The presence of flats at Site 11 is highly variable. The mud flats, algal flats, and sand flats are rarely available and the total amount in hectares is unknown due to the high variability in the amount of available habitat at any given time.

HABITAT TYPES

Habitats were classified as surf zone, upper beach, fill, sand flats, mud flats, and algal flats based on physical appearance exhibited in the locations. The surf zone occurs along the beach side of South Padre Island from beach access point number 3 northward to the end of Highway 100. Here the gulf waves crash on the shore and run up a few meters up over the sand. The substrate of the surf zone is usually wet sand and light brown in color.

The upper beach consists of the sandy shore above the high tide line and the primary dunes. It is light brown in color and the sand is mostly dry (Nicholls and Baldassarre 1990a).

Fill are low lying areas on the bay side which have been filled with sand and leveled, raising their elevations in preparation for future construction on private property, (primarily Franke Brothers property). They may once have been sand flats, mud flats or algal flats.

Sand flats are areas on the bay side facing the Laguna Madre that are sandy, and light brown in color. When wet, they are soft and when dry, firm to walk on. They consist of high intertidal flats and areas around tidal pools (Nicholls and Baldassarre 1990a). They are sometimes covered with water, but at most times are exposed.

Mud flats are on the bay side facing the Laguna Madre

and usually contain a thin scattered layer of water over the substrate. They are dark brown in color and soft to walk on (Nicholls and Baldassarre 1990a). They consist of a veneer of mud over sand, and may be considered sandy mud flats in contrast to true mud flats at other locations. They are the most frequently flooded bay side habitat (Brush 1995).

Algal flats are areas on the bay side facing the Laguna Madre that contain well-developed blue-green algal mats over sand. They are covered with water during strong northwest winds or seasonal high water and exposed by strong south and southeast winds (Brush 1995). They are higher than mud flats but lower than sand flats.

METHODS

Preliminary research was conducted between 9 October 1994 and 13 November 1994. The main purpose of the preliminary research was to familiarize myself with Piping Plovers and determine the study design. In this short time I learned to accurately identify Piping Plovers by plumage and found areas that contained Piping Plover habitat which could be censused. During this time, finding accessible routes to areas along the Laguna Madre on the bay side of South Padre Island was very important because at times these areas were difficult to access due to heavy rainfall or high tides. Another important reason for the preliminary research was to determine the best methods of collecting data and censusing the areas on South Padre Island. Based on preliminary research, I generally hypothesized that certain factors affected the use and activities of Piping Plovers on different sites and habitats wintering on South Padre Island. Therefore, the following methods were used to gather data which may help learn more about the habitat use and activities of Piping Plovers wintering on South Padre Island.

Fifteen sites containing suitable habitat for Piping Plovers were censused weekly on South Padre Island as accessibility and other factors allowed. Only surveys in which all sites where surveyed were included in the results.

There were 14 sites on the bay side facing the Laguna Madre to the end of Park Road 100 and one site along the beach side of South Padre Island. The beach site extends from beach access point number 3 northward to the end of Park Road 100. Weekly censuses were conducted from 29 January 1995 to 11 May 1996; except for 5 May to 14 July 1995, when the plovers were presumably on their breeding grounds. All areas were censused on the same day. The areas on the bay side facing the Laguna Madre within the city limits were censused from a vehicle. The areas along the bay side north of the South Padre Island Convention Center were also censused by vehicle when the weather and road conditions permitted; otherwise, they were censused by walking (Haig and Plissner 1993, Nicholls and Baldassarre 1990a, 1990b). The beach side from beach access point 3 to the north end of highway 100 was censused from a vehicle by driving along the beach.

Charadrius melodus were identified based on plumage. A pair of 7 X 50 binoculars were used to scan for the Piping Plover, and a 20-60 X spotting scope was used to identify the Piping Plovers. Activities were recorded using a scan sampling method (Altman 1974). This involves censusing all the individuals of the group at regular intervals (once a week in this study) and recording their activities at the time of the census. It is a sample of conditions not

events. Such sampling has been used to study the percent of time spent in various activities (Altman 1974). A database was established to record the total number of Piping Plovers, the type of habitat they were using, and their activities. The activities recorded were foraging, roosting, or exhibiting aggressive behavior. Other information recorded were the time, location, date, air temperature, windspeed, direction, and a description of the habitat conditions at each site i.e., approximate tide levels. Each site was mapped and used for each census to indicate where the Piping Plovers were found. One of the crucial items, densities, were determined by calculating the total area of each habitat type censused and the total area of habitat for each of the 15 sites (Figs. 3, 4, and 5), the amount of each habitat type at each site, and determining the mean number of Piping Plovers per 10 hectares of habitat type throughout the study period.

One null hypothesis is that the number of Piping Plovers is equal at all sites and habitats because there are no factors that affect the use of each site or habitat by these birds. Therefore, I compared the mean densities of Piping Plovers at each site and in each habitat type. I also compared the total number of Piping Plovers found during different months of the year and at specific temperature ranges using Chi-square tests. Temperature

ranges were separated into 7 groups which were represented most equally throughout the study period, each group contained between 25 and 35 observations at that specific temperature range. The groups contained the number of Piping Plovers found when temperatures were at specific temperature ranges. Piping Plovers found when temperatures were below 16°C were placed in group 1, group 2 (17-20°C), group 3 (21-23°C), group 4 (24-26°C), group 5 (27-28°C), group 6 (29-31°C) and group 7 (32-33°C).

For site comparisons, expected values were derived by calculating the total expected number of Piping Plovers based on percentage of habitat at each site. For habitat comparisons, expected numbers were generated based on the total amount of each habitat present. For temperature and monthly comparisons, expected numbers are based on equal numbers of plovers for each group.

A factor that may affect habitat use by Piping Plovers is the amount of habitat at a site and whether the site was disturbed or undisturbed. Therefore, I compared small and large sites, disturbed and undisturbed sites separately and together to determine if densities on these types of sites were significantly different from each other. Small sites were less than 10 hectares, and included Sites 1 to 9, 10 to 15 were classified as large sites. Disturbance was based on factors such as extreme habitat changes i.e., fill,

vegetation encroachment or heavy recreational use. Small disturbed sites included: 2, 3, 5, 6, and 8; while Sites 1, 4, 7, and 9 although within the city limits, were not heavily disturbed by such factors and were classified as undisturbed small sites. Disturbance in the larger sites was limited to Sites 11 and 15, while Sites 10, 12, 13, and 14 were labeled as large undisturbed sites.

A second null hypothesis is that foraging, roosting, and aggressive activities were conducted in equal amounts of time and equally on different habitats by the Piping Plovers. Consequently, using Chi-square analysis I compared the total number of Piping Plovers exhibiting each activity on specific habitats to determine if there is an association between particular activities and particular habitats.

RESULTS

A total of 1,328 Piping Plovers were censused throughout the 16 month study period from 29 January 1995 to 11 May 1996. The number of Piping Plovers found in each habitat is listed in Table 2. The highest numbers of Piping Plovers were observed in mud flats and sand flats. The activities of the Piping Plovers throughout the entire study period are listed in Table 3. Most birds were observed foraging.

The density of Piping Plovers per 10 hectares of habitat type is indicated in Fig. 6. Density of Piping Plovers was marginally higher in the mud flat habitat than in any other habitat type (Table 6). Densities were also calculated for each survey site based on the average number of Piping Plovers counted at each site throughout the 61 survey days. Densities were calculated as density of Piping Plovers per 10 hectares of habitat at each site and are indicated in Fig. 7. Piping Plover density was highest at Site 9, a relatively small site. Additionally, this figure shows that Sites 4 and 10 had the next highest mean densities.

The monthly mean number of Piping Plovers on South Padre Island during the study period is indicated in Fig. 8. Piping Plover numbers were highest from September through November (1995) and again in January (1996). Habitat use

can be separated into bay side habitats and beach habitats. The total number of Piping Plovers using specific habitats on the bay side is listed on a monthly basis and is indicated in Fig. 9. Sand flats were most heavily used from August to October 1995, but mud flats were most heavily used during most other months. The total number of Piping Plovers using specific habitats on the beach is listed on a monthly basis and is indicated in Fig. 10. Surf zone habitat was used more regularly than the upper beach.

Table 2. Total number of Piping Plovers counted by habitat type on South Padre Island, January 1995 - March 1996. This data was collected from 61 survey days. Also shown are the total amount of each habitat surveyed and density per 10 ha. of habitat type.

Habitat type	Surf Zone	Upper Beach	Mud flats	Algal flats	Sand flats	Fill	Total
No. Piping Plovers	83	23	536	192	489	5	1,328
Amt. of habitat in hectares	62.4	67.5	26.7	49.2	205.4	80.5	491.7
Density per 10 ha.	0.22	0.06	3.3	0.64	0.4	0.01	0.44

Table 3. Total numbers of Piping Plovers performing specific behaviors on South Padre Island, January 1995 - March 1996.

Foraging	Aggression	Roosting	Total
1,114	7	207	1,328

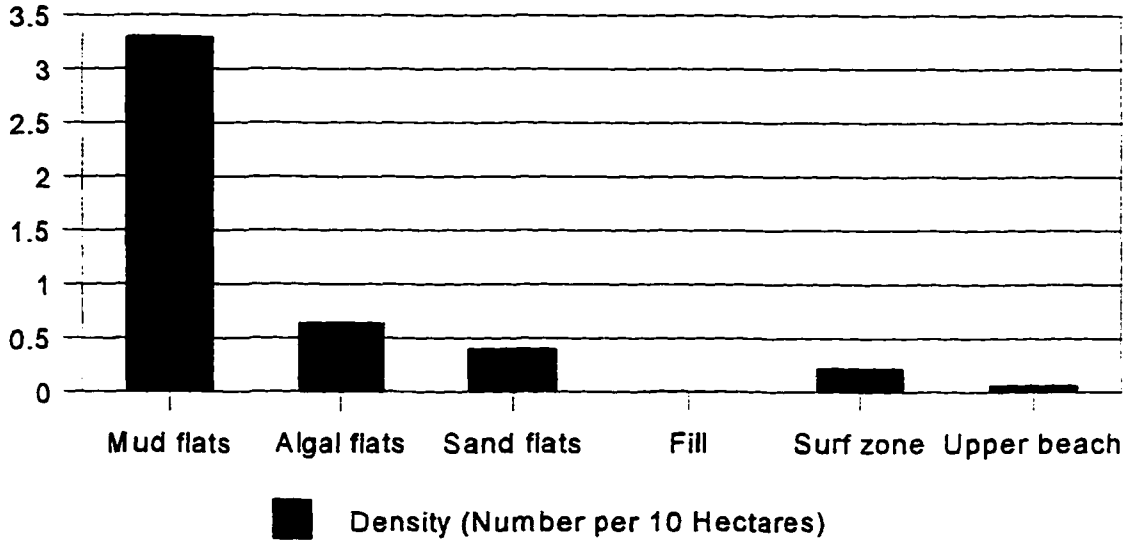

Fig. 6. Mean Piping Plover density per 10 hectares of each habitat type studied on S.P.I. Densities are based on the average number of Piping Plovers counted throughout 61 surveys.

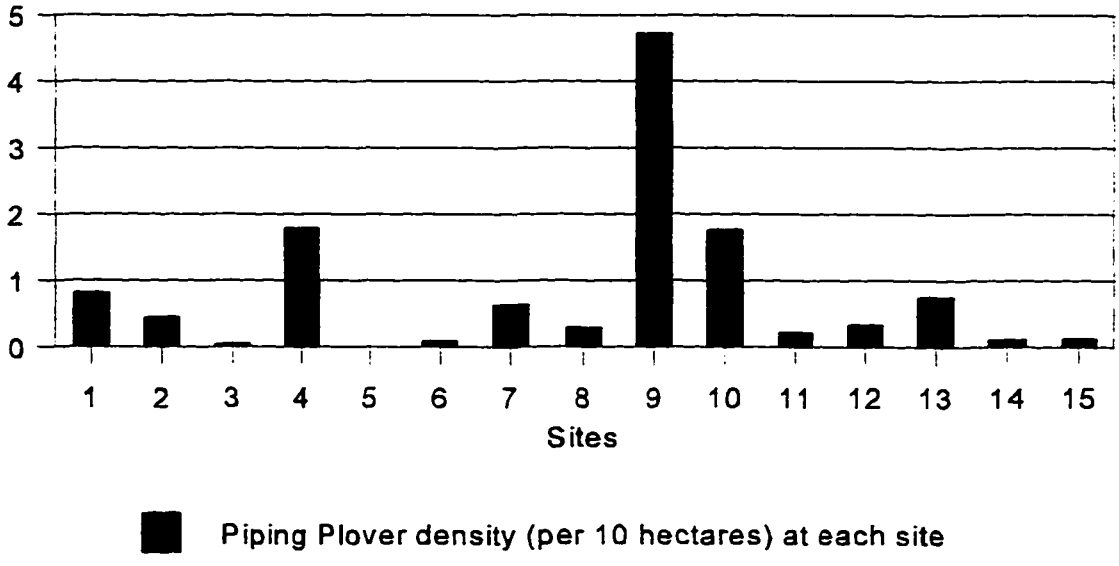

Fig. 7. Mean Piping Plover density per 10 hectares of habitat at each study site on S.P.I. These densities are based on the average number of Piping Plovers counted throughout 61 surveys.

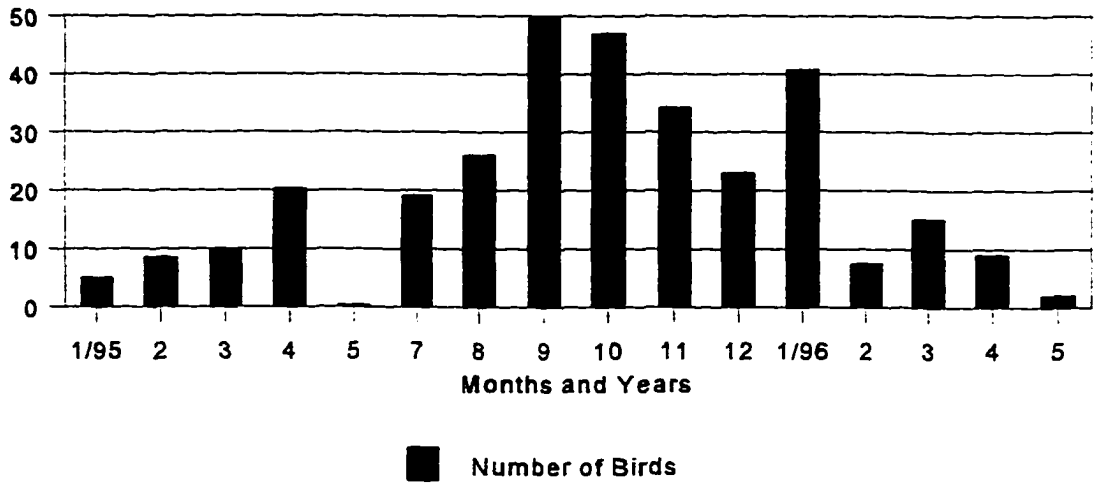

Fig. 8. Monthly mean number of Piping Plovers per survey at South Padre Island study areas. Numbers indicate the average number of Piping Plovers per survey on South Padre Island study sites, based on 61 surveys throughout the non-breeding season, on all plots combined.

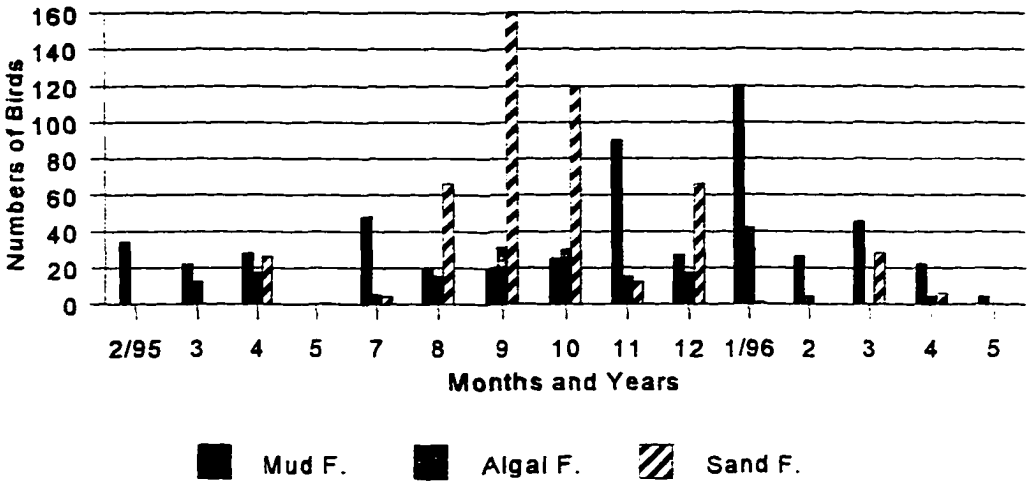

Fig. 9. Total numbers of Piping Plovers detected on a monthly basis on the bay side of South Padre Island. One to five censuses were conducted monthly, depending on the number of weeks in the month. Fill was omitted because of the small numbers of observations (see text).

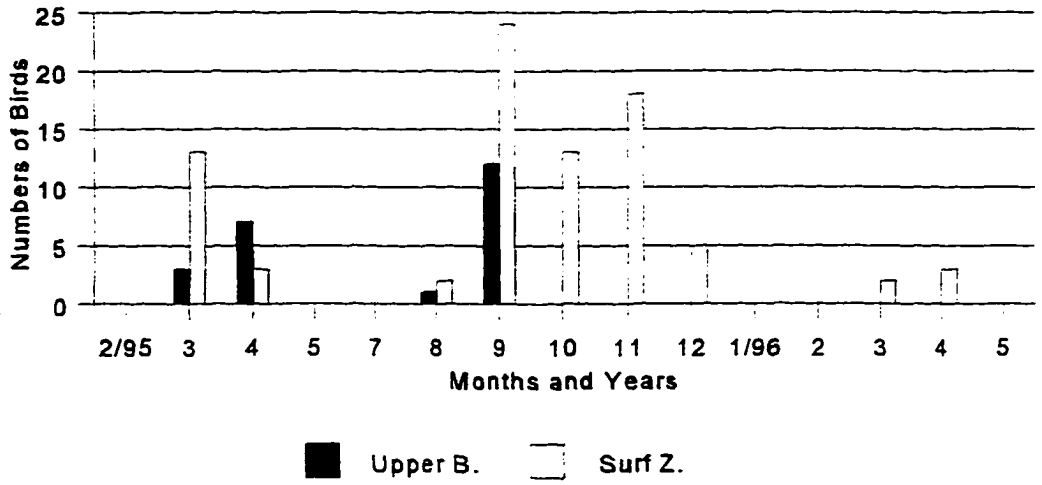

Fig. 10. Total numbers of Piping Plovers detected on a monthly basis on the beach of South Padre Island. 1 - 5 censuses were conducted monthly, depending on the number of weeks in the month or the time of the year.

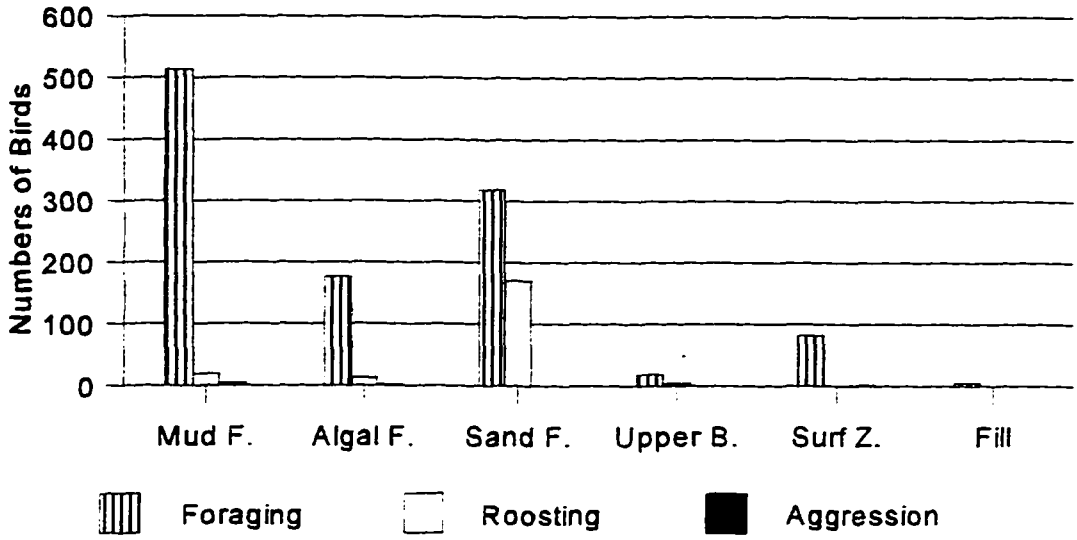

Fig. 11. A comparison between habitat use and activities of Piping Plovers on S.P.I. Numbers are the total numbers of birds observed performing specific activities on different habitat types during surveys on South Padre Island study sites.

Temperature significantly affects the presence of Piping Plovers on South Padre Island (Table 4). Piping Plovers appeared to be most abundant on the island at lower temperatures. However, I feel that temperature ranges vary due to the time of the year. Therefore, significant differences in Piping Plover numbers at different temperature ranges may be due to time of the year.

Table 4. Chi-square analysis: Comparing numbers of Piping Plovers on South Padre Island at different temperature ranges in degrees Celsius.

Temp. in°C	13-16	17-20	21-23	24-26	27-28	29-31	32-33°C
Obs.	184	322	235	93	151	139	204
Exp.	189.7	189.7	189.7	189.7	189.7	189.7	189.7
d.f.	6	Calc. Chi	175.2	Table Chi	12.592	Conf. Lev.	<.05

Chi-square analysis was also used to determine if monthly totals of Piping Plovers were the same throughout the year on South Padre Island. The chi-square analysis shows that there is a significant difference in the number of Piping Plovers in the areas surveyed on South Padre Island during different months of the year (Table 5).

Habitat use was compared based on density of Piping Plovers per 10 hectares of each habitat type. Chi-Square analysis shows that there was a marginally significant difference in habitat type use based on density (Table 6). However, mud flats support higher densities of these birds.

Table 5. Chi-square analysis: Monthly comparisons based on numbers of surveys per month on South Padre Island.

Month and No. of surveys	Observed	Expected
Jan. 95 (1 survey)	5	21.77
Feb. 95 (4 surveys)	34	87.06
March 95 (5 surveys)	50	108.9
April 95 (4 surveys)	81	87.06
May 95 (3 surveys)	1	65.3
July 95 (3 surveys)	57	65.3
Aug. 95 (4 surveys)	104	87.06
Sept. 95 (5 surveys)	248	108.9
Oct. 95 (4 surveys)	188	87.06
Nov. 95 (4 surveys)	137	87.06
Dec. 95 (5 surveys)	115	108.9
Jan. 96 (4 surveys)	163	87.06
Feb. 96 (4 surveys)	30	87.06
March 96 (5 surveys)	75	108.9
April 96 (4 surveys)	36	87.06
May 96 (2 surveys)	4	43.55
d.f. = 15 Conf. Lev. <.05	Calc. Chi. 648.26	Table Chi. 24.996

Mud flats were used much more than expected. The algal flats, sand flats, surf zone and upper beach were used less than expected, while fill was almost never used.

A comparison between the Piping Plover densities at all 15 sites shows that there is a significant difference in the mean densities at the different sites (Table 7). The most heavily used are Sites 4, 9, and 10.

Table 6. Chi-square analysis: Density per 10 ha. of each distinct habitat type at South Padre Island.

Habitat type	Observed	Expected
Mud flats	3.3 per 10 ha.	.77 per 10 ha.
Algal flats	.65 per 10 ha.	.77 per 10 ha.
Sand flats	.40 per 10 ha.	.77 per 10 ha.
Fill	.01 per 10 ha.	.77 per 10 ha.
Surf zone	.22 per 10 ha.	.77 per 10 ha.
Upper beach	.06 per 10 ha.	.77 per 10 ha.
d.f. = 5, P <.05	Calc. Chi = 10.42	Table Chi = 11.070

Table 7. Chi-square analysis: Density per 10 ha. at each of the 15 study sites on South Padre Island. Based on 61 surveys.

Site No.	Observed	Expected
1	.8	.801
2	.44	.801
3	.053	.801
4	1.76	.801
5	0	.801
6	.09	.801
7	.631	.801
8	.29	.801
9	4.7	.801
10	1.74	.801
11	.214	.801
12	.33	.801
13	.74	.801
14	.112	.801
15	.134	.801
d.f.= 14, P <.05	Calc. Chi = 25.89	Table Chi = 25.76

Sites were also compared based on size and disturbance factors. Significant differences were found when comparing all small sites together (Table 8) and only small undisturbed sites (Table 9). No significant difference was found when comparing only small disturbed sites to each other (use of these sites was virtually nil)(Table 10). However, significant differences were found when comparing all large sites (Table 11); only large disturbed sites (Table 12) and only large undisturbed sites (Table 13).

Table 8. Chi-square analysis: Comparing number of Piping Plovers between all small sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
1	13	18.7
2	3	8
3	1	21.7
4	58	38.2
5	0	1.6
6	1	13.1
7	36	66.1
8	3	12.1
9	86	21.5
d.f. = 8, P <.05	Calc. chi = 261.6	Table Chi = 15.5

Table 9. Chi-square analysis: Comparing number of Piping Plovers between small undisturbed sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
1	13	25.1
4	58	51
7	36	88.2
9	86	28.6
d.f. = 3, P <.05	Calc. Chi = 152.88	Table Chi = 7.815

Table 10. Chi-square analysis: Comparing number of Piping Plovers between small disturbed sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
2	3	1.13
3	1	3.08
5	0	.22
6	1	1.86
8	3	1.71
d.f. = 4, P <.05	Calc. Chi = 5.89	Table Chi = 9.488

Table 11. Chi-square analysis: Comparing number of Piping Plovers between all large sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
10	483	110.4
11	105	196.1
12	151	182.6
13	226	121.7
14	56	199.5
15	106	315.6
d.f. = 5, P <.05	Calc. Chi = 1637	Table Chi = 11.070

Table 12. Chi-square analysis: Comparing number of Piping Plovers between large disturbed sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
11	105	80.8
15	106	130.2
d.f. = 1, P <.05	Calc. Chi = 11.7	Table Chi = 3.841

Table 13. Chi-square analysis: Comparing number of Piping Plovers between large undisturbed sites at South Padre Island. Expected values are based on habitat percent at each site.

Site No.	Observed	Expected
10	483	164.9
12	151	272.1
13	226	181.4
14	56	296.8
d.f. = 3, P <.05	Calc. Chi = 873.9	Table chi = 7.815

A Chi-square contingency analysis was also conducted on the data to determine if one factor (habitat use) was influenced by another factor (activities). A higher calculated Chi-square value shows that significant interaction occurs between habitat use and activities of Piping Plovers (Table 14). Piping Plovers foraged more on mud flats and roost more on sand flats (Fig. 11).

Table 14. Chi-square contingency analysis: Determining the effect activity has on Piping Plover habitat preference at South Padre Island. Only mud flat and sand flat habitat were tested against foraging and roosting activities.

	Mud flats	Sand flats	Total interactions
Foraging	513 (a)	318 (b)	(a+b)= 831
Roosting	19 (c)	171 (d)	(c+d)= 190
			T = (a+b+c+d)= 1021

$$\text{Chi-square} = \frac{(|a*d-b*c| - 0.5*T) * (|a*d-b*c| - 0.5*T) * (T)}{(a+b)(a+c)(b+d)c+d)}$$

d.f. = 1
P <.05
Calc. Chi-square = 164.1
Table Chi = 3.841

DISCUSSION

Piping Plovers use a variety of habitats on South Padre Island, but densities are highest in mud flats, intermediate in algal flats and lower in other habitats, suggesting that mud flats are preferred by Piping Plovers at South Padre Island. Similarly, Johnson and Baldassarre (1988) indicate that Piping Plovers in coastal Alabama used mud flats and sand flats >85% of the time during each month. Although sand flat use is fairly high at South Padre Island, most of their use may be due to roosting activity, or to high rainfall or high tides which cover the mud flats limiting their use. During September and October of 1995, increased rainfall and high wind driven tides caused the mud flat habitats on the larger sites to become inundated and virtually unusable by Piping Plovers. The decrease in usable mud flats and the increasing number of returning Piping Plovers at this time of the year may have forced birds to use the sand flats at a much higher rate than usual.

Although increased water levels may cover some habitat, it appears that most Piping Plovers prefer to forage within 20 m of the water level and most birds in this zone forage at the water's edge. The area at the water's edge is the softest area and may be the easiest in which to capture prey for the Piping Plovers. It may not matter in which habitat

the water's edge lies, that is where the Piping Plovers will forage the most. Thus, tide levels may be the major contributing factor affecting habitat preference by the Piping Plovers. One reason for this may be because tide levels affect prey availability and foraging space (Burger et. al. 1977).

Although Haig and Plissner's (1993) results from the international census indicate that Piping Plovers were found using beach habitats 51% of the time, Piping Plover use of beach habitat on South Padre Island was quite low. Factors affecting beach use are unknown, but may include the high level of vehicular and pedestrian use on South Padre Island. Several times throughout the study I censused the area just north of Site 15. This area was approximately 14.4 km long and is affected less by vehicular and pedestrian traffic than Site 15. Piping Plover use of this area was usually slightly higher than in Site 15; however, on 21 October, 1995 I counted 41 Piping Plovers using the surf zone in the area north of Site 15, and in Site 15 I counted only 2 Piping Plovers. The difference in the use of these areas by Piping Plovers was probably due to differing levels of public use. There were many more vehicles and people in Site 15 than North of it. Regular surveys in less heavily-used areas such as northern South Padre Island should be conducted to further evaluate this relationship.

Although temperature was found to significantly affect the number of Piping Plovers on South Padre Island, this may be mostly due to the time of the year, which also significantly affects the presence of Piping Plovers on South Padre Island. I found that at certain times of the year there were significant changes in the abundance of Piping Plovers on South Padre Island. A comparison of monthly averages of Piping Plovers (Fig. 7), show that small numbers of plovers return from their breeding sites by mid - July to August, while larger numbers return later and are present by September and October. Similar migration trends were observed by Eubanks (1994) for the entire Texas Coast. Piping Plover numbers drop slightly in November. At this time the birds may be scattering throughout the area. In January there is a sharp increase which may have resulted because of an unusually low water level in the Laguna Madre which exposed larger areas of mud flats. In February numbers drop again until the end of the migration period.

It appears that early arrivers from the breeding grounds reach South Padre Island by mid-July to early August. In mid-August to September, the remaining breeders arrive along with many unaccompanied young. Early arrivals are still in adult breeding plumage, while later arrivals are in non-breeding plumage. Piping Plovers arriving at

South Padre Island increase the population of the area and may cause competition for food sources. The unaggressive nature of the Piping Plover may cause many to move further south to other, possibly less competitive, areas of the island and perhaps into Mexican coastal areas that are less populated by birds. Alternatively, birds may be drifting toward habitats with greater food abundance along the Lower Laguna Madre. Many sites along the Lower Laguna Madre show such trends (Brush 1995). More extensive surveys of the Lower Laguna Madre, as well as the Laguna Madre of Tamaulipas, will be needed to assess these alternatives.

Comparisons show that there is a marginally significant difference in the density of Piping Plovers among habitat types (Table 6). However there are significant differences in the densities by sites (Table 7). Overall densities on the mud flats were higher than in any other habitat type. This was unexpected, given the habitat association with beaches and sand flats mentioned in earlier studies (Johnson and Baldassarre 1988). However, the sandy substrate of South Padre Island mud flats may make them somewhat different ecologically than mud flats else where along the Gulf Coast.

Larger sites, (i.e. those with more than 10 hectares of available habitat), generally supported a higher density of Piping Plovers than small sites. However, Site 9 (a small

site) supported high densities of Piping Plovers. Thus, it does not appear to be the size of the site that supports high density, but rather food availability may be the more important factor. Sites 4 and 9 for example are small undisturbed sites yet during the study both supported higher densities of Piping Plovers than did Site 14, one of the largest undisturbed sites. Site 9 appears to be the most important site for foraging Piping Plovers based on density. The reason may be due to availability of food on those sites. Unfortunately, I did not sample sites for food sources and can't shed light on the question. However, both Sites 4 and 9 were affected greatly by daily tide levels which may increase prey abundance and make foraging easier for Piping Plovers. Sites 1 and 7 are also small undisturbed sites that supported more plovers than the small disturbed sites which were rarely used.

Disturbance to habitat is a major factor that affects habitat use. Small disturbed sites were rarely used, yet other small undisturbed sites were used repeatedly when food availability probably was high. In Site 10, the smallest of the large sites, I found most of the Piping Plovers. This area is between Site 9 (a highly used small site) and Site 11 (fill). Sites 9 and 10 appear to be the best sites, and they may contain higher food availability than other areas. These sites are also highly affected by tide levels

throughout the year.

Birds appeared to avoid the fill on Site 11. Only 5 plovers were located on the fill area. Due to low tide levels at certain times of the year some flats were exposed at Site 11. One hundred birds were located at Site 11. They were found on a few days when the tides were very low in the area and other habitats were exposed (mainly mud flats). This suggests that this area may have supported many Piping Plovers in the past before it was filled in for development. The site still could support many Piping Plovers if it were not filled and was still in its natural state. Site 15, the beach area, is highly disturbed by recreational use because it is close to the city and is the only beach area accessible to vehicles. Many of the Piping Plovers on this site were found when beach recreation was limited by bad weather. Although the Piping Plovers that were found near and around people did not appear to be bothered by them, the numbers indicate that they prefer to be where there are few, if any, people. On South Padre Island, those areas are on the bay side of the island and sometimes North of Site 15. I indicated earlier that the beach area North of Site 15 on South Padre Island was used more than Site 15. This appears to be due to different levels of recreational use in the two areas.

Piping Plovers were found to forage more than they

roost and to exhibit little aggressive behavior. Aggressive behavior appeared to be limited to foraging areas that were highly populated by foraging shorebirds. Fig. 11 shows that most foraging activity was conducted in mud flats, algal flats, and sand flats. Although these three habitat types are important foraging areas and were widely used, the majority of foraging occurred in the mud flats (especially when area coverage is considered). There is only 26.7 ha. of mud flats as compared to 205.4 ha. of sand flats. Algal flats were used approximately in proportion to their availability; thus they appear to be neither preferred or avoided.

Although roosting Piping Plovers were found in all habitat types except the surf zone and the fill, the sand flats were the areas in which most Piping Plovers were found roosting. This is similar to the findings of Johnson and Baldassarre (1988). They state that Piping Plovers roost in areas adjacent to sandy intertidal feeding areas. I found three roosting sites that were used most often by the Piping Plovers during cold, windy, or rainy weather. These areas contained natural shelters such as rocks, small holes or bumps in the sand that offered some protection from the weather and also from visibility by predators. Areas in Sites 10 and 12 appear to be the most important for roosting Piping Plovers. These roosting areas were close to foraging

areas. These same areas were used more often in the early mornings than later in the day. This suggests that Piping Plovers roost more in bad weather and at night than during the day. Although Staine et. al.(1994) observed night-time foraging in Piping Plovers, they also linked foraging activity to tidal rhythms and human disturbance.

This study suggests that specific habitats appear to be preferred by Piping Plovers, but the conditions of the habitat may be more important than habitat type *per se*. Future studies should focus on the proximity of Piping Plovers to tide levels or to the water's edge in these habitat types. Studies should monitor the areas during tidal changes to determine if, in fact, the Piping Plovers are following the water's edge. If color-banding or radio telemetry were done, patterns of habitat use could be determined for each individual banded Piping Plover. This would be useful in determining factors affecting habitat use and abundance during the non-breeding season.

Several conditions affect the use of areas by Piping Plovers. Disturbance is one factor that appears to outweigh the tidal influence, because all of the small sites appeared to be strongly affected by the tide levels. However, disturbed sites were rarely used by Piping Plovers even if other shorebirds such as Sanderlings (*Calidris alba*) were always found using these sites. The other shorebirds may be

less susceptible to disturbance.

A way to limit disturbance on some of these smaller sites would be to fence them off to vehicular traffic. Many fishermen drive their vehicles to the water's edge in small bay side areas to fish. Such activity is harmful in small sites because of the limited amount of habitat available. The same problem exists on larger sites when the tides are low. This disturbance is verified by the presence of many vehicle trails which run throughout all of the important Piping Plover habitats on the bay side of South Padre Island. This excessive activity could be stopped by closing off-road entrances from Park Road 100 to the bay side areas. This would also eliminate trespassing on private land which covers all this area. I have found that the sand flats are the most important roosting areas for the Piping Plovers. If access roads were eliminated; it might not only increase foraging activity in the larger areas, but also increase safety for the roosting Piping Plovers.

Recreational development is a major negative impact to the Piping Plovers. Its effects are greatly expressed by examining and comparing data at Sites 10, 11, and 12. All three sites are connected to one another. Site 10 is just South of the fill area that makes up Site 11 (filled in for developmental project) and Site 12 is just North of it. Piping Plovers used Sites 10 and 12 much more than Site 11.

Note that only 5 Piping Plovers were actually observed in fill habitat at Site 11. The only difference in these three areas is that Site 11 is filled and the others are natural. The only time Site 11 was used was when the water level was so low as to expose large areas of mud flats along the bay side. If further development occurs and the city grows northward, this development will affect the amount of important wintering habitat on South Padre Island. To protect the remaining Piping Plover habitat, efforts should be made to limit northward expansion of urban development.

This study has shown that Piping Plovers occur on South Padre Island eleven months of each year (Fig. 9); thus this is their home most of the year. In fall and early winter Piping Plovers are particularly abundant on South Padre Island. Mud flat habitats are most heavily used for foraging, while sand flats are the major roosting habitat. Other studies should look at use at mud flat habitats in other areas of the Gulf Coast where the mud flats may differ in their nature. It is important to protect Piping Plovers and their habitat on South Padre Island, to allow them to winter successfully, so they can migrate and breed successfully in the Great Lakes and Northern Great Plains.

LITERATURE CITED

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

Bent, A.C. 1929. Life histories on North American shorebirds. U.S. Natl. Museum, Wash. D.C.

Brush, T. 1995. Habitat use by shorebirds wintering in the Lower Laguna Madre, Texas. Texas J. Sci. 47:179-190.

Burger, J., M. Howe, D.C. Hahn and J. Chase. 1977. Effects of tide cycles and habitat selection and habitat partitioning by migrating shorebirds. Auk 94: 743-758.

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

Cairns, W. E., and I. A. McLaren. 1980. Status of the Piping Plover on the east coast of North America. Am. Birds 34: 206-208.

Eubanks, T. L. 1994. The status and distribution of the Piping Plover in Texas. Bull. Texas Ornith. Soc. 27: 19-25.

Federal Register. 1985. Endangered and threatened wildlife and plants; determination of endangered status for Piping Plover; final rule 50: 50726-50734.

Haig, S. M. 1986. Piping Plover Biology. Endangered Species Information System Workbook II. U.S. Fish and Wildlife Service, Endangered Species Office, Twin Cities, MN.

Haig, S. M. 1992. Piping Plover. *In* The Birds of North America, No.2 (A. Poole, P. Stettenheim, and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Haig, S. M., and L. W. Oring. 1985. Distribution and status of the Piping Plover throughout the annual cycle. J. Field Ornith. 56: 334-345.

Haig, S. M., and L. W. Oring. 1987. The Piping Plover: species description and natural history. Audubon Wildlife Report 509-519.

Haig, S. M., and J. H. Plissner. 1993. Distribution and abundance of Piping Plovers: Results and implications of the 1991 International census. Condor 95:145-156.

Johnson, C. M., and G. A. Baldassarre. 1988. Aspects of the wintering ecology of the Piping Plovers in coastal Alabama. Wilson Bull. 100: 214-233.

Mitchell, M. 1993. Piping Plover and Peregrine Falcon habitat use. Final Report. Texas Parks and Wildlife Department, Fisheries and Wildlife Division.

Nicholls, J. L., and G. A. Baldassarre. 1990a. Habitat associations of Piping Plovers wintering in the United States. Wilson Bull. 102: 581-590.

Nicholls, J. L., and G. A. Baldassarre. 1990b. Winter distribution of Piping Plovers along the Atlantic and Gulf Coast of the U.S. Wilson Bull. 102: 400-412.

Palmer, R.S. 1967. "Piping Plover," in G.D. Stout Ed., The Shorebirds of North America. Viking Press. New York.

Staine, K. J., and J. Burger. 1994. Nocturnal foraging behavior of breeding Piping Plovers (*Charadrius melodus*) in New Jersey. Auk 111: 579-587.

Wilcox, L. 1959. A twenty year banding study of the Piping Plover. Auk 76: 129-152.

VITA

Humberto Garza, Jr., son of Mr. and Mrs. Humberto Garza, was born on September 18, 1970, in McAllen, Texas. He attended the San Isidro Independent School District and graduated from San Isidro High School, San Isidro, Texas in 1989. In May 1989, he entered The University of Texas-Pan American, Edinburg, Texas, and received a Bachelor of Science Degree (Biology) in December 1993. Humberto completed two 900 hour terms in National Service (Americorps), assisting wildlife biologists in conducting Section 7 Consultations for compliance to Endangered Species Act. He entered Graduate School, The University of Texas-Pan American, in September 1994, in pursuit of a Master's Degree in Biology. Currently, he is a Forestry Technician with the U.S. Fish and Wildlife Service.

Permanent Address: 87 Ranch, Santa Elena, Texas. 78591