18047

Northern Debris

Three (3) pieces of debris that are located in the refuge North of Hwy 4, are indicated in the map below. These pieces all remain as found and have not been moved.

The red line from the Forward Dome indicates 407' from the edge of the highway.

The blue line from the North Sheet 1 indicates 137' from the edge of the highway.

Detail Pictures

North Sheet 1

North Sheet 2

Forward Dome

Thank You,

Randy Rees
Environmental Health and Safety Manager
Chief of Emergency Operations
Space Exploration Technologies (SpaceX)

South Texas
Launch Operations

South Texas Physical
[redacted]

W: (956) | M: (515) [redacted]
: [redacted] : www.spacex.com

MEMBER
INTERNATIONAL ASSOCIATION OF FIRE CHIEFS
www.iafc.org

From:	Winton, Bryan
To:	Edler, Scot; Orms, Mary; Gardiner, Dawn; Reyes, Ernesto; delaGarza, Laura; Kendal Keyes
Subject:	Fw: SpaceX Debris Locations / Details
Date:	Monday, March 2, 2020 7:22:30 AM
Attachments:	image003.png image004.png image005.png image007.png

Scot and I will be meeting with CBBEP (Stephanie Bilodeaux) at 10am this morning to see where if any birds are nesting in proximity to the debris that needs removed.
bryan

From: Randy Rees <[redacted]
Sent: Saturday, February 29, 2020 10:10 PM
To: Winton, Bryan <[redacted] Extranet Contact - Tom.hushen <[redacted] Extranet Contact - Stacey.Zee <[redacted] Extranet Contact - kendal.keyes <[redacted]
Cc: Matthew Thompson <[redacted] Paul Sutter <[redacted] Kyle Meade <[redacted]
Subject: [EXTERNAL] SpaceX Debris Locations / Details

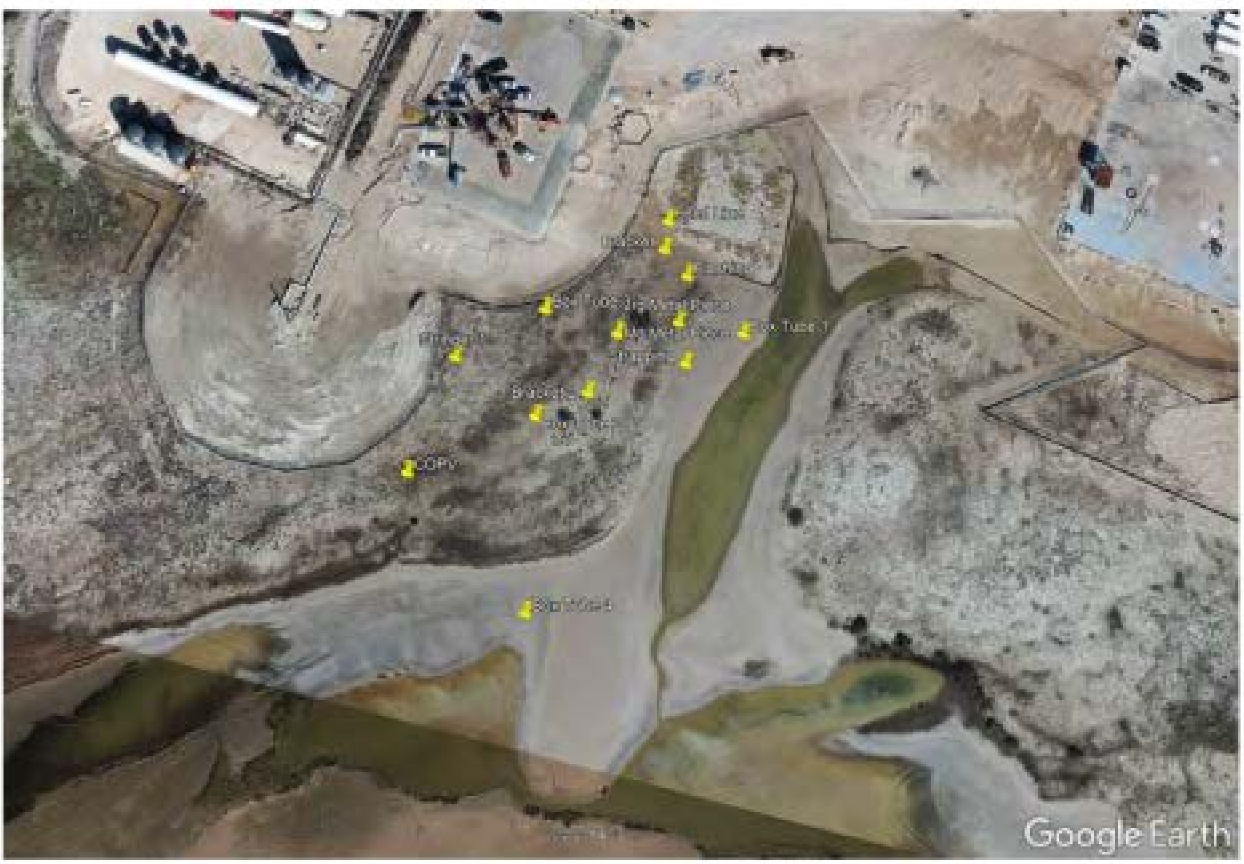
All,

Below is a recap of all the debris from our SN1 test anomaly, that we located outside of the SpaceX physical fence-line.
Notes are included with each of the maps. Debris surveys were performed with the permission of USFW, in both the Northern and Southern Debris areas, utilizing 4-wheel ATVs where appropriate and personnel on foot.
The individual pieces were each photographed and geo-tagged prior to being recovered (if recovery was possible by hand and on foot). No recovery by any mechanical means was authorized or executed.

Today, while performing evaluations, we did not come across any birds nests within the Northern or Southern Debris areas. In general the water covered areas of both South Bay and the Rio Grande tidal flats were about 6"-8" deep.

Southern Debris

Each of the pins on the image below indicates a small hand carried piece of debris that was logged and recovered.
There were no pieces of debris to the South of the Launch Pad, that we were unable to recover back to our debris processing area, on foot. SpaceX personnel took the opportunity, while out in this area, to also collect general litter that was found during the search for SpaceX debris.



Northern Debris

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The blue line from the North Sheet 1 indicates 137' from the edge of the highway.

Detail Pictures

North Sheet 1

North Sheet 2

Forward Dome

Thank You,

Randy Rees

Environmental Health and Safety Manager
Chief of Emergency Operations
Space Exploration Technologies (SpaceX)

South Texas
Launch Operations

South Texas Physical
[redacted]

[redacted] M: (515) [redacted]
: [redacted] : www.spacex.com

MEMBER
INTERNATIONAL ASSOCIATION OF FIRE CHIEFS
www.iafc.org

From: [redacted]
To: [redacted] Orms, Mary; [redacted]
Cc: Reyes, Ernesto; Spier, Mark E; Winton, Bryan; Clements, Pat; Ardizzone, Chuck CA; Gardiner, Dawn; Jess, Robert RJ; [redacted]
Subject: [EXTERNAL] RE: SpaceX
Date: Friday, April 26, 2019 10:31:40 AM
Importance: High

Hi Kendel – We are putting together a summary of the plans we have sent you in the past and will get you files. My goal is to get a response by COB today – or Monday at the very latest.
Thanks.

From: Kendal Keyes <[redacted]
Sent: Friday, April 26, 2019 10:41 AM
To: Zee, Stacey (FAA) <[redacted] Reagan Faught <[redacted] Michael Strutt <[redacted] Greg Creacy <[redacted]
Cc: [redacted]
Murray, Daniel (FAA) <[redacted] Searight, Howard (FAA) <[redacted] Thomas, Lemuel (FAA) <[redacted] Reagan Faught <[redacted] Greg Creacy <[redacted] David Kroskie <[redacted] Michael Strutt <[redacted]
Jackie Robinson <[redacted]
Subject: RE: SpaceX

Hi Stacey:

I order to prepare for the May 8th meeting, we really need to have this information today or Monday at the latest. As I said below, we do not have the final version of various plans, permits, and agreements that have been developed, or even a comprehensive list. A summary of these materials, with current status, and the final or most recent version of each would be really useful.

We would especially like to have a copy of the final version of the Security Plan.

Please let me know if there is anything we can do to help.

Thank you,

Kendal

Kendal Keyes, Regional Natural Resources Coordinator
Texas Parks & Wildlife Department - State Parks Division
715 S. Hwy. 35, Rockport, TX 78382
office [redacted]
mobile [redacted]

From: [redacted] [mailto:[redacted]
Sent: Friday, April 12, 2019 7:51 AM
To: Kendal Keyes <[redacted]
Cc: [redacted] Reagan Faught <[redacted] Greg Creacy <[redacted]
David Kroskie <[redacted] Michael Strutt <[redacted] Jackie Robinson <[redacted]
Subject: RE: SpaceX

We will send out an update with the latest files within the next week

Thanks!

From: Kendal Keyes <[redacted]
Sent: Thursday, April 11, 2019 2:13 PM
To: Zee, Stacey (FAA) <[redacted]
Cc: [redacted]
Murray, Daniel (FAA) <[redacted] Searight, Howard (FAA) <[redacted] Thomas, Lemuel (FAA) <[redacted] Reagan Faught <[redacted] Greg Creacy <[redacted] David Kroskie <[redacted] Michael Strutt <[redacted]
Jackie Robinson <[redacted]
Subject: RE: SpaceX

Stacey:

In trying to brief new staff I have discovered that I do not have the final version of various plans, permits, and agreements that have been developed, or even a comprehensive list. A summary of these materials, with current status, and the final or most recent version of each would be really useful.

The Environmental Impact Statement, Biological and Conference Opinion, Record of Decision, Programmatic Agreement, and Memorandum of Agreement are posted at
https://www.faa.gov/about/office_org/headquarters_offices/ast/environmental/nepa_docs/review/launch/spacex_texas_launch_site_environmental_impact_statement/

This is very helpful. Are the other plans, permits, and agreements which are included within the various documents, like fixing the historical marker, developing the interpretive signage and website, posted anywhere? If not, can we arrange for all of this information to be listed, the status summarized, and the latest versions distributed to us all or posted somewhere?

Thank you,

Kendal

Below is a partial list of plans, permits, and agreements that have been developed:

Environmental Impact Statement
Biological and Conference Opinion
Record of Decision
Programmatic Agreement
Memorandum of Agreement
Unanticipated Discoveries Plan
Final Archaeological Resources Investigation
Final Architectural Survey
FAA-Launch-Specific License
FAA-Launch Operator License
FAA-Experimental Permit
USACE-Section 404 Permit
PA Appendix D Required Plans:

a. Lighting Management Plan
b. Facility Design Plan

c. Vibration Monitoring Plan
d. Unanticipated Discoveries Plan
e. Hurricane Plan
f. Construction Stormwater Pollution Prevention Plan
g. Operation Stormwater Pollution Prevention Plan
h. Spill Pollution and Prevention Plan
i. Hazardous Materials Emergency Response Plan
j. Emergency Action Plan
k. Security Plan

Kendal Keyes, Regional Natural Resources Coordinator
Texas Parks & Wildlife Department - State Parks Division
715 S. Hwy. 35, Rockport, TX 78382
office [redacted]
mobile [redacted]

From: [redacted] [mailto:[redacted]]
Sent: Wednesday, April 10, 2019 3:17 PM
To: [redacted]
Cc: Kendal Keyes <[redacted]
Subject: RE: SpaceX

Mary –

Thank you for this information and thank you for your comments on the WR. Much of this was covered in our discussion from last fall and a letter we sent you earlier.

We are pulling your WR comments and various emails into a table and will provide comment responses and previous documents and letters to help the understanding. We are working to get something to you early next week.

-Stacey

From: Orms, Mary <[redacted]
Sent: Friday, April 05, 2019 2:54 PM
To: Zee, Stacey (FAA) <[redacted] Matthew Thompson <[redacted]
Cc: Kendal Keyes <[redacted] Ernesto Reyes <[redacted] Mark Spier <[redacted] Bryan Winton <[redacted] Pat Clements <[redacted] Chuck Ardizzone <[redacted] Dawn Gardiner <[redacted] Robert Jess <[redacted]
Subject: SpaceX

Stacey,

As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

I received a drone video of the current site. I compared its location and size to the original project site we analyzed under the BO. What I noticed was that the location of the piping plover habitat impacts we assessed is not the same. It has moved further west into another area that was not presumed to have the same impacts because of the site configuration. Therefore, "take" of that habitat has not been assessed and the one we did is not longer valid. Therefore, the current vegetation monitoring plan that is being implemented is no longer valid because the area is not being impacted. The "take" issued will have to be reanalyzed and the vegetation monitoring plan revised. I have attached pictures that show the old and new location of the site and the areas analyzed and Figure 15 and 16 of the BO for you to compare.

The closures are another issue. We understand there is an agreement between The Texas General Land Office and Cameron County. It includes holidays that SpaceX cannot have activities and authorizes Cameron County to issue the notices of closure. However, our consultation is with FAA. FAA authorized the activities under the waiver, and the BO is the agreement we have with FAA, therefore, measures as to how to conduct those closures should be undertaken as the FAA has agreed to under the BO. The Service has informed FAA several times that it is not in compliance, yet the closures continue in a manner unacceptable under the BO.

As added information sea turtles have started nesting south of the border, therefore we expect sea turtles to start nesting any day along our beaches, in particular Boca Chica. We know Sea Turtle Inc. and SpaceX have had discussions and hopefully if all goes well Sea Turtle Inc. will be able to arrive at the SpaceX station on Monday and begin their patrols on Tuesday.

We recommend a meeting or call to discuss the 1) piping plover issue, because, at this time FAA is not covered for impacts to the plover; 2) closures as FAA is out of compliance; 3) Reinitiation of the BO and/or how to handle all the changes in project purpose, location, design, operation and monitoring.

--

Mary Orms
U.S. Fish and Wildlife Service
Ecological Services Field Office
[redacted]

Orms, Mary <[redacted]

SpaceX

14 messages

Orms, Mary <[redacted] Fri, Apr 5, 2019 at 1:54 PM
To: [redacted] Matthew Thompson <[redacted]
Cc: Kendal Keyes <[redacted] Ernesto Reyes <[redacted] Mark Spier <[redacted] Bryan Winton <[redacted] Pat Clements <[redacted] Chuck Ardizzone <[redacted] Dawn Gardiner <[redacted] Robert Jess <[redacted]

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--
Mary Orms
U.S. Fish and Wildlife Service
Ecological Services Field Office
P.O. Box 81468
Corpus Christi, TX 78468-1468
[redacted]

2 attachments

pictures of new impact for take analyzes.pdf
507K

Figure 15 and 16.pdf
243K

Pat Clements <[redacted] Fri, Apr 5, 2019 at 2:00 PM
To: [redacted]

Gardiner, Dawn <[redacted] Fri, Apr 5, 2019 at 2:03 PM
To: [redacted]

Your message

To: Gardiner, Dawn
Subject: SpaceX
Sent: 4/5/19, 1:54:02 PM CDT

was read on 4/5/19, 2:03:08 PM CDT

Gardiner, Dawn <[redacted] Fri, Apr 5, 2019 at 2:03 PM
To: Alejandro Rodriguez <[redacted]
Cc: Mary Orms <[redacted] Chuck Ardizzone <[redacted]

[Quoted text hidden]
--

--

Dawn Gardiner

Assistant Field Supervisor

Texas Coastal Ecological Services Field Office

U.S. Fish and Wildlife Service

4444 Corona Drive, Suite 215

Corpus Christi, TX

[redacted] **x26310**

[redacted] **direct line**

[redacted]

Working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats in South Texas for the continuing benefit of the American people.

---

3 attachments

image003.jpg
3K

pictures of new impact for take analyzes.pdf

507K

Figure 15 and 16.pdf
243K

Reyes, Ernesto <[redacted] Fri, Apr 5, 2019 at 2:15 PM
To: [redacted]

Your message

To: Reyes, Ernesto
Subject: SpaceX
Sent: 4/5/19, 1:54:02 PM CDT

was read on 4/5/19, 2:15:46 PM CDT

Winton, Bryan <[redacted] Mon, Apr 8, 2019 at 9:10 AM
To: [redacted]

Your message

To: Winton, Bryan
Subject: SpaceX
Sent: 4/5/19, 1:54:02 PM CDT

was read on 4/8/19, 9:10:20 AM CDT

Orms, Mary <[redacted] Wed, Apr 10, 2019 at 1:53 PM
To: [redacted]

---------- Forwarded message ---------
From: **Orms, Mary** <[redacted]
Date: Fri, Apr 5, 2019 at 1:54 PM
Subject: SpaceX
To: <[redacted] Matthew Thompson <[redacted]
Cc: Kendal Keyes <[redacted] Ernesto Reyes <[redacted] Mark Spier <[redacted] Bryan Winton <[redacted] Pat Clements <[redacted] Chuck Ardizzone <[redacted] Dawn Gardiner <[redacted] Robert Jess <[redacted]

[Quoted text hidden]
[Quoted text hidden]

---

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507K

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243K

[redacted] <[redacted] Wed, Apr 10, 2019 at 3:17 PM
To: [redacted]

Cc: [redacted]

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-Stacey

[Quoted text hidden]

Orms, Mary <[redacted] Wed, Apr 10, 2019 at 7:10 PM
To: [redacted]
Cc: Matthew Thompson <[redacted] Kendal Keyes <[redacted] Ernesto Reyes <[redacted] Mark Spier <[redacted] Bryan Winton <[redacted] Pat Clements <[redacted] Chuck Ardizzone <[redacted] Dawn Whitehead <[redacted] Robert Jess <[redacted]

Sounds good. Thanks for the update.
[Quoted text hidden]

Kendal Keyes <[redacted] Thu, Apr 11, 2019 at 1:12 PM
To: "[redacted]
Cc: "[redacted] Reagan Faught <[redacted] Greg Creacy <[redacted] David Kroskie <[redacted] Michael Strutt <[redacted] Jackie Robinson <[redacted]

Stacey:

In trying to brief new staff I have discovered that I do not have the final version of various plans, permits, and agreements that have been developed, or even a comprehensive list. A summary of these materials, with current status, and the final or most recent version of each would be really useful.

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This is very helpful. Are the other plans, permits, and agreements which are included within the various documents, like fixing the historical marker, developing the interprev e signage and website, posted anywhere? If not, can we arrange for all of this informaon t o be listed, the status summarized, and the latest versions distributed to us all or posted somewhere?

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Final Architectural Survey

FAA-Launch-Specific License

FAA-Launch Operator License

FAA-Experimental Permit

USACE-Secon 404 P ermit

<u>PA Appendix D Required Plans:</u>

a. Lighng Manag ement Plan

b. Facility Design Plan

c. Vibraon Monit oring Plan

d. Unancipa ted Discoveries Plan

e. Hurricane Plan

f. Construcon St ormwater Polluon Pr evenon Plan

g. Operaon St ormwater Polluon Pr evenon Plan

h. Spill Polluon and Pr evenon Plan

i. Hazardous Materials Emergency Response Plan

j. Emergency Acon Plan

k. Security Plan

Kendal Keyes, Regional Natural Resources Coordinator

Texas Parks & Wildlife Department - State Parks Division

715 S. Hwy. 35, Rockport, TX 78382

office [redacted]

mobile [redacted]

[redacted]

[Quoted text hidden]

[redacted] < [redacted] Fri, Apr 12, 2019 at 7:50 AM
To: [redacted]
Cc: [redacted]

We will send out an update with the latest files within the next week

Thanks!

[Quoted text hidden]

Kendal Keyes < [redacted] Fri, Apr 26, 2019 at 9:41 AM
To: ' [redacted] < [redacted] ' [redacted] < [redacted]
' [redacted] < [redacted] Reagan Faught
< [redacted] Michael Strutt < [redacted] Greg Creacy
< [redacted]
Cc: ' [redacted] < [redacted] ' [redacted] < [redacted]
' [redacted] < [redacted] ' [redacted] < [redacted]
' [redacted] < [redacted] ' [redacted] < [redacted]
' [redacted] < [redacted] ' [redacted] < [redacted]
' [redacted] < [redacted] ' [redacted] < [redacted] Reagan
Faught < [redacted] Greg Creacy < [redacted] David Kroskie
< [redacted] Michael Strutt < [redacted] Jackie Robinson
< [redacted]

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Thank you,

Kendal

[Quoted text hidden]

[redacted] < [redacted] Fri, Apr 26, 2019 at 11:31 AM
To: [redacted]
Cc: [redacted]

Hi Kendel – We are putting together a summary of the plans we have sent you in the past and will get you files. My goal is to get a response by COB today – or Monday at the very latest.

Thanks.

[Quoted text hidden]

Kendal Keyes < [redacted] Fri, Apr 26, 2019 at 11:34 AM
To: " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] Reagan Faught < [redacted] Michael Strutt < [redacted] Greg Creacy < [redacted]
Cc: " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] " [redacted] < [redacted] Reagan Faught < [redacted] Greg Creacy < [redacted] David Kroskie < [redacted] Michael Strutt < [redacted] Jackie Robinson < [redacted] " [redacted] < [redacted]

That's terrific. It will help a lot.

Thank you

[Quoted text hidden]

Figure 15. Potential piping plover critical habitat vegetation conversion.

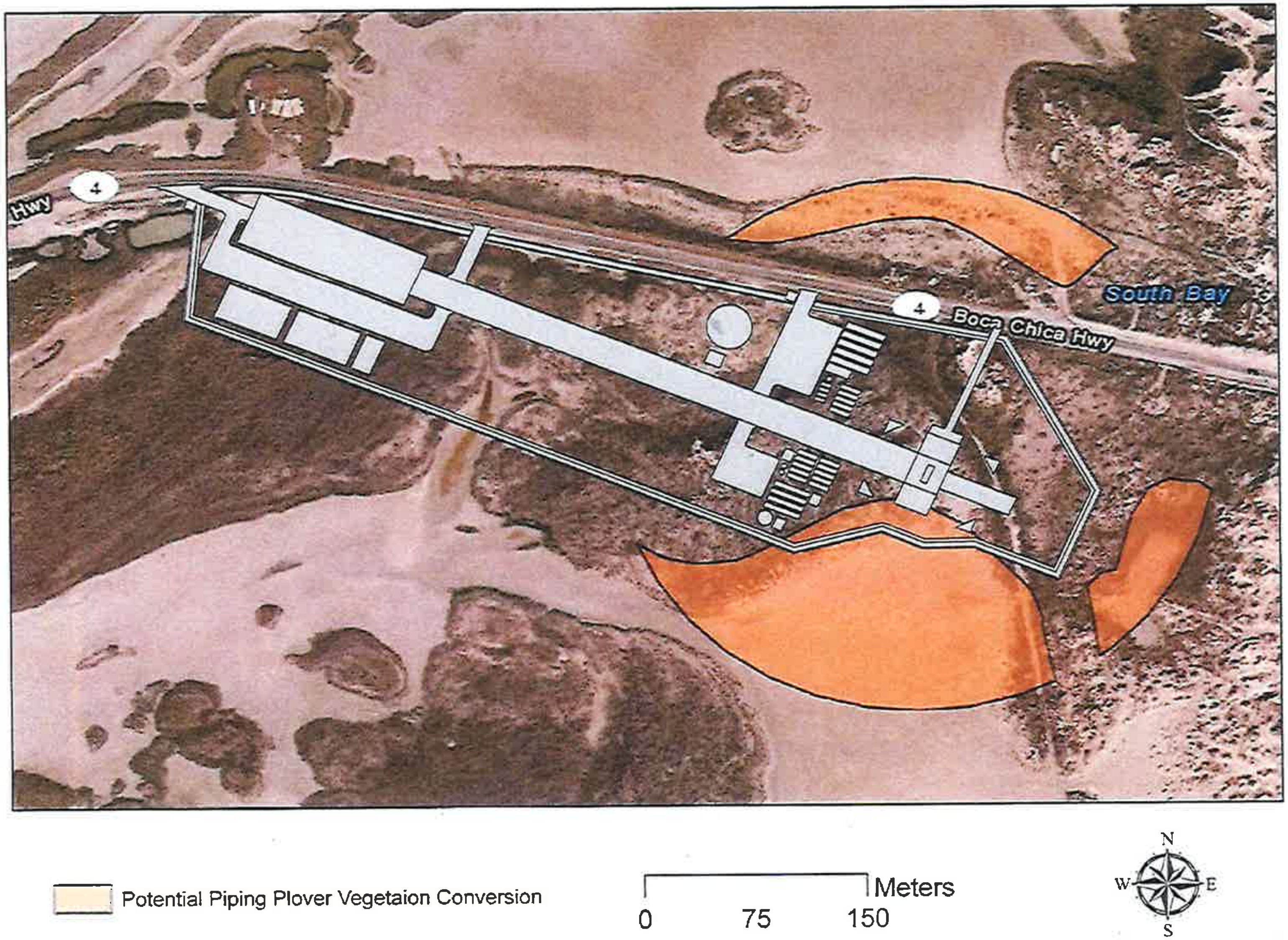
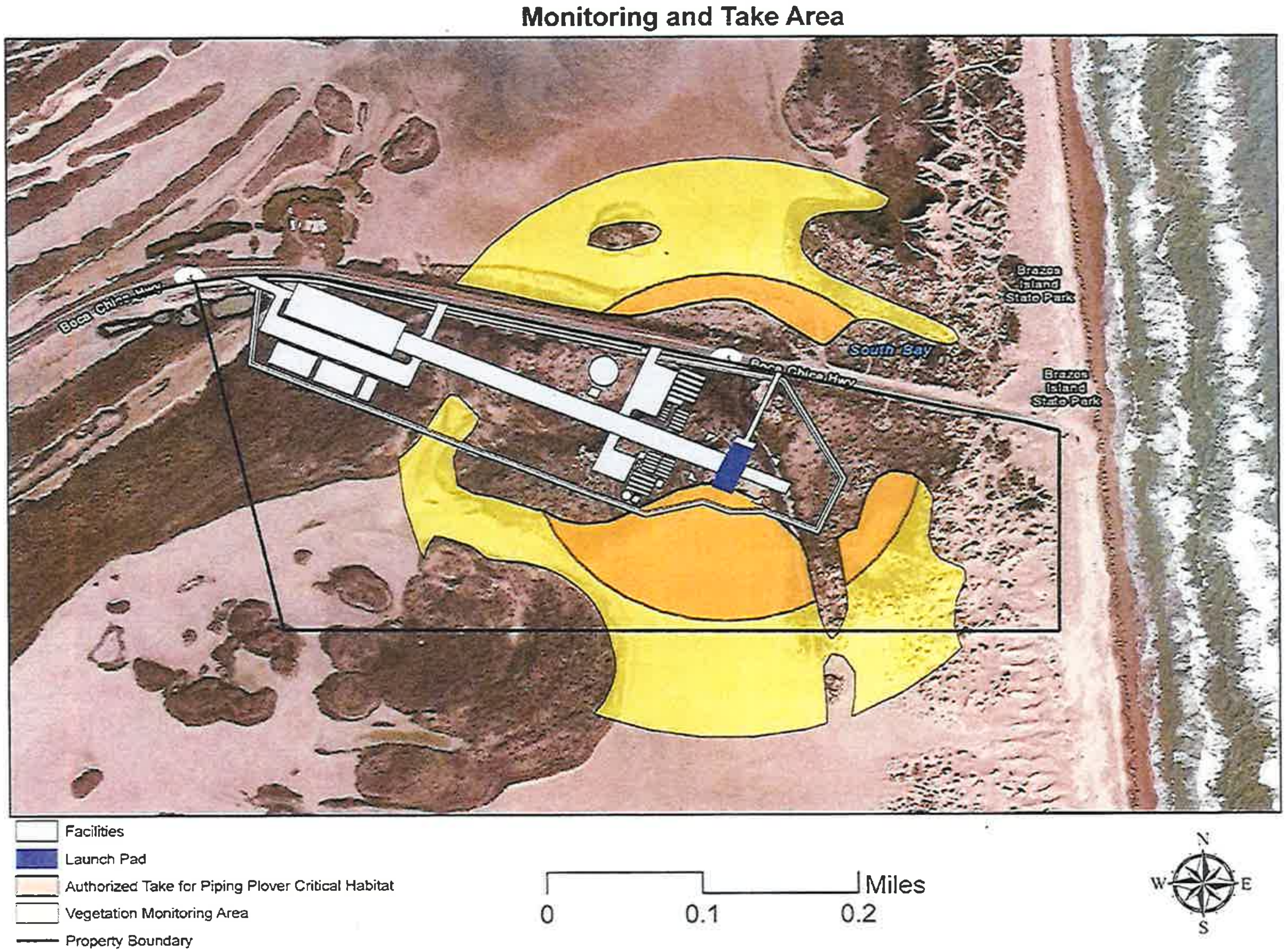


Figure 16. Authorized take for piping plover critical habitat, and 1,000 foot vegetation monitoring area.



This is the area that was analyzed for impacts to piping plover habitat in the BO. As you can see the area of impact has changed and needs to be analyzed and vegetation monitoring plan must be re-evaluated to address the new area of impact.

New piping plover habitat that needs to be assessed for take.

Runoff from construction getting into new area that needs to be analyzed for take

New area of impact where piping plover habitat may potentially be converted as construction runoff and/or stormwater comes off the site and into the tidal flats.

Red circle is where take and monitoring was analyzed as shown in figure 15 and 16 of the BO


4-21-2091 SpaceX Stuck Vehicles
Write a description for your map.
Legend
26.003382, -97.158092 SpaceX stuck vehicles
26.002242, -97.158854 Snowy plovers
4
SpaceX Launch site
SpaceX launch Pad
Boca Chica Bl
Google Earth
© 2018 Google
© 2018 INEGI
1000 ft
N

From:	Zee, Stacey (FAA)
To:	Orms, Mary
Cc:	Gardiner, Dawn; Reyes, Ernesto; Clements, Pat; Winton, Bryan; delaGarza, Laura; Grey, Leslie (FAA)
Subject:	[EXTERNAL] RE: Space X - Refuge fire
Date:	Sunday, July 28, 2019 11:01:42 PM
Importance:	High

Hi Mary – Thank you for reaching out. Matt Thompson called out about this on Friday. I asked him to coordinate with Bryan on a way forward. I'll be out of town this week – but let's plan on touching base the week of Aug 5th.

Could you all propose a few times for a call next week. Leslie Grey, from my office, is copied on the email and can set up a meeting time with a conference call number for whatever time works for you all.

Also – I will pass the reporters contact info onto our external affairs contact.

Thank you

-Stacey

From: Orms, Mary <[redacted]
Sent: Friday, July 26, 2019 4:44 PM
To: Zee, Stacey (FAA) <[redacted]
Cc: Dawn Gardiner <[redacted] Ernesto Reyes <[redacted] Pat Clements <[redacted] Bryan Winton <[redacted] delaGarza, Laura <[redacted]
Subject: Space X - Refuge fire

Stacey,

I sending this email to inform you that last night at 11 pm Space-X was testing their Hopper and it started a fire on the refuge. Brownsville Fire Dept. showed up but did not pursue putting out the fire due to its location and lack of access. Today, the fire has kicked up again, and about 15-20 acres of refuge land burned, still with no vehicle access available. If access was available the refuge would have also been concerned with the damage it may have caused because of the risk of getting stuck. In the original BO, fire was not really assessed because at that time, the project included deluge water poured on the rocket, thus the evaporation cloud. Bryan Winton of the refuge will be putting together a report to document when, where and how the fire started. I think we need to discuss measures to avoid such fires again if possible. Maybe, restricting testing during certain conditions, having fire trucks on hand to put it out on the pad, I am not sure, but we can brainstorm it.

Also, a reporter contacted the refuge. He requested a copy of the FAA's written reevaluation. The Service considers that to be a FAA document and not for us to release. Therefore, I have provided his name and contact information below in the event that you would like to respond.

Dave Mosher
Senior Correspondent - Space, Science & Technology

Insider

Publications of Insider Inc.

Office & Mobile: +[redacted] / **Mailing address**: Dave Mosher, Insider Inc., One Liberty Plaza, 8th FL, New York, NY 10006, USA / **Stories & Confidential Messages**: bit.ly/InsiderDave
--
Mary Orms
U.S. Fish and Wildlife Service
Ecological Services Field Office
P.O. Box 81468
Corpus Christi, TX 78468-1468
[redacted]

From:	David Newstead
To:	Winton, Bryan; Kendal Keyes; Perez, Sonny; Perez, Chris; Russell Hooten; Jackie Robinson; Natalie Bell; Stone, Kelli L; Carter Smith; McDowell, Kelly; Gardiner, Dawn; Orms, Mary
Cc:	Kacy Ray; Hardegree, Beau; Moczygemba, Jonathan; Woodrow, Woody
Subject:	[EXTERNAL] Memo re: inability to continue research/monitoring in the Boca Chica/South Bay area
Date:	Wednesday, January 20, 2021 11:00:08 AM
Attachments:	Nest locations of Snowy Plovers in vicinity of SpaceX launch site 2017-2020.pdf BocaChica_Roadkill_2020.xlsx Boca Chica closures Jan_04 thru Jan_19_2021.xlsx

MEMO to: US Fish & Wildlife Service, Texas Parks & Wildlife Department, Texas General Land Office (selected employees)
RE: Continuation of shorebird research and monitoring in the Boca Chica/South Bay area

As many of you are aware, CBBEP and partners have conducted several monitoring and research projects in the Boca Chica/South Bay areas over the past five years. It has been a pleasure to do so, and we appreciate the support of your agencies in permitting us to do this work. We had intended to continue with the Beach Nesting Bird Monitoring project in 2021, which would typically begin in mid-February. Due to the near-constant closure notifications from SpaceX, there does not seem to be a way to continue the work going forward under anything resembling the current situation.
Based on emails from SpaceX and Cameron County closure notices, I assembled a chronology of closure announcements from December 30, 2020 through January 19, 2021 (spanning closure dates of Jan 4-20). A total of 32 announcements were made, coming from three different SpaceX employees. Three were corrections of errors in previous emails. Of the seventeen-day (408 hour) span, a full-day closure was announced for eleven of those days (all weekdays, totalling 117 hours). Basing the estimated closure time from the time when the closure was to go into effect up to the notice that the area was now open, the total closure time was 80 hours and 45 minutes. On several occasions a notice of the area reopening came well after the end of the announced closure window. Only six of the eleven announced closure days appear to have been approved by Cameron County based on notices available on the website, totaling 51 hours. Seven additional days totaling 63 hours were also approved as alternate dates. Revocation of closure announcements mostly came either late in the evening prior to the announced closure (after 6:00 pm), or *on the day of* the closure announcement after the announced closure period had begun (in one case, over 6 hours AFTER). For planning purposes, an announced closure (whether revoked or not) on the next day is effectively a day that a biologist cannot plan to access the site. This makes planning work that requires 4-5 visits/week impossible, even if one were to have complete flexibility to be at the whim of the SpaceX closure schedule. During the 2020 nesting season, our biologist had to watch the announcements very carefully to determine when he could access the area, usually going very early in order to work for a few hours before a closure began, or working on weekends. Based on our efforts to track the

closure announcements in 2020, the closures accounted for nearly 1,200 hours, with 173 days announced as either primary or backup closure dates. On 104 of those days, there either was a closure, or an announced backup date closure was never revoked.

The projects we conduct on the State Park and National Wildlife Refuge area, and the Gulf beach since 2017 require that visits be made no more than two days apart over the course of several months. It is clear that this type of project will no longer be even remotely possible given the magnitude and frequency of the closures, and the last-minute (and after-the-fact) notices. Since primary closure days are sometimes not revoked until the day of the closure, at which point back-up closure days are invoked, strings of days are effectively inaccessible. At this point, most of January 2021 has been inaccessible, as was much of December 2020.

As unworkable as the situation is at present, it seems likely to only get worse with the ongoing increase in activities and the major industrial expansion that SpaceX seeks to implement in a revised permit from FAA.

We currently have funding to continue our projects but will have to notify our partners and funding entities that the projects cannot be conducted, and alternate staffing decisions will need to be made.

For those that have not seen them, I have attached a few items that may be of interest which are based on some of the monitoring we've done there over the past years:

A series of images showing the nest locations of Snowy Plovers in the near vicinity of the SpaceX launchsite (we have been monitoring the whole Boca Chica area – this is just a snapshot of that vicinity).

A spreadsheet showing roadkill mortalities that were documented by one of our biologists while transiting to and from the site, starting in mid-February and continuing through mid-July 2020. Subsequent visits were less frequent due to restricted access and no ongoing regularly-scheduled project following the breeding season. These were opportunistic – just stopping to document when something was noticed – not part of a systematic roadside survey.

A spreadsheet detailing, to the best of my ability, the series of closure-related announcements affecting dates in January 2021 up to this morning.

I am not aware how the official closure days and hours (relative to the 12 days/total 180 hours per year in the permit) are being measured, but as an entity trying to accomplish our work out there, it is essentially all but shut down for us. Closures also appear to be occurring outside of those approved by the Cameron County Judge/Commissioners Court, which is the only way I'm aware of for the public to go to seek out closure information. Basically, a private company appears to have been given, or is taking, nearly unilateral authority to close down a public highway and access to public lands including the Gulf beach. Never thought I'd see that in Texas.

Please let me know if you have any questions. We really appreciate your support and interest in our work, and we do plan to continue and expand conservation work where we can elsewhere in the Laguna Madre/Rio Grande Valley area.

Thanks

David Newstead
Director, Coastal Bird Program
Coastal Bend Bays & Estuaries Program
[redacted]

[redacted]

[redacted]

From:	Kendal Keyes
To:	Gardiner, Dawn; Perez, Chris; Winton, Bryan
Cc:	Orms, Mary; Reyes, Ernesto; delaGarza, Laura; Perez, Sonny; Ardizzone, Chuck CA
Subject:	[EXTERNAL] RE: Boca Chica monitoring
Date:	Wednesday, September 16, 2020 12:01:01 PM

I am wondering at what point a law suit is filed to force compliance, and who does that? Some of you may have been on the call several months ago when we were talking about Sec 4(f) and I asked Stacy what our recourse was when agency personnel disagree with determinations made by the FAA and she very matter-of-factly said that filing a suit was the usual course of action.
I have no idea and have never been involved in anything like this, but maybe filing a suit sooner than later would result in the actions necessary to manage this better?

Kendal Keyes, Regional Natural Resources Coordinator
Texas Parks & Wildlife Department - State Parks Division
[redacted]
office [redacted]
mobile [redacted]
[redacted]

From: Gardiner, Dawn <[redacted]
Sent: Wednesday, September 16, 2020 11:31 AM
To: Perez, Chris <[redacted] Winton, Bryan <[redacted]
Cc: Orms, Mary <[redacted] Kendal Keyes <[redacted] Reyes, Ernesto <[redacted] delaGarza, Laura <[redacted] Perez, Sonny <[redacted] Ardizzone, Chuck CA <[redacted]
Subject: Re: Boca Chica monitoring

I think we are the experts for our own property. I would see if I&M can give approved methodology for monitoring and assessment. In the meantime, take plenty of pictures and document what you saw and that you took the pictures and when and where. Mary and I would defer to your expertise as we work through amending or redoing the biological opinion with FAA or if SpaceX starts an HCP.

From: Perez, Chris <[redacted]
Sent: Wednesday, September 16, 2020 10:13 AM
To: Winton, Bryan <[redacted]
Cc: Gardiner, Dawn <[redacted] Orms, Mary <[redacted] Kendal Keyes <[redacted] Reyes, Ernesto <[redacted] delaGarza, Laura <[redacted] Perez, Sonny <[redacted]

Subject: Re: Boca Chica monitoring

Yes. However, I could see that SpaceX may have a credibility issue with us doing the work considering the circumstances?...Probably something a neutral third party should undertake for all involved if we decided it was something worth pursuing...?

From: Winton, Bryan <[redacted]
Sent: Wednesday, September 16, 2020 9:54 AM
To: Perez, Chris <[redacted]
Cc: Gardiner, Dawn <[redacted] Orms, Mary <[redacted] Kendal Keyes <[redacted] Reyes, Ernesto <[redacted] delaGarza, Laura <[redacted] Perez, Sonny <[redacted]
Subject: Re: Boca Chica monitoring

I want to take the lead in documenting the effects of their activity. I agree Space X should pay for this but I have no confidence or expectation that they will. Time is on their side not ours. We can't go anywhere near our 22K acres of refuge at the whim of Space X now which is supported by the county with no regard for us, the wildlife or the public. We need a 3rd party to enact the research design and monitoring we develop to insure the findings are credible... although the impacts are intuitively obvious with respect to noise, vibration, lighting, traffic, and air quality deterioration. We should ask for the moon (or Mars) in the BO but expect they will do nothing toward that end as they have demonstrated since 2013, except continue to do whatever they want with no concern for the impacts to the natural world their activity causes.

Bryan

Get Outlook for iOS

From: Perez, Chris <[redacted]
Sent: Wednesday, September 16, 2020 8:58:26 AM
To: Winton, Bryan <[redacted]
Cc: Gardiner, Dawn <[redacted] Orms, Mary <[redacted] Kendal Keyes <[redacted] Reyes, Ernesto <[redacted] delaGarza, Laura <[redacted] Perez, Sonny <[redacted]
Subject: Fw: Boca Chica monitoring

Good morning Bryan:

Ok. I'm thinking we'll have to do some research on this to see if and what type of equipment has been used to monitor vibration and noise impacts to (I'm assuming nesting birds, wintering birds, and sea turtles). I think that's something we could probably ask for in the BO from SpaceX but could be something we or academia could implement? For sure I don't see why we should have to fund it as this is something SpaceX should fund?! We should bring this up at our next meeting if we agree that's something worth pursuing and expected product outcomes. Also, would this need to be added to our recently approved 15-year IMP plan for LRGV? Let me know.

Thanks.

From: Winton, Bryan <[redacted]
Sent: Tuesday, September 15, 2020 11:34 PM
To: Perez, Chris <[redacted]
Subject: Boca Chica monitoring
When you get settled in from your move and are able to get back in the groove, can you search the web for vibration and noise monitoring equipment we can buy, deploy and monitor at set distances surrounding Space X launch site. I smell another publication or 2 for you. Bryan
Get [Outlook for iOS]()

From:	Eric Schroeder
To:	Zee, Stacey (FAA); [redacted] Cushman, Anna (FAA); Cantin, Jacob (FAA); Murray, Daniel (FAA); Searight, Howard (FAA); Shabanowitz, Jamison L (FAA); Andrus, Katherine (FAA); Thomas, Lemuel (FAA); [redacted] Pallante, Amy J; Liverman, Astrid B; Brunnemann, Eric J; Rice, Heather E; Henderson, Justin K; Meyer, Mark E; Fernandez, Oralia Z; Stanley, Randy GRS; Garza, Rolando L; Todd, Shelley A; [redacted] Emily Dylla, PhD; [redacted] Hansel Hernandez; [redacted] David Kroskie; Jackie Robinson; Kendal Keyes; Laura Zebehazy; Leslie Koza; Melissa Jones (WBC); Michael Strutt; Reagan Faught; Russell Hooten; Ted Hollingsworth; Winton, Bryan; Perez, Chris; Ardizzone, Chuck CA; Gardiner, Dawn; Wasmund, Dayma L; Orms, Mary; Perez, Sonny; [redacted] Skaar, Karen S; Clarkson, Chelsea (FAA); Hanson, Amy (FAA)
Cc:	Katy Groom; Justin Kockritz; Bill Irwin; Sarah Banco
Subject:	[EXTERNAL] RE: SpaceX Boca Chica site - noon - eastern
Date:	Friday, March 12, 2021 11:38:18 AM

Hi Stacy: Thank you for putting this PA meeting together. I would like to echo Sara's concerns regarding the need to update the PA to include the mitigation of impacts due to the operation of the SpaceX facility at Boca Chica. In terms of impacts due to operations of the facility, there have been several anomalies that have had failures that resulted in a debris field that scatters onto the neighboring properties. One of these properties is a wildlife management area owned by Texas Parks and Wildlife Department that has archeological sites recorded on it. I'm concerned with not only the damage caused by the initial impact of the debris in an area having potentially significant archeological sites, but also the potential damage that might occur due to the removal of the debris by SpaceX. The other issue is that only a small portion of the Boca Chica Wildlife Management area has been surveyed for cultural resources and we are unsure that all historic properties have been discovered or adequately delineated that would provide the fidelity of information TPWD would need to fully evaluate such impacts as they occur.

Looking forward to further discussion on how we might structure an operational PA that all parties can live with.

Respectfully,

Eric

Eric Schroeder, **Ph.D.**
Registered Professional Archaeologist #10197
Cultural Resources Coordinator – Wildlife Division
Private Lands and Public Hunting Program
Office: (512) [redacted] Cell: (512) [redacted]

-----Original Appointment-----
From: Zee, Stacey (FAA) <[redacted]
Sent: Friday, March 12, 2021 10:57 AM
To: [redacted] Cushman, Anna (FAA); Cantin, Jacob (FAA); Murray, Daniel (FAA); Searight, Howard (FAA); Shabanowitz, Jamison L (FAA); Andrus, Katherine (FAA); Thomas, Lemuel (FAA); [redacted] David Kroskie; Jackie Robinson; Kendal Keyes; Laura Zebehazy; Leslie Koza; Melissa Jones (WBC); Michael Strutt; Reagan Faught; Russell Hooten; Ted Hollingsworth; [redacted] Skaar, Karen S; Eric Schroeder; Clarkson, Chelsea (FAA); Hanson, Amy (FAA)
Cc: Katy Groom; Justin Kockritz; Bill Irwin; Sarah Banco
Subject: SpaceX Boca Chica site - noon - eastern
When: Friday, March 12, 2021 12:00 PM-1:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: UPDATE - using SpaceX TEAMS info to facilitate SpaceX presentaiton and screensharing

ALERT: This email came from an external source. Do not open attachments or click on links in unknown or unexpected emails.

SpaceX Teams teams info:

Meeting Info:

Join Microsoft Teams Meeting
[redacted] United States, Hawthorne (Toll)
Conference ID: 472 836 65#
Local numbers | Reset PIN | Learn more about Teams

Dear Consulting Parties:

The FAA has scheduled the SpaceX Boca Chica Launch Site Section 106 Annual Meeting (Stipulation IX of the Programmatic Agreement (PA)). We will host a virtual meeting on **Friday, March 12th from noon to 1pm, eastern.** I will follow this email with an Outlook meeting invitation.

The purpose of the meeting is to discuss 2020 activities and activities scheduled for 2021. I will provide an agenda prior to the meeting. One of the discussion items will be amending the PA to account for the change to the undertaking (i.e., from Falcon launch vehicles to Starship/Super Heavy launch vehicles).

Space-X

Winton, Bryan <[redacted]

Mon 3/25/2019 12:17 PM

To: Orms, Mary <[redacted]

Randy Rees left me a message a 09:54am stating the road would be closed today from 10-4, and again Tomorrow and Wednesday. This will be 6 consecutive days of closure not counting the weekend. Can you contact Cameron County and inform them there road closure is violating the terms of agreement between all the agencies and Space-X which agreed to 14-day notice in advance BEFORE road closures so the public could be advised. This is totally unacceptable. If we don't stop this now, we'll never be able to reel it back in. The damage will be done. The public trust will be lost and nobody will go out to Boca Chica again for fear the road will be closed with no notice. What about the Spring Breakers? Sea Turtle Inc? The Refuge. We need to be collecting milkweed and yucca seed right now for our native habitat program, plants are in bloom now, birds are nesting now. Advance notice would give us time to evaluate what all entities and species will be impacted. We had the first snowy plover chicks hatch today. We have other shorebirds nesting in the vicinity of the Space-X site. Cameron County and TxDOT obviously didn't read the EIS for Space-X project. How do we stop this thing in its tracks and start over?

bryan

--

Bryan R. Winton, Wildlife Refuge Manager
Lower Rio Grande Valley National Wildlife Refuge
[redacted]
[redacted] office; (956) [redacted] cell
[redacted]

BISON CONNECT

Orms, Mary <[redacted]

Fwd: [EXTERNAL] SpaceX removal of debris North of Hwy 4

1 message

Winton, Bryan <[redacted] Fri, Nov 29, 2019 at 9:32 AM
To: Sonny Perez <[redacted] Scot Edler <[redacted] Imer Dela Garza <[redacted] Chris Perez <[redacted] Ernesto Reyes <[redacted] Laura <[redacted] Iriz Elizondo Navarro <[redacted] Romeo Garcia <[redacted] Gerardo Longoria <[redacted] Ellissa Martinez <[redacted] "Whitehead, Dawn" <[redacted] "Orms, Mary" <[redacted]

For your records. FAA has called for a Dec 5, 2019 meeting to revisit the EA and Biological Opinion that we worked on since April 2011, which did not turn out to accurately reflect what they (Space-X) have been doing. Their action differs significantly from what they proposed. The road closures and interruptions to the refuge/public beach is considerably more than was anticipated, and the action is now testing, rather than launches, which is inherently more inclined to result in a failure and thus damage to the refuge.

Hopefully their explosions will deter the LNG's from developing our area though. The air quality, viewshed impacts, and degradation of the Boca Chica area would be accelerated if one or more of these industrial energy projects ultimately proceeds.

bryan

---------- Forwarded message ---------
From: **Randy Rees** <[redacted]
Date: Sat, Nov 23, 2019 at 5:09 PM
Subject: [EXTERNAL] SpaceX removal of debris North of Hwy 4
To: Extranet Contact - bryan_winton <[redacted] <[redacted]
Cc: Extranet Contact - Stacey.Zee <[redacted] Matthew Thompson <[redacted] Katy Groom <[redacted] Paul Sutter <[redacted]

Hello Bryan,

For Official Use Only

Per my discussion with Scot, I wanted to send some pictures from the removal operation. The team was able to pull the debris with 2 high capacity tow trucks, over to the ATV Barrier. There the debris was rigged and flown with a crane onto our Construction Dump truck for transport to our build area for inspections.

The ATV Barrier is all there, but one bollard needs to be reset/replaced, and then the cable re-tensioned. I can work with you next week on a plan to accomplish the necessary repair.

We have had crews on foot out yesterday and today using metal detectors to ensure any small pieces aren't missed.

No vehicles or ATVs of any type crossed the ATV barrier location during the operation.

PICTURES

Initial location of debris with arrows showing direction of removal.

After the drag began.

Largest piece almost pulled in.

Final location of the drag removal operation.

Due to the weight of the debris and load bearing limitations of the sand for the crane, they had to drag into the ATV barrier several feet. This is the unset bollard. The cable tension was released at a nearby cable clamp.

If you have any questions or concerns, please call anytime.

Thank You,

Randy Rees

Environmental Health and Safety Manager

Chief of Emergency Operations

Space Exploration Technologies (SpaceX)

South Texas Launch Operations

[South Texas Physical]

[redacted]

☎ W: (956)[redacted] | ☎ M: (515)[redacted]

: [redacted] : www.spacex.com

MEMBER
INTERNATIONAL ASSOCIATION OF FIRE CHIEFS
www.iafc.org

--

Bryan R. Winton, Wildlife Refuge Manager
Lower Rio Grande Valley National Wildlife Refuge
[redacted] office; (956) [redacted] cell
[redacted]

18059

From: Josette Cruz ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 10:33 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

There has been no consent or acknowledgement of the original people of the land, the Carrizo Comecrudo Tribe of Texas. There needs to be a consultation with the tribe as well as a comprehensive environmental impact study.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

An accident on the scale of a Starship/SuperHeavy launch vehicle would be a devastating catastrophe for the Laguna Atascosa Wildlife refuge, the Lower Rio Grande Valley Wildlife refuge as well as for nearby communities of color and endangered species like the ocelot and aplomado falcon.

At the very least, the FAA should conduct a comprehensive Environmental Impact Statement because of the size and scale of SpaceX?s new launching operations. This Environmental Assessment is extremely inadequate, because it only evaluates an ?initial mission profile,? and does not address:

1. The FAA's claims that SpaceX?s mission is to launch larger rockets in pursuit of National Space Policy goals, which were updated by Trump in 2020. These policy goals should be evaluated by the new Biden Administration, and actually reflect whether space exploration is in the interest of the public rather than private corporations seeking to profit.
2. The already damaged land and wildlife that SpaceX has already caused, in addition to the new plans that will permanently destroy acres wetlands and floodplains, 3. SpaceX?s rocket launching schedule results in beach closures that would further strip away people of color?s rights to fish and recreate at Boca Chica Beach by up to 800 hours per year, about an entire month.
4. Elon Musk, using his social media platforms to attract outsiders to displace a historically marginalized community. Already, longtime residents are being forced away from their beach and homes, and it doesn?t help when outsiders, attracted by Elon Musk and his social media presence, displace residents by moving here or soliciting comments and opinions from people who've never even been to the region.
5. SpaceX has never consulted with the Carrizo/Comecrudo Tribe of Texas, who have ancestral ties to the region, about operations. Under the United Nation?s Free, Prior, and Informed Consent, SpaceX should not be authorized without consultation and consent of the Tribe.

Additionally, the FAA should have to redo its regulatory process to accommodate the Spanish-speaking population because the public hearings and materials are not translated.

About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Josette Cruz
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18060

From: Delia Ybarra ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 11:37 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

We need human infrastructure!

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Delia Ybarra
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

From: Yvonne Reyes Rocha ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 11:39 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I see my grandchildren living in a cleaner, better word. That?s the reason behind me signing this today.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Yvonne Reyes Rocha
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18062

From: Kimberly Rendon [redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 11:40 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

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Additionally, the FAA should have to redo its regulatory process to accommodate the Spanish-speaking population because the public hearings and materials are not translated.

About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach

because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Kimberly Rendon
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18063

From: Amanda Ybarra ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 11:41 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Quit your stupid [redacted]

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

An accident on the scale of a Starship/SuperHeavy launch vehicle would be a devastating catastrophe for the Laguna Atascosa Wildlife refuge, the Lower Rio Grande Valley Wildlife refuge as well as for nearby communities of color and endangered species like the ocelot and aplomado falcon.

At the very least, the FAA should conduct a comprehensive Environmental Impact Statement because of the size and scale of SpaceX?s new launching operations. This Environmental Assessment is extremely inadequate, because it only evaluates an ?initial mission profile,? and does not address:

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Sincerely,

Amanda Ybarra
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18064

From: Susan Lippman [redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 11:54 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Boca Chica Beach was a place that was special to me when I was a child living with my family in Brownsville. I still come to visit the area, and as such I'm part of the tourist and nature-tourism economy of this still-beautiful and biologically significant area. Please don't think there is still plenty of unspoiled Texas coastline elsewhere; there is not, and the heavily industrialized areas have a harsh impact on the health of the communities that live there and on the environment. This expansion should not be allowed.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

An accident on the scale of a Starship/SuperHeavy launch vehicle would be a devastating catastrophe for the Laguna Atascosa Wildlife refuge, the Lower Rio Grande Valley Wildlife refuge as well as for nearby communities of color and endangered species like the ocelot and aplomado falcon.

At the very least, the FAA should conduct a comprehensive Environmental Impact Statement because of the size and scale of SpaceX?s new launching operations. This Environmental Assessment is extremely inadequate, because it only evaluates an ?initial mission profile,? and does not address:

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Additionally, the FAA should have to redo its regulatory process to accommodate the Spanish-speaking population because the public hearings and materials are not translated.

About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Susan Lippman
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18065

From: Brian Gordon ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 12:02 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Brian Gordon
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18066

From: Linda Black Elk ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 12:07 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Linda Black Elk
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

From: Gab Guti?rrez ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 12:22 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

SpaceX has no business in this region. The impacts of this project on local human and wildlife are entirely overlooked. Leave us alone and stop trying to profit off of our communities!

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Gab Guti?rrez
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18068

From: Moore Delysia ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 12:43 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

The Boca Chica region is a Texas and national treasure that should belong to all of us to enjoy. We should not be giving it away to a billionaire for exploitation.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Moore Delysia
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18069

From: Raeann Rojas ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 9:31 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

This area is my home, and to see it overtaken by SpaceX is heartbreaking. Not only is there a significant environmental impact, but also this expansion will lend to gentrification of the area and will negatively affect people in all of Brownsville. My family has always been in Brownsville, and I worry that the expansion of SpaceX will make it difficult to stay.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Raeann Rojas
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

From: Valerie Morales ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 1:11 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Please make sure that proper measures are taken to protect our wildlife and fragile eco systems.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Valerie Morales
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18071

From: Patricia S Castillo ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 2:05 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Protect Texas from this totally unnecessary encroachment by billionaires who could care less about the beautiful, unique Texas environment.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Patricia S Castillo
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18072

From: Prisilla Cope ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 2:22 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Nature must rule for our survival!!!

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

An accident on the scale of a Starship/SuperHeavy launch vehicle would be a devastating catastrophe for the Laguna Atascosa Wildlife refuge, the Lower Rio Grande Valley Wildlife refuge as well as for nearby communities of color and endangered species like the ocelot and aplomado falcon.

At the very least, the FAA should conduct a comprehensive Environmental Impact Statement because of the size and scale of SpaceX?s new launching operations. This Environmental Assessment is extremely inadequate, because it only evaluates an ?initial mission profile,? and does not address:

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Sincerely,

Prisilla Cope
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18073

From: Jim Summers [redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 2:36 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

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Sincerely,

Jim Summers
[redacted]

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18074

From: Eddie Tizon ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 9:49 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

It?s time to care about people over profits.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Eddie Tizon
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

From: Madison Harris [redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 3:20 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

SpaceX's proposed expansion can be devastating to the environment and ecosystem in South Texas. Please reconsider allowing someone with no environmental concern to continue to harm our home. There are many endangered species that reside in South Texas and SpaceX and Elon Musk do not care about them. They would rather go to another planet than fix the one we are on.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Madison Harris
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18076

From: Maya De Castro ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 3:26 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

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Sincerely,

Maya De Castro
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

From: Megan Soetaert ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 3:39 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

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Sincerely,

Megan Soetaert
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18078

From: Christopher Basald? ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 4:01 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I live in Brownsville, TX, and I grew up in Brownsville and Corpus Christi, Texas. I am indigenous to this area, and I am a descendent of the original Native people of the Rio Grande Valley and the Coast.

The original EIS for the SpaceX project at Boca Chica Beach, within the National Wildlife Refuge was incomplete and inadequate and reflects a failure of the company to do its due diligence.

One key issue overlooked in both the original EIS and in the current process to expand the project is the lack of consultation with the original indigenous people of the land upon which the SpaceX project occupies. The Carrizo Comecrudo Tribe of Texas represents the original and ancestral indigenous people of the land in question. SpaceX has neglected to speak with and to consult with the Indigenous people of the land. The Carrizo Comecrudo Tribe of Texas are Esto?k Gna, the Human Beings original to the land. Their ancestors are buried in this land. Sacred sites exist in this land. There are multiple ancestral village sites throughout the region and area and are connected to one another through these ancestral ties. The SpaceX project and its proposed expansion will threaten to further damage these sites as well as restrict indigenous access to these sites and sacred lands. For these reasons, I ask the FAA to reject the permits for the SpaceX project expansion.

SpaceX has also ignored the city of Matamoros, Tamaulipas, Mexico. Even though there is an international boundary placed in the center of the Rio Grande, environmental impacts and pollution do not ?stop at the border?. It is extremely shortsighted of SpaceX to not communicate nor consult on this project with our sister city across the river. The SpaceX project can impact people and communities and environment on the south side of the river also. This permit for expansion should be denied.

SpaceX has not provided language in Spanish nor in American Sign Language (ASL) in order to properly communicate its projects and intentions to this area and our diverse communities. Many people who live in Brownsville and the surrounding communities speak Spanish. SpaceX did not provide adequate materials in Spanish, nor did they provide adequate nor fully adequate translation services throughout their public hearings and processes. This is both unfair and offensive. Please deny the permit for expansion of the SpaceX project.

SpaceX proposes to drill for gas in order to fuel its experimental rocket ships. They propose to use hydraulic fracturing, ?fracking? in order to access these gasses from underground underneath the launch site and the surrounding area. Fracking is an extremely environmentally damaging practice that has been linked to non-natural earthquakes, and to contaminating water. Fracking also destroys natural rock formations that are vital to protecting both soil integrity and fresh water quality. We do not want, nor do we consent to the poisoning of our water and wetlands. Please deny any and all permits to the SpaceX project. The SpaceX company has not thoroughly conducted both environmental and community impact studies in good faith. Again, SpaceX has not consulted with the Indigenous people and community of the land which is further evidence of their disregard of their responsibility to conduct their due diligence.

There are many plant and animal species that are and will continue to be negatively impacted by the SpaceX project. Especially noteworthy animal species are the ocelot, the jaguarundi, the piping plover, the aplomado falcon, and several species of sea turtle, such as the Kemps Ridley Sea Turtle. The original EIS did not do a thorough enough job in studying then potential and now real impacts. The several rockets that have exploded at the launch site have scattered pollution and dangerous debris across the delicate coastal wet land environment. If SpaceX is pretending that this impact is harmless, then they are delusional. Moreover, SpaceX is required to mitigate land loss of wet lands if they destroy delicate wet lands. They must replace and mitigate the same amount of wet lands. They cannot be permitted if they have not provided a mitigation plan, such a plan is missing or inadequate in their current statements.

SpaceX wishes to expand by also making a desalination plant. Such a plant would create hyper saline waste that would negatively impact the delicate ecosystems of these coastal wetlands. Excess salt/salinity can poison the land and endanger any and all plant and animal and marine life. This permit must be denied.

SpaceX is a private company. It is trying to colonize space and make money. This venture is not about providing for the common good nor to better society. SpaceX is a colonizing project that is damaging our community and environment and sacred lands here.

At the very least, the FAA must demand a new and more robust Environmental Impact Statement from SpaceX. It is in SpaceX?s interest to make an incomplete and misleading EIS at the lowest bid possible. FAA must demand a full EIS before moving forward with any new permitting. SpaceX brags about launching the largest rocket in human history. How could such a project have minimal to no impact on the area? The carbon emissions alone from one attempted launch would continue to add to atmospheric greenhouse gasses and pollution thus perpetuating climate change and climate catastrophe. I encourage the FAA to simply deny the permit for expansion.

It bears repeating that SpaceX has not yet done their due diligence and has obscured the truth about its environmental and community impacts, or SpaceX simply ignores their negative impacts. Also, SpaceX has grossly exceeded the number of hours it was allowed to close Highway 4 and deny residence access to Boca Chica Beach. SpaceX has proven that it will chose to be dishonest about its functions, and that it will not hold itself accountable to the agreements that it has made. The FAA much therefore hold SpaceX accountable. Again this is yet another reason to deny the permit for the proposed expansion of the SpaceX project.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

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Sincerely,

Christopher Basald?
[redacted]

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18079

From: Maya Rasmussen ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 4:03 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

We have so much at stake. Cameron County economy is funded by our eco tourism. By ruining our public lands, not only we lose the wonders of our ecosystem but we can loose the tourist that visit us. We also know that Space X does not properly mediate its waste as seen by the numerous crashes. The waste left by these rockets can/will hurt our ecosystem and community for decades.

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5. SpaceX has never consulted with the Carrizo/Comecrudo Tribe of Texas, who have ancestral ties to the region, about operations. Under the United Nation?s Free, Prior, and Informed Consent, SpaceX should not be authorized without consultation and consent of the Tribe.

Additionally, the FAA should have to redo its regulatory process to accommodate the Spanish-speaking population because the public hearings and materials are not translated.

About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Maya Rasmussen
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18080

From: Christopher Basald? ([redacted] Sent You a Personal Message <[redacted]
Sent: Monday, November 1, 2021 4:08 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

Please deny the permit for SpaceX expansion. SpaceX has never consulted with the Carrizo Comecrudo Tribe of Texas, nor have they obtained free prior and informed consent. SpaceX expansion will destroy sacred land and sacred sites of the original indigenous people of this land. SpaceX projects are therefore racist and genocidal by erasing indigenous histories and ignoring Native people?s requests to preserve sacred land, delicate habitats of coastal wet lands, and keeping endangered plant and animal species safe from destruction. SpaceX will creat environmental damage through air, water, noise, and light pollution. They will foul fresh water. They will put the area at risk for constant pollution and destruction. Please deny the expansion permit. I live and grew up in Brownsviile, TX. I want SpaceX to go away and never return

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

An accident on the scale of a Starship/SuperHeavy launch vehicle would be a devastating catastrophe for the Laguna Atascosa Wildlife refuge, the Lower Rio Grande Valley Wildlife refuge as well as for nearby communities of color and endangered species like the ocelot and aplomado falcon.

At the very least, the FAA should conduct a comprehensive Environmental Impact Statement because of the size and scale of SpaceX?s new launching operations. This Environmental Assessment is extremely inadequate, because it only evaluates an ?initial mission profile,? and does not address:

1. The FAA's claims that SpaceX?s mission is to launch larger rockets in pursuit of National Space Policy goals, which were updated by Trump in 2020. These policy goals should be evaluated by the new Biden Administration, and actually reflect whether space exploration is in the interest of the public rather than private corporations seeking to profit.
2. The already damaged land and wildlife that SpaceX has already caused, in addition to the new plans that will permanently destroy acres wetlands and floodplains, 3. SpaceX?s rocket launching schedule results in beach closures that would further strip away people of color?s rights to fish and recreate at Boca Chica Beach by up to 800 hours per year, about an entire month.
4. Elon Musk, using his social media platforms to attract outsiders to displace a historically marginalized community. Already, longtime residents are being forced away from their beach and homes, and it doesn?t help when outsiders, attracted by Elon Musk and his social media presence, displace residents by moving here or soliciting comments and opinions from people who've never even been to the region.

5. SpaceX has never consulted with the Carrizo/Comecrudo Tribe of Texas, who have ancestral ties to the region, about operations. Under the United Nation?s Free, Prior, and Informed Consent, SpaceX should not be authorized without consultation and consent of the Tribe.

Additionally, the FAA should have to redo its regulatory process to accommodate the Spanish-speaking population because the public hearings and materials are not translated.

About 80% of the Rio Grande Valley community, which is directly impacted by SpaceX, speaks primarily Spanish at home. The FAA should not allow SpaceX to continue to expand to launch the Starship/Super Heavy project at Boca Chica Beach because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Christopher Basald?
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18081

From: Raphael Schwartz ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 4:50 PM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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because the potential for further wildlife and land damage along with the potential explosions it could cause is just not safe for the residents of the area and is not safe for the environment.

Sincerely,

Raphael Schwartz
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18082

From: Daughenbaugh Laura ([redacted] Sent You a Personal Message
<[redacted]
Sent: Monday, November 1, 2021 8:55 AM
To: SpaceXBocaChica
Subject: Re: Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program

Dear Federal Aviation Administration,

This is the exact opposite of what we do. It is not only about stopping new fossil fuel infrastructure, we also should be stopping all climate killing space flight.

I am writing in opposition to SpaceX?s proposed Starship/Super Heavy Launch Vehicle expansion project on Boca Chica Beach.

The SpaceX expansion project would be incredibly detrimental not only to the wildlife habitat and wetland ecosystems around it, but to the nearby communities of Brownsville, South Padre Island, and Port Isabel as well.

This project will require a massive scale of new industrialization that includes a rocket launch pad, gas power plants, desalination plant, gas drilling, and more near residential communities, between wildlife refuges, and at a public beach. Not to mention, the explosive rocket launch operations are less than six miles away from two highly flammable proposed liquefied natural gas (LNG) and a pre-existing gas pipeline.

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Sincerely,

Daughenbaugh Laura
[redacted]

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at [redacted] or [redacted]

18083

From: Andrea Martinez <[redacted]
Sent: Monday, November 1, 2021 10:13 AM
To: SpaceXBocaChica
Subject: Re: Expansion of SpaceX

Dear FAA Committee,

As someone who was born and raised in Brownsville, I am writing out of the sincere love and care I have for this city's well-being, pleading with you to stop the expansion of SpaceX. I am not an environmental expert, but I am a public health worker who has been keeping up with the developments SpaceX has made since it moved to Boca Chica, and I am deeply concerned about where this is heading for my beloved hometown.

To begin, it is highly inaccessible for citizens of Brownsville who have been here for generations to be fully aware of what SpaceX's presence involves, even when they are able to experience some of the effects. It is highly unjust that many people with no ties to Brownsville were able to voice support for Elon Musk and SpaceX during the public hearings last week; meanwhile, the voices of the majority undereducated, overworked, underpaid populace of Brownsville have no accessible way of being thoroughly informed, let alone heard, on their thoughts regarding SpaceX and its intended expansion, indicating a monumental failing on behalf of city officials to look out for and represent its citizens.

Moreover, SpaceX's presence in Boca Chica beach has already had detrimental effects on Brownsville's environment. Boca Chica beach is home to many wildlife whose patterns have already been affected, like that of snowy plovers, who have had fewer and fewer nests in the last two years; additionally, former rocket explosions have even happened close to the nests of sea turtles. South Texas has long been a haven to many species who are often not found anywhere else, and SpaceX's presence alone has disrupted that in its short time in their home. Already questions about SpaceX's compliance with previous environmental requirements has been questioned, and lack of enforcement by the interests of Brownsville elite is not in the best interest of the city and its human, wildlife, and flora inhabitants. This has been reported on many news outlets within the last year, but I am linking this article from *The Guardian* as a concise, reputable reference.

Please do not turn Brownsville into something it is not - a playground for the tech industry to exploit, a beach to be dumped on, a haven to be disrupted. Please do not let this be another example where the interests of a powerful few outweighs the well-being of the many marginalized. There is a lot of brilliance and potential *within* Brownsville, so many talented and passionate individuals with ties and love to the land, its history, and its culture. We don't need people with more wealth than that of all Brownsvillians combined to come and rob us of opportunities, safety, and the utility we have a history of providing many flora and fauna species with.

Respectfully,
Andrea Martinez

18088

From: David Newstead [redacted]
Sent: Monday, November 1, 2021 3:18 PM
To: SpaceXBocaChica
Subject: re: SpaceX Draft PEA: Additional reports referenced in comment letter just sent
Attachments: Zonick_2000_PhDDissertation.pdf; Maddock PIPL winter gulf coast EC Report 2008-2009 Final.pdf

To whom it concerns,

I transmitted a comment letter on ***SPACEX Draft Programmatic Environmental Assessment for Starship/Super Heavy Program*** at 5:14 pm Central today. The comment letter references two pieces of grey literature that the preparer of the Draft PEA may be unfamiliar with or had difficulty accessing. I am attaching those documents here for reference.

Sincerely,

David Newstead
Director, Coastal Bird Program
Coastal Bend Bays & Estuaries Program
[redacted]

Wintering Piping Plover Surveys 2008-2009

Boca Chica, Texas to Marco Island, Florida

December 2, 2008 – March 13, 2009

Final Report, Contract # K4E21-08-0662

Prepared For:

Dr. C. L. Gratto-Trevor
Research Scientist
Prairie and Northern
Wildlife Research Centre
Science and Technology Branch
Environment Canada
[redacted]

Prepared By:

Sidney B. Maddock
[redacted]

August 22, 2010

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Acknowledgements

This work is part of Dr. Cheri Gratto-Trevor's Environment Canada research project to study Canadian Great Plains Piping Plovers. Environment Canada provided the financial support that allowed the field work to be conducted. In addition, these surveys would not have been possible without the assistance from biologists, land managers, non-profit organizations, and public and private landowners. Many people shared data on Piping Plover survey numbers and information on habitat conditions. This assistance helped direct where survey efforts could be most effectively focused.

Elise Elliot-Smith, United States Geological Survey, shared preliminary wintering data from the 2006 International Piping Plover Census from Florida, Alabama, Mississippi, Louisiana, and Texas.

In Florida, Patty Kelly, U.S. Fish and Wildlife Service, provided information about locations in north Florida and assisted with surveys at Tyndall Air Force Base. Richard Hilsenbeck, The Nature Conservancy, authorized a survey at Phipps Preserve and Dog Island. Joe Mitchell, Specialist, St. Joseph Peninsula State Park, provided information about the park. Daniel Larremore, Biologist, Honeymoon Island State Park, provided information about Honeymoon Island, Anclote Key, and Three Rooker Bar. Casey Lott, North American Bird Conservancy, and Nancy Douglas, Biologist, Florida Fish and Wildlife Conservation Commission, provided information about North Captiva Island.

In Alabama, Roger Clay, biologist, Alabama Department of Conservation and Natural Resources, and Jereme Phillips, Refuge Manager, Bon Secour National Wildlife Refuge, provided information about Piping Plovers.

In Mississippi, Nick Winstead, State Ornithologist with the Mississippi Department of Wildlife, Fisheries, and Parks, provided data from surveys for Piping Plovers and information about where to concentrate survey efforts. Gary Hopkins, Biologist, Gulf Islands National Seashore, provided information about Piping Plover use of the Seashore.

In Louisiana, Michael Seymour, Ornithologist with the Louisiana Department of Wildlife and Fisheries (LDWF) shared data from state surveys that were conducted in 2007-2008 winter and Mike Carloss provided information about coastal habitat conditions. Todd Baker, Biologist, LDWF, provided information about surveys in the Mississippi Delta, arranged for the use of an airboat to access South Pass, and allowed me to stay at the LDWF camp. The Caillouet Land Company and Edward Wisner Donation authorized access to private lands east of Port Fourchon.

In Texas, Robyn Cobb and Bo Hardegree, U.S. Fish and Wildlife Service, provided information about Piping Plover use of the Texas coast, and assisted with surveys in the Redfish Bay area. Chad Stinson, biologist with Aransas/Matagorda Island National Wildlife Refuge Complex, secured an airboat to do the first Shoalwater Bay survey and also allowed me to accompany a refuge volunteer on a survey at Matagorda Island NWR. Wade Stablein, Biologist, Padre Island National Seashore, assisted with several surveys and provided information about Piping Plover use of the Seashore. Leo Gustafson, biologist with Laguna Atascosa NWR, provided information about Piping Plover use of South Padre Island and South Bay and assisted with the research permit. Shane Kasson, Refuge Manager at San Bernard NWR, provided information about Piping Plovers at the west end of the refuge and assisted with the research permit.

Information on banded Piping Plovers was provided by Cheri Gratto-Trevor and Sharilyn Westworth of the Canadian Wildlife Service, Dan Catlin and Maggi Sliwinski of Virginia Tech, Dave Prescott of Alberta Fish and Wildlife Division, Erin Roche of the University of Minnesota, Jennifer Stucker of USGS, and Mary Brown of the University of Nebraska.

I would like to thank my wife, Ann Maddock, for assisting with the surveys in Mississippi and Louisiana, and for supporting this work. Walker Golder, my boss at the National Audubon Society, allowed me to do these surveys for Environment Canada.

These surveys were conducted under National Park Service Permits GUIS-2008-SCI-0026 (Gulf Islands National Seashore) and GUIS-2008-SCI-0026 (Padre Island National Seashore), U.S. Fish and Wildlife Service Permits # 21553-LA-09-003 (Laguna Atascosa and Lower Rio Grande National Wildlife Refuges) and # 21541-09-003 (San Bernard National

Wildlife Refuge), and a permit from the Florida Park Service Permit (St. Joseph Peninsula State Park). A Wild Louisiana Stamp, # [redacted]064, was purchased.

Suggested Citation: Maddock, S.B. 2010. Wintering Piping Plover Surveys 2008-2009, Boca Chica, Texas to Marco Island, Florida, December 2, 2008 – March 13, 2009, Final Report. Unpublished report prepared for Environment Canada, Saskatoon, Saskatchewan. vi +34 pp.

Cover photograph: Lf,OL:X,Y, a Great Plains Canada Piping Plover, photographed by Sidney Maddock on March 8, 2009 at Cat Island, Gulf Island National Seashore, Mississippi.

Summary

Surveys to locate banded Piping Plovers (*Charadrius melodus*) were conducted on the Gulf of Mexico between December 2, 2008, and March 13, 2009. Seventy eight locations were visited from Marco Island in southwest Florida to Boca Chica beach in Texas near the United States border with Mexico. Ninety seven surveys were conducted, and twelve locations in Texas were surveyed two or more times to increase the dectectabity of banded birds.

There were 3,300 observations of Piping Plovers, with 236 observations in Florida, 50 in Alabama, 172 in Mississippi, 214 in Louisiana, and 2,628 in Texas. There were 397 observations of banded Piping Plovers, about 12% of all observations. There were 44 band observations in Florida, 7 in Alabama, 19 in Mississippi, 32 in Louisiana, and 295 in Texas. By population, 170 of the banded Piping Plover observations were from Great Plains Canada, 176 were from Great Plains United States, 29 were unknown, 22 were from the Great Lakes, and 0 were from Atlantic Canada or Atlantic United States.

Introduction

These surveys were conducted to locate the Piping Plover (*Charadrius melodus*), a small shorebird with a short, stout bill, pale upperparts, and orange legs (Haig 1992). The known wintering range of Piping Plovers includes the Atlantic Coast of the United States, the Gulf Coast of the United States and northern Mexico, and the Bahamas, Cuba, and other Caribbean islands (Ferland and Haig 2002, Elise Elliot Smith et al. 2009).

In Canada and the United States, scientists on the breeding grounds of Piping Plovers have conducted studies that include banding adults, chicks, or both, with a series of unique and non-unique color band and flag combinations. These programs have provided extensive data regarding breeding behaviors. However, it has become apparent that these programs also have generated helpful data regarding non-breeding Piping Plovers, such as wintering locations for the populations. In addition, resightings from the wintering grounds may give a more accurate survival estimate as birds that were not seen during the summer may be detected during winter observations.

This survey effort is a continuation of a series of surveys on the wintering grounds that were initiated by the Canadian Wildlife Service (Stucker et. al. 2003, Maddock 2008).

Methods

The goal of this survey effort was to find and accurately identify banded Piping Plovers wintering on the Gulf of Mexico. Between December 2, 2008 and March 13, 2009, surveys were conducted from Marco Island in southwest Florida (25.96653 -81.74993) to Boca Chica beach in Texas near the United States border with Mexico (25.95377 -97.14883). Most of the known sites on the Gulf with relatively large numbers of Piping Plovers were searched. Some high quality sites were not surveyed if Piping Plover surveys already were being conducted by others, and for a few sites, most notably the Chandeleur Islands, if poor weather conditions prevented access to survey the area.

These surveys followed the methods discussed in Maddock (2008), where more detailed information is provided. Surveys were conducted on foot, by all terrain vehicle, and by four-wheel drive vehicle. Vehicle surveys were conducted at low speed (<10 mph) unless suitable Piping Plover habitat was not present. Particular attention was given to locations where Piping Plovers could be easily missed, such as roosting habitats. When a Piping Plover was seen, a spotting scope was used to scan the legs for color bands. If possible, a picture was taken of the band combination using a high quality digital camera (Canon 1Ds MkIII or 40 D) and high power lens (600mm with 2X converter (1200mm)) to confirm the band locations and colors. The band combination was recorded on written data sheets.

The following abbreviation system identifies the band combination:

- Band location on the leg is listed in the following order: left tibia, left tarsus: right tibia, right tarsus.
- If there were two bands on a tibia or tarsus, the band combination is presented as top band first and bottom band second, with no comma between the bands.
- Band or flag color abbreviations are: R = red, P= pink, G = dark green, g = light green, U=purple, B = dark blue, b = light blue, V = violet, W = white, A = gray, S = salmon, P = Pink, O = orange, Y = yellow, and L = black.
- A split band is indicated with a forward slash (L/A) and a triple split band has two forward slashes (g/O/g); the colors of the split are listed from the top to bottom of the band on the leg.

- Band types are: X for metal band, – for no band, N for not able to observe if a band was present; a single letter means a plastic band unless f is added after the letter, which means flag.

Information on the observed band combination was provided to banders on the breeding grounds in the Great Plains and Great Lakes to confirm the observed combination and the population identification.

Results

Ninety seven surveys were conducted over 70 full or partial field days; 78 different locations were visited. There were 3,300 observations of Piping Plovers. Of those observations, 12% (n=397) were banded Piping Plovers.

Not all observations were of different individuals. Some individuals moved between adjoining survey sites. In addition, in Texas, there were repeat visits to twelve sites to increase the detectability of banded birds, and in Alabama, there was overlap on two survey sites. Thus, some banded birds were seen more than once. While it is possible to identify repeat observations of uniquely marked birds, there also were non-unique band combinations that were observed multiple times.

Table 1 provides a breakdown of surveys, locations, total Piping Plover observations, and band observations by state.

Table 1. Piping Plover Survey Days, Survey Numbers, Survey Locations, Total Observations, and Band Observations By State

State	Survey Days	Surveys	Survey Locations	Total PIPL Observations	Band Observations
Florida	9	16	16	236	44
Alabama	3	5	4	50	7
Mississippi	9	11	11	172	19
Louisiana	10	13	13	214	32
Texas	39	52	34	2,628	295
Total	70	97	78	3,300	397

Table 2 provides a breakdown of banded Piping Plovers by state and population.

Table 2. Piping Plover Band Observations By State and Population

State	Great Plains Canada	Great Plains US	Great Lakes	Unknown	Atlantic Canada or US	Total State
Florida	6	22	14	2	0	44
Alabama	2	5	0	0	0	7
Mississippi	8	7	2	2	0	19
Louisiana	6	20	4	2	0	32
Texas	148	122	2	23	0	295
Total Pop.	170	176	22	29	0	397

Florida

In Florida, sixteen surveys were conducted over nine days; 16 locations were visited. There were 236 observations of Piping Plovers and 44 observations of banded Piping Plovers. By population, 6 observations of banded Piping Plovers were birds from the Canadian Great Plains, 22 from the United States Great Plains, 14 from the Great Lakes, 2 were unknown, and 0 from Atlantic Canada or Atlantic United States.

The 44 band observations represent at least 40 individuals: five birds from the Canadian Great Plains, 20 from the United States Great Plains, and 14 from the Great Lakes. One uniquely marked bird from the U.S. Great Plains, -,LW:Gf,GW was seen on both the north end of Honeymoon Island and Three Rooker Bar, two adjoining islands. One uniquely marked bird from the Canadian Great Plains, -,RY:Wf,OX, and one uniquely marked bird from the U.S. Great Plains, -,WW:Gf,LL, were observed on both Phipps Preserve and the mainland beach just to the north, an interesting movement across the bay.

Another combination, -,-:-,BX, also was seen on both Honeymoon Island and Three Rooker Bar. From the first observation, this particular combination was identified as a bird that was banded in the Great Lakes, based on photographs of the metal band numbers. The next observation, the metal band was not photographed closely enough to allow identification of the numbers. However, as the bird with this combination was missing the lower right tarsus with the break in a similar location, had an old style metal band, and the two islands are next to each other separated by only a small inlet, it is likely the observations were of the same bird. While the second observation of this combination is listed as “unknown” in Table 1, the bird likely is from the Great Lakes. Another combination, -,-:X,b, with vertical lettering on the joint, was seen at Charley Pass, is listed as “unknown” but likely was from the Great Lakes. The Great Lakes uses this combination and the same style of metal band, and no other banders claimed this combination. However, possible use by other banders could not be ruled out.

The following habitat changes were noted since the 2005-2006 winter surveys for CWS. Vegetative succession covered previously unvegetated areas of roosting or intertidal habitats at Marco Island, Honeymoon Island, and Phipps Preserve. Increases in the area of upland or intertidal habitats were observed at Three Rooker Bar and Anclote Bar, due to accretion. At the other sites, habitat changes were not significant enough to be remembered or noted, or the sites were not previously visited. On North Captiva Island, “Charley Pass” was created by Hurricane Charley in 2004 (Casey Lott, Pers. Comm. 2009). While this site was not previously visited in the 2005-2006 surveys, it now contains high quality habitat Piping Plover, though vegetative succession appears to be occurring, based on a comparison of the Google Earth satellite imagery and habitat conditions during the time of visit.

Alabama

In Alabama, five surveys were conducted over three days. Four locations were visited; however, one of those locations was covered twice as part of a survey of a larger area of habitat on the west end of Dauphin Island.

There were 50 observations of Piping Plovers including seven observations of banded Piping Plovers: two observations of birds from the Canadian Great Plains and five observations of birds from the U.S. Great Plains. Due to resightings of two individuals at adjoining survey locations, five individuals were observed, representing two birds from the Canadian Great Plains and three birds from the U.S. Great Plains.

A significant habitat change was the creation of a new inlet at Dauphin Island in 2005 from Hurricane Katrina. The west end of Dauphin Island was not visited during the 2005-2006 surveys for Canadian Wildlife Service. During this trip, the area was visited and high quality

Piping Plover habitat was seen at either side of the newly created inlet. Another change is that the west end of Pelican Island is no longer separated from Dauphin Island.

One interesting observation was Piping Plovers and large numbers of other shorebirds were using an overwash fan area just east of the west end of the developed area of Dauphin Island; this area was surrounded by buildings to the east and west and a road and buildings to the south. It is possible that the moderately high winds on this day may have caused birds to congregate in this area as an alternative roost during bad weather. When the area was viewed a few days later as part of a larger survey that covered areas of the west end of Dauphin Island, only one Piping Plover was seen in the area, with the others at the inlet spit and scattered along the bay shoreline.

Mississippi

In Mississippi, 11 locations were surveyed over 9 days. There were 172 observations of Piping Plovers, including 19 observations of banded Piping Plovers. Eight observations were of birds from the Canadian Great Plains, seven observations were of birds from the U.S. Great Plains, two observations were from the Great Lakes, and two were unknown. At least 18 of the banded Piping Plovers were different individuals. One non-unique band combination from Great Plains Canada, Lf,-:X,-, was seen on the east end of Petit Bois Island on December 12, 2008, and on the southwest end of Cat Island on March 8, 2009.

High quality Piping Plover habitat was observed in Gulf Islands National Seashore on East Ship Island, Horn Island, Cat Island, and Ship Island. All these islands had areas of overwash, though it was not possible to tell which were from Hurricane Katrina and which were from more recent hurricanes.

Moderate numbers of Piping Plovers were counted on the mainland beaches. These beaches originally were not scheduled for surveys, as the Mississippi Department of Wildlife, Fisheries, and Parks conducts Piping Plover surveys there. However, due to poor weather conditions precluding boat access to the offshore barrier islands in December, mainland beach locations were walked instead, albeit in dense fog that may have influenced the results. Between Waveland and Long Beach, there were 31 observations of Piping Plovers. After Hurricane

Katrina, there was a beach replenishment project for these areas (Nick Winstead, Pers. Comm. 2009). The profile of these replenished beaches in the intertidal area is relatively flat, with moderate areas of intertidal habitat available for feeding at mid and low tides at certain areas. There were activities that could adversely affect Piping Plover use of these beaches, such as the human disturbance as well as the observed practice of raking of the beach to remove wrack. However, the moderately high number of Piping Plovers raises an interesting question whether replenished beaches on the Gulf of Mexico can have design standards that mimic natural beaches and allow regular wintering use by Piping Plovers and other shorebird species.

Louisiana

In Louisiana, 13 locations were surveyed in 10 days. There were 214 observations of Piping Plovers, including 32 banded Piping Plovers. There were six birds from the Canadian Great Plains, 20 birds from the U.S. Great Plains, four from the Great Lakes, and two that were unknown. The 32 banded Piping Plovers that were observed were different individuals.

As in the 2006-2007 surveys, areas of high quality Piping Plover habitat were observed. One area of improvement was the east end of Elmers Island, where the old inlet had closed, providing extensive high quality, low energy feeding habitat on bay-side flood bar and overwash fans. Large numbers of Piping Plovers were present at certain locations, including 30 at West Bell Pass and 53 at the west end of Raccoon Island.

Extensive habitat changes were observed at all of the locations that were previously visited in the 2006-2007 surveys. On September 1, 2008, Hurricane Gustave made landfall near Cocodrie, Louisiana as a Category 2 hurricane with maximum winds near 90 knots (Beven and Kimberlain 2009). In addition, Hurricane Ike, which made landfall at Galveston Island on September 13, 2008 as a Category 2 storm, caused a storm surge of 3-6 feet along Louisiana with 5 – 10 feet along the coast of south-central Louisiana and 10-13 feet in southwestern Louisiana (Berg 2009). These hurricanes caused varying levels of habitat impacts. On East Grand Terre, Grand Terre, Fourchon Beach, and West Belle Pass, moderate to extensive erosion of the Gulf beach backshore occurred. In certain areas, the area between the vegetation and the water was very narrow, with the loss of much of the backshore beach, so higher elevation roosting habitats were reduced. These islands also had new low overwash fans, new intertidal feeding habitats on the backside of the overwash fans in some areas, and new small inlets on East Grand Terre and West Belle Pass. The high levels of erosion that have been experienced at some locations along the Louisiana coast (Sallenger 2009) raise concerns about loss of piping plover habitat in Louisiana.

Texas

In Texas, 52 surveys were conducted over 39 field days; 34 locations were visited. Twelve locations were surveyed more than once to increase the detectability of banded Piping Plovers that may not have been observed in the first survey. There were 2,628 observations of Piping Plovers, including 295 observations of banded Piping Plovers. There were 148 observations of banded Piping Plovers from the Canadian Great Plains, 122 from the U.S. Great Plains, two from the Great Lakes, and 23 that were unknown.

Of the 75 uniquely marked Great Plains Piping Plovers banded by Dr. Cheri Gratto-Trevor that were observed in Texas, 21 were observed twice. Of those repeat observations, 15 were resightings on a subsequent survey at the same location, one was a movement across an inlet, four were movements along the bayside shoreline across adjoining survey boundaries, and one was a movement from a bayside shoreline at Mollie Beattie Coastal Habitat Community to a shoal in the bay off Mustang Island State Park.

In South and Central Texas, no significant changes to habitat conditions were observed since the prior CWS surveys, other than habitat availability changes due to varying water levels in the Laguna Madre. There was a large flats area exposed west of Mustang Island State Park during the first part of the visit that was flooded during the return visit to Mustang Island. At Boca Chica beach, the water level in interior lagoon area south of the road and west of the beach was very low, with much of the area being exposed, dry flats; when the area was visited one winter ago, that interior lagoon area was almost fully flooded.

In North Texas, there were extensive habitat changes since the 2006-2007 CWS surveys. On September 13, 2008, Hurricane Ike made landfall on Galveston Island as a strong Category 2 storm with winds of 110 mph; on the Bolivar Peninsula, the storm surge was estimated to be between 15 and 20 feet by ground assessment teams (NHC 2009).

On Bolivar Peninsula, Galveston Island, and between San Louis Pass and Surfside, there was extensive erosion of the Gulf backshore roosting habitat; in many locations, areas that previously would have been backshore or vegetated uplands were at or near the elevation of the intertidal beach with scattered new ephemeral ponds. Gulf beach intertidal feeding habitats remained, though their location may have moved landward.

There were several locations where feeding habitats were adversely impacted. At Bolivar Flats, there was extensive erosion of the intertidal feeding habitats. The preferred feeding substrate of sand with a thin top layer of mud or algal growth was missing in large areas and in its place was either a sand substrate in certain areas of the flats or in other areas, the intertidal area was no longer exposed, even at low tide. East of the Town of Gilchrist, the beach was much narrower than in the 2006-2007 survey, with a very limited intertidal area; as a result, a survey was not done at this beach due to limited habitat.

Not all habitat changes from the Hurricane Ike were adverse. Near the western boundary of San Bernard National Wildlife Refuge at Cedar Creek Cut, there were extensive new overwash fans, with large areas of high quality intertidal feeding habitat as well as new areas of roosting habitat. At Rollover Pass, the intertidal feeding habitat appeared larger than when a visit was made to this site in 2006-2007; the area now has large overwash fans on the bayside.

There were several interesting results from the Texas surveys. First, over 100 Piping Plovers were seen on both surveys at Cedar Creek Cut near the western boundary of San Bernard NWR. In contrast, in the 2006-2007 season CWS survey, 24 were seen in the same area (Maddock 2006). The sharp increase may be due to the extensive new flats that were observed.

Second, 239 Piping Plovers were seen during a survey of the west and south sides of South Bay. This area has high quality habitat. However, it may be difficult to locate the Piping Plovers due to how remote and expansive the habitat is in this area. Depending on water levels in the bay, Piping Plovers in this area may move between South Bay on the north side of the road, the south side of the road, and Boca Chica beach.

Third, 344 Piping Plovers were observed on South Padre Island between 26.31659, -97.22882 and 26.34347, -97.26362, a distance of about 2.8 miles of bayside shoreline. Over 200

Piping Plovers were visible in less than 400 yards of shoreline. However, when the survey resumed three days later at this location, Piping Plovers were not observed. The area where the birds were seen previously was under water due to a shift in the wind direction and an increase in the wind speed after a cold front came through the area.

Fourth, sharply lower numbers of Piping Plovers were observed at Bolivar Flats during these surveys. Prior to Hurricane Ike, this location was known for high numbers of Piping Plovers. Due to a concern that wintering banded Piping Plovers might have been missed at this location, this area was surveyed four times, and 0, 17, 83, and 0 Piping Plovers were seen. As discussed above, Hurricane Ike caused the loss and degradation of intertidal feeding habitats at Bolivar Flats. The high count of 83 Piping Plovers was on a day when there were strong northeast winds that would have raised water levels on the bayside habitats and increased the chance of Piping Plovers being present on the Gulf beach. On both days when Piping Plovers were seen at Bolivar Flats, after the tide dropped to a certain level, Piping Plovers were observed flying towards the bay so it is possible that a bayside feeding location was being used.

A serious long term conservation concern is habitat loss on developed areas of the Gulf beach as erosion brings the high tide line closer to existing line of development. At Quintana, Surfside to San Louis Pass, Galveston Island, and Bolivar Peninsula, in certain areas, structures now are located close to the high tide line, reducing the available area of roosting habitat. In contrast, there were areas of beach without buildings – such as the inlet spit at the west end of Galveston Island, or the flats west of San Bernard National Wildlife Refuge – where the hurricane did not adversely affect habitat or increased the size of available habitat. As erosion continues on developed beaches, roosting habitat could be lost. Other conservation concerns were the mechanized raking to remove wrack that was seen in certain locations and high levels of human disturbance and ORV use on certain beaches.

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Table 3. Florida Surveys, Date, Survey Location, Site Access, Survey Method, and Total Number of Piping Plovers and Banded Piping Plovers

Survey	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
1	12/2/08	Honeymoon Island State Park	Boat	Foot	19	4
2	12/2/08	Anclote Key, South End	Boat	Foot	17	3
3	12/3/08	Anclote Bar	Boat	Foot	4	2
4	12/3/08	North Three Rooker Bar	Boat	Foot	8	1
5	12/3/08	Three Rooker Bar	Boat	Foot	45	7
6	12/4/08	St. Joseph Peninsula State Park	Car	ATV/foot	8	0
7	12/5/08	Tyndall – West Crooked Island	Car	UTV/foot	9	1
8	12/5/08	Tyndall – East Crooked Island	Car	UTV/foot	0	0
9	12/6/08	Phipps Preserve	Boat	Foot	29	5
10	12/6/08	Franklin County Shoreline	Boat	Foot	6	3
11	12/6/08	Lanark Reef West	Boat	Foot	12	2
12	12/7/08	Dog Island East	Boat	Foot	4	2
13	3/11/09	Charley Pass, North Captiva Island	Boat	Foot	19	4
14	3/12/09	Estero Lagoon	Car	Foot	7	1
15	3/12/09	Bunche Beach	Car	Foot	11	2
16	3/13/09	Marco Island, Tigertail Beach	Car	Foot	38	7
16 Surveys	**9 Days**	**16 Locations**	**6 Car** **10 Boat**	**13 Foot** **1 ATV/Foot** **2 UTV/Foot**	**236**	**44**

Table 4. Florida Surveys, Banded Piping Plovers

#	Date	Location	Pop.	Band String	Pic.	Lat.	Long.	Notes
1	12/2/2008	Honeymoon Island S.P North	GP US	-,WR:Gf,RG	Y	28.08657	-82.83392	
2	12/2/2008	Honeymoon Island S.P North	GL US	X,O/L:O,-	Y	28.08715	-82.83309	
3	12/2/2008	Honeymoon Island S.P North	GP US	-,LW:Gf,GW	Y	28.08831	-82.83405	
4	12/2/2008	Honeymoon Island S.P North	GL US	-,-:-,BX	Y	28.08959	-82.8345	Missing part of left tarsus; ID by metal band number
5	12/2/2008	Anclote Key South	GP US	Gf,GY:-,RG	Y	28.16333	-82.84547	
6	12/2/2008	Anclote Key South	GP US	L/YA,-:Gf,-	Y	28.16424	-82.84637	
7	12/2/2008	Anclote Key South	GL US	Of,GB:X,Y	Y	28.16442	-82.84653	
8	12/3/2008	Anclote Bar	GP C	Lf,Gg:X,Y	Y	28.23413	-82.83791	
9	12/3/2008	Anclote Bar	GP US	-,LL:Gf,LL	Y	28.23234	-82.83984	
10	12/3/2008	North Three Rooker Bar	GL US	Of,YB/O:X,g	Y	28.13014	-82.83088	
11	12/3/2008	Three Rooker Bar	GP US	Gf,WL:-,RR	Y	28.11099	-82.8347	
12	12/3/2008	Three Rooker Bar	GL US	-,gO:X,Y	Y	28.11136	-82.83693	
13	12/3/2008	Three Rooker Bar	GP US	-,LW:Gf,GW	Y	28.11136	-82.83694	
14	12/3/2008	Three Rooker Bar	GL US	X,b/O:O,-	Y	28.11385	-82.83864	
15	12/3/2008	Three Rooker Bar	?	-,-:-,BX	Y	28.11401	-82.83861	Likely same bird as seen 12/2; missing part of left tarsus; old style metal band
16	12/3/2008	Three Rooker Bar	GP US	-,YL:Gf,LY	Y	28.11407	-82.83898	
17	12/3/2008	Three Rooker Bar	GP C	Lf,YB:X,G	Y	28.11578	-82.83899	
18	12/5/2008	Tyndall – West Crooked Island	GP C	X,-:Wf,OB	N	30.06648	-85.61691	CLGT: Missing band is B; seen Tyndall last winter
19	12/6/2008	Phipps Preserve	GP US	-,WW:Gf,LL	Y	29.91516	-84.4399	
20	12/6/2008	Phipps Preserve	GL US	-,-:-,O/LX	Y	29.91465	-84.43966	
21	12/6/2008	Phipps Preserve	GP US	-,AA:Gf,LA	Y	29.90761	-84.42969	
22	12/6/2008	Phipps Preserve	GP C	-,RY:Wf,OX	Y	29.91232	-84.43632	
23	12/6/2008	Phipps Preserve	GP US	-,AL:Gf,GA	Y	29.91279	-84.4369	

#	Date	Location	Pop.	Band String	Pic.	Lat.	Long.	Notes
24	12/6/2008	Bay Shoreline, Franklin County	GL US	Of,LY:X,b	Y	29.92705	-84.43921	
25	12/6/2008	Bay Shoreline, Franklin County	GP US	-,WW:Gf,LL	Y	29.92682	-84.4386	
26	12/6/2008	Bay Shoreline, Franklin County	GP C	-,RY:Wf,OX	Y	29.92697	-84.43893	
27	12/6/2008	Lanark Reef West	GP US	X,R:Yf,RB	Y	29.87441	-84.58159	
28	12/6/2008	Lanark Reef West	GP US	-,AR:Gf,LL	Y	29.87453	-84.58138	
29	12/7/2008	Dog Island East	GL US	Of,BL/O;X,Y	Y	29.82568	-84.57854	Holding up left leg and limping
30	12/7/2008	Dog Island East	GP US	PB/R,-;Gf,-	Y	29.82569	-84.57886	
31	3/11/2009	Charley Pass, North Captiva Island	GL US	X,L:Of,RL	Y	26.56888	-82.20478	
32	3/11/2009	Charley Pass, North Captiva Island	GP US	X,B:Yf,RL	Y	26.56855	-82.20461	
33	3/11/2009	Charley Pass, North Captiva Island	GL US	X,G/O:O,-	Y	26.56888	-82.20478	
34	3/11/2009	Charley Pass, North Captiva Island	?	-,-:X,b	Y	26.56888	-82.20478	Probable Great Lakes; combination used by Great Lakes but use by others could not be ruled out.
35	3/12/2009	Estero Lagoon	GP US	Gf,WY:-,RG	Y	26.40594	-81.89779	
36	3/12/2009	Bunche Beach	GL US	Of,Y/O/YL;X,g	Y	26.47711	-81.97028	
37	3/12/2009	Bunche Beach	GP US	Gf,YG:-,RG	Y	26.47759	-81.97559	
38	3/13/2009	Marco Island, Tigertail Beach	GL US	-,b:X,O/b	Y	25.94923	-81.74797	010 on b plastic band
39	3/13/2009	Marco Island, Tigertail Beach	GP US	-,WY:Gf,GA	Y	25.94849	-81.74722	
40	3/13/2009	Marco Island, Tigertail Beach	GL US	X,g:O,-	Y	25.94886	81.7477	018 on g plastic band
41	3/13/2009	Marco Island, Tigertail Beach	GP US	-,WG: Gf,GW	Y	25.95963	81.75362	
42	3/13/2009	Marco Island, Tigertail Beach	GP C	X,-:-,-	Y	25.95963	81.75362	801[]-4557[] visible on X band; no number in front of 8, last number consistent with 5. Matches 8011-45575, seen Marco Island 12/2003
43	3/13/2009	Marco Island, Tigertail Beach	GP US	Gf,LW:-,RR	Y	25.95963	81.75362	
44	3/13/2009	Marco Island, Tigertail Beach	GP US	-,RG:Gf,GL	Y	25.95891	81.75386	

Table 5. Alabama Surveys, Date, Survey Location, Site Access, Survey Method, and Total Number of Piping Plovers and Banded Piping Plovers

Survey	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
1	12/8/08	Pelican Island	Car	Foot	14	1
2	12/9/08	Little Dauphin Island	Boat	Foot	4	0
3	12/9/08	Dauphin Island Washover Fan (West End)	Car	Foot	11	4
4	12/13/08	West Dauphin Island, East End	Boat	Foot	2	0
5	12/13/08	Dauphin Island, West End Inlet and Bayside	Car	Foot	19	2
5 Surveys	**3 days**	**4 locations**	**3 Car 2 Boat**	**5 Foot**	**50**	**7**

Table 6. Banded Piping Plovers in Alabama

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
1	12/8/2008	Pelican island	GP C	Lf,GO:-,GX	Y	30.23134	-88.11543	
2	12/9/2008	Dauphin Island Overwash	GP US	-,LG:Gf,RL (?)	N	30.249537	-88.189324	Observed for short time before bird flew; think string is correct but not sure
3	12/9/2008	Dauphin Island Overwash	GP US	Gf,-:YL/P	Y	30.249537	-88.189324	
4	12/9/2008	Dauphin Island Overwash	GP US	Gf,WG:-,RW	Y	30.249537	-88.189324	
5	12/9/2008	Dauphin Island Overwash	GP C	X,-:Wf,LR	Y	30.249537	-88.189324	CGT: Missing band is O; seen Dauphin Island winter 06
6	12/13/2008	Dauphin Island West End	GP US	Gf,-:YL/P	Y	30.24932	-88.1961	
7	12/13/2008	Dauphin Island West End	GP US	Gf,WG:-,RW	Y	30.25023	-88.19408	

Table 7. Survey Number, Date, Location, Site Access, Survey Method, and Total Number of Piping Plovers and Banded Piping Plovers Observed in Mississippi

Survey #	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
1	12/12/08	Petit Bois Island East End	Boat	Foot	14	2
2	12/14/08	Deer Island, East and West Ends	Boat	Foot	8	1
3	12/17/08	Long Beach	Car	Foot	13	1
4	12/18/08	Pass Christian	Car	Foot	0	0
5	12/18/08	Bay St. Louis	Car	Foot	12	2
6	12/19/08	East Long Beach	Car	Foot	3	0
7	12/21/08	Lakeshore – Waveland	Car	Foot	3	0
8	3/03/09	East Ship Island	Boat	Foot	24	3
9	3/04/09	Horn Island, East and West Ends	Boat	Foot	29	3
10	3/08/09	Cat Island, Southwest Spit	Boat	Foot	41	5
11	3/08/09	Ship Island, East End	Boat	Foot	25	2
11 Surveys	**9 days**	**11 Locations**	**6 Boat 5 Car**	**11 Foot**	**172**	**19**

Table 8. Banded Piping Plovers in Mississippi

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
1	12/12/08	Petit Bois Island East end	GP C	X,R:Lf,Lg	Y	30.20793	-88.41483	
2	12/12/08	Petit Bois Island East end	GP C	Lf,-:X,-	Y	30.20704	-88.42043	
3	12/14/08	Deer Island West and East Ends	GP C	X,Yg:Lf,L	Y	30.36645	-88.82062	
4	12/17/08	Long Beach	GL US	-,O:X,b/O/b	Y	30.33623	-89.17142	
5	12/18/08	Bay Saint Louis	GP C	Lf,L:X,YR	Y	30.31672	-89.32246	
6	12/18/08	Bay Saint Louis	GL US	O,-:X,g	Y	30.28767	-89.36112	
7	3/3/2009	East Ship Island	GP US	A,R/B:Gf,-	Y	30.24466	-88.87688	
8	3/3/2009	East Ship Island	GP US	L/YO,-:Gf,-	Y	30.24497	-88.87505	
9	3/3/2009	East Ship Island	GP C	-,X:-,W/LL/W	Y	30.24009	-88.88748	
10	3/4/2009	Horn Islands, East and West Ends	GP US	Gf,RL:-,RY	Y	30.24195	-88.77038	
11	3/4/2009	Horn Islands, East and West Ends	GP US	Yf,BB:X,Y	Y	30.24087	-88.76646	
12	3/4/2009	Horn Islands, East and West Ends	GP US	-,CA:Gf,- (?)	Y	30.24112	-88.76439	"C" band color uncertain from fading; most likely P based on color and what bands were issued.
13	3/8/2009	Cat Island, Southwest Spit	GP US	Gf,AG:-,RL	Y	30.21021	-89.08869	
14	3/8/2009	Cat Island, Southwest Spit	GP C	Lf,-:X,-	Y	30.21263	-89.08814	
15	3/8/2009	Cat Island, Southwest Spit	?	-,RX:-,W	Y	30.21017	-89.08916	
16	3/8/2009	Cat Island, Southwest Spit	GP C	Lf,OL:X,Y	Y	30.21037	-89.0892	
17	3/8/2009	Cat Island, Southwest Spit	GP US	Gf,WG:-,RG	Y	30.2101	-89.08902	
18	3/8/2009	Ship Island, East End	GP C	X,R:Wf,OB	Y	30.21545	-88.94804	
19	3/8/2009	Ship Island, East End	?	-,-:X,-	Y	30.21545	-88.94804	

Table 9. Survey Number, Date, Location, Site Access, Survey Method, and Total Number of Piping Plovers and Banded Piping Plovers Observed in Louisiana

Survey #	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
1	12/23/08	East Grand Terre	Boat	Foot	12	1
2	12/24/08	Grand Terre	Boat	Foot	4	0
3	12/25/08	Grand Isle East End	Car	Foot	0	0
4	12/27/08	West Belle Pass	Boat	Foot	30	4
5	12/28/08	Fourchon Beach East	Car	Foot	26	3
6	12/29/08	East Timbalier Island, East and West Ends	Boat	Foot	3	1
7	12/30/08	Elmers Island East	Boat	Foot	22	4
8	12/31/08	Raccoon Island West	Boat	Foot	53	6
9	1/2/09	Whisky Island West End	Boat	Foot	24	4
10	1/2/09	Whisky Island East End	Boat	Foot	11	3
11	1/2/09	Trinity Island/East Island East End	Boat	Foot	13	3
12	3/06/09	South Pass, East and West Sides	Airboat	Foot	16	3
13	3/06/09	Islands West of South Pass	Airboat	Foot	0	0
13 Surveys	**10 days**	**13 Locations**	**9 Boat 2 Airboat 2 Car**	**13 Foot**	**214**	**32**

Table 10. Banded Piping Plovers in Louisiana

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
1	12/23/08	East Grand Terre	GP US	-,WL:Gf,GL	Y	29.30918	-89.88502	
2	12/27/08	West Belle Pass	GP US	-,Y:Gf,LW	Y	29.09796	-90.25182	
3	12/27/08	West Belle Pass	GL US	X,L:O,-	Y	29.09796	-90.25182	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
4	12/27/08	West Belle Pass	GP US	Gf,-:PR/W,-	Y	29.09498	-90.24918	Picture of all bands but P
5	12/27/08	West Belle Pass	GL US	-,b:X,O/b	Y	29.09550	-90.24960	
6	12/28/08	Fourchon Beach East	GP US	Yf,BY:X,Y	Y	29.11209	-90.17889	
7	12/28/08	Fourchon Beach East	GP US	Yf,b:X,G	Y	29.11230	-90.17883	
8	12/28/08	Fourchon Beach East	GP C	Lf,Rg:-,XO	Y	29.11431	-90.17657	
9	12/29/08	East Timbalier Island, East and West Ends	GP US	Gf,Y/L:W,-	Y	29.07154	-90.31676	
10	12/30/08	Elmers Island East	GP US	-,RL:Gf,LG	Y	29.18424	-90.06293	
11	12/30/08	Elmers Island East	GP US	-,b:Yf,Gb	Y	29.18430	-90.06456	
12	12/30/08	Elmers Island East	GP US	O,P/L:Gf,-	Y	29.18343	-90.06763	
13	12/30/08	Elmers Island East	UK	X,-:-,-	Y	29.18374	-90.06748	
14	12/31/08	Raccoon Island	GP US	X,R:Yf,BL	Y	29.05993	-90.94122	
15	12/31/08	Raccoon Island	GP US	Yf,OR:X,B	Y	29.05980	-90.94147	
16	12/31/08	Raccoon Island	GP US	X,A:bf,G	Y	29.06106	-90.94357	
17	12/31/08	Raccoon Island	GP C	X,b:Lf,OY	Y	29.06310	-90.94778	
18	12/31/08	Raccoon Island	GP US	R,-:Gf,P/L	Y	29.06348	-90.94841	
19	12/31/08	Raccoon Island	GP C	L/W,-:X,W	Y	29.06573	-90.95191	
20	1/2/09	Whisky Island, West End	GP US	-,AG:Gf,GL	Y	29.05446	-90.85658	
21	1/2/09	Whisky Island, West End	GP US	Gf,-:YP,-	Y	29.05458	-90.85791	
22	1/2/09	Whisky Island, West End	GP C	Lf,gR:X,O	Y	29.05480	-90.85868	
23	1/2/09	Whisky Island, West End	GP C	X,GO:Wf,-	Y	29.05527	-90.85873	X,GO:Wf,B seen at this location 12/28/06
24	1/2/09	Whisky Island, East End	GP US	Yf,LL:X,Y	Y	29.06188	-90.80260	
25	1/2/09	Whisky Island, East End	GP US	-,YW:Gf,GW	Y	29.06213	-90.80265	
26	1/2/09	Whisky Island, East End	GP C	W,-:-,X	Y	29.06228	-90.80256	
27	1/2/09	Trinity Island/East Island East End	GP US	Gf,LG:-,RR	Y	29.06453	-90.65620	
28	1/2/09	Trinity Island/East Island East End	GP US	Gf,LL:-,RG	N	29.06457	-90.65627	
29	1/2/09	Trinity Island/East Island East End	UK	O,-:-,-	Y	29.06469	-90.65596	O,X:-,- seen at this location 12/28/06
30	3/6/2009	South Pass, East and West Sides	GL US	-,LX:-,OL	Y	29.01999	-89.13818	
31	3/6/2009	South Pass, East and West Sides	GL US	Of,Y/O/YR;X,g	Y	29.02004	-89.13792	
32	3/6/2009	South Pass, East and West Sides	GP US	Yf,OB:X,L	Y	29.02004	-89.13792	

Table 11. Survey Number, Date, Location, Site Access, Survey Method, and Total Number of Piping Plovers and Banded Piping Plovers Observed in Texas

Survey #	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
1	1/4/09	San Louis Pass to Surfside	Car	ORV	41	8
2	1/5/09	San Louis Pass to Galveston Seawall	Car	ORV	89	10
3	1/6/09	Quintana Beach	Car	ORV	11	0
4	1/7/09	Dewberry Island and Shoalwater Bay	Airboat	Airboat/ Foot	63	8
5	1/8/09	Matagorda NWR	Boat	ORV	2	1
6	1/9/09	Dewberry Island and Shoalwater Bay	Boat	Foot	94	13
7	1/11/09	Surfside to San Louis Pass	Car	ORV	14	5
8	1/11/09	San Louis Pass East Bayside Flats	Car	Foot	9	0
9	1/12/09	Bolivar Flats	Car	Foot	0	0
10	1/12/09	Rollover Pass East	Car	Foot	15	2
11	1/13/09	Sargent Beach to San Bernard NWR	Car	ORV/ Foot	136	15
12	1/14/09	Redfish Bay	Boat	Foot	28	3
13	1/14/09	San Jose Island Bayside, North Pass Center and South	Boat	Foot	92	5
14	1/15/09	San Jose Island Bayside, North Pass	Boat	Foot	73	11
15	1/15/09	Redfish Bay East	Boat	Foot	55	8
16	1/16/09	Mustang Island Beach, Inlet to Jetty at MISP	Car	ORV	0	0
17	1/17/09	Mollie Beattie	Car	Foot	56	3
18	1/18/09	Mustang Island Bayside Flats	Car	Foot	161	17
19	1/19/09	Padre Island National Seashore (PINS) N End No ORV Beach to MP 15	Car	ORV	7	0
20	1/19/09	Yarbrough Pass North	Car	Foot	8	0
21	1/20/09	PINS S End No ORV Beach to Mansfield Pass	Car	ORV	1	0

Survey #	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
22	1/23/09	PINS – Nighthawk Bay Flats	Foot	Foot	118	20
23	1/25/09	Mustang Island, Wilson's Cut Bayside Flats	Car	Foot	0	0
24	1/31/09	Boca Chica Beach and Inlet Shoreline	Car	ORV	3	1
25	1/31/09	Boca Chica Interior Overwash Fans and Interior Flats (South of road and north of road (South Bay South))	Car	Foot/ ATV	63	5
26	2/1/09	South Padre Island Beach, Atwood Park to Mansfield Channel	Car	ORV	0	0
27	2/3/09	South Bay, South and West Sides	ATV	Foot/ATV	239	26
28	2/4/09	South Padre Island Bayside, 26.27442 -97.20823 to 26.31659 -97.22882 (5)	ATV	Foot/ATV	85	12
29	2/5/09	South Padre Island Bayside, 26.31659 -97.22882 to 26.34347 -97.26362 (6)	ATV	Foot/ATV	344	31
30	2/6/09	South Padre Island Bayside, 26.23860 -97.19531 to 26.27442 -97.20823 (4)	ATV	ATV/Foot	21	1
31	2/6/09	Convention Center Bayside Flats 26.14650 -97.17915 to 26.13451 -97.17744 (2)	Car	ORV/Foot	5	2
32	2/8/09	South Padre Island Bayside, 26.34838 -97.25242 to 26.52671 -97.34589 (7)	ATV	ATV/Foot	2	0
33	2/9/09	Convention Center Bayside Flats (2)	Car	ORV/Foot	40	6
34	2/9/09	South Padre Island Bayside, Bridge Flats (1)	ATV	Foot	0	0
35	2/11/09	South Padre Island Bayside, 26.15570 -97.18124 to 26.23860 -97.19530 (3)	ATV	ATV/Foot	47	6
36	2/11/09	South Padre Island Bayside, (4)	ATV	ATV/Foot	39	6
37	2/12/09	South Padre Island Bayside, 26.55370 -97.34488 to 26.53348 -97.32872 (8)	Boat	Foot	164	16
38	2/17/09	East Bayside Flats and Pelone Island Flats, Mustang Island	Boat	Boat/Foot	0	0
39	2/18/09	Padre Island National Seashore Bayside	Car	Foot	15	1
40	2/19/09	Padre Island National Seashore Bayside	Car	Foot	3	0
41	2/19/09	Padre Island National Seashore Gulf Beach	Car	ORV	29	3

Survey #	Date	Location	Site Access	Survey Method	Total Number of PIPL	Number of Banded PIPL
42	2/20/09	Quintana Beach	Car	ORV/Foot	9	0
43	2/21/09	Surfside to San Louis Pass	Car	ORV	74	11
44	2/22/09	Big Reef (East End Galveston Island)	Car	Foot/ORV	0	0
45	2/23/09	Bolivar Flats	Car	Foot	17	1
46	2/23/09	East Boundary Bolivar Flats to Gilchrist	Car	ORV	48	3
47	2/24/09	San Louis Pass to Galveston Seawall, 29.24229, -94.86973	Car	ORV/Foot	87	12
48	2/27/09	Sargent Beach to San Bernard National Wildlife Refuge	Car	Foot/ORV	115	15
49	2/28/09	East Boundary Bolivar Flats to Crystal Beach	Car	ORV	3	0
50	2/28/09	Bolivar Flats	Car	Foot	83	6
51	3/2/09	Bolivar Flats	Car	Foot	0	0
52	3/2/09	Rollover Pass – East Side of Pass	Car	Foot	20	2
52 Surveys	**39 days**	**34 Locations**	**34 Car 8 Boat 8 ATV 1 Foot 1 Airboat**	**21 Foot 14 ORV 8 Foot/ATV 7 ORV/Foot 1 Airboat/ Foot 1 Boat/Foot**	**2628**	**295**

Table 12. Banded Piping Plovers in Texas

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
1	1/4/09	San Louis Pass to Surfside	GP US	-,GG:Gf,GG	Y	29.05687	-95.14326	
2	1/4/09	San Louis Pass to Surfside	GP C	-,-:X,WW	Y	29.04349	-95.16283	CLGT: CHAPLIN L SK chick from 2003 (missing celluloid bicolour up left)
3	1/4/09	San Louis Pass to Surfside	GP C	X,O:Lf,GG	Y	29.03785	-95.17091	
4	1/4/09	San Louis Pass to Surfside	GP C	X,G:Wf,Rg	Y	29.00898	-95.21193	
5	1/4/09	San Louis Pass to Surfside	GP C	Lf,gB:X,Y	Y	29.00756	-95.21372	
6	1/4/09	San Louis Pass to Surfside	GP US	-,LG:Gf,GR	Y	29.00599	-95.21571	
7	1/4/09	San Louis Pass to Surfside	GP US	Gf,-:L/YO,-	Y	29.02357	-95.19115	
8	1/4/09	San Louis Pass to Surfside	GP C	Lf,gL:X,G	Y	29.06743	-95.12858	
9	1/5/09	San Louis Pass to Galveston Seawall	GP US	-,YY:Gf,LG	Y	29.08952	-95.10642	
10	1/5/09	San Louis Pass to Galveston Seawall	GP C	Lf,OX:-,YG	Y	29.09348	-95.10348	
11	1/5/09	San Louis Pass to Galveston Seawall	GP C	Lf,-:X,-	Y	29.10894	-95.08622	
12	1/5/09	San Louis Pass to Galveston Seawall	GP C	Lf,GG:X,Y	Y	29.11351	-95.07987	
13	1/5/09	San Louis Pass to Galveston Seawall	GP US	Gf,-:-,AG	Y	29.11828	-95.07309	
14	1/5/09	San Louis Pass to Galveston Seawall	GP US	Gf,-:-,L/PW	Y	29.16395	-95.00141	
15	1/5/09	San Louis Pass to Galveston Seawall	GP C	X,-:Lf,-	Y	29.16445	-95.00054	
16	1/5/09	San Louis Pass to Galveston Seawall	GP C	Lf,O:X,gB	Y	29.19165	-94.95530	
17	1/5/09	San Louis Pass to Galveston Seawall	GP US	Gf,-:AL/Y,-	Y	29.18476	-94.96706	
18	1/5/09	San Louis Pass to Galveston Seawall	GP US	Gf,WG:-,RY	Y	29.20949	-94.92535	
19	1/7/09	Dewberry Island and Shoalwater Bay	GP US	X,R:Yf,YR	N	28.32236	-96.61871	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
20	1/7/09	Dewberry Island and Shoalwater Bay	GP US	L/PY,-:Gf,-	N	28.32236	-96.61871	
21	1/7/09	Dewberry Island and Shoalwater Bay	?	-,-:-,b	N	28.35877	-96.57294	
22	1/7/09	Dewberry Island and Shoalwater Bay	GP C	Lf,-:X,-	N	28.37370	-96.53825	
23	1/7/09	Dewberry Island and Shoalwater Bay	GP US	Gf,LR:-,RR	N	28.37557	-96.53271	
24	1/7/09	Dewberry Island and Shoalwater Bay	GP C	X,-:Wf,-	N	28.37557	-96.53271	
25	1/7/09	Dewberry Island and Shoalwater Bay	GP US	-,YR:Gf,GR	N	28.37557	-96.53271	
26	1/7/09	Dewberry Island and Shoalwater Bay	GP C	Lf,R:X,RO	N	28.37557	-96.53271	
27	1/8/09	Matagorda NWR	?	-,Y:-,-	Y	28.09454	-96.81258	
28	1/9/09	Dewberry Island and Shoalwater Bay	GP C	Lf,RY:X,Y	Y	28.37614	-96.53238	
29	1/9/09	Dewberry Island and Shoalwater Bay	GP C	Lf,R:X,RO	Y	28.37614	-96.53238	
30	1/9/09	Dewberry Island and Shoalwater Bay	GP C	W,Y:-,X	Y	28.37614	-96.53238	
31	1/9/09	Dewberry Island and Shoalwater Bay	GP C	X,-:Wf,-	Y	28.37614	-96.53238	
32	1/9/09	Dewberry Island and Shoalwater Bay	GP US	-,YR:Gf,GR	Y	28.37614	-96.53238	
33	1/9/09	Dewberry Island and Shoalwater Bay	GP US	Gf,LR:-,RR	Y	28.37614	-96.53238	
34	1/9/09	Dewberry Island and Shoalwater Bay	GP C	Lf,B:X,Lg	Y	28.37614	-96.53238	
35	1/9/09	Dewberry Island and Shoalwater Bay	GP US	Gf,GG:-,RL	Y	28.33908	-96.60440	
36	1/9/09	Dewberry Island and Shoalwater Bay	GP C	X,g:Lf,gL	Y	28.33908	-96.60440	
37	1/9/09	Dewberry Island and Shoalwater Bay	GP C	Wf,-:X,-	N	28.33908	-96.60440	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
38	1/9/09	Dewberry Island and Shoalwater Bay	GP C	Lf,RY:X,O	Y	28.33908	-96.60440	
39	1/9/09	Dewberry Island and Shoalwater Bay	GP C	-,YX:Wf,LB	Y	28.33908	-96.60440	Left leg limp, holding foot up.
40	1/9/09	Dewberry Island and Shoalwater Bay	GP US	L/PY,-:Gf,-	Y	28.33908	-96.60440	
41	1/11/09	Surfside to San Louis Pass	?	-,G:-,-	Y	29.97046	-95.26159	
42	1/11/09	Surfside to San Louis Pass	GP C	X,GR:Wf,O	Y	29.97046	-95.26159	
43	1/11/09	Surfside to San Louis Pass	GP C	Lf,-:X,-	Y	29.97046	-95.26159	
44	1/11/09	Surfside to San Louis Pass	GP C	X,-:Wf,RR	Y	29.97046	-95.26159	
45	1/11/09	Surfside to San Louis Pass	GP US	Gf,-:L/YO,-	Y	29.03555	-95.17342	
46	1/12/09	Rollover Pass	GP US	Gf,R/WB:-,-	Y	29.51388	-94.49698	
47	1/12/09	Rollover Pass	GP US	X,B:Yf,OL	Y	29.51385	-94.49887	
48	1/13/09	Sargent Beach to San Bernard NWR	GP US	Gf,RY:-,RL	Y	28.81761	-95.52600	
49	1/13/09	Sargent Beach to San Bernard NWR	GP C	X,RO:Wf,g	Y	28.81761	-95.52600	
50	1/13/09	Sargent Beach to San Bernard NWR	GP C	X,O:Lf,RB	Y	28.81825	-95.52639	
51	1/13/09	Sargent Beach to San Bernard NWR	GP US	Yf,BL:X,R	Y	28.81825	-95.52639	
52	1/13/09	Sargent Beach to San Bernard NWR	GP US	Gf,YL:-,RL	Y	28.81843	-95.52734	
53	1/13/09	Sargent Beach to San Bernard NWR	GP C	L/W,X:-,-	Y	28.81843	-95.52734	
54	1/13/09	Sargent Beach to San Bernard NWR	GP C	Lf,BB:X,Y	Y	28.81843	-95.52734	
55	1/13/09	Sargent Beach to San Bernard NWR	GP US	BL/Y,-:Gf,-	Y	28.81937	-95.52665	
56	1/13/09	Sargent Beach to San Bernard NWR	GP C	X,B:Lf,GY	Y	28.82065	-95.52696	
57	1/13/09	Sargent Beach to San Bernard NWR	GP C	Lf,R:X,LB	Y	28.82020	-95.52657	
58	1/13/09	Sargent Beach to San Bernard NWR	GP C	X,YR:Wf,Y	Y	28.82020	-95.52657	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
59	1/13/09	Sargent Beach to San Bernard NWR	GP US	Gf,RG:-,RL	Y	28.82020	-95.52657	
60	1/13/09	Sargent Beach to San Bernard NWR	GP C	X,-:-,R/bL/W	Y	28.82004	-95.52695	
61	1/13/09	Sargent Beach to San Bernard NWR	GP C	-,-:L/W,W/LX	Y	28.82004	-95.52695	
62	1/13/09	Sargent Beach to San Bernard NWR	GP US	-,R/WB;Gf,-	Y	28.82004	-95.52695	
63	1/14/09	Redfish Bay	GP C	-,OL/W;X,-	Y	27.91611	-97.08248	
64	1/14/09	Redfish Bay	GP C	X,BG:Wf,G	Y	27.98693	-97.06614	
65	1/14/09	Redfish Bay	GP US	A,-:Gf,R/B (?)	Y	27.98693	-97.06614	Pictures match combination but unsure
66	1/14/09	North Pass, Center and South	GP US	Yf,LG:X,Y	Y	27.89861	-97.03993	
67	1/14/09	North Pass, Center and South	GP C	Lf,O:X,OL	Y	27.89861	-97.03993	
68	1/14/09	North Pass, Center and South	GP US	Gf,RG:-,RY	N	27.89670	-97.04053	
69	1/14/09	North Pass, Center and South	GP US	X,O:bf,G	N	27.89670	-97.04053	
70	1/14/09	North Pass, Center and South	GP US	X,-:Gf,OY	N	27.89670	-97.04053	
71	1/15/09	North Pass	GP C	Lf,O:X,OL	N	27.89541	-97.04103	
72	1/15/09	North Pass	GP US	Gf,RG:-,RY	N	27.89541	-97.04103	
73	1/15/09	North Pass	GP C	X,-:Lf,-	N	27.89541	-97.04103	
74	1/15/09	North Pass	GP US	-,LL:Gf,LW	Y	27.89627	-97.04082	
75	1/15/09	North Pass	GP US	-,LA:Gf,GG	Y	27.89580	-97.04089	
76	1/15/09	North Pass	GP US	Yf,RG:X,b	Y	27.89678	-97.04070	
77	1/15/09	North Pass	?	-,X:-,-	Y	27.89678	-97.04070	
78	1/15/09	North Pass	GP US	Yf,LG:X,Y	Y	27.89722	-97.04069	
79	1/15/09	North Pass	GP US	-,YR:Gf,LG	Y	27.89745	-97.04060	
80	1/15/09	North Pass	GP C	-,X:-,W/LL/W	Y	27.89654	-97.04073	
81	1/15/09	North Pass	GP US	X,O:bf,G	Y	27.89547	-97.04103	
82	1/15/09	Redfish Bay East	GP US	-,LA:Gf,GG	N	27.91510	-97.08222	
83	1/15/09	Redfish Bay East	GP US	X,O:bf,G	Y	27.91510	-97.08222	
84	1/15/09	Redfish Bay East	GP US	-,YR:Gf,LG	Y	27.91510	-97.08222	
85	1/15/09	Redfish Bay East	?	-,X:-,-	Y	27.91510	-97.08222	
86	1/15/09	Redfish Bay East	GP US	Gf,GL/Y:-,-	Y	27.91454	-97.08247	
87	1/15/09	Redfish Bay East	GP C	-,OL/W:X,-	N	27.91478	-97.08221	
88	1/15/09	Redfish Bay East	?	Y,-:-,R/B	Y	27.91478	-97.08221	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
89	1/15/09	Redfish Bay East	GP US	X,-:Gf,OY	Y	27.91477	-97.08221	
90	1/17/09	Mollie Beattie	GP C	X,L:Lf,OG	Y	27.63389	-97.21342	
91	1/17/09	Mollie Beattie	GP C	Lf,LO:X,g	Y	27.63606	-97.21387	
92	1/17/09	Mollie Beattie	GP US	X,L:bf,G	Y	27.63791	-97.21504	
93	1/18/09	Mustang Island Bayside Flats	GP US	X,RG:Gf,RR	Y	27.68300	-97.20723	
94	1/18/09	Mustang Island Bayside Flats	GP C	X,L/Wb/R:-,-	Y	27.68300	-97.20723	
95	1/18/09	Mustang Island Bayside Flats	GP C	X,RO:Wf,R	Y	27.68300	-97.20723	
96	1/18/09	Mustang Island Bayside Flats	GP C	W,Y:B,X	Y	27.68300	-97.20723	
97	1/18/09	Mustang Island Bayside Flats	GP US	-,LW:Gf,LA	Y	27.68305	-97.20946	
98	1/18/09	Mustang Island Bayside Flats	GP C	X,B:Lf,GB	Y	27.68305	-97.20946	
99	1/18/09	Mustang Island Bayside Flats	GP C	X,R:Lf,LB	Y	27.68305	-97.20946	
100	1/18/09	Mustang Island Bayside Flats	GP C	Lf,YG:-,OX	Y	27.68306	-97.20531	
101	1/18/09	Mustang Island Bayside Flats	GP C	Lf,-:X,-	Y	27.68306	-97.20531	
102	1/18/09	Mustang Island Bayside Flats	GP C	W,X:-,R	Y	27.68306	-97.20531	
103	1/18/09	Mustang Island Bayside Flats	GP US	X,YG:bf,G	Y	27.68299	-97.20625	
104	1/18/09	Mustang Island Bayside Flats	GP US	Gf,-:-,g/VY	Y	27.68273	-97.20824	
105	1/18/09	Mustang Island Bayside Flats	GP US	Gf,-:O,(?)	N	27.68291	-97.20793	
106	1/18/09	Mustang Island Bayside Flats	?	-,LG:-,RY	Y	27.68291	-97.20793	Would match GP US if Gf fell off
107	1/18/09	Mustang Island Bayside Flats	GP C	X,L:Lf,OG	Y	27.68291	-97.20793	
108	1/18/09	Mustang Island Bayside Flats	GP US	-,GL/P:Gf,-	Y	27.68291	-97.20793	
109	1/18/09	Mustang Island Bayside Flats	GP C	-,gB:Wf,YX	Y	27.68302	-97.20595	All bands very faded
110	1/23/09	PINS – Nighthawk Bay Flats	GP US	W,P/L:Gf,-	Y	27.53587	-97.27755	
111	1/23/09	PINS – Nighthawk Bay Flats	GP C	-,-:X,L/W	Y	27.53758	-97.27612	
112	1/23/09	PINS – Nighthawk Bay Flats	GP C	W,X:O,R	Y	27.53746	-97.27667	
113	1/23/09	PINS – Nighthawk Bay Flats	GP US	Gf,GG:-,WG	Y	27.53746	-97.27667	
114	1/23/09	PINS – Nighthawk Bay Flats	GP C	Lf,GG:X,B	Y	27.53746	-97.27667	
115	1/23/09	PINS – Nighthawk Bay Flats	GP US	-,YG:Gf,GW	Y	27.53746	-97.27667	
116	1/23/09	PINS – Nighthawk Bay Flats	GP C	Lf,G:X,OY	Y	27.53746	-97.27667	
117	1/23/09	PINS – Nighthawk Bay Flats	GP C	-,L/W:X,W/L	N	27.53746	-97.27667	
118	1/23/09	PINS – Nighthawk Bay Flats	GP C	W,Y:-,X	Y	27.53746	-97.27667	
119	1/23/09	PINS – Nighthawk Bay Flats	GP C	W,G:-,X	Y	27.53746	-97.27667	Location estimated
120	1/23/09	PINS – Nighthawk Bay Flats	GP C	Lf,RB:X,Y	Y	27.53948	-97.27648	
121	1/23/09	PINS – Nighthawk Bay Flats	GP C	-,-:X,W	Y	27.53948	-97.27648	
122	1/23/09	PINS – Nighthawk Bay Flats	GP US	-,RL:Gf,GA	Y	27.53956	-97.27564	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
123	1/23/09	PINS – Nighthawk Bay Flats	GP C	X,-:Wf,-	Y	27.53956	-97.27564	
124	1/23/09	PINS – Nighthawk Bay Flats	?	-,Y:-,-	Y	27.53956	-97.27564	Location estimated
125	1/23/09	PINS – Nighthawk Bay Flats	GP C	Lf,YO:-,OX	Y	27.53922	-97.27667	
126	1/23/09	PINS – Nighthawk Bay Flats	GP C	Lf,GX:-,gO	Y	27.53922	-97.27667	
127	1/23/09	PINS – Nighthawk Bay Flats	GP US	Yf,R:X,G	Y	27.53952	-97.27753	
128	1/23/09	PINS – Nighthawk Bay Flats	GP C	W,X:b,B	Y	27.53952	-97.27695	
129	1/23/09	PINS – Nighthawk Bay Flats	GP US	X,R:Yf,BR	Y	27.53542	-97.27760	
130	1/31/09	Boca Chica Beach and Inlet Shoreline	?	-,X:-,-	Y	25.99273	-97.14979	
131	1/31/09	Boca Chica Interior Overwash Fans, Interior Flats, and South Bay	GP US	?Y,-:Gf,-	Y	25.97269	-97.15812	South of Road; bird flew N towards South Bay.
132	1/31/09	Boca Chica Interior Overwash Fans, Interior Flats, and South Bay	GP C	Lf,O:X,BR	Y	25.99711	-97.18549	
133	1/31/09	Boca Chica Interior Overwash Fans, Interior Flats, and South Bay	GP US	-,R/WL:Gf,-	Y	25.99711	-97.18549	
134	1/31/09	Boca Chica Interior Overwash Fans, Interior Flats, and South Bay	GP US	Gf,YG:-,GA	Y	25.99711	-97.18549	
135	1/31/09	Boca Chica Interior Overwash Fans, Interior Flats, and South Bay	GP US	Gf,-:-,PL/Y	Y	25.99739	-97.18519	
136	2/3/09	Boca Chica - South Bay	GP US	Gf,LR:-,LY	N	26.00220	-97.20258	
137	2/3/09	Boca Chica - South Bay	GP US	Gf,LW:-,RY	Y	26.00397	-97.20190	
138	2/3/09	Boca Chica - South Bay	GP C	Lf,O:X,BR	Y	26.00397	-97.20190	
139	2/3/09	Boca Chica - South Bay	GP US	X,R:Yf,OR	Y	26.00397	-97.20190	
140	2/3/09	Boca Chica - South Bay	GP US	-,LW:Gf,GL	Y	26.00397	-97.20190	
141	2/3/09	Boca Chica - South Bay	GP C	X,B:Wf,RY	Y	26.00397	-97.20190	
142	2/3/09	Boca Chica - South Bay	GP US	-,RA:Gf,GA	N	26.00420	-97.20364	
143	2/3/09	Boca Chica - South Bay	GP US	-,R/AL:Gf,-	N	26.00420	-97.20364	
144	2/3/09	Boca Chica - South Bay	GP C	X,L:Lf,YR	Y	26.00420	-97.20364	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
145	2/3/09	Boca Chica - South Bay	GP US	Gf,-:O,W/R	Y	26.00420	-97.20364	Position estimated
146	2/3/09	Boca Chica - South Bay	GP US	WY,-:Gf,- (?)	Y	26.00420	-97.20364	Position estimated
147	2/3/09	Boca Chica - South Bay	GP C	Lf,B:X,GY	Y	26.00289	-97.20467	
148	2/3/09	Boca Chica - South Bay	GP C	Lf,g:X,GL	Y	26.00289	-97.20467	
149	2/3/09	Boca Chica - South Bay	GP C	X,YY:Wf,B	Y	26.00289	-97.20467	Poor picture quality.
150	2/3/09	Boca Chica - South Bay	GP US	-,YW:Gf,LL	Y	26.00289	-97.20467	
151	2/3/09	Boca Chica - South Bay	GP C	X,Y:Wf,AR	Y	26.00289	-97.20467	
152	2/3/09	Boca Chica - South Bay	GP US	G,R/B:Gf,-	Y	26.00289	-97.20467	
153	2/3/09	Boca Chica - South Bay	GP US	-,AA:Gf,GA	Y	25.99747	-97.20145	
154	2/3/09	Boca Chica - South Bay	GP US	Gf,YG:-,GA	Y	25.99747	-97.20145	
155	2/3/09	Boca Chica - South Bay	GP US	Gf,-:L/YA,-	Y	25.99747	-97.20145	
156	2/3/09	Boca Chica - South Bay	GP US	Gf,P/L:R,-	Y	25.99747	-97.20145	
157	2/3/09	Boca Chica - South Bay	GP C	X,AB:Wf,g	Y	26.00059	-97.20190	
158	2/3/09	Boca Chica - South Bay	GP C	W,LL:-,X	Y	26.00059	-97.20190	
159	2/3/09	Boca Chica - South Bay	GP US	Gf,RG:-,GR(?)	N	26.00059	-97.20190	
160	2/3/09	Boca Chica - South Bay	GP US	-,GL:Gf,LA	Y	25.99891	-97.19797	
161	2/3/09	Boca Chica - South Bay	GP C	-,-:X,L/Wb/R	Y	25.99891	-97.19797	
162	2/4/09	South Padre Island Bayside (5)	?	-,X:-,Y	N	26.27590	-97.21119	
163	2/4/09	South Padre Island Bayside (5)	GP US	Yf,OL:X,B	Y	26.28504	-97.21446	
164	2/4/09	South Padre Island Bayside (5)	GP C	Lf,O:X,LR	N	26.29819	-97.22213	
165	2/4/09	South Padre Island Bayside (5)	GP C	Lf,BR:X,Y	Y	26.29819	-97.22213	
166	2/4/09	South Padre Island Bayside (5)	GP US	-,LL:Gf,GL	Y	26.29819	-97.22213	
167	2/4/09	South Padre Island Bayside (5)	GP US	-,-:Gf,?	N	26.30146	-97.22440	
168	2/4/09	South Padre Island Bayside (5)	?	-,-:X,-	Y	26.30146	-97.22440	
169	2/4/09	South Padre Island Bayside (5)	GP C	X,Y:Lf,Og	Y	26.29880	-97.22424	
170	2/4/09	South Padre Island Bayside (5)	GP US	-,AW:Gf,LL	Y	26.30974	-97.22877	
171	2/4/09	South Padre Island Bayside (5)	?	R,-:X,Y	N	26.31322	-97.23158	
172	2/4/09	South Padre Island Bayside (5)	GP C	X,OY:Wf,-	Y	26.31322	-97.23158	GLGT: missing dark green
173	2/4/09	South Padre Island Bayside (5)	GP C	W,X:O,O	Y	26.31322	-97.23158	
174	2/5/09	South Padre Island Bayside (6)	GP US	-,GY:Gf,RR	Y	26.33165	-97.25072	
175	2/5/09	South Padre Island Bayside (6)	GP C	Lf,BR:X,Y	Y	26.33255	-97.25156	
176	2/5/09	South Padre Island Bayside (6)	GP C	W,X:-,Y	Y	26.33255	-97.25156	
177	2/5/09	South Padre Island Bayside (6)	GP US	Gf,-:GP,-	Y	26.33255	-97.25156	
178	2/5/09	South Padre Island Bayside (6)	?	-,-:X,-	N	26.33255	-97.25156	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
179	2/5/09	South Padre Island Bayside (6)	GP US	Yf,OL:X,B	Y	26.33638	-97.25494	
180	2/5/09	South Padre Island Bayside (6)	GP US	-,YL/Y:Gf,-	Y	26.33638	-97.25494	
181	2/5/09	South Padre Island Bayside (6)	?	-,-:-,B	Y	26.33693	-97.25589	
182	2/5/09	South Padre Island Bayside (6)	GP US	Gf,YY:-,RL	Y	26.33693	-97.25589	
183	2/5/09	South Padre Island Bayside (6)	GP US	Gf,AR/W:-,-	Y	26.34135	-97.25900	
184	2/5/09	South Padre Island Bayside (6)	GP C	X,g:Lf,YL	Y	26.34135	-97.25900	
185	2/5/09	South Padre Island Bayside (6)	GP C	-,-:L/W,g	Y	26.34135	-97.25900	
186	2/5/09	South Padre Island Bayside (6)	GP C	W,X:G,W	Y	26.34135	-97.25900	
187	2/5/09	South Padre Island Bayside (6)	GP US	-,-:Gf,L/YL/Y	Y	26.34344	-97.25976	
188	2/5/09	South Padre Island Bayside (6)	GP US	-,LL:Gf,GG	Y	26.34353	-97.25988	
189	2/5/09	South Padre Island Bayside (6)	?	-,-:-,X	Y	26.34353	-97.25988	
190	2/5/09	South Padre Island Bayside (6)	GP C	X,O:Lf,Og	Y	26.34353	-97.25988	
191	2/5/09	South Padre Island Bayside (6)	GP C	Lf,O:X,GY	Y	26.34028	-97.26105	
192	2/5/09	South Padre Island Bayside (6)	?	-,X:-,BL/A	N	26.34028	-97.26105	
193	2/5/09	South Padre Island Bayside (6)	GP C	X,OY:Wf,-	Y	26.34028	-97.26105	GLGT: missing dark green
194	2/5/09	South Padre Island Bayside (6)	GP C	-,X:-,b/RL/W	Y	26.34028	-97.26105	
195	2/5/09	South Padre Island Bayside (6)	GP C	X,-:-,WW	Y	26.34028	-97.26105	
196	2/5/09	South Padre Island Bayside (6)	GP US	L/PG,-:Gf,-	Y	26.34028	-97.26105	
197	2/5/09	South Padre Island Bayside (6)	GP C	W,-:-,WX	Y	26.34149	-97.26131	
198	2/5/09	South Padre Island Bayside (6)	GP C	Lf,R:X,LY	Y	26.34303	-97.26339	
199	2/5/09	South Padre Island Bayside (6)	GP US	X,R:Yf,RR	Y	26.34303	-97.26339	
200	2/5/09	South Padre Island Bayside (6)	GP US	Gf,LG:-,RG	Y	26.34303	-97.26339	
201	2/5/09	South Padre Island Bayside (6)	GP C	Lf,OB:X,O	Y	26.34303	-97.26339	
202	2/5/09	South Padre Island Bayside (6)	GP C	-,-:X,W/L	Y	26.34303	-97.26339	
203	2/5/09	South Padre Island Bayside (6)	GP US	Yf,OR:X,Y	Y	26.34303	-97.26339	
204	2/5/09	South Padre Island Bayside (6)	GP US	Gf,AL/Y:-,-	Y	26.34303	-97.26339	
205	2/6/09	South Padre Island Bayside (4)	GP C	Lf,O:X,GY	Y	26.26275	-97.20407	
206	2/6/09	Convention Center Bayside Flats (2)	?	-,-:-,X	Y	26.13766	-97.17714	
207	2/6/09	Convention Center Bayside Flats (2)	GP C	Lf,OX:-,GL	Y	26.13766	-97.17714	
208	2/9/09	Convention Center Bayside Flats (2)	GP C	X,LL:Lf,g	Y	26.14178	-97.17819	
209	2/9/09	Convention Center Bayside Flats	?	-,-:-,X	Y	26.14227	-97.17830	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
		(2)						
210	2/9/09	Convention Center Bayside Flats (2)	GP C	Lf,OX:-,GL	N	26.14293	-97.17838	
211	2/9/09	Convention Center Bayside Flats (2)	GP US	Gf,-:PL/P,-	Y	26.14604	-97.17973	
212	2/9/09	Convention Center Bayside Flats (2)	GL	O,-:X,O/g	Y	26.14623	-97.17979	
213	2/9/09	Convention Center Bayside Flats (2)	GP C	W,X:O,-	Y	26.14636	-97.17950	
214	2/11/09	South Padre Island Bayside (3)	GL	O,-:X,O/g	N	26.16440	-97.18179	
215	2/11/09	South Padre Island Bayside (3)	?	-,-:-,X	N	26.16440	-97.18179	
216	2/11/09	South Padre Island Bayside (3)	GP US	Gf,-:PL/P,-	N	26.16440	-97.18179	
217	2/11/09	South Padre Island Bayside (3)	GP C	X,LL:Lf,g	Y	26.19361	-97.18725	
218	2/11/09	South Padre Island Bayside (3)	GP C	Lf,O:X,OO	Y	26.19361	-97.18725	
219	2/11/09	South Padre Island Bayside (3)	GP US	P(?)A,-:Gf,-	N	26.22082	-97.19283	Not sure on upper band left leg - possible split
220	2/11/09	South Padre Island Bayside (4)	GP US	L/PG,-:Gf,-	Y	26.24696	-97.19642	
221	2/11/09	South Padre Island Bayside (4)	GP US	Gf,LY:-,RY	Y	26.24800	-97.19658	
222	2/11/09	South Padre Island Bayside (4)	?	-,-:-,W	N	26.25665	-97.20119	
223	2/11/09	South Padre Island Bayside (4)	GP US	Yf,OL:X,B	Y	26.26129	-97.20181	Poor quality picture
224	2/11/09	South Padre Island Bayside (4)	GP C	-,X:-,b/RL/W	Y	26.26129	-97.20181	Poor quality picture
225	2/11/09	South Padre Island Bayside (4)	GP C	W,X:-,-	N	26.26268	-97.20335	
226	2/12/09	South Padre Island Bayside (8)	GP US	Gf,LL:-,RY	N	26.55687	-97.33219	
227	2/12/09	South Padre Island Bayside (8)	GP C	-,X:-,b/RL/W	N	26.55687	-97.33219	
228	2/12/09	South Padre Island Bayside (8)	GP C	X,B:Lf,BL	Y	26.54038	-97.33265	
229	2/12/09	South Padre Island Bayside (8)	GP C	X,AA:Wf,G	Y	26.53395	-97.32904	
230	2/12/09	South Padre Island Bayside (8)	GP US	L/PB/R,-:Gf,-	N	26.53382	-97.32874	
231	2/12/09	South Padre Island Bayside (8)	GP US	Gf,-:R,g	N	26.53551	-97.32828	
232	2/12/09	South Padre Island Bayside (8)	GP C	X,RO:Wf,G	Y	26.53551	-97.32828	
233	2/12/09	South Padre Island Bayside (8)	GP C	X,-:L/W,-	N	26.53689	-97.32874	
234	2/12/09	South Padre Island Bayside (8)	GP C	X,R:Lf,BG	N	26.53723	-97.32848	
235	2/12/09	South Padre Island Bayside (8)	GP C	X,-:Wf,-	N	26.53723	-97.32848	
236	2/12/09	South Padre Island Bayside (8)	GP C	Lf,gL:X,Y	Y	26.53822	-97.32774	
237	2/12/09	South Padre Island Bayside (8)	GP US	-,WW:Gf,GL	N	26.53822	-97.32774	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
238	2/12/09	South Padre Island Bayside (8)	GP US	Gf,WL:-,RY	Y	26.53822	-97.32774	
239	2/12/09	South Padre Island Bayside (8)	GP US	X,R:bf,Y	Y	26.53915	-97.32761	
240	2/12/09	South Padre Island Bayside (8)	GP C	Lf,-:X,-	N	26.54043	-97.32842	
241	2/12/09	South Padre Island Bayside (8)	GP US	Gf,-:N,GP(?)	N	26.54140	-97.32860	
242	2/18/09	Padre Island National Seashore Bayside	GP C	X,O:Lf,gR	Y	27.30013	-97.37000	
243	2/19/09	Padre Island National Seashore Beach	GP C	Lf,BY:X,Y	Y	27.27276	-97.34898	
244	2/19/09	Padre Island National Seashore Beach	GP C	Lf,-:X,-	Y	27.19525	-97.36600	
245	2/19/09	Padre Island National Seashore Beach	GP C	W,-:-,X	Y	27.18288	-97.36808	
246	2/21/09	Surfside to San Louis Pass	?	-,X:O,W	N	28.99770	-95.22657	
247	2/21/09	Surfside to San Louis Pass	GP US	-,LG:Gf,GR	N	29.00471	-95.21713	
248	2/21/09	Surfside to San Louis Pass	GP C	X,G:Wf,Rg	N	29.00995	-95.21012	
249	2/21/09	Surfside to San Louis Pass	GP C	Lf,gB:X,Y	N	29.01157	-95.20792	
250	2/21/09	Surfside to San Louis Pass	GP US	Gf,-:L/YO,-	N	29.01727	-95.19997	
251	2/21/09	Surfside to San Louis Pass	GP C	Lf,gL:X,G	N	29.06752	-95.12852	
252	2/21/09	Surfside to San Louis Pass	GP C	-,-:L/WW/LX	N	29.05988	-95.13882	
252	2/21/09	Surfside to San Louis Pass	GP US	Gf,LR:-,-	N	29.03296	-95.17809	
254	2/21/09	Surfside to San Louis Pass	GP C	-,-:X,WW	N	29.03269	-95.17857	
255	2/21/09	Surfside to San Louis Pass	GP C	X,-:Wf,RR	Y	28.97450	-95.25696	CLGT: missing dark blue
256	2/21/09	Surfside to San Louis Pass	?	N,G:N,N	N	28.97056	-95.26173	Would match -,G:-,- seen previous survey near here
257	2/23/09	Bolivar Flats	GP C	X,-:Lf,-	N	29.36620	-94.74335	
258	2/23/09	Bolivar Flats East Boundary to Gilchrist	GP C	X,Y:Lf,OY	N	29.41443	-94.69502	
259	2/23/09	Bolivar Flats East Boundary to Gilchrist	GP C	X,-:Lf,-	N	29.41805	-94.69039	
260	2/23/09	Bolivar Flats East Boundary to Gilchrist	?	N,X:gY:,-	N	29.41488	-94.69531	
261	2/24/09	San Louis Pass to Galveston Seawall	GP C	X,O:Lf,GG	N	29.09361	-95.11589	
262	2/24/09	San Louis Pass to Galveston Seawall	GP C	Lf,-:X,-	N	29.09350	-95.11619	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
263	2/24/09	San Louis Pass to Galveston Seawall	GP US	X,B:Yf,OY	Y	29.09292	-95.11563	
264	2/24/09	San Louis Pass to Galveston Seawall	GP US	-,AW:Gf,LW	N	29.15181	-95.02082	
265	2/24/09	San Louis Pass to Galveston Seawall	GP US	Gf,WY:-,RR	N	29.15754	-95.01170	
266	2/24/09	San Louis Pass to Galveston Seawall	GP C	X,L:Lf,Rg	Y	29.18467	-95.96700	Galveston Island State Park
267	2/24/09	San Louis Pass to Galveston Seawall	GP C	Lf,O:X,gB	Y	29.19129	-94.95571	Galveston Island State Park
268	2/24/09	San Louis Pass to Galveston Seawall	GP US	R,P/L:Gf,-	Y	29.19290	-94.95282	Galveston Island State Park
269	2/24/09	San Louis Pass to Galveston Seawall	GP C	Lf,GG:X,Y	Y	29.11377	-95.07959	
270	2/24/09	San Louis Pass to Galveston Seawall	GP US	-,YY:Gf,LG	Y	29.08733	-95.10893	
271	2/24/09	San Louis Pass to Galveston Seawall	GP C	-,-:X,WW	Y	29.08571	-95.11084	
272	2/24/09	San Louis Pass to Galveston Seawall	GP C	Lf,GB:X,R	Y	29.08571	-95.11084	
273	2/27/09	Sargent Beach to San Bernard NWR	GP US	Gf,YL:-,RL	N	28.82654	-95.52534	
274	2/27/09	Sargent Beach to San Bernard NWR	GP US	-,R/WB:Gf,-	N	28.82654	-95.52534	
275	2/27/09	Sargent Beach to San Bernard NWR	GP US	Gf,RY:-,RL	N	28.82654	-95.52534	
276	2/27/09	Sargent Beach to San Bernard NWR	GP C	Lf,R:X,LB	N	28.82672	-95.52584	
277	2/27/09	Sargent Beach to San Bernard NWR	GP US	BL/Y,-:Gf,-	N	28.82672	-95.52584	
278	2/27/09	Sargent Beach to San Bernard NWR	GP C	L/W,X:-,-	N	28.82696	-95.52681	
279	2/27/09	Sargent Beach to San Bernard NWR	GP US	Gf,RG:-,RL	N	28.82696	-95.52681	
280	2/27/09	Sargent Beach to San Bernard	GP C	X,RO:Wf,g	N	28.82681	-95.52348	

#	Date	Location	Pop.	Bands	Pic.	Lat.	Long.	Notes
		NWR						
281	2/27/09	Sargent Beach to San Bernard NWR	GP C	X,-:-,L/WA/R	N	28.82571	-95.52272	
282	2/27/09	Sargent Beach to San Bernard NWR	GP US	Gf,-:AB/R,-	N	28.82557	-95.52279	
283	2/27/09	Sargent Beach to San Bernard NWR	GP US	-,-:Gf,L/PA	Y	28.82519	-95.52278	
284	2/27/09	Sargent Beach to San Bernard NWR	GP C	Lf,BB:X,Y	N	28.82679	-95.52258	
285	2/27/09	Sargent Beach to San Bernard NWR	GP C	X,B:Lf,GY	N	28.82570	-95.52182	
286	2/27/09	Sargent Beach to San Bernard NWR	GP C	X,O:Lf,RB	N	28.82446	-95.52564	
287	2/27/09	Sargent Beach to San Bernard NWR	GP C	X,YR:Wf,Y	N	28.82446	-95.52564	
288	2/28/09	Bolivar Flats	GP C	Lf,B:X,BO	Y	29.36470	-94.73713	
289	2/28/09	Bolivar Flats	GP C	X,B:Lf,OG	Y	29.36470	-94.73713	
290	2/28/09	Bolivar Flats	GP C	Lf,Rg:X,B	Y	29.36448	-94.73828	
291	2/28/09	Bolivar Flats	GP C	X,-:Wf,YG	Y	29.36453	-94.73875	
292	2/28/09	Bolivar Flats	GP C	W,YR:-,X	Y	29.36453	-94.73875	
293	2/28/09	Bolivar Flats	GP C	X,Og:Lf,B	N	29.36453	-94.73875	
294	3/2/09	Rollover Pass – East Side of Pass	GP US	Gf,R/WB:-,-	N	29.51292	-94.49804	
295	3/2/09	Rollover Pass – East Side of Pass	GP US	X,B:Yf,OL	N	29.51298	-94.49774	

THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

A Dissertation
presented to
the Faculty of the Graduate School
University of Missouri - Columbia

In Partial Fulfillment
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Doctor of Philosophy

by
CURTIS A. ZONICK

Dr. Mark Ryan, Dissertation Supervisor

JULY 2000

The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

presented by Curtis A. Zonick

a candidate for the degree of Doctor of Philosophy

and hereby certify that in their opinion it is worthy of acceptance.

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THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

Curtis A. Zonick
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ABSTRACT

Piping Plovers were monitored along the Texas Gulf Coast during the nonbreeding season (July – April) from 1991-1994. Groups of study sites were established within Texas' 2 coastal ecosystems (bay and lagoon ecosystems) and a coastal ecotone. Plovers were regularly counted at these sites and observed to determine habitat use patterns, diet, foraging effort, foraging efficiency, energy expenditure and factors influencing site abundance. Prey populations were sampled in areas used by foraging plovers for comparison to plover diets in different habitats and ecosystems.

Plovers were found to use bayshore tidal flats when bayshore tides were low and tidal flats were emergent. As bayshore tides inundated tidal flat habitat, plovers moved to beach habitat at most sites. Plovers density at beach and bayshore habitat varied in the 2 ecosystems and the ecotone. Plovers occurred at disproportionately high density at ecotone beaches and bay ecosystem tidal flats. In the lagoon ecosystem, where tides were controlled predominantly by winds, plovers used beaches less frequently, apparently also using mainland tidal flats and washover passes as secondary habitats.

Plover diet differed considerably in the 2 ecosystems. In the bay ecosystem, plovers fed predominantly on polychaetes, whereas plovers in the lagoon ecosystem were observed to feed largely on insects and other arthropods. Plovers in the ecotone exhibited a mixed diet of polychaetes and insects. Prey samples established that plover diets in these areas closely reflected the available prey communities. Plover flock size was

positively correlated with total benthic density and polychaete density in the bay ecosystem and the ecotone, but negatively correlated with these prey in the lagoon ecosystem, where plovers fed to a much greater extent on insects.

Plovers captured about 10 animals/minute in both ecosystems and the ecotone, and at beach and bayshore habitats. However, plovers foraging at beach habitat appeared to invest much more energy responding to human disturbance, territorial aggression, avoiding the swash. This additional energy investment likely resulted in a substantially lower energy intake rate for plovers foraging at beach habitat, and may explain why beaches were generally used only when bayshore flats were inundated. Plovers spent approximately 77% of their time foraging during daylight hours, and were more likely to roost during high bayshore tides and at beach and washover pass habitat.

Mean plover study site abundance was related to several environmental parameters (beach benthic density, bayshore benthic density, bayshore surface prey density, bayshore area, beach length, beach vehicular density). A stepwise multiple regression model selected beach length (positive) and beach vehicular density (negative) as the factors most strongly influencing plover site abundance. These results suggest that, although plovers may use beaches as a secondary habitat, degradation to this habitat may be limiting plover carrying capacity on Texas barrier islands. Given these findings, the large number of Piping Plovers wintering in Texas (~50% of the global population), and the extended length of the nonbreeding period (9-10 months), the protection of beach habitat should be among the highest priorities for Piping Plover recovery.

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CHAPTER I. INTRODUCTION AND STUDY AREA

INTRODUCTION

Few animals better symbolize the challenges associated with preserving biodiversity than the federally-protected Piping Plover (*Charadrius melodus* Ord). Like many other American species, the Piping Plover was reduced to near extinction in the late 1800's by unregulated hunting (Bent 1929). Plover populations recovered in the early 1900's after the establishment of the Migratory Bird Treaty Act and other laws designed to control the harvest of wildlife only to suffer another more recent decline caused by habitat loss and other impacts associated with human encroachment (U.S. Fish and Wildlife Service 1985).

In 1985, the Piping Plover was added to the group of plants and animals on the list of federally threatened and endangered species protected under the Endangered Species Act (ESA). There are now over 1,200 species on this list (U.S. Fish and Wildlife Service 2000), but in the 27 year history of the ESA, only 6 species have recovered to the point that they have been removed from the list (Mann and Plummer 1995). As is the case for most other species still on the federal list, the Piping Plover persists in the wild but continues to decline.

The federal agency responsible for enforcing the ESA for terrestrial species, the U.S. Fish and Wildlife Service (Service), admits on their worldwide web site that the ESA has succeeded in doing little more than preventing the extinction of listed species:

> "Of all the species listed between 1968 and 1995, only 7 -- or less than 1 percent -- have been recognized as extinct, and subsequently de-listed. The fact that almost 99 percent of listed species have not been lost speaks to the success of the Act as a mechanism for conservation of species that are at risk of extinction."

Millions of dollars have been spent toward Piping Plover recovery, no doubt greatly reducing the species' decline and improving its recovery potential. In this regard the Piping Plover is not typical of other listed species, most of which have received little or no funds for research or recovery efforts. More is known about the Piping Plover, and more protective measures have been undertaken on behalf its recovery, than for most of the other listed species combined. Despite such disproportionate investments, however, demographic models project the extinction of the Great Lakes/Great Plains populations sometime near the middle of the current century (Ryan et al. 1993, J. Plissner, pers. comm.)

The Piping Plover is one of about 650 species with an approved recovery plan. A recovery plan is essentially a set of goals and strategies, written by a group of biologists (i.e., a recovery team) with species-related expertise, and designed with the goal of recovering the listed species. The research described in this manuscript addresses many of the winter recovery goals set in the Piping Plover recovery plans.

Project Description

This dissertation details research I conducted between July 1991 and April 1994 describing the ecology of the federally - protected Piping Plover (*Charadrius melodus*) on wintering grounds along the Texas Gulf Coast (TGC). The northern and southern regions of the TGC present 2 different coastal ecosystems to nonbreeding Piping Plovers. One of the primary focuses of my research was to determine whether Piping Plover ecology differed substantially among these two coastal ecosystems. I approached this question by studying plover populations at 18 study sites along the TGC. I monitored plovers at 3 or more representative study sites within each coastal ecosystem, and within the ecotone region where the 2 ecosystems meet. I evaluated the effects of several habitat parameters and environmental variables on plover abundance and density, studied the diet and foraging ecology of plovers, and collected samples to describe the prey populations used by plovers at the 18 study sites. I used these measures to estimate and compare the resources available to plovers and the foraging success of plovers among the two coastal ecosystems.

The Focus of Piping Plover Recovery Efforts

On 11 December 1985, the Service issued a final rule recognizing 3 distinct breeding populations of Piping Plovers worldwide (U.S. Fish and Wildlife Service 1985). The larger 2 populations, breeding along the Atlantic Coast of North America and the North American Great Plains, were listed as threatened. A third population, much smaller than the others and breeding only along the shores of the North American Great Lakes, was listed as endangered. Two recovery teams were created by the Service, one to plan the recovery of the Atlantic Coast Population, and a second to do the same for both interior populations. Recognizing the link between species conservation and habitat conservation, both recovery teams placed a high priority on determining the habitat requirements of each population. Most research and management efforts focused on breeding populations (e.g., Prindiville-Gaines and Ryan 1988, MacIvor 1990, Nordstrom 1990, Mayer and Ryan 1991a, Mayer and Ryan 1991b), despite the fact that Piping Plovers spend the vast majority of their life cycle away from the breeding grounds (Bent 1929). The early bias toward breeding ecology was necessary to stem the species' steep decline (Ryan et al. 1993). The major causes for the decline of Piping Plovers were attributed primarily to the loss of breeding habitat (to development and water-control projects), increased depredation on eggs and juveniles, and the direct destruction of nests by human activities (Haig and Oring 1985).

More recently though, it has become apparent that the recovery of the Piping Plover may hinge on an understanding of the species non-breeding ecology and responsible stewardship of winter habitat. Recent events have focused increasing attention on the potential for a catastrophic loss of Piping Plovers during the 9-month nonbreeding period.

These include a series of hazardous material spills near Galveston Island and a persistent brown tide episode in the Texas Laguna Madre (Dunton 1994, Edwards 1995). Piping Plover winter habitat is threatened by hydrological changes associated with the Gulf Intracoastal Waterway (GIWW; Farmer 1991, Diaz and Kelly 1994), commercial development, and predicted sea level rises (Bildstein et al. 1991). These events pose less immediate, but potentially greater threats to the long-term population viability of the Piping Plover.

Research has begun to fill in the gaps in our understanding of the key aspects of Piping Plover winter ecology. Most work has focused on defining the species' winter range (Haig and Oring 1985, Nicholls and Baldassarre 1990a, Haig 1992). Early investigations have begun into such aspects of Piping Plover ecology as habitat associations (Nicholls and Baldassarre 1990b), movement patterns (Johnson and Baldassarre 1988), and activity budgets (Johnson and Baldassarre 1988). Most of these studies, however, have been limited by either time (a single field season; Nicholls and Baldassarre 1990b), or geography (a single study location; Johnson and Baldassarre 1988).

The winter distribution of Piping Plover populations is becoming clearer due to several recent census efforts (Haig and Oring 1985, Nicholls and Baldassarre 1990b, Haig and Plissner 1993, Eubanks 1994, Zonick and Ryan 1995, Elliott 1996). The first International Piping Plover Census (IPPC) was conducted in 1991. The winter portion of the 1991 IPPC accounted for a total of 3,451 Piping Plovers during a 2-week census of the presumed winter range of the species. The 1991 IPPC count represented approximately 60% (3,451 out of 5,482) of the number of breeding Piping Plovers recorded during the 1991 IPPC summer count of breeding Piping Plovers (not counting the number of young produced in 1991). Wintering Piping Plovers were observed along the Atlantic Coast from the southern tip of Florida to the upper portion of North Carolina.

Wintering birds also were recorded on the shores of the Bahamas and Cuba, but the majority of the winter population was observed along the Gulf Coast of the United States. Over 92% (3,206 out of 3,451) of all of the Piping Plovers observed during the non-breeding portion of the IPPC occurred along the Gulf Coast. Of these, nearly 60% (1,905 out of 3,206) were observed along the TGC. Several large regions of the TGC (e.g., the Land-Cut, Baffin Bay, and North Padre Island) received only partial coverage during the 1991 IPPC. Also, despite admirable efforts by a few individuals, the Gulf Coast of Mexico has yet to be surveyed to the extent of the United States Gulf Coast. It is very possible that a large portion of the birds unaccounted for on the winter portion of the IPPC occurred in these areas.

The second IPPC was conducted in 1996 (Elliott 1996). A total of 1333 Piping Plovers were recorded in Texas in 1996, down substantially from the 1991 count of 1905. Several factors varied between the 2 counts, however, and the 1996 count is almost certainly a less accurate count than was the 1991 IPPC. Whereas many sites that were missed in the 1991 IPPC were covered in the 1996 count, many areas that were covered in 1991 were omitted from the 1996 count. The difference in the coverage in 1996 was due in large part to an extended period of extremely low tides that made many areas inaccessible, and to a government furlough that greatly reduced the manpower available for the 1996 IPPC.

Piping Plover winter habitat requirements also have been recently investigated. Johnson and Baldassarre (1988) and Nicholls and Baldassarre (1990) described aspects of the major habitat types utilized by Piping Plovers, as well as some of the microhabitat characteristics that are predictive of Piping Plover presence. Johnson and Baldassarre (1988) observed Piping Plovers in the Mobile Bay complex of the Alabama Gulf Coast to use "sandflats," "mudflats," and "beaches" as winter habitats. Their research indicated that sandflats and mudflats were "used for feeding", and sandy beaches were used for "resting and probably roosting" (Johnson and Baldassarre 1988).

Nicholls and Baldassarre (1990b) used discriminant function analysis (DFA) to investigate the relationship between a number of microhabitat characteristics and the presence/absence of Piping Plovers throughout most of their winter range. Their analyses selected "...greater beach width, greater % mudflat, lower % beach and more small inlets ..." as the winter habitat characteristics predictive of Piping Plover presence/absence along the Gulf Coast of the United States. Along the Atlantic Coast, DFA selected "...the number of large inlets and passes, number of tide pools, % mudflat, beach width, and % sandflat as the major factors affecting (Piping Plover) presence or absence." (Nicholls and Baldassarre 1990b).

The nonbreeding behavior of Piping Plovers has been described for only selected locations. Piping Plovers wintering along the Alabama Gulf Coast were observed to spend the majority (76%) of their time foraging (Johnson and Baldassarre 1988). Tidal height was negatively correlated with plover foraging activity in Alabama. After resighting 12 of 19 plovers color-banded at Dauphin Island, Alabama, Johnson and Baldassarre (1988) concluded that Piping Plovers exhibit "relatively high site-fidelity...to wintering sites in coastal Alabama." Elliott and Teas (1996) described the behavior of plovers using beach habitat at 3 locations along the central Texas coast. Plovers at these 3 sites spent most of their time foraging (86.7%, 89.5%, and 96.2%). Elliott and Teas estimated levels of human disturbance at the sites based upon counts of vehicles and pedestrians and found pedestrian encounters caused plovers to shift from foraging behavior to some other activity. Vehicles did not have the same effect, suggesting plovers were less affected by this form of disturbance. However, Elliott and Teas found plover abundance to be negatively correlated with vehicle abundance.

Unanswered Questions

Most of the previous work done on nonbreeding *Piping Plovers* has been spatially or temporally restricted. For example, the conclusions by Nicholls and Baldassarre (1990a, 1990b) were founded primarily upon data collected from a collection of onetime visits to a large number of study sites throughout the winter range. Conversely, the research by Johnson and Baldassarre (1988) addressed specific aspects of Piping Plover ecology through multiple visits to a very small portion of the winter range. Whereas these approaches were appropriate for the scope of each project and provided a foundation toward an understanding of the winter requirements of Piping Plovers, they did not answer several key questions.

The habitat associations derived by Nicholls and Baldassarre (1990b) reflect only a portion of the parameters that might play a role in habitat selection by Piping Plovers. For instance, they did not consider such factors as tidal stage, prey density, and human disturbance in their analyses, yet these factors have been shown to significantly influence shorebird site-use and behavior (Burger et al. 1977, Connors et al. 1981, Hicklin and Smith 1984).

Johnson and Baldassarre (1988) provided new insight into the winter movements and winter activity of Piping Plovers. However, the limited spatial scale of their research constrains the degree to which their results can be used to describe general winter movements and behaviors of Piping Plovers, particularly within markedly different ecosystem types like the Laguna Madre systems in Texas and Mexico. Here also, the habitat descriptions were general in nature (e.g., sandflat, beaches) and were not related to proximate influences such as prey density or human disturbance.

Of central relevance to the recovery of the Piping Plover is the identification and protection of high quality winter sites. Generally, the quality of a particular habitat or location to Piping Plovers has been determined indirectly, based upon survey information or the presence of habitat features commonly associated with Piping Plover presence. In 1990, Nicholls and Baldassarre broadened the criteria for appraising a location's value to

Piping Plovers by ranking winter sites using a formula that incorporated judgments about the quality of local habitat features. According to their formula, sites having more than 40 plovers were ranked as "1" (i.e. most important sites). Sites were ranked as "2" (i.e. of secondary importance) if the site had between 20 and 40 plovers and met at least 2 of 3 criteria. The criteria were:

> "(1) habitat quality, i.e., excellent, with expansive mudflats adjacent to sandy beach; (2) historical data, i.e., presence on Christmas Bird Count at least once in previous five years; and (3) disturbance level, i.e. moderate to no disturbance at site (e.g., < 1.4 people and/or 0.2 off-road vehicles observed per km)."

Although the system's measure of habitat quality was subjective (by their own admission) and relied heavily on census data, the consideration of habitat features by Nicholls and Baldassarre resulted in a more credible ranking scheme by reducing the likelihood that a site might be given inflated stature based upon a single anomalous census. The consideration of human disturbance as one of the ranking criteria added another important dimension to the scheme. Nicholls and Baldassarre recognized that, when appraising a site's value to Piping Plovers, it was important to determine not only how many plovers occurred at a site, but also whether the habitat at that site was of sufficient quality to support the population (or an expanding population during the recovery process), and whether other environmental variables (e.g., human disturbance) were present that might compromise the site's apparent value.

Study Focus

In this study I present a site appraisal model predicting Piping Plovers abundance, and compare the quality of different habitat types and ecosystem types for Piping Plovers. I support these models by relating 3-year measures of Piping Plover site quality estimators (e.g., Piping Plover abundance, foraging efficiency) to an assemblage of simultaneously monitored habitat components (e.g., estimates of available habitat, prey population measures) and environmental variables (e.g., human disturbance measures) that are most likely to affect Piping Plover site quality.

My research focused on describing the effects of key habitat components and environmental variables on the abundance and foraging ecology of Piping Plovers in different habitats and ecosystem types along the TGC. I evaluated Piping Plover foraging success using several approaches and used these measures as a means of appraising the relative success of nonbreeding populations. I contend that, in addition to abundance, foraging success is one of the most appropriate means of appraising the quality of different habitats, sites and landscapes for Piping Plovers. Foraging activity has been shown to occupy the largest proportion of the diurnal activity of wintering Piping Plovers (Johnson and Baldassarre, Teas and Elliott unpublished data, pers. obs.). Maintaining fat stores is of primary importance to plovers and other migratory shorebirds (Evans 1976, Davidson 1981, Myers et al. 1987, Helmers 1992). Furthermore, because Piping Plovers are a federally-protected species, other means of appraising the relative condition of plovers (e.g., by direct measurement of fat stores from harvested birds) in different areas or habitats were not justifiable.

Research Objectives

The primary objectives of the research were as follows.

Objective 1. Characterize and compare the relative density of Piping Plovers among 2 coastal ecosystems and their ecotone.

Because Piping Plovers winter over a wide geographic range, encompassing several ecosystem types, this comparison is expected to guide Piping Plover recovery by determining how ecosystem type affects plover density.

Objective 2. Identify the spatial, temporal, and environmental factors that affect Piping Plover densities.

A specific goal associated with this objective was to determine whether differences in Piping Plover density can be explained by specific spatial, temporal or environmental parameters, or combinations of these conditions acting together. This will greatly extend the current knowledge associated with Piping Plover winter habitat use patterns.

Objective 3. Characterize the prey resources potentially available to Piping Plovers among the habitats and ecosystems used by Piping Plovers along the TGC.

These data will help determine the relationship between potential prey density and Piping Plover density and will support habitat quality appraisals.

4. Characterize the foraging ecology of Piping Plovers along the TGC, and identify the factors affecting foraging success.

Specific goals associated with this objective were to determine and compare:

a. The amount of time Piping Plovers spend foraging among major habitat types along the TGC;
b. Piping Plover diets among major habitat types and ecosystems along the TGC;
c. Estimated energy expenditures by Piping Plovers among major habitat types and ecosystems along the TGC;
d. Piping Plover foraging efficiency among major habitat types and ecosystems along the TGC;
e. Agonistic behavior by Piping Plovers among major habitat types and ecosystems along the TGC;

This information will provide additional knowledge about Piping Plover diets in different habitats and ecosystems and will allow for a comparison of the quality of the habitat types and ecosystems used by Piping Plovers along the TGC as appraised by the relative costs and benefits associated with foraging.

Objective 5. Identify the habitat components and environmental conditions that most strongly influence Piping Plover abundance at sites along the TGC.

Accomplishing this objective will help prioritize sites, or perhaps entire ecosystems, for conservation. This model will help direct the preservation or restoration of areas with quality habitat for wintering Piping Plovers by identifying the habitat components that are most likely to influence Piping Plover carrying capacity. With this knowledge, high quality habitat might be preserved in areas that are subject to development or other human modifications by guiding the design of future projects in a manner that is likely to minimize impacts to key habitat components. Similarly, this model will allow resource managers to more accurately predict the effects of changes associated with environmental conditions (e.g., bayshore tidal regimes, human disturbance), potentially leading to more effective habitat management for Piping Plovers during the nonbreeding season.

The research associated with these objectives is presented in 3 different, but interrelated chapters. Chapter 2 describes research addressing Piping Plover population density and the environmental factors affecting Piping Plover habitat use along the TGC (Objectives 1-3). Chapter 3 describes Piping Plover foraging ecology, and the factors that influence foraging success (Objective 4). Chapter 4 describes the factors influencing Piping Plover site abundance (Objective 5). In a summary chapter I discuss the implications of the findings on efforts to recover the Piping Plover, and recommend steps to improve the management of habitat along the TGC for plovers.

STUDY AREA

I selected the Texas coast as the geographic focus of this research because Texas supports the largest known portion of the Piping Plover winter population (Haig and Plissner 1993, Nicholls and Baldassarre 1990b). I examined the non-breeding ecology of Piping Plovers at 18 study sites along the Texas Gulf Coast (TGC). Three or more sites each were located within the 2 coastal ecosystems represented in Texas, the estuarine bay ecosystem, and the hypersaline lagoon ecosystem (Figure 1). Four more sites were located within the ecotonal transition between the 2 coastal ecosystems.

All sites but one (Laguna Atascosa National Wildlife Refuge) contained a stretch of ocean beach. Although site beaches differed somewhat with regard to prey population densities, levels of human disturbance, and beach width, beach habitat structure was similar at all study sites.

In contrast, bayshore habitat structure differed greatly among my study sites. Changes associated with a few key geomorphologic and environmental factors along the TGC have produced 2 markedly different coastal ecosystems, each characterized by very different bayshore habitats. Two factors, tidal regime and salinity, strongly influence the habitats that occur along the TGC.

Tidal amplitudes are attenuated along the entire TGC relative to other, less sheltered North American coastlines (Britton and Morton 1989). Tides affecting beach shore are similar along the Texas Gulf coastline. In contrast, the bayside tides vary markedly in different regions of the TGC, and often are not synchronized with beach tides.

The salinities of Texas bays also varies markedly. From Galveston Bay in the north to South Bay bordering Mexico, there is a progressive increase in salinity. Southern bays are saltier because they receive less freshwater from rains and riparian inflows, and lose greater relative volumes of freshwater to evaporation.

In the northern region of the TGC, extending from the Houston Ship Channel Pass south to Aransas Pass (Figure 1), tides are controlled predominantly by astronomical forces, baywater salinities are generally brackish (15 - 30 ppt), and the climax intertidal community is dominated by cordgrass (*Spartina alterniflora*). This region can most accurately be described as an estuarine bay ecosystem, and is referred to by this term, or by the term "bay ecosystem" hereafter in this report.

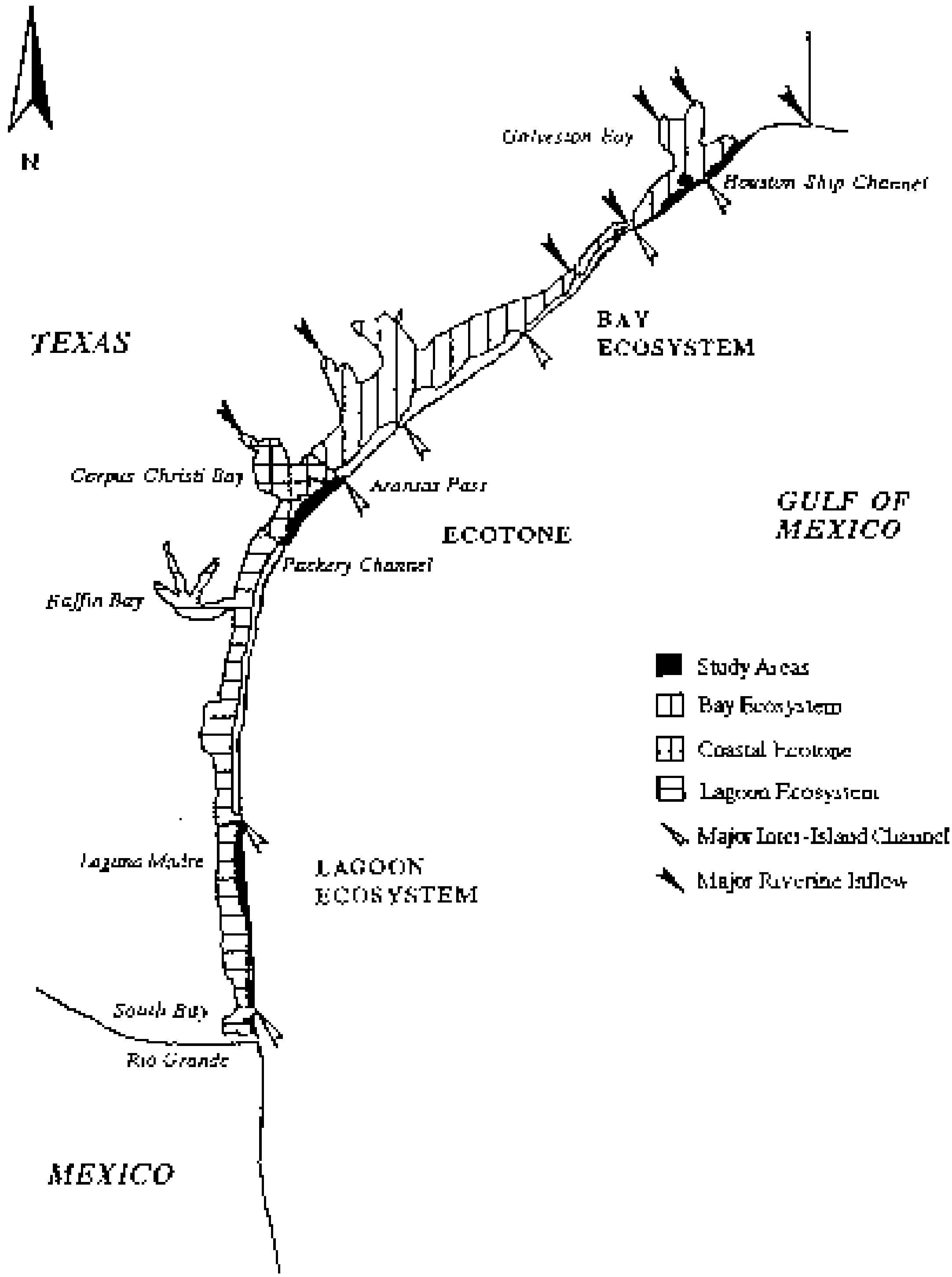


Figure 1. Schematic diagram of the Texas Gulf Coast illustrating the relative positions of the two major coastal ecosystems and the coastal ecotone.

About 50 km to the south, a different ecosystem becomes evident near Packery Channel and extends to the Rio Grande (Figure 1). In this region, tides are controlled mostly by shifts in winds and atmospheric pressure, particularly those accompanying winter cold fronts. Baywater salinities are often extreme (> 50 ppt), and the climax intertidal community is dominated by blue-green algal flats. This unique ecosystem is best described as a hypersaline lagoon ecosystem because it is characterized and maintained by recurrent periods of hypersalinity due to relative geographic isolation from other permanent bodies of water. This region is referred to as either the "hypersaline lagoon ecosystem" or the "lagoon ecosystem" hereafter.

Between these 2 ecosystems exists a transitional region where the tides are affected in mixed fashion by both winds and astronomical forces, salinities fluctuate between brackish and extreme, and the intertidal community is dominated neither by cordgrass, nor algal flats, but a mixture of both communities (Figure 1). This region can best be described as a coastal ecotone and is identified by this term, or by the term "ecotone" hereafter.

The Estuarine Bay Ecosystem and Study Sites

The Galveston Bay system of the upper Texas Coast typifies the landscape and habitat features of the estuarine bay ecosystem. The climate in this ecosystem ranges from humid to subhumid with average annual rainfalls between 80 - 125 cm (Texas General Land Office 1994). Temperatures generally range from winter minimum lows near 7°C to average summer highs near 35°C (Texas General Land Office 1994). Baywaters within the estuarine bay ecosystem are deeper than those in the lagoon ecosystem. Maximum depths of primary bays in the estuarine bay ecosystem range from about 1.3 m (Galveston Bay) to 4.0 m (Matagorda Bay) compared to the hypersaline lagoon ecosystem's shallow primary bay (Laguna Madre) which reaches a maximum depth of only about 1 m (Britton and Morton 1989). Primary bay salinities range from about 18 ppt in Galveston Bay to 23 ppt in Matagorda Bay (Texas General Land Office 1994). The intertidal regions of the bayshore in the estuarine bay ecosystem are dominated by densely-vegetated cordgrass marshes. Other typical plant species that flourish within this ecosystem include Marshhay cordgrass (*Spartina patens*), Glasswort (annual: *Salicornia bigelovii*, perennial : *Salicornia virginica*), Saltwort (*Batis maritima*) and Gulf cordgrass (*Spartina spartinae*). Unvegetated sand and mud flats appear as a narrow fringe along the marsh's border during periods of low tide. A few large (> 20 ha) unvegetated sand and mud flats occur in the bay ecosystem, usually adjacent to large tidal channels, or on the accreting side of jetties, but these flats comprise only a small percentage of the total area of bayshore habitat, most of which occurs as cordgrass marsh. The tides occur at a diurnal to semi-diurnal frequency, so that the unvegetated flats become available to shorebirds once or twice every 24 hours. The 3 sites monitored in the bay ecosystem were Bolivar Flats, Big Reef, and San Luis Pass (Figure 2).

Bolivar Flats. This site, located at the southeastern tip of Bolivar Peninsula in Galveston County, was composed of a single muddy sand flat, sandwiched between the northern jetty along the Houston Ship Channel and a cordgrass marsh (Figure 3). The marsh and sand flats at this site were growing as a result of the accretion of sediment transported by the Gulf longshore current, and trapped by the north jetty. Bolivar Flats was accorded protection via a 100-year lease to the National Audubon Society in 1992.

Big Reef. This site, located on Galveston Island in Galveston County, was an accreting wetland situated along the northern edge of the Houston Ship Channel's southern jetty (Figure 3). This site contained a small lagoon surrounded by a vegetated sandy spit. However, salinities in the lagoon were usually well below that of seawater (i.e., < 35 ppt). The lagoon was bordered by several small muddy sand flats fringed by patches of cordgrass marsh. A small tidal channel at the site's west side maintained a constant tidal exchange between the lagoon and the Houston Ship Channel. The City of

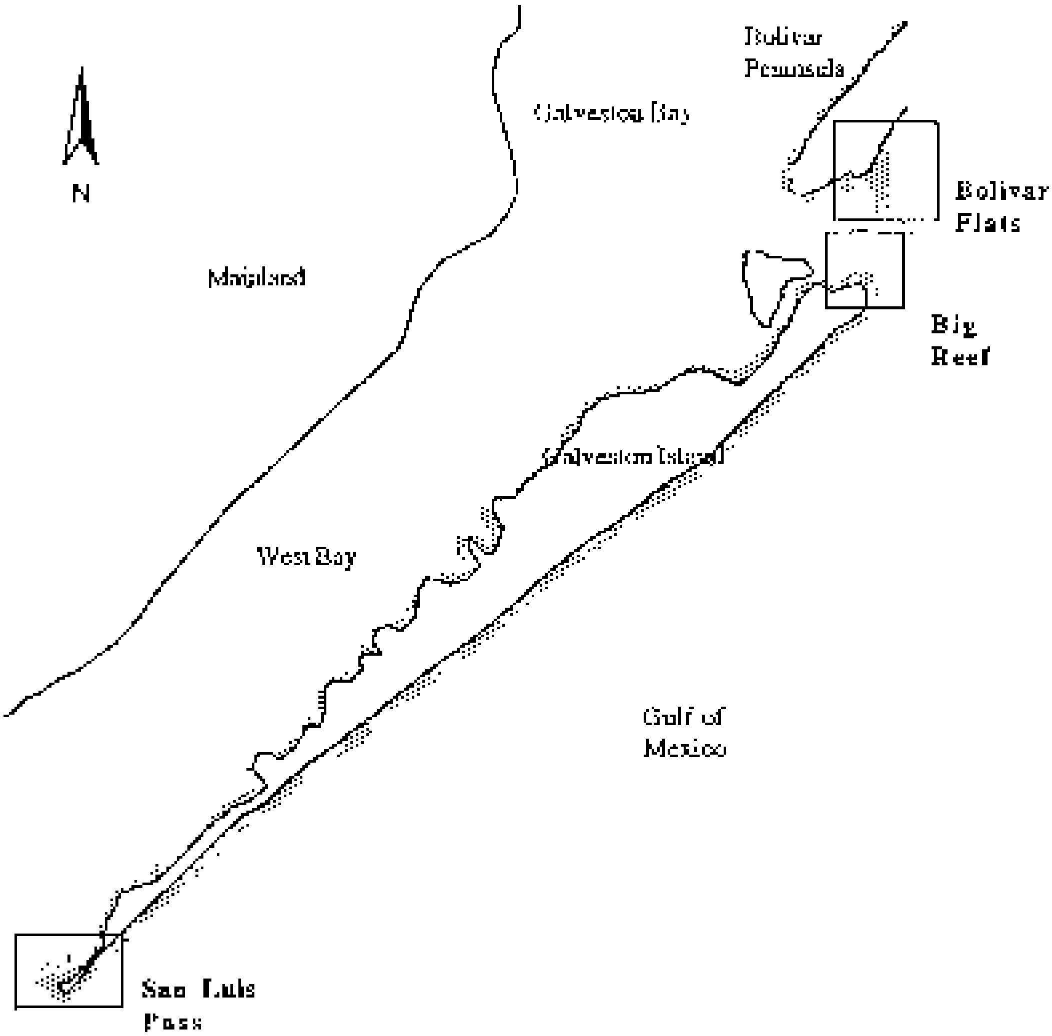


Figure 2. The relative locations of the study sites representing the bay ecosystem are illustrated. Bolivar Flats is located on Bolivar Peninsula. Big Reef and San Luis Pass are located on Galveston Island.

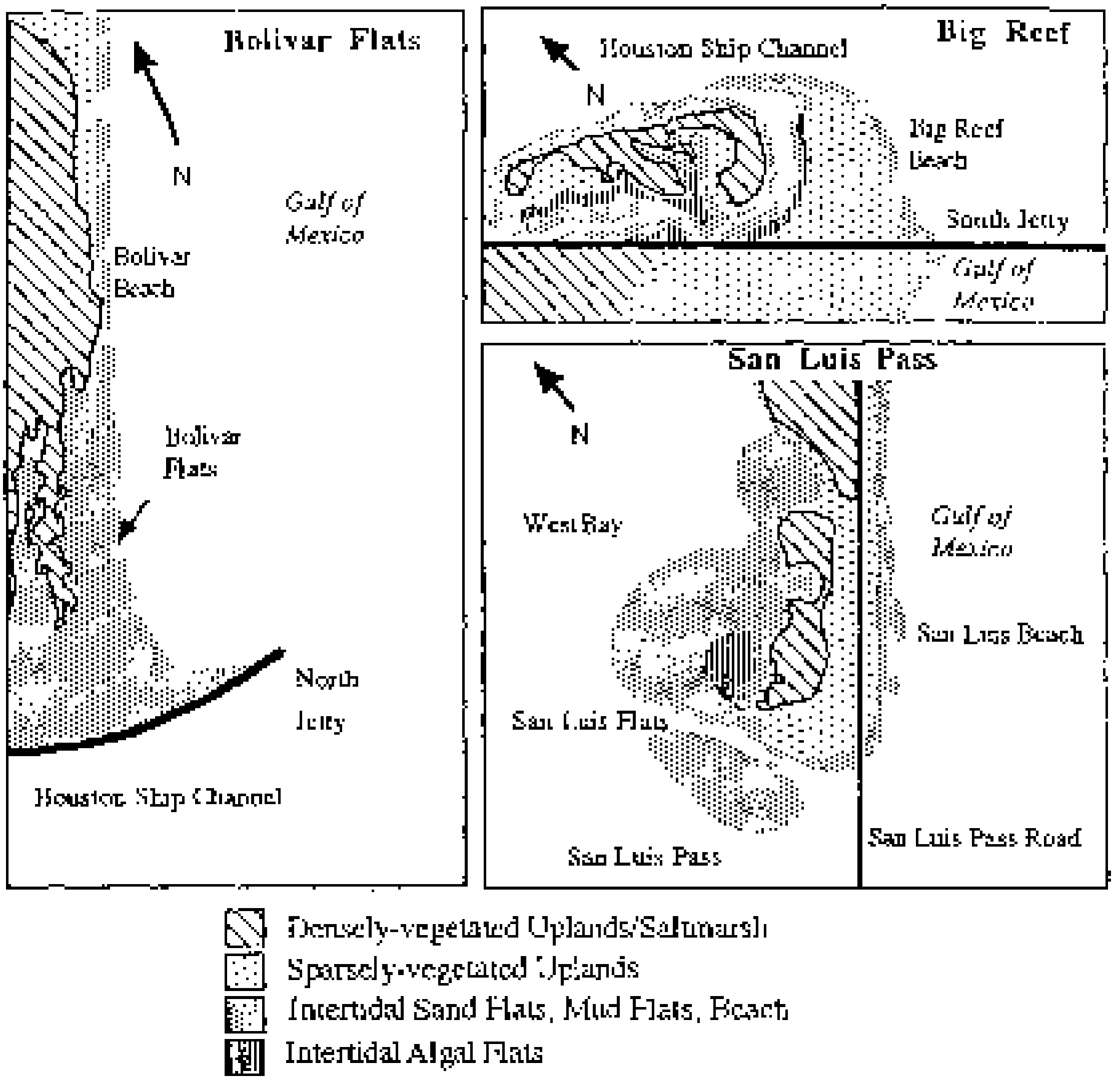


Figure 3. Schematic maps of the 3 Estuarine Bay Ecosystem Sites.

Galveston established the Big Reef study site as the Big Reef Nature Park soon after the conclusion of the study in 1994.

San Luis Flats. This site, located along San Luis Pass on the southwest tip of Galveston Island in Galveston County, was composed of several large sand flats bordered by coastal prairie (Figure 3). It was the only estuarine bay ecosystem study site that was not largely created by a man-made structure.

The Central Ecotone and Study Sites.

The ecotone exhibits habitat features diagnostic of each bordering ecosystem. Cordgrass marshes are present, but reduced in comparison to the bay ecosystem. The ecotone also is reflective of the lagoon ecosystem, as permanent algal flats occur in many locations. The vegetative community and baywater salinities are a blend of those typifying the 2 ecosystems, and tides are driven by both winds and astronomical forces. The 3 sites monitored in the ecotone were East Flats, Mustang Island State Park, and Packery Channel (Figure 4).

East Flats. This site, located near the northern tip of Mustang Island in Nueces County, was composed of a series of algal flats and mud flats separated by small patches of upland, and fingers of cordgrass and cattail (*Typha* spp.) marsh (Figure 5). A wastewater reclamation facility released a treated, low-salinity effluent into this wetland from its eastern border. Once sharing a broad tidal exchange with the waters of Corpus Christi Bay and Redfish Bay, this wetland had been surrounded to such a great extent by dredge spoil from the Corpus Christi Ship Channel and a residential access channel that the only remaining tidal exchange between the site's tidal flats and the surrounding baywater occurred through a few small channels along the site's southern border. The periodicity and magnitude of inundation experienced by the flats was erratic due to the restricted tidal flow.

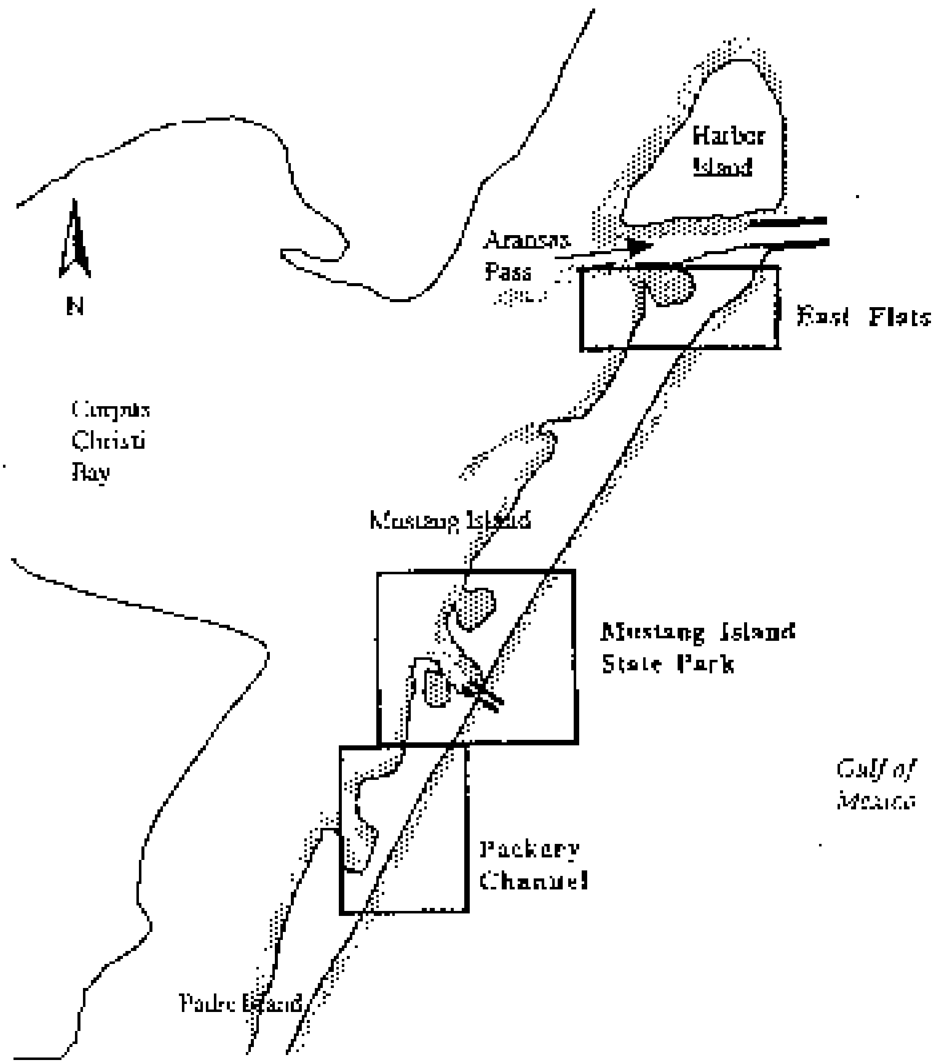


Figure 4. The locations of the study sites representing the Coastal Ecotone. All 3 sites are located on Mustang Island.

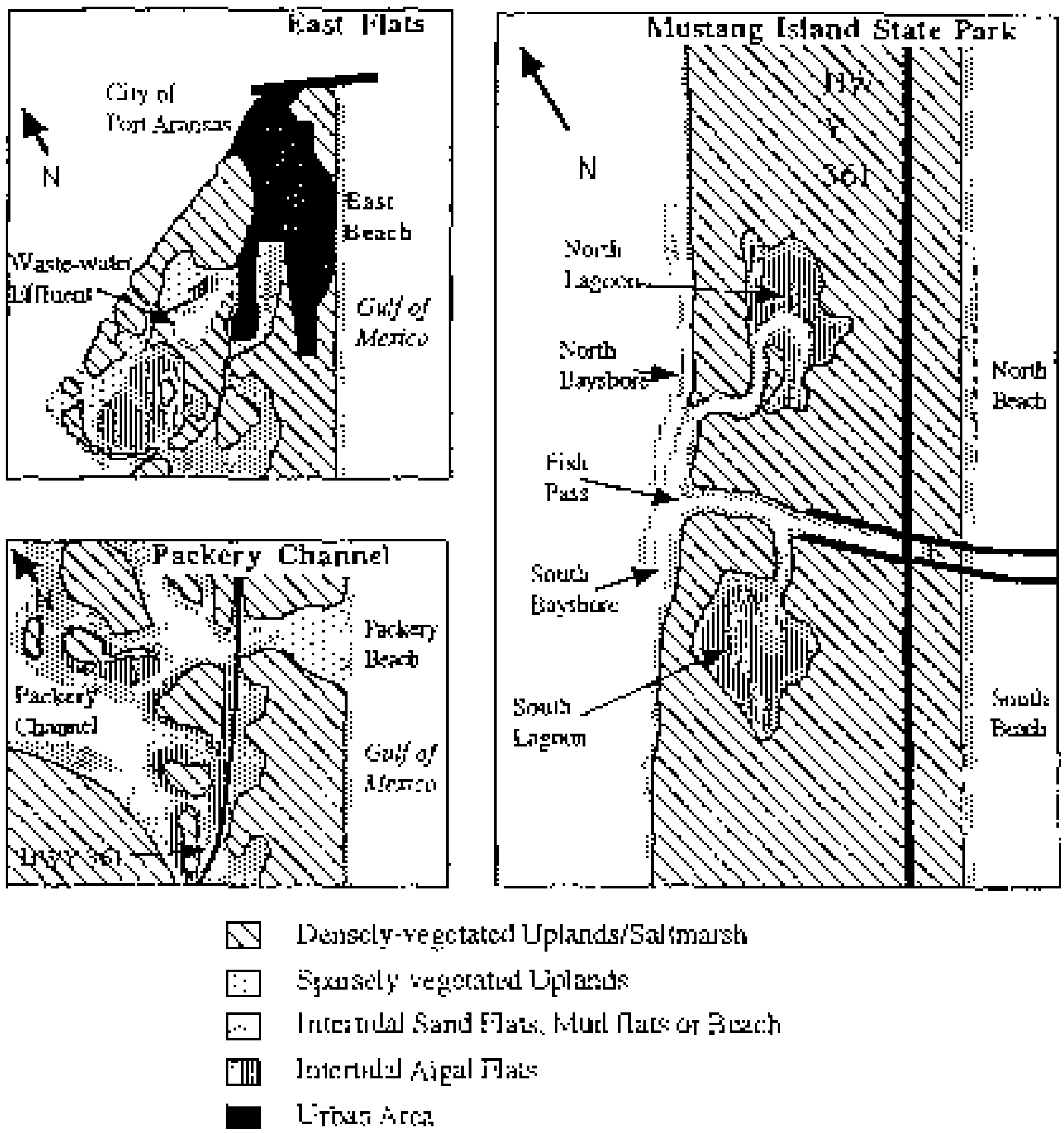


Figure 5. Schematic maps of the 3 Coastal Ecotone Sites.

Effluent released by the treatment facility into the wetlands probably contributed as much to the regular inundation of the wetland as did baywater swells.

Mustang Island State Park. This site, contained within the boundaries of the Mustang Island State Park (MISP), Nueces County, was divided by a man-made boat channel, identified on most maps as Fish Pass (Figure 5). The elevated banks along Fish Pass had eliminated most of the tidal exchange between the Park's tidal flats and the waters of Corpus Christi Bay, effectively splitting 1 large lagoon into 2 small lagoons, 1 each on the north (MISP - North) and south (MISP - South) side of the pass. An artificial channel re-established an effective tidal exchange between the northern lagoon and the bay, but the southern lagoon remained isolated from baywater tidal exchanges to a large extent during the study.

Packery Flats. This site, located along the northern shoreline of Packery Channel in Nueces County, was composed of sand flats and algal flats surrounded by coastal prairie (Figure 5). Due in part to its proximity to Corpus Christi, the beach at this site often experienced high levels of human disturbance.

The Hypersaline Lagoon Ecosystem and Study Sites.

The climate in this ecosystem ranges from subhumid to semiarid with average annual rainfalls between about 65 - 80 cm (Texas General Land Office 1994). Temperatures generally range from winter minimum lows near 9°C to average summer highs near 36°C (Texas General Land Office 1994). The lagoon ecosystem borders an extreme-saline lagoon, the Laguna Madre. The Laguna Madre has probably been without a significant riverine influence since the Rio Grande filled its estuary approximately 4,000 years ago (Rusnak 1960). The low relative amount of freshwater entering the Laguna Madre from rain or riverine inflow, coupled with a high evaporative rate, contributes to high local salinities (> 80 ppt) compared with those of the Gulf of Mexico (36 ppt), or the primary bays of the estuarine bay ecosystem (13 - 23 ppt; Britton and Morton 1989, Hedgpeth

1967). Smaller lagoons and tide pools associated with the Laguna Madre often exceeded 100 ppt during the study (pers. obs.). Few intertidal organisms flourish under these severe conditions (Copeland and Nixon 1974). The hypersaline environment of the Laguna Madre is probably most challenging to life at the lower trophic levels (e.g., plants, invertebrates), and it was at these levels that the hypersaline lagoon ecosystem appeared to differ most noticeably from the estuarine bay ecosystem (e.g., insects replacing polychaetes as the dominant intertidal macrofaunal groups). The life forms that are able to survive in this ecosystem, however, often occur in great numbers (Carpelan 1967, pers. obs.), presumably because they are released from competition with their saline-sensitive
counterparts in the estuarine ecosystem.

A considerable portion of the intertidal area in the lagoon ecosystem is covered by a sheet-like matrix described as a "blue-green algal mat" or "algal mat." Flats covered by algal mats are referred to as "algal flats" (regardless of the underlying substrate) and cover hundreds of square kilometers in the lagoon ecosystem (Pulich and Rabalais 1986, Tunnell 1989). Algal mats are composed of a mix of blue-green algae, dominated by *Lyngbya confervoides*. Algal mats also contain a variety of pennate diatoms (Pulich and Rabalais 1986, Sorensen and Conover 1962). Although most algal mats are only a few millimeters thick, algal flats have been shown to be 20-40% as productive as cordgrass marshes (Pulich and Rabalais 1986).

Plant species that flourish in the lagoon ecosystem include Glasswort (annual: *Salicornia bigelovii*, perennial: *Salicornia virginica*), Saltwort (*Batis maritima*), Sea lavender (*Limonium nashii*), Key Grass (*Monanthochloe littoralis*), and Sea Purslane (*Sesuvium portulacastrum*). Only a handful of hypersaline ecosystems exist world-wide, and the Laguna Madre is one of the largest and most extensively studied (Britton and Morton 1989).

Due to several unique characteristics of the wind-tidal flats along the Laguna Madre (e.g., hypersalinity, low-human population density), the bayshore margins of the mainland land mass also exhibit large areas of unvegetated intertidal flat habitat. In contrast, mainland shores in the bay ecosystem are generally narrow and are dominated by densely-vegetated cordgrass marsh habitat, or have been converted to human developments. Because Piping Plovers generally avoid densely-vegetated habitat (pers. obs., Brush 1995), much of the mainland intertidal habitat in the bay ecosystem is unsuitable for Piping Plovers, whereas the mainland flats in the lagoon ecosystem exhibit large areas of suitable habitat. Accordingly, both mainland and barrier landforms were represented by study sites within the lagoon ecosystem.

The 3 sites monitored in the lagoon ecosystem were Laguna Atascosa National Wildlife Refuge, South Padre Island, and South Bay (Figure 6). At 1 of the sites (South Bay), the mainland and the local barrier (Brazos Island) were connected by a land bridge formed by Highway 4, and there was no clear division between the 2 landforms. To clarify this situation, I defined all flats $\geq$ 5 km from the Gulf shoreline as "mainland" flats, and all flats < 5 km from the Gulf shoreline as "barrier" flats. Because the beach habitat was, by definition, always associated with the barrier landform (i.e., < 5 km from Gulf Coastline), this landform classification existed only for bayshore habitat. Furthermore, because none of the study sites in the bay ecosystem nor the ecotone were $\geq$ 5 km from the Gulf Coastline, mainland sites occurred only within the lagoon ecosystem, and comparisons between parameters among the mainland flats and barrier flats are restricted to those within this ecosystem.

Laguna Atascosa National Wildlife Refuge. This site, located within the boundaries of Laguna Atascosa National Wildlife Refuge (LANWR) in Cameron County, was composed of a series of large algal flats and mud flats (Rincon Buena Vista Flats, Elephant Head Cove Flats, Horse Island Flats, Redhead Cove Flats and Yucca Flats)

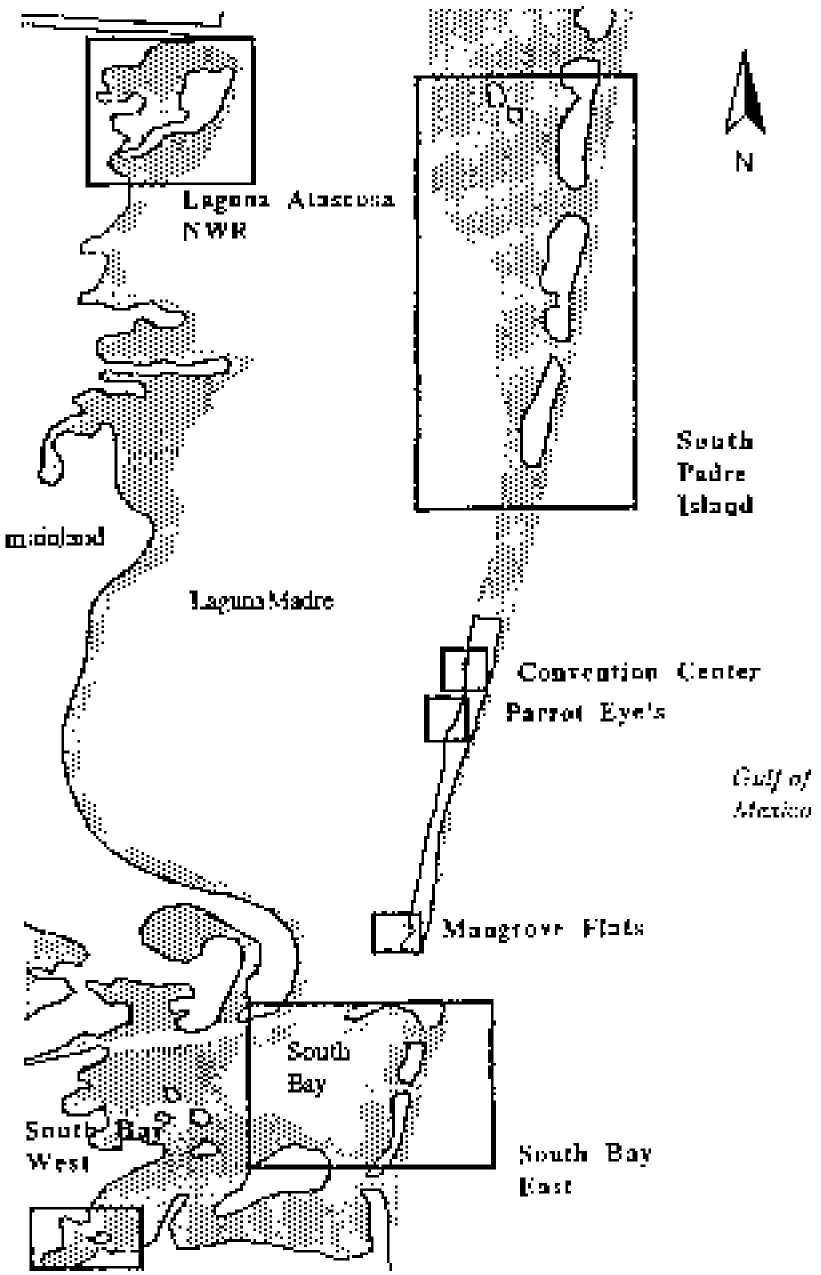


Figure 6. The locations of the study sites representing the Hypersaline Lagoon Ecosystem. Sites are located at Laguna Atascosa National Wildlife Refuge (mainland sites only), South Bay (mainland and barrier island site) and South Padre Island (barrier island sites only)

associated with a system of coves near Horse Island (Figure 7). All of the flats were > 5 km from Gulf Coastline, and were thus classified as "mainland" flats. The flats were bordered by a dense coastal thicket of Tamaulipan thorn scrub elevated from the flats by a 1-3 m steep cliff-line. Like the East Flats study site, this site had been nearly removed from tidal exchange from the Laguna Madre by dredge spoil deposits and an elevated access road. This site occurred at roughly the same latitude as the South Padre Island site (Figure 6).

South Bay. This site, located along the shoreline of South Bay in Cameron County, was composed of 2 large algal flats and mud flats surrounded by an elevated coastal prairie/savanna (Figure 7). One of the flats, South Bay West, was located $\geq$ 5 km from the Gulf, and was classified as a "mainland" flat. The other flat, South Bay East, was located within the 5 km zone, and was classified as a "barrier island" flat. Dredge spoil deposits associated with the Brownsville Ship Channel had substantially reduced the natural tidal exchange between South Bay and the Laguna Madre.

South Padre Island. This site on South Padre Island in Cameron County, was composed of 1 large flat and a series of small, isolated flats (Figure 7). The smaller flats (Mangrove Flats, Parrot Eye's Flats and Convention Center Flats) were situated within the commercially-developed, southern tip of the island. The large flat (North Flat) was located immediately north of all development at the northern terminus of highway P100. All of the flats were within the 5 km zone of the Gulf and were classified as "barrier island" flats. Algal flats and sand flats were the dominant habitat types at all of the locations on South Padre Island

Wetland Classification of Study Sites

I classified the landscape and wetland habitat features at the sites (Table 1) using a slightly modified version of the wetland classification system developed by Cowardin et

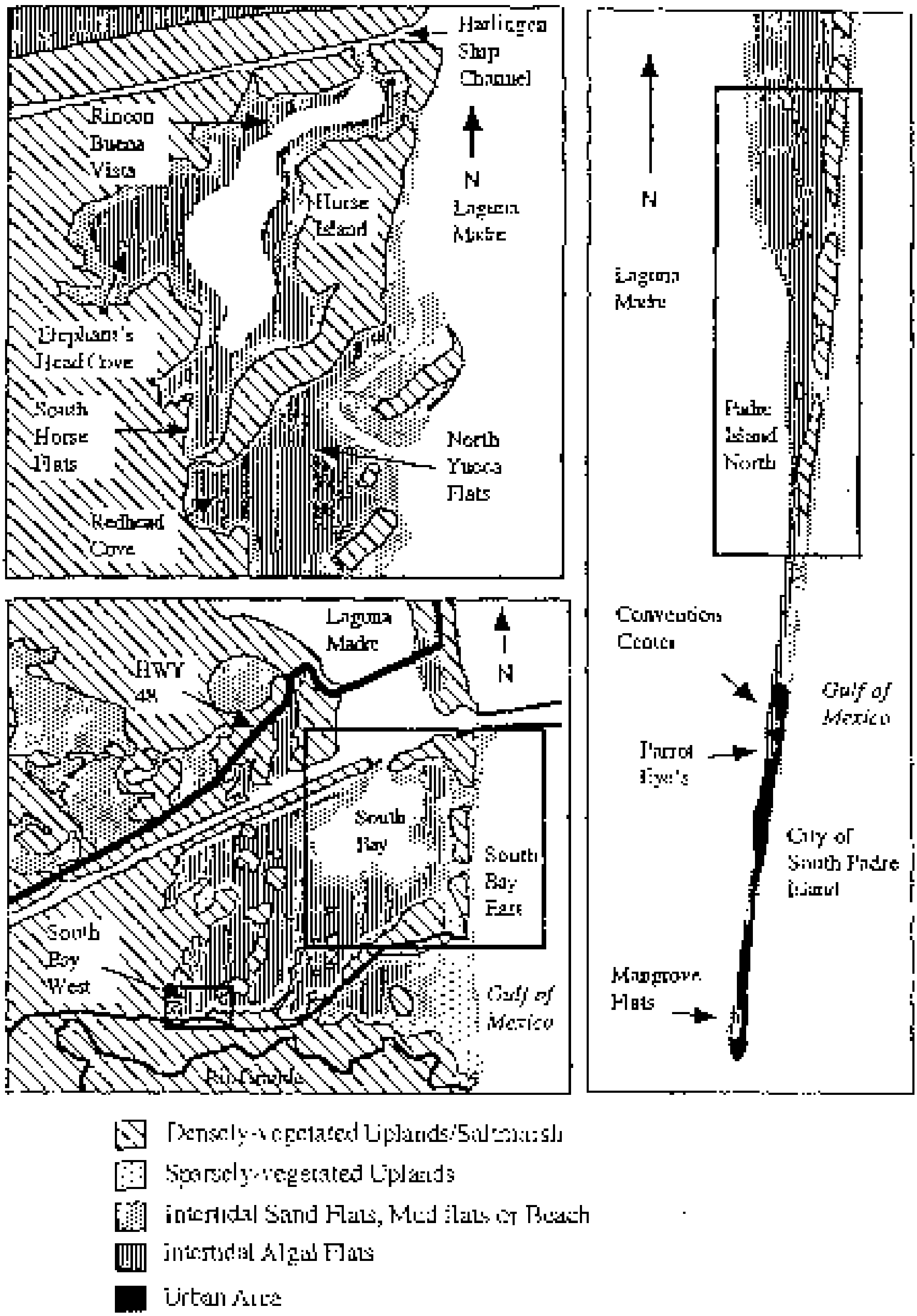


Figure 7. Schematic maps of the 3 Hypersaline Lagoon Study Sites

Table 1. Classification of beach and bayshore habitat among study sites based on a modification of the wetland classification system designed by Cowardin et al. (1979). Modifiers for such parameters as tidal regime and algal mat prevalence have been added to augment the wetland characteristics that provide distinction among study locations.

Study Site	System	Subsystem	Tidal Regime	Tidal Force	Substrate Subclass	Salinity Modifier	Algal Mat
Beaches							
Estuarine Bay Ecosystem							
Bolivar Flats	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Big Reef	Estuarine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
San Luis	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Coastal Ecotone							
East Flats	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
MISP	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
Packery	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Hypersaline Lagoon Ecosystem							
South Bay	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
South Padre	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
Tidal Flats							
Estuarine Bay Ecosystem							
Bolivar Flats	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Absent
Big Reef	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Ephemeral
San Luis	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Ephemeral
Coastal Ecotone							
East Flats	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Euhaline	Present
MISP	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Euhaline	Present
Packery Flats	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Polyhaline	Present
Hypersaline Lagoon Ecosystem							
LANWR	Marine	Intertidal	Irregular	Wind	Mud	Euhaline	Dominant
South Bay	Marine	Intertidal	Irregular	Wind	Mud	Hyperhaline	Dominant
South Padre	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Hyperhaline	Dominant

al. (1979). Modifiers were added to the classification system to describe the tidal regime, tidal force, salinity and presence of algal mats at each site.

Site Visitation Schedule

The bay ecosystem, lagoon ecosystem, and the ecotone were visited in alternating fashion throughout the nonbreeding period, with visits to each area lasting approximately 1 month. In this way, each area was visited for approximately 3 months during each 9 month field season. During each of the 1 month visits, the sites within the site group were visited in alternating fashion. Because some sites were more difficult to access, and required the availability of an ATV, or relatively dry roads, some sites were visited more frequently than others. For example, the large, northern flat on South Padre Island (Figure 7) was accessible only with an ATV. Because ATVs were not always available, this site was visited less frequently than were the other 2 sites in the lagoon ecosystem. The East Flat site (Figure 5), located in the ecotone, was added to the study late in the second year, and was visited less frequently than were the other 2 sites in the ecotone.

Site Selection Criteria

I selected study sites that were reasonably accessible (e.g., by car, ATV or walking) and supported large numbers of Piping Plovers and Snowy Plovers (*Charadrius alexandrinus*) during either the 1991 IPPC, or during preliminary surveys I conducted between July 1991 - September 1991. In general, natural land formations were used to delineate site boundaries (e.g., habitat transitions, water boundaries, lomas [islands of upland prairie surrounded by tidal flats]). I selected sites that were representative of their respective ecosystems. The lagoon ecosystem study sites were larger than the sites within the bay ecosystem, reflecting the more expansive nature of the wind-tidal flats of the Laguna Madre. The bay ecosystem sites were composed predominantly of sparsely vegetated and unvegetated sand flats. The lagoon ecosystem sites were composed predominantly of sparsely vegetated and unvegetated mud flats, sand flats and algal flats.

The sites within the ecotone were intermediate in size compared to the sites in the 2 ecosystems, and contained a combination of sand flats and algal flats.

Human-engineered Alterations

To varying degrees, all of the study sites owe their present form to the influences of human-engineered manipulations. Bolivar Flats and Big Reef are supplied by sediment that is either trapped or redirected by the jetties erected to maintain the channel depth of the Houston Ship Channel. In contrast, the tidal flats at San Luis Pass may have been reduced by the presence of the jetties which trap sediment at Bolivar Flats and Big Reef that normally may have accreted at San Luis Pass. The flats associated with the East Flats, Mustang Island State Park, Laguna Atascosa National Wildlife Refuge, and South Bay study sites all appear to have been substantially affected by dredge spoil (pers. obs) Portions of Packery Channel are occasionally deepened by dredging.

Without question the large northern flat on South Padre Island has been less affected by human manipulation than any of the other study sites I monitored for this research. But this site too, was has been substantially altered by human design. Spoil dredged from Mansfield Channel erodes onto the flats during periods of strong north winds associated with winter fronts. The foredunes along the flat's Gulf border, stripped of large tracts of stabilizing vegetation by ATVs, release large volumes of sand into the prevailing southeastern winds (F. Judd, pers comm.). The sand, in turn, has begun to swamp hundreds of hectares of intertidal habitat. Waters entering the Laguna Madre through the Mansfield Channel, the Harlingen Ship Channel, and the Land Cut (a section of the GIWW connecting the once isolated upper and lower Laguna Madre systems) have reduced the overall salinity of the Laguna Madre (Diaz and Kelly 1994). The Harlingen Ship Channel carries hazardous materials from the Rio Grande Valley agricultural industry into the lagoon.

Study Period

I collected these data over a period of 3 consecutive years incorporating large portions of 3 consecutive nonbreeding seasons beginning in July 1991 and ending in April 1994. Although I collected some data during very early (i.e., July) and very late (i.e., April) portions of the nonbreeding period, most of the data were collected between mid-August and late-March.

CHAPTER II. PIPING PLOVER DENSITY

INTRODUCTION

The largest concentrations of nonbreeding Piping Plovers occur along the western Gulf Coast, particularly in Texas (Nicholls and Baldassarre 1990b, Haig and Plissner 1993, Elliott 1996). The local distribution of nonbreeding Piping Plovers along the Gulf Coast has been linked to such habitat features as wide beaches, large mudflats and small inlets (Nicholls and Baldassarre 1990a). However, other habitat and environmental features that are known to affect shorebird abundance have not been studied in association with Piping Plover distribution. Climatic factors and tide cycles often strongly influence shorebird activity and habitat use patterns (Pienkowski 1983, Puttick 1984, Colwell 1993). Human disturbance also has been shown to alter shorebird behavior in ways that might affect population density (Burger and Gochfeld 1991, Pfister et al. 1992, Elliott and Teas 1996). Spatial and temporal factors, such as habitat interspersion (Connors et al. 1981, Handel and Gill 1992, Farmer and Parent 1997), time of day (Robert et al. 1989, Thibault and McNeil 1994, McNeil and Rompre 1995), and time of year (Baker and Baker 1973, Withers and Chapman 1993) also can affect shorebird behavior, habitat use, and population density.

Identifying the habitat and environmental parameters that most strongly influence Piping Plover habitat use patterns and population density will provide valuable insight for the process of preserving locations and habitat types important to Piping Plovers. To address this goal I monitored Piping Plover density and abundance in association with the factors described above. I monitored plovers at different times of the day during the winter period and both migratory periods (spring and fall) to address temporal variations in nonbreeding ecology. I focused my research within 4 nested spatial scales: 1) the ecosystem scale, 2) the site scale, 3) the habitat scale, and 4) the microhabitat scale.

METHODS

Objective 1. Piping Plover Density

In objective 1, I proposed to establish and compare the relative densities of Piping Plovers among the dominant habitat types and ecosystem types along the TGC. To accomplish this objective, I conducted regular censuses at the 2 dominant habitat types (beach and bayshore) at 18 study sites located within the 2 ecosystems and the ecotone zone between the 2 ecosystems.

I counted Piping Plover populations during each site visit (see Study Areas for site visitation schedule). Because beach and bayshore habitats were spatially disjunct at most of the sites, I counted these areas separately. However, within each of these 2 habitats, bird counts were of the entire site. In general, I conducted only 1 survey/habitat during each site visit, however when tide levels changed dramatically during a site visit, I occasionally conducted a second survey under the altered tidal condition.

Beach Piping Plover density was calculated by dividing plover beach by the length of beach surveyed. Bayshore Piping Plover density was calculated by dividing plover bayshore counts by the average area of bayshore habitat available at each site during the study. The average area of available bayshore habitat was estimated by multiplying the total potential area of bayshore habitat at each site by the average percent bayshore tidal amplitude (described below) recorded at that site during the study.

Objective 2. Factors affecting Piping Plover density.

In objective 2, I sought to identify the factors affecting Piping Plover density. To accomplish this objective, I monitored an array of environmental, temporal, and spatial variables.

Variables evaluated for their effects on Piping Plover density were 1) bayshore tidal amplitude, 2) beach tidal amplitude, 3) climatic conditions, 4) human disturbance,

5) season, 6) time of day, 7) habitat and microhabitat types, and 2 spatial variables: 8) landform and 9) ecosystem.

Bayshore tidal amplitude

During each site visit, I recorded the level of bayshore tidal inundation as one of 5 ranked values. The ranks corresponded to visual estimates of percent tidal inundation of the total available area of Piping Plover habitat at each site. The ranks (very low, low, moderate, high and very high) corresponded to estimated percent tidal inundation levels equal to 0, 1 - 24, 25 - 75, and 76 - 99, and 100, respectively. During very low tides (i.e., ~ 0% inundation) the tidal flats were judged to be emergent to the maximum extent possible. During very high tides (i.e., 100% inundation), the flats were completely submerged, and only upland habitat remained emergent. Very high tide conditions usually were associated with storm tides during the summer-fall hurricane season or strong north fronts during the winter period.

Visual estimates of tidal inundation were used instead of tide gauges because the substrate associated with most of the bayshore habitat was often unstable, preventing the use of permanently located tide gauges on many of the tidal flats. Initial attempts to place site-associated tide markers resulted in almost complete loss due to tidal erosion in some areas and vandalism in others. Whereas professional tide monitors are maintained in some locations along the Texas coast these gauges measure the tidal amplitude in areas that were often far removed from the study sites. These monitors were designed to measure tide levels within the deeper regions of the bays, and would have provided very poor estimates of tidal inundation of the broad wind tidal flats at many of the sites. For these reasons, I determined visual estimation to be the best method for accurately documenting the local bayshore tidal conditions.

For the purpose of data analyses, I ranked bayshore tidal conditions as either emergent or inundated. Bayshore conditions were considered emergent if the tide was either very low, low or moderate (i.e., if inundation was estimated to be < 75%). If the tide was estimated to be high or very high (i.e., ≥ 75% inundation) the bayshore tidal conditions were ranked as inundated.

I appraised the total potential area of bayshore habitat at each site by digitizing the boundaries of all intertidal and sparsely-vegetated supratidal habitat from U.S. Geological Survey Topographic Quadrangle Maps into a geographic information system (Atlas Geographic Information System, Strategic Mapping Inc., Santa Clara, California). I referred to aerial infrared photographs to guide the delineation of tidal boundaries. In many cases, man-made or natural structures (e.g., seagrass beds, upland vegetation transitions, duck blinds) helped locate the extreme low and high tide boundaries.

Beach Tidal Amplitude

I estimated beach tidal amplitude by measuring beach width. I measured beach width at 3 sites (Bolivar Flats, Mustang Island State Park North Beach, and Packery Channel). These were the only sites that had stable beach landmarks, such as beach mileage signs, that I was able to use as consistent reference points to collect comparable beach width measures. I defined beach width as the distance between the swash boundary and the vegetation line on the upper beach.

Climatic Conditions

During each site visit, I measured air temperature, wind speed, and precipitation and used these data to classify climatic conditions as either harsh or mild. All three of these variables have been shown to adversely affect the foraging effectiveness of plovers and other visually foraging shorebirds, often reducing their net energy intake rates (Goss-Custard 1984, Davidson 1981, Pienkowski 1981). Plovers and other visually foraging shorebirds have been observed to feed more slowly during cold periods and rainy periods, possibly due to reduced prey activity (Goss-Custard 1970, Pienkowski 1981).

Air temperatures ranged from near 0°C to greater than 30°C during the study (data not shown). Winter precipitation varied from very dry during drought periods to very wet during El Niño cycles, or during months when the coast experienced heavy rain in association with tropical storms or winter north fronts. Winds were generally most strong during storm events or winter north fronts, often topping 30 knots during these periods.

Rather than attempt to analyze the effects of individual climatic variables on Piping Plovers, my analyses focused on comparing the ecology of Piping Plovers during periods of severe climatic stress (i.e., those typical of winter storm events) against that during periods of more clement conditions (i.e. those between winter storm events).

I classified climatic conditions as harsh if the air temperature was ≤ the average associated with north fronts (10-14°C), and if the wind speed was also ≥ the average associated with north fronts (5 - 20 knots). Climatic conditions also were considered harsh if it was extremely cold (0 - 4°C), regardless of the wind speed or precipitation, or if it was raining, regardless of the air temperature or wind speed. Between 5 - 14°C, the wind speed-temperature combination determined my ranking. Harsh conditions were judged to have occurred if the air temperature was between 10 - 14°C, and the wind speed was > 20 knots, or if the air temperature was between 5 - 9°C, and the wind speed was above 5 knots.

Human Disturbance

I recorded the number of vehicles present during each of the plover surveys and used vehicular density (vehicles/ha at bayshore habitat and vehicles/km at beach habitat) as an estimate of human disturbance

Season and Time of Day

I classified seasons according to the migratory period and the winter period, which are the 2 major stages of the annual life cycle when Piping Plovers occur in Texas. The winter period was defined as 1 November - 20 February, and the migratory period was defined as 1 July - 30 October, and 21 February - 15 May. These periods closely reflect the boundaries of the migratory and winter periods reported by others (Eubanks 1994, Haig 1992). I classified surveys as either morning (<12:00) or afternoon (>12:00).

Habitats and Microhabitats

During bird counts, I classified habitat as either beach or bayshore habitat. I considered beach habitat to be that directly bordering the Gulf of Mexico. All other foraging habitat (i.e., that directly bordering baywater) was considered bayshore habitat. At locations where the two habitats meet, such as at the end of a barrier island (e.g., San Luis Beach and San Luis Flats), the point at which the shoreline bends away from the Gulf was considered the transition between the two habitats.

I distinguished 2 microhabitats on beaches, both occurring within the intertidal zone where the sand was still moist at the surface due to recent inundation. I classified the portion of the intertidal zone where the swash regularly wetted the substrate as the swash zone. The moist portion of the intertidal zone that lies adjacent to, but above, the swash zone was classified as the upper beach.

I recognized 2 microhabitats on bayshore flats. Flats with an algal mat were classified as algal flats, and those without an algal mat were classified as sand flats.

Data Analysis

All analyses were performed using JMP, version 3.1. JMP is a statistical program written by SAS Institute Inc., Cary, NC. Advanced statistical analyses (i.e., beyond the calculation of means, standard errors, etc.) consisted of one-way and multi-factor analyses of variance (ANOVA), linear regressions, and multiple regressions.

One-Way ANOVA

One-way ANOVAs were employed to compare numerous relationships, primarily the effects of habitat components, environmental variables, temporal variables and spatial variables on the density of Piping Plovers or prey populations. Where appropriate, one-way ANOVAs were accompanied by multi-factor ANOVAs to support the evaluation of a particular parameter's effect either alone, or in combination with other related parameters.

Multi-factor ANOVA

Multi-factor ANOVA models were constructed to investigate the relative influences of habitat components, environmental variables, temporal variables and spatial variables on the density of Piping Plovers, total benthic prey, polychaetes, crustaceans, and insects. To build models incorporating all of the relevant parameters, it was necessary to omit some of the sites with smaller data sets from some of the models. For example, a model investigating the full complement of environmental factors affecting Piping Plover bayshore densities must contain data collected at each site during each of the following 8 different sets of conditions:

1. Emergent bayshore habitat, migratory season, mild climate;
2. Emergent bayshore habitat, migratory season, harsh climate;
3. Emergent bayshore habitat, winter season, mild climate;
4. Emergent bayshore habitat, winter season, harsh climate;
5. Inundated bayshore habitat, migratory season, mild climate;
6. Inundated bayshore habitat, migratory season, harsh climate;
7. Inundated bayshore habitat, winter season, mild climate;
8. Inundated bayshore habitat, winter season, harsh climate:

In this particular example, all 8 condition sets did not occur at all of the sites during the study. Therefore, I developed a multi factor ANOVA model using data collected at a smaller group of sites (4 sites, in this example) where I had obtained data under all of the above conditions.

Nested Parameters

The study site variable was built into the multi-factor ANOVA model as a nested parameter. Each site contributing data to the model was nested within the ecosystem (or ecotone) in which it occurred. Nesting the study site parameter within the ecosystem parameter instructed the model to assess the contribution of intra-ecosystem (i.e., inter-site) variability as a component of the effect of the ecosystem parameter on the response variable.

Regression Analysis

Relationships between 2 continuous variables were investigated using linear regression (e.g., the relationship between Piping Plover beach density and beach vehicular density).

RESULTS

Objective 1. Piping Plover Density

Beach Density

Piping Plover beach density varied from about 0.4 birds/km to > 3.5 birds/km (Table 2). When only foraging birds were considered, the smallest average spacing between plovers ranged from about 1 bird every 50 m at the Mustang Island State Park - South site to about 1 bird every 840 m at the South Padre Island - North site. At most sites, plovers were spaced 100 - 200 m apart during the period of high abundance of foraging birds.

Mean Piping Plover density was below 3 birds/km at all but one of the sites within the bay and lagoon ecosystems, but exceeded 3 birds/km at all of the ecotone sites (Figure 8).

Bayshore Density

Piping Plover bayshore density varied from 0 birds/100 ha to almost 150 birds/100 ha (Table 3; Figure 9). The highest average densities throughout the study were observed at the 3 small flats on South Padre Island. Of the flats larger than 10 ha, high plover densities (> 49 birds/100 ha) were recorded at all 3 bay ecosystem sites, and at the South Padre Island - North site (Table 3; Figure 9).

Objective 2. Factors Affecting Piping Plover Density

Ecosystem Type and Bayshore Tidal Amplitude

Ecosystem type ($P < 0.0001$) and bayshore tidal amplitude ($P < 0.0001$) had a significant effect on Piping Plover beach density. Plover populations were significantly higher at ecotone beaches than at bay beaches ($P < 0.0001$; Table 4) or lagoon beaches ($P = 0.0002$; Table 4). There was no difference in plover density at bay and lagoon beaches ($P = 0.5767$, Table 4)

Ecosystem type ($P = 0.0448$) and bayshore tidal amplitude ($P < 0.0001$) had a significant effect on Piping Plover bayshore density. I performed this analysis using barrier island data only. Piping Plover density was significantly higher on barrier island

Table 2. Abundance, spacing, and density estimates of Piping Plovers at beach habitats at sites along the Texas Gulf Coast, 1991-1994. The length of beach (BL) monitored at each site is presented in kilometers. Abundance is presented as the mean and maximum (Max.) number of Piping Plovers recorded at each site. Spacing describes the minimum (Min.) average distance (m) between Piping Plovers as estimated by dividing the maximum abundance of foraging Piping Plovers only (data not shown) by the length of beach at each site. Mean and maximum density were estimated by dividing the mean and maximum abundance estimates by the length of the beach monitored at each study site.

Study Location	N	BL (km)	Abundance			Spacing	Density		
			Mean	SE	Max.	Min.	Mean	SE	Max.
Bay Ecosystem									
Bolivar Flats	35	4.8	15.3	3.96	83	177.8	3.19	0.81	17.3
Big Reef	17	3.2	1.2	5.63	12	237.5	0.37	0.22	3.8
San Luis Pass	64	6.3	12.3	4.47	32	240.0	1.87	0.21	5.1
Ecotone									
East Flats	7	2.8	9.9	8.78	24	133.3	3.54	1.27	8.6
Mustang Island State Park - North	66	3.2	10.3	2.86	38	88.9	3.22	0.49	11.9
Mustang Island State Park - South	32	2.6	8.5	4.11	55	47.3	3.26	1.00	21.2
Packery Channel	58	3.9	14.0	3.05	87	70.9	3.59	0.75	22.3
Lagoon Ecosystem									
South Bay East	25	7.6	22.6	4.65	254	233.3	2.97	1.54	33.4
South Padre Island North Area	27	25.1	12.3	4.47	171	836.7	0.49	0.26	6.8

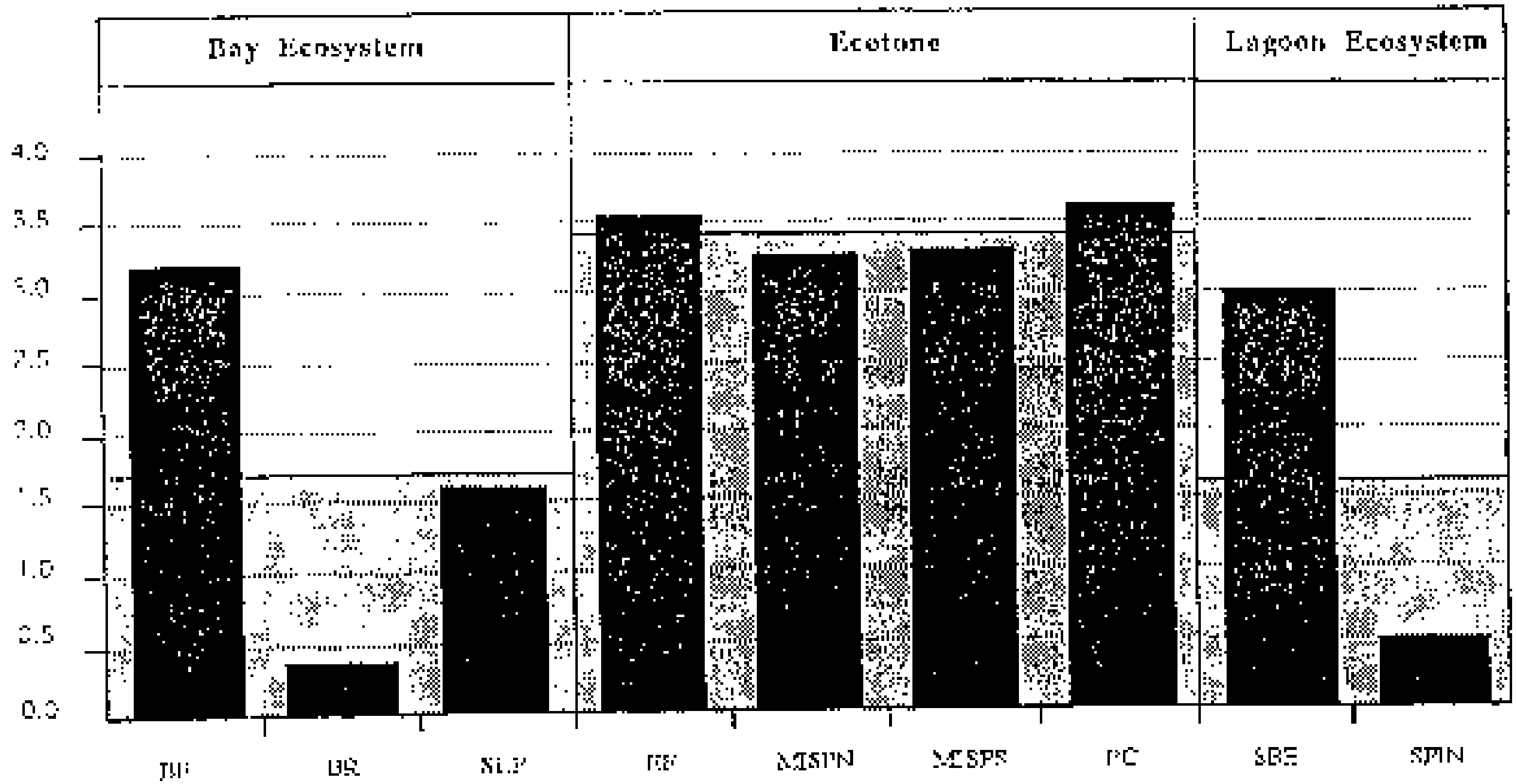


Figure 8. Mean site density and ecosystem density of Piping Plover at beach habitat along the Texas Gulf Coast, 1991 - 1994. Black bars represent site density estimates, gray bars illustrate mean density estimates for each ecosystem (calculated as the average of the mean density estimates for each site in each ecosystem).

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS - Mustang Island State Park - South, PC - Packery Channel, SBE = South Bay East, SPIN = South Padre Island - North

Table 3. Total abundance, highest study counts, and densities of Piping Plovers on bayshore tidal flats at sites along the Texas Gulf Coast, 1991 - 1994. Piping Plover (PIPL) density is expressed as the number of birds/100ha. The area of bayshore habitat at each site (BA) report the total potential area of bayshore habitat at each site (Max.) and the mean area of bayshore habitat at each site throughout the study (see page 27 for more information on this estimate).

Study Location	N	BA		Abundance			Density		
		Max.	Mean	Mean	SE	Max.	Mean	SE	Max.
Bay Ecosystem									
Bolivar Flats	40	188	102	50.2	4.26	119	49.2	5.2	116.7
Big Reef	23	58	29	19.7	6.78	54	68.1	13.2	203.4
San Luis Pass	65	72	42	23.4	4.03	75	56.3	6.3	192.3
Ecotone									
East Flats	7	246	136	49.3	12.29	189	36.2	19.8	139.0
Mustang Island State Park - North	30	61	33	7.4	4.79	39	22.3	5.1	118.2
Mustang Island State Park - South	13	69	40	0.0	0.0	0	0.0	0.0	0.0
Packery Channel	47	179	107	14.7	4.74	75	13.7	2.6	70.1
Lagoon Ecosystem									
LANWR - Rincon Buena Vista	31	161	95	17.4	5.37	100	18.5	5.5	112.4
LANWR - South Horse Flats	35	28	16	1.2	5.49	40	7.9	6.7	235.3
LANWR - Redhead Cove	37	36	27	5.7	5.34	130	21.0	13.7	500.0
LANWR - North Yucca Flats	43	91	50	17.1	4.96	97	34.4	7.4	167.2
South Bay - West	21	100	51	0.0	0.00	0	0.0	0.0	0.0
South Bay - East	29	642	270	19.1	3.17	202	7.8	3.4	82.8
SPI - North Area	6	812	508	355.3	13.27	543	69.9	11.5	106.9
SPI - Convention Center	19	4	2	2.9	3.91	18	144.7	65.3	900.0
SPI - Parrot Eye's	21	4	2	2.5	3.72	16	123.8	50.4	800.0
SPI - Mangrove Flats	25	8	4	3.1	3.41	17	78.0	25.1	425.0

Abbreviations: LANWR = Laguna Atascosa National Wildlife Refuge, SPI = South Padre Island.

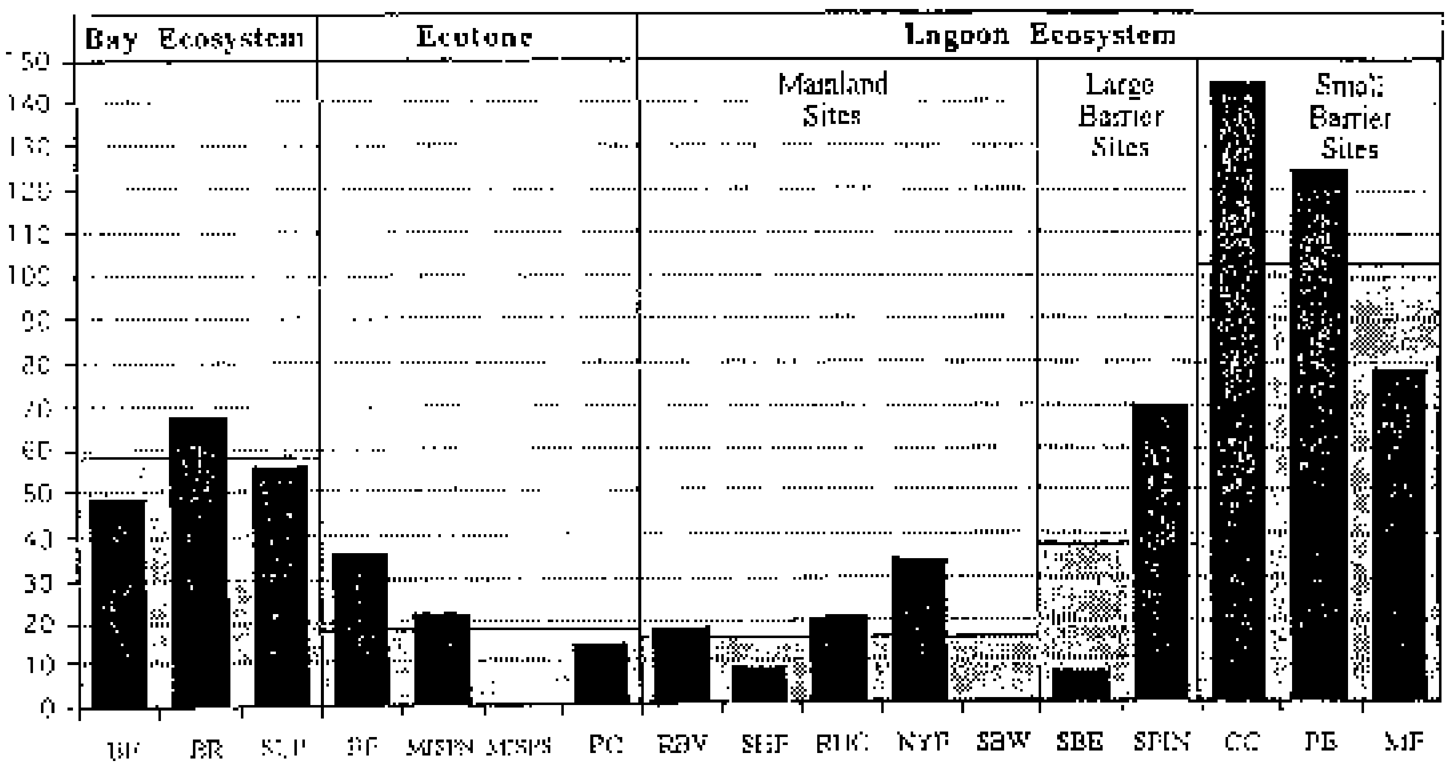


Figure 9. Mean site density and ecosystem density of Piping Plover at bayshore habitat along the Texas Gulf Coast, 1991 - 1994. Black bars represent site density estimates, gray bars represent ecosystem density estimates. Different lagoon ecosystem density estimates are presented for mainland sites, large barrier island sites and small barrier island sites.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, RBV = Rincon Buena Vista, SHF = South Horse Flats, RHC = Redhead Cove, NYF = North Yucca Flats, SBW - South Bay - West, SBE = South Bay East, SPIN = South Padre Island - North, CC = Convention Center, PE - Parrot Eyes, MF = Mangrove Flats

Table 4. Piping Plover population density and human disturbance at beach and bayshore habitat from the 2 ecosystems and the ecotone along the Texas Gulf Coast. Parameters are summarized as means for each location. Multi-factor ANOVA results of pair-wise comparisons between the ecosystems and the ecotone are presented in the last 3 columns. Piping Plover site density is represented as the number of plovers/km at beach habitat, and as the number of plovers/100ha at bayshore habitat. Human disturbance was estimated as the mean number of vehicles/km at beach habitat, and as the mean # vehicles/100ha at bayshore habitat.

Parameter	Bay Ecosystem			Ecotone			Lagoon Ecosystem			Bay	Bay	Eco.
	mean	N	SE	mean	N	SE	mean	N	SE	vs. Lag.	vs. Eco.	vs. Lag.
Beach Density	1.90	119	0.41	3.37	163	0.35	1.68	52	0.62	0.5787	< 0.0001	0.0002
Beach Disturbance	1.89	87	0.29	2.65	109	0.26	1.97	35	0.46	0.5045	0.4341	0.9413
Bayshore Density	58.2	127	7.1	42.0	135	8.4	69.5	100	8.1	0.0284	0.0304	0.7835
Bayshore Disturbance	8.8	69	1.9	4.8	90	1.6	2.3	81	1.7	0.0027	0.0834	0.3729

Bay = bay ecosystem, Eco = ecotone, Lag.= lagoon ecosystem.

+flats than on mainland flats within the lagoon ecosystem during emergent tide conditions ($P = 0.0139$). For this reason, data from the lagoon ecosystem mainland sites were excluded from other analyses to avoid compromising comparisons using data from sites in the bay ecosystem and ecotone which were located exclusively on barrier islands.

I observed a significantly higher mean density of Piping Plovers at bay ecosystem flats than at lagoon ecosystem flats ($P = 0.0284$; Table 4) or at ecotone flats ($P = 0.0304$; Table 4). I detected no difference in the density of Piping Plovers at lagoon ecosystem flats and ecotone flats ($P = 0.7835$; Table 4).

Piping Plovers used beaches when the bayshore tides were high and bayshore tidal flats were inundated. Bayshore tidal amplitude was strongly associated with Piping Plover density at beach habitat in both ecosystems and the ecotone (Table 5). As bayshore flats became inundated, the density of Piping Plovers at beaches increased significantly at the bay ecosystem ($P < 0.0001$), ecotone ($P < 0.0001$), and lagoon ecosystem ($P = 0.0021$).

Bayshore tidal amplitude also strongly influenced the density of Piping Plovers at bayshore habitat (Table 5). As bayshore flats became inundated, the total density of Piping Plovers using bayshore habitat decreased in the bay ecosystem ($P = 0.0011$; Table 5) and the lagoon ecosystem ($P = 0.0046$; Table 5). However, there was no detectable tide effect in the ecotone ($P = 0.3652$; Table 5).

Climatic Conditions, Time of Day and Season

With one exception, climatic conditions (Table 6), time of day (Table 7), and season (Table 8) were not related to Piping Plover density at beach habitat. Piping Plover density was higher at ecotone beaches during migration than during the winter period ($P = 0.0173$; Table 8). Human disturbance also did not significantly affect Piping Plover density at beach habitat ($P = 0.3817$; Figure 10).

Climatic conditions (Table 6), time of day (Table 7), season (Table 8) and bayshore

Table 5. The effects of bayshore tidal amplitude on Piping Plover density. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during emergent and inundated tidal conditions. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 tide ranks.

Ecosystem	**Emergent**			**Inundated**			***P*-value**
	mean	**N**	**SE**	**mean**	**N**	**SE**	
Beach Habitat							
Bay Ecosystem	0.60	89	0.26	3.91	46	0.36	< 0.0001
Ecotone	1.81	118	0.39	7.48	45	0.64	< 0.0001
Lagoon Ecosystem	0.35	40	0.79	6.12	12	1.44	0.0021
Bayshore Habitat							
Bay Ecosystem	71.5	85	4.9	31.4	42	7.0	0.0011
Ecotone	40.0	87	8.9	31.1	38	14.9	0.3652
Lagoon Ecosystem	46.6	211	8.5	23.7	74	14.9	0.0046

Table 6. The effects of climate on Piping Plover density along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during mild and harsh climatic conditions. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 climate ranks.

Ecosystem	Mild			Harsh			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.40	69	0.32	1.24	34	0.45	0.9169
Ecotone	3.54	94	0.53	3.38	53	0.71	0.5241
Lagoon	0.92	27	0.71	2.14	12	1.06	0.8601
Bayshore Habitat							
Bay Ecosystem	68.0	60	6.7	60.6	31	9.3	0.6845
Ecotone	31.7	93	9.2	28.7	47	13.0	0.6816
Lagoon Ecosystem	53.2	166	9.4	25.1	82	13.4	0.4427

Table 7. The effects of time of day on Piping Plover density along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during morning (0600 - 1200) and afternoon (1200 - 1800) periods. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 time of day ranks.

Ecosystem	Morning			Afternoon			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.75	86	0.32	2.50	23	0.62	0.5289
Ecotone	3.83	73	0.54	2.37	21	1.00	0.3657
Lagoon	0.67	26	1.13	3.61	19	1.33	0.1596
Bayshore Habitat							
Bay Ecosystem	53.2	75	5.3	56.7	29	8.5	0.9422
Ecotone	30.6	46	18.4	72.2	45	18.6	0.9724
Lagoon Ecosystem	45.6	131	10.9	48.2	122	11.3	0.5154

Table 8. Piping Plover densities during the winter and migratory periods at sites along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during migratory and winter periods. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 season ranks.

Ecosystem	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.84	77	0.33	1.58	58	0.38	0.6149
Ecotone	4.61	58	0.64	2.69	105	0.48	0.0173
Lagoon Ecosystem	1.50	24	1.14	1.83	28	1.05	0.8314
Bayshore Habitat							
Bay Ecosystem	55.0	76	5.6	63.0	51	6.9	0.3724
Ecotone	38.3	70	11.7	37.2	94	10.1	0.9452
Lagoon Ecosystem	37.7	110	11.6	43.2	175	9.7	0.7163

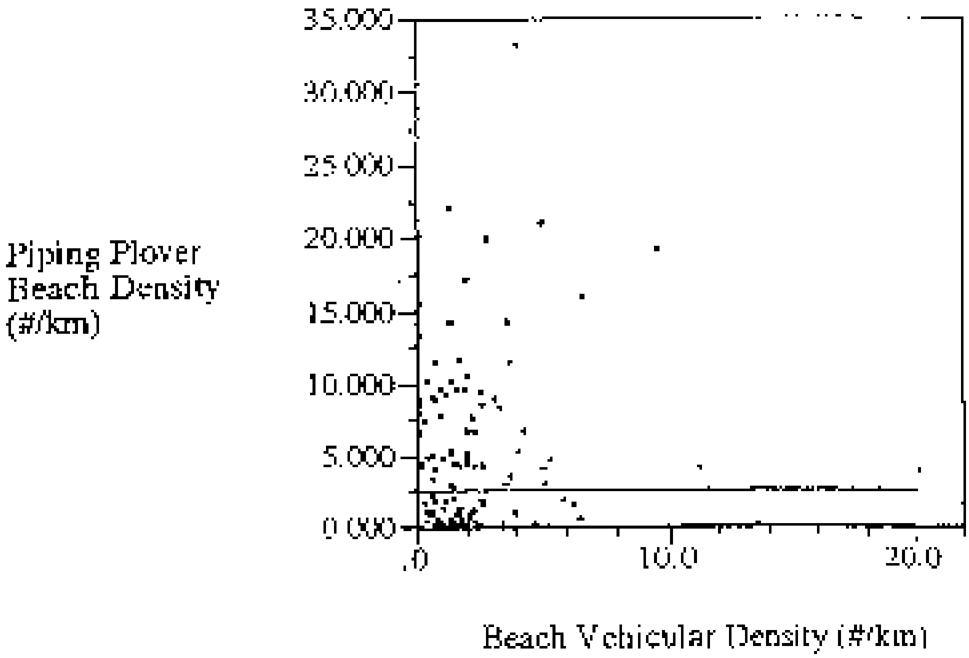


Figure 10. The effects of human disturbance on Piping Plover beach density at sites along the Texas Gulf Coast, 1991-1994. A solid regression line illustrates the relationship between human disturbance (estimated as the density of vehicles present at site beaches during the beach plover counts) and Piping Plover beach density. The analyses suggests that human disturbance had no direct effect on the use of beach habitat by Piping Plovers (P = 0.3817).

human disturbance (# vehicles/ha; Figure 11) seemingly were not related to Piping Plover density at bayshore habitat.

Beach Tidal Amplitude

I analyzed Piping Plover beach density in relation to beach tidal amplitudes at 3 sites where I was able to accurately monitor beach tidal amplitude during at least a portion of the study. As beach tidal amplitude increased, Piping Plover beach density also increased at Mustang Island State Park - North ($P = 0.0051$; Table 9). However, Piping Plover beach density was unrelated to beach tidal amplitude at Packery Channel ($P = 0.8764$; Table 9) and at San Luis Pass ($P = 0.6419$; Table 9). In comparison, bayshore tidal amplitude was significantly associated with Piping Plover beach density at Mustang Island State Park - North ($P = 0.0099$; Table 9) and Packery Channel ($P = 0.0017$; Table 9), but not San Luis Pass ($P = 0.3278$; Table 9).

Whereas the tidal regime influenced both beach and bayshore habitats, the most salient effect of the tides appeared to be how they affected the local availability of bayshore tidal flats. Distinguishing between the effects of the tidal regime on beach and bayshore was confounded by the fact that beach and bayshore tides were synchronous along many portions of the Texas coast (pers. obs.). That is, as tides rose and covered bayshore tidal flats, the high tide changed the level of the beach intertidal zone (i.e., swash zone) at many of the sites. This situation raises the possibility that plovers used beaches not because the tides made bayshore tides unavailable, but rather because high tides increased the availability of preferred habitat along the beach shoreline. This might result, for example, if the availability of prey populations residing within higher zones of the forebeach habitat increased significantly as high tides inundated these zones. If this were true, plovers should use beach habitat in response to beach tidal amplitude and not bayshore tidal amplitude at a site where the beach and bayshore tidal regimes are asynchronous. Fortunately, one of the sites I monitored exhibited asynchronous tides.

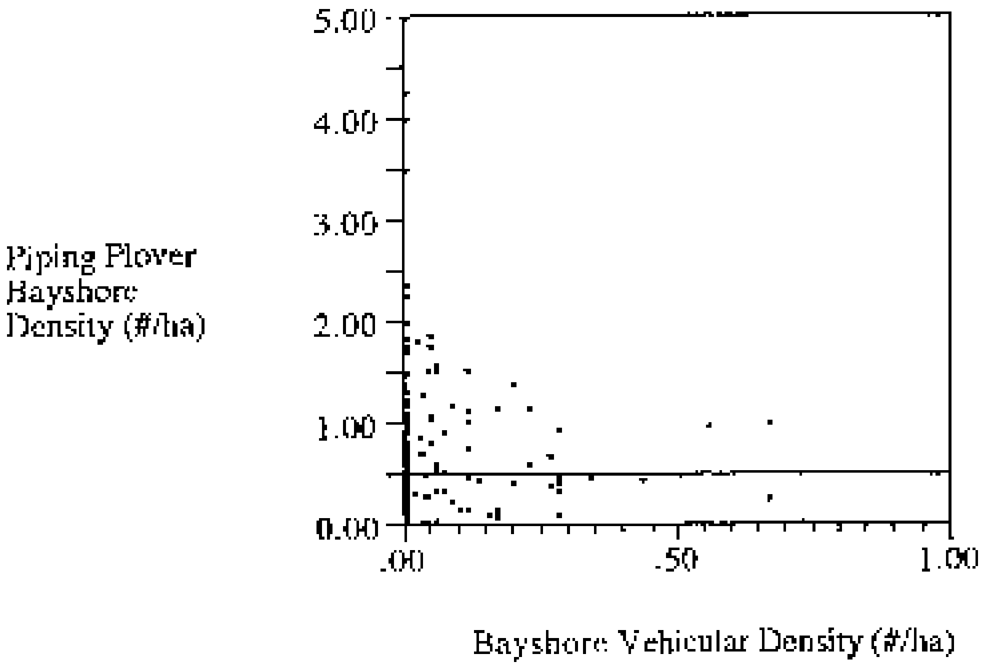


Figure 11. The effects of human disturbance on Piping Plover bayshore density at sites along the Texas Gulf Coast, 1991-1994. A solid regression line illustrates the relationship between human disturbance (estimated as the density of vehicles present at site bayshore habitat during the bayshore plover counts) and Piping Plover bayshore density. The analyses suggests that human disturbance had no direct effect on the use of bayshore habitat by Piping Plovers ($P = 0.9984$).

Table 9. The effects of beach tidal amplitude on Piping Plover density. Mean Piping Plover density at beach and bayshore habitats are presented for the 3 sites where beach tidal amplitude was measured. The proportional effect on Plover density caused by beach tidal amplitude is expressed as R^2. The significance of the effect is expressed as a *P*-value in the last column. Abbreviations: MISP = Mustang Island State Park.

Ecosystem	N	R^2	*P*-value
Beach Density			
MISP - North	22	0.2624	0.0051
Packery Channel	27	0.0008	0.8764
San Luis Pass	24	0.0148	0.6419
Bayshore Density			
MISP - North	22	0.2221	0.0099
Packery Channel	27	0.2916	0.0017
San Luis Pass	24	0.0638	0.3278

Among the 3 sites I monitored for beach tidal amplitude, beach and bayshore tides were synchronous at San Luis Pass ($P < 0.0001$, N = 17) and Mustang Island State Park - North ($P = 0.0170$, N = 29), but asynchronous at Packery Channel ($P = 0.8764$, N = 31). At Packery Channel, Piping Plover density was correlated with bayshore tides but not beach tides. Considered together, these data suggest that bayshore tidal amplitude was a better predictor of Piping Plover habitat use than was beach tidal amplitude.

DISCUSSION

Objective 1. Piping Plover Density

Beach Habitat

My estimates of Piping Plover density compare closely with most estimates from other studies in Texas. With 2 exceptions (Big Reef and South Padre Island), I found Piping Plovers to use beach habitat at a higher density than the 1.4 - 1.6 birds/km estimate reported for Texas by Nicholls and Baldassarre (1990b). Elliott and Teas (1996) reported beach densities of 1.11 birds/km, 3.13 birds/km and 4.51 birds/km at 3 Texas coastal sites. One of the sites monitored by Elliott and Teas (1996) was the same site I refer to as Packery Channel (the site was called Surfer Beach by Elliott and Teas). Their 2-year mean estimate of 3.13 plovers/km at Packery Channel beach compares closely with my 3-year mean of 3.59 plovers/km.

Lee (1995) reported a mean density of 3.41 Piping Plovers/km at the Mustang Island State Park - North site during portions of the nonbreeding season in 1990 and 1991. This estimate compares closely with my estimate of 3.22 plovers/km at the same site. Chapman (1984) reported a diurnal mean of 3.0 Piping Plovers/km along an 8.1 km stretch of beach located just south of the Packery Channel site. During surveys conducted between 1992 - 1995, Chaney et al. (1995) reported that the annual Piping Plover beach density on Padre Island National Seashore (located just south of the Packery

Channel site, and the same area counted by Chapman (1984)) varied from 0.48 plovers/km to 2.1 plovers/km. Their estimates were based upon counts made throughout the year, however, including the summer period when many Piping Plovers were at breeding sites away from Texas. For this reason, the density values reported by Chaney et al. (1995) almost certainly underestimated the mean beach density of plovers on North Padre Island during the winter period.

Whereas the southern portion of the Padre Island National Seashore can be accurately classified as belonging to the lagoon ecosystem, most of the density estimates described above were measured at ecotone beaches. My data suggest that Piping Plovers used beaches in the ecotone at greater densities than those located in the bay or lagoon ecosystem. Plovers occurred at an average density of about 1.75 plovers/km in the bay ecosystem and lagoon ecosystem. Whereas my density estimates for beach sites in the 2 ecosystems more closely approximate those by Nicholls and Baldassarre (1990b), the average beach density of Piping Plovers at all of the sites, 2.29 plovers/km, was appreciably higher than their estimate of 1.4 - 1.6 plovers/km.

Bayshore Habitat

Density estimates for Piping Plover use of bayshore habitat are rare, probably due to the difficulty associated with accessing bayshore sites, and accurately quantifying the area of tidal flat habitat being counted. Garza (1997) reported bayshore densities for Piping Plovers using 15 sites on South Padre Island in 1994. With a single exception (Site 9, which supported an average of about 48 plovers/100 ha), all of the sites monitored by Garza were estimated to support fewer than 20 plovers/100 ha. Surprisingly, these findings contrast starkly with my estimates of approximately 78 - 145 plovers/100 ha at many of the same locations.

In the Laguna Madre, the mainland sites I monitored supported a much lower density of Piping Plovers than did the barrier island sites. However, under certain conditions the mainland flats supported very large flocks (> 95 birds) of Piping Plovers. Peak use of mainland sites by Piping Plovers occurred during emergent conditions. On the mainland, these conditions were most common during the passage of winter north fronts. The strong winds accompanying these fronts often caused mainland flats to become emergent, and barrier island flats to become inundated. These conditions presumably caused plovers to migrate across the Laguna Madre from barrier islands flats to mainland flats. Until recently, such movement patterns were largely speculative. However, a radiotelemetry study investigating the movement patterns of Piping Plovers in the Lower Laguna Madre has confirmed that many Piping Plovers regularly migrate between the barrier island and mainland flats during the same winter period (Zonick et al. 1998).

Objective 2. Factors affecting Piping Plover density.

The local density of Piping Plovers at the beach and bayshore sites was most strongly influenced by 2 parameters, bayshore tidal amplitude and ecosystem type.

Bayshore Tidal Amplitude

Bayshore tidal amplitude affected density in a proximate fashion by directing the short-term movements of Piping Plovers between beach and bayshore habitat. As rising bayshore tides covered local bayshore feeding areas, plovers sought out alternative feeding habitat or suitable roost sites. Beach habitat was frequently used as a secondary habitat during periods of bayshore inundation, but washover passes and mainland tidal flats also appeared to provide important secondary habitats for Piping Plovers.

Lee (1995) found Piping Plover beach density to increase with falling beach tidal amplitude and decreasing availability of bayshore habitat (i.e., increasing bayshore tidal amplitude). My observations at the Mustang Island State Park and Packery Channel sites, which together encompass both of Lee's beach sites, suggest that bayshore tidal amplitude, and not beach tidal amplitude, directs the movements of plovers between beach and bayshore habitats. This finding suggests that plovers used beach habitat as a secondary feeding site, preferring bayshore habitat when available. Connors et al. (1981) reported a similar tidal response by Sanderlings (*Calidris alba*) and Snowy Plovers (*Charadrius alexandrinus*) along the California coast. There, Sanderlings and Snowy Plovers cycled between beach and bayshore habitat, using beaches during periods of bayshore tidal inundation.

Interestingly, Elliott and Teas (1996) reported no relationship between Piping Plover beach density and bayshore tidal amplitude at 7 ecotone beaches, but did find a positive relationship between bayshore tidal amplitude and Snowy Plover beach density. Furthermore, Withers (1994) reported a positive relationship between bayshore tidal amplitude and Piping Plover bayshore density at Corpus Christi Pass, a site situated between the Packery Channel and Mustang Island State Park - South sites. In fact, Withers observed all shorebird species but Snowy Plovers to increase in abundance at bayshore habitat with increasing bayshore tide height. Withers detected a decrease in Snowy Plover abundance with bayshore tidal inundation (Withers 1994). These findings contrast with my findings and with those reported by Lee (1995) regarding the response by Piping Plovers to bayshore tidal conditions.

Withers' observations were restricted to bayshore habitat, so I will limit comparisons of our findings to that habitat. My data suggest high bayshore tides caused Piping Plover bayshore density to drop in the bay and lagoon ecosystems, but not in the ecotone. In the ecotone, I observed plover bayshore abundance to decline somewhat during periods of tidal inundation relative to periods of emergence (by ~ 23%; Table 5), but the difference was not significant. Furthermore, Piping Plovers often declined at the ecotone sites as bayshore tide levels dropped from moderate - very low. I scored bayshore tidal amplitude into 1 of 5 ranks (very high, high, moderate, low and very low; ranks are described in the Methods section). At Packery Channel, the mean number of Piping Plovers using bayshore habitat during very high, high, moderate, low and very low bayshore tides was 2.3, 10.4, 18.9, 16.9, and 14.6, respectively. Therefore, plover bayshore abundance peaked near the moderate-low tide ranks, and declined somewhat if the tide dropped to a very low state. Presumably, during low and very low tides Piping Plovers moved to rarely-exposed off-site feeding areas.

The reduction in plover abundance at ecotone sites during extreme low tide episodes complicated the relationship between bayshore tidal amplitude and the use of bayshore habitat by plovers. However, my data suggest that plovers were much more common at bayshore habitat during emergent conditions (i.e., very low - moderate bayshore tides), even though they occasionally sought out off-site feeding areas during very low tide events. Plovers moved to beach habitat and washover pass habitat during periods of bayshore inundation (i.e., high-very high bayshore tides).

The Elliott and Teas (1996) study was restricted to beach habitat where they initially reported Piping Plover beach density to be unaffected by bayshore tidal conditions. My findings disagree with their reported findings and indicate bayshore tides strongly affect plover beach use. At Packery Channel, I recorded mean Piping Plover beach abundance during very high, high, moderate, low and very low bayshore tides of 44.1, 27.8, 9.9, 2.6, and 0, respectively. Furthermore, at Mustang Island State Park - North, a site lying just north of Elliott and Teas' Surfer Beach site (i.e., Packery Channel), the mean number of Piping Plovers using beach habitat during very high, high, moderate, low and very low bayshore tides was 16.7, 23.0, 5.3, 2.6, and 0, respectively. I never visited Mustang Island State Park - South during very high or high bayshore tides, and therefore have data only for moderate-very low tide ranks. However, during moderate, low and very low bayshore tides, I found 13.0, 1.0, and 0 Piping Plovers using beach habitat, respectively. Thus, at 3 south ecotone sites located near Elliott and Teas' Surfer Beach site, I observed a steady and significant ($P < 0.0001$ for Packery Channel and Mustang Island State Park - North, $P = 0.0105$ for Mustang Island State Park - South; data not shown) decline in the abundance and density of plovers on beaches as the bayshore habitat became emergent.

Based upon these findings, the authors (L. Elliott) conducted a revised analysis of their data and concluded that bayshore tides did correlate with Piping Plover beach density ($R^2 = 0.403$, $P < 0.0001$), and the contrary finding in Elliott and Teas (1996) was inaccurate (L. Elliott, pers. comm.).

The apparent preference by Piping Plovers for bayshore habitat is supported by another observation. Whereas beach use clearly appeared to be controlled by bayshore tidal amplitude, high bayshore tides did not always cause plovers to move to beach habitat. I was occasionally unable to locate Piping Plovers during periods of high bayshore tide. Such occurrences were most common in the lagoon ecosystem where bayshore tides were influenced to a much greater degree by wind forces and where mainland tidal flats were much more suitable as feeding areas than were those in the bay ecosystem and in the ecotone. Wind tides often had local effects, inundating one flat while exposing a neighboring flat (e.g., this would occur at 2 flats on opposing sides of a small lagoon). With the exception of those associated with tropical storms, wind tides in the lagoon ecosystem usually exposed new areas of bayshore habitat as others were becoming flooded. Therefore, plovers feeding in the lagoon ecosystem often had an alternative to beach habitat during periods of locally high bayshore tides. They were able move to alternative bayshore habitat sites that had become emergent by the same tide that inundated the site they were forced to abandon. Under this scenario, a plover being forced off of a tidal flat along a lagoon might fly into the wind to cross the lagoon and light on the opposite shoreline where baywaters were being blown off of the flats.

During the study, I observed several Piping Plovers that had been color banded by other biologists. Among those plovers that I was able to resight more than once during the study was an individual that used all 3 of the lagoon ecosystem sites during the same winter. These observations suggest that, in addition to crossing the Laguna Madre to move between mainland and barrier island sites, some Piping Plovers appeared to use a mosaic of many bayshore sites throughout the winter. Radiotelemetric tracking of Piping Plovers in the lagoon ecosystem has further supported this hypothesis (Zonick et al. 1998). Presumably, movements among these sites are directed to a great extent by the local availability and productivity of bayshore feeding areas.

Ecosystem Features and Landscape

Piping Plover density was also affected by ecosystem and landscape features along the Texas Gulf Coast. Plovers were more common at ecotone beaches than in either ecosystem. Whereas my data do not directly demonstrate why plover beach density was highest in the ecotone, I believe indirect inferences can be drawn from information presented in this chapter and that presented in the following chapter.

As previously demonstrated, one of the major features distinguishing the 3 coastal regions was the tidal regime, and the way the tides influenced local bayshore feeding areas. The discussion above describes clearly why plovers may have been less common at lagoon ecosystem beaches than at those in the ecotone throughout the tidal cycle. Plovers in the lagoon ecosystem were more likely to seek out alternative bayshore feeding areas in preference to beach habitat when local bayshore feeding sites became inundated.

However, tidal variations among the 2 ecosystems and the ecotone did not appear to explain all of the differences in local plover density. Multi-factor ANOVA models identified an ecosystem effect on plover density that was independent of the bayshore tidal effect, suggesting some other factor may affect the use of beach habitat. As I describe in the next chapter, the bayshore prey communities at the sites also differed markedly among 2 ecosystems and the ecotone. Bayshore habitat in the bay ecosystem supported a much higher mean prey density than did that in the ecotone or the lagoon ecosystem. Therefore, plovers wintering within the bay ecosystem may have been able to build sufficient fat stores to allow them to seek most refugia during many high tides rather than risk predation and other potential deleterious effects that might be incurred by periods of extended feeding. Bayshore flats in the ecotone may not have been sufficiently productive to allow resident plovers to avoid as many high tide foraging episodes as plovers in the bay ecosystem.

An alternative explanation may be that periods of bayshore inundation lasted longer in the ecotone than in the bay ecosystem, thereby forcing plovers in the ecotone to seek alternative feeding sites (e.g., beach habitat) more often. Unfortunately, my data allow for only a crude investigation of this hypothesis. I encountered inundating tides during 33.6% of all censuses in the bay ecosystem, but during only 26.9% and 25.5% of all censuses in the ecotone and lagoon ecosystem, respectively. These data suggest that ecotone tidal flats (and lagoon tidal flats) were not inundated longer than bay ecosystem tidal flats and probably were inundated for shorter periods of time. Tidal flats in the ecotone and lagoon ecosystem may often have been subject to only partial inundation. This, combined with higher baywater salinities relative to the bay ecosystem, may have limited the availability of productive bayshore habitat in the ecotone and forced plovers to use beach habitat to a greater extent.

Finally, Piping Plovers were more common on emergent barrier island tidal flats than on emergent mainland tidal flats. The prey density data I collected can be used to suggest an hypothesis as to why this might be so. As I discuss in Chapter III, benthic prey density was significantly higher at lagoon ecosystem barrier island flats than at mainland flats. Therefore, the observed higher use of barrier islands may simply reflect a preference by Piping Plovers for more productive feeding areas.

CHAPTER III. PREY DYNAMICS AND PIPING PLOVER BEHAVIOR

INTRODUCTION

Perhaps more than any other parameter, prey density has been associated with shorebird ecology and linked to local abundance and fitness (Goss-Custard 1984, Hicklin and Smith 1984, Wilson 1990, Colwell 1993). This is particularly true for wintering shorebirds (Duffy et al.1981, Myers and McCaffery 1984, Myers et al. 1987). Because of their demanding life strategy, involving long migratory journeys and the reliance upon numerous ephemeral staging sites, the winter period is considered critical for shorebirds (Myers et al. 1987). During winter, shorebirds must rebuild fat stores that have been depleted during fall migration to levels that will allow them to survive the winter period and help power a return migration to their breeding grounds in the spring (Blem 1990). Individuals that are best able to find and capture prey during the winter and maintain optimal fat stores are presumably most likely to arrive early and fit at their breeding grounds. Thus, shorebirds benefit reproductively by occupying winter sites with a reliable food supply. For this reason, estimating the availability of food to plovers among the different habitats and ecosystems of the Texas Coast was an important goal of my research.

The diet of wintering Piping Plovers had only been partially characterized at the time this study was initiated (Nicholls and Baldassarre 1990a). A better understanding of the species diet in Texas was required to evaluate what portions of the available prey community were available to the plovers. The task of describing and quantifying prey availability to plovers was complicated by observations indicating plovers fed in large part on surface prey populations (e.g., flies and other non-burrowing insects), particularly in the lagoon ecosystem (pers. obs, T. Eubanks pers. comm.). I addressed these problems by documenting the diet of plovers while concurrently sampling the prey community in areas where plovers were feeding using several different techniques.

Due to the rarity of the Piping Plover, some techniques commonly employed to evaluate bird diets (e.g., the evaluation of stomach contents from dissected birds or birds palpated to induce regurgitation) could not be used. The analysis of fecal dropping is a non-invasive technique that has been used to evaluate Piping Plover diet (Nicholls 1989, Shaffer and LaPorte 1994). Nicholls (1989) analyzed a small number of fecal samples from Piping Plovers wintering in Texas. From 4 samples collected from habitats at Bolivar Flats and 1 sample collected at San Luis Pass (all at bayshore habitat), Nicholls observed fragments of polychaetes in all samples, insects in 3 samples, and fragments of bivalves, ostracods, and copepods in 2 -3 samples each. In 2 samples collected at beach habitat on Mustang Island, Nicholls found polychaetes and crustaceans (Copepoda) in 1 sample, and insect fragments (Diptera) and amphipods (Haustoriidae) in another. From 2 samples collected at bayshore habitat in the lagoon ecosystem, Nicholls found insect fragments in 1 and polychaete fragments in the other.

Unfortunately, fecal sample analysis provides only a crude assessment of a shorebird's diet. Soft-bodied organisms are rapidly and nearly totally digested, resulting in an under-representation of annelids and other soft-bodied animals in the description of the diet (e.g., Shaffer and Laporte 1994). Additionally, shell and carapace fragments residing in the sediment can be ingested incidentally by foraging plovers leading to the inaccurate inclusion of non-prey taxa. I evaluated the Piping Plover diet among different habitats and ecosystem types by observing feeding plovers and directly characterizing the prey they captured into 2 categories (polychaetes and arthropods)

Another important aspect of Piping Plover foraging ecology is foraging success. The rate at which plovers capture prey (i.e., gross intake rate) and the energy plovers expend while feeding are both important factors in determining the net energy return (i.e., net intake rate; Goss-Custard 1984) plovers experience during foraging bouts. Plovers are visual foragers, relying upon visual cues to detect prey (Pienkowski 1979). Factors that reduce the surface activity of prey animals (e.g., soil desiccation, low air temperature, high winds, precipitation) can also reduce the rate at which plovers capture prey (Pienkowski 1981).

One of the primary focuses of my research involved evaluation of Piping Plover diet in the 2 ecosystems and the ecotone. I also analyzed foraging success to determine whether plovers were able to forage more efficiently in either ecosystem. Additionally, I compared prey populations and plover foraging success at bayshore tidal flats and beaches, the 2 major habitat types used by plovers along the TGC.

I addressed these goals by monitoring 1) the amount of time plovers spent foraging, 2) an index of the amount of energy plovers expended while foraging, and 3) the rate at which plovers captured prey among ecosystems and habitat types. Collectively, these data allowed me to describe the prey resources that were most available to Piping Plovers, as well as investigate how these prey resources differed in availability among habitat types, ecosystem types and landscape types along the TGC, and how well plovers were able to exploit these resources. These observations address large gaps in the current understanding of Piping Plover winter ecology.

Data from this section also were used in the development of the model predicting the factors that most strongly affected Piping Plover site abundance. This model is presented in Chapter IV.

METHODS

Prey Dynamics

I sampled potential prey populations from areas that were being used by foraging Piping Plovers at the time of sample collection. During preliminary observations, I found Piping Plovers to forage on prey animals occurring below the ground (benthic prey), and also on prey animals occurring at or above the ground surface (surface prey)

To address this, I sampled prey populations in several different ways. Sampling strategies consisted of the collection of soil cores (benthic prey), the deployment of sticky traps (surface prey), visual surveys of prey using a spotting scope (surface prey), and the collection of algal mat cores (benthic to surface prey, depending upon the developmental stage of the prey animal).

Transect Layout

All prey samples were collected along transects established within areas recently (within minutes) used by one or more foraging Piping Plovers (Figures 12 and 13). The dimensions of the transects were dictated by either the dimensions of the foraging flock being sampled, or the area used by an isolated plover subject (if the plover was foraging alone).

Plovers often fed in large flocks at bayshore habitat. Foraging flocks were sampled in order of size, beginning with the largest flock. The number of samples/day I collected was limited only by the number of foraging flocks of Piping Plovers observed, by the time required to collect and transport the samples back to research vehicles from the study area, and by the physical weight of the samples I was capable of carrying. Prey samples also were collected in areas where individual plovers were foraging alone, particularly at beach habitat where plovers aggressively defended foraging territories. Samples collected in association with solitary plovers using bayshore habitat were compared to those collected in association with foraging plover flocks.

My samples were specifically directed at appraising the prey community locally available to Piping Plovers during foraging episodes. They do not necessarily reflect the prey density available throughout the study site.

Benthic Prey Samples

Macroscopic benthic (i.e., subsurface) animals were sampled via a series of 5 soil cores/transect (Figures 12 and 13). Each core was 10 cm deep x 7.5 cm in diameter.

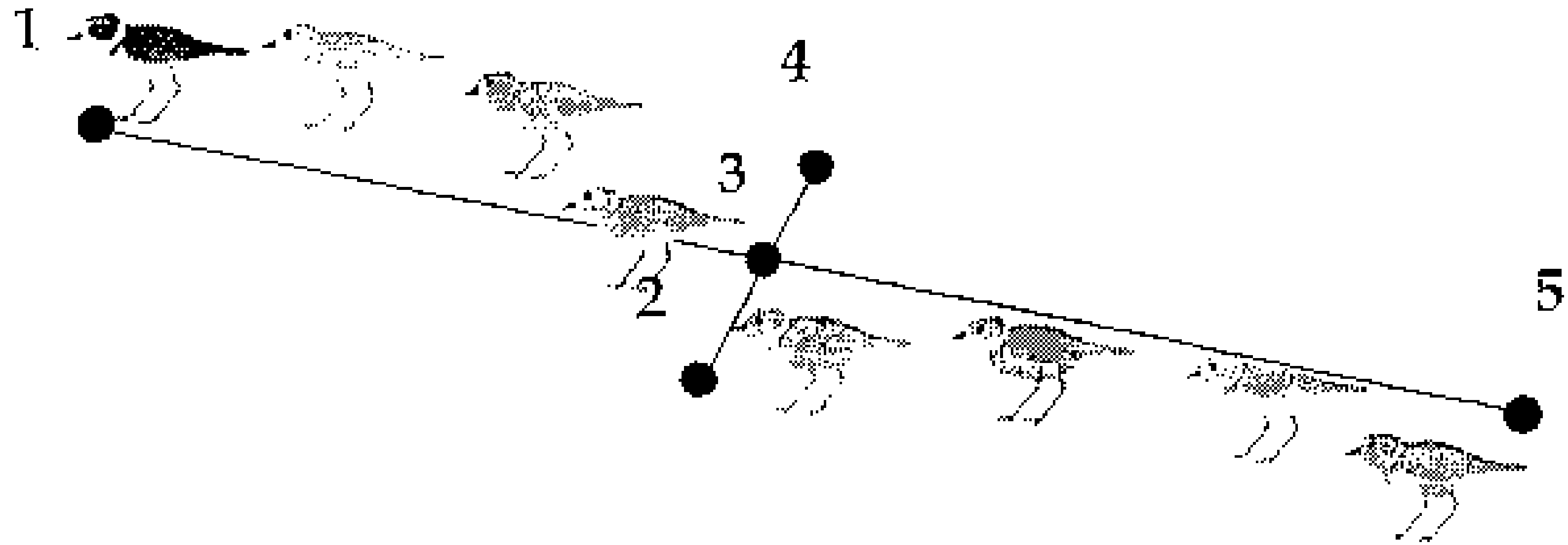


Figure 12. Strategy used to collect prey samples in areas occupied by a single foraging Piping Plover. A +-shaped transect was positioned within the area used by the plover immediately preceeding sample collection. In this figure, the single foraging Piping Plover is represented by a darkly shaded figure on the extreme left. To its right, are several lightly shaded figures representing the hypothetical path of the plover immediately prior to sample collection. The sample locations are depicted by filled circles, labelled 1 - 5. I collected sample 3 from the center of the area covered by the plover. Samples 1 and 5 were collected from the outer limits of the area's long dimension. Samples 2 and 4 were collected 3 - 5 meters on each side of the center sample (sample 3) along an axis perpendicular to the area's long dimension.

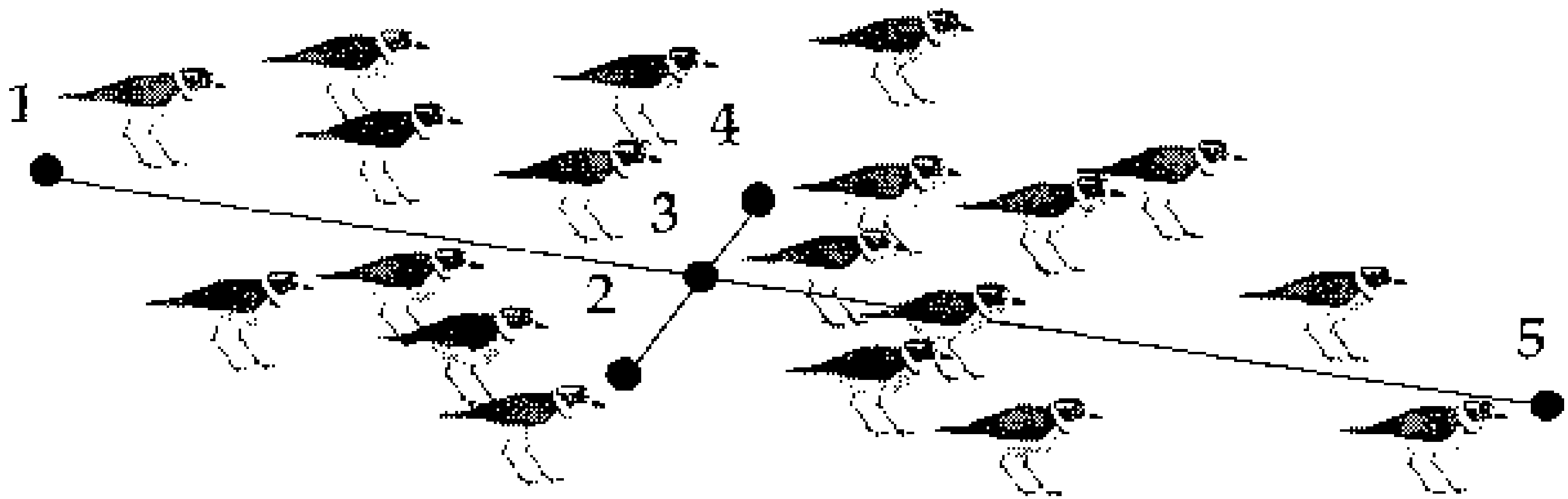


Figure 13. Strategy used to collect prey samples in areas occupied by a flock of foraging Piping Plovers. A +-shaped transect was positioned within the flock. The sample locations are represented by filled circles, labelled 1 - 5. I collected sample 3 from the center of the flock. Samples 1 and 5 were collected from the outer limits of the flock's long dimension. Samples 2 and 4 were collected 3 - 5 meters on each side of the center sample (sample #3) along an axis perpendicular to the flock's long dimension.

After retrieval, cores were placed in plastic bags and sieved (600 µm) and scored later the same day or early the next morning. Each prey item was classified into one of 4 prey groups (polychaetes, crustaceans, insects, other). Benthic prey were investigated in this way on both beach and bayshore habitat.

Surface Prey Samples

During the 1991 IPPC, I observed Piping Plovers foraging on flies and other prey located above the ground, especially on bayshore habitat. Because these animals (mostly adult insects and spiders) were highly mobile, and could not be accurately represented in core samples, I employed 2 additional techniques, sticky traps and spotting scope sampling, to obtain systematic samples of this portion of the prey community.

Sticky Trap Samples

To estimate surface insect abundance, I used modified sticky traps (Southwood 1996, MacLean and Pitelka 1971, Nordstrom 1990). Each foraging flock was sampled using five square flooring tile pieces (each – 2 mm x 15 cm x 15 cm) placed directly on the ground along the same transect used to sample benthic prey (Figure 13). Each tile was displaced approximately 1 m from the position where a soil core was retrieved. The tiles were coated with a 1-2 mm layer of Stickem Special™ (Seabrite Enterprises, Emeryville, CA 94608) filling a 12.5 cm diameter circle. These sticky traps were left in position along the transect for 60 minutes. During this period, small animals crawling onto, or landing within the layer of adhesive became trapped and were collected and scored later that night or early the next morning. Because sticky traps were "active" for a full hour, tallies could not be used to estimate above ground prey density, but were used only as relative measures of abundance.

Spotting Scope Samples

I developed and implemented a second technique during the final year of the study to collect instant counts of the above-ground fauna and allow for instantaneous density estimates of this portion of the prey community. A spotting scope was positioned at a consistent and reproducible height (tripod legs fully extended, center tripod support fully retracted) near the spot of each sampling position within the transect. The scope was then near-focused to its limit, and pointed down toward the surface until the ground became focused. The scope/tripod-head complex was spun and allowed to come to rest. The radius of ground that the scope was pointing to was "angled into focus" to reveal a 0.95 m^2 patch of ground that was surveyed (without moving the scope) for surface animals. Animals walking or flying into the field of view during the survey were not counted.

Algal Mat Samples

Where Piping Plovers were observed feeding on algal flats, a single core was taken of the mat near the center of the transect (i.e., sample location #3; Figure 11). Each core was ~ 2 cm deep, and 7.5 cm in diameter. Each core was sealed in a separate Zip lock[TM] bag with trapped air, and incubated under a controlled light cycle of 12 hours light /12 hours dark. Each core was checked once per week, throughout a six week period. All emergent animals were collected and scored.

Behavior

I characterized the foraging ecology of Piping Plovers along the TGC, and identified the factors affecting foraging success. One of my goals under this objective was to describe the diets of Piping Plovers in the 2 ecosystems and the ecotone, and among the major habitat types. The other goals of this objective related to foraging effort and foraging success.

To estimate foraging effort and success, I identified Piping Plovers involved in foraging activity during daily bird counts. I approached foraging groups of plovers and monitored randomly selected subjects with regard to their style of locomotion and the efficiency with which they captured different types of prey. The parameters I monitored are described in more detail below under "Piping Plover Foraging Locomotion" and

"Piping Plover Foraging Efficiency".

I used multi-factor models to investigate the relative effects of habitat type, ecosystem type and season on each estimate of foraging success. Additionally, I evaluated the foraging effort of Piping Plovers in relation to the density of different benthic prey groups. Finally, I measured the frequency with which foraging Piping Plovers exhibited aggressive behavior and investigated its expression among the different habitats and microhabitats used by plovers.

Piping Plover Activity

During daily bird counts, I scored the activity of each Piping Plover as either "foraging" or "roosting." I considered foraging plovers to be those that were actively feeding, or that were nearby other foraging plovers during the same count, and were not bathing, roosting or preening (i.e., plovers that appeared to be momentarily pausing between foraging attempts). Plovers scored as "roosting" were birds that were either bathing, roosting, or preening during the count.

Piping Plover Diet

I evaluated the Piping Plover diet from observations of those individuals that I was able to approach closely enough during the foraging efficiency records to identify the types and frequencies of prey that were captured.

I scored prey captured into 1 of 3 classes: 1) polychaetes and other worm-like prey, 2) arthropods and other non-worm like prey, or 3) unknown. Polychaete captures were usually very obvious, as plovers often pull them out of the sand slowly to avoid breaking the worm.

Piping Plover Foraging Locomotion

I observed Piping Plovers to use 2 predominant styles of foraging motions. One motion, henceforth described as reserved foraging locomotion (RFL), consisted of repeated, short, conserved movements toward prey animals located within 1-2 body lengths of the plover. The second type of motion was more prolonged, and was often very rapid, and is henceforth described as prolonged foraging locomotion (PFL). Plovers engaged in PFL moved beyond the normal 1-2 body lengths typical of RFL, often not pausing until it reached an area far beyond its initial location.

Because plovers presumably expend more energy during PFL periods relative to RFL periods, I monitored this type of locomotion as a factor potentially affecting a foraging plover's energy costs, and thereby its net energy intake rate. To document PFL, I watched randomly selected, foraging Piping Plovers for a period of 120 seconds and recorded the amount of time the plover spent in PFL. I defined PFL as any movement beyond 2 plover body lengths, and I timed the duration of all such movements using a stopwatch. I recorded a maximum of 10 records/habitat during each site visit.

During the 120 second period, I also recorded 1) the number of times the plover took flight, 2) the number of aggressive interactions involving the plover, and 3) the number of noticeable human disturbances (e.g., passing vehicles, beachcombers walking by, low-flying airplanes).

Piping Plover Foraging Efficiency

To appraise foraging efficiency, I observed foraging Piping Plovers at close range with a high-resolution spotting scope. During foraging efficiency records, a single, randomly selected plover was observed until it made 50 attempts to capture prey (pecks). Occasionally plovers moved beyond the range necessary for accurate observation, and the record was discontinued before 50 attempts were observed. Among the data recorded during the record were 1) the number of animals captured, 2) the number of pecks [if < 50], 3) the time of record, 4) the number of each prey type captured, 5) the species of nearest shorebird neighbor and 6) the number of aggressive interactions involving the plover during the record. As many records as possible were collected, up to a maximum of 10/habitat/site visit.

To score captures with accuracy it was usually necessary to approach birds to $\leq$ 50 m. Rather than attempting to sequentially approach each bird present, I sampled plovers by moving in increments of about 100 m through or around foraging flocks. Records were collected by scanning the flock in a complete 360° circle, pausing throughout the scan to monitor each bird that was close enough to accurately monitor foraging efficiency. After all of the plovers within viewing range were monitored at one position, I moved another 100 m to the next position and waited a short period to allow the birds to become accustomed to my presence before data collection resumed.

Foraging Ecology and Prey Density

Foraging efficiency and foraging effort were compared to benthic prey density and surface prey abundance (prey density and abundance are described in Chapter IV). Foraging effort was estimated as the mean number of pecks/minute exhibited by foraging plovers. For these comparisons, the daily means for benthic prey density and surface prey abundance were regressed against the daily mean for foraging efficiency and foraging effort. All data were collected in areas occupied by foraging Piping Plovers.

Intraspecific and Interspecific Interactions

To investigate associations between foraging Piping Plovers and other nearby birds, I recorded the species identification of the bird located closest to the plovers I was monitoring during foraging efficiency and foraging locomotion records. I recorded all acts of aggression involving Piping Plovers (i.e., intraspecific and interspecific aggressions) that I observed during the foraging locomotion and foraging efficiency records.

Data Analysis

All analyses were performed using JMP, version 3.1. JMP is a statistical program written by SAS Institute Inc., Cary, NC. Advanced statistical analyses (i.e., beyond the calculation of means, standard errors, etc.) consisted of one-way and multi-factor

Table 10. Mean macrobenthic polychaete, crustaceans and total prey density collected at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Density represented as the mean number of animals per square meter based upon core samples collected along transects associated with foraging Piping Plovers. Abbreviations: MISP = Mustang Island State Park.

Study Location	N	Polychaetes		Crustaceans		Insects		All Prey	
		mean	SE	mean	SE	mean	SE	mean	SE
Bolivar Flat	100	1577.5	182.81	1710.8	228.28	13.8	2.73	3304.1	347.76
Big Reef	35	3383.5	420.16	490.7	93.34	0.0	7.05	3887.2	385.46
San Luis Pass	155	2140.4	229.62	1278.7	197.23	0.0	2.19	3425.0	343.51
East Flats	35	678.0	117.20	1607.8	297.32	0.0	4.62	2298.7	338.21
MISP - North	165	920.4	111.93	880.7	170.56	0.0	2.13	1845.0	222.03
MISP - South	52	1799.3	236.41	1303.9	259.97	0.0	3.79	3155.3	307.45
Packery Channel	175	732.2	70.84	2005.6	241.97	0.0	2.06	2783.0	250.83
South Bay - East	45	693.1	121.98	597.64	117.18	0.0	4.07	1295.7	166.04
South Padre Island	45	783.5	118.37	838.71	106.20	0.0	4.07	1622.2	174.66

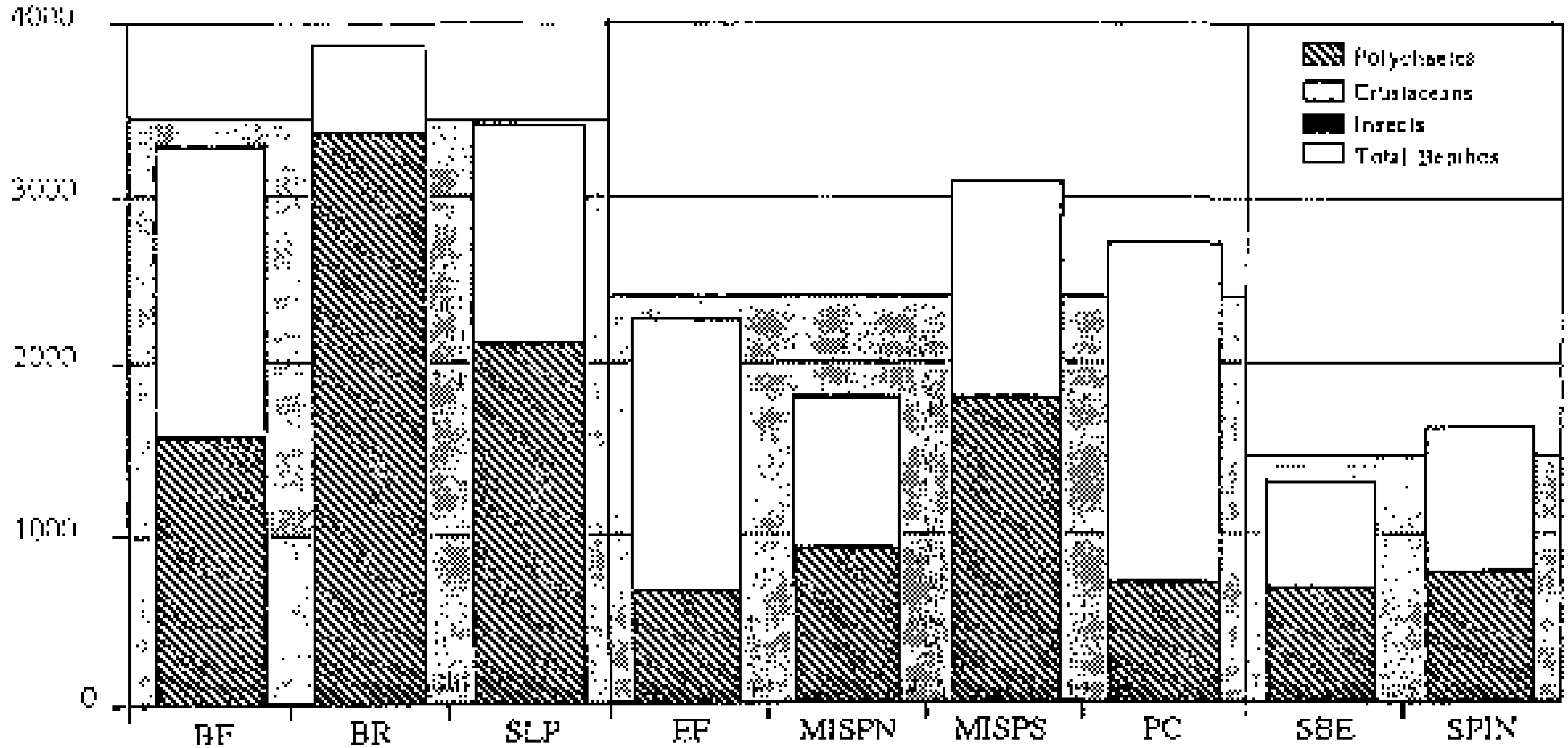


Figure 14. Macrobenthic density at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Stacked bars illustrate polychaete density, crustacean density, insect density, and (collectively) total mean benthic density recorded at locations occupied by foraging Piping Plovers. Wide gray bars in background illustrate mean total benthic density for both ecosystems and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, SBE = South Bay East, SPIN = South Padre Island - North

Total beach benthos differed significantly among both ecosystems and the ecotone (Table 11). Total benthic prey density was much higher in the bay ecosystem than the lagoon ecosystem ($P < 0.0001$) or the ecotone ($P < 0.0001$). Much of the variation in total benthos among the 3 regions was due to variation in polychaete populations. Polychaete densities were higher at bay beaches than at ecotone beaches ($P < 0.0001$) or lagoon beaches ($P < 0.0001$). I also recovered more polychaetes in samples from ecotone beaches relative to lagoon beaches ($P = 0.0020$). There were fewer crustaceans at lagoon ecosystem beaches than at those in the bay ecosystem ($P = 0.0210$) or the ecotone ($P = 0.0033$), however, crustacean density did not differ between the bay ecosystem and the ecotone ($P = 0.5893$). None of the 3 coastal regions differed with regard to benthic insect density at beach habitat.

There was no difference in total benthic density ($P = 0.3528$), polychaete density ($P = 0.1057$), or crustacean density ($P = 0.9846$) in the swash zone and upper beach zone (Table 12). There also was no detectable difference in the density of the dominant beach benthic prey groups in the winter and migratory periods (Table 13).

Bayshore Benthos

Benthic prey density ranged widely at bayshore habitats from just over 100 animals/m^2 to over 7000 animals/m^2 (Table 14; Figure 15). Total benthic prey varied significantly among the 3 coastal regions (Table 11). I detected higher benthic prey density in the bay ecosystem relative to the lagoon ecosystem ($P < 0.0001$) and the ecotone ($P < 0.0001$). Total benthic density also was greater in the ecotone than the lagoon ecosystem ($P = 0.0010$).

Polychaetes were often the most numerous prey group in samples, but polychaete density ranged widely from 0 to over 7,000 worms/m^2. Polychaete density was higher in the bay ecosystem than in either the lagoon ecosystem ($P < 0.0001$; Table 11) or the ecotone ($P < 0.0001$, Table 11) and was lower in the lagoon ecosystem than the ecotone

Table 11. Piping Plover bayshore flock size and prey population measures at beach and bayshore habitat from the 2 ecosystems and the ecotone along the Texas Gulf Coast. Parameters are summarized as study means for each location. Multi-factor ANOVA results of pair-wise comparisons between the ecosystems and the ecotone are presented in the last 3 columns. Bayshore flock size represents the mean number of Piping Plovers within foraging flocks as recorded during prey sampling periods at bayshore habitat. Benthic prey parameters are represented as the mean number of animals/m². Surface prey, as estimated by sticky traps (ST), and scope surveys (SS), are represented as the mean number of animals/100m². Insect larval density, as estimated by algal mat cores samples (AC) is represented as the mean number of larva/m².

Parameter	Bay Ecosystem			Ecotone			Lagoon Ecosystem			Bay	Bay	Eco.
	mean	N	SE	mean	N	SE	mean	N	SE	vs. Lag.	vs. Eco.	vs. Lag.
Bayshore Flock size	12.8	550	0.6	9.4	401	0.7	16.6	230	0.9	0.1945	0.2608	0.0714
Beach Total Benthos	3439.1	290	185.9	2426.2	427	153.2	1459.0	90	333.7	< 0.0001	< 0.0001	0.0010
Beach Polychaetes	2096.3	290	106.6	930.5	427	87.8	738.3	90	191.3	< 0.0001	< 0.0001	0.0020
Beach Crustaceans	1332.6	290	139.1	1452.9	427	114.6	718.2	90	249.6	0.0210	0.5893	0.0033
Beach Insects	4.7	290	1.6	0.0	427	1.3	0.0	90	2.9	0.1719	0.4369	0.3750
Bayshore Total Benthos	5067.7	550	168.0	1317.7	401	196.7	864.7	230	259.8	< 0.0001	< 0.0001	0.0010
Bayshore Polychaetes	5041.9	550	155.3	796.1	375	188.1	495.2	230	240.1	< 0.0001	< 0.0001	< 0.0001
Bayshore Crustaceans	18.9	550	59.0	604.1	370	71.9	211.3	230	91.2	0.0309	< 0.0001	< 0.0001
Bayshore Insects	6.2	550	5.0	15.9	370	6.1	158.2	230	7.7	< 0.0001	0.3925	< 0.0001
Surface Prey - ST	15.5	401	17.2	160.9	330	16.3	225.6	445	16.3	0.0082	0.0296	0.0142
Surface Prey - SS	0.6	206	8.0	81.4	95	11.8	58.1	205	8.0	0.0330	0.1638	0.4710
Insect Larva - AC	--	--	--	522.6	32	162.6	838.1	72	108.4	--	--	0.0865

Bay = bay ecosystem, Eco = ecotone, Lag = lagoon ecosystem

Table 12. Comparison between the swash zone and the upper beach, the 2 microhabitats used most frequently by Piping Plovers along the Texas Gulf Coast.. All numbers represent means for all sites and years. Piping Plover (PIPL) abundance is reported as the number of plovers/transect as measured during prey sampling. Benthic parameters are reported as the number of animals/m². Foraging efficiency estimates are reported as the number of captures/minute, and foraging locomotion is reported as the number of seconds/minute spent in prolonged locomotion.

Ecosystem	Swash Zone			Upper Beach			P-value
	mean	N	SE	mean	N	SE	
PIPL Abundance	1.42	315	0.10	1.20	346	0.09	0.0224
Total Benthos	2621.6	315	189.3	2641.5	346	180.6	0.1528
Benthic Polychaetes	1427.8	315	110.8	1224.7	346	105.8	0.1057
Benthic Crustaceans	1151.5	315	136.9	1401.1	346	130.6	0.9816
Benthic Insects	0.0	315	1.7	3.9	346	1.6	0.0558
Foraging Efficiency	13.7	66	0.8	7.0	38	1.1	< 0.0001
Foraging Locomotion	10.0	54	0.8	5.7	81	0.7	0.0002

Table 13. The effects of season on benthic prey density along the Texas Gulf Coast, 1991 - 1994. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing benthic prey density among the 2 seasons.

Ecosystem	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Total benthos	2468.9	397	161.7	2888.9	410	159.1	0.7602
Polychaetes	1247.8	397	95.4	1405.6	410	93.9	0.6069
Crustaceans	1186.4	397	119.1	1464.6	410	117.2	0.2898
Insects	3.4	397	1.4	0.0	410	1.4	0.0417
Bayshore Habitat							
Total benthos	2176.2	561	179.7	3186.4	725	158.1	0.3858
Polychaetes	2031.5	540	176.9	2905.4	720	153.2	0.7270
Crustaceans	182.9	540	58.0	261.4	715	50.4	0.8616
Insects	46.5	540	6.0	42.7	715	5.2	0.5662

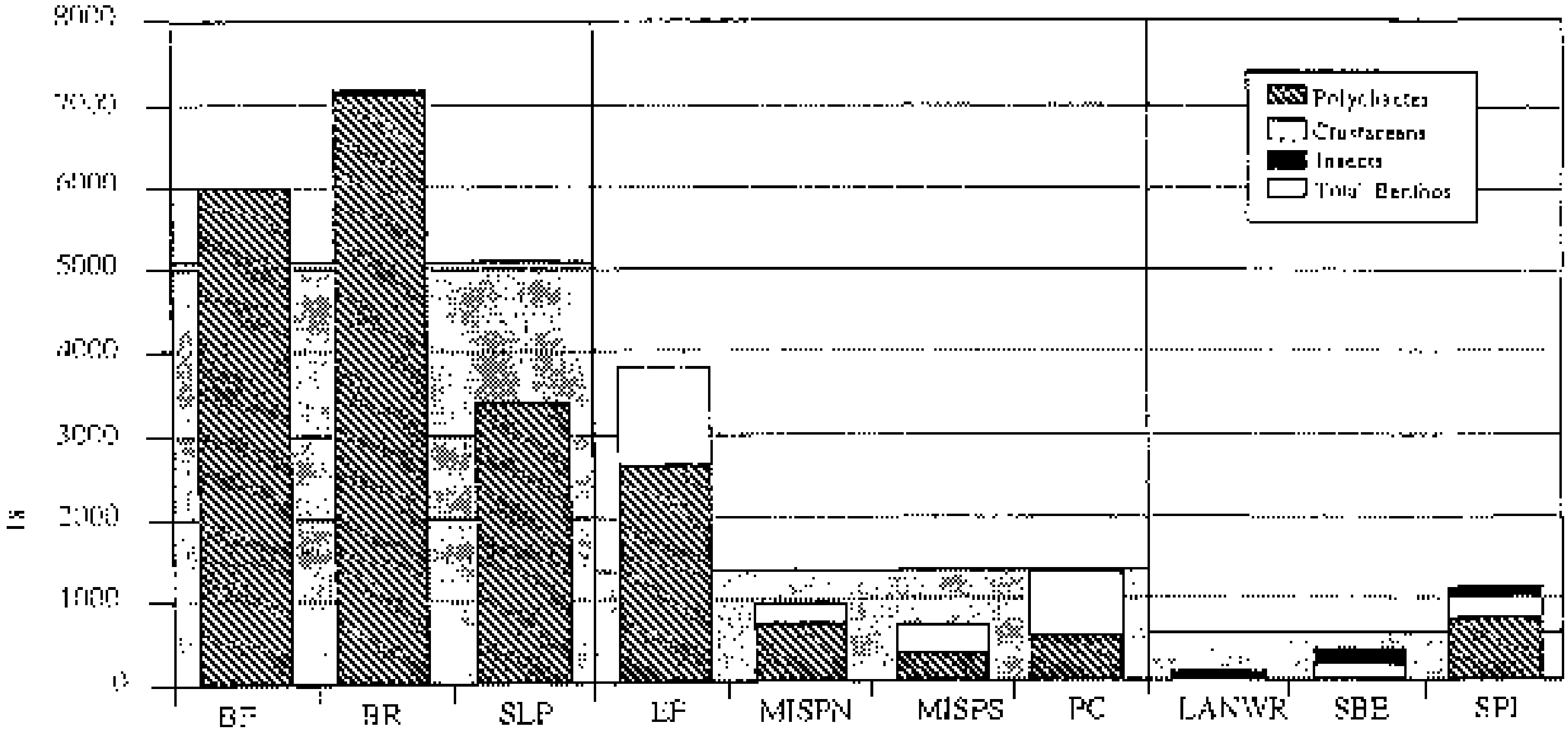


Figure 15. Mean site density and ecosystem density of Piping Plover at bayshore habitat along the Texas Gulf Coast, 1991 - 1994. Stacked bars illustrate polychaete density, crustacean density, insect density, and (collectively) total mean benthic density recorded at locations occupied by foraging Piping Plovers. Wide gray bars in background illustrate mean total benthic density for both ecosystems and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, LANWR = Laguna Atascosa National Wildlife Refuge, SBE = South Bay East, SPI = South Padre Island

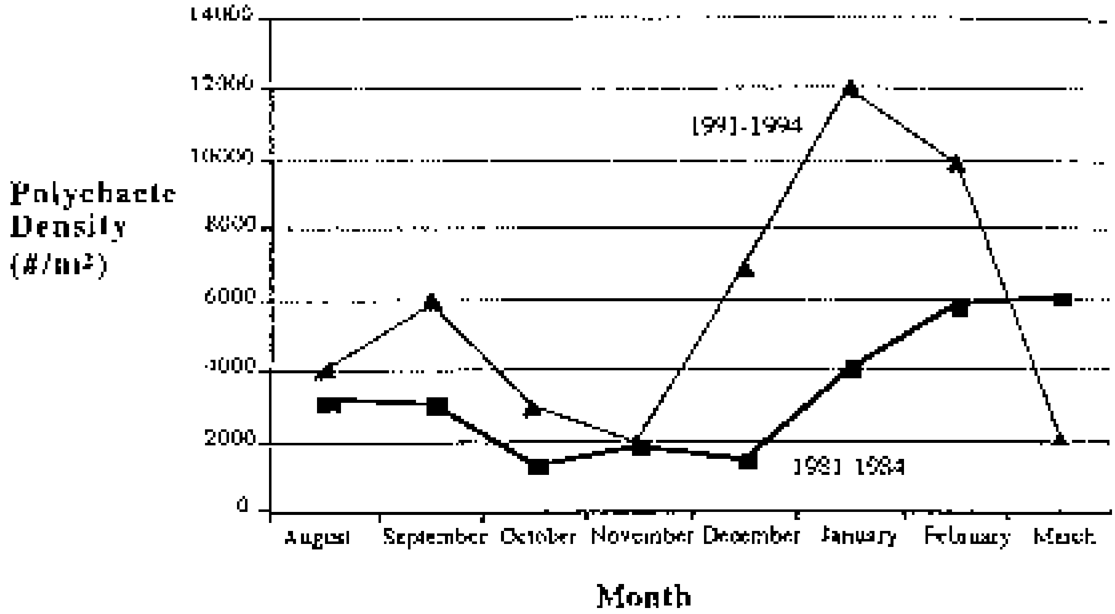
($P < 0.0001$; Table 11). Polychaete density in my samples from Bolivar Flats and Big Reef was similar to polychaete density estimates reported by Sears and Mueller (1989) for those 2 sites (Figure 16). Sears and Mueller sampled polychaetes along a fixed transect, and therefore their samples were not necessarily associated with areas recently used by foraging Piping Plovers. When the samples from both studies are compared on a monthly basis (as the data from Sears and Mueller (1989) were summarized) polychaete density was higher in my samples in 7 out of 8 months at Bolivar Flats, but just 3 out of 6 months at Big Reef. Both studies suggest that peak polychaete density occur in winter (January - February) in the bay ecosystem.

Crustacean density ranged from 0 to over 1,100 animals/m^2 at bayshore habitat (Table 14). Large crustacean counts were usually associated with local blooms of tanaids. Crustacean density was much higher in the ecotone ($P < 0.0001$; Table 11) and the lagoon ecosystem ($P = 0.0309$; Table 11) relative to the bay ecosystem. The highest crustacean density occurred in the ecotone, where I collected nearly 3 times as many crustaceans as in the lagoon ecosystem ($P < 0.0001$; Table 11).

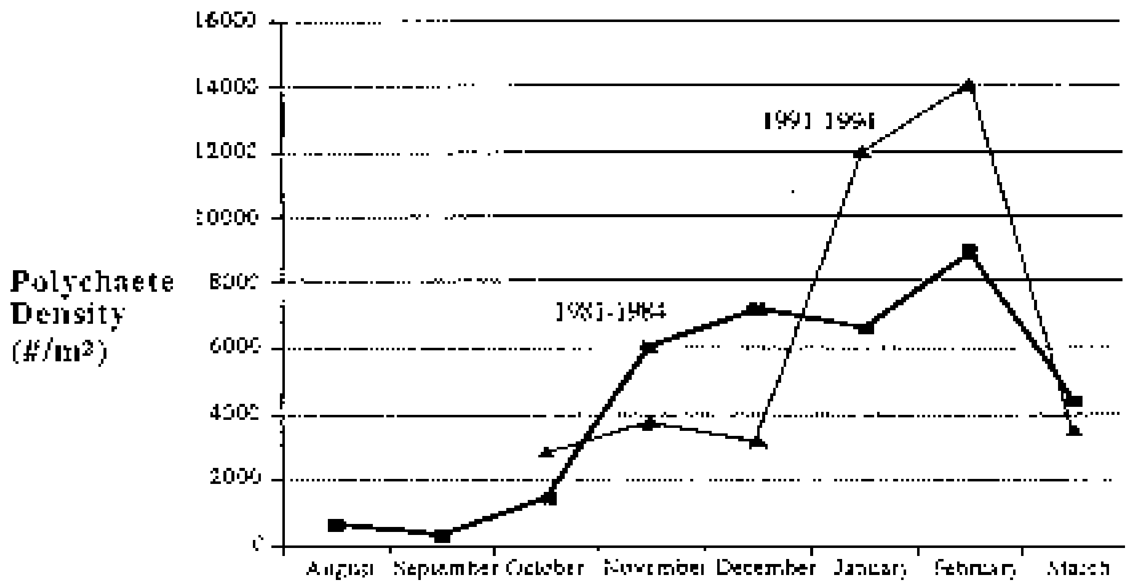
Insects were much less common in bayshore benthic samples relative to polychaetes or crustaceans, and most insects collected in subsurface samples were fly larva. I recorded densities of < 100 insects/m^2 at most of my sites, however, insect density exceeded this amount at all 3 study areas in the lagoon ecosystem (Table 14; Figure 16).

Total benthic prey density was similar in areas used by flocks and individual plovers ($P = 0.4925$, Table 15). Crustacean density was greater in areas used by plover flocks ($P = 0.0015$; Table 15), but neither polychaete density ($P = 0.3829$; Table 15) nor benthic insect density ($P = 0.2408$; Table 15) differed among areas used by flocks or solitary plovers.

Total benthic prey density ($P < 0.0001$) and polychaete density ($P < 0.0001$) were higher at sand flats than at algal flats (Table 16). Benthic insect density was higher at



A. Bolivar Flats



B. Big Reef

Figure 16. Polychaete density at Bolivar Flats (A) and Big Reef (B) as measured in 1981 - 1982 (thick line with rectangles) by Sears and Mueller (1989) and in 1991 - 1994 (thin line with triangles) for this study.

Table 15. Comparison of prey populations collected in association with flocks of Piping Plovers and solitary Piping Plovers. All numbers represent means for all sites throughout the study. Benthic parameters are reported as the number of animals/m². Sticky trap (ST) estimates of surface prey are reported as the number of insects captured/100 trap hours.

Ecosystem	Plover Flocks			Solitary Plovers			*P*-value
	mean	N	*SE*	mean	N	SE	
Total Benthic Prey	2895.8	1066	130.9	2018.6	220	288.2	0.4925
Benthic Polychaetes	2636.7	1048	127.5	2007.4	212	283.4	0.3829
Benthic Crustaceans	260.9	1048	41.6	59.0	207	93.6	0.0015
Benthic Insects	47.0	1048	4.3	30.6	207	9.7	0.2408
Surface Prey - ST	141.8	1028	11.1	94.6	148	29.2	0.9687

Table 16. Comparison between sand flat and algal flat habitat with regard to several study parameters. All numbers represent means for all sites throughout the study. Piping Plover (PIPL) abundance is reported as the number of plovers/transect during prey sampling. Benthic parameters and spotting scope survey (SS) estimates of surface prey are reported as the number of animals/m². Sticky trap estimates of surface prey are reported as the number of insects captured/100 trap hours. Foraging efficiency estimates are reported as the number of captures/minute, and foraging locomotion is reported as the number of seconds/minute spent in prolonged locomotion.

Ecosystem	Sand Flats			Algal Flats			P-value
	mean	N	SE	mean	N	SE	
PIPL Abundance	12.7	754	0.5	12.7	532	0.6	0.8373
Total Benthos	4316.5	754	140.5	519.6	532	167.2	< 0.0001
Benthic Polychaetes	4021.5	754	135.1	309.5	506	165.0	< 0.0001
Benthic Crustaceans	275.8	754	49.1	155.2	501	60.2	0.1037
Benthic Insects	18.6	754	5.0	83.0	501	6.1	< 0.0001
Surface Prey - ST	87.0	604	15.0	187.0	572	14.0	< 0.0001
Surface Prey - SS	0.27	336	0.6	0.71	140	0.1	0.0002
Foraging Efficiency	10.3	336	0.3	9.8	168	0.4	0.9114
Foraging Locomotion	1.25	167	0.22	1.54	118	0.26	0.0027

algal flats than at sand flats ($P < 0.0001$). Crustacean density did not differ among bayshore microhabitat types ($P = 0.1037$). All types of benthic prey were more abundant at barrier island sites relative to mainland sites (Table 17).

Bayshore Surface Prey as Estimated Using Sticky Traps

With the exceptions of a few spiders, all of the animals captured by the sticky traps were flies and other small adult insects. My samples suggest that surface prey density varied widely along the coast. The mean number of insects captured using sticky traps ranged from < 10 to nearly 1000 insects/100 trap hours (Table 18; Figure 17).

Surface prey abundance was lower in the bay ecosystem than the ecotone ($P = 0.0296$) or the lagoon ecosystem ($P = 0.0082$). The lagoon supported the highest abundance of surface prey, where levels exceeded those collected at sites in the ecotone ($P = 0.0142$). Total surface prey abundance was similar in areas used by flocks and individual plovers ($P = 0.9687$; Table 15).

Bayshore Surface Prey as Estimated Using Spotting Scope Surveys

Mean surface animal density, as estimated by spotting scope surveys, varied from 0 to over 200 animals/m^2 (Table 18; Figure 17). I observed significantly more surface prey in the lagoon ecosystem than in the bay ecosystem ($P = 0.0330$). However, surface prey density did not differ significantly between bay ecosystem and the ecotone ($P = 0.1638$) or the ecotone and the lagoon ecosystem ($P = 0.4710$).

Bayshore Emergent Prey Density as Estimated Using Algal Cores

I collected and monitored 104 algal mat core samples for emerging prey animals (Table 18; Figure 17). I did not collect any samples from the bay ecosystem because algal mats were extremely rare in this ecosystem and plovers were never observed to feed at algal flats during the 2 years algal cores were collected. Because there were no adult prey on the surface of the algal mat cores when they were collected, the insects scored from algal cores were mostly adult stages that had developed from eggs, larvae or pupae

Table 17. Mean prey population estimates on barrier island and mainland bayshore tidal flats in the lagoon ecosystem, 1991 - 1994 as estimated from samples collected in association with foraging Piping Plovers. Benthic prey density is expressed as the mean number of prey/m². Surface prey is expressed as the number of prey/100 trap hour for sticky traps, and the number of prey/m² for scope surveys and algal core samples. The *P*-values presented in the last column are associated with one way ANOVA analyses comparing benthic prey density among the 2 landform types.

Ecosystem	Barrier Island			Mainland			*P*-value
	mean	N	SE	mean	N	SE	
Benthos							
Total benthos	831.5	240	89.5	109.0	85	150.4	< 0.0001
Polychaetes	474.6	240	79.1	0.0	85	133.0	< 0.0001
Crustaceans	202.5	240	32.1	0.0	85	54.0	< 0.0001
Insects	154.4	240	14.5	109.0	85	24.4	0.0147
Surface Prey							
Sticky Traps	191.6	215	29.1	257.8	230	28.1	0.4906
Scope Surveys	0.40	180	0.07	1.86	25	0.21	< 0.0001
Algal Cores	1013.6	33	239.0	1321.2	39	219.8	0.7320

Table 18. Mean surface prey density collected at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Surface prey populations are represented as relative abundance (# animals/100 trap hours) as estimated by sticky traps, and prey density (# animals/100 m²) as estimated by spotting scope counts and incubated algal core samples. Abbreviations: LANWR = Laguna Atascosa National Wildlife Refuge, MISP = Mustang Island State Park.

Study Location	Sticky Traps			Spotting Scope			Algal Mat Cores		
	N	mean	SE	N	mean	SE	N	mean	SE
Bolivar Flats	150	60.0	22.7	75	0.0	12.2	0	--	--
Big Reef	90	42.2	29.3	55	0.0	14.2	0	--	--
San Luis Pass	161	9.3	21.9	99	28.8	10.6	0	--	--
East Flats	31	971.0	499.7	25	223.7	211.0	4	1299.5	658.5
MISP North Area	121	75.2	25.3	25	19.0	21.1	2	1356.0	931.2
Packery Flats	168	81.5	21.5	39	42.7	16.9	26	1451.6	258
LANWR	220	266.8	34.5	25	185.6	21.1	39	1321.2	210.9
South Bay East	50	78.0	39.3	35	23.8	17.8	13	851.9	365.2
South Padre Island	100	230.0	27.8	117	30.5	9.8	20	1118.7	294.5

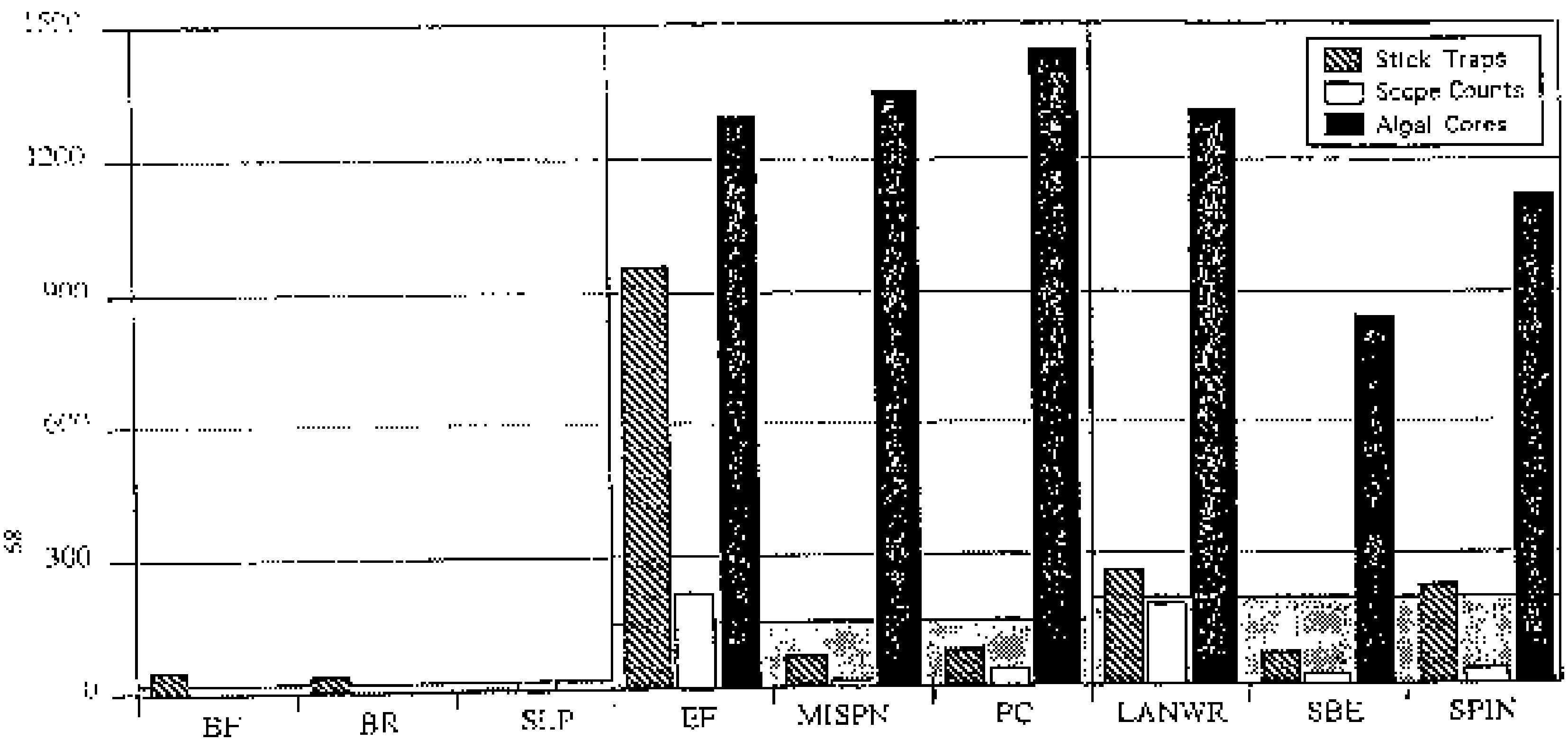


Figure 17. Mean surface prey density collected at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Surface prey populations are represented as relative abundance (striped bars # animals/100 trap hours) as estimated by sticky traps, and prey density (# animals/100 square meter) as estimated by spotting scope counts (white bars) and incubated algal core samples (black bars). Wide gray bars in background illustrate mean relative surface abundance from sticky traps at each ecosystem and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park South, PC = Packery Channel, LANWR = Laguna Atascosa National Wildlife Refuge, SBE = South Bay East, SPI = South Padre Island.

present in the mat. Therefore, these samples estimate the short-term (6 week) insect productivity potential of algal mats.

Emergent insect density ranged from about 850 to nearly 1,500 insects/m^2 (Table 18; Figure 16). Emergent insect density was somewhat lower in the ecotone than the lagoon ecosystem ($P = 0.0865$; Table 11).

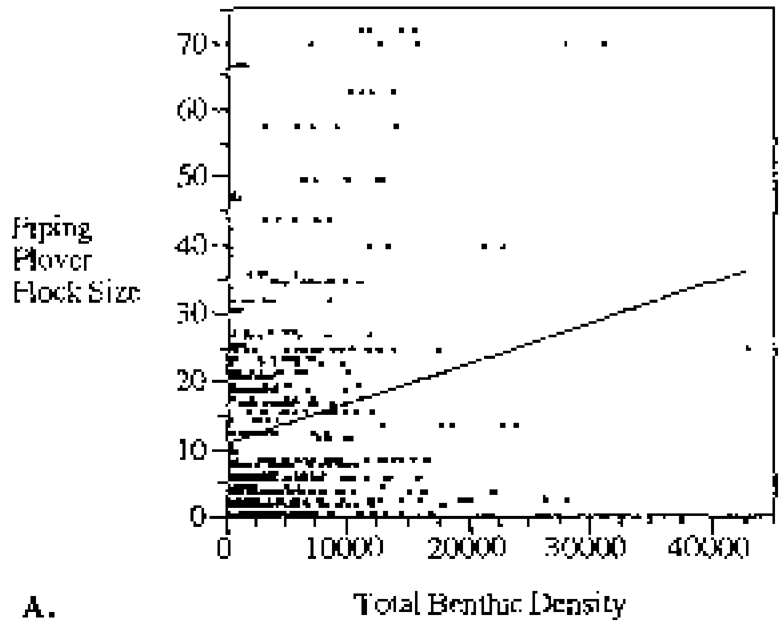
Relationship Between Prey Density and Piping Plover Flock Size

Whereas bayshore plover flock size did not differ significantly in the 2 ecosystems and the ecotone (Table 11), there was a strong relationship between Piping Plover foraging flock size and total benthic prey density. When I pooled data from both ecosystems and the ecotone I detected a positive relationship between the number of Piping Plovers feeding in an area and the density of total benthos ($P < 0.0001$; Figure 18A) and polychaetes ($P < 0.0001$; Figure 18B) within the area used by the flock. There was no such relationship between plover flock size and benthic crustacean density ($P = 0.0885$, Figure 19A) or benthic insect density ($P = 0.0594$; Figure 19B).

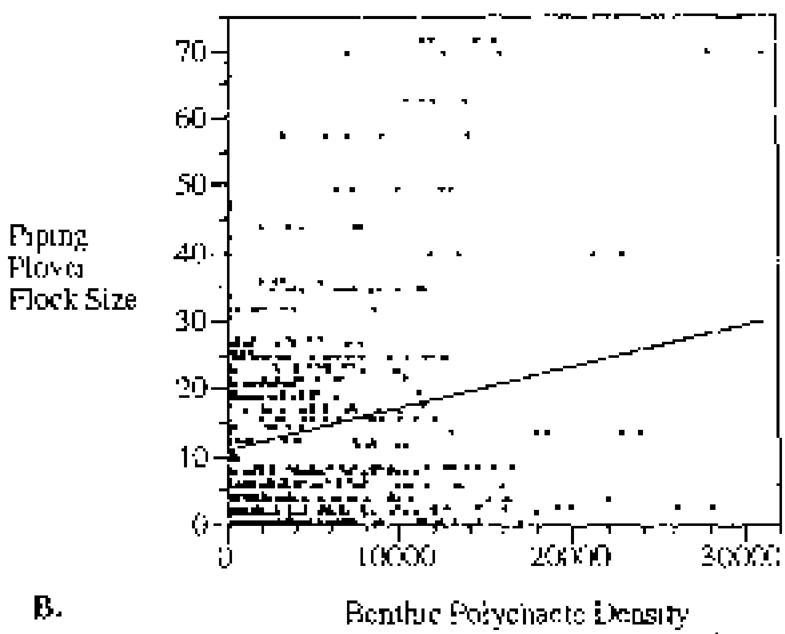
Different relationships become apparent when the data from each of the ecosystems and the ecotone were investigated independently. Within the bay ecosystem, Piping Plovers were attracted to concentrations of polychaetes. Flock size increased in areas with high total benthic density ($P < 0.0001$; Figure 20A), high benthic polychaete density ($P < 0.0001$; Figure 20B), and low benthic insect density ($P = 0.0035$; Figure 21B). There was no relationship between flock size and benthic crustacean density in the bay ecosystem ($P = 0.2420$, Figure 21A)

In the ecotone, plover flocks were associated with concentrations of total benthos ($P = 0.0003$; Figure 22A), polychaetes ($P = 0.0054$; Figure 22B) and crustaceans ($P = 0.0016$; Figure 23A). Benthic insect populations were not related to Piping Plover concentrations in the ecotone ($P = 0.1034$; Figure 23B).

In the lagoon ecosystem, the larger flocks of Piping Plovers were associated with

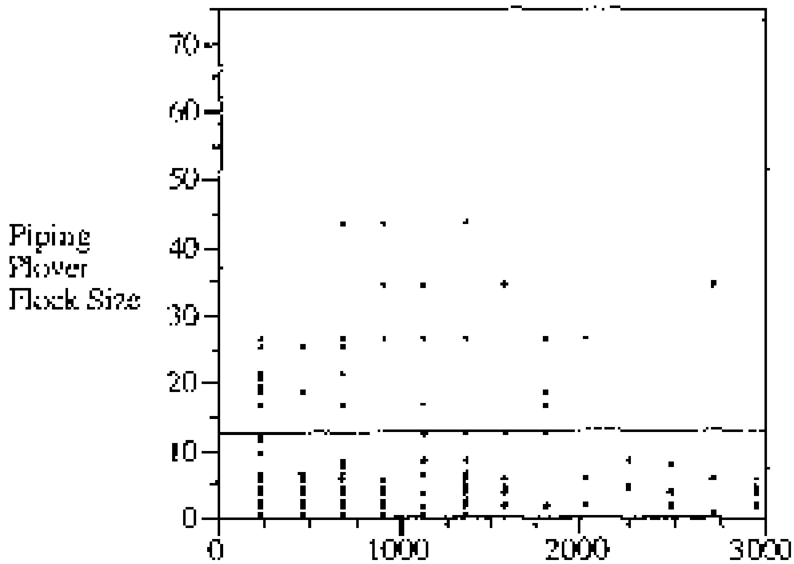


A.

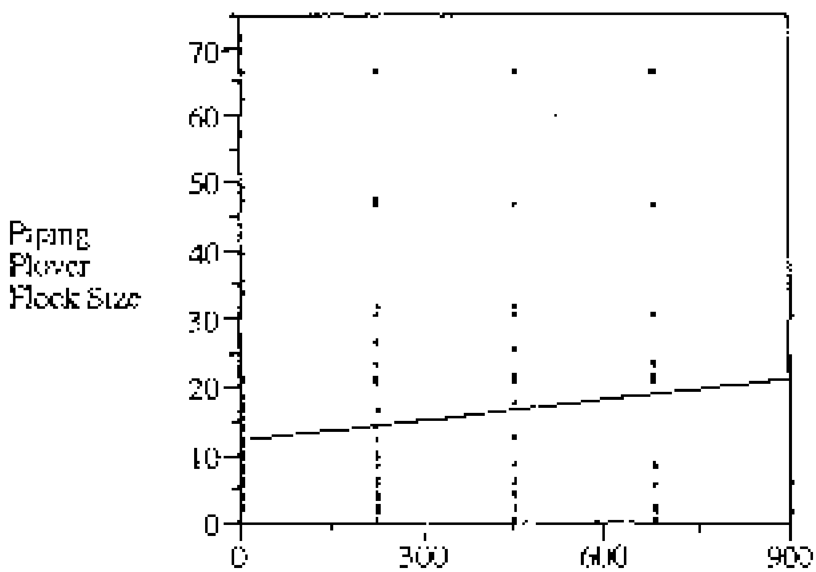


B.

Figure 18. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (*A*; $P < 0.0001$) and benthic polychaete density (*B*; $P < 0.0001$). Data are pooled from all sites.

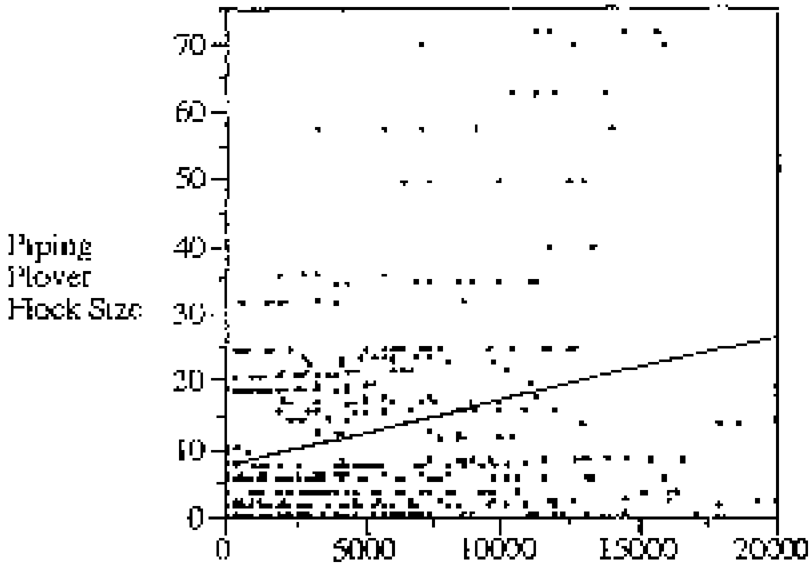


A.

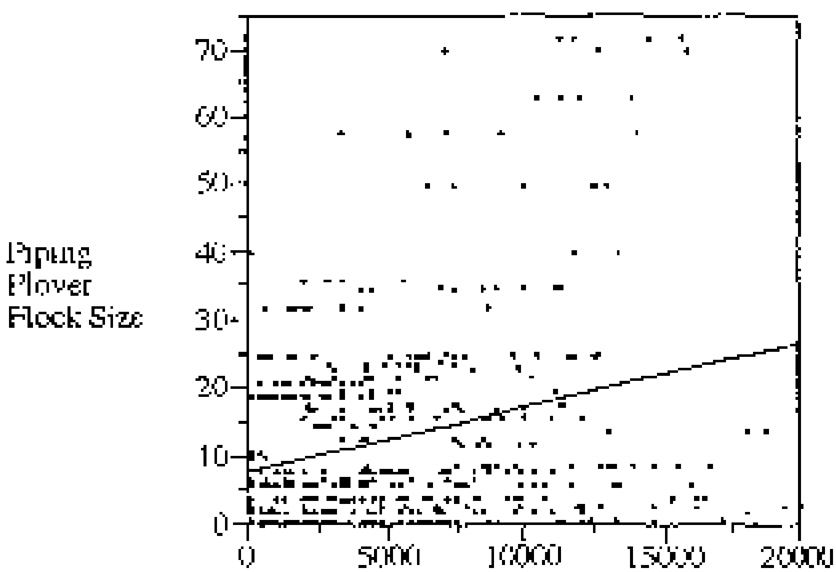


B.

Figure 19. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0885$) and benthic insect density (B; $P = 0.0594$). Data are pooled from all sites.



A.



B.

Figure 20. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P < 0.0001$) and benthic polychaete density (B; $P < 0.0001$). Data are from bay ecosystem sites only.

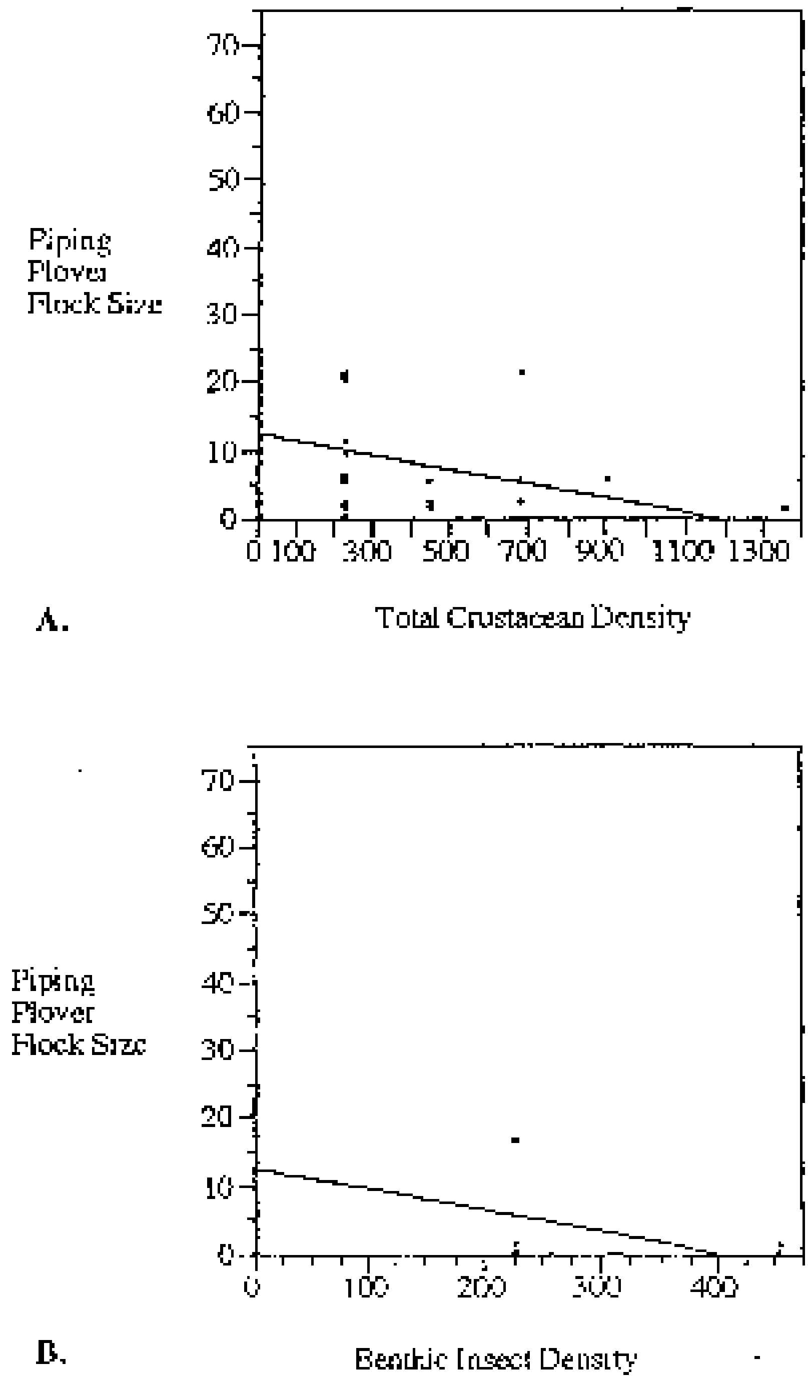
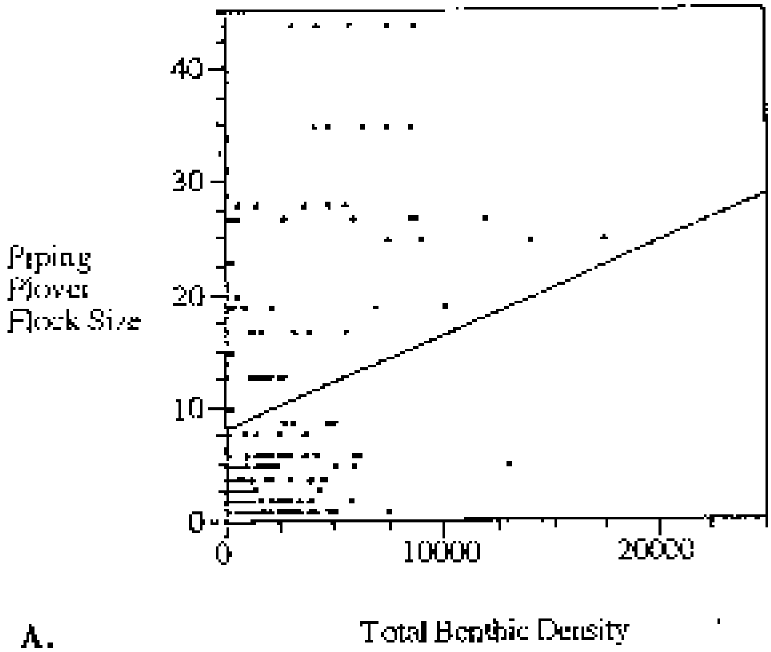
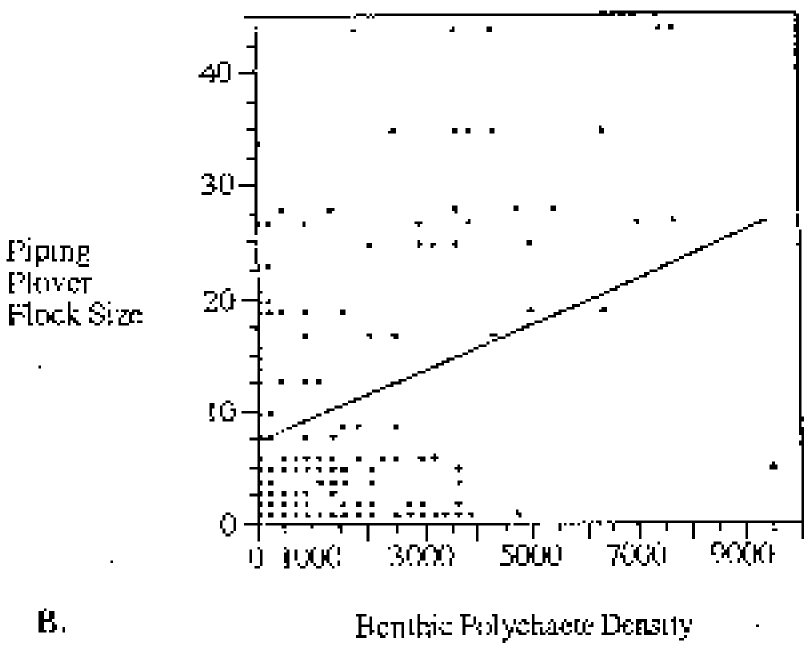


Figure 21. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.2420$) and benthic insect density (B; $P = 0.0035$). Data are from bay ecosystem sites only.

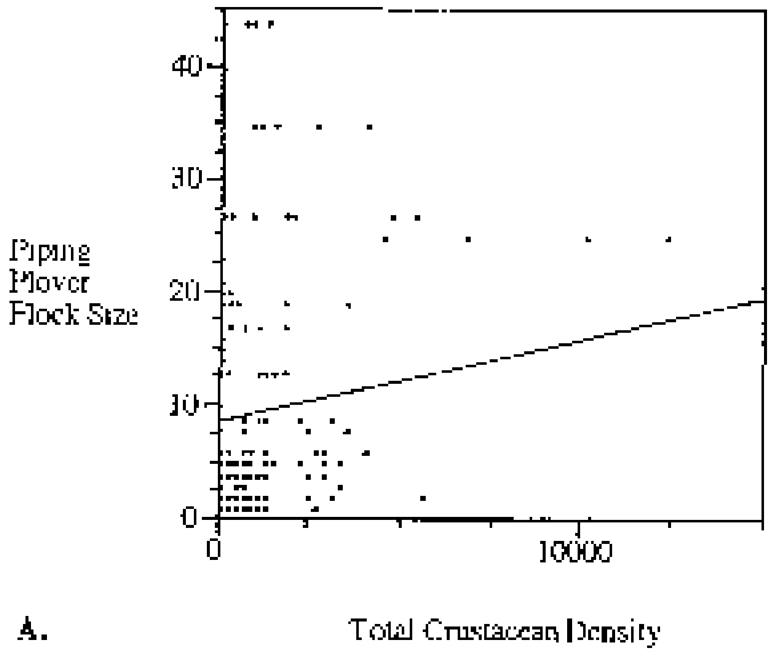


A.

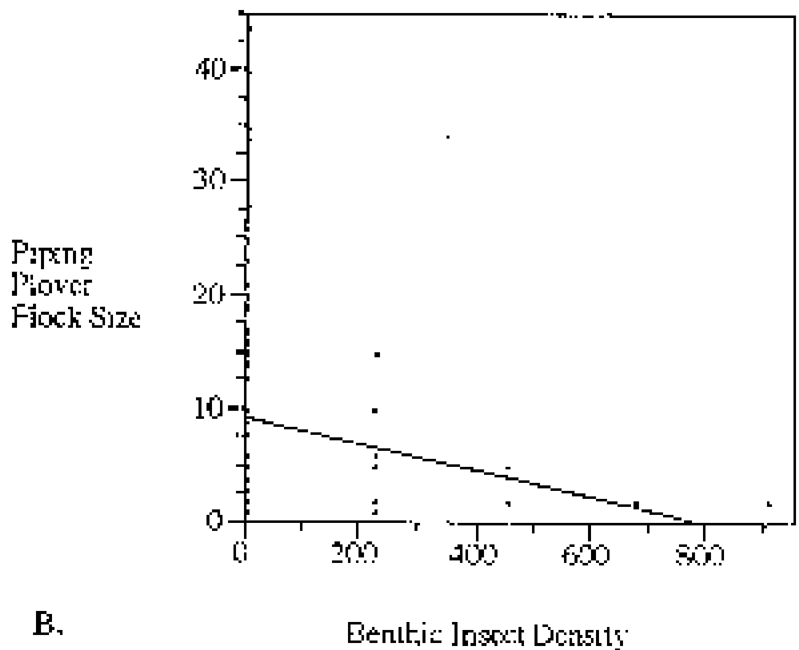


B.

Figure 22. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P = 0.0003$) and benthic polychaete density (B; $P = 0.0054$). Data are from the ecotone sites only.



A.



B.

Figure 23. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0016$) and benthic insect density (B; $P = 0.1034$). Data are from ecotone sites only.

areas of the flats that exhibited the lowest concentrations of total benthos ($P = 0.0004$; Figure 24A), polychaetes ($P = 0.0019$; Figure 24B) and crustaceans ($P = 0.0048$; Figure 25A). Benthic insect density did not significantly affect Piping Plover flock size in the lagoon ecosystem ($P = 0.2845$; Figure 25B).

There was no relationship between flock size and surface prey abundance at all sites combined ($P = 0.9568$; Figure 26A) or in the bay ecosystem ($P = 0.9568$; Figure 26B) or the ecotone ($P = 0.1402$; Figure 27A). Surprisingly, flock size was negatively associated with surface prey abundance in the lagoon ecosystem ($P < 0.0001$; Figure 26B).

Behavior

Piping Plover Activity

The majority of the Piping Plovers I encountered during shorebird counts were engaged in foraging activity (Figure 28). Plovers using beach habitat were more likely to be roosting than were plovers using bayshore habitat ($P < 0.0001$)

Most roosting activity by Piping Plovers at my sites occurred during high bayshore tide conditions ($P < 0.0001$). Piping Plovers roosted most commonly in washover pass regions of beach habitat and on high flat areas of bayshore habitat. Washover passes are broad, unvegetated barrier island landscapes that are formed and maintained by hurricanes and tropical storms. Because they occur at higher elevations than the forebeach, and receive less human disturbance, they provide ideal roost habitat for plovers. In washover passes, plovers often roosted along the front (Gulfward) margin of the pass in *Sargassum*-based coppice dune fields. Roosting in washover passes also occurred in areas where trash and other flotsam accumulated, and in tire tracks and other depressions. Unfortunately, these latter associations caused plovers to be more susceptible to disturbance as these areas were popular driving corridors for people seeking to access the bayshore areas for fishing, windsurfing, etc.

On bayshore flats, plovers often roosted in patches of dried algal mat and seagrass

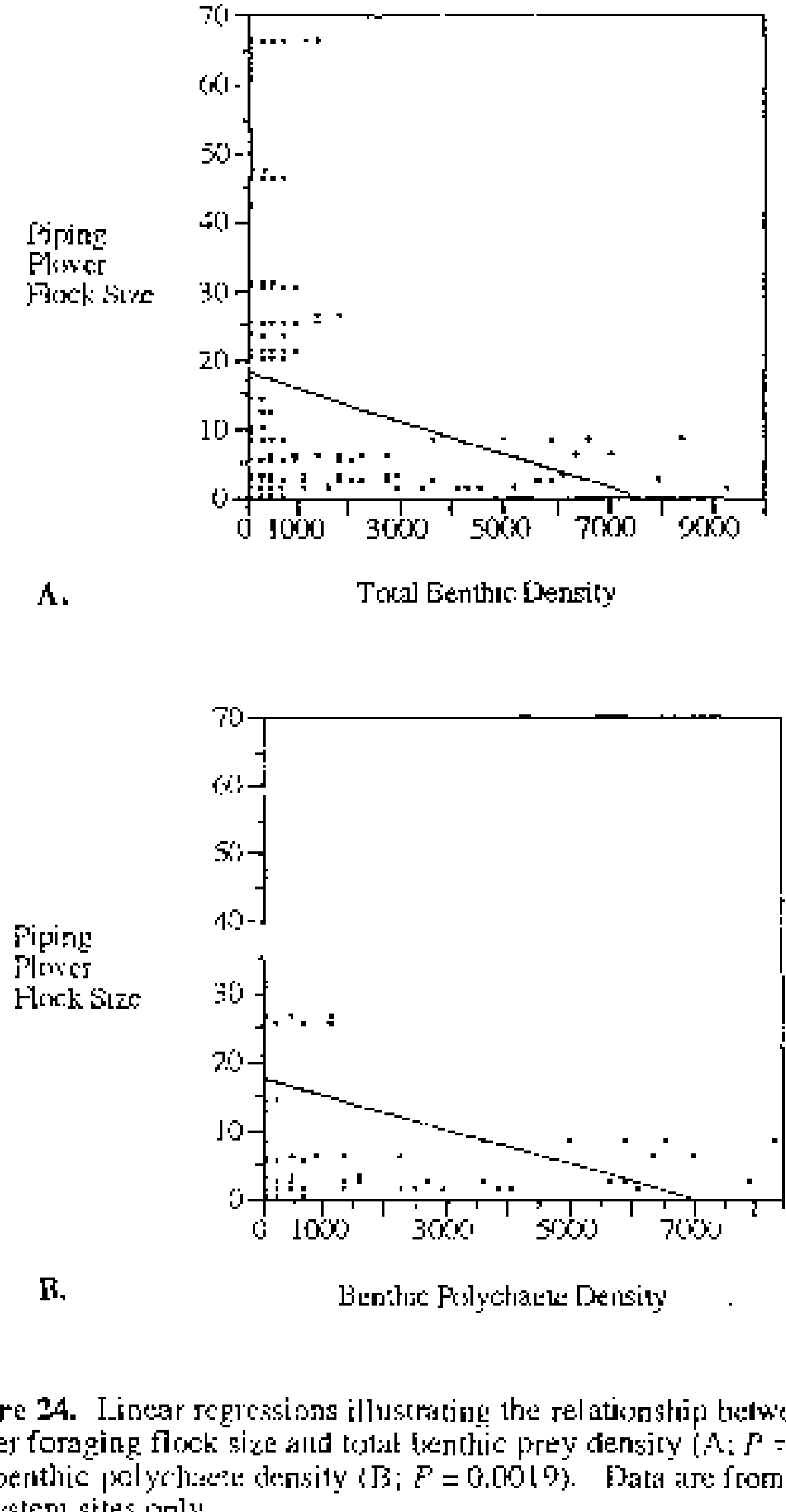
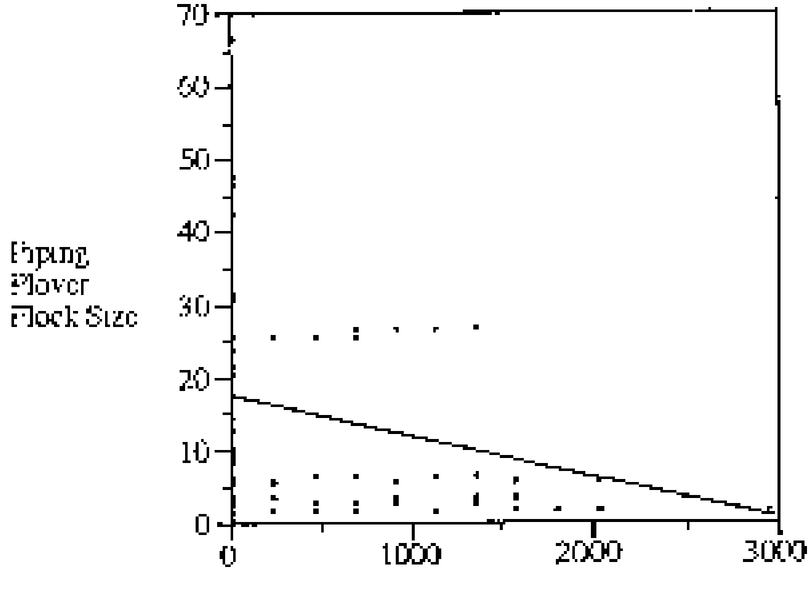
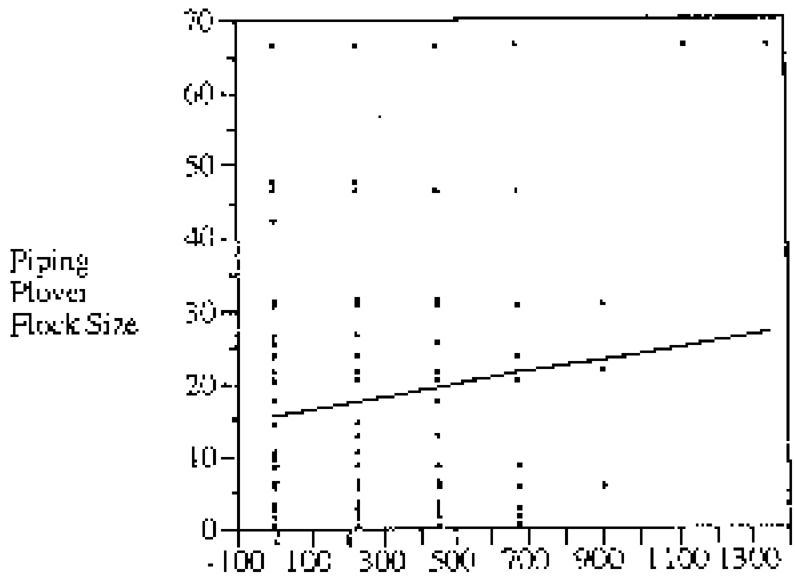


Figure 24. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P = 0.0004$) and benthic polychaete density (B; $P = 0.0019$). Data are from lagoon ecosystem sites only.



A.



B.

Figure 25. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0048$) and benthic insect density (B; $P = 0.2845$). Data are from lagoon ecosystem sites only

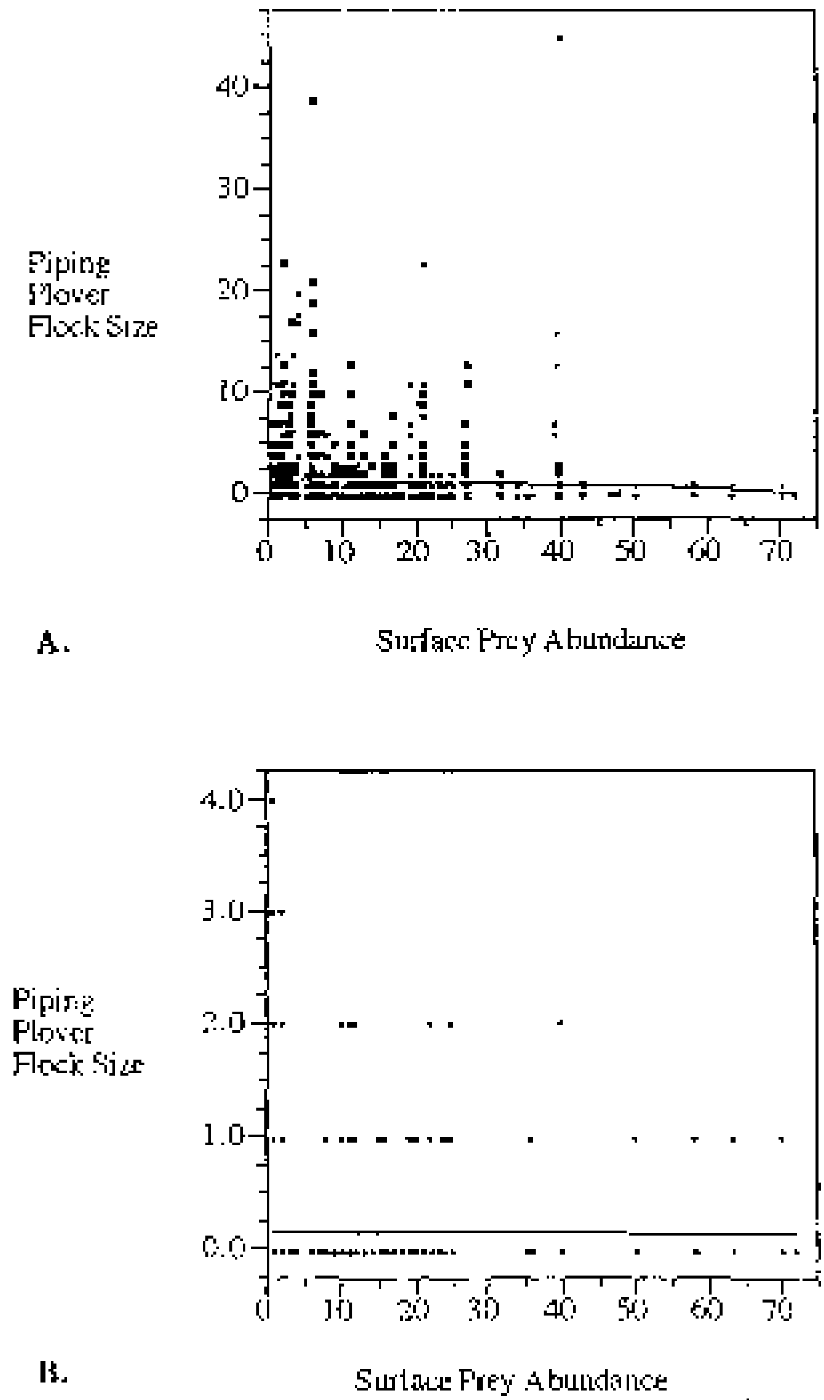
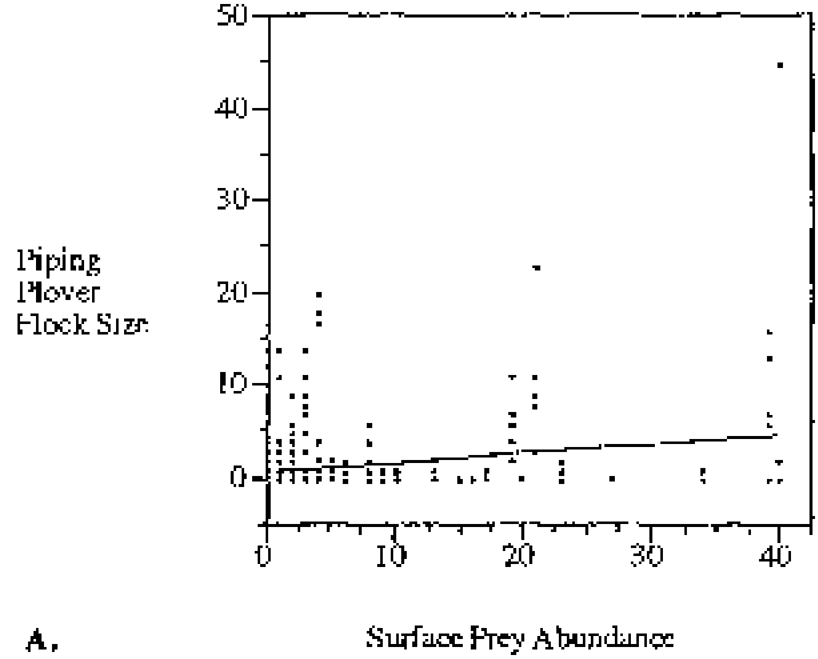


Figure 26. Linear regressions illustrating the relationship between Piping Plover foraging flock size and surface prey abundance at all sites (A; $P = 0.0501$) and at bay ecosystem sites (B; $P = 0.4080$).



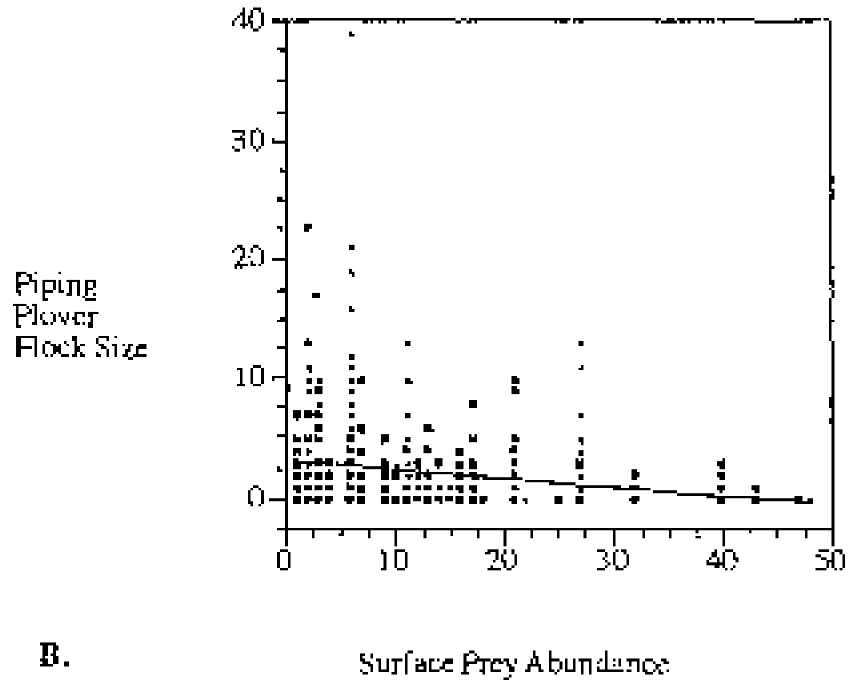


Figure 27. Linear regressions illustrating the relationship between Piping Plover foraging flock size and surface prey abundance at ecotone sites (A; $P = 0.1402$) and at lagoon ecosystem sites (B; $P < 0.0001$).

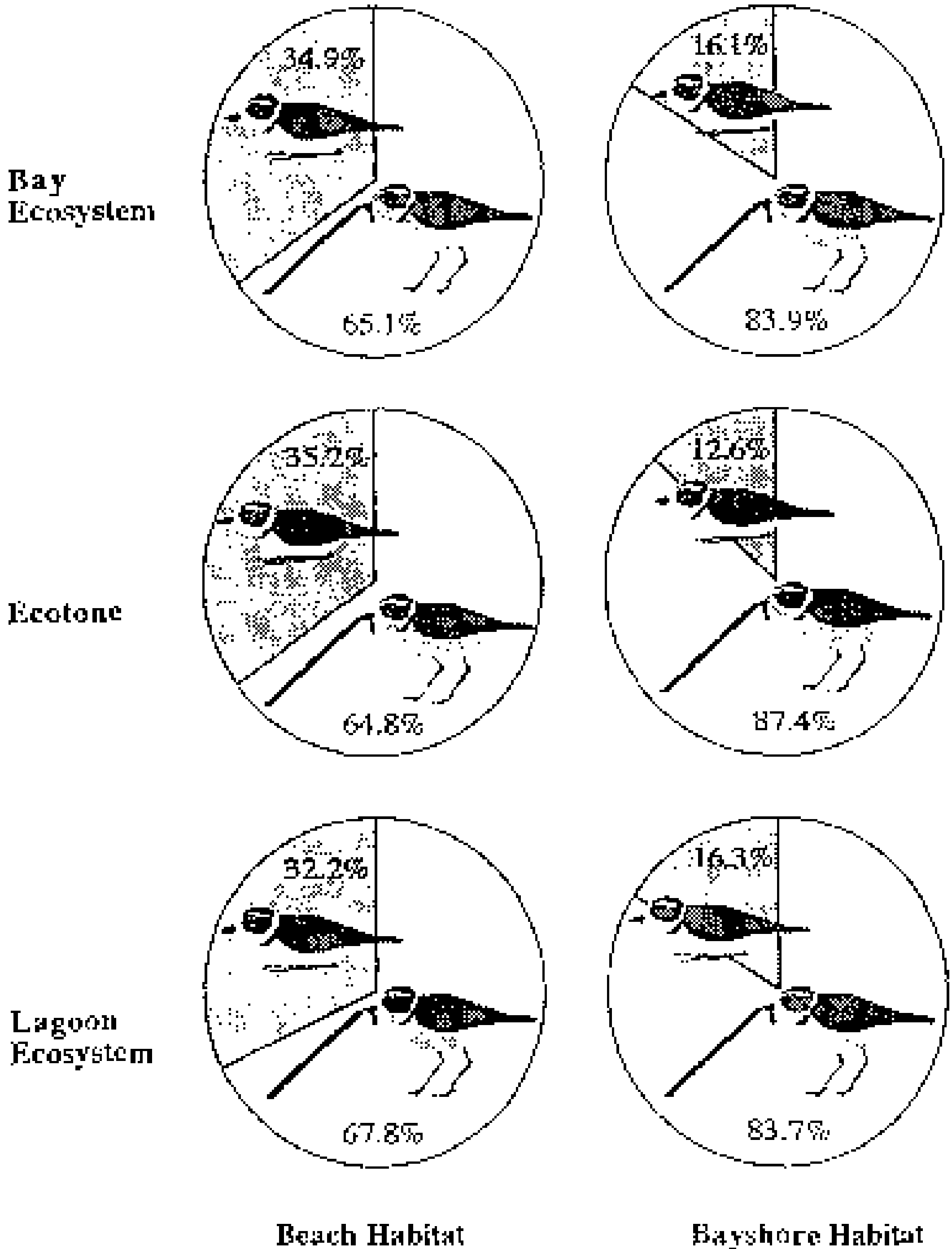


Figure 28. Mean Piping Plover activity for beach and bayshore habitat at the bay and lagoon ecosystem and the ecotone. Activity was assessed during daily, sites-wide shorebird counts. The area of each unshaded pie wedge is proportionate to the percentage of plovers that were foraging during the counts. Shaded pie wedges reflect the proportion of plovers that were roosting, preening or bathing during the counts.

wrack (primarily shoalgrass, *Halodule wrightii*). As higher areas of the algal mat became desiccated, the mat cracked and separated into pieces. As these pieces dried further, their corners curled upward creating small windbreaks behind which plovers often roosted. The colors of the Piping Plover nonbreeding plumage are ideally suited for all of these roosting environments. Despite great efforts, I often became aware of many roosting plovers only after one or more of the birds in the roosting flock moved into the open. Fortunately, in most cases, roosting plovers tolerated some disturbance, and often settled back into roosts if they were not unduly disturbed. The exception to this rule occurred in washover passes, where plovers were often more easily flushed. Plovers flushed from washover pass roost sites usually flew completely out of the pass to the bayshore.

Piping Plover Diet at Beach Habitat

Polychaetes were the dominant prey group captured by Piping Plovers at beach habitat. Nearly 70% of all identifiable prey captured by Piping Plovers at beach habitat were polychaetes (Table 19; Figure 29). At beach habitat, the polychaete group included all worm-like animals captured by plovers. I was able to identify most polychaete captures at beach habitat as *Scolelepis squamata* based on size and color characteristics.

Arthropods composed just under 30% of the known beach diet of Piping Plovers (Table 19; Figure 29). The arthropod prey group included amphipods, mole crabs and other crustaceans, as well as insects (larvae, pupae, and adults). The large majority of captures scored as arthropods at beach habitat appeared to be amphipods.

Plover diet at beach habitat in the 2 ecosystems and the ecotone was fairly similar (Figure 30). Polychaetes made up over half of the diet of plovers in all 3 regions. The higher proportion of polychaetes in the diet of plovers using lagoon ecosystem beaches may be an artifact of the small sample size (N = 9).

Piping Plover diet differed strongly at the 2 distinct beach microhabitats. Piping

Table 19. The relative proportions of polychaetes and arthropods in the diet of Piping Plovers at different locations and habitat types along the Texas Coast.

Parameter	Polychaetes			Arthropods		
	mean	N	SE	mean	N	SE
All sites and habitats	59.1	609	1.7	28.9	609	1.7
Bay Ecosystem - all habitats	77.7	308	1.9	7.6	308	1.3
Ecotone - all habitats	55.2	155	3.0	28.3	155	3.1
Lagoon Ecosystem - all habitats	23.9	146	3.3	74.7	146	3.4
Beach	68.7	123	2.9	18.9	123	2.8
Beach - swash zone	84.8	67	2.6	5.9	67	1.9
Beach - upper zone	38.1	32	5.9	39.3	32	7.4
Bayshore Flats	56.6	486	2.0	31.5	486	2.0
Sand Flats	75.0	340	2.0	13.1	340	1.7
Algal Flats	13.8	146	2.4	74.3	146	3.5

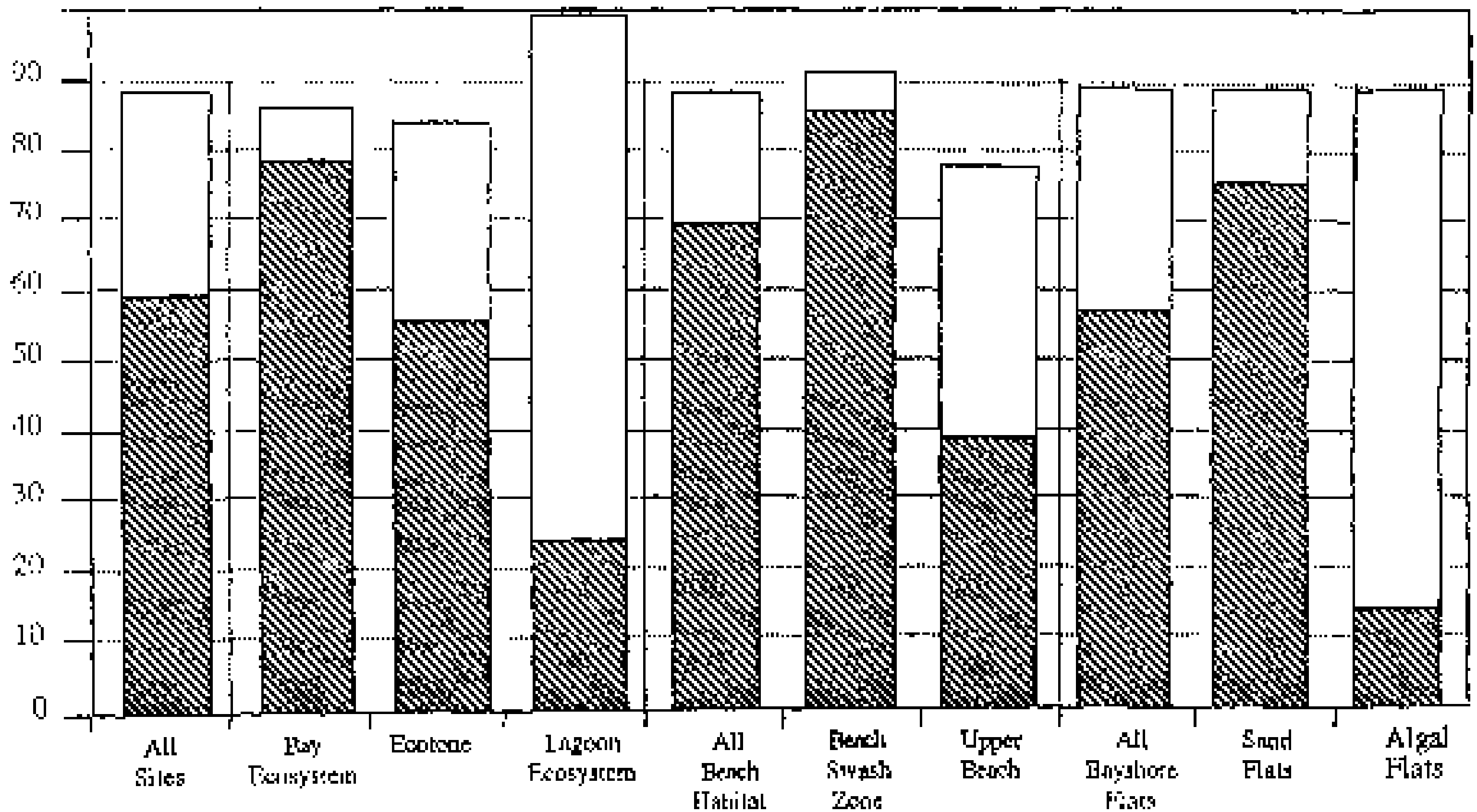


Figure 29. The proportion of polychaetes (▨) and arthropods (▭) in the diet of Piping Plovers along the Texas Coast. Bars illustrate the identifiable proportion of plover prey captures.

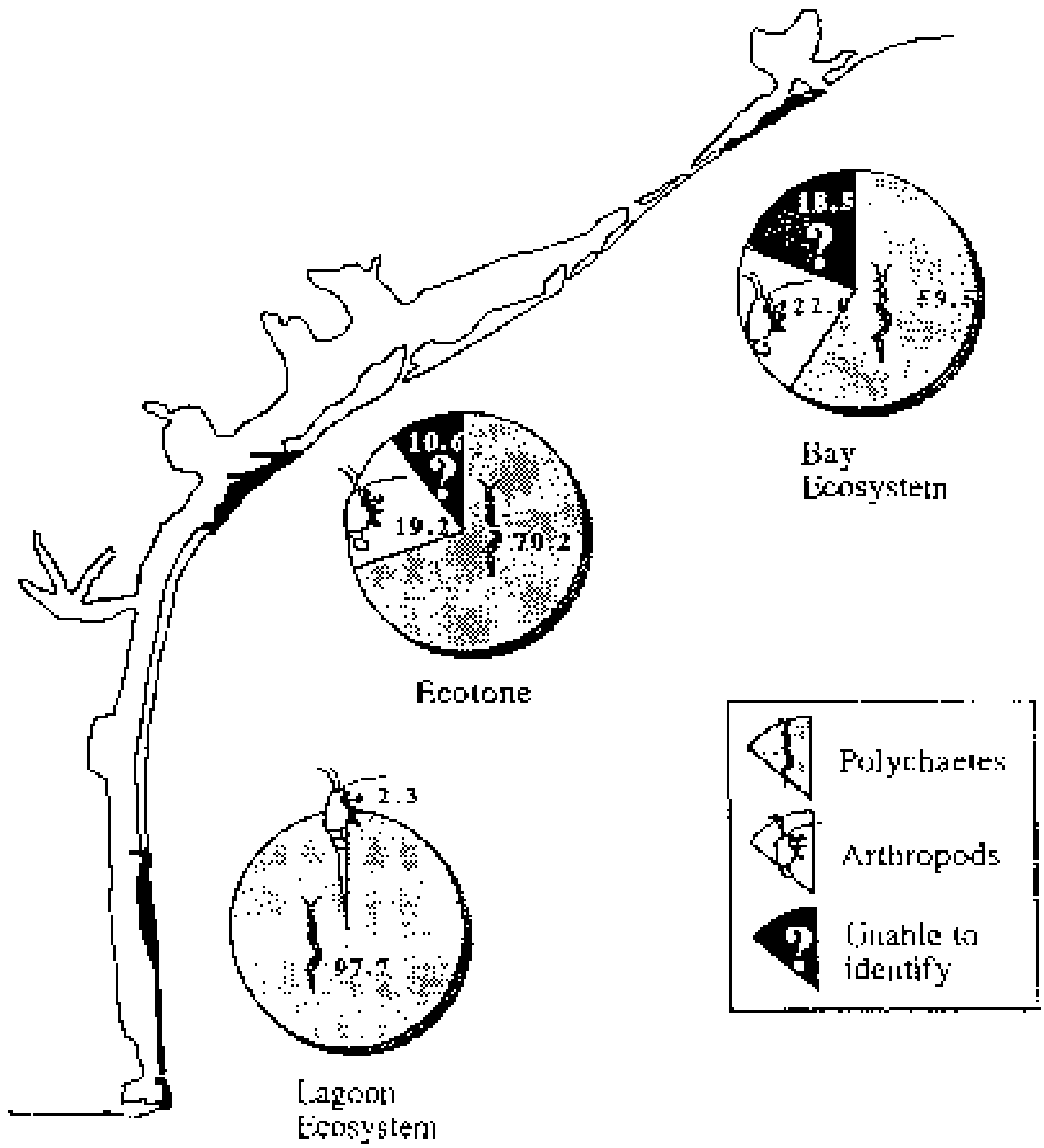


Figure 30. Piping Plover diet at beach habitat in the 2 ecosystems and the ecotone. Pie charts illustrate the proportion of polychaetes and arthropods captured by foraging plovers.

Plover captured mostly polychaetes in the lower beach swash zone ($P < 0.0001$; Table 19; Figure 29). Plovers foraging higher up on the beach captured a much greater proportion of arthropods ($P < 0.0001$). Above the swash, plovers captured a similar proportion of polychaetes and arthropods (Table 19; Figure 29).

Piping Plover Diet at Bayshore Habitat.

Piping Plovers captured more polychaetes than arthropods on bayshore flats. However, the ratio of these 2 prey types was not as pronounced as at beach habitat (Table 19; Figure 29). At bayshore habitat, the arthropod prey group was very broad including tanaids and all other types of crustaceans, spiders and insects (larvae, pupae, and adults). Strong dietary changes were observed when Piping Plovers moved among bayshore microhabitats. At sand flats, plovers fed mostly on polychaetes, capturing approximately 5 polychaetes for every arthropod (Table 19; Figure 29). At algal flats, the reverse was true, as plovers captured about 5 arthropods for every polychaete (Table 19; Figure 29).

Plover diet among the 2 ecosystems and the ecotone reflected the relative availability of sand flats and algal flats, the 2 dominant types of bayshore microhabitat used by Piping Plovers along the Texas Gulf Coast (Figure 31). In the bay ecosystem, where sand flats were much more common, polychaetes made up over 75% of the diet of Piping Plovers (Figure 31). In the lagoon ecosystem, where algal flats were much more common, arthropods comprised about 75% of the diet (Figure 31). At the ecotone sites, where a mosaic of sand flats and algal flats occurred, polychaetes and arthropods both comprised substantial portions of the Piping Plover diet (Figure 31).

Foraging Locomotion

Piping Plovers foraging at beach habitat spent > 12% of their time in prolonged foraging locomotion (PFL), compared to < 3% for plovers foraging on bayshore flats ($P = 0.0413$; Table 20). PFL bouts often occurred when plovers were engaged in territorial interactions with other Piping Plovers or when plover that were feeding in the beach

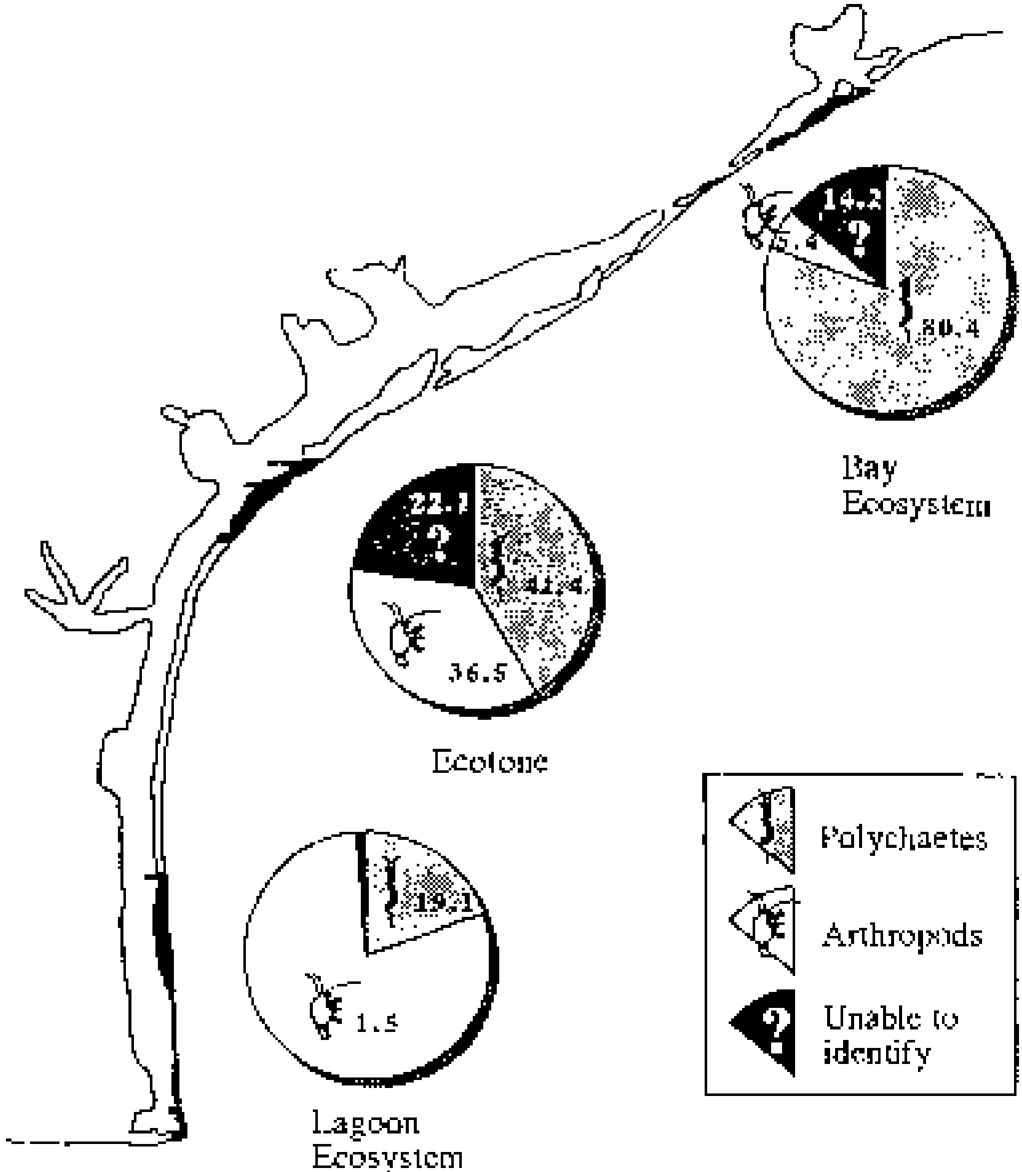


Figure 31. Piping Plover diet at bayshore habitat among the 2 ecosystems and the ecotone. Pie charts illustrate the proportion of polychaetes and arthropods captured by foraging plovers.

Table 20. Foraging efficiency (FE) and prolonged foraging locomotion (PFL) among different habitats and coastal regions of the Texas Gulf Coast, 1991 - 1994. All numbers represent means for all sites throughout the study. Foraging efficiency estimates are reported as the number of prey captured/minute, and foraging locomotion is reported as the % time plovers spent in PFL.

Parameter	FE			*P*	PFL			*P*
	mean	N	SE		mean	N	SE	
Beach	11.0	127	0.5		12.5	154	0.7	
Bayshore	10.1	504	0.2	0.3726	2.3	285	0.5	0.0413
Sand Flats	10.3	336	0.3		2.1	167	0.4	
Algal Flats	9.8	168	0.4	0.9114	2.6	118	0.4	0.0027
Beach Swash Zone	13.7	66	0.8		16.6	54	1.3	
Upper Beach Zone	7.0	38	1.1	< 0.0001	9.5	81	1.2	0.0002
All Beach:								
Bay Ecosystem	10.2	40	1.1		11.8	47	1.5	
Ecotone	10.9	78	0.8		13.5	90	1.1	
Lagoon Ecosystem	16.2	9	2.3	0.1285	9.2	17	2.6	0.1626
All Bayshore:								
Bay Ecosystem	10.8	272	0.3		1.9	141	0.4	
Ecotone	11.2	95	0.5		2.5	99	0.5	
Lagoon Ecosystem	8.0	137	0.4	0.2321	3.2	45	0.7	0.2454

swash zone were forced to retreat to the upper beach to avoid an incoming swell of water. I also observed PFL as a response to the approach of a beachcomber walking through a feeding territory. The effect of the swash on PFL is supported by the fact that plovers foraging in the swash zone spent nearly twice as much time in PFL as did plovers feeding on the upper beach ($P = 0.0002$; Table 20). However, movements to avoid the swash did not completely account for elevated PFL at beach habitat. Piping Plovers foraging on upper beach habitat (i.e., those plovers that were not forced to move to avoid the swash) still exhibited significantly greater PFL than did plovers foraging at bayshore tidal flats ($P < 0.0001$; Table 20). Territorial interactions ($P < 0.0001$) and human disturbance ($P = 0.0002$) also were important factors contributing to PFL. Plovers that exhibited at least 1 display of aggression toward another plover spent an average of 9.3% (N = 16, SE = 0.6) of their time in PFL compared to just 1.8 % (N = 269, SE = 0.2) for nonaggressive plovers. Plovers that experienced at least 1 encounter with a beachcomber or other type of pedestrian spent more time in PFL (mean = 11.8%, N = 16, SE = 1.3) than did plovers that did not encounter pedestrians (mean = 5.6%, N = 423, SE = 0.3).

Foraging locomotion did not differ significantly at beach habitat among the 2 ecosystems and the ecotone ($P = 0.1626$; Table 20). I detected no difference in foraging locomotion between the migratory and winter seasons at beach habitat ($P = 0.5584$; Table 20).

At bayshore habitats, plovers spent slightly more time in PFL on algal flats than on sand flats ($P = 0.0027$; Table 20). Territorial displays also affected foraging locomotion at bayshore habitat. Plovers that exhibited at least 1 display of aggression toward another plover during the record spent an average of 9.3% (N = 16, SE = 1.1) of their time in PFL compared to just 1.8% (N = 269, SE = 0.2) for nonaggressive plovers ($P < 0.0001$).

Plovers in both ecosystems and the ecotone spent similar amounts of time in PFL at bayshore habitat ($P = 0.2454$; Table 20). I detected no difference in foraging locomotion between the migratory and winter seasons at bayshore habitat ($P = 0.2672$)

Foraging Efficiency

Piping Plovers captured an average of about 10 animals/minute among all habitats at my study sites (Tables 21 and 22). Foraging efficiencies were similar at beach and bayshore habitats ($P = 0.3726$). Plovers also foraged with similar efficiency among the 2 ecosystems and the ecotone at beach habitat ($P = 0.1285$; Table 21). However, Piping Plovers foraged more efficiently within the swash zone of the beach habitat relative to the upper beach zone ($P < 0.0001$; Table 12).

Plovers foraged with similar efficiency among the 2 ecosystems and the ecotone at bayshore habitat ($P = 0.1626$; Table 22). Plovers captured prey at about the same rate on sand flats and algal flats ($P = 0.9114$; Table 18).

Piping Plovers were more efficient at capturing polychaetes than arthropods ($P < 0.0001$; Table 23). At beach habitat, plovers captured *Scolelepis squamata* and other polychaetes more efficiently than amphipods and other beach arthropods ($P = 0.0351$; Table 23). At bayshore habitat, plovers captured polychaetes more efficiently than insects and other types of arthropods ($P < 0.0001$; Table 23).

Foraging Ecology and Prey Density

Piping Plovers foraged more actively and efficiently in areas of high benthic prey density. At beach habitat, plover foraging effort increased from about 10 pecks/min in areas of low prey density (< 1000 animals/m^2) to about 20 pecks/min in areas of high prey density (> 5000 animals/m^2; $P = 0.0208$; Figure 32A). Foraging effort was positively related to polychaete density ($P = 0.0306$; Figure 32B) but was not related to crustacean density ($P = 0.1642$, Figure 33A) or insect density ($P = 0.5953$; Figure 33B). Plovers also captured more prey in areas of the beach with dense prey populations ($P = 0.0132$; Figure 34A).

Table 21. Mean foraging efficiency of Piping Plovers at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Capture efficiency of all prey types, polychaetes, and arthropods are represented as the number of prey captured/minute. Abbreviations: MISP = Mustang Island State Park.

Study Location	All Prey			Polychaetes			Arthropods		
	mean	N	SE	mean	N	SE	mean	N	SE
Bolivar Flat	11.9	20	1.5	8.6	20	1.7	1.7	20	0.7
Big Reef	4.9	6	2.7	1.7	6	3.1	1.4	6	1.3
San Luis Pass	10.0	14	1.8	7.9	14	2.0	1.7	14	0.9
East Flats	5.2	2	4.8	4.0	2	5.4	0.0	2	2.3
MISP - North	10.5	28	1.3	7.8	24	1.5	1.9	24	0.7
MISP - South	11.8	20	1.5	9.7	20	1.7	1.0	20	0.7
Packery Channel	11.1	28	1.3	8.7	22	1.6	3.3	22	0.7
South Bay - East	14.9	2	4.8	13.9	2	5.4	1.0	2	2.3
South Padre Island	16.5	7	2.5	16.5	7	2.9	0.0	7	1.2

Table 22. Mean foraging efficiency of Piping Plovers at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Capture efficiency of all prey types, polychaetes, and arthropods are represented as the number of prey captured/minute. Abbreviations: MISP = Mustang Island State Park.

Study Location	All Prey			Polychaetes			Arthropods		
	mean	N	SE	mean	N	SE	mean	N	SE
Bolivar Flat	11.9	143	0.4	9.9	142	0.5	0.7	142	0.3
Big Reef	8.7	42	0.8	6.5	41	1.0	1.2	41	0.5
San Luis Pass	10.0	127	0.5	8.5	121	0.6	0.1	121	0.3
East Flats	8.5	8	1.8	1.0	8	2.2	7.2	8	1.2
MISP - North	10.4	59	0.7	7.2	45	0.9	1.1	45	0.5
Packery Channel	11.6	86	0.6	5.7	67	0.8	3.3	67	0.4
South Bay - East	9.3	8	1.8	6.3	8	2.2	2.7	8	1.2
South Padre Island	9.9	64	0.7	3.3	64	0.8	6.6	64	0.4

Table 23. Comparison of foraging capture rate (number of prey captured/minute) among different prey groups. Data represented are from only those records in which each prey group represented at least 75% of the total captures. For example, arthropods comprised 75% or more of the prey captured at beach habitat for 16 foraging efficiency records, compared to 321 records at beach habitat in which polychaetes comprised 75% or more of the prey captured.

Parameter	**Polychaetes**			**Arthropods**			***P*-value**
	mean	N	SE	mean	N	SE	
All Habitats	12.3	243	0.3	8.6	143	0.5	< 0.0001
Beach Habitat	11.7	321	0.3	8.8	16	1.5	0.0351
Bayshore Habitat	12.3	243	0.4	8.5	137	0.5	< 0.0001

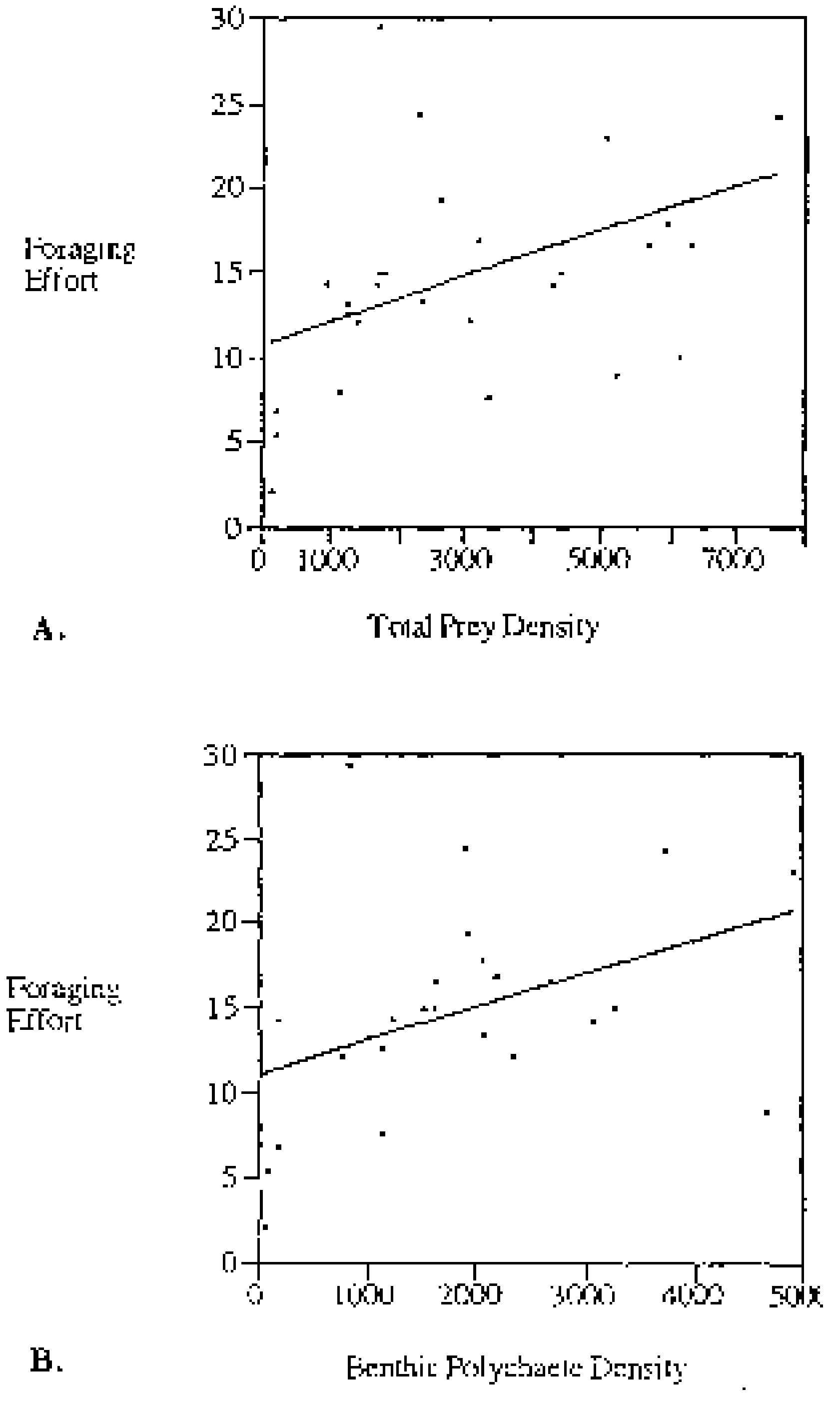


Figure 32. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A; $P = 0.0208$) and benthic polychaete density (B; $P = 0.0306$) at beach habitat. Data are from all sites.

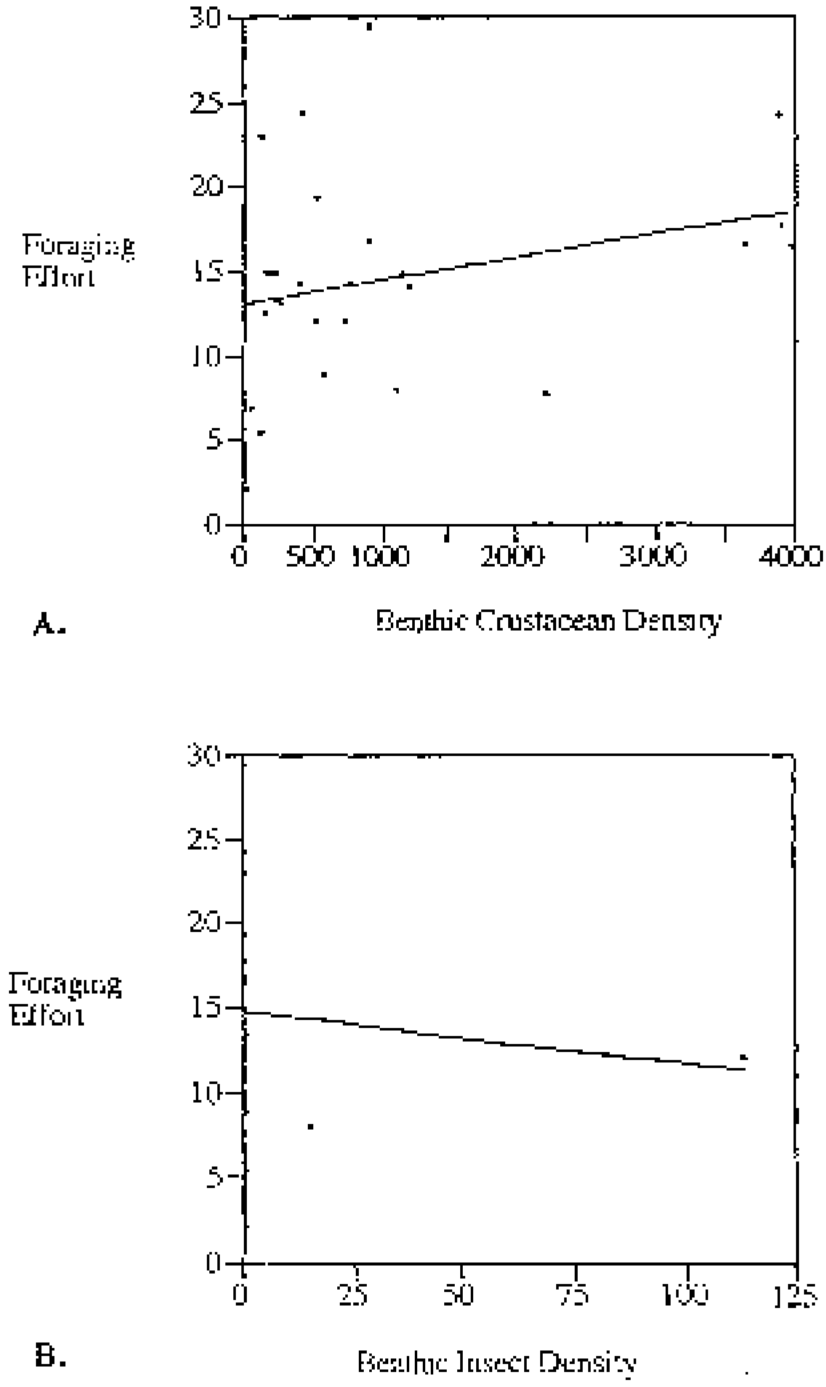


Figure 33. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to benthic crustacean density (A; P = 0.1642) and benthic insect density (B; P= 0.5953) at beach habitat. Data are from all sites.

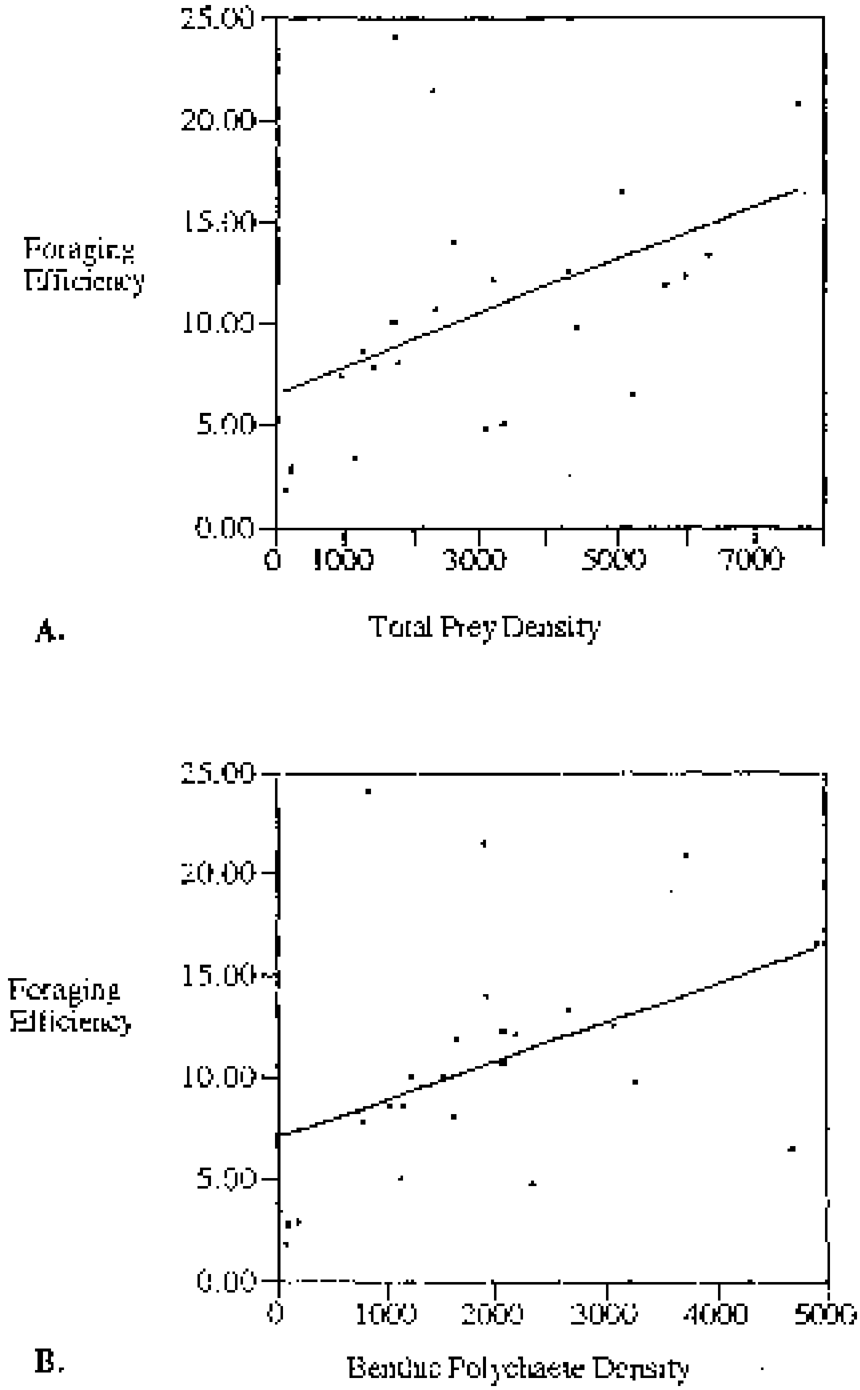


Figure 34. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A; $P = 0.0132$) and benthic polychaete density (B; $P = 0.0245$) at beach habitat. Data are from all sites.

Foraging efficiency was positively related to polychaete density ($P = 0.0245$; Figure 34B), but was not related to crustacean density ($P = 0.1206$; Figure 35A) or benthic insect density ($P = 0.5636$; Figure 35B).

At bayshore habitat, foraging effort also was positively related to total benthic prey density ($P < 0.0001$; Figure 36A) and polychaete density ($P < 0.0001$; Figure 36B), but was unrelated to benthic crustacean density ($P = 0.5222$; Figure 37A) or benthic insect density ($P = 0.2858$; Figure 37B). Plovers captured more prey on tidal flats with high total prey density ($P = 0.0094$; Figure 38A) and polychaete density ($P = 0.0109$; Figure 38B). Foraging efficiency on tidal flats was not affected by crustacean density (P 0.8491; Figure 39A), or benthic insect density ($P = 0.9731$; Figure 39B).

Interestingly, plovers foraged less actively ($P = 0.0096$; Figure 40) and less efficiently ($P = 0.0183$; Figure 41) in areas of the tidal flat with high surface prey abundance. However, polynomial fits explained the greatest amount of variability among the data (e.g., quartic fit, $P = 0.0784$, $R^2 = 0.113$; Figure 41B) and suggest the existence of a threshold abundance of surface prey, above which plovers may have foraged less efficiently.

Intraspecific and Interspecific Interactions

Piping Plovers were more likely to occur in close proximity to another Piping Plover at bayshore habitat than at beach habitat ($P < 0.0001$; Figure 42). At beaches, the nearest species to Piping Plovers were Sanderlings (*Calidris alba*). Western Sandpipers (*C. mauri*) and other Piping Plovers were the most common nearest neighbors at sand flats, and *C. mauri*, Least Sandpipers (*C. minutilla*) and other Piping Plovers were the most common nearest neighbors at algal flats

The large majority of aggressive interactions I observed during the study were intraspecific. The majority of interspecific aggressions involving Piping Plovers were with another *Charadrius* spp., usually Snowy Plovers (*Charadrius alexandrinus*) or

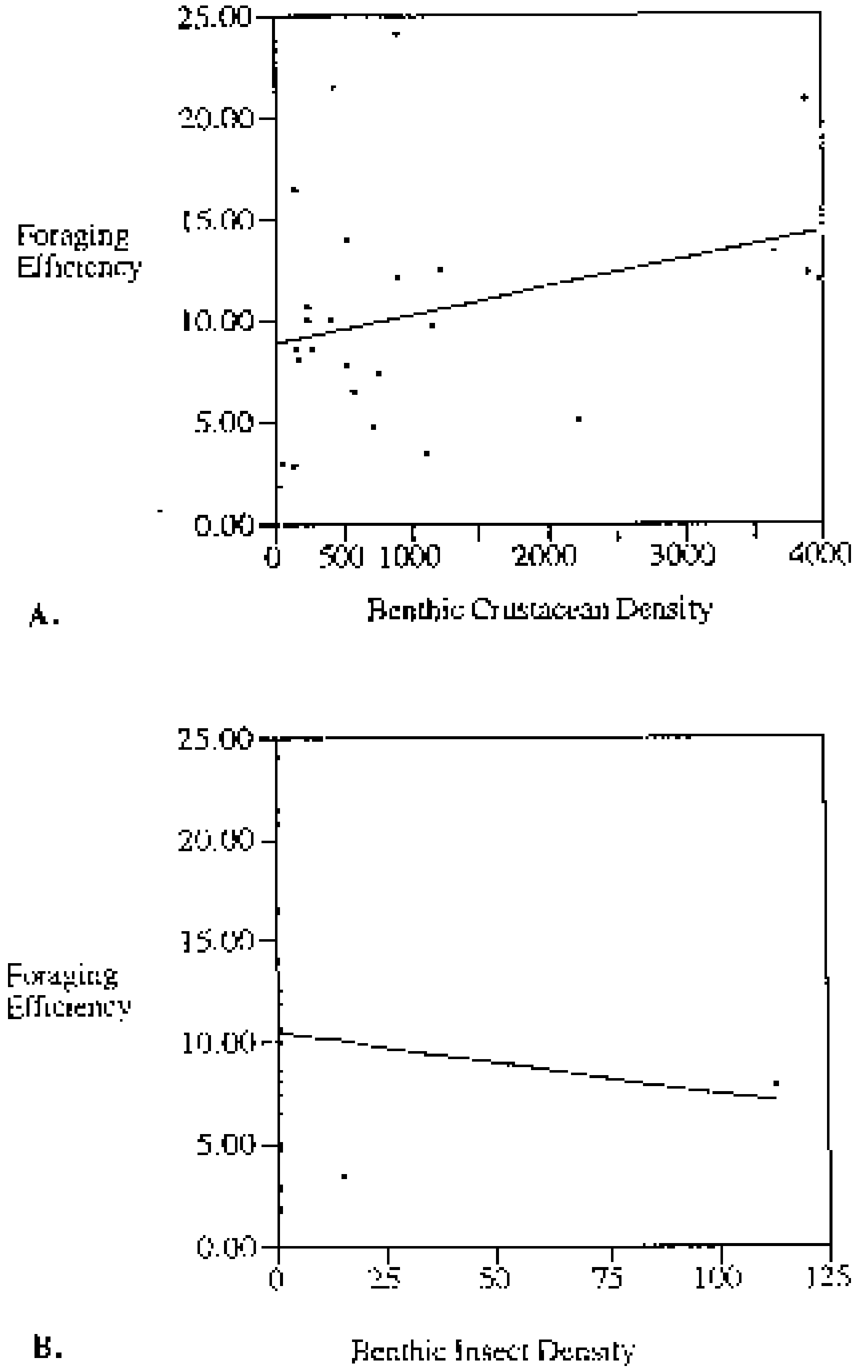


Figure 35. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to benthic crustacean density (A: $P = 0.1206$) and benthic insect density (B; $P = 0.5636$) at beach habitat. Data are from all sites.

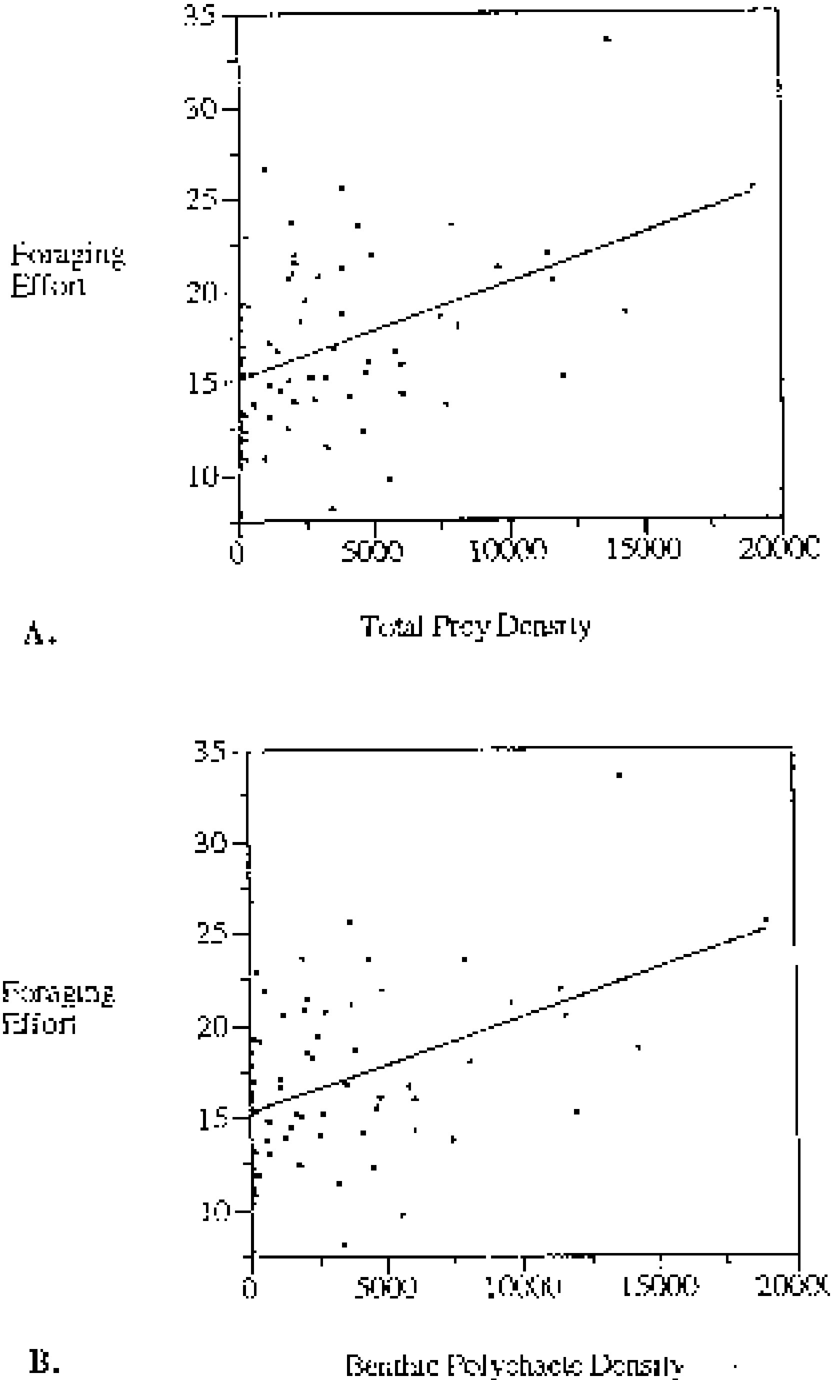
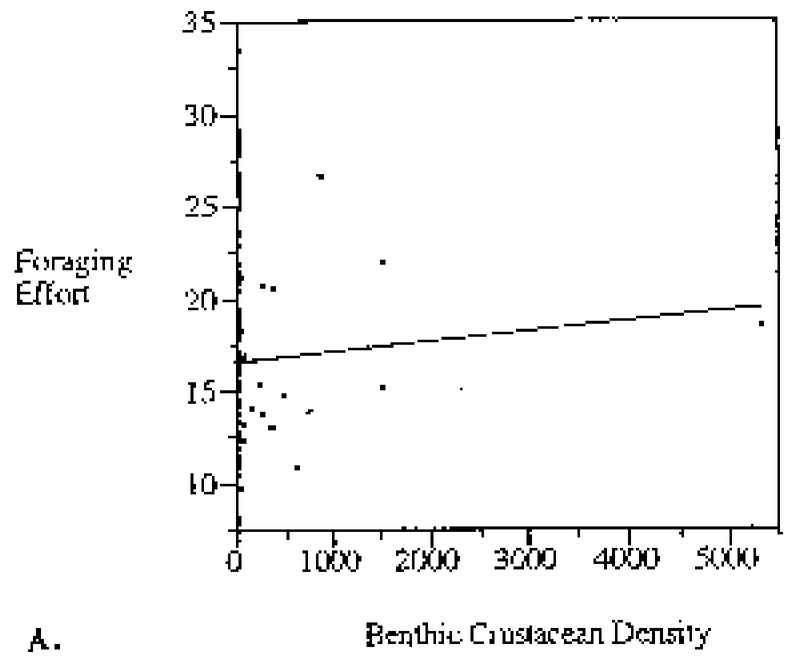
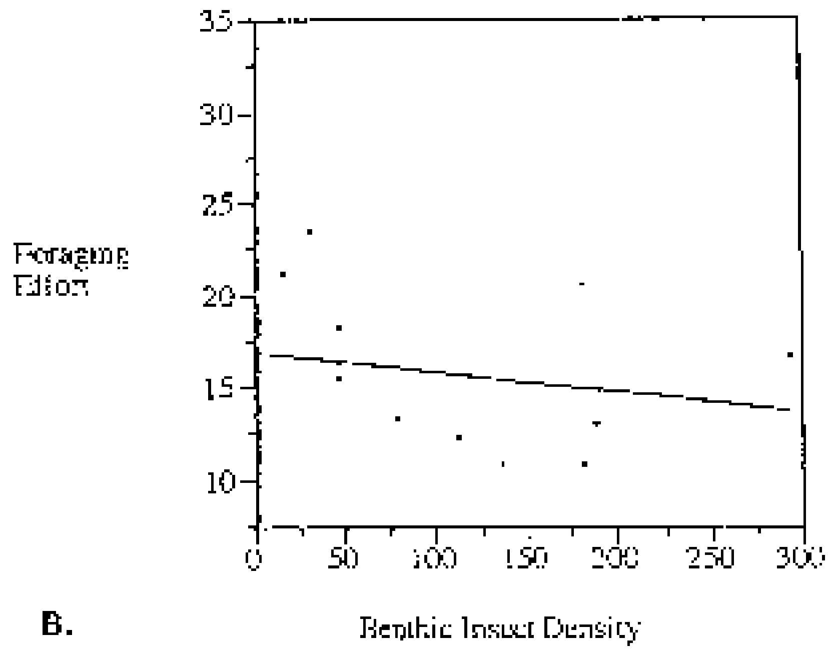


Figure 36. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A: $P < 0.0001$) and benthic polychaete density (B: $P < 0.0001$) at bayshore habitat. Data are from all sites.



A.



B.

Figure 37. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to benthic crustacean density (A; P = 0.5222) and benthic insect density (B; P = 0.2858) at bayshore habitat. Data are from all sites.

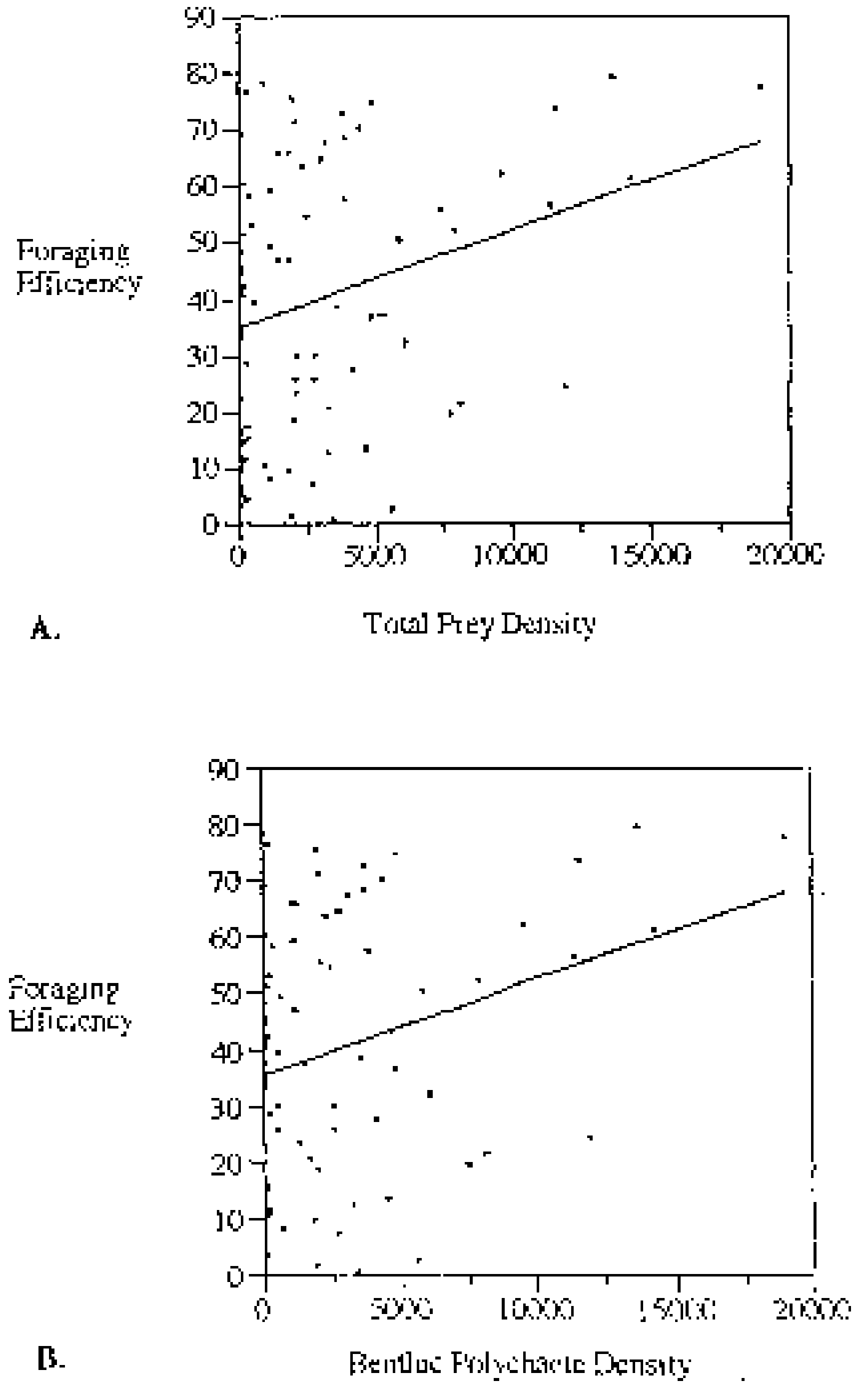


Figure 38. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to total benthic density (A: P = 0.0094) and benthic polychaete density (B, P = 0.0109) at bayshore habitat. Data are from all sites.

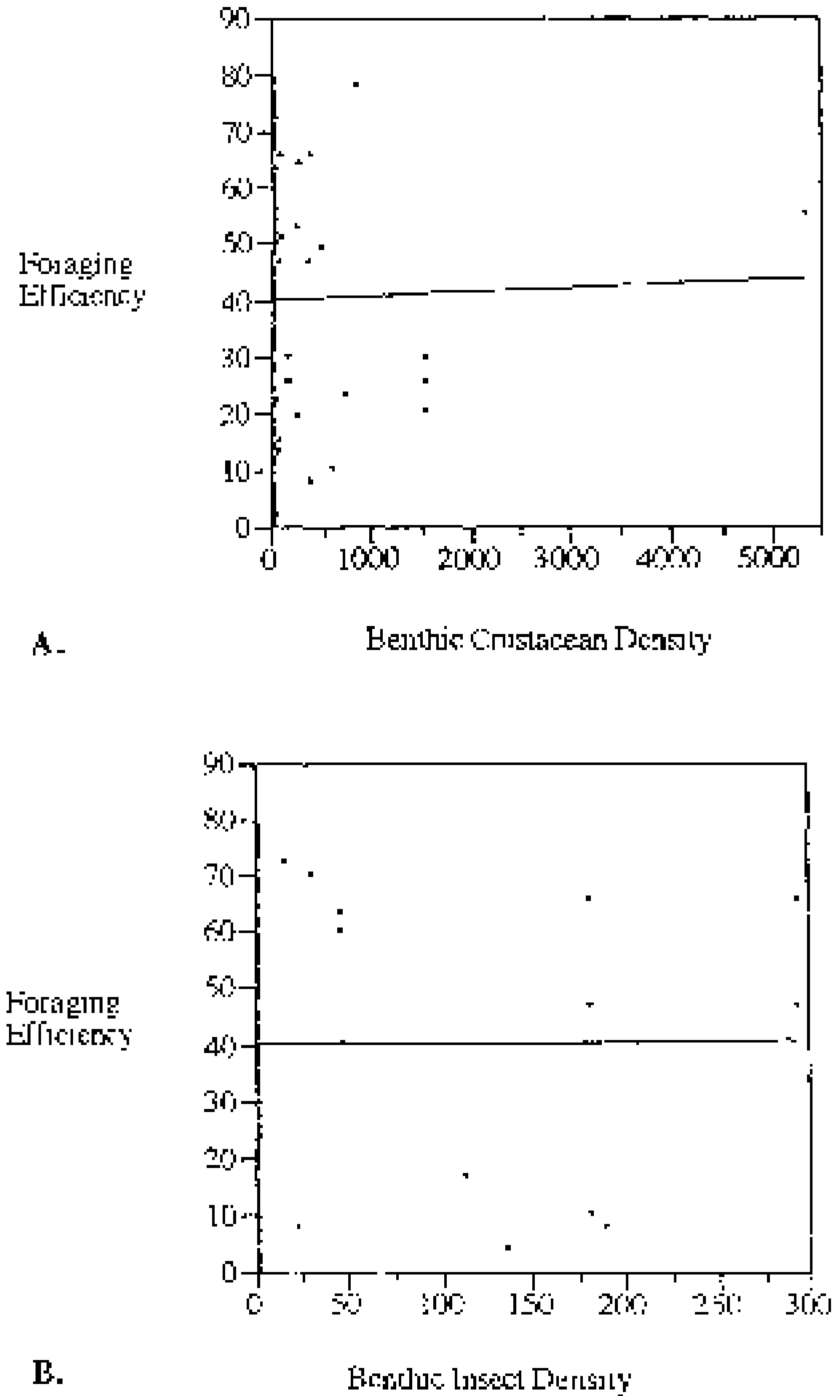


Figure 39. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to benthic crustacean density (A; r^2 = 0.8491) and benthic insect density (B; r^2 = 0.9731) at bayshore habitat. Data are from all sites.

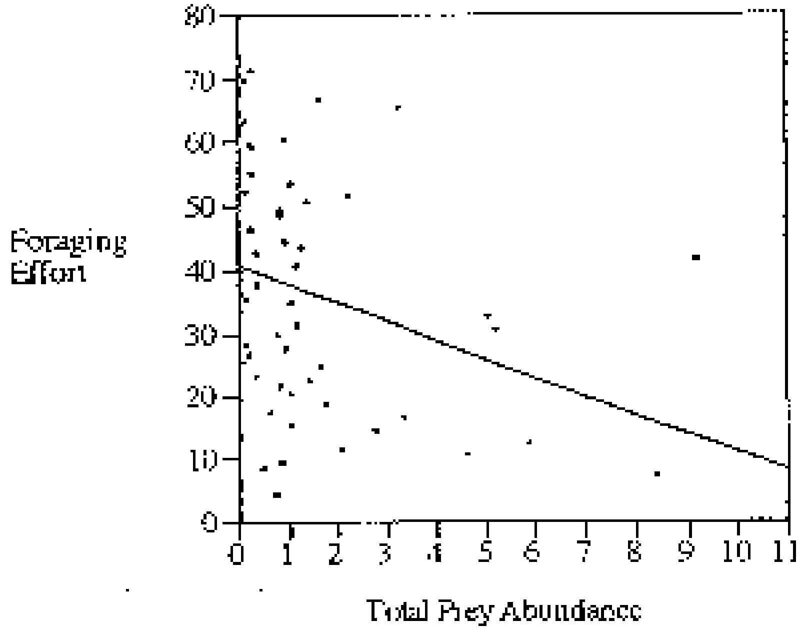


Figure 40. Linear regressions illustrating the relationship between Piping Plover foraging effort (number of pecks/minute) and total surface prey abundance at bayshore habitat (P . 0.0096). Data are from all sites as appraised by sticky trap prey assays.

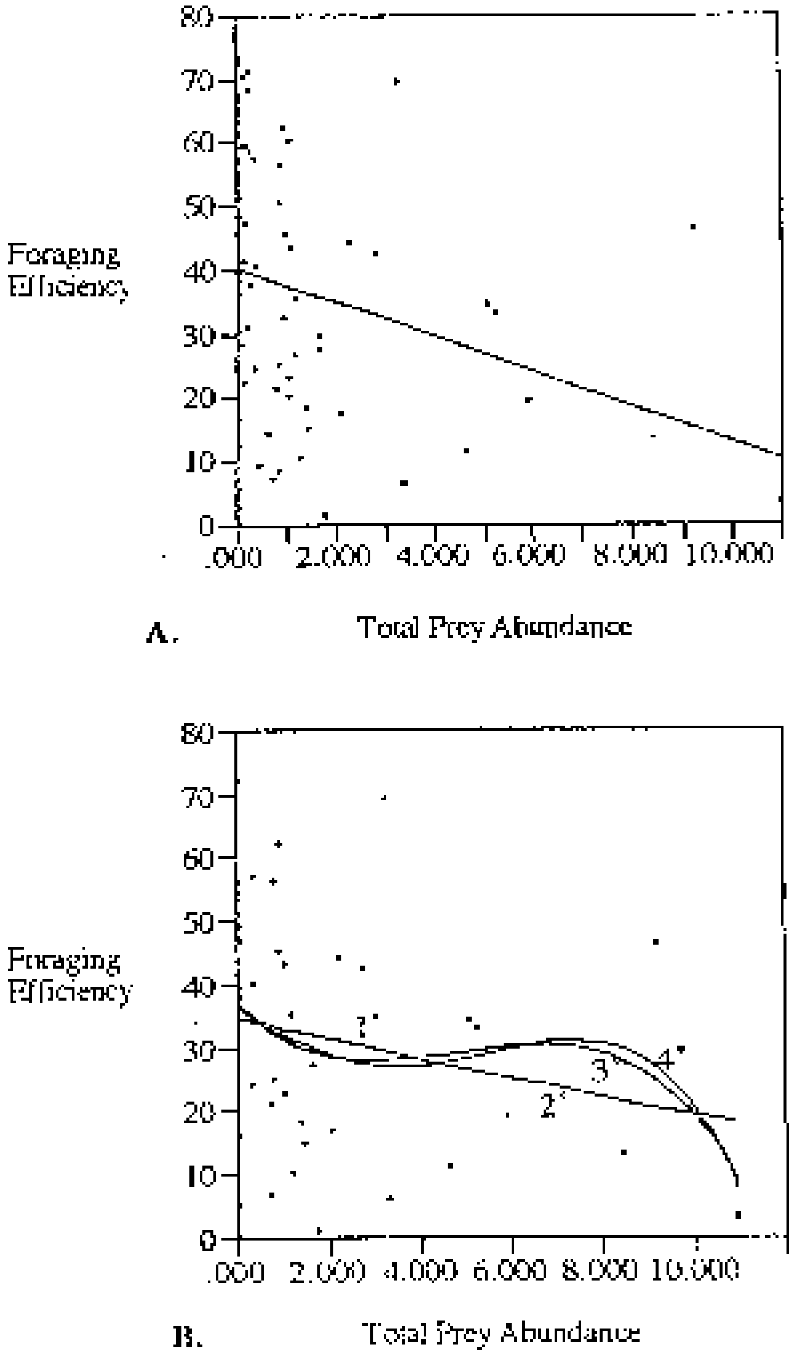


Figure 41. Linear regressions illustrating the relationship between Piping Plover foraging efficiency (number of captures/minute) and total surface prey abundance at bayshore habitat at all sites as appraised by sticky trap prey assays. Figure A illustrates a linear regression line ($P = 0.0303$, $r^2 = 0.064$), and (B) the linear fit in relation to various polynomial fits. The quartic fit (4°; $P = 0.0784$, $r^2 = 0.113$) and cubic fit (3°; $P = 0.0436$, $r^2 = 0.109$) explain a greater amount of variation in the data relative to the linear fit or quartic fit ($P = 0.0589$, $r^2 = 0.077$).

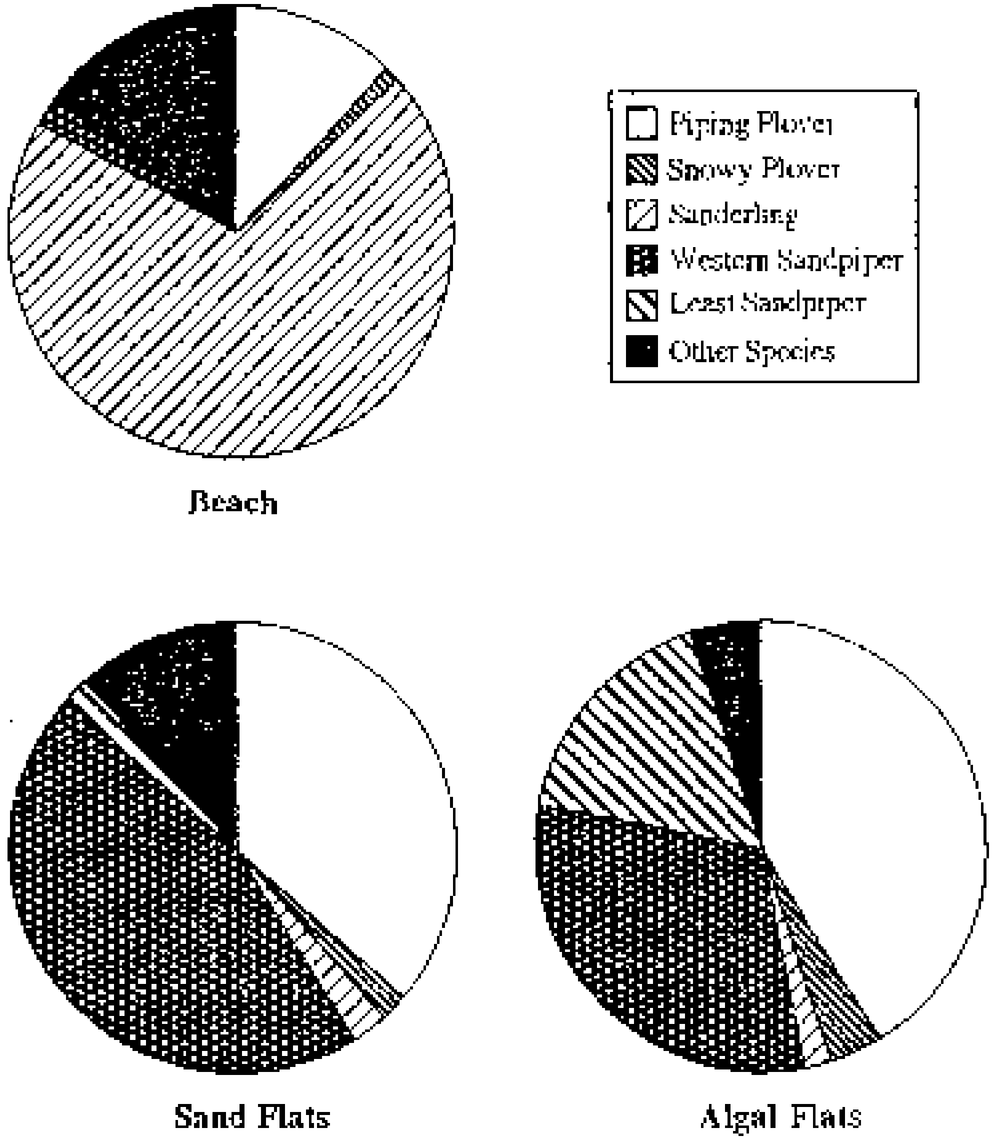


Figure 42. Species that were closest to Piping Plovers foraging at beach, sand flat, and algal flat habitat. Pie sections correspond to the 4 shorebird species most commonly associated with foraging Piping Plovers. The area of the pie wedge is proportional to the frequency with which each species occurred as the nearest neighbor to a Piping Plover as it was observed during a foraging efficiency record

Semipalmated Plovers (*C. semipalmatus*). Interspecific interactions were generally restricted to bayshore habitat, as *C. alexandrinus* and *C. semipalmatus* only rarely utilized beaches as foraging habitat at my study sites (pers. obs.). Interactions between Piping Plovers and Sanderlings (the other common shorebird utilizing beach intertidal habitat) occurred, but were rare (pers. obs.).

Foraging Piping Plovers were observed to exhibit some form of aggression about once every 8 minutes (mean = 0.119 acts of aggression/min., SE = 0.019, N = 533 records [1926.8 minutes of observation]) as appraised via FE records, and about once every 15 minutes (mean = 0.068 acts of aggression/min., SE = 0.014, N = 441 records [882 minutes of observation]) as appraised via PFL records.

Using FE data, I found Plovers to be no more aggressive at beach habitat (mean = 0.066 acts of aggression/min, SE = 0.044, N = 102) than at bayshore habitat (mean = 0.131 acts of aggression/min, SE = 0.021, N = 431; $P = 0.3065$). However plovers were significantly more aggressive during the migratory period than during the winter period ($P = 0.0018$; Table 24) at beach habitat. Season did not affect plover behavior at bayshore habitat (Table 24).

Using PFL data, I found Plovers to be no more aggressive at beach habitat (mean = 0.075 acts of aggression/min, SE = 0.025, N = 154) than at bayshore habitat (mean = 0.0645 acts of aggression/min, SE = 0.018, N = 287; $P = 0.1162$). Plovers were no more aggressive during the migratory period than during the winter period at beach or bayshore habitat based upon the PFL data (Table 24).

DISCUSSION

Prey Dynamics

Piping Plovers wintering in the bay and lagoon ecosystems of the TGC encountered very different bayshore prey communities. In the bay ecosystem plovers fed at tidal flats

Table 24. Seasonal variation in the frequency of aggressive displays by Piping Plovers along the Texas Gulf Coast, 1991 - 1994. The mean number of aggressive displays/minute as recorded during foraging efficiency (FE) and foraging locomotion (PFL) records is reported by season among different habitat types. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover aggression between the 2 seasons. N = the number of FE or PFL records supporting the estimates.

	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
FE Data							
Beach	0.124	54	0.030	0.000	48	0.032	0.0018
Bayshore	0.121	231	0.032	0.144	200	0.034	0.6281
Sand Flats	0.141	187	0.040	0.225	125	0.049	0.5958
Algal Flats	0.033	44	0.016	0.008	75	0.012	0.5607
PFL Data							
Beach	0.077	84	0.031	0.071	70	0.034	0.6413
Bayshore	0.034	119	0.030	0.086	168	0.025	0.3727
Sand Flats	0.024	83	0.042	0.157	86	0.041	0.1424
Algal Flats	0.056	36	0.032	0.012	82	0.021	0.8977

that supported an extremely rich benthic food base dominated by polychaetes but containing only a sparse population of insects and other types of surface prey. Conversely, plovers wintering in the lagoon ecosystem fed at tidal flats that were benthos-poor, but rich in surface prey relative to the bay ecosystem. Prey populations in the ecotone were mixed, offering both benthic and surface prey to plovers.

Withers (1994) also reported abundant populations of polychaetes, crustaceans, and insects (adults and larvae) between 1991 - 1993 at Corpus Christi Pass (a small tidal flat situated in the ecotone between my Packery Channel and Mustang Island State Park - South sites). Withers recorded between 225 polychaetes/m^2 and 1335 polychaetes/m^2 in 3 microhabitat types. In samples collected in association with foraging Piping Plovers I recovered an average of 339 polychaetes/m^2 at the Mustang Island State Park - North site and 557 polychaetes/m^2 at Packery Channel site. Although surface prey populations were not sampled, Withers found between 455 insects/m^2 and 729 insects/m^2 in benthic samples. Benthic insect density was much lower among samples collected in association with foraging Piping Plover flocks, ranging from 3 insects/m^2 at the Packery Channel site to 41 insects/m^2 at Mustang Island State Park - North site.

Diet

In general, I found the diet of Piping Plovers to reflect the relative availability of the major prey groups. Plovers in the bay ecosystem fed primarily on polychaetes, whereas plovers in the lagoon ecosystem relied more heavily on surface prey. Plovers wintering in the ecotone, where a mix of habitats and prey communities occurs, exhibited a mixed diet, incorporating more surface prey than the diet of plovers wintering in the bay ecosystem and more polychaetes than the diet of plovers wintering in the lagoon ecosystem.

On beaches, plovers fed primarily on the polychaete *Scolelepis squamata* and on small amphipods. These organisms, along with small clams (*Donax* spp.; not regularly eaten by plovers), dominated the beach invertebrate community at all of my sites. Polychaete densities were highest in the bay ecosystem, lowest in the lagoon ecosystem, and intermediate in the ecotone. Crustacean densities were also lower in the lagoon ecosystem than the bay ecosystem and the ecotone.

At McFaddin Beach (a site located in the bay ecosystem ~ 50 km north of Bolivar Flats) and Malaquite Beach (a site located in the ecotone ~ 10 km south of Packery Channel) Shelton and Robertson (1981) found *S. squamata* and haustoriid amphipods to be the most abundant fauna in random samples of the mid and upper intertidal zones These are the 2 zones I found plovers to use most frequently. They found *S. squamata* to be more abundant at their bay ecosystem site (McFaddin Beach), and amphipods to be more abundant at their ecotone site (Malachite Beach). They reported an average of 591 *S. squamata*/m^2 and 436 amphipods/m^2 at their bay ecosystem beach and ~ 313 *S. squamata*/m^2 and 2598 amphipods/m^2 at their ecotone beach (based upon 6 visits to eac7h site). These findings compare reasonably well with the data I gathered from samples collected in association with foraging plovers at beach habitat. The higher relative density of polychaetes in my samples at bay ecosystem and ecotone beach compared to the random samples collected by Shelton and Robertson (1981) may indicate a selection by plovers for areas where *S. squamata* were most abundant.

I rarely observed plovers feeding on any prey other than amphipods and polychaetes at beach habitat. Therefore, despite their abundance, bivalves appeared to comprise a very small part of the Piping Plover diet. The bivalve fragments Nicholls (1989) recovered from plover fecal pellets may have been incidentally ingested by plovers along with sand as they were capturing other prey Shelton and Robertson (1981) found *Donax* sp. to be the most abundant prey at both of their sites, but found them to be concentrated at lower tidal zones, which are often not available to Piping Plovers.

Foraging Efficiency

Interestingly, plovers foraged with similar efficiency at both major habitats, and in both ecosystems and the ecotone. Piping Plovers captured about 10 animals/min. whether feeding at beach habitat or bayshore habitat, or whether feeding in the polychaete-rich bay ecosystem flats, the insect-rich lagoon ecosystem flats or the mixed community ecotone flat.

The only detectable shift in foraging efficiency occurred at beach habitat when plovers moved from the upper beach microhabitat into the lower swash zone. After such a move, the primary diet of plovers shifted from amphipods to polychaetes, and foraging efficiency nearly doubled from about 7 animals/min. to 14 animals/min. My prey samples suggest that *S. squamata* were present at equal densities in both microhabitats. By closely watching *S. squamata* feed, however, it seems likely that this polychaete is much more readily available to plovers in the swash zone. *S. squamata* appeared to actively forage at the surface only when they were covered with water. As the swash zone became covered, *S. squamata* extended palps into the thin film of water in the receding swash in order to trap food particles. Presumably, *S. squamata* became visually detectable to plovers under these conditions, for it was during the period when the swash was receding that plovers ran into the swash zone and switched from amphipods to *S. squamata*. Once in the swash zone, plovers collected as many *S. squamata* as they could before an incoming swell forced them to again move up into the upper beach zone and shift back to an amphipod diet.

Prolonged Foraging Locomotion

The repeated movement between the swash zone and the upper beach illustrates another distinguishing feature in Piping Plover behavior at beach habitat and bayshore habitat along the Texas coast. Plovers appeared to expend much greater energy on beach habitat than at bayshore habitat. Plovers spent about 12% of their time in prolonged foraging locomotion (PFL) at beaches compared to less than 3% at bayshore habitats. Much of the PFL appeared to be explained by movements in and out of the swash, territorial defense (which was much higher on beach habitat), and running to avoid people using the beach.

These results complement and perhaps partially explain my findings in Chapter II suggesting Piping Plovers preferred bayshore habitat over beach habitat in Texas. One hypothesis for this preference is that plovers suffered a lower net energy intake at beaches. The lower net energy intake may be due, not to a lower direct energy intake since plovers captured about the same number of prey in both habitats, but to an increased energy investment required to capture the same number of prey at both habitats.

Connors et al. (1981) demonstrated a directed response by Sanderlings to tides and prey availability along the California coast. They found Sanderlings to forage on beach habitat at high and mid-level tides but switch to protected bayshore sand flats as the tides receded. They related these movements to the availability of prey at different tide levels and found a strong correlation between prey availability and Sanderling density at both beach and bayshore habitats, suggesting birds were visiting each habitat type when it was most productive.

Because the beach and bayshore sites monitored by Connors et al. (1981) were closely situated and the tides synchronous, they were unable to evaluate whether Sanderlings shifted to beach habitat because bayshore flats were inundated, or because beach sites became more productive. In this way their study area was similar to my bay ecosystem sites and my 2 northern ecotone sites (East Flats and Mustang Island State Park), where bayshore tides and beach tides were synchronous. At these sites, Piping Plovers behaved like the Sanderlings in California, using beaches during high tides and bayshore flats at low tides. However, one of my ecotone sites (Packery Channel) experienced asynchronous beach and bayshore tides. At Packery Channel, Piping diet in the lagoon ecosystem.

A negative correlation between flock size and prey abundance might have occurred if plovers foraging in large flocks were able to rapidly deplete local surface prey populations. Therefore, an alternative hypothesis is that plovers were attracted by locally abundant surface prey populations, but harvested these populations to such an extent that my prolonged sampling technique (1 hour sticky traps) measured the depleted population rather than the initial population abundance that attracted the plover flock.

Another important feature to consider when comparing benthic and surface prey communities is prey mobility and the way it affects a plover's ability to detect and capture prey. Most of the benthic prey eaten by plovers (polychaetes and crustaceans) were sessile or sedentary. The detectability of these prey to Piping Plovers may have been governed simply by whether these organisms were present at the surface (when feeding or defecating) or were not (when burrowing or residing in a tube, etc.) Surface prey were probably more detectable to Piping Plovers than most benthic prey, but may have been more difficult to catch due to their mobility. The mobility feature of surface prey also may have reversed the effect of prey density on Piping Plover foraging efficiency. Perhaps, at some point, too many mobile surface prey caused a reduction in the intake rate by plovers. Plovers may have become confused about which prey to pursue, just as do predators foraging on schooling fish or flocking birds (Page and Whitacre 1975).

Could there have been a maximum surface prey density threshold above which foraging efficiency was compromised? Some support for this hypothesis is found in the negative relationship between foraging efficiency and surface prey abundance and the apparent existence of a threshold of foraging efficiency for plovers feeding on surface prey. The predicted threshold, 10 animals/sticky trap, was higher than I commonly observed among most of my samples, but suggests that a threshold might exist and may affect how plovers select local feeding areas in the lagoon ecosystem.

I did not assess the caloric value of different prey groups to Piping Plovers, but this measure clearly affects the net energy plovers realize and presumably governs their selection of prey from among the available population. Pienkowski (1981) found Ringed Plovers (*Charadrius hiaticula*) and Black-bellied Plovers (*Pluvialis squatarola*) to feed selectively on large lugworms (*Arenicola marina*) when environmental conditions increased the activity of this species. The plovers fed at greater rates on lugworms, even though a smaller polychaete species (*Notomastus latericeus*) was more common than *Arenicola*, and also became more available to plovers under the same conditions that increased *Arenicola* availability.

Withers (1994) measured both biomass and prey density at 2 ecotone sites. Withers found benthic density rather than biomass to most often affect shorebird abundance. However, the biomass measures reported by Withers provide a means of estimating the relative caloric potential of the major prey groups eaten by plovers. At Corpus Christi Pass, Withers found polychaetes to have a biomass of about 0.86 mg/animal. Adult insects and amphipods had about 1/2 the biomass of polychaetes (0.48 mg/animal and 0.36 mg/animal, respectively). Larval insects and tanaids had only a fraction of the biomass available from polychaetes (0.27 mg/animal and 0.07 mg/animal, respectively). Based upon the biomass estimates by Withers, polychaetes appear to offer a substantially higher relative energy return to plovers than do insects, amphipods and tanaids. This may explain the ability of plovers wintering in the bay ecosystem to spend less time at beach habitat relative to plovers wintering in the ecotone. Polychaetes comprised a much greater proportion of the bayshore diet of plovers wintering in the bay ecosystem relative to plovers wintering in the ecotone (Figure 31). Whereas the diet of plovers in the lagoon ecosystem contained an even smaller proportion of polychaetes, beach habitat may have offered a poor alternative to these birds. Beach benthic populations were apparently less dense in the lagoon ecosystem (Figure 14). The increased energy expenditures required of plovers foraging at beach habitat coupled with the reduced benthic populations occurring there may partially explain why lagoon plovers also used beaches less than ecotone plovers. However, my data suggest that when Piping Plovers did use lagoon beaches, they fed almost exclusively on polychaetes (Figure 30).

Roosting Behavior

I found Piping Plovers to spend about 34% of the diurnal period roosting or preening while at beach habitat and about 18% of the diurnal period roosting or preening while at bayshore habitat (i.e., foraging rates of 66% and 82% for beach and bayshore habitats, respectively). These estimates compare well with those reported for plovers wintering in Alabama (Johnson and Baldassarre 1988). Elliott and Teas (1996) reported a much higher estimate of foraging activity for Piping Plovers using 3 Texas beaches (86.7%, 89.5%, and 96.2%). This apparent incongruity may stem from the way in which beach habitat was delineated in both studies. I included all washover passes that occurred at my sites as a part of the beach habitat. Because they occur at higher elevations than the beach, and receive less human disturbance, washover passes provide ideal roost habitat and many of the plovers I found roosting at beach habitat at my sites occurred in washover passes. The foraging activity estimates developed by Elliott and Teas (1996) were for only those plovers using the forebeach habitat, and did not account for the activity of plovers using nearby washover passes, where roosting behavior was more common (L. Elliott, pers. comm.).

Human Disturbance

My data suggest human activity reduced the net foraging success of Piping Plovers at beach habitat by increasing the amount of energy plovers had to expend while foraging. Vega (1988) reported an apparent reduction in the abundance of *S. squamata* and *Haustorius* sp. at beaches experiencing vehicular traffic, suggesting human activity at beach habitat may be the source of both direct and indirect impacts to Piping Plovers.

Elliott and Teas (1996) reported a negative relationship between Piping Plover beach density and vehicular density at the Packery Channel site (referred to as Surfer Beach in Elliott and Teas 1996). Whereas Elliott and Teas (1996) detected no relationship between Piping Plover density and pedestrian density, they found pedestrian encounters reduced the amount of time plovers were able to spend foraging. Elliott and Teas (1996) concluded that "Reductions in time spent foraging may be sufficient to cause birds to move to habitats where time budgets are unaffected by human disturbance. This may entail moving to bayshore habitats or beaches occupied by fewer pedestrians." I found no relationship between Piping Plover density and vehicular density at beach habitat. In fact, the trend between plover density and beach vehicular density was positive at the Packery Channel site. My data indicate that plover movements between beach and bayshore habitat were predominantly controlled by bayshore tidal amplitude. However, in addition to disrupting foraging efforts, human disturbance appeared to have a significant effect on Piping Plover abundance at my sites. This relationship is described further in Chapter IV.

CHAPTER IV. PIPING PLOVER SITE ABUNDANCE

INTRODUCTION

The recovery of rare plants and animals must be founded on thorough knowledge of the features that define and threaten the species' niche. This knowledge guides both the preservation of sites that exhibit optimal habitat and the sound management of sites where habitat quality has been compromised. The final objective of my study was to identify the habitat components and environmental conditions that affect the abundance of Piping Plovers along the TGC. Accomplishing this objective will identify the environmental features that are most important to winter recovery throughout a major portion of the species nonbreeding range.

Nicholls and Baldassarre (1990b) used discriminant function analysis (DFA) to investigate the relationship between a number of microhabitat characteristics and the presence/absence of Piping Plovers throughout most of their winter range. Their analyses selected "...greater beach width, greater % mudflat, lower % beach and more small inlets..." as the winter habitat characteristics predictive of Piping Plover presence/absence along the Gulf Coast of the United States. Along the Atlantic Coast, DFA selected "...the number of large inlets and passes, number of tide pools, % mudflat, beach width, and % sandflat as the major factors affecting (Piping Plover) presence or absence." (Nicholls and Baldassarre 1990b).

However, Nicholls and Baldassarre's conclusions were founded primarily upon data collected during single visits to a large number of study sites throughout the winter range. Furthermore, the habitat associations evaluated by Nicholls and Baldassarre (1990b) include only a portion of the parameters that may play a role in habitat selection by Piping Plovers. For instance, such factors as tidal stage, prey density, and human disturbance were not considered in their analyses, yet these factors have been shown to significantly influence shorebird site-use and behavior (Burger et al. 1977, Connors et al. 1981, Hicklin and Smith 1984). I sought to build upon the foundation developed by Nicholls and Baldassarre. I did this by developing a site abundance model that incorporated several factors that were not considered by Nicholls and Baldassarre's model, and supported the new model with data collected from multiple visits to several sites.

METHODS

To address this objective I developed a multiple regression model predicting local Piping Plover abundance based upon the following 6 habitat and environmental parameters measured at each study site:

1. Available beach habitat area.
2. Available bayshore habitat area.
3. Macrobenthic prey density at beach habitat.
4. Macrobenthic prey density at bayshore habitat.
5. Surface prey abundance at bayshore habitat.
6. Human disturbance at beach habitat.

I employed a step-wise regression model to select, from among these 6 parameters, those that most significantly predicted variation in the number of Piping Plovers occurring at all of the barrier island study sites I monitored. Data collected at Laguna Atascosa National Wildlife Refuge, the 3 southern sites on South Padre Island and the South Bay -West site were omitted from this model because these sites either did not possess beach habitat, or because data were not collected at beaches for these sites. Including these sites would not have allowed the incorporation of beach-associated parameters in the model. Additionally, the Mustang Island State Park -South site was omitted from this analysis because this site was not representative of its geographic region (the ecotone), and Piping Plovers were never found at this site. This site was monitored only to support comparisons to the Mustang Island State Park - North site.

I selected the habitat parameters because they have all been associated with shorebird abundance or quality shorebird habitat (e.g., habitat area; Goss-Custard et al. 1995, prey abundance; Cullen 1994, Withers 1994, Connors et al. 1981, human disturbance; Staine and Burger 1994), and were variables that had the potential to vary substantially among my study sites.

To support the model, I monitored Piping Plover populations and the above 6 independent variables at my study sites from July - May in 1993 and 1994 (i.e., the last 2 years of the study). Whereas many of the above parameters were monitored during the study's first field season (July 1991- May 1992), human disturbance and surface prey were not measured until the second year of the study, and therefore data collected in the first year of the study are not incorporated into the model.

To maximize the number of samples used to support the model, I partitioned the study period into 4 temporal periods comprised of the migration season (fall and spring) and the winter season for each of the last 2 years of the study. Season and study year also were built into the model as independent variables to factor variability associated with these parameters into the analysis. Thus, each of the 8 barrier island study sites could potentially be represented by as many as 4 samples, yielding a potential maximum of 32 samples. However, because weather and other factors limited access to some of the sites during one or more of the 4 periods, most sites were represented in the model by fewer than 4 samples, and the model was supported by a total of 19 samples.

Piping Plover site abundance for each period was estimated as the sum of the mean number of Piping Plovers recorded during all beach and bayshore surveys conducted during each temporal sampling period at each site. For instance, during the 1993 fall migratory season at Bolivar Flats, I recorded an average of 46.0 plovers using bayshore habitat and 17.4 plovers using beach habitat, yielding an estimated site abundance for that period of 63.4 plovers

I selected the most robust model using backwards stepwise regression analysis. To investigate the effects of autocorrelation, I compared the relationships among the means of the 6 variables and Piping Plover abundance among the 19 samples using nonparametric correlation (Spearman Rho test).

Data Analysis

The analyses were performed using JMP, version 3.1 (SAS Institute Inc., Cary, NC). I programmed entry and exit criteria for the backward stepwise analyses to initially incorporate all 8 parameters (year, season, beach vehicular density, bay area, beach length, beach benthos, bayshore benthos, bayshore surface prey). Through backward stepwise regression, all parameters were removed from the model, beginning with the parameter that least affected plover abundance, and ending with the parameter than explained the greatest amount of variation in abundance. Akaike's Information Criterion was used to determine which parameters collectively constituted the model that best fit my data.

RESULTS

Mean abundance at beach habitats varied from < 1 birds/count to > 20 birds/count (Table 25). The highest single day counts at beach habitats were of roosting flocks and occurred at washover passes in the lagoon ecosystem or at the Packery Channel site, which was the only site outside of the lagoon ecosystem that had a washover pass (Table 26).

Mean abundance at bayshore habitats ranged from 0 plovers to > 355 plovers (Table 25). Nine of the 10 highest single day counts in bayshore habitat were in the lagoon ecosystem, most of these counts coming at the South Padre - North Area site (Table 26). In contrast to my observations of plovers at beach habitat, most plovers counted during

Table 25. Estimated mean site abundance of Piping Plovers on bayshore tidal flats and beach habitats at sites along the Texas Gulf Coast, 1991 - 1994. Mean site abundance was estimated as the sum of the mean bayshore flat abundance and the mean beach abundance at each site. Abbreviations: LANWR = Laguna Atascosa National Wildlife Refuge, MISP = Mustang Island State Park, NB = no beach at site, ND = no data, NYF = North Yucca Flats, RBV = Rincon Buena Vista, RHC = Redhead Cover, SHF = South Horse Flats, SPI = South Padre Island.

Study Location	Beach Abundance			Bayshore Abundance			Total
	N	mean	SE	N	mean	SE	
Bay Ecosystem							
Bolivar Flats	35	15.3	3.9	40	50.3	5.3	65.5
Big Reef	17	1.2	0.7	23	18.4	3.8	19.6
San Luis Pass	64	12.3	6.5	65	27.4	2.5	39.7
Ecotone							
East Flats	7	9.9	3.5	7	49.3	26.9	59.2
MISP - North	66	10.3	1.6	30	7.4	1.7	17.7
MISP - South	32	8.5	2.6	13	0.0	0.0	8.5
Packery Channel	58	14.0	2.9	47	14.7	2.8	28.7
Lagoon Ecosystem							
LANWR - RBV	NB	0.0	--	31	17.4	4.9	17.4
LANWR - SHF	NB	0.0	--	35	1.2	1.1	1.2
LANWR - RHC	NB	0.0	--	37	5.7	3.6	5.7
LANWR - NYF	NB	0.0	--	43	17.1	4.3	17.1
South Bay - West	NB	0.0	--	21	0.0	0.0	0.0
South Bay - East	25	22.6	11.7	29	19.1	8.2	41.7
SPI - North Area	27	12.3	6.5	6	355.3	58.3	367.6
SPI - Convention Center	ND	--	--	19	2.9	1.3	2.9
SPI - Parrot Eye's	ND	--	--	21	2.5	1.0	2.5
SPI - Mangrove Flats	ND	--	--	25	3.1	1.0	3.1

Table 26. High single day counts of Piping Plovers at beach and bayshore habitats along the Texas Gulf Coast, 1991 - 1994.

Location	Date	# Piping Plovers	
		Total	Roosting
Beach Habitat			
South Bay - East	2/10/93	254	254
South Padre Island - North	2/4/93	171	171
South Bay - East	2/26/93	153	121
Packery Channel	2/25/93	87	87
Bolivar Flats	2/18/93	83	56
Bolivar Flats	1/22/93	80	80
Packery Channel	11/2/92	76	76
South Bay - East	10/8/93	74	45
Packery Channel	2/11/93	63	63
Packery Channel	2/5/93	61	6
Bayshore Habitat			
South Padre Island - North	3/2/93	543	0
South Padre Island - North	1/27/94	489	223
South Padre Island - North	12/5/91	400	no data
South Padre Island - North	12/9/93	254	0
South Padre Island - North	10/1593	251	13
Laguna Atascosa NWR - Yucca Flats	1/28/93	238	0
South Bay - East	3/3/92	202	no data
South Padre Island - North	3/1/92	195	no data
East Flats	3/26/93	189	0
Laguna Atascosa NWR - Redhead Cove	11/18/91	130	0

the high single day counts at bayshore habitats were engaged in foraging behavior.

Mean total site abundance (i.e., beach and bayshore counts combined) ranged from 0 plovers to over 350 plovers (Table 25). With one exception, all of the sites with small plover populations (< 10 plovers) were either very small (e.g., the 3 sites on the southern end of South Padre Island) or were situated away from the barrier island chain on the mainland coastline (e.g., the South Bay-West site and the Laguna Atascosa National Wildlife Refuge sites).

The exception to this rule was one of the Mustang Island State Park (MISP) sites. Whereas the MISP - South site was neither small (40 ha tidal flats, 2.6 km beach) nor on the mainland, it supported a site population of just 8.5 plovers. All of the plovers in this mean population estimate were observed at beach habitat. No Piping Plovers were observed using bayshore flats at this site during the study. The MISP - North site, which was similar in size (33 ha tidal flats, 3.2 km beach) and borders the south site, supported a much larger site population (17.7 plovers). Furthermore, Piping Plovers consistently used bayshore flats at the MISP - North site (Table 3).

The difference in plover site abundance at these 2 sites is less confounding when the habitat features of the sites are compared more closely. The bayshore portions of the MISP sites consist of 2 lagoons, one lagoon forms part of MISP - North, and a second lagoon forms part of MISP - South (Figure 5). The 2 lagoons were once part of a single large lagoon, but they were isolated by a man-made channel (Fish Pass). In addition to splitting the large lagoon into 2 smaller lagoons, the channel also interrupted tidal flow into both lagoons. A second artificial channel was dredged into the north lagoon to re-establish a tidal exchange between the MISP - North lagoon and Corpus Christi Bay, but the MISP - South lagoon remained relatively isolated from tidal influences throughout the study. The MISP - South site was drier and more heavily vegetated, and these factors appear to have affected the value of the site to Piping Plovers.

Factors Affecting Piping Plover Site Abundance

Data from 8 sites were evaluated to investigate the relationship between Piping Plover site abundance and habitat and environmental conditions occurring at the sites. Mean Piping Plover site abundance at the 8 sites varied from < 3 plovers to > 370 plovers (Table 27).

The habitat and environmental parameters also varied widely. Mean bayshore area at the sites varied from about 20 ha to > 500 ha (Table 27). Beach length for most of the sites ranged from about 3 km to about 7 km, with the long (> 25 km) South Padre Island - North site being the exception (Table 27). Human disturbance, estimated as beach vehicular density, ranged from 0 vehicles/km to almost 6 vehicles/km (Table 27). Bayshore benthic density ranged from 0 animals to > 12,000 animals/m^2 (Table 27). As expected, beach benthic populations were more consistent, ranging from about 560 to about 7,000 animals/m^2, with most samples ranging from about 1,000 to about 3,500 animals/m^2 (Table 26). Finally, insects and other surface prey ranged from 0 to nearly 1400 animals captured/100 trap hr. (Table 27).

Pairwise correlation analyses revealed that some of the independent parameters were significantly correlated with each other (Figure 43). Among these were bay area/beach vehicular density (P= 0.0007), bay surface prey/beach length (P= 0.0112), and bay surface prey abundance/bay benthic density (P= 0.0243). All of these correlations were negative.

The effects of each of the measured parameters on Piping Plover abundance were independently evaluated. The area of bayshore habitat (positive relationship; R^2 = 0.3770, P = 0.0052) explained the greatest amount of variability in plover abundance at my sites (Figure 44). Beach vehicular density (negative relationship; R^2 = 0.3277, P = 0.0104; Figure 44), and beach length (positive relationship; R^2 = 0.2259, P = 0.0397; Figure 45) also each explained over 20% of the variability in Piping Plover abundance at

Table 27. Mean values for the environmental and habitat variables used in the multiple regression models. Each figure represents the mean value of the variable over the 3 year study period.

Study Site	Yr.	Sea.	Beach Variables: Bl.	Beach Variables: Benthic Density mean	N	SE	Beach Variables: Vehicular Density mean	N	SE	Bayshore Variables: Bayshore Area mean	N	SE	Bayshore Variables: Benthic Density mean	N	SE	Bayshore Variables: Surface Prey mean	N	SE	Piping Plover Abundance mean	N	SE
BF	Y2	Mig	4.8	1239	25	203	1.56	7	0.54	78.3	6	23.2	4765	35	697	0.07	30	0.05	63.4	7	18.0
BF	Y2	Wint	4.8	6418	40	564	0.83	7	0.30	100.7	7	15.5	11998	45	841	0.13	45	0.05	90.6	7	29.2
BF	Y3	Mig	4.8	1266	30	167	2.22	7	0.38	105.8	8	21.1	2757	30	469	0.03	30	0.02	59.0	7	14.7
BF	Y3	Wint	4.8	949	5	512	0.58	5	0.23	131.6	5	27.4	7110	35	843	0.00	10	0.00	55.2	5	21.3
BR	Y2	Wint	4.4	7142	5	361	3.65	3	0.83	34.8	5	5.3	12340	15	734	0.75	15	0.28	2.8	3	5.8
BR	Y3	Mig	4.4	3104	15	939	5.10	6	1.13	19.3	6	5.3	2260	15	669	1.00	15	0.20	7.1	6	7.9
SLP	Y2	Mig	6.3	3633	40	560	5.83	13	2.17	27.0	12	5.2	4076	30	670	0.35	20	0.15	30.8	13	5.4
SLP	Y2	Wint	6.3	3824	90	511	1.24	24	0.13	47.1	21	3.7	4294	90	322	0.12	66	0.05	29.7	24	6.3
SLP	Y3	Mig	6.3	1654	25	484	2.75	6	0.56	33.0	6	7.6	2296	25	470	0.00	25	0.00	32.5	6	7.2
EF	Y2	Mig	2.8	3345	10	559	0.00	2	0.00	123.0	2	0.0	0	6	0.0	13.83	6	2.52	34.5	2	61.5
EF	Y3	Mig	2.8	2140	15	437	0.00	2	0.00	123.0	2	35.5	0	25	0.0	8.72	25	0.99	74.0	2	38.9
MISPN	Y2	Wint	3.2	3464	55	531	1.21	25	0.26	25.9	20	17.4	329	55	102	0.54	80	0.15	16.2	20	11.0
MISPN	Y3	Wint	3.2	1695	10	324	4.06	2	2.19	44.8	2	13.2	1996	25	318	1.04	25	0.25	18.0	2	13.5
PC	Y2	Wint	3.9	563	45	90	1.73	30	0.39	102.0	25	10.5	600	125	132	0.68	125	0.37	32.1	25	8.3
PC	Y3	Mig	3.9	2066	35	341	2.91	3	1.51	29.8	3	16.7	0	5	375	5.00	5	0.46	43.0	3	15.2
PC	Y3	Wint	3.9	4449	35	317	2.65	3	1.37	89.5	3	25.8	3179	15	298	0.73	15	0.21	46.0	3	15.4
SBE	Y3	Mig	7.6	712	20	200	1.49	3	0.48	267.5	3	40.1	859	20	341	0.70	20	0.21	47.3	3	27.4
SBE	Y3	Wint	7.6	1808	20	238	2.57	2	0.59	120.4	4	76.8	181	5	132	0.00	5	0.00	4.5	4	4.5
SPIN	Y3	Wint	25.1	1740	40	185	0.00	3	0.00	507.5	2	101.5	663	45	107	1.09	45	0.35	372.8	3	118.8

Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN = Mustang Island State Park, PC = Packery Channel, SBE = South Bay - East, SPIN = South Padre Island - North, Wint = Winter, Mig = Migration, Y = year

Variable	by Variable	Spearman Rho	Prob>|Rho|
Beach Veh	Year	0.1170	0.6334
Bay Area	Year	0.2629	0.2769
Bay Area	Beach Veh	-0.7086	0.0007
BL	Year	0.1474	0.5471
BL	Beach Veh	0.0444	0.8569
BL	Bay Area	0.2295	0.3445
Be Tot Benth	Year	-0.3892	0.0995
Be Tot Benth	Beach Veh	0.1160	0.6363
Be Tot Benth	Bay Area	-0.4142	0.0779
Be Tot Benth	BL	-0.2028	0.4049
Bay Tot Benth	Year	-0.2925	0.2244
Bay Tot Benth	Beach Veh	0.2095	0.3893
Bay Tot Benth	Bay Area	-0.1653	0.4989
Bay Tot Benth	BL	0.3461	0.1467
Bay Tot Benth	Be Tot Benth	0.2320	0.3392
Bay Surf Pry	Year	0.0683	0.7812
Bay Surf Pry	Beach Veh	-0.0872	0.7227
Bay Surf Pry	Bay Area	0.0325	0.8948
Bay Surf Pry	BL	-0.5677	0.0112
Bay Surf Pry	Be Tot Benth	0.2497	0.3026
Bay Surf Pry	Bay Tot Benth	-0.5143	0.0243

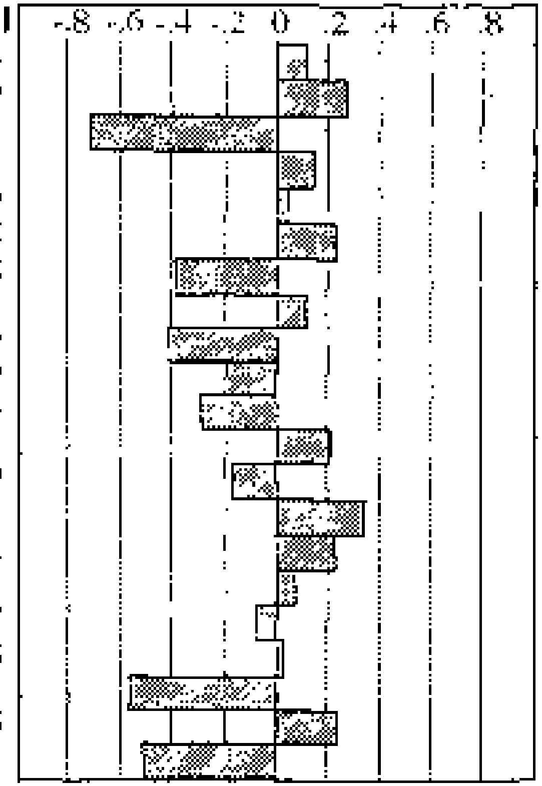


Figure 43. Nonparametric pairwise correlations between the 6 independent environmental parameters evaluated for thier effect on Piping Plover abundance. Year and season are also shown. Abbreviations: Veh = vehicle density, BL = beach length, Be Tot Benth = beach benthos density estimate, Bay Tot Benth = bayshore benthos density estimate, Bay Surf Pry = relative bayshore surface prey abundance estimate.

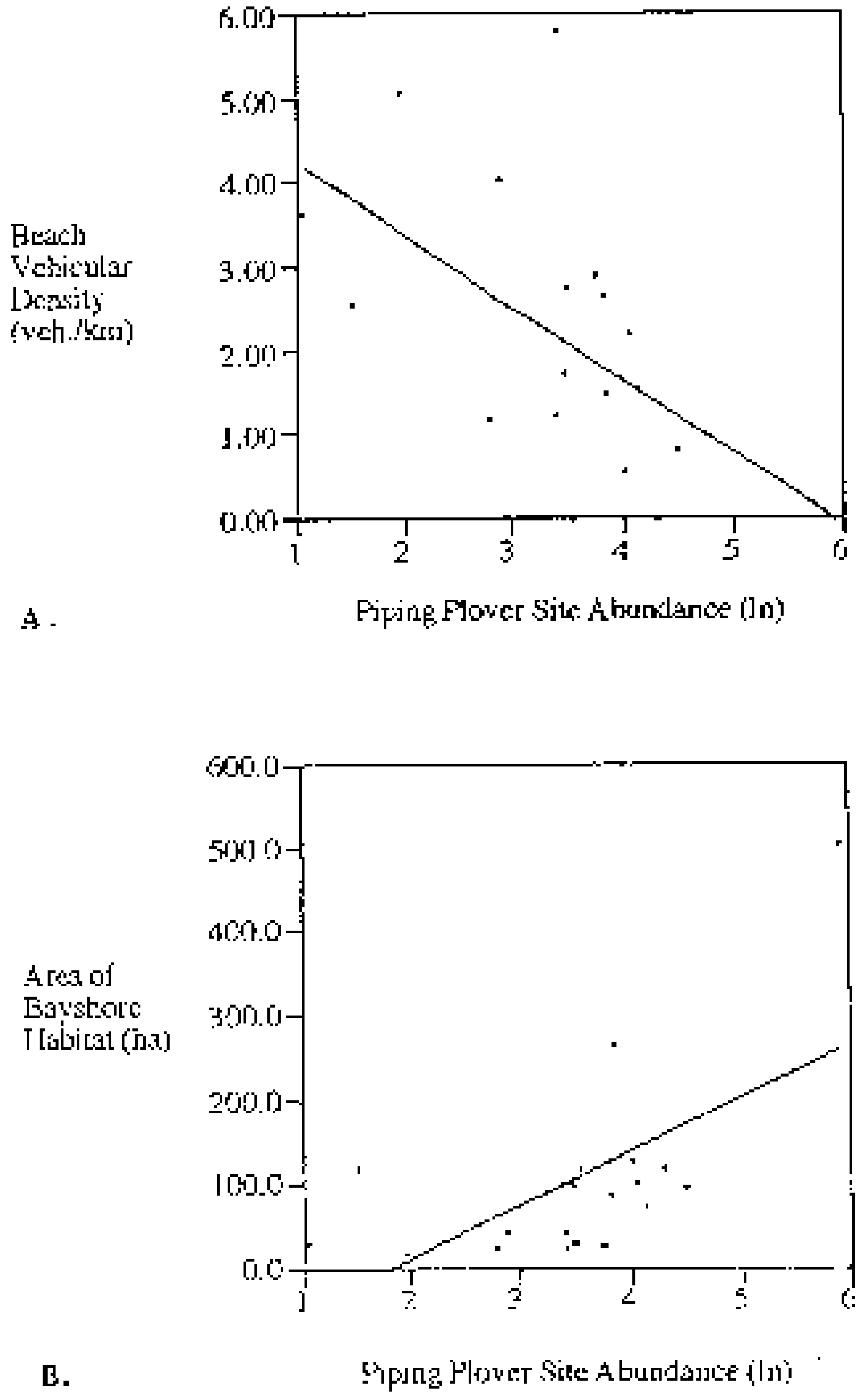


Figure 44. Simple regressions evaluating the effects of (A) beach vehicular density (vehicles/kilometer; $P = 0.0104$, $R^2 = 0.3277$) and (B) bayshore area (hectares; $P = 0.0052$, $R^2 = 0.3770$) on Piping Plover site abundance.

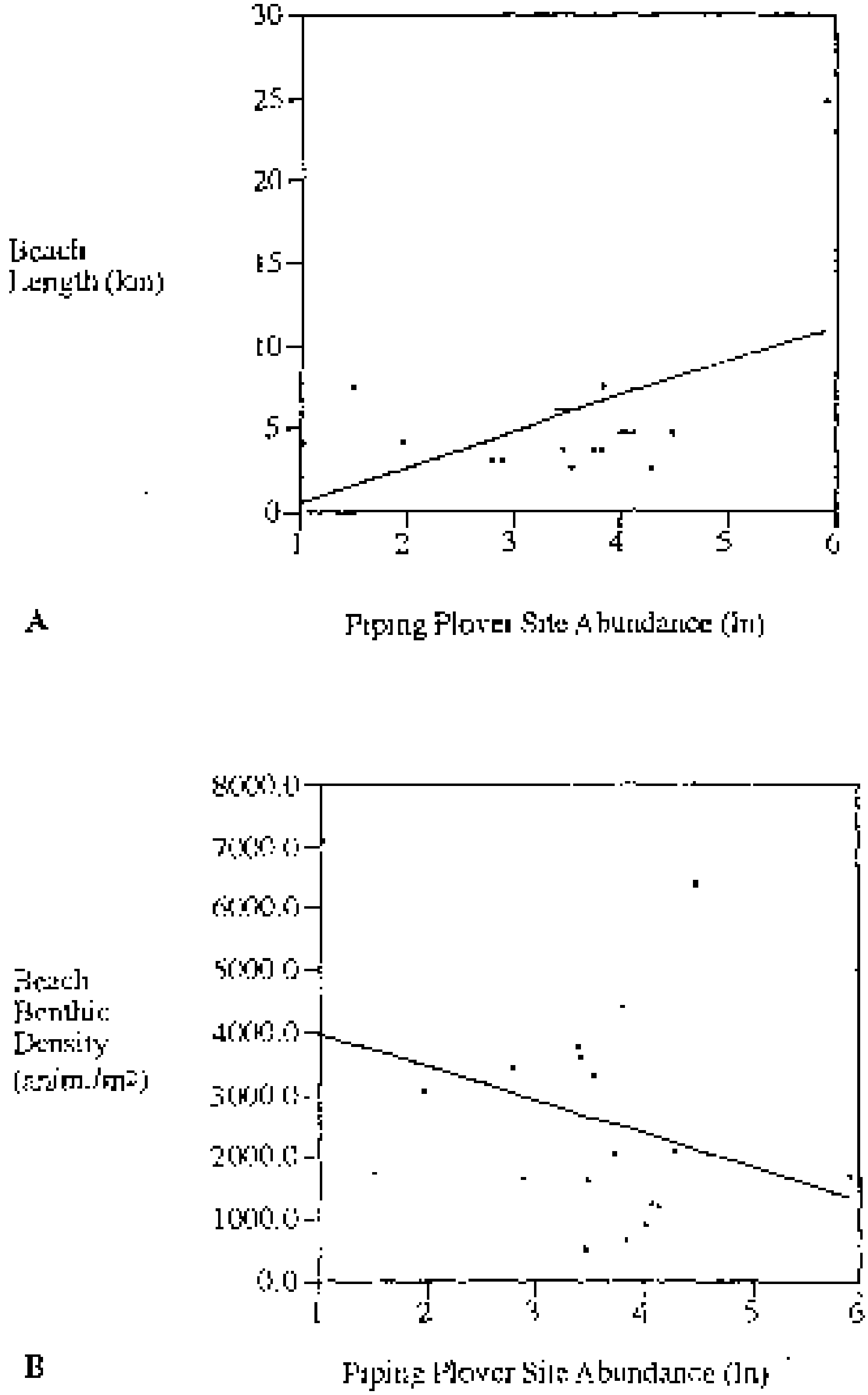


Figure 45. Simple regressions evaluating the effects of (A) beach length (kilometer; $P = 0.0397$, $R^2 = 0.2259$) and (B) beach benthic density (# animals/square meter; $P = 0.1762$, $R^2 = 0.1049$) on Piping Plover site abundance.

my sites.

None of the prey measures strongly or significantly influenced plover abundance (Figures 45 and 46). Beach benthic density (negative relationship; $R^2 = 0.1049$, $P = 0.1762$), bayshore benthic density (negative relationship; $R^2 = 0.0232$, $P = 0.5333$), and bayshore surface prey density (positive relationship; $R^2 = 0.0151$, $P = 0.6157$) all explained only a small amount of the variability in the abundance of Piping Plovers at my sites. The sites with the largest plover populations were those that had the largest area of bayshore flat, the largest area of beach habitat, and the lowest level of human disturbance.

The most robust multiple regression model selected by stepwise regression identified beach vehicular density ($P = 0.0106$), beach length ($P = 0.0396$), and season ($P = 0.1105$) as the most important factors explaining Piping Plover site abundance. This 3-factor model explained over half of the variability associated with Piping Plover abundance at my sites ($P = 0.0052$; $R^2 = 0.5396$). The regression formula describing the effect of these parameters on Piping Plover abundance was:

ln # Piping Plovers	=	3.69 (y - intercept)
	-	0.3525 (beach vehicular density [#/km])
	+	0.3309 (Season [Fall = 1, Winter = 2])
	+	0.0934 (beach length [km])

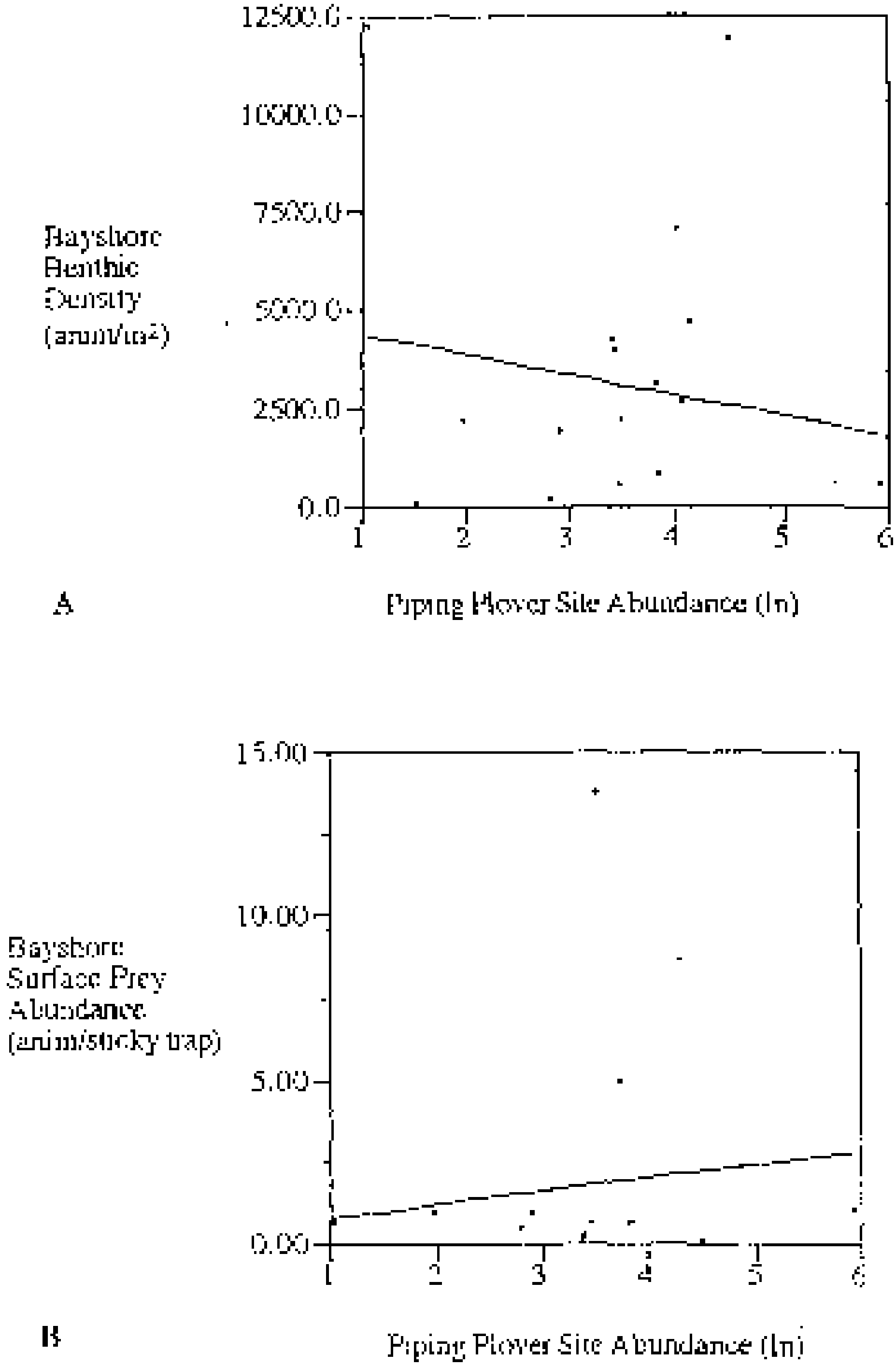


Figure 46. Simple regressions evaluating the effects of (A) bayshore benthic density (# animals/square meter; $P = 0.5333$, $R^2 = 0.0232$) and (B) bayshore surface prey abundance (# animals/sticky trap; $P = 0.6157$, $R^2 = 0.0151$) on Piping Plover site abundance.

The full model, incorporating all 6 habitat and environmental parameters and the seasonal effect into the analysis was only marginally better at predicted Piping Plover abundance ($P = 0.2210$; $R^2 = 0.5714$) than was the 3 parameter model:

ln # Piping Plovers = 3.90 (y - intercept)
- 0.3475 (beach vehicular density [#/km])
+ 0.3753 (season [Fall = 1, Winter = 2])
+ 0.0581 (beach length [km])
+ 0.0016 (bayshore habitat area [ha])
+ 0.000038 (bayshore benthic density [#/m^2])
- 0.000074 (beach benthic density [#/m^2])
- 0.0348 (bayshore surface prey density [#/sticky trap])

DISCUSSION

My site abundance estimates compare well with counts from the 1991 and 1996 International Piping Plover Censuses (IPPC). Piping Plover site abundance was estimated at Bolivar Flats, Big Reef and San Luis Pass during the 1991 and 1996 International Piping Plover Census. Seventy-three Piping Plovers were counted at Bolivar Flats in 1991 and 101 were counted in 1996 (mean = 87). Nicholls and Baldassarre (1990a) found 66 Piping Plovers at Bolivar Flats. I used data from the last 2 years of my study for the regression models presented in this chapter, resulting in an abundance estimate of 65.5 plovers at Bolivar Flats.

At Big Reef, 25 Piping Plovers were counted during the 1991 IPPC, while none were found there in 1996 (mean = 12.5). My 2-year estimate of plover abundance at Big Reef was 19.6. Bolivar Flats and Big Reef are separated only by the Houston Ship Channel, and plovers often move between these sites (pers. obs.). This probably explains why the number of plovers counted during the 1996 IPPC rose by 28 plovers at Bolivar Flats while it dropped by 25 at Big Reef. The cumulative 1991 and 1996 IPPC counts for both sites were very similar (98 and 101), and the mean of these 2 counts (99.5) was similar to my mean estimate for both sites (85.1).

Forty-one Piping Plovers were counted during the 1991 IPPC at San Luis Pass (beach and bayshore potions of the count), and 29 were counted in 1996 (mean = 35). Both IPPC counts were similar to my 2-year estimate of 39.7 Piping Plovers for the site. Nicholls and Baldassarre (1990a) found 39 Piping Plovers at San Luis Pass. Unfortunately, comparative site abundance data are not available from the 1991 or 1996 IPPC to support comparisons with my other study sites because the boundaries of those counts differed from the boundaries of my study sites.

The regression model I present in this chapter indicates Piping Plover recovery efforts may need to be reevaluated. In Texas, most recovery activity for the federally-listed Piping Plover has focused on preserving bayshore habitat on barrier islands. Examples of this trend include the establishment of the Mollie Beattie Sanctuary in 1997 (which includes the bayshore portion of the Packery Channel site), the 1992 establishment of a Western Hemispheric Shorebird Reserve Network (WHSRN) site at Bolivar Flats, the establishment of preserves at Big Reef in 1995 and San Luis Pass (in progress, P. Glass pers comm.), and the acquisition by the U.S. Fish and Wildlife Service of the eastern portion of South Bay in 1998. Preserving habitat for the Piping Plover was one of the primary goals of each of these actions. However, most of these sites include large tracts of barrier island bayshore tidal flat habitat, but contain very little of the other habitat types used by Piping Plovers (e.g., beaches, mainland tidal flats, washover passes).

Indeed, my data do strongly suggest barrier island tidal flats are the preferred habitat of Piping Plovers wintering in Texas. Beach habitat, washover passes and mainland tidal flats (in the lagoon ecosystem) clearly appeared to be secondary habitats that primarily were used by plovers during periods when barrier island tidal flats were unavailable due to tidal inundation. Clearly any site that supports Piping Plovers must have bayshore tidal flats. In fact, plover abundance and bayshore tidal flat area were positively correlated at my sites, indicating that a reduction in the amount of bayshore tidal flat habitat may reduce a site's plover population. By itself, bayshore area explained 38% of the variability in plover abundance.

The strong correlation between bayshore area and beach vehicular density further muddies an appraisal of the isolated effects of bayshore area on plover abundance. However, the 3-factor model presented above (that excluded bayshore area) was generated by backward stepwise regression analysis. Backward stepwise regression evaluates interactions among parameters before removing the parameters one at a time in reverse order of fit. This approach identifies those parameters that best explain plover abundance while also considering how these parameters interact. Whereas bayshore area explained a large amount of variation in plover abundance, when evaluated in combination with the other parameters, its effect was diminished, and it was omitted from the most robust model.

The fact that bayshore area was not incorporated into the best-fit model does not mean that protecting large areas of bayshore habitat is fruitless. However, my data suggest that the carrying capacity of barrier island sites is presently limited to a greater extent by the availability of protected beach habitat than bayshore habitat. Therefore, the present strategy of protecting barrier island tidal flats to the exclusion of beach habitat may prove ineffective in the long-term recovery of the Piping Plover.

There is recent evidence to suggest that mainland tidal flats and washover passes also function as important secondary habitats for Piping Plovers, particularly in the lagoon ecosystem (Zonick 1997, Zonick et al. 1998). Mainland tidal flats in the lagoon ecosystem are seriously threatened by human-induced alterations. Broad areas of mainland flats once experienced numerous flooding and drying cycles throughout the winter as winter fronts pushed Laguna Madre waters into and out of the mainland coastline (Farmer, 1991). Large tracts of mainland flats, however, have become extensively isolated from these waters by miles of continuous dredged spoil banks associated with Gulf Intracoastal Waterway (GIWW) and the Harlingen Ship Channel. Rincon Buena Vista, Elephant's Head Cove, South Horse Flats (Figure 7) and other mainland tidal flats used by Piping Plovers during my study have undergone an extensive and progressive encroachment by Glasswort (*Salicornia bigelovii*), Saltwort (*Batis maratima*), and other salt-tolerant plants. Whereas these plants are not unusual in the tidal flat landscape, tidal flats surrounded by dredged spoil appear to exhibit much higher levels of encroachment. These, and perhaps several other mainland tidal flats may require expeditious management (e.g., removal of dredged spoil banks blocking tidal waters) if they are to remain intertidal wetlands.

However, the trend associated with human influences on beach habitat is most alarming. The Texas Gulf Coast supports thriving petrochemical refining and offshore drilling industries. Texas beaches are exposed to small scale oil and tar exposure on a constant basis. Bolivar Flats and other sites situated nearby the mouths of ship channels are particularly vulnerable to catastrophic oil spills.

Human presence on beaches, however, may be a greater long-term threat to Piping Plovers in Texas. Piping Plovers primarily used beaches during periods when bayshore flats were flooded. The availability of high quality beach habitat to plovers during these periods may be critical to their survival. Human disturbance at beach habitat was identified by stepwise regression as the most important factor affecting the abundance of Piping Plovers at my sites. By itself, beach vehicular density explained 33% of the variability in Piping Plover abundance among my study sites. The area of beach habitat (i.e., beach length) also significantly affected plover abundance, independently explaining 23% of the variability in Piping Plover abundance among my study sites.

CHAPTER V. CONCLUSIONS & MANAGEMENT RECOMMENDATIONS

Along the TGC, Piping Plovers occupy sparsely-vegetated beach, and bayshore tidal flat habitat (e.g., sand flats and algal flats) throughout a 9-10 month non-breeding period (Haig 1992). At my study sites, plovers used both beach and bayshore habitat, but preferred bayshore habitat when both habitat types were emergent and thereby available to plovers. During periods of high bayshore tides, when tidal flats were inundated and were not available, Piping Plovers moved to beach habitat at most sites and foraged within the beach intertidal zone until bayshore tides receded and bayshore habitat was again available to plovers.

The preference for bayshore habitat could not directly be explained by differences in prey availability or plover foraging efficiency in the 2 habitat types. Whereas prey were more abundant at bayshore habitat than at beach habitat in the bay ecosystem, the relationship was reversed in the lagoon ecosystem and the ecotone. Furthermore, Piping Plovers foraged with similar efficiency at beach and bayshore habitats. Plovers also foraged with similar efficiency at bayshore tidal flats in the bay and lagoon ecosystems, even though these ecosystems supported starkly different bayshore prey communities.

The preference for bayshore habitat may have been due to factors that reduced net energy intake rates of plovers using beach habitat. Piping Plovers were much more territorial when feeding at beach habitat, often interacting aggressively to defend feeding areas along the forebeach from other Piping Plovers. Plovers also experienced greater levels of human disturbance at beach habitat than at bayshore habitat. Finally, to feed on their preferred prey at beach habitat, plovers had to repeatedly run into and out of the swash zone. These factors caused plovers to spend considerably more time in prolonged foraging locomotion (PFL), and presumably expend more energy to obtain a similar rate of prey intake. The result was probably a lower net energy intake rate on beaches relative to bayshore flats, resulting in the observed preference for bayshore habitat.

The importance of beach habitat to Piping Plovers

Although plovers preferred to feed at bayshore habitat, beaches provided alternative feeding and roosting habitat for plovers during periods when bayshore feeding areas were unavailable. Changes in atmospheric pressure and wind conditions accompanying winter cold fronts often created extremely high bayshore tides that covered all bayshore tidal habitat at many of my sites. A plover's ability to survive the harsh conditions accompanying these fronts may depend on its ability to find suitable roost sites or alternative feeding sites. In many parts of the Texas coast, beaches appeared to provide the only suitable alternative to bayshore tidal flats. The importance of beaches is underscored by the habitat model described in Chapter IV, which identified undisturbed beach habitat as the key component affecting local Piping Plover abundance at my study sites. Beaches appeared to be most critical in the ecotone, where plovers occurred at higher densities relative to the bay or lagoon beaches.

The importance of mainland habitat in the lagoon ecosystem

Plovers used beaches somewhat less frequently in the lagoon ecosystem, particularly along the long (25.4 km) South Padre Island study site. There is recent evidence to suggest that, in the lagoon ecosystem, mainland tidal flats may serve the same role for plovers as do beaches in the bay ecosystem and ecotone (Zonick et al. 1998). My mainland study sites had lower average densities of plovers throughout the year, but occasionally supported large plover flocks (> 90 birds). As described in the Study Area section, tides in the lagoon ecosystem were controlled to a much greater extent by wind forces which often created new emergent flats at mainland sites just as flats on the barrier island became flooded. Plovers in the lagoon ecosystem appeared to react to this tidal regime by moving among several barrier island and mainland tidal flats as they became emergent under the wind-tidal regime. This hypothesis is supported by my observations of what appeared to be the same color banded Piping Plover using all 3 of my lagoon ecosystem sites during the same non-breeding period (Zonick and Ryan 1994, 1995), and by a recent study demonstrating the use of both barrier island and mainland sites by radiofitted plovers (Zonick et al. 1998).

Large areas of mainland tidal flats in the lagoon ecosystem are threatened by indirect effects of maintenance operations on the Gulf Intracoastal Waterway (GIWW). Dredged material removed from the GIWW is placed on dredged material placement areas (DMPAs; also referred to as "spoil islands") that lie along the channel. DMPAs located near Laguna Atascosa National Wildlife Refuge and South Bay have formed barriers that have greatly altered the natural tidal inundation regime of neighboring mainland tidal flat systems (Farmer 1991, pers. obs.). These flats began exhibiting unusually dense blooms of *Salicornia bigelovii* and other vascular plant species in 1992 (Zonick and Ryan 1994). These blooms have persisted and may represent the first stage in the successional replacement of tidal flats by upland habitat (Zonick and Ryan 1994, Brush 1995). The importance of mainland tidal flats to Piping Plovers in the lagoon ecosystem underscores the need for remedial measures to restore a more natural tidal regime to these mainland systems (Zonick et al. 1998).

Washover pass habitat

The washover pass is another habitat that appeared to offer critical high tide refugia to Piping Plovers. Washover passes were used by Piping Plovers both as feeding and roosting areas during the study and also provide important roosting, feeding and nesting habitat for other plover species (e.g., Snowy Plovers and Wilson's Plovers: Zonick 1997). During tropical storm events, all tidal flat habitat in the lagoon ecosystem may be submerged for days or weeks. Such a phenomenon occurred in the fall of 1992 following Hurricane Andrew. Though Hurricane Andrew did not strike the Texas Coast directly, it caused extreme high tides in the Laguna Madre which inundated South Bay and other rarely submerged tidal flats for a period lasting several weeks. A similar episode occurred following Tropical Storm Josephine in 1997 (Zonick 1997). During these events, washover passes provided critical foraging and roosting habitat for Piping Plovers and other waterbirds. Newport Pass, one of the washover passes at the Packery Channel site, consistently supported large flocks of Piping Plovers during and beyond the study period (Zonick 1997).

Threats associated with the human use of Piping Plover habitat

The increasing human use of Texas beaches appears to be the greatest immediate threat to the long term recovery of Texas Piping Plover populations. For example, human use of Nueces County beaches (Nueces County includes Mustang Island, including all 3 ecotone sites, and the city of Corpus Christi) has increased at an annual rate of nearly 10% in the last decade. The rate of human use of Mustang Island may soon increase. Nueces County has recently announced its intent to elevate the causeway connecting Mustang Island to Corpus Christi, and reopen Packery Channel as a recreational waterway connecting Corpus Christi Bay with the Gulf of Mexico. These projects would clearly stimulate greater human use of the barrier island, further degrading the quality of beaches along the Texas coastal ecotone, where plovers are most dependent on protected beach habitat.

The Great Lakes and Northern Great Plains Piping Plover Recovery Plan requires that the 1998 interior population of Piping Plovers be nearly doubled (from ~ 2,500 breeding pairs to ~ 4,000 breeding pairs) before the Piping Plover interior population be delisted (U.S. Fish and Wildlife Service 1988). It is logical to expect that the Texas Gulf Coast will need to support many of these additional birds. The potential for the TGC to support an expanding Piping Plover population may hinge on the availability of protected beach habitat, particularly in the ecotone and the bay ecosystem where plovers have no alternative habitat during high tide episodes. Piping Plovers are highly territorial at beach habitat. Whereas the mean Piping Plover density approached or exceeded 3 birds/km at 6 of my 9 beach sites, none of the beaches supported an average > 3.6 birds/km. During maximum use, plovers were spaced less than 90 m apart at 3 of the 4 ecotone beaches. These sites may already be at or near their carrying capacity due to limitations to beach habitat.

In 1997, Nueces County, in cooperation with the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department, and the National Audubon Society designated Newport Pass, one of the 2 washover passes at the Packery Channel site, as a sanctuary to protect an important Piping Plover roost site. Vehicular barriers and interpretive signs will reduce disturbance at the roost site and educate visitors to the beach about the importance of beach and washover pass habitat to Piping Plovers and other coastal species. The Newport Pass Sanctuary was the first area preserved with the goal of protecting secondary habitat for Piping Plovers, but must not be the last if the species is to expand to recovery levels.

Mainland tidal flats, washover passes, and particularly beach habitat must be protected along with barrier island tidal flats, and these habitats must be managed to reduce or mitigate human impacts. The broad tidal flats in the ecotone and lagoon ecosystem must be preserved to support recovering plover populations. The system of washover passes on Matagorda Peninsula, San Jose Island, Mustang Island, Padre Island and Brazos Island must be protected as high water refugia for Piping Plovers and nesting habitat for the Snowy Plover. The effects of the GIWW on mainland tidal flats must be understood and, if necessary, corrected before these crucial alternative winter sites are no longer suitable for Piping Plovers.

However, the transformation of Texas' beaches from free-access lands to pedestrian-only beaches should be the highest priority for the recovery of Piping Plovers on the wintering grounds. It is true that pedestrian traffic has been shown to reduce plover habitat quality, and the conversion to pedestrian-only beach access might increase pedestrian traffic along some areas of the coast. However, the areas that are likely to suffer the greatest level of pedestrian disturbance following such a conversion already face very high levels of both pedestrian and vehicular disturbance (e.g., Packery Channel, San Luis Pass). Many other beach areas located away from public parking facilities would likely experience a reduction in human disturbance were vehicles prohibited on Texas beaches. Furthermore, if Texas beaches were established as pedestrian-access only, there would be no need to manage the beaches for vehicular access. Vehicular traffic appears to reduce the abundance of important Piping Plover prey species at beach habitat (Vega 1988). A reduction in mechanical scraping and raking would likely reduce the erosion of beach habitat, and allow the beach benthic community to recover from impacts that may be associated with beach grooming practices, potentially increasing the carrying capacity of such beaches for Piping Plovers. Piping Plovers would clearly benefit from these changes.

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18091

From: Daniel Tingdahl <[redacted]
Sent: Monday, November 1, 2021 7:42 AM
To: SpaceXBocaChica
Subject: regarding the draft pea for SpaceX

Hi,
I'm a space enthuasist who would like to see rockets flying orbital from Boca Chica, but I guess that some aspects (for example regarding the launch tower) of the application from SpaceX may be missing. I understand that they need to be addressed, maybe in additional documents that SpaceX would need to send, and that therefore an immediate "yes" may not be possible to give once the response period ends later today, Nov 1st.
But if there is a straight "no", that would probably not only kill the chance of going to the Moon for a long time (and maybe Mars, and maybe in the long run SpaceX as a whole), but would also make the chinese leadership and rocket industry to laugh from Bejing to Shanghai, and further out. The US would risk to lose it's renewed position as a leader in space technology and could in some sense shrink as a nation.

Regards,
Daniel Tingdahl

18092

From: Bruce Perens <[redacted]
Sent: Monday, November 1, 2021 11:28 AM
To: SpaceXBocaChica
Subject: Reply Comment of Bruce Perens
Attachments: FAA_SpaceX_1.pdf

This is in reply to the FAA Proposed Environmental Finding regarding SpaceX.
I have no acknowledgement of my original comment, nor any evidence that my comment was considered. Thus, I have attached my original comment for consideration.

I am concerned by the opaque nature of this proceeding. Comments are not visible for others to peruse. Comments are not acknowledged. The proceeding is operated by an NGO, ICF, rather than by FAA. Other government entities, for example FCC, provide a better example of the comment process, with all comments going back to 1996 visible to the public online.

Please consider the attached document,

Respectfully Submitted

Bruce Perens

--

[redacted]

Before The
Federal Aviation Administration
Washington, D.C. 20591

In the Matter of:

SpaceX Boca Chica Launch and Manufacturing Site: Public Scoping of Issues for Analysis in Environmental Assessment.

Comment of Bruce Perens

Publication encouraged, please attribute properly. 20-January-2021

1 Overview

In this comment, I introduce the Rocket Launch, Operations, and Recovery Observer ("Launch Observer") as a stakeholder, a beneficial public influence, an environmental impactor and (when managed appropriately) an environmental impact mitigator.

I request a Supplemental Environmental Analysis dealing with the issues of the Launch Observer near the Boca Chica site, which would be applied programmatically regarding all further environmental assessments of the facility.

I discuss issues of the Launch Observer and their environmental impact at and around SpaceX Boca Chica. As applicable examples of future activity at Boca Chica, I discuss Launch Observers at Kennedy Space Center and Cape Canaveral Space Force Station, and the Vandenberg Air Force Base.

I present a suggested policy and process framework for appropriately managing and accommodating the Launch Observer and their environmental impact in planning rocket manufacture, ground support, launch, and recovery operations. I present suggested requirements concerning Launch Observers to be used in future Environmental Impact Assessments.

1 Request for Supplemental Environmental Analysis

The 2014 Environmental Impact Statement for the SpaceX Boca Chica facility and all subsequent written re-evaluations through December, 2020 have not sufficiently taken into account the environmental impact of the Launch Observer and their issues. The locations where observers are likely to congregate, their numbers, their potential environmental impact and processes for mitigation are not mentioned in those documents.

Recent operations by SpaceX at Boca Chica *have* involved a significant number of Launch Observers, and they have had an environmental impact. Fortunately the impact appears to have been favorable this time, due to a cleanup operation organized by the Launch Observers themselves. Further operations are expected to have greater environmental impact. Thus, the 2014 EIS is no longer current nor substantially valid without the addition of a supplemental EIS regarding Launch Observers.

2 The Launch Observer

People have been entranced by rocket viewing for the two millenia that fireworks have existed, a trait that evolved into us as primitive humans sat around a community fire. The modern Rocket Launch, Operations, and Recovery Observer ("Launch Observer") includes the same motivations, as well as an appreciation of science, of astronauts as heroes, and of the hope for an interplanetary, and even interstellar, human race as passenger space vehicles become a reality.

2.1 The Launch Observer Has Standing In Space-Related Environmental Proceedings

This is a proceeding under the National Environmental Protection Act. That act establishes the purpose of encouraging *productive and* ***enjoyable*** *harmony between man and his environment.*

Obvious in the idea of *managing* the environment is the fact that it is *not* simply the natural space and resources around us, but the impingement upon that space and those resources of human beings and all of their works.

Thus, **the Launch Observer has standing** under this proceeding as someone who simply wishes to view a launch *for their own enjoyment. However,* the Launch Observer is not *merely* someone out for a good time:

2.2 The Launch Observer is a Stakeholder

Both private and government rocketry are taxpayer-funded, the private ones through various research and development programs and the support of many and various facilities, including the FAA itself, the launch sites, the International Space Station, and the *Eastern and Western Ranges,* launch telemetry ranges managed by the 30th and 45th Space Wings of the United States Space Force and NASA.

The Federal Aviation Act of 1958 establishes the FAA as an entity operating *in the public interest.* The 1st amendment of the Constitution guarantees the right of citizens to peacefully assemble, observe, and (when necessary) seek redress to the operation of their government. More generally, the citizen has a right to *know what their government is doing,* and of course this is necessary if they are to be informed voters.

Voluminous case law interpreting the 1st amendment (to a great extent concerning the observation of police officers, but applying equally to other government departments and their functionaries) supports the right of the public to be present to observe, and to photograph and make video recordings and other records.

The Launch Observer, as taxpayer, voter, and citizen; thus has a *constitutional right* to observe the operation of FAA regulated and/or government funded rocketry and space operations, within sensible limits of safety, privacy, and national security. **Launch Observers are thus stakeholders whose rights must be considered by the FAA and other authorities.** But their rights are often ignored, even thwarted, by poorly-informed authorities where many space operations take place, since of all such facilities *only* Kennedy Space Center has any reasonable plan and accommodation for Launch Observers.

2.3 The Launch Observer Performs a Public Benefit

FAA is fundamentally a science-based organization: Aircraft aren’t held aloft by politics or the power of crystals. This is evident as FAA acts upon the results of scientific investigations such as those carried out by NTSB.

Increase in the scientifically-educated portion of the electorate is in the interest and mission of FAA: these are the people who will operate, advance, and patronize aviation and space travel; and operate the FAA itself. More generally, science is critical to the Federal Government and all citizens: It is only through science that we will solve public issues such as COVID-19 and the effects of pollution and global warming upon our nation and people.

Launch Observers in general encourage science and particularly science education. They are, to a great extent, there because they are excited by the science of rocketry and its potential for the human race. They transmit this to their children, who grow up to be excited by science.

Launch Observers perform a public benefit: they promote science, technology, engineering, and mathematics; and education in those fields, supporting our national security and competitiveness. They should be supported and encouraged.

2.4 The Launch Observer Has an Environmental Impact

Launch Observers, by their presence at a launch, space operation, or recovery, can have a significant environmental impact. This impact can be easily mitigated *if planned for,* but at facilities other than Kennedy Space Center, *no entity takes responsibility* for Launch Observers, and *there is no budget* for their accommodation.

This means that Launch Observers are handled as a general policing problem, staffed by small-town police or soldiers, neither of whom have much training or experience in crowd management. With no good policies or processes in place, and no financial responsibility for the accommodation of Launch Observers, the sole extent of the policing effort is to block them, move them on, and to in general harass them.

Just outside of Vandenberg Air Force Base in the City of Lompoc, I witnessed a significant environmental impact due to the unacceptable lack of preparation for the thousands of Launch Observers for the October 8, 2018 launch and landing of the Falcon 9 at the base. This was the first landing of a Falcon first stage there, and a dramatic just-past-sunset launch (see Section 4.1.5: *The Twilight Phenomenon*).

The base operates an inadequate facility called “Hawk’s Nest”, 10.5 miles from the launch pad, as their only official observation site. This site did not have a view of the launch or landing pad and was much too far away. The first 300 vehicles through the gate to Hawks Nest were admitted, and then the gates were closed, leaving many thousands of people to find an unofficial observing location.

I observed from Ocean Avenue in the City of Lompoc, at a site approximately 5 miles from the launch pad, an appropriate distance considering both safety and what could be observed. There is no nice way to say this: thousands of people were there for as long as 10 hours, with not one potty. The few City of Lompoc police present, restricting their activity to traffic-management, were quick to render their only response to complaints: “We didn’t invite you to come here”. Human waste was inappropriately deposited around the site. After the launch and landing, there was an hours-long traffic jam during which many people left their cars, in panic, to run into farmers fields in pursuit of the few potties left out for the harvesters. They trampled revenue crops and in general created a mess for the farmers.

This ugly and even dangerous situation could have been avoided with a score of potties placed in likely locations and appropriately serviced. It wasn't, because no appropriate policies and processes were in place, and nobody was told to foot the relatively small bill.

The SpaceX Boca Chica launch facility is in an ecologically sensitive area including South Padre Island, Texas, and its surrounding wetlands, Boca Chica State Park and Brazos Island State Park, the Las Palomas Wildlife Management Area; Playa Bagdad and the adjacent wetlands of Matamoros, Mexico. **There must be a plan to properly manage and accommodate tens of thousands of Launch Observers who are likely to come to such events as the first orbital flight attempt of the Starship / Super Heavy combination.** Similarly, management and accommodation of Launch Observers at sites like Vandenberg Air Force Base and the surrounding City of Lompoc must be improved.

2.5 The Launch Observer Is An Environmental Impact Mitigator, When Properly Managed

At the December 9, 2020 first 12.5 kilometer flight test of the SpaceX Starship, Emmett Osborne, a 19-year-old engineering student, was disquieted by the condition of Isla Blanka park, which was to be the - entirely unofficial - site of hundreds or thousands of observers for the Starship flight. It was a mess. With the help of internet influencers, Osborne organized a park cleanup before the launch, leaving the park in much better shape than before the Launch Observers arrived.

This event received news coverage at https://www.mysanantonio.com/sa-inc/article/SpaceX-Starship-chasers-converge-in-South-Texas-15813022.php

When properly managed, Launch Observers are an effective cleanup crew for the areas they visit.

2.6 The Launch Observer is a Safety and Security Issue To Be Managed

The SpaceX Boca Chica launch site, though private, will inevitably be the site of government missions, and is presently the home of much information restricted under the International Traffic in Arms Regulations and the Export Administration Regulations, and subject to industrial and national espionage. Like any launch or construction site, it's a dangerous place for the staff, and worse for uninvited interlopers.

Vandenberg Air Force Base ("VAFB") is no amusement park. There are nuclear-weapon-related facilities and much more of a National Security nature that is not disclosed. Rockets and satellites kept there carry hypergolic fuels that are intensely toxic. A brush fire at the huge base shut down our nation's polar launch capability for months.

Adjacent to VAFB is a Federal prison with its own security issues, and a reserve for the endangered Snowy Plover that can not tolerate more than a handful of entrances by untrained people during the breeding season. The beach and wetlands within the base and around it are sites for marine mammal haul-out and breeding, waterbird nesting, and are in general animal habitat.

In contrast, the Kennedy Space Center Visitor Center *is* an amusement park (as well as a historical and educational center) and manages tourists and launch viewing events within controlled areas at Kennedy Space Center and the adjacent Canaveral Space Force Base. Visitor management and operations are contracted to Delaware North Corporation as a for-profit activity.

The more interesting events at Kennedy Space Center and Canaveral easily overflow the base, with viewers for 10 miles in every direction *and* in vessels within protected wetlands and navigable waterways, making them a management problem for many different agencies.

3 Who Should Pay?

The failure of Vandenberg Air Force Base and the City of Lompoc stated in Section 2.4, above, is due to several factors:

- No FAA, nor environmental, proceeding placed responsibility for managing Launch Observers and their impact upon any entity.
- The successive Commanders of Vandenberg Air Force Base have obviously not considered the management and accommodation of Launch Observers to be within their mission, or there would be more provided for the observers than a single, inappropriately-distant and too-small viewing site. It is probable that Launch Observers are considered to be a low-priority issue within the public-relations budget for the base, and no more.
- By default, management fell to mere traffic control and exclusion from areas by the base and the City of Lompoc.

The first step in preventing future failures is to determine who shall pay for management and accommodation of Launch Observers.

Obviously, there *is* money: The Kennedy Space Center Visitor Center is operated at no government expense, and produces 300 Million dollars a year in income. Launch is an *extremely* lucrative business, with SpaceX, the least-expensive vendor per kilogram to various orbits; charging around 66

Million dollars for commercial launches of the *Falcon 9,* and approximately 120 Million dollars for Government launches mainly operated on behalf of the National Reconnaissance Organization by the Space Force.

Somewhere in there, we can find money to pay for potties.

Of course, accommodating the Launch Observer also means operation and management of appropriate viewing sites and the visitors to them. But the first priority must be reducing their environmental impact, and not subjecting them to unnecessary indignity.

Managing and accommodating Launch Observers and their environmental impact should be billed to the launch customer by the launch facility, and should be an item for consideration in each Environmental Impact Assessment concerning the launch facility. No Environmental Impact Statement for a launch facility should be considered complete without an appropriate statement of the expected attendance by Launch Observers for various sorts of launch or recovery, the accommodation that will be provided for them, and how their environmental impact is to be be managed.

Accommodation of Launch Observers is potentially a profitable opportunity, as it is today for Delaware North Corporation at the Kennedy Space Center Visitor Center. I gladly paid $200 to be hosted at the Saturn V Center during the first Falcon Heavy launch and double-landing, and tickets for that venue quickly sold out. Delaware North also offered less expensive viewing venues which all sold out, and viewing overflowed onto roads, shorelines, and waterways for 10 miles in every direction and hotel rooms were full all up and down the Florida coast. Launch Observers provided significant income to the area.

It is an unfortunate fact that many military families live at the edge of poverty. This is coupled with social ills and suicide among them. Perhaps paid viewing opportunities at military launch sites like Vandenberg Air Force Base, Canaveral Space Force Station, and Patrick Air Force Base can be operated to benefit military families in need.

4 Process Framework

This section is a suggested process framework for launch facilities, which would help them to satisfy future Environmental Impact Assessments that include concerns regarding Launch Observers.

4.1 Identify The Interest and Potential Attendance

For each launch, it is necessary to identify the public interest in the mission and the potential attendance resulting from that interest. These factors should be considered:

4.1.1 Historical Attendance Data

Attendance data should be collected for each launch and other space operation, carefully noting the type of mission (as explained below), since that is the main factor influencing overall interest in the mission. Keeping this information at hand will help to forecast future attendance. Potential sources of this information are:

- Photos showing attendance at viewing sites. There are software applications and published methodologies for calculating attendance from photographic data.
- Ticket sales at paid viewing sites, local park ticket sales and admissions.
- Lodging occupancy reports generated from the payment of lodging taxes; from hotels, motels; Air B&B and VRBO for home-sharing; heavily-used travel agencies such as Travelocity, Orbitz, Hotels.com; the local Chamber of Commerce and Tourism Bureau.
- Flight occupancy reports from the airports, air carriers, and ticketing agencies.
- Rental car usage reports from the various car rental companies, ticketing agencies, and from taxes paid on car rentals.
- Parking lot or structure occupancy data.
- Traffic sensor data from the local agencies operating highways and roads, and from commercial traffic data reporting companies such as Idealspot.
- Cell phone location data sold by Google, Apple, etc.

4.1.2 Crewed Missions

The presence of a crew on the space vehicle will always increase interest, due to the perception of astronauts as heroes who are risking their lives to advance science and the future prospects of the human race.

4.1.3 First-Time Missions

Firsts generate interest. The first crewed flight on the SpaceX Dragon, the first launch and landing of Falcon Heavy, the first landing of a Falcon 9 at Vandenberg Air Force Base, these all generated very large crowds. Future heavily-attended events will include the first orbital flight and stage recoveries of the SpaceX Starship / Super Heavy combination, the first crewed flight and stage returns of that combination, the launches of various crewed missions

4.1.4 Space Company Identity

Today, SpaceX generates interest far exceeding other space companies. Their daring technical achievements, appearing to outpace NASA and every other aerospace company at a fraction of the cost; have captured the hearts of many, providing hope of an interplanetary future for humanity when good news was in short supply. There is also the interest in Elon Musk as an innovator, and as the most wealthy person in the world. Blue Origin could join SpaceX in generating this sort of interest, if their New Glenn vehicle succeeds and they are able to scale up flights. As new technical achievements are made, other companies may take a turn as the momentary darlings of space enthusiasts.

4.1.5 The Twilight Phenomenon

An article explaining the Twilight Phenomenon is on Wikipedia at https://en.wikipedia.org/wiki/Twilight_phenomenon. Twilight launches can exceed the beauty of any firework show. Thus, expect greater attendance at launches occurring just before dawn or after sunset.

4.1.6 Weather

Good weather and, especially, clear sky will increase attendance.

The presence of fog will cause Launch Observers to relocate to fog-free vantages. These will often be at higher altitudes or outside of prevailing breezes that bring fog ashore.

4.1.7 Other Ambient Influences

The amount of media coverage of the mission has a very strong influence on attendance. Launch Observers are probably more influenced by internet sources today than television and radio.

4.1.8 Offshore Launch and Recovery

The distance of offshore space operations from land will encourage Launch Observers to embark upon sea observation voyages, which will sail to viewing positions just outside of the range safety zone. These voyages must then be managed by the Coast Guard.

4.2 Identify The Viewing Areas

Once the potential attendance is estimated, the areas that will be used by Launch Observers should be identified, and the number of observers at each site must be estimated.

It is best to provide sufficient officially-sanctioned observing areas to accommodate all Launch Observers, but observers are likely to eschew inappropriate locations like Hawk's Nest at VAFB. An appropriate observing site should be as close as possible to the launch or recovery area while outside of the range safety zone, and should have an unobstructed line of sight to the launch or recovery area if that is possible. The better the view, the easier it will be to attract Launch Observers to your official location.

4.3 Provide Mitigation of Environmental Impact At The Viewing Areas

The first concern will be providing sufficient porta-potties at the viewing areas, to prevent the environmental impact of human waste. This will also reduce the impact of those who would otherwise be motivated to trample environmentally fragile areas in order to find a private place to relieve themselves. Secondarily, impacts such as parking and litter should be managed.

Communication channels to the Launch Observers should be established. These will in general take the form of press releases or internet media sites which regularly carry information about opportunities for launch or recovery observation. Short-range AM or FM radio broadcasts are sometimes used to inform crowds as they approach a facility. Where tickets are issued or admission fees are collected, a paper handout with instructions is appropriate.

Attendees should always be asked to bring a garbage bag, to pack out their own trash and to remove other trash that is evident, and to always take the garbage bag with them when they leave. Launch Observers *will* leave an area cleaner than when they arrived, if organized properly.

Launch Observers should be informed of the potential for environmental damage and how they can avoid it, for example by keeping to established trails, or by staying away from bird nesting areas.

4.4 Receive and Report Feedback

Launch and recovery sites that bear a responsibility to mitigate environmental concerns associated with Launch Observers should operate a means of receiving feedback regarding that impact. Such feedback might include reports of the intrusion of Launch Observers into ecologically sensitive land, the failure of facilities provided for Launch Observers (perhaps within sufficient time to resolve them) and ideas and concerns of locals and the observers. Feedback should be acted upon, and should be a topic of all subsequent environmental assessments and re-evaluations.

5 Concerns Regarding Offshore Launch Observation

5.1 SpaceX Offshore Platforms

SpaceX has purchased two offshore oil platforms to be repurposed for offshore launch and recovery of the Starship / Super Heavy combination. Operations using these platforms are likely to be sited about 20 miles from populated land, due to noise and range safety concerns. I surmise that one or both platforms might eventually be sited in the Gulf of Mexico, offshore of Brownsville, Texas, as far South as practical within the 24-mile Contiguous Zone of the United States.

Such platforms would be close to Starship / Super Heavy manufacturing in Boca Chica and could be serviced from the Brownsville Ship Harbor. There will be an environmental impact from operation of these platforms and transport to and from them. The platforms may eventually offload launch and recovery of rockets from the Boca Chica site, reducing chemical and noise impact at that site, but perhaps requiring channelization of the South Bay and Boca Chica Bay to the Brownsville Ship Channel for SpaceX barge operations.

Once in operation, sea voyages for observation of launches from the platforms will be an issue for management by the Coast Guard.

5.2 DM-1 Toxic Incident

There was an intrusion of unauthorized boaters into the range safety zone of the SpaceX DM-1 recovery. This occurred offshore of Pensacola, Florida on August 3, 2020. Boaters were exposed, at an apparently sub-clinical level, to highly toxic hypergolic or pyrophoric fuel. This fuel was still evident in the atmosphere around the Dragon vehicle for another half hour, including after it was hoisted onto its recovery vessel. To protect themselves from the chemicals, the recovery crew were required to withdraw from around the Dragon, except for persons equipped with the proper personal protective equipment who continued to monitor the chemical presence. The astronauts were required to sequester themselves within the sealed Dragon vehicle and to make use of its independent air supply until the chemicals dissipated.

This exposure of unauthorized persons to toxic chemicals was a result of an inaccurate estimation of the interest in the mission and the resources necessary to establish an interdiction zone, probably by the Coast Guard.

The Coast Guard also appears to have inadequately informed its officers of their jurisdiction to carry out an interdiction effort within the United States 24-mile Contiguous Zone or international waters, even though the boats involved bore US registry and were thus subject to US law.

The intruding boaters were, of course, at fault. The Coast Guard appeared to bear most of the blame, although certainly NASA and SpaceX were also involved.

I suggest specific rules for Launch Observation voyages, most of which overlap rules already in place for larger vessels:

- The vessels must be documented with the National Vessel Documentation Center.
- The vessels must carry AIS Class A transceivers, and must configure them to continuously beacon their documented vessel name and port of call, and their location, and to respond to digital selective calling ("DSC"). The crew must respond to DSC hails appropriately.
- The vessels must carry a second radio transceiver which is set to continuously monitor marine channel 16. The crew must respond to channel 16 hails appropriately.
- The vessels must, before departure, download from an official source on the internet a map of the range safety zone (this would be a Local Notice to Mariners today), and use it in conjunction with a GPS moving map during the entire voyage to ensure that they do not inadvertently enter the range safety zone.
- There should be a second, larger range safety zone which would exclude all vessels that are not equipped to comply with the above rules. A vessel that enters this zone without beaconing the proper AIS information would be turned away.

6 Requirements for Environmental Assessments, Environmental Impact Statements, and Re-Evaluations

In the above, I have established the right of Launch Observers to be present under the applicable laws and the Constitution. I have laid out a process for managing their accommodation and mitigating their environmental impact.

Every Environmental Impact Statement of a rocket launch or recovery facility should include a plan to accommodate Launch Observers and to mitigate their environmental impact, in a similar manner to the process framework I have laid out in Section 4 of this comment. Thus, these issues must be examined as part of Environmental Assessments. The facility should be required to report upon their continuing implementation of accommodation and mitigation of Launch Observers as part of each successive re-evaluation of the EIS.

I suggest that launch and recovery facilities use Section 4 of this comment as a template in creating their plan.

7 Service, Standing and Filing

There appears to be no requirement for service in this informal public scoping. But if requested, I will acknowledge service of replies via email to [redacted]

This comment is timely filed, having been served via email to the address indicated in FAA's solicitation during the period that this issue was open for comment.

While FAA appears to use the Regulations.gov web site for NPRM comments, this scoping is confusingly being carried out using an email address at ICF, a for-profit consultancy that acts like an NGO. A more formal framework for submission of comments which would facilitate public viewing of comments, and replies to comments by the public, would be appreciated. I like the example of FCC's Electronic Comment Filing System, which provides a view of all proceedings, comments, and replies for the past 30 years.

Since the address given for comments is at ICF rather than FAA itself, I have also served this comment directly via email to relevant parties at FAA and commercial space vendors.

As a taxpayer, citizen, interested and impacted party: I claim standing under, but not limited to, the following laws:

- Federal Aviation Administration Act of 1958
- National Environmental Protection Act of 1969
- National Environmental Improvement Act of 1970

18093

From: Molly Smith <[redacted]
Sent: Monday, November 1, 2021 1:26 PM
To: SpaceXBocaChica
Subject: Save RGV comments on SpaceX Draft PEA FAA
Attachments: Save RGV SpaceX FAA comments.pdf

Save RGV prepared comments for the Space X Draft PEA. This 25 page document is attached to this email. It has also been sent through the FAA site ([redacted] in the message box.

Thank you,
Molly Smith, Board Member Save RGV

Save RGV
Bill Berg, Agent
[redacted]

November 1, 2021

Ms. Stacy Zee, SpaceX PEA
c/o ICF
9300 Lee Highway
Fairfax, VA 22031
Email: SpaceXBocaChica@icf.com

Dear Ms. Zee,

Save RGV hereby submits the following comments regarding the Draft Programmatic Environmental Assessment for the Boca Chica Texas SpaceX Starship/Super Heavy Launch Vehicle Program (Draft PEA.) Incorporated in the State of Texas, Save RGV is a non-profit corporation organized for educational and environmental advocacy to promote environmental justice and sustainability primarily in the Rio Grande Valley. Members of Save RGV primarily reside in Cameron County, Texas. We request that all comments received during the draft PEA comment period be published and included as an Appendix to the Final PEA.

NEED FOR AN EIS AND ACCOUNTING FOR ALL INFRASTRUCTURE, OPERATIONS, AND CUMULATIVE IMPACT (NOT JUST AN EA)

The FAA's NEPA procedures implementing the National Environmental Policy Act define when a Supplemental Environmental Impact Statement (EIS) is needed, or not. This was cited in the FAA's 2014 SpaceX EIS. [FAA Order 1050.1F, Section 9-2] "A Supplemental EIS is not needed if:

1. “The proposed Action conforms to plans or projects for which a prior EIS has been filed and there are no substantial changes in the Proposed Action that are relevant to environmental concerns.”

SpaceX has in fact never launched a Falcon 9 or Falcon Heavy rocket from Boca Chica and now has no plans to do so. It has instead turned its site and activities into something unrecognizable in the original 2014 EIS and Record of Decision (ROD); a large and expanding complex to manufacture, fabricate, assemble and test the Starship and Super Heavy booster rocket in addition to producing fuel and power for the Starship and Super Heavy operations (e.g. power plant, gas extraction, gas delivery, gas treatment, gas liquefaction). The Starship and Super Heavy booster together will be larger than the approved Falcon 9 and Falcon Heavy by an order of magnitude, standing 39 stories tall, with 16 million lbs. of propellants, nearly 50% more than NASA’s Saturn V rocket used to launch moon-landing missions. Round-the-clock experimental testing has already increased significantly. SpaceX has enlarged its footprint (and they plan to expand further) by increasing its acreage, its number of buildings, its number of employees and contractors, its hours of beach and refuge closure, and its number of static test firings and pressure tests. All these events significantly increase environmental impacts and none of them were analyzed in the original EIS.

Additionally, in the short time since SpaceX has conducted operations at the Boca Chica site, there have been multiple explosions that disrupted resident’s lives, scattered fuel laden rocket debris and caused wildfires that have consumed more than 100 acres of sensitive native habitat on national wildlife refuge land. These serious impacts illustrate how critical it is for the FAA to initiate a new EIS process, and for federal regulators to exercise meaningful, legally required oversight.

2. “Data and analysis contained in the previous EIS are still substantially valid and there are no significant new circumstances or information relevant to environmental concerns and bearings on the Proposed Action or its impacts.”

Most of the 2014 data and analysis is now not only invalid but wrong and misleading and significantly out of date by over seven years. The construction, testing and firing of the massive Starship and Super Heavy Booster will have much greater impacts than the rockets approved in the 2014 EIS. Because of the very substantial and significant changes to the actions taking place at Boca Chica, virtually all the impact analysis in the 2014 EIS is now out of date and inaccurate. Specifically, new analysis needs to be prepared for the significant effects that are occurring, such as noise, light, frequency of events, fires and explosions, larger areas of direct and indirect impacts (most likely to include the towns of South Padre Island, Port Isabel, Long Island Village and the permitted but not yet built liquefied natural gas (LNG) export terminals on the Brownsville Ship Channel namely Texas LNG and Rio Grande LNG, and the proposed Jupiter MLP crude upgrader facility and off-shore VLCC loading terminals, the storage of much more highly volatile rocket propellant that is more explosive, has greater impacts to wildlife, wetlands, vegetation and endangered and threatened species, and increased denial of public access to marine recreation and Boca Chica beach.

Under economic impacts another issue is missing entirely. The latest license for the Starship tests requires \$198 million in third party liability, and federal indemnification for losses beyond that. This is higher than is required for any Falcon 9 or Falcon Heavy launch from Vandenberg AFB or Kennedy/Cape Canaveral, suggesting a far larger risk zone than was included in the FEIS or ROD. This probably doesn't include liability for the potential \$20 billion LNG terminals and LNG tankers that will likely be in the expanded risk zone, nor the proposed Centurion condensate upgrader facility with offshore export loading terminals. This list is by no means comprehensive.

3. "All pertinent conditions and requirements of the prior approval have, or will be, met in the current actions."

The FAA has done an inadequate job in ensuring SpaceX compliance with many of the conditions in its 2014 Record of Decision. One example is the closure of State Highway 4 and Boca Chica beach, which was to be limited to no more than 180 hours per year. Within the first six months of 2021, closures exceeded 225 hours, often with confusing and inadequate prior notifications and last-minute changes, cancellations and revocations. Nevertheless, SpaceX now wants to nearly triple its beach closure "quota" with no opportunity for public discussion and comment. To increasingly deny access to eight miles of public beach, state parkland and national wildlife refuge is a significant human impact and needs to be addressed, particularly as much of the experimental engine and rocket testing could be done at a safer and less public testing location elsewhere. Given the wholly different purpose of the project, FAA, as part of the Supplemental EIS, needs to revisit the alternatives evaluation.

TIERED REVIEWS

All elements to SpaceX proposals (identified in 2-1 p. 9) are, according to SpaceX's purpose and need, essential to SpaceX's Starship/Super Heavy operations. However, in the PEA Section 2.1: Proposed Federal Action, it states, *"Detailed information about some of the launch-related infrastructure (e.g., exact location and design) is not currently available."* Therefore, the draft PEA makes assumptions about these unknowns. It also states, "*The FAA may conduct environmental reviews of additional proposed launch and reentry sites if SpaceX further develops proposals. Such reviews may be tiered off this PEA as appropriate."* The practice of FAA "tier reviews" that allows further SpaceX expansion is a loophole that avoids additional environmental review, project scrutiny, and public comment. This loophole of tiered analysis to avoid environmental reviews, has been used since 2014 and it violates the standards of NEPA. It is not a sustainable method of accountability. According to FAA's order 1050.1F, "NEPA compliance and other environmental responsibilities are integral components of that mission. The FAA is responsible for complying with the procedures and policies of NEPA and other environmental laws, regulations, and orders applicable to FAA actions." (p. 1-2).[1]

The FAA should not "tier" reviews simply because information is not currently available from SpaceX. Due to the fact that elements like the power plant, gas treatment, and liquefaction are critical to the development and operations of the Starship and Super Heavy, all elements must be analyzed collectively as opposed to a tiered analysis. Launch/landing locations also need to be determined conclusively. An EIS is needed to determine, with specificity, all of Spacex's plans and to accurately account for the cumulative impacts of all of SpaceX's proposals of the Starship/Super Heavy program in order to avoid, minimize, and mitigate impacts.

[1] **https://www.faa.gov/documentLibrary/media/Order/FAA_Order_1050_1F.pdf**

INCREASED SCOPE & OPERATIONS

LAUNCH SITES

SpaceX has indicated it is considering additional launch (which includes landing for suborbital missions) and reentry locations for the Starship/Super Heavy program beyond the Boca Chica Launch Site. These launch and reentry locations are in addition to the VLA and should also be considered to be alternatives to launching/landing at the VLA. Thus, the platforms and launch locations should be fully analyzed and their impacts assessed prior to licensing. SpaceX has not planned or provided details of additional/alternative launch/reentry sites. Consequently, SpaceX is negligent in its responsibilities to avoid, minimize, and mitigate impacts of the Starship/Super Heavy program, which violates NEPA standards.

LAUNCH VEHICLE

PEA Section 2.1.2: Launch Vehicle. This overview appears to be lacking and inadequate per the FAA licensing code Title 14, Chapter III, Subchapter 3, Sections 450.43 Payload Review and Determination; and 450.45. Safety Review and Approval.

The Falcon rockets use the proven Merlin engine, which produces 0.63 MN (146,000 lb_f) of thrust. The Starship and Super Heavy use the unproven Raptor engine, which can produce approximately 2.3 MN (520,000 lb_f) of thrust. Thrust on lift-off for the Falcon Heavy is approximately 17.5 MN. Super Heavy, with all 37 engines, will have a maximum lift-off thrust of 74 meganewtons (MN).

Comparison between Falcon rockets and Starship rockets

	Falcon9	Falcon Heavy	Starship	Super Heavy
Weight (lbs)	1,100,000	3,400,000		
Thrust at Lift-off (KN)	5,844 KN	17,532 KN	12,000 KN	74,000 KN/
Thrust at Lift-off (Klbf)	1,314 Klbf	3,942 Klbf	2,700 Klbf	16,600 Klbf

To convert between metric units of thrust, kilonewtons, KN, and non metric units, kilopounds force, Klbf, an online force unit converter was used.

The Starship Super Heavy has over four times the thrust of the Falcon Heavy.

The Falcon rockets use RP-1 fuel (similar to jet fuel) and liquid oxygen. The Starship and Super Heavy Rockets use liquid methane and liquid oxygen.

These are very major changes from the 2014 EIS which was for 12 launches per year of the tested, approved, and reliable Falcon rocket (that was actually never even launched at Boca Chica per the 2014 EIS) to an experimental testing, launch and landing program for unapproved rockets. The Super Heavy, with over four times the launch thrust of the largest Falcon, will include expected explosions, twenty Starship launches per year, and fuel and oxidizer tank testing day and night with anticipated explosions once a month. Up to 300 hours of State Highway 4 road closures are anticipated to be required for debris removal from Boca Chica beach and neighboring wildlife refuges due to expected test failures and explosions. Such major changes are not a few tweaks to a running program that can be "tiered" on the EIS, but rather are entirely new programs that require an EIS.

These major changes and many others described in the PEA and discussed below demand the scrutiny of an EIS to make sure that the fragile ecosystems that support a massive variety of wildlife, some threatened and endangered, can thrive within the radically and more threatened habitat caused by their neighbor SpaceX.

PEA Section 1.1 Operational Activities, p.2-2 This section states, "In 2019 SpaceX developed the Starship technology as part of the reusable suborbital launch vehicle classification analyzed in the 2014 EIS." However, the 2014 EIS only included a possible permit or license for Boca Chica suborbital launch vehicles smaller than Falcon 9. The Super Heavy violates that condition in the 2014 EIS.

A vehicle smaller than, or equal to, the Falcon 9 first stage would carry less fuel and produce equal or less noise and light at launch than the Falcon 9. Such a vehicle would create equal or less of a disturbance to wildlife, fauna and flora, than the Falcon 9 and therefore meet the environmental requisites of the 2014 EIS. It was designed and built for the Starship prototype, and tested outside of the requirements of the original EIS. Any significant environmental impact that will be made by a new addition to what was approved in the 2014 EIS requires a new EIS.

TANK TESTS

PEA Section 2.1.3.1: Tank Tests. *"SpaceX is proposing to conduct approximately 10 tank tests a month. SpaceX estimates a 10 percent rate of anomalies during tank testing. An anomaly would result in an explosion and the spread of debris."* If SpaceX is expecting about 10 percent of tests will result in explosions, they are not anomalies. The definition of anomaly is "unexpected event." Since one explosion is expected a month, will the noise, light, and debris from the explosion all be contained within the property line of SpaceX? If not, there is no reference in the section about discussions and sign-off by the interested parties who represent wildlife welfare and habitats. This may call for an EIS to bring the parties together. Furthermore, given the apparent lack of understanding of the outcome of the tests, it would be prudent for an EIS to be written. Additionally, this indicates additional closures not specified or calculated in the Draft closure proposal.

Section 2.1.3.1 inadequately factors in the cumulative noise, lights, debris, closures, and air quality impacts of the project.

DESALINATION PLANT

PEA Section 2.1.4.5 p. 31 Desalination Plant. A desalination plant will pump groundwater and inject the waste brine deep underground. The entire plan description for operating the plant is fewer than 200 words, even though it involves the "installation" of two 2950 deep reinjection wells. SpaceX indicates that it will extract water from two new wells and extract water at a rate of 40 gallons per minute (gpm) and inject brine into an injection well at a rate of 15 gpm. It is not indicated if water extraction is the amount for one or both wells. SpaceX also does not indicate how often these operations will occur, nor do they disclose the use of chemicals such as copper and chlorine that are often used in the desalination process. An EIS is needed to assess impacts of these operations including, but not limited to air emissions, water quality, aquifer impacts, sound, and light, in addition to avoiding, minimizing, and mitigating impacts.

NATURAL GAS PLANT

PEA Section 2.1.4.10 p32 The natural gas "pretreatment" plant for purifying the natural gas that will be used for rocket fuel and other plant needs is described in about 100 words. The power plant and liquefier are likewise very briefly described. SpaceX has not provided design plans, source of natural gas, source of gas delivery, pipeline locations (if using pipelines), or the amount of gas to be processed annually. With regard to pipelines to deliver gas, as reported by

Tech Crunch, SpaceX inquired about reusing a defunct natural gas pipeline running through the Lower Rio Grande Valley National Wildlife Refuge. However, that pipeline was permanently abandoned in 2016, according to the official and state records. The official told TechCrunch that the defunct pipeline now houses fiber optic cable for a University of Texas Rio Grande Valley internet connection.[2]

Details (e.g. location, emissions, design plans, visual impacts, etc.) of purification and liquefaction are not mentioned including, but not limited to, thermal oxidizers, heaters, flares, pipelines, and storage tanks. These elements will have impacts on environmental impact categories identified in the PEA, particularly regarding land use compatibility, air emissions, sound, visual effects, cultural resources, and biological resources. Lacking specificity, the emission total in Table 3-2 (p. 44) is not substantiated nor can it be verified. Without full disclosure of these proposals in an EIS, the impacts cannot be identified and assessed. Additionally, alternatives have not been evaluated.

POWER PLANT

PEA Section 2.1.4.7 Power Plant: The 250-megawatt power plant that will generate power for activities at all SpaceX facilities, including the VLA, would normally qualify as a major new source of air pollution under the Clean Air Act. Therefore, the impacts of this plant need to be fully disclosed, analyzed, and mitigated to properly comply with NEPA. Alternatives to this proposal are not identified. If it is for electricity, even hundreds of megawatts, the electricity can be provided by SpaceX's electricity provider using the new three phase electric line to be built for SpaceX. Additionally, the source of the natural gas to feed the natural gas turbines for the power plant is not identified. Sourcing of gas is an impact that is potentially significant, especially if it requires pipelines outside the region of influence or requires a route through environmentally protected areas.

ORBITAL LAUNCHES

PEA Section 2.1.3.4 Orbital Launches: There are several undetermined scenarios proposed by SpaceX, in regard to the exhaust plume. This is a new level of rocket energy discharge and needs a full EIS. SpaceX admits in Appendix G-Exhaust Plume Calculations (pp. 9-10) of the PEA that *"Due to the complexity of how the 31 engines are integrated into the base of the Super*

[2] https://techcrunch.com/2021/10/08/the-mystery-of-elon-musks-missing-gas/

Heavy vehicle, there is not a simplified method to directly predict the air entrainment and exhaust burnout chemistry for the installed engines. An extensive computational fluid dynamics (CFD) analysis would likely be needed to fully address the entrainment process." This is an admitted unknown regarding a fundamental aspect of the entire program. An EIS would provide more confidence in the projections.

PEA Section 2.1.3.4: Orbital Launches. The Draft PEA references SpaceX's launch manifest is still being developed at this time. To avoid, minimize, and mitigate impacts, a draft schedule is needed to provide the public, federal, state, and local agencies to identify any conflicts in wildlife biological cycles (e.g. migrations, breeding) to ensure that impacts to wildlife are minimized during critical life cycle stages.

PEA Section 2.1.3.4: Orbital Launches. SpaceX states, during unmanned orbital launches that require expending Super Heavy or Starship, that they would not attempt recovery unless they receive reports of large debris. Because SpaceX is claiming their project is needed to achieve National Space Policy goals, FAA and cooperating agencies should ensure that SpaceX be held accountable to National Space Policy goals, one of which is to *"create a safe, stable, secure, and sustainable environment for space activities, in collaboration with industry and international partners, through the development and promotion of responsible behaviors".*[3] FAA and NOAA must hold SpaceX accountable with regards to debris from intentional and unintentional consequences.

GROUND CLOSURES

PEA Section 2.1.3.5.1 Ground Closures: For purposes of commenting on the draft PEA, we believe the Texas General Land Office (GLO) recommendation, dated January 22, 2021, during the scoping period for the EA, best describes how closure hours should be calculated. *"An option is to count closure hours as the time State Highway 4 and Boca Chica Beach are publicly scheduled to be closed, unless notice of different hours or a cancellation is given at least 48 hours before the closure is scheduled to begin."* The ongoing inconsistencies in process, notification, and exceedance of closure hours impede on operations of federal and state land managers, and other stakeholders, who support federal and state agencies in land and wildlife management.

[3] National Space Policy of the United States of America. December 9, 2020, p5.

SODAR

Section 2.1.3: Operations. This mentions SODAR (sonic detection and ranging), which operates 24/7 and “sends out a short sonic pulse every 15 minutes that can reach 92 decibels (dB) at the source…” This was omitted from the noise impacts section and needs to be addressed as it relates to cumulative impacts on beachgoers, and wildlife. This, along with the continuous lighting, increases the possibility or probability of this area being unsuitable to humans for recreation and unsuitable and discouraging, (if not fatal) to wildlife for their survival.

SAFETY, HEALTH & CLIMATE

NEED OF A LAUNCH FAILURE ANALYSIS

The draft PEA does not address the significant concern voiced in the January 22, 2021 FAA public scoping comments regarding the need for a *launch failure analysis* (PEA p. 6) Commenters pointed out the proximity of two LNG facilities (Rio Grande LNG and Texas LNG) at the Port of Brownsville that have been in process prior to SpaceX’s Starship/Super Heavy activity. The Department of Interior commented on the 2017 Written Re-Evaluation stating, “*the construction of the Stargate Building and the three proposed Liquefied Natural Gas Terminals at the Port of Brownsville that have filed for a FERC permit constitutes significant new circumstances and/or information that is relevant to evaluating the cumulative effects of the expanded SpaceX project.”* The response in the Written Re-Evaluation stated, *“The FAA disagrees with the NPS. The Stargate building and Port of Brownsville LNG facility were analyzed in the cumulative impacts chapter of the 2014 EIS. The additional infrastructure SpaceX is proposing to construct in largely the same footprint that was analyzed in the EIS does not substantially change the cumulative impacts analysis in the EIS.”* This was an inaccurate statement. An analysis on the impact to Rio Grande LNG and Texas LNG still remains to be analyzed by the FAA and/or the Federal Energy Regulatory Commission. The 2014 EIS referenced only one LNG project, Gulf Coast LNG Export LLC.

Additionally, a cumulative analysis and launch failure analysis must also include Centurion’s/Jupiter MLP’s proposed crude upgrading, processing, and export facility that includes marine loading berths 6 miles off shore for the loading of barges and VLCC ships (65,000dwt Panamax sized) at 30,000 barrels per hour. The FAA and SpaceX, in the interest of public safety, must account for worst case scenarios when Starship/Super Heavy explodes during launches and landings. According to the PEA, such “anomalies” are expected (and in fact have already occurred). Without a launch failure analysis, the Port of Brownsville, Port Isabel, South Padre Island, and Long Island Village, as well as the immediately adjacent wildlife refuges and state parks, cannot adequately plan for emergencies. A launch failure analysis is also needed to determine the impacts to the surrounding environment and wildlife.

The Anomaly Response Plan that addresses road closures, based on the prediction of one anomaly per month, assumes that 300 hours/year (PEA p. 9), or 25 hours per anomaly, will be sufficient to clean up the area. Considering the amount of time that it took to clear the March 30, 2021, explosion that involved three Raptor engines, this is likely an underestimation of the time that roads and the beach will have to be closed for anomalies. This is in violation of the Code of Federal Regulations 450.110 Physical Containment, and 450.133 Flight Hazard Area Analysis. Additionally, the definition of the word anomaly is “something that deviates from what is standard, normal, or expected.” It is therefore misleading to use the word anomaly to describe potential launch failures, operational failures or explosions that are expected during testing.

AIR QUALITY/CLIMATE

The Draft PEA does not include the cumulative amount of Green House Gasses (GHG) emissions from auxiliary infrastructure and operations. It should include the total emissions from all proposed launches, landings, testing, as well as emissions from construction, methane venting, the natural gas pretreatment system, the power plant, the desalination plant, vehicular traffic, and road maintenance. These contributing emissions are significant. Consequently, the PEA’s greenhouse gas/global warming analysis is inadequate. If one day of the 2018 US total GHG emissions is compared to (their estimate of) the annual SpaceX operations, the SpaceX annual is 0.34%. (PEA Table 3-3. Estimated Carbon Dioxide Equivalent Emissions Comparison).

It should be noted that Port Isabel Junior High is just over six miles away (PEA p. 137). Children’s proximity to the SpaceX complex is glossed over in Section 3.15.3.3. A full EIS would give a more complete analysis of air quality issues for children and others with compromised health issues as well as the cumulative effects of pollutants that tend to be present in areas with lower economic opportunities.

ENVIRONMENTAL JUSTICE & SOCIOECONOMICS

BEACH ACCESS

PEA Section 3.15.4.2 Closing Boca Chica Beach is an environmental justice issue. With a population of 186,738, the 2020 census reports Brownsville residents are 95.2% Hispanic and other minorities. The median income in 2019 dollars was $38,588, with a poverty rate of 29.3%. For many Hispanic and low-income residents of Brownsville, Boca Chica is “their” beach, as it is closer than the beaches on South Padre Island. It is easily accessible, except for the closure hours, and especially in the summer months and during holiday weekends, when traffic to/from South Padre Island routinely backs-up on State Hwy 48 and State Hwy 100. And most importantly to a low-income community, entrance to Boca Chica Beach is free compared to $14 (March-Sept., off season $12) per daily visit to Cameron County Beach Access 5, which allows drive-on visits and best replicates the natural beach experience at Boca Chica. Cameron County Beach Access 6 is free off-season, but requires use of a 4x4 vehicle which is not an available or affordable option for many. The other free SPI Beach Access points located behind the beachfront hotels, are not drive-on beaches and are much more challenging (in-season parking availability near access points is very, very limited) for day visitors. The approximate driving time from Brownsville to Beach Access 5 is approximately 50 minutes during the off-season and at times when there are no traffic back-ups. When traffic backs-up, driving time for the trip could extend to approximately 2.5-3 hours. The conclusion that there are other cost-free public beach access locations within the vicinity of local communities does not accurately and appropriately consider the actual logistics involved in getting to the other beach locations, especially for a low-income minority community. The PEA lists 500 closure hours for launches and tests and an additional 300 closure hours for the clean up of anomalies (predicted to be one per month). Using this plan, the beach will be closed a considerable number of partial days, making the number of days that this Brownsville minority group of residents will be denied beach access very high. Therefore, the proposed action, which includes the closing of State Hwy 4 and Boca Chica Beach, would result in disproportionately high and adverse impacts to lower income indigenous populations who for generations have relied on access to the waters for economic and familial subsistence.

IMPACT ON INFRASTRUCTURE

The Draft PEA (PEA Section 3.5, p. 52) authors admit there is structural damage potential due to orbital launch events and predicts the percent of the people from South Padre Island, Laguna Vista, and Tamaulipas, Mexico who will likely file a damage complaint: *KBR assessed the potential for structural damage due to orbital launch events using the potential for structural damage claims. An applicable study of structural damage claims from rocket static firing tests indicates that, based on Maximum Unweighted Sound Level (Lmax), approximately one damage claim will result per 100 households exposed at 120 dB and one damage claim per 1,000 households exposed at 111 dB (Guest and Slone 1972)*. SpaceX does not, however, address possible damage to current and proposed infrastructure at the Port of Brownsville and the Brownsville Channel as is required in Code of Federal Regulations § 450.110 Physical containment. Sonic booms, in particular from Super Heavy landings will cause structural damage: *Predicted overpressure levels for a Super Heavy landing range from 2.5 psf to 15 psf. Brazos Island State Park, Boca Chica Bay, Boca Chica State Park, portions of the NWR, Boca Chica Village, and Tamaulipas, Mexico would experience levels up to 15 psf. Boca Chica Beach and the southern tip of South Padre Island are within the 6.0 psf contour. South Padre Island, including residences, Port Isabel, and the Port of Brownsville ship channel are included in the 4.0 psf contour* (PEA p. 57). These psf values cause “regular failures” of glass and plaster at the least, and damage to sinks, roofs, walls and water pipes at the higher levels (PEA pp. 58-9). Significantly, the single bridge from Port Isabel to South Padre Island is not mentioned in the noise damage (long and short term) assessment in Appendix B.

LOCATION

Section 2.1.1: Location only mentions distances from the Launch and Loading Control Center (LLCC) and the Vertical Launch Area (VLA) to Mexico, which are only 1.3 miles and 2.2 miles respectively. Full analysis of distances to closest points of populated land, (e.g. Matamoros, City of South Padre, Port Isabel, Long Island Village, Laguna Vista, Port of Brownsville), as well as South Bay Coastal Preserve is necessary information. Other necessary information is the distance to the causeway-- most importantly the highest point of the causeway, as well as data on cumulative vibrational impacts over time from launch, reentry and/or sonic booms and anomalies (explosions). This data should include projected model trajectories of debris to any portion of the causeway, drawbridges, and the ship channel.

ECONOMICS

PEA Section 1.3: One of the purposes of this project is mentioned as benefiting the public interest, yet this entire section only cites U.S. Government goals of space travel and "commercial customers." As this is taxpayer funded, the vague term *commercial customers* needs clarification. It further states that the goal is to encourage private sector activities through the cost effective delivery of cargo to the moon and Mars. A discussion of the scope of the private sector activities, identification of types of commercial customers, and project cost effectiveness is necessary.

PEA Section 1.4: Public Involvement. (PEA p. 6) There were twice as many negative concerns (than positive) that covered issues of environmental justice, social justice, public safety, constitutional rights, and cultural impacts. The positive comments were potential for jobs and economic gain, innovation in space technology and ideal southerly location. Employment data that shows fully what is or has been the economic and job growth to date, and more importantly, from the local labor force is needed, in addition to realistic projections for economic benefit to the area when costs are factored in.

Airport closures: According to the document (PEA pp. 23-4), there is the possibility of airport closures. Is Brownsville ready to relinquish control of its flight schedule to an outside company? Will airlines want to relocate here (to our newly expanded airport) if they know that SpaceX can mandate an airway closure and idle planes, or force flight cancelations?

PEA Section 2.1.3.5.1: SpaceX identifies that the Brownsville Shipping Channel would be temporarily restricted during launches. SpaceX does not provide an estimate on the amount of time of restrictions of activity in the shipping channel. If the shipping channel restrictions undergo a similar process and procedure to what has occured with road closures (e.g. last minute cancellations, rescheduling, etc.), potential economic impact could result. An EIS is needed to identify the cumulative socioeconomic impact on the businesses (current and proposed) and operations at the Port and the Channel, and other economies such as charter fishing operations, and commercial fishing operations as well as tour boat operations, recreational fishing and all recreational, commercial and science research activities conducted in the bodies of water that are adjacent to and/or are enjoined by the channel.

Additionally, a cumulative analysis of socioeconomic impacts in a new EIS is needed to assess the impacts on:

- 3.14.4.1:Energy Supply and Consumption: SpaceX has not demonstrated they can source their own natural gas, let alone in enough quantities for their operations and in the time period of which they will operate at Boca Chica. SpaceX has not defined the total amount of natural gas they will use for their cumulative operations. It is more plausible that SpaceX will require the sourcing of gas via a pipeline connection or use of their own pipeline from Eagle Ford Shale region or elsewhere. An EIS is needed with a full disclosure of the amount of resources used to examine socioeconomic impacts.
- An EIS is needed to examine the number of new employees, available housing, the impact to the housing market, gentrification, and the pricing out of low income residents from housing and neighborhoods. Gentrification and pricing out of low income residents has been identified by the Brownsville Commissioners and Cameron County Commissioners.

ECOLOGY AND WILDLIFE

2.1.1 Location: The location description is mischaracterized. The majority of adjacent surrounding land is part of the Lower Rio Grande National Wildlife Refuge, and also fails to mention the proximity of the South Bay Ecological Preserve, and near the lower Laguna Madre. The omission of protected lands surrounding the Boca Chica Launch Site undermines the recognized importance and presence of the ecology and habitat that are protected. Regulatory decisions regarding SpaceX's proposals must bear in mind and account for these protected lands surrounding SpaceX's Boca Chica Launch Site. Figure 2-2 further mischaracterizes the location. The image predates much of SpaceX's development. Current and closer aerial imagery should be used to reflect the current state of habitat and development. Considerable habitat damage has occurred since the current image was taken, most of which has been in the period between the previous EIS and the multiple addendums and Written Re-Evaluations were implemented.

Section 2.1.1 inadequately describes features of the ecosystems as it states the location is characterized as having "salt flats" and low dunes. Salt flats are dried up desert lake beds. There are no salt flats at this location and the dunes are relatively high, as some can block the view of the LLCC. Tidal flats are rich in marine vegetation and support a wide range of life and are considered critical habitat. To correct these misconceptions of the local ecosystems, an EIS should be done.

The EPA has designated aquatic habitats at the site as Aquatic Resources of National Importance, which brings with it special procedural requirements for Clean Water Act, Section 404 permit review. This would seem to suggest that the impacts of the proposed actions may be significant as well, suggesting in turn that the FAA should prepare an EIS.

On page 99 of the PEA it is stated that, *"The Proposed Action would adversely affect approximately 11 acres of piping plover critical habitat in the floodplain....Unit TX-1 is 7,217 acres, and the total designated piping plover critical habitat in all of Texas is 71,053 acres. Thus the amount affected by the Proposed Action (11 acres) would make up a small percentage of all available piping plover critical habitat. Accordingly these impacts are not considered significant as the habitat loss represents only a small percentage of similar habitat located within the floodplain."* This is a narrow view of the impacts on floodplains as it does not take into account the compounding of the problems for migratory and nesting birds created by the disturbances from light and noise from the whole of operations at SpaceX. The piping plover is listed as a threatended species and their habitat is also classified as critical. Both circumstances consequently mean that any impact to the piping lover, or their habitat, is significant. Impacts to the piping plover and their habitat must be avoided.

PEA Section 3.9.3.1 and 3.9.3.2 Surface Water and Ground Water: The construction will cause "*increased turbidity in surface waters that may smother fish eggs, aquatic insects, and oxygen producing plants, increase water temperatures, and reduce oxygen levels. Use of construction equipment could result in release of contaminants (e.g., leaks, drips, and spills of petro-chemicals) that could reach nearby waterways and adversely affect water quality. SpaceX would implement its Spill Prevention, Control, and Countermeasures (SPCC) Plan".* The SPCC should be included in its entirety in an EIS. Any permit requirements applicable should also be summarized and included. Additionally, the frequency of water sampling by TCEQ Texas Surface Water Quality should be defined.

In section 3.14.4.2 Natural Resources, it is stated that *"SpaceX uses groundwater for various operations and for personnel use at the facilities. Potable water would either be delivered by truck or pumped from an existing on-site well at the VLA. SpaceX would install water distribution lines to distribute the potable water from the water tower to the facilities to provide potable water* *to the area. The existing well at the VLA would draw water from the Gulf Coast Aquifer (the Chicot Aquifer)."* The Chicot Aquifer in the Houston area has been pumped intensively which has resulted in "significant water-level declines" (https://setgcd.org/maps/). The south end of these aquifers are already briney, mostly due to oil and gas development. At what increased rate will land subsidence occur with the increased pumping? Where is the equation that has been calculated for that proportional rate? In the original 2014 EIS, personnel levels were expected to be a single shift of 30 full-time employees working 8:00 to 5:00 except for during launch operations when there would be more. It was stated that between 2016 and 2025 the number would be 130-250. The plan for potable water to "be delivered by truck to a holding tank at the VLA or pumped from a well on the property" and the plan for a "septic system (that) would consist of a mobile above ground processing unit and holding tank" needs reevaluation for the greatly increased, multiple-shift work force. Only with an EIS, can the impact of water resource use, including Brownsville's municipal sources, by SpaceX operations be adequately analyzed.

Disturbance of the Rio Grande Alluvium. Alluvial soils are important as they remove sediments and nutrients flowing in the adjacent water. They can also remove other contaminants from rivers and improve water quality for downstream communities. SpaceX says this won't be affected by pile driving, however, the PEA insufficiently analyzes this issue.

The disturbance to wildlife is downplayed in the discussion of "noise-induced startle response" (PEA pp.113-114). While it is acknowledged that, "A startle response from nesting birds can result in broken eggs or cause immature young that are not flight-capable to flee the nest. Repeated nest failures could eventually trigger desertion of a nesting area." The issue is not resolved since, "There are no mitigation measures currently available to reduce the chances of noise-induced startle responses but monitoring of select species could determine if noise was responsible for reduced reproductive success." It then speculates that "Noise from the Proposed Action would not be expected to cause a significant impact because the noise events are infrequent and short-term and would not result in impacts at the population level." The words *infrequent* and *short term* downplay the effects, especially when other negative effects of increased lighting and road traffic are added to the day-to-day conditions.

In the Starship Noise Assessment for Operations at the Boca Chica Launch Facility found in Appendix B of the Draft PEA it states, *"As mentioned, DNL is necessary for policy. The next two metrics (LAmax and SEL) are A-weighted and provide a measure of the impact of individual* *events. Loud individual events can pose a hearing damage hazard to people and can also cause adverse reactions by animals. Adverse animal reactions can include flight, nest abandonment, and interference with reproductive activities. The last two metrics, OASPL or Lmax (the maximum overall sound pressure level), for individual events; and spectra, may be needed to assess potential damage to structures and adverse reaction of species whose hearing response is different from that of humans. Reported levels are A-weighted unless otherwise noted." (p. 3 Starship Noise Assessment for Operations at the Boca Chica Launch Facility; 8/18/2021)* What is not even addressed is the effect of the shock wave that will occur from the launch of the Starship. Since the integrated Starship/Super Heavy will be twice the power of the Saturn V, that would make the "noise" at launch 230 decibels. At 190 decibels a shock wave occurs. This is not noise. Sound of this magnitude will deafen anything living in the area, and for animals, deafening is fatal. An EIS is needed to assess the adverse reaction of all species.

In the PEA Appendix E Section 4(f), p. 5-6, the FAA states that it is seeking input regarding the effect of road closures and other access restrictions and noise levels on the NWR. Unless an EIS is completed, how will this NWR assessment be implemented?

Section 2.1.3.7: SpaceX has not coordinated closely with USFWS and TPWD for debris removal to ensure minimal damage to the tidal flats. Previous debris removal of failed Starship landings has resulted in damage to refuge areas, particularly in tidal flats. This has demonstrated either a lack of an anomaly response plan, or a failure in implementation. In coordination with applicable agencies and organizations, an anomaly response plan that includes restoration strategies for damaged areas should be completed and included in an EIS. An EA without this plan fails to identify avoidance, minimization, and mitigation of impacts to the ecology and wildlife of the surrounding NWRs, violating NEPA.

Section 3.10.3.2 references the Marine Habitats and Wildlife impact assessment. This only addresses activities related to downrange recovery or landing of rockets in the Gulf of Mexico. The Essential Fish Habitat Assessment completely ignores the adjacent South Bay, which provides EFH for a wide range of commercially/recreationally important fish and shellfish. It is also considered to be a nursery area for Atlantic bottlenose dolphins.

Section 3.10.4.1: An EIS is needed for SpaceX proposals particularly regarding impacts to wildlife from construction expansion of the VLA and construction of launch related infrastructure such as the power plant, LNG plant, and desalination plant and impacts on wildlife. The claim that SpaceX construction would be short term is not accurate as evidenced from non-stop construction operations since initial ground breaking at the Boca Chica site. Currently, it has been reported that increased traffic (e.g. SpaceX employees, workers contracted with SpaceX, visitors, etc.) and traffic exceeding the speed limit has led to an increase of wildlife mortality on State Hwy 4. An EIS is needed to account for all construction and operations, including a timeline of SpaceX proposals. Cooperating agencies should identify avoidance and mitigation strategies, as well as implement a plan for enforcement. To the north and south of State Hwy 4 is the Lower Rio Grande National Wildlife Refuge that provides habitat for federally Threatened or Endangered species. Without specifics of design plans and construction timelines, SpaceX's claim that construction impacts on habitats and wildlife are anticipated to be less than significant and that construction under the proposed action have a similar negligible impact is not substantiated.

In reference to contracting a qualified biologist for pre/during/post construction monitoring (Section 3.10.5), SpaceX does not identify who or what entity would be contracted. Save RGV recommends USFWS and TPWD be consulted and be responsible for selecting the qualified biologist (Coastal Bend Bays and Estuaries has been used in the past). Furthermore, the monitoring, documentation, and data particularly during bird migration season, needs to be openly shared with USFWS, TPWD, and openly published and accessible to the public.

3.12.4: Environmental Consequences: The determination that the *"Proposed Action is not expected to result in significant land use impacts because the Proposed Action is consistent with existing uses of land, would not change land use, and would occur according to existing plans and procedures"* is not substantiated due to inadequate and missing information about proposed infrastructure and operations. An EIS is needed to determine compatibility of land use and environmental consequences. For instance, the gas treatment and liquefaction (LNG) infrastructure and operations are not fully detailed. Potential land use conflicts arise with the source of gas and delivery of gas to the power plant and LNG facility which would likely require a pipeline to go through either the Lower Rio Grande Valley National Wildlife Refuge, Boca Chica State Park, or Laguna Atascosa National Wildlife Refuge.

Section 3.9.4.3 p. 95: The determination that "*the Proposed Action includes all practicable measures to minimize harm to wetlands that may result from construction*" is erroneous and not substantiated. As stated in the PEA, "*Construction activities could also affect adjacent wetlands* *through ground disturbance activities and use of construction equipment"* is a recognition that all practicable measures to minimize impacts have not been taken. In fact, it is admitted to in the PEA that the USACE has not yet completed its evaluation of SpaceX's proposed impacts and wetland mitigation pursuant to CWA section 404(b)(1) Guidelines (40 CFR 230) and section 404q.

PEA Section 3.10.4.1. Terrestrial Habitats and Wildlife. It is stated that the 2014 EIS speed reduction measures will be implemented to mitigate construction vehicle strikes and fatalities with wildlife. Unfortunately, the situation has gotten worse as vehicular traffic has increased. Roadkill events need to be quantified based on what has occurred so far with the current amount of vehicular construction traffic.

ALTERNATIVES

The PEA should examine more alternatives, rather than just the "all or nothing" alternatives. One of the other alternatives that should be included in an EIS is moving the *testing of Super Heavy* to a designated large rocket testing site, such as Provo, Utah or Stennis AFB in Mississippi. The latter is where the Saturn V rocket was tested, and where the Space Launch Systems (SLS) rocket is currently being tested. Another alternative should include test launching Super Heavy offshore or from Cape Canaveral. Noted is a reference in Appendix A, page 3, indicating that NASA has already completed an environmental assessment for launching the Starship Super/Heavy at KSC "NASA.2019. Environmental Assessment for the SpaceX Starship and Super Heavy Launch Vehicle at Kennedy Space Center (KSC).[4] Alternatives considered are only those pertaining to launches/landings. Alternatives to minimize impacts of other operations have not been considered. SpaceX's proposed operations include elements that are identified as necessary for their launch operations (identified in Table 2-1 p. 9) including, but not limited to, the power plant, and gas treatment and liquefaction. Alternatives to avoid, minimize and mitigate impacts from such elements of SpaceX operations have not been considered. These elements to operations need more analysis to determine impacts and alternatives, particularly the source and delivery of natural gas for the power plant and natural gas treatment and liquefaction but also for other elements such as the desalination plant.

Other elemental alternatives not considered to reduce impact is off site parking lots and use of shuttle busses, carpools or vanpools. These alternatives would mitigate impacts to runoff, aquatic habitats, ongoing issues with traffic, violation of speed limits, and wildlife mortality on

[4] https://netspublic.grc.nasa.gov/main/20190919_Final_EA_SpaceX_Starship.pdf p256

State Hwy 4. The proposed parking lot could potentially impact 14 acres of seagrasses that lie within 1 km to the north. Parking lot construction could result in increased sediment loading to Boca Chica Bay, potentially resulting in increased light attenuation on the seagrass beds. Seagrasses are highly sensitive to reductions in light availability. Dunton et al (2003) recommended no dredging within 1 km of seagrass beds in Laguna Madre.

LAWS AND REGULATIONS

- Table 2-1 lists elements of the proposed action. SpaceX has already been constructing some of the infrastructure prior to approval of this PEA. As one example, SpaceX has been violating this by continuing to build infrastructure including a 450 foot integration tower. NEPA is very clear that project construction cannot begin ("irretrievable and irreversible commitment of resources") until the environmental review is done. SpaceX must be held accountable for any and all NEPA violations for unapproved/permitless construction.

- SpaceX must be prohibited from operating in the Boca Chica / refuge area. 40 CFR1501.3 requires a full Environmental Impact Statement (EIS) because SpaceX's activities violate strictly enforced federal law, the Refuge Improvement Act, which mandates that no use of the refuge is allowed if it is incompatible with purposes of refuge, which is conservation of lands for the benefit of wildlife. SpaceX's activities are incompatible with the Refuge and must be disallowed altogether. Additionally, the Department of Transportation Act requires the consideration of natural resources during project development. 23 U.S.C. § 138 Federal regulations state that a constructive use of property protected by Section 4(f) occurs when a project does not incorporate land from a Section 4(f) property, but the project's proximity impacts are so severe that the protected activities, features, or attributes that qualify the property for protection under Section 4(f) are substantially impaired. Substantial impairment occurs only when the protected activities, features, or attributes of the property are substantially diminished. 23 C.F.R. § 774.15 identifies potential causes of constructive use include shifts in user population because of direct use of bordering properties, and/or non-physical intrusions such as noise, air pollution, or other effects that would substantially impair the resource's use." Constructive use is occuring around the SpaceX site with regards to accessibility to Boca Chica Beach, South Bay Coastal Preserve, Lower Rio Grande NWR, and Palmito

Ranch Battle Field, and declining nesting of certain bird species in NWR areas near SpaceX as documented by the Coastal Bend Bays and Estuary Program. Section 4 (f) requires all possible planning to minimize harm resulting from the *use*; this has not been practiced, documented, or evidenced on the behalf of SpaceX or in the PEA. Furthermore, an accurate determination of impact is not achievable due to lacking information on elements of SpaceX's operations, and has thus failed to avoid, minimize, and mitigate impacts. A true and accurate finding of effects of SpaceX's proposals under Section 4(f) and Section 106 is not possible. In all of the foregoing, FAA is overstepping its statutory authority in making a compatibility determination. That is a call that only USFWS can make, not the FAA.

- The Endangered Species Act: the scope of activities vastly exceeds that to which the original biological opinion responds, since that opinion was issued for regular launches of a smaller, proven rocket only, not one in its testing and development phases, when explosions and failures are expected.

- Texas Open Beaches Laws are being violated. *Texas Constitution. Art. 1 sec. 33; 61 Tex. Nat. Res. Code Sec. 61.011: The public has an unrestricted right to use and a right of ingress to and egress from a public beach*. Closure of Boca Chica beach and State Highway 4 for SpaceX activities, deprives the public of the use of the beach, and therefore is in violation of the constitutional rights of the people of the State of Texas. Closures are also violations of Section 4(f) of Department of Transportation Act of 1966. Letters to the FAA from the Department of the Interior, dated January 10, 2014 and October 7, 2020 identifies the ongoing issues and lack of avoidance with regards to constructive use relating to closures.

- Part of the existing facility lies within Coastal Barrier Resources System Unit T12. Therefore, if this existing project includes any Federal funding, it would violate the Coastal Barrier Resources Act (CBRA). Similarly, if any Federal funding is involved in the current proposed expansion, it too would violate the Coastal Barrier Resources Act. Finally, FAA's statement that SpaceX intends to use the site to meet what it claims are official US space program goals, suggests that SpaceX intends to use the site to accomplish US government funded missions, which would appear to violate the CBRA.

Violations may include federal funding of $14.4 million.[5]

- Even more egregious, the PEA explicitly states that it is SpaceX's intent to participate in FEMA's National Flood Insurance Program (NFIP) (3.9.4.4 Floodplains; p. 98; 1st complete paragraph; 2nd sentence). Note that, ***in particular***, the CBRS is intended to restrict the ability to obtain National Flood Insurance in CBRS units. The PEA must be revised to reflect this, and FAA must acknowledge that it is unacceptable for SpaceX to pursue Federal flood insurance for portions of the project that are on, or would be on, CBRS units. Regarding the following assertions, as stated in *3.9.4.4 p98: "The design engineer will certify that the design elevation will withstand the depth and velocity of 100-year flood events (hydrostatic and hydrodynamic loads), any potential increase in wind load, or any other relevant load factors. Compliance with the NFIP as well as county regulations would ensure that the construction will have no significant impacts on floodplain storage and base flood elevations".* This is not possible. The close proximity to the Gulf of Mexico shoreline and the extremely low topography surrounding the site, virtually guarantee significant damage to the existing and proposed facilities during future tropical storms, due to storm surge and overwash.

- 2.1.3.4 (p. 17): States SpaceX "*would develop appropriate sampling protocols and water quality criteria in coordination with the Texas Commission on Environmental Quality (TCEQ)."* This is not the legal process as outlined in Texas Administrative Code Chapter 307. It is TCEQ, not SpaceX, that is responsible for sampling and water quality criteria. However, SpaceX would be required to monitor discharge in accordance to permit conditions as mandated by TCEQ. SpaceX determining their own protocols regarding sampling and water quality criteria is not in accordance with Texas Administrative Code. In the absence of design plans of elements of their proposals, a full accounting and disclosure of what the stormwater pollutant load might be is lacking. An EIS is needed to account for all elements which include various types of industrial activities.

- The USACE public notice for SpaceX's current application for a Clean Water Act Section 404 permit suggests that SpaceX's application may not be compliant with CWA Section 404(b)(1) Guidelines. SpaceX has not demonstrated required avoidance and

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5 https://spacenews.com/blue-origin-rocket-lab-spacex-ula-win-space-force-contracts-for-rocket-technology-projects/

minimization of impacts to aquatic habitats. They have not demonstrated required consideration of alternatives. They have not demonstrated that their proposal is the Least Environmentally Damaging Practicable Alternative (LEDPA), as required by the Guidelines. Nor have they provided the public with any information regarding proposed mitigation for unavoidable impacts to aquatic habitats.

- Considerations regarding alternatives are inadequate and have not been analyzed to the fullest extent as required by 2 U.S.C. 4332(E), 40 C.F.R. 1501.5(2), 40 C.F.R. 1501.5(4), Section 102(2)(E) of NEPA.

OMISSIONS

The following documents were referenced, but not provided in the PEA. WIthout access to these documents, the public can only speculate as to their existence and efficacy, and therefore makes them unenforceable.

1. Anomaly Response Plan
2. Security Plan
3. Fire Mitigation and Response Plan
4. Applicable Site Plans
5. Facility Design and Lighting Plan
6. SpaceX Roadway Closure and Traffic Control Plan
7. Flight Package Safety Data
8. Closure Notification Plan
9. Speed Monitoring Plan (at construction and operations site)
10. The Communication Process, or Plan, with the GLO, TPWD, and USFW for Debris Removal
11. Spill Prevention, Control, and Countermeasures (SPCC) Plan
12. Mitigation Plans for identified filling or destruction of wetlands
13. Stormwater Pollution Prevention Plan (SWPPP)
14. Safety Risk Analysis (missing from Draft EA)
15. Hazard Risk Analysis (missing from Draft EA)
16. Identification of the emergency response team. (Are public resources used? if so, what is the cost to Cameron County?)

17. The Letter of Agreement which outlines procedures and responsibilities applicable to operations including notification of launch activity; communication procedures prior to, during, and after a launch; planning for contingencies/emergencies; NOAA issuance; and any other measures necessary to protect public health and safety.

Lacking the proof of existence, creation, or updates to the aforementioned plans, the prevention, response, avoidance, minimization, or mitigation to impacts cannot adequately be determined. Additionally, phrases used such as "to the extent practicable" makes plans and operations unenforceable, such as found in the PEA's light plan. These phrases are vague, lack detail, and are open to interpretation. Due to the lack of the inclusion of the aforementioned plans and language in reference to the plans, an EIS is needed.

Thank you for holding this important Public Hearing and giving the public an opportunity to comment on the Draft PEA.

Respectfully,
Save RGV

From: Rob Wilson <[redacted]
Sent: Monday, November 1, 2021 12:31 PM
To: SpaceXBocaChica
Subject: Space Exploration Technologies Corporation Boca Chica Launch Site

To all that it may concern:

I am a US citizen that has always been interested in space flight, since the early sixties. I am writing in support of Space Exploration Technologies Corporation(SpaceX) license application to build a heavy lift launch and manufacturing facility in Boca Chica, Texas.

The reasons that i feel that it is important is that there are limited opportunities to get into space and that SpaceX is doing a fantastic job making the effort to get to space much lower. Boca Chica is one of the few places that this effort can succeed at making the new generation of rockets that are fully reusable. It is interesting to note that Jules Verne in his novel from the Earth to the Moon had down selected two places in America to launch a moon shot. One was near Cape Canaveral Florida, the other is south coast Texas. In a literary sense, launching rockets from South Texas would complete a prophecy.

When looked at from a very low altitude, the site at Boca Chica is relatively small. The development that occurs and has occurred on South Padre Island is much worse to any environmental effects that that SpaceX can impinge on Boca Chica. The corresponding good results that will result from building new generation rockets are almost incalculable. The most important result will be large scale access to space that presents itself to the human race. Because of the sensitive nature of the locality, SpaceX is building the densest rocket manufacturing facility in the world, while at the same time limiting its effects to as small as possible. A lot of appreciation should be given to that. In the long term, Boca Chica will be a manufacturing facility with limited launches, so short term the launches forecast will be events and not obnoxious.

I am in favor of the approval of the license and hope that the FAA will support it as much as they can.

Rob Wilson
[redacted]

18095

From: Miguel Santos <[redacted]
Sent: Monday, November 1, 2021 9:52 AM
To: SpaceXBocaChica
Subject: Space X - Letter of Support
Attachments: CDOB-Space X FAA.pdf

Greetings,

Kindly see letter attached.

Best regards,

Miguel Santos
Director of Strategy and Development
Catholic Diocese of Brownsville
[redacted]
Mobile [redacted]
www.cdob.org

Federal Aviation Administration (FAA) c/o ICF
Attn: Ms. Stacey Zee
Environmental Specialist
9300 Lee Highway, Fairfax, VA 22031

Dear Ms. Zee:

May this find you doing well. We write you in support of Space X and their work in our community. The Diocese of Brownsville is responsible for the pastoral care of more than one million Catholic faithful across the four counties that comprise the Rio Grande Valley. In addition, our broader call is to be a force for good in the community and to serve all people, Catholic or not. The Diocese of Brownsville is a proud supporter of SpaceX's work to inspire hope in the hearts and minds of youth across the Rio Grande Valley.

One of our principal priorities is the care for our young people. Temptations are prevalent in youth, with drug trafficking organizations, criminal groups and gangs working to entice youth with the promise of money and power. SpaceX is offering realistic alternatives and inspiration for youth to pursue their education in science and technology. We are so grateful for all the outreach they have done with elementary school students all the way through college. SpaceX employees have already hosted nearly 2,000 students for tours, and have developed an internship program with the local colleges and universities providing people with a path to space technology that did not previously exist in the region.

Beyond their efforts in youth outreach, SpaceX has proven to be good stewards of the community, working with conservation organizations to protect wildlife in the local area, conducting regular beach and road cleanups, and co-sponsoring the Annual Texas International Fishing Tournament.

Our Diocese oversees the work of 73 parishes, 42 mission churches, 11 Catholic schools, and a number of social service agencies. As religious leaders in the community, it is our hope that we can encourage youth to turn towards activities that will keep them safe and prosperous, and we feel that we have a partner in accomplishing this goal with SpaceX.

With the aforementioned in mind, we express our enthusiastic support of SpaceX's application to the FAA to conduct Starship orbital launch operations from Starbase in Cameron County, Texas. We look forward to continuing to have their positive influence and ambitious spirit in the region.

With kind regards,

Miguel Santos
Director of Strategy and Development
Catholic Diocese of Brownsville

18096

From: Sid Maddock <[redacted]
Sent: Monday, November 1, 2021 8:14 PM
To: SpaceXBocaChica
Subject: Space X, Wallops facility BO
Attachments: Wallops.2016BO.pdf

Attached please find for submission to the administrative record for the SpaceX DPEA the BO for activities at the Wollops facility.

Sidney Maddock

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Virginia Field Office
[redacted]

June 22, 2016

Mr. Joshua A. Bundick
Lead, Environmental Planning
Code 250.W
Wallops Flight Facility
Wallops Island, VA 23337

Re: Wallops Flight Facility Proposed and Ongoing Operations and Shoreline Restoration/Infrastructure Protection Program, Accomack County, VA, Project # 2015-F-3317

Dear Mr. Bundick:

This document transmits the U.S. Fish and Wildlife Service's (Service) revised biological opinion based on our review of the referenced project and its effects on the federally listed threatened piping plover (*Charadrius melodus*) (plover), red knot (*Calidris canutus rufa*) (knot), and loggerhead sea turtle (*Caretta caretta*) Northwest Atlantic Ocean distinct population segment (loggerhead) in accordance with section 7 of the Endangered Species Act (16 U.S.C. 1531-1544, 87 Stat. 884), as amended (ESA). The National Aeronautics and Space Administration's (NASA) August 18, 2015 request for formal consultation was received August 18, 2015. The Service provided our biological opinion December 22, 2015.

On January 20, 2016, the Service received NASA's request for revisions to the project description, incidental take statement, and Term and Condition 5, which are incorporated in this revised biological opinion. This biological opinion replaces the December 22, 2015 biological opinion. This letter should be appended to the December 22, 2015 biological opinion and maintained as part of the decision document and administrative record.

This biological opinion is based on information provided in the August 18, 2015 biological assessment (BA), the project proposal, telephone conversations, field investigations, and other sources of information. A complete administrative record of this consultation is on file in this office.

NASA determined in its BA that the proposed and ongoing actions may affect, but are not likely to adversely affect the federally listed endangered roseate tern (*Sterna dougalii dougalli*), and leatherback (*Dermochelys coriacea*), Kemp's ridley (*Lepidechelys kempii*), and green (*Chelonia mydas* [rangewide listed and proposed North Atlantic distinct population segment]) sea turtles, and the federally listed threatened seabeach amaranth (*Amaranthus pumilius*). The Service concurs with NASA's determination and these species are not considered further in this biological opinion.

We concur with your determination that the federally listed threatened Northern long-eared bat (*Myotis septentrionalis*) (NLEB) is not likely to be adversely affected by the proposed and ongoing actions if the proposed avoidance and minimization measures, which NASA has incorporated into its proposed and ongoing actions, are followed:

- To the extent practicable, NASA will conduct tree removal activities outside of June 1 to July 31.
- Should NASA deem it necessary to remove trees of 3 inches diameter at breast height (DBH) or greater between June 1 and July 31, it will either:
    1. Conduct a bat emergence survey (1 surveyor per 10 trees) 1 to 2 days prior to the scheduled tree removal; or
    2. Conduct a presence/absence survey of the affected area, employing a qualified bat surveyor.

All survey results will be provided to the Service at the contact information provided below. If NLEB identified maternal roost tree removal is planned between June 1 and July 31, additional consultation with the Service will be required. Activities conducted by NASA consistent with the conservation measures outlined in the ESA 4(d) rule for the NLEB (81 Federal Register 1900-1922) are addressed under the Service's January 5, 2016, "Programmatic Biological Opinion on Final 4(d) Rule for the Northern Long-Eared Bat and Activities Excepted from Take Prohibitions."

NASA ongoing launch operations include launching scientific balloons. Balloons launched from WFF may be latex balloons 600 to 3,000 grams in mass, or polyethylene balloons up to 1,132,673 cubic meters (m) in volume. Latex balloons will burst at altitude, dropping the scientific payload into the Atlantic Ocean. Polyethylene balloons are terminated by remotely detonating a small charge to puncture the balloon and separate the payload from the balloon. The process of launching and detonating balloons is gradual enough that plovers and knots will be able to avoid colliding with balloons. Noise associated with launch and detonation is not expected to startle plovers, knots or loggerheads. Scientific balloons are large enough that they will not be ingested by plovers, knots, or loggerheads after they burst. Polyethylene balloons and the associated payload are generally recovered so they will not pose a hazard to marine life after detonation. The Service has determined that use of scientific balloons is not likely to adversely affect listed species over which the Service has jurisdiction.

NASA developed a plan to reduce the hazard posed by *Phragmites australis* stands on Wallops Island, with the highest priority being those in the vicinity of the launch area (NASA 2014a). A combination of control methods are employed including aerial spraying (via rotary-wing aircraft), hand spraying, controlled burning, and mowing; in addition to “cleanliness” requirements for operating heavy equipment in *Phragmites* infested areas (NASA 2014a). Small fixed or rotary wing unmanned aerial systems (UAS) may be employed to monitor effectiveness of the program. Due to the lack of suitable habitat for listed species in locations where burns will occur, the Service has determined that *Phragmites* control is not likely to adversely affect listed species.

This biological opinion is valid from the date of signature through January 1, 2031. No later than June 1, 2030, the Service and NASA will meet to discuss the process for the next iteration of consultation.

CONSULTATION HISTORY

05-10-2010 The Service issued NASA a non-jeopardy biological opinion for expansion of WFF and ongoing operations.

07-30-2010 The Service issued NASA a non-jeopardy programmatic biological opinion on the SRIPP.

09-22-2011 The Service provided concurrence on NASA’s no effect determination for construction of a UAS airstrip at the northern portion of the island. The Service provided a not likely to adversely affect determination for several species associated with the operation of the new airstrip.

9-11-2014 The Service provided concurrence on the U.S. Navy’s (Navy) not likely to adversely affect determinations for installation and operation of a 5 inch powder gun and electromagnetic railgun at WFF.

11-20-2014 The Service provided concurrence on NASA’s not likely to adversely affect determination for relocation of the 50k sounding rocket launcher and construction of a new flat pad to support sounding rocket launches.

01-12-2015 Red knot federally listed as threatened.

08-18-2015 The Service received NASA’s request to reinitiate formal consultation on the 2010 biological opinions.

09-28-2015 The Service acknowledged receipt of initiation of formal consultation request.

10-16-2015 A Service biologist conducted a site visit of the project areas.

12-22-2015 The Service provided our non-jeopardy biological opinion.

01-20-2016 The Service received NASA's request for revisions to the biological opinion.

BIOLOGICAL OPINION

This biological opinion consolidates 2 biological opinions issued in 2010. The first analyzed effects associated with proposed and ongoing launch operations at WFF and the second analyzed effects associated with implementation of the SRIPP at WFF. Only proposed, undocumented, or ongoing activities are analyzed in this document.

DESCRIPTION OF PROPOSED ACTION

The proposed action includes completing and continuing several actions to support proposed and ongoing launch operations and SRIPP at WFF (Wallops Main Base, South Wallops Island, North Wallops Island). Table 1 provides a summary of the individual actions and each is described in further detail following the table.

Table 1. Proposed and ongoing launch operations and SRIPP at WFF.

Action	Location	Frequency	Time of Year	Time of Day
Liquid Fueled Expendable Launch Vehicle (ELV) Launches	Pad 0-A	6/year	Year-round	Either
Solid Fueled ELV launches	Pad 0-B	12/year	Year-round	Either
ELV Static Fires	Pad 0-A	2/year	Year-round	Either
Sounding Rocket Launches	Current: Pad 1 and Pad 2 Future: Pad 2 and south UAS airstrip flat pad	60/year	Year-round	Either
Sounding Rocket Static Fires	Pad 2	33.5 tons double base & 38.3 tons composite propellants/12-month period	Year-round	Either
Disposal of Defective or Waste Rocket Motors	Open Burn Area, south Wallops Island		Year-round	Either
Drone Target Launches	Pad 1, 2, 3 or 4	30/year	Year-round	Either
UAS Flights	Wallops Main Base, South Wallops Island, North Wallops Island	75 missions/week	Year-round	Either
Piloted Aircraft Flights	Wallops Main Base and adjacent airspace	61,100 operations/year	Year-round	Either
Restricted Airspace Expansion	Main Base, Wallops Island, and adjoining airspace	No change in type or tempo or aircraft activity	Year-round	Either
Range Surveillance/Facility Security	Wallops Island	N/A	Year-round	Either
Construction	Wallops Island	N/A	Year-round	Either
Routine Facility Maintenance	Wallops Main Base, Wallops Island	As needed	Year-round	Day
Launch Pad Lighting	Wallops Island	30 days/launch	Year-round	Night
Recreational/ Off-road Vehicle (ORV) Beach Use	Wallops Island	N/A	Year-round	Day
Protected Species Management	Wallops Island	N/A	Spring and Summer	Day
Miscellaneous Activities on Wallops Island Beach	Wallops Island	As needed	Year-round	Day
Education Use of Wallops Island Beach	Wallops Island	Several trips/week	Year-round	Day
Seawall Repair	Wallops Island	As needed	Year-round	Day
Shoreline Reconstruction Monitoring	Wallops Island	2/year	August – October and March - May	Day
Beach Renourishment and Long-term Project Maintenance	Wallops Island	Every 2-7 years	Year-round	Day

Proposed and Ongoing Launch Operation Activities

Liquid and Solid Fueled ELV Launches and Static Fires - ELVs are launched from Launch Complex 0 at the south end of Wallops Island, between the southernmost extent of the sea wall and the UAS runway. Pad 0-B is topped with a permanent gantry. A transporter erector launcher raises and launches rockets from Pad 0-A. Both launch pads are illuminated with broad spectrum night lighting for up to several weeks on either side of the launch window; effectively resulting in up to 30 calendar days of night lighting per launch event. Exhaust ports on each launch pad direct rocket motor exhaust to the east, across a narrow strip of steep sandy beach and over the Atlantic Ocean. Launches from either pad may occur at any time of day, on any day of the year, as dictated by weather conditions and program needs.

Rockets launched from Pad 0-B use solid fuel systems based on an ammonium perchlorate/aluminum (AP/AL) or nitrocellulose/nitroglycerine (NC/NG) combination. Many classes of rockets may be launched from this site, the largest of which would be equivalent to the LMLV-3(8). Rockets launched from Pad 0-A will use liquid fuel systems with refined petroleum (RP-1) or liquid methane and liquid oxygen (LOX) as propellants, thus requiring liquid nitrogen prior to launch for cooling the propellants, and gaseous helium and nitrogen as pressurants and purge gases. The largest vehicle proposed to launch from Pad 0-A would be Orbital ATK's Antares 200 Configuration ELV. Orbital rockets deliver spacecraft into orbit that may utilize hypergolic propellants.

The Antares 200 Configuration ELV employs 2 NPO Energomash provided RD-181 engines, which also use LOX and RP-1. These motors will be more powerful (up to 17 percent more thrust at sea level) than the previous AJ-26 engines and consequently will allow for a heavier payload to be placed into orbit. The Antares 200 Configuration also utilizes modifications to valves and piping in the first stage fuel feed system, modifications to structural and thermal components in the first stage, and changes to avionics and wiring, and requires slightly different ground support equipment (used to handle and test rocket components) and fueling infrastructure. The Antares 200 Configuration will be launched from Pad 0-A, with up to 6 launches per year, and 2 static test fires per year.

Sounding Rocket Launches - Sounding rockets are currently launched from 2 launch pads in the vicinity of Launch Pad 1 and 2. In the future, sounding rockets will be launched from 2 launch pads in the vicinity of Launch Pad 2 and the south UAS airstrip flat pad. These launch pads are topped with mobile shroud sheds rather than gantries, and temporary rail launchers are used to orient the rockets for launch. Sounding rockets do not have a long loiter time on the launch pad after ignition, therefore these launch pads are not equipped with exhaust ports. Many classes of sounding rockets are used at these sites, the largest of which is the Black Brant XII burning 3,350 kilograms (kg) of solid propellant. Propellants used are based on an AP/AL or NC/NG combination. Sounding rockets do not deliver spacecraft into orbit, and therefore do not carry hypergolic propellants. As many as 60 sounding rockets are launched per year, at any time of day, on any day of the year, as dictated by weather conditions and mission needs.

Sounding Rocket Motor Static Fire Testing - NASA performs sounding rocket motor static fire tests so that motor operations can be observed in a non-flight position. Rocket motors may be static test fired from either a horizontal or vertical position. WFF has been authorized by the Virginia Department of Environmental Quality (VDEQ) Air Division to perform static fire tests on solid propellant sounding rocket motors from Pad 2. The envelopes for static fire tests are governed by the limits set forth in the Wallops Island State operating permit. Exhaust from static test firings will be directed through a trench and over the Atlantic Ocean. The deluge system used for orbital launches from Pad 0-A will be used to cool the launch pad and dampen vibration during static firing tests. Sounding rocket motor static fire testing encompasses 33.5 tons of double base and 38.3 tons of composite propellants over a 12-month period.

Disposal of Defective or Waste Rocket Motors - Defective or waste rocket motors are ignited at the open burn area south of the UAS runway on the south end of Wallops Island. Motors that cannot be returned to the manufacturer or repurposed for other projects are placed on a concrete pad or bolted to a subunit and ignited to burn off any stored propellant. Multiple motors can be consolidated into a single burn. Ash remaining after a burn is burned again or shipped off-site for disposal. The remaining motor casings are steam cleaned and disposed of as scrap metal. The water used for steam cleaning is captured and tested for toxins before disposal under a VDEQ permit. The maximum amount of propellant to be disposed of per year at the open burn area for sounding rocket static fires and disposal of defective or waste rocket motors is 33.5 tons double base and 38.3 tons composite propellants. Burns are infrequent and have not approached the disposal permit limit.

Drone Target Launches - Drone targets are launched from WFF or air launched from military aircraft in support of Navy missile training exercises. These targets use a variety of fuels, including liquids such as JP-5 jet fuel or hydrazine derivatives, or solid fuels such as AP/AL or NC/NG. Drones travel on preprogrammed flight paths and are engaged by shipboard interceptor systems over the Virginia Capes Operating Area (VACAPES OPAREA), with all debris from the intercept falling within the VACAPES OPAREA boundary. Drone flights may occur at any time of day, on any day of the year, as dictated by training needs and may occur up to 30 times per year.

UAS Flights - UAS are used at WFF in support of scientific missions. UAS flights may use the UAS runway on the south end of Wallops Island, between Pad 0-B and the open burn area, as well as the runways on the Main Base. The largest anticipated UAS that may be flown from the WFF Main Base runways will have engines and fuel capacity one-fifth those of a Boeing 757, though most are considerably smaller.

A new UAS airstrip is planned for construction on the north end of Wallops Island. When this airstrip is operational, the south Wallops Island airstrip will be decommissioned. UAS flown from the North Wallops Island UAS airstrip cannot exceed the noise generated by the Viking 300 or the size (in terms of physical size and quantities of onboard materials) of the Viking 400 (NASA 2012a). UAS operations are projected to occur at a frequency of 75 missions per week and will not exceed 1,040 sorties per year.

<u>Piloted Aircraft Operations</u> - Piloted aircraft use the runways on WFF Main Base. Aircraft using the runways range from small single propeller designs up to the Boeing 747, and include such military designs as the F-16 and F-18. Many of the airfield operations conducted at WFF include military pilot proficiency training that consists primarily of "touch-and-go" exercises in which the aircraft wheels touch down on the airstrip but the aircraft does not come to a complete stop. The U.S. Air Force, Air National Guard, U.S. Army, U.S. Coast Guard, and Navy conduct pilot proficiency training at WFF runways.

An airfield operation represents the single movement or individual portion of a flight in the WFF airfield airspace environment, such as 1 takeoff, 1 landing, or 1 transit of the airport traffic area. The baseline airfield operation level for WFF of 12,843 was established in 2004 using annual airfield operations data for that year with an envelope that included a 25 percent increase above the total. Since 2013, WFF's piloted aircraft operating envelope was increased to include an additional 45,000 operations. The current operating envelope is limited to 61,000 operations per year. Air traffic from Wallops Main Base flies over Wallops Island.

<u>Restricted Airspace Expansion</u> - NASA has requested the Federal Aviation Administration (FAA) grant additional Restricted Airspace such that NASA can conduct experimental aircraft test profiles with a lower risk of encountering non-participating aircraft. No changes are proposed to either the types of aircraft or the types and number of operations conducted within the airspace adjacent to WFF. Consistent with existing practices, aircraft operating within the new restricted airspace would be required to maintain at least a 610 m altitude when operating above the Service's Chincoteague National Wildlife Refuge (CNWR).

<u>Range Surveillance/Facility Security</u> - In general, UH-1 helicopter surveillance flights occur twice per launch countdown and range in altitude from 61 m above ground level (AGL) to 1,524 m AGL. Each flight is approximately 2.5 hours in duration, with the helicopter's primary surveillance responsibility being the lagoon area between Wallops Island and the mainland Eastern Shore of Virginia; however, flights can range up to 1.85 kilometers (km) offshore.

Contracted fixed wing radar surveillance aircraft operate the majority of the time at 4,572 m AGL and remain within the VACAPES OPAREA airspace. Fixed wing spotter aircraft operate in the same area but their altitude varies between 152 m and 4,572 m AGL. The spotters spend less than 10 percent of their flight time below 457 m; only descending to low altitudes to visually obtain a call sign from an intruding boat or get the attention of the crew. Most of the spotters fly for around 4 hours total; the radar planes fly between 4 and 5.5 hours per mission. A typical ELV mission requires 1-2 fixed wing surveillance aircraft.

Surface surveillance and law enforcement vessels can include up to 8 inboard- or outboard-powered boats, up to approximately 13 m in length. Generally, the larger inboard vessels range between 10 and 12 knots (kt) cruising speed, whereas the small inboard vessels cruise between approximately 25 and 30 kt.

Navy and NASA facilities on Wallops Island are equipped with exterior lights at ground level, along catwalks, and at FAA mandated heights for aircraft orienteering. Security of facilities on Wallops Island is maintained by a private contractor. Individuals on foot or in vehicles tour the perimeter of Wallops Island, including the beach areas on the north and south end of the island. These patrols may be performed as often as deemed necessary to maintain base security. Security may transition from the current system of frequent roving patrols to a closed circuit television system. If the closed circuit surveillance system is installed, security officer beach access would be reduced to the minimum required to augment the cameras in providing facility security. Construction - NASA is currently relocating the Wallops Island fire station adjacent to Navy Building V-024. Consistent with the external lighting employed on the Horizontal Integration Facility (HIF) and Pad 0-A, the new fire station will employ long wavelength exterior lighting to reduce potential effects on nesting loggerheads and their hatchlings (Witherington and Martin 2003).

Routine Facility Maintenance - The operation of WFF requires continuing routine repairs and ongoing maintenance of buildings, grounds, equipment, aircraft, vehicles, laboratory equipment, and instrumentation. Existing infrastructure, such as roads and utilities are maintained on a regular basis to ensure their safety and operational capacity. Existing buildings also require ongoing maintenance. Buildings or utility systems may be rehabilitated or upgraded to meet specific project needs. Brush and trees may be removed to construct a new building, keep the airfield's clear airspace free of intrusions, maintain the facility's perimeter fence, manage wildlife, maintain radar and tower line of sight, or enhance operation of other radio frequency equipment. Routine repairs are often required after hurricanes or intense storms. NASA contractors use heavy equipment to clear roads and stormwater systems.

The boat dock at the north end of Wallops Island receives equipment such as rocket components that cannot be delivered to the island by truck. The existing access channel and boat basin will be maintained via dredging to a depth of 4 feet at low tide to accommodate deliveries at any time of day.

Launch Pad Lighting - During orbital and suborbital launch operations, bright, broad-spectrum area lighting is required. Observations of operations at both Pads 0-A and 0-B have shown that broad spectrum night lighting can be required for up to several weeks on either side of the launch window, effectively resulting in up to 30 calendar days of night lighting per launch event. During non-critical operations, the launch pad area will be illuminated by a combination of amber light emitting diode (LED) and low pressure sodium (LPS) fixtures.

Recreational/ORV Beach Use - WFF personnel and their families are allowed to use the north end of Wallops Island for recreation outside of NASA operations periods. Recreational use may involve operation of vehicles on the beach, in addition to foot traffic. Users access the beach by the north Wallops Island ORV access. Beach access is year-round and is not expected to increase in frequency from the level previously considered. The northernmost extent of Wallops Island beach is closed to all recreational use from March 16 through August 31, or until the last plover chicks fledge. The south end of Wallops Island is closed to recreational use year-round.

Protected Species Management - In accordance with its Protected Species Management Plan (NASA 2015a), NASA will continue to monitor Wallops Island beach for beach nesting species activity. Protected species management activities involve conducting frequent monitoring surveys, implementing area closures and posting signage, placing plover nest exclosures, and similar actions. Additional protective measures, including employee education, seasonal closure of the northernmost extent of Wallops Island beach, nest exclosures, and predator management will continue.

Miscellaneous Shoreline Activities - Occasional shoreline debris (biotic and abiotic) removal is necessary within all areas of Wallops Island beach. For example, if a large tree limb is deposited on the shoreline during a storm, it will be removed. Likewise, following rocket launches from Launch Complex 0, particularly Pad 0-B, miscellaneous metallic and non-metallic debris is often deposited on the nearby shoreline. Similarly, these items will be removed. While in recent years such debris could be reasonably removed by hand, it is possible that in certain cases mechanized equipment will be required to extract a partially buried or heavy item. Finally, there could be instances where mechanized equipment will be necessary within this area to conduct miscellaneous activities that do not relate to typical beach debris removal or periodic renourishment activities. An example of such an instance occurred in July 2013, when a deceased juvenile humpback whale (*Megaptera novaeangliae*) was buried on the north Wallops Island beach; requiring use of a backhoe.

Educational Use of Wallops Island Beach - Students affiliated with NASA and the Chincoteague Bay Field Station of the Marine Science Consortium education programs regularly use Wallops Island beach for field trips and related activities. Such use of the beach occurs year-round with activity levels peaking during the summer months. Groups range in size from 5 to 20 students. These groups access the beach by either the north Wallops Island ORV access or the path east of the Island helicopter pad. Groups may only access the beach on-foot and must be under the supervision of a trained faculty or staff member.

Proposed and Ongoing Shoreline Restoration and Beach Renourishment Activities

The SRIPP is intended to use a multi-tiered approach to reduce damages to Wallops Island facilities from ongoing beach erosion and storm wave damage incurred during normal coastal storms including tropical systems and nor'easters. NASA has identified the SRIPP’s design target performance of providing significant defense against a 100-year return interval storm with respect to storm surge and waves. The performance is provided by a combination of the reconstruction of a beach, berm, and dune that will help to absorb and dissipate wave energy before it nears NASA infrastructure, and a rock seawall embedded within the dune that will protect against the most severe energy. For these features to provide reliable protection for the SRIPP’s design lifetime of 50 years, the beach must be maintained routinely throughout 50 year lifetime. The shoreline on the southern end of Wallops Island has been retreating at a rate of approximately 10 feet (ft) per year as a result of erosion (U.S. Army Corps of Engineers [Corps] 2010).

Seawall Repair - A seawall composed of large rock is currently located along 15,900 ft of the Wallops Island shoreline. This seawall was built in 1992 and protects WFF infrastructure within the northern portion of the eroding shoreline from damage due to storms and large waves. The wall has prevented overwash and storm damage, but erosion of the shoreline seaward of the wall has continued, resulting in an increased risk of damage to the seawall. NASA may repair and extend the existing rock seawall up to an additional 4,600 ft. Additional maintenance of the existing seawall may include operation of heavy equipment and placing or replacing dirt and/or rock in previously disturbed areas behind the seawall to maintain and augment the function of the existing seawall and protection resulting from these features.

In conjunction with construction activities, qualified biologists will continue to regularly survey the beaches in the vicinity of the project for use by sea turtles, plovers, and other species. If nesting activity of protected species is recorded, NASA will avoid work in areas where nesting occurs and/or implement other appropriate mitigation measures.

Shoreline Reconstruction Monitoring - As part of the SRIPP, NASA is conducting a shoreline monitoring program to record and document changes in shoreline characteristics over time as the project is subjected to normal weathering and storm events. The monitoring effort began prior to construction of the seawall, beach, and dune to establish a baseline condition and record any changes that occur between design and implementation.

A monitoring survey of the shoreline in the vicinity of Wallops Island is conducted twice a year. The first monitoring event is conducted along the entire lengths of Wallops and Assawoman Islands, a distance of approximately 8.5 miles. The second monitoring event is limited to the length of shoreline from Chincoteague Inlet south to the former Assawoman Inlet, which defines the south end of Wallops Island. In the cross-shore direction, elevation data is collected from behind the dune line to seaward of the depth of closure (the eastern edge of the underwater fill profile), estimated to be at approximately -15 to -20 ft below mean low water (MLW). Near Chincoteague Inlet the ebb shoal complex creates a large shallow offshore area; therefore, surveys in this area extend a maximum of 2 miles offshore if the depth of closure is not reached. These surveys will be repeated annually once at the end of summer (August to October) and once at the end of winter (March to May).

Cross-sections of the beach have been taken along new and/or previously established baselines on set stations every 500 ft from Chincoteague Inlet to Assawoman Inlet and every 1,000 ft from Assawoman Inlet to Gargathy Inlet. The beach surveys extend from the baseline to a depth of -4 ft below MLW offshore. An offshore hydrographic survey along the previously established baseline on set stations every 500 ft was conducted. The offshore survey extended from -3 ft below MLW to the depth of closure, anticipated to be between -15 to -20 ft below MLW. The hydrographic survey was conducted within 2 weeks of the beach survey. LIDAR data will continue to be obtained for the monitoring area approximately once a year. Both horizontal and vertical survey datum will be obtained. The survey of the beach, surf zone, and offshore area, will document changes in the Wallops Island shoreline in addition to areas adjacent to Wallops

Island. The results of these monitoring efforts are being used to measure shoreline changes to evaluate the performance of the project, potential impacts to resources, and to aid in planning renourishment when needed to ensure continued project function.

Beach Renourishment and Long-Term Project Maintenance - To maintain a beach and dune at a fixed location in a condition to effectively buffer wave energy, NASA plans beach renourishment cycles throughout the 50-year life of the SRIPP as determined by the proposed monitoring program. The location, extent, and magnitude of renourishment events may vary significantly as a result of the frequency and severity of storm activity and subsequent shoreline erosion. The availability of funding, logistical constraints, and other issues may also affect the implementation of renourishment. Even if renourishment is needed based on the modeled project performance and intent, NASA may choose to forego or delay renourishment because the project will retain most of its intended and designed storm protection function even if renourishment is not implemented as envisioned in the Programmatic Environmental Impact Statement (PEIS) (NASA 2010a).

The projected renourishment frequency and amounts are based on the modeled average rates of sand loss, with models based on the historic meteorological conditions recorded at and near the project area. Based on available modeling of project performance over time, the SRIPP identified an expected renourishment frequency of approximately every 5 years for the 50-year life of the project, but which may be as frequent as every 2 years or may be delayed to every 7 years. Based on the general characterization of function, the SRIPP estimates that each renourishment cycle will require approximately 806,000 cubic yards ($yd^{3)}$ of sand placed on the beach in each of the 9 renourishment events, for a total expected renourishment volume of 7,254,000 yd^3 of sand over the life of the project, excluding the amount required for the initial beach and dune reconstruction.

If future renourishments use sand of smaller grain size or reduced quality, more frequent renourishment or larger volumes of sand may be required. If there are changes in the pattern of sand movement along the shoreline, such as reduced southerly transport over time, renourishment may be needed less frequently. In the PEIS, NASA considers the addition of breakwaters or groins, and while not included in the current proposed action, addition of these features may result in reduced sand requirements.

The Wallops Island shoreline will experience effects of future sea level rise, and this has been anticipated by providing an additional sediment volume during each renourishment event that would raise the level of the entire beach fill by an amount necessary to keep pace with the projected rise rate (Corps 2010). Applying the Corps' standard sea level rise equation based on local measurements to a 50-year project at Wallops Island yields sea level elevations between 0.84 ft and 2.53 ft above present levels. For project planning purposes, a target fill volume 85 percent of the upper estimates of the amount needed to match the 50-year projected sea level rise was selected, but the SRIPP includes adding that volume in constant increments over time instead of in a pattern that would match anticipated increases. This means that in the early years of the project the amount of fill being added will exceed the amount necessary to match the expected amount with the crossover point being in the 28th year (2038) of the project. This way, the sea level fill volume could be increased, if needed, during later renourishment events. The sea level rise volume, which is an additional amount added during each renourishment event (assuming a 5-year interval between events), is 112,000 yd^3. Deviations from existing modeled or projected sea level rise scenarios may change the amount of sand needed for renourishment.

The number of uncertainties included in the projections resulting from the modeling, model assumptions, limitations of the records of past meteorological and climatological measurements in the area, current understanding of meteorological and climatic patterns, and future decisions of NASA and other agencies are likely to result in deviations from the projected renourishment.

Based on the information provided by NASA, we are analyzing effects of the proposed action assuming a renourishment frequency of every 5 years.

Sources of Sand for Renourishment – Three borrow sites have been identified as sources for potential future beach renourishment: the on-shore north Wallops Island borrow area, unnamed shoal A (the source of material for the initial beach/dune reconstruction), and unnamed shoal B (located east of shoal A). All of these sites have been determined to be consistent with the project purpose and suitable, but all have different costs and concerns associated with their use that must be evaluated prior to use in each proposed future renourishment.

Unnamed shoal A, the source of sand for the initial reconstruction, may be used as the source for renourishment. The shoal covers an area of approximately 1,800 acres and the total predicted volume of shoal A is approximately 40 million yd^3. The sand grain size (0.46 mm) is the largest of the 3 sources.

Unnamed shoal B is located offshore approximately 12 miles east of the southern portion of Assateague Island. This shoal covers an area of approximately 3,900 acres. The total predicted sand volume of this shoal is approximately 70 million yd^3. The average sand grain size is 0.34 mm and the transit distance from the shoal to the pump out location is approximately 19 miles.

The north Wallops Island borrow area is located on NASA property in the sand accretion zone on the northern end of Wallops Island. It is delineated for planning purposes as the seaward-most portion of the beach area where sand has accreted in recent years. The borrow area is approximately 150 acres in size. Excavation depth is expected to be limited to about 3.5 ft below the ground surface due to tidal fluctuations and high soil permeability. Up to half of the projected fill volume for each renourishment cycle could be provided by the north Wallops Island borrow site. The remaining half of the expected needed volume, or the entire volume, would be obtained from one of the offshore borrow areas. The mean grain size (0.20 millimeters [mm]) at the north Wallops Island borrow area is the smallest of the 3 sites considered and is currently below the target grain size for renourishment (but still within the suitable range). The average grain size in this borrow area is expected to increase following placement of material from shoal A in the initial beach and dune reconstruction as this larger material is transported to this accretion area. Material from a combination of the sources may be feasible for future renourishments, subject to constraints of future funding, permitting, logistics, and other considerations.

Sand Removal Methods – The proposed sand removal, transportation, and placement from either of the 2 offshore sites for future renourishment is planned to be the same as that discussed for the initial beach reconstruction project.

Sand from north Wallops Island will be removed from the beach using a pan excavator or other heavy earth-moving equipment. Sand will be stockpiled, loaded onto trucks, trucked to the off-loading point on the beach, and spread by bulldozers. Off-road dump trucks will likely be used and travel up and down the beach from the stockpile area to the fill site. However, road dump trucks could also be used in some circumstances. No constraints have been placed on the timing and methods of excavation at the north Wallops Island borrow area, but NASA has identified the intent to avoid excavation and disturbance near any plover nests, sea turtle nests, or occurrences of other listed species.

Action Area

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. In their BA, NASA determined that the action area encompasses the entire land area of Wallops Island, the shoreline and beaches of Assawoman Island, the aquatic environment adjacent to these lands, 3 borrow sites including unnamed shoals A and B, and north Wallops Island, and the waters through which dredges could transit from borrow sites to pump out areas. In addition to the action area defined by NASA, the Service has determined that the action area includes the: Hook and Overwash segments of Assateague Island; all of barrier islands from Metompkin Island to the south through the northern end of the Public Beach on CNWR; sea space over which rockets, projectiles, UAS, and surveillance aircraft can fly; sea space within which surface surveillance vehicles will operate; sea space within which jettisoned flight hardware can land under nominal or off-nominal flight conditions; and airspace within which Wallops-launched vehicles and surveillance aircraft can fly (Figure 1).

Figure 1. Action area for proposed and ongoing launch operations and SRIPP at WFF.

STATUS OF THE SPECIES AND CRITICAL HABITAT RANGEWIDE

Plover

The species description, life history, population dynamics, status and distribution, and critical habitat description, if applicable are at: Bent 1929; Wilcox 1939, 1959; Palmer 1967; Cairns 1977, 1982; Burger 1981, 1987, 1991, 1993, 1994; Johnsgard 1981; Tate 1981; Welty 1982; Tull 1984; Griffin and Melvin 1984; Haig and Oring 1985, 1988; Gibbs 1986; Gilpin 1987; Goodman 1987; MacIvor et al. 1987; Patterson 1988; Fleming et al. 1988; Canadian Wildlife Service 1989; Nicholls 1989; Riepe 1989; Cross 1990, 1996; Goldin 1990, 1993, 1994; MacIvor 1990; Strauss 1990; Rimmer and Deblinger 1990; Coutu et al. 1990; Eddings et al. 1990; McConnaughey et al. 1990; Bergstrom 1991; Patterson et al. 1991; Haig 1992; Loegering 1992; Hoopes et al. 1992; Melvin et al. 1992, 1994; Hake 1993; Hoopes 1993; Cross and Terwilliger 1993, 2000; Howard et al. 1993; Elias-Gerken 1994; Hoopes 1994; Thomas 1994; Jenkins and Nichols 1994; Melvin and Gibbs 1994; Loegering and Fraser 1995; Service 1996, 1998, 2002, 2009b, c; Watts et al. 1996; Canale 1997; Wolcott and Wolcott 1999; Jenkins et al. 1999; Erwin et al. 2001; Lauro and Tanacredi 2002; Mostello and Melvin 2002; National Park Service 2003, 2007; Melvin and Mostello 2003; Seymour et al. 2004; Amirault et al. 2005; Noel et al. 2005; Daisey 2006; Stucker and Cuthbert 2006; Cohen et al. 2006, 2009; Boettcher et al. 2007; Brady and Inglefinger 2008; Hecht and Melvin 2009; Miller et al. 2010; Hecht et al. 2014; and Davis 2015.

Knot

The species description, life history, population dynamics, status and distribution, and critical habitat description, if applicable are at: Wander and Dunne 1982; Dunne et al. 1982; Davis 1983; Kochenberger 1983; Harrington et al. 1986, 1988, 2007, 2010; Summers and Underhill 1987; Morrison and Ross 1989; Titus 1990; Tomkovich 1992, 2001; Morrison and Harrington 1992; Piersma and Davidson 1992; Zwarts and Blomert 1992; Piersma et al. 1993, 1999; Harrington 1996, 2001, 2005a, 2005b, 2008; Antas and Nascimento 1996; Cadee et al. 1996; Gonzalez et al. 1996, 2006; Nordstrom 2000; Piersma and Baker 2000; Brown et al. 2001; Nordstrom and Mauriello 2001; Morrison et al. 2001a, b, 2004, 2006; Atkinson et al. 2002; Blomqvist et al. 2002; Buehler 2002; Greene 2002; Ferrari et al. 2002; Scavia et al. 2002; Philippart et al. 2003; Schekkerman et al. 2003; Piersma and Lindstrom 2004; Baker et al. 2004, 2005; Gonzalez 2005; Buehler and Baker 2005; Peterson and Bishop 2005; van Gils et al. 2005a, b; Morrison 2006; Buehler et al. 2006; Guilfoyle et al. 2006, 2007; Karpanty et al. 2006, 2011, 2012, 2014; Peterson et al. 2006; Anderson 2007; Burger et al. 2007, 2011, 2012a, b; Kuvlesky et al. 2007; Meltlofte et al. 2007; Kalasz 2008; Niles et al. 2008, 2010, 2012; Andres 2009; Gerasimov 2009; Rice 2009, 2012; Watts 2009, 2010; Clark et al. 2009; Cohen et al. 2009, 2010, 2011; Defeo et al. 2009; Lott et al. 2009; Titus et al. 2009; Service 2011b, 2012, 2014c; Schneider and Winn 2010, Bhatt et al. 2010; Conklin et al. 2010; Smith et al. 2010; Dey et al. 2011, 2014; Duerr et al. 2011; Niles 2011a, b, 2013, 2014; Piersma and van Gils 2011; McGowan et al. 2011; Smith et al. 2011; Hurlbert and Liang 2012; Scherer and Petry 2012; Anderson et al. 2012; Escudero et al. 2012; Feng et al. 2012; Musmeci et al. 2012; Schwarzer et al. 2012; Burger and Niles 2013a, b; Smith and Stephenson 2013; Carmona et al. 2013; Gill et al. 2013; Grabowski et al. 2013;

Iwamura et al. 2013; Newstead et al. 2013; Root et al. 2013; Bauers 2014; Jordan 2014; Newstead 2014; Russell 2014; Bimbi et al. 2014; Galbraith et al. 2014; Liebezeit et al. 2014; and Wallover et al. 2014.

Loggerhead

The species description, life history, population dynamics, status and distribution, and critical habitat description, if applicable are at: Dolan et al. 1973; Hosier et al. 1981; Carr 1982; Mrosovsky et al. 1984; Anders and Leatherman 1987; Nelson and Dickerson 1987, 1988; Nelson et al. 1987; Dodd 1988; Christens 1990; National Research Council 1990; National Marine Fisheries Service (NMFS) and Service 1991, 2007, 2008; Cox et al. 1994; Witherington and Martin 1996, 2003; Bouchard et al. 1998; Hanson et al. 1998; Steinetz et al. 1998; Bollmer et al. 1999; Turtle Expert Working Group 2000; Snover 2002; Avens 2003; Bolten 2003; Lohmann and Lohmann 2003; Carthy et al. 2003; Ehrhart et al. 2003; Miller et al. 2003, Schroeder et al. 2003; Bowen et al. 2005; Hawkes et al. 2007; and Service 2011a, 2014b.

ENVIRONMENTAL BASELINE

Status of the Plover Within the Action Area - Plovers use wide sandy beaches on Metompkin, Assawoman, Wallops, and Assateague Islands for courtship and nesting. Suitable habitat has a variable distribution along the seaward edge of islands within the action area year-to-year due to the competing effects of erosion and vegetation succession. Annual plover production within the action area indicates that all islands possess some nesting habitat, with the most extensive areas of suitable beach occurring on Assawoman Island and in the Hook, Overwash, and Public Beach portions of Assateague Island (Service 2009a). Metompkin Island supports large numbers of plovers, with larger numbers occurring in the portion owned by The Nature Conservancy (TNC) (Smith et al. 2009). Little potential habitat is available for plover nesting on the south end of Wallops Island, but the north end of Wallops Island has been rapidly accreting and appears to offer increasing quantities of wide sandy beach on which plovers may seek to nest. Shoreline restoration created a substantial increase in beach available on Wallops Island north of the reconstructed seawall and south of the north Wallops Island area (NASA 2015b).

In 2009, the Service documented 3 plover nests that fledged 1 chick on the Assateague Island Overwash and 23 pairs that fledged 12 chicks on Assateague Island Hook (Service 2009a). In 2009, 42 pairs of plovers nested on Metompkin Island and fledged 51 chicks (Smith et al. 2009). In 2009, 26 pairs of plovers nested on Assawoman Island and fledged 31 chicks (Service 2009a). In 2010, the Service documented 32 plover nests on Assateague Island that fledged 54 chicks and 24 plover nests on Assawoman Island that fledged 35 chicks. On North Metompkin Island, 3 plover nests fledged 4 chicks (Service 2014a).

In 2011, the Service documented 27 plover nests on Assateague Island that fledged 41 chicks and 32 plover nests on Assawoman Island that fledged 52 chicks. On North Metompkin Island, 8 plover nests fledged 11 chicks. In 2012, the Service documented 20 plover nests on Assateague Island that fledged 9 chicks and 39 plover nests on Assawoman Island that fledged 78 chicks. On

North Metompkin Island, 11 plover nests fledged 15 chicks. In 2013, the Service documented 31 plover nests on Assateague Island that fledged 29 chicks and 40 plover nests on Assawoman Island that fledged 60 chicks. On North Metompkin Island, 14 plover nests fledged 15 chicks. In 2014, the Service documented 33 plover nests on Assateague Island that fledged 58 chicks and 40 plover nests on Assawoman Island that fledged 71 chicks. On Metompkin Island, 10 plover nests fledged 18 chicks. In 2014, the Service documented 42 plover nests on Assateague Island that pledged 70 chicks, and 40 plover nests on Assawoman Island that fledged 71 chicks. On Metompkin Island, 53 plover nests fledged 82 chicks. In 2015, the Service documented 47 plover nests on Assateague Island that fledged 59 chicks, and 33 plover nests on Assawoman Island that fledged 28 chicks. On Metompkin Island, 61 plover nests fledged 78 chicks (Service 2014a).

NASA documented 4 plover nests on the northern end of Wallops Island in 2009, which successfully fledged 10 chicks. NASA initiated a formal monitoring program in 2010, and documented 4 plover nests on the northern end of Wallops Island. Two nests were washed out before eggs hatched, 1 was predated and the final nest fledged 4 chicks successfully (NASA 2010b). The 2011 nesting season produced 3 plover nests on Wallops Island with 1 nest on the south beach and 2 nests on the north beach. The 3 nests fledged 3 chicks each (NASA 2011).

The 2012 nesting season yielded 6 nests on north Wallops Island and the recreational beach; however, due to predation and inundation from storm tides, only 1 nest fledged chicks (NASA 2012b). In 2013, NASA undertook a similar monitoring effort, during which 3 nests were found on north Wallops Island and the recreational beach. Two nests had a 100 percent fledge rate and the third had a 50 percent fledge rate (NASA 2013).

In 2014, 5 nests were found on the recreational beach and the north end of Wallops Island. Nest success during 2014 ranged from 66 percent with 2 of 3 chicks fledging from 1 nest, to another being completely unsuccessful with 0 of 3 chicks fledging due to predation. The remaining 3 nests experienced fledge rates of 25 percent (n=2) and 50 percent (n=1) (NASA 2014b).

In 2015, NASA conducted plover surveys 3-4 times per week from March through August and documented 6 nests. Three nests were found on the recreational beach, 2 nests were found on north Wallops Island, and for the first time since renourishing the beach, 1 nest was discovered between the 2 Navy facilities (V-010/V-020 and V-024) on mid-Wallops Island (NASA 2015b). The 6 nests fledged a total of 8 chicks (NASA 2015b).

Most plovers that nest farther north within the Atlantic population are likely to pass through the action area during migration between mid-February and mid-May in the spring and from mid-July to mid-October in the fall. This may involve birds passing through in flight, but many of these birds may stop and roost or feed on beaches, tidal flats, and overwash areas within the action area. Little is known about the extent of use of the action area by migrating plovers beyond knowledge that they use the area.

<u>Status of the Knot Within the Action Area</u> – Following migration from southern overwintering areas, the majority of knots arrive in the mid-Atlantic between late April and early June. The

Delaware Bay has long been regarded as the final and most crucial stopover during the springtime northern migration. At this stopover, the birds gorge on eggs of spawning horseshoe crabs (*Limulus polyphemus*) in preparation for their nonstop flight to the Arctic (Karpanty et al. 2006). Wallops Island also provides important stopover habitat (Watts and Truitt 2015).

The majority of knot activity on Wallops Island historically occurred on the north end of the island, well north of launch Complex 0 (NASA 2012b, 2013, 2014b). During monitoring efforts in 2012, observed flocks ranged in size from less than 10 to approximately 675 individuals (NASA 2012b). All observed knots were on the recreational beach and north end “curve” of Wallops Island (NASA 2012b, 2013, 2014b). In May 2013, NASA observed flocks of knots on Wallops Island ranging in size from approximately 20 to 1,160 individuals (NASA 2013). During 2014, the fewest numbers of knots, 87 individuals, were observed on Wallops Island since NASA began its protected species monitoring in 2010 (NASA 2014b). In 2015, the numbers of knots on Wallops Island beach peaked in late May, during which total counts exceeded 500 individuals (NASA 2015b). Although the potential exists for knot foraging activity to occur within the renourished beach area adjacent to the launch pads, their presence on the regularly nourished beach is unlikely due to the suppressed forage base and resultant lower habitat value.

Knots have been observed on Assawoman, Metompkin, and Assateague Islands. Assawoman Island had a range of knots, from 26 birds in 2009 to 420 in 2013; averaging 73 birds per survey. Metompkin Island averaged 376 birds per survey; from approximately 30 birds in 2008 to a high of 1,853 birds in 2014. Assateague Island averaged 154 birds per survey; from approximately 60 birds in 2005 to 522 birds in 2007.

<u>Status of the Loggerhead Within the Action Area</u> – The loggerhead occurs in waters adjacent to and offshore of islands within the action area. Loggerheads are known to occasionally nest within the action area. In mid-July 2008, a loggerhead nest was discovered by NASA personnel on north Wallops Island. Following flood inundation from several fall storms, CNWR personnel recovered approximately 170 non-viable eggs from the nest in October 2008.

In 2010, NASA documented 4 nests and 2 false crawls. Three nests were located on the recreational beach, with the fourth located to the south in front of the rockwall. The recreational beach nests showed a hatch success from 49 to 52 percent. The southern nest showed a much lower success rate of approximately 2 percent. DNA analysis determined that all 4 nests were dug by a single female (NASA 2010b). No loggerhead nesting activity was observed in 2011. In 2012, NASA documented 2 loggerhead nests. The first nest was located in June within the recreational beach and was ultimately predated. In early July, 2 false crawls on different days led to a nest on the crest of the newly constructed dune just east of Navy Building V-010. After the closure of the hatch window, the nest was excavated and showed a success rate of approximately 78 percent (NASA 2012b). In late July 2013, NASA located a false crawl and 2 loggerhead nests on Wallops Island beach. The first nest was located just north of launch pad 0-A, and the second was discovered north of the HIF (NASA 2013). The southernmost nest had an approximately 80 percent hatch rate, whereas the nest near the HIF was inundated during an October storm and was unsuccessful. No evidence of sea turtle nesting was documented on Wallops Island in 2014 or 2015 (NASA 2014b, 2015a).

A low level of sea turtle nesting has become relatively common on CNWR (Service 2009d). Table 2 provides recorded nesting behavior for loggerheads within the action area.

Table 2. Loggerhead nest activity within the action area from 1974 - 2015 (Service 2009d, 2015).

Location	**False Crawls**	**Nests**	**Total Activity**
Metompkin Island	0	0	0
Assawoman Island	1	0	1
Wallops Island	9	13	22
Assateague Island - Hook	19	5	24
Assateague Island - Overwash	7	5	12

Factors Affecting the Species Environment Within the Action Area – Listed species on Wallops Island are affected by a suite of existing actions associated with flight operations and support operations performed by NASA, various military branches, Mid-Atlantic Regional Spaceport, and private contractors. Wallops Island is primarily owned and managed by NASA with operations by the Navy onsite. The portions of Assateague and Assawoman Islands within the action area are part of the Service's CNWR. Metompkin Island is composed of private lands with the majority owned by TNC and managed as a natural area. Wallops, Assateague, Assawoman, and Metompkin Islands are managed to conserve natural resources, including listed species. Plovers, knots, and loggerheads are potentially impacted by ongoing rocket launches and related training, testing, and preparation; maintenance of existing buildings and infrastructure; shoreline restoration and construction of shoreline stabilization structures; and operation of UASs and aircraft overhead, primarily launched from Wallops Main Base.

On Wallops Island, Service lands, and TNC lands within the action area, personnel actively manage to minimize and prevent invasive vegetation. *Phragmites* is found on all islands within the action area and is controlled with herbicides on Wallops, Metompkin, and Assawoman Islands, and in the Hook and Overwash areas of Assateague Island. NASA, the Service, Virginia Department of Game and Inland Fisheries (VDGIF), TNC, contractors, and universities conduct surveys for breeding birds and sea turtle nests. Predator control of mammalian and avian predators occurs on both Wallops Island and CNWR. These efforts affect both plover and loggerhead reproduction within the action area by increasing human activity in areas of use by plover, knot, and loggerheads. Plovers and knots may be startled by increased activity and plover nesting attempts may be disturbed, causing a reduction in nesting success. Activity in the vicinity of beaches used by loggerhead for nesting may reduce nesting attempts or hatching success.

Recreational use of CNWR and the northern portion of Wallops Island (NASA personnel after-hours recreational area) occurs seasonally, with most activity concentrated in spring and summer months. On CNWR, limited seasonal use of recreational vehicles on the beach occurs. Other recreational use includes wildlife observation, sunbathing, and other typical beach recreation. CNWR staff post signage and implement closures to aid in protecting sensitive resources and routinely patrol the beach and recreational use areas. Plovers and knots may be disturbed during foraging or sheltering by activity on the beach during shorebird migration. Seasonal recreational use overlaps with plover and loggerhead nesting season and may disturb nesting attempts or reduce hatching success for loggerhead or hatching and fledging success for plovers in these areas.

Storms and ocean currents contribute to erosion, accretion, and sand transport along the islands within the action area. NASA reports an erosion rate of 3.3 m/year on southern Wallops Island. Similar erosion has occurred on portions of Assawoman Island. In contrast, the beach on the north end of Wallops Island has been rapidly accreting, and the feature known as Fishing Point, the southernmost point of land on the Hook section of CNWR, has been similarly accreting. This mass movement of sand influences where exposed sandy beach habitat will be available for plovers and loggerheads in any given year. Storms occur frequently, with widely varying effects on the shoreline and beach habitats. Both tropical storms and nor-easters (winter low pressure systems that tend to hug the Atlantic coast) can greatly alter the profile and amount of beach habitat among years, and these storms create and maintain the overwash areas where most plovers nest.

The beach and dune habitat found on the seaward side of islands within the action area is prone to stabilization and vegetation succession proceeding from sheltered areas toward areas more exposed to overwash and erosion during storms. This can render areas unsuitable for plover use and loggerhead nesting. Wild bean (*Strophostyles holvola*) has been discovered on the southern end of Assawoman Island. The growth habit of this native plant may limit plover nesting habitat on the island in the future. Asiatic sand sedge (*Carex kobomugi*) has been found on the beach dune near the southern end of Wallops Island. This invasive non-native species has not spread significantly from where it was first observed, but it represents a potential threat because of its potential to spread and reduce the suitability of habitat for plovers and possibly loggerheads.

Recreational boating and fishing is common immediately offshore of all of islands within the action area. Some boat landings and recreational use of otherwise inaccessible beaches occurs, both permitted and illegally. The Chincoteague inlet, a well-used channel located between CNWR and Wallops Island, is maintained to provide boat passage from the ocean to Chincoteague Bay. Use of these beaches has caused disturbance to migrating, foraging and rest plovers and knots and may have discouraged nesting by loggerheads.

During launches, NASA implements closures of areas of both land and water adjacent to launch sites to ensure safety. The U.S. Coast Guard enforces such closures. NASA also has controlled airspace in the vicinity of both Wallops Island and Wallops Main Base. Controlled airspace is closed during launches and potentially during military air operations and training; however, during periods when operations are not ongoing, civilian flight traffic may occur. Civilian flight traffic may cause a startle response in plovers or knots, reducing their ability to forage, shelter or nest within controlled airspace. Loggerheads may be discouraged from nesting attempts.

Navy and NASA facilities on Wallops Island are equipped with exterior lights at ground level, along catwalks, and at FAA mandated heights for aircraft orienteering. Exterior lights can disorient hatchling loggerheads and may cause them to crawl toward the light rather than into the surf (NASA 2010a).

EFFECTS OF THE ACTION

Direct and Indirect Effects – Direct effects are the direct or immediate effects of the project on the species, its habitat, or designated critical habitat. Indirect effects are defined as those that are caused by the proposed action and are later in time, but still are reasonably certain to occur (50 CFR 402.02).

Table 3. Expected direct and indirect effects of the proposed actions.

	Direct and Indirect Effects					
Action	**Noise**	**Vibration**	**Rocket Exhaust**	**Use Related Disturbance**	**Lighting**	**Habitat Loss/Suitability**
Liquid Fueled ELV Launches	X	X	X		X	
Solid Fueled ELV Launches	X	X	X		X	
ELV Static Fires	X	X	X		X	
Sounding Rocket Launches	X	X	X		X	
Sounding Rocket Static Fires	X	X	X		X	
Disposal of Defective or Waste Rocket Motors	X		X			
Drone Target Launches	X	X	X		X	
UAS Flights	X	X			X	
Piloted Aircraft Flights	X	X			X	
Restricted Airspace Expansion	X					
Range Surveillance/Facility Security	X			X		
Construction	X				X	
Routine Facility Maintenance	X					
Launch Pad Lighting					X	
Recreational/ ORV Beach Use				X		
Protected Species Management				X		
Miscellaneous Activities on Wallops Island Beach				X		
Education Use of Wallops Island Beach				X		
Seawall Repair				X		
Shoreline Reconstruction Monitoring				X		
Beach Renourishment				X		X

Noise

Effects on plover, knot, and loggerhead from liquid fueled ELV launches, solid fueled ELV launches, ELV static fires, sounding rocket launches, sounding rocket static fire testing, disposal of waste rocket motors, drone target launches

Support activities prior to a rocket launch include transportation of rocket parts between storage facilities and the launch complex and other associated activities. Support activities often result in an increase in noise and general activity due to additional presence of people in the vicinity of the rocket launch areas. Increased noise from support activities may disturb loggerheads attempting to nest and nesting plovers on the sound end of Wallops Island.

Ignition of rocket engines for orbital launches or static tests will produce instantaneous noise audible for a considerable distance from Launch Complex 0. In close proximity to the launch sites, the noise generated will be high intensity across a broad range of frequencies. Sound intensity may exceed 160 decibel (dB) on the beach and dune in close proximity to launch sites. The WFF Range Safety Office, using the NASA rocket size/noise equation (NASA 2009), estimated noise levels expected to occur during launches of envelope vehicles from each launch pad in the complex. An LMLV-3(8) rocket launched from pad 0-B will produce a noise level of 129 dB at 1.1 kilometer (km), attenuating to 108 dB up to 12.6 km from pad 0-B. As many as 12 such launches could be performed per year at pad 0-B. Noise levels from static tests performed at pad 0-A would reach 124 dB within a 1.55 km radius, attenuating to 108 dB at a distance of 9.6 km from pad 0-A. As many as 6 launches and 2 static tests could be performed per year at pad 0-A. These noise levels are expected to be sustained for 30 to 60 seconds during a launch and for up to 52 seconds during a static test. Plover and loggerhead nests may occur within 100 m of the launch sites, and when they occur between 100 m and 1.55 km of launches, they will be subjected to high intensity sound. The majority of knot activity on Wallops Island occurs on the north end of the island, more than 3 km north of Pad 0-A (NASA 2012b, 2013, 2014b). Knot presence on the regularly nourished beach is unlikely due to the suppressed forage base. It is unlikely that knot would be subjected to high intensity sound on north Wallops Island.

Deafening of plovers, knots, and loggerheads is not expected at the decibel levels predicted at 1.1 to 1.5 km from launches, but progressively closer to the rockets, the noise intensity may reach levels that could cause tissue damage. While not known in birds specifically, sound intensity of near 180 dB can result in nearly instantaneous tissue damage (McKinley Health Center 2007). Exposure to noises within these radii could deafen plovers or knots present during ignition if exposed to high intensity noise. Deafness would significantly impair the ability of a plover or knot to breed, shelter, and behave normally. In addition to deafening, low frequency and high intensity sound expected in very close proximity to the launch sites may be debilitating and cause disorientation or loss of balance, but these effects are not well established (Leventhall et al. 2003). Birds may be able to recover from sound-induced deafening over time (Adler et al. 1995), but some period of deafness may result from loud noises. Birds may recover from disorientation and other sound-induced effects, but the amount of time required is not known for plover or knot.

Debilitated birds will be subject to increased vulnerability to predators and physiological stress, resulting from inability to detect and avoid predators, feed, care for eggs/young, and seek shelter.

Burger (1981) demonstrated startle effects in birds exposed to anthropogenic sound pressure of 108 dB. Within 9.6 km of pad 0-A, such noise levels will occur as a result of rocket launches or static tests as many as 20 times per year. Several other sources of loud noises exist in the action area. Anthropogenic sources include: sounding rocket and drone target launches from Wallops Island, waste engine disposal at the open burn area on Wallops Island, and aircraft landing and taking off from Wallops Main Base and the UAS runway on Wallops Island. Collectively, several thousand such events take place within WFF annually (NASA 2005, 2015b). Some of these activities produce noise levels similar to the noise expected to be produced by the large rocket launches. While many of these sounds are of similar intensity, the frequency of the sounds varies, with noise generated from rocket launches generally in the low frequency range and aircraft noise generally in higher frequency ranges.

Plovers and knots not debilitated by high intensity noise are expected to be disturbed by launches and exhibit a startle response that interferes with normal behaviors, including breeding, feeding, and sheltering. It is not likely that plovers and knots will startle or flush from all of the relatively intense sound disturbances. Individual birds may become habituated to the noises. Some of the noises are likely below the disturbance threshold, will be attenuated by atmospheric conditions, or may occur during periods of elevated natural noise intensity (e.g., strong winds, large waves) so that the noises would be less intense relative to background noise levels.

In response to high intensity noises, plovers are not expected to permanently abandon nests, but may flush from nests. More significant effects result from exposure to predators as a result of flushing. This species relies largely on its cryptic coloration and concealment for protection from predators, and flushing from nests will alert predators to the location of the nest and leave eggs or chicks exposed. Startle responses to noises and associated visual stimuli are expected to result in an incremental reduction in nest success and/or chick survival. Knots are not expected to permanently abandon migratory stopover locations, but may flush from Wallops Island roosting or foraging locations, resulting in an expenditure of energy.

Atmospheric noise has been demonstrated to prevent loggerheads from entering an area (Manci 1988). In the beach areas adjacent to rocket launch pads, the high intensity noise that occurs during rocket launches is expected to prevent loggerheads from coming ashore to nest. The intensity of noise close to launch pads is not expected to be sufficient to impair development of loggerhead eggs. Sand above the eggs is expected to attenuate the sound, but the degree of attenuation is not known. Noise is not expected to have an effect on loggerheads that come ashore to nest in habitat not located in the vicinity of the launch pads.

Effect on plover and knot from UAS flights, piloted aircraft operation, expansion of restricted airspace, range surveillance, and facility security

Jones et al. (2006) reported that wading birds were not disturbed by UAS overflights in excess of 100 m above the birds. Similarly, Sarda-Parlomera et al. (2012) did not observe notable responses when they repeatedly overflew black-headed gull (*Chroicocephalus ridibundus*) colonies with small UAS at altitudes between 20 and 40 m AGL. Most UAS flights originating from the north Wallops Island airstrip are expected to maintain at least 152 m AGL except during landing and take-off (NASA 2012a). Therefore, UAS flights conducted from north Wallops Island airstrip have a minimal potential for disturbing plovers or knots.

Peak noise levels generated by aircraft at WFF range from 67 dB for a single-engine propeller airplane landing on Wallops Main Base to 155 dB for an F-18 conducting a touch and go maneuver at Wallops Main Base. Studies of the effects of helicopter overflight on waterbirds have shown (1) temporary behavioral response to low-altitude overflight, ranging from assuming an alert posture to taking flight; (2) responses decreasing in magnitude as overflight elevation increases; and (3) rapid resumption of the behaviors exhibited prior to the overflight (Komenda-Zehnder et al. 2003). Early research in Florida detected limited adverse effects when a helicopter overflew nesting waders (Kushland 1979). The majority of birds overflown did not exhibit any response to the stimulus and those that left their nests returned in less than 5 minutes. Smit and Visser (1993) found shorebirds and curlew to be particularly sensitive to helicopter overflights at less than 250 m AGL, resulting in flushing of 33 to 75 percent of birds overflown, depending on the species. Flushing a bird from its nests can result in a range of potential adverse effects, from predation or abandonment of the chicks to unnatural energy expenditure of the parents.

Plovers may be disturbed by the operation of aircraft maneuvering or overflying the area where nesting occurs. Not all aircraft operation is likely to result in disturbance, and plovers are most likely to be disturbed by flights at low altitude down the beach or just offshore. Effects to plovers may include flushing from nests when incubating eggs, interruption of feeding or courtship, or similar responses. Effects to knots may include interruption of feeding or sheltering behaviors. Most noises are of short duration and plovers and knots are expected to return to normal behavior within a few minutes of the noise.

Potential effects on waterbirds can be reduced substantially if helicopters maintain minimum altitudes of at least 450 m (Komenda-Zehnder et al. 2003). Birds may become habituated to aircraft overflight in an area of somewhat regular disturbance, such as the marshes between Wallops Main Base and Island or along the Wallops Island beach. Birds in more remote areas subject to surveillance flights, such as the barrier islands south of Wallops Island, could be more sensitive to overflights. NASA determined in their BA that maintaining an altitude in excess of 450 m would be possible for aircraft transiting from the Main Base airfield to an offshore surveillance area; however, aircraft conducting surveillance operations between Wallops Mainland and Island will be required to fly below 450 m, which is expected to startle plovers and knots. Most noises are of short duration and plovers and knots are expected to return to normal behavior within a few minutes of the noise.

There is potential for a bird strike to occur (Washburn et al. 2014). Bird strikes are most common in months when plovers and knots are not expected to be present, with 51 percent of strikes occurring between September and February (Washburn et al. 2014). In addition, airfield activities conducted at Wallops Main Base are not expected to strike plovers or knots, as there is no suitable habitat present adjacent to the airfield. The new UAS airstrip is located in closer proximity to suitable habitat for plovers, although it will be located inland and away from nesting, foraging and roosting areas. Although it is possible that plovers or knots may be involved in a bird strike with aircraft it is likely to be a rare occurrence.

The expansion of restricted airspace is likely to result in similar effects to those expected as a result of UAS and piloted aircraft operation, simply in an expanded area. There is no expected change to either the types of aircraft or the types and number of operations conducted within the airspace adjacent to WFF. As a result, the scale of overall impacts will not change, rather, they will be spread over a larger geographic area. Knots or plovers may be impacted by flights at low altitude or just offshore by disturbance to migrating behavior as described above.

Effect on plover, knot, and loggerhead from construction and routine facility maintenance

Construction will increase noise as a result of the presence of additional people and associated activities. Potential effects will be confined to the vicinity of the new fire station location adjacent to Navy Building V-024 and are not expected to result in more than minor behavioral responses from all 3 species.

Road resurfacing and infrastructure replacement will use heavy equipment and may elicit a startle response from plovers and knots in response to increased noise. Effects to loggerheads are unlikely as infrastructure projects are not located in proximity to areas used for nesting attempts.

Routine repairs are often required after hurricanes or intense storms. Heavy equipment is used to clear roads and stormwater systems. Activities conducted away from the beach are less likely to affect listed species. Maintenance activities on the beach are likely to create a startle response and may cause plovers or knots to temporarily cease foraging or resting and plovers may temporarily cease nesting.

Effects of noise from construction and routine maintenance to plovers may include flushing from nests when incubating eggs, interruption of feeding or courtship, or similar responses. Effects to knots may include interruption of feeding or sheltering behaviors. Most noises are of low intensity but long duration and plovers and knots are expected to habituate to the noise and return to normal behavior over time.

Vibration

Effect on plover, knot, and loggerhead from liquid fueled ELV launches, solid fueled ELV launches, ELV static fires, sounding rocket launches, sounding rocket static fire testing, drone target launches, UAS flights, piloted aircraft flights

Some energy from rocket launches, static tests, drone target launches, UAS flights, and piloted aircraft flight on Wallops Island will manifest as vibration in the ground near the launch pad or airstrip. Vibration may be significant from rocket launches, engine tests, and open burns. Effects from vibrations are likely to be confined to an additive disturbance to adult plovers, adult knots, and nesting loggerheads that may cause birds and turtles to temporarily cease normal behaviors. Due to the distance between rocket launch sites and nesting habitat for plovers and loggerheads, it is unlikely that vibrations will be significant enough to affect egg viability. Vibration at other NASA launch facilities has not been demonstrated to harm bird or sea turtle eggs (NASA 2009). In potential habitat close to launch sites, vibrations may be significant enough to affect egg viability for plovers and loggerheads nesting within the new beach. Knot activity in the vicinity of Launch Complex 0 is low; therefore effects to knots from vibration are unlikely.

Rocket Exhaust

Effect on plover, knot, and loggerhead from liquid fueled ELV launches, solid fueled ELV launches, ELV static fires, sounding rocket launches, sounding rocket static fire testing, disposal of waste rocket motors, drone target launches

Rocket exhaust from Pad 0-B is directed over the Atlantic Ocean by a vent located in the base of the gantry. Exhaust from launches and static tests at Pad 0-A is directed over the Atlantic Ocean through a flame trench in the launch pad. Wildlife within 200 to 300 m of the exhaust ports during engine ignition may be injured or killed. Plovers, knots, or loggerheads exposed directly to the exhaust could be burned by hot gas or by caustic combustion products. To be exposed, birds would need to be flying through the path of the exhaust plume at the time of ignition. Given the distribution of knot and plover habitat north and south of the launch complex and the likelihood that individual plovers will move around while establishing breeding territories or feeding and a plover or knot will likely pass through the area during migration, plovers and knots may be injured due to rocket exhaust, but the likelihood of this occurring is low. In 2013, a loggerhead nest was located just north of Pad 0-A suggesting that loggerheads may nest in proximity to the launch pads in the future and hatchlings or adults may be injured by hot exhaust.

Aluminum oxide particles in the atmosphere are efficient scavengers of water vapor and hydrogen chloride, and these particles produce hydrochloric acid. The combination of atmospheric and oceanic dilution and the buffering capacity of the ocean will prevent hydrochloric acid from impacting pH of habitats within the action area. Hydrogen chloride vapor may exist in hazardous quantities in the immediate vicinity of launch pad 0-B at the completion of a launch. A plover or knot flying through the area could be exposed to a caustic cloud of such vapor; however the disturbance of the launch event itself would likely repel birds from the immediate area for some time after engine ignition. Therefore, hydrochloric acid is not expected to adversely affect plovers, knots, or loggerheads (NASA 2005, 2009).

Estimates of carbon monoxide concentrations on the beach at the south end of Wallops Island following a launch or static test at either pad in Launch Complex 0 are between 0.9 and 1.1 parts per million, depending on weather conditions. These are below human exposure thresholds and believed to be below observable effects thresholds in wildlife. Atmospheric mixing and conversion of carbon monoxide to carbon dioxide will quickly diminish these concentrations; therefore, the concentration of carbon monoxide is not expected to adversely affect plovers, knots, or loggerheads (NASA 2005, 2009).

Lighting

Effect from liquid fueled ELV launches, solid fueled ELV launches, ELV static fires, sounding rocket launches, sounding rocket static fire testing, drone target launches, UAS flights, piloted aircraft flights, construction, launch pad lighting

Plover and knot - Rockets staged at Launch Complex 0 are up lit with metal halide lighting for up to several weeks prior to and several weeks following a launch. Other structures within the launch complex use amber LEDs or low pressure sodium bulbs for exterior night lighting. The close proximity of several facilities to the newly created beach is likely to result in elevated levels of light at this beach.

Other structures within the launch complex, as well as Payload Fueling Facility, Payload Processing Facility, and HIF, use amber LEDs or low pressure sodium bulbs for exterior night lighting. Additional lighting may also be used during construction of new facilities. Most of the existing and new facilities are not located immediately adjacent to the beach, which limits the potential effects on listed bird species; however, they do contribute to elevated levels of ambient lighting, and are some of the only lights on barrier islands within the action area. Amber LED and low-pressure sodium fixtures reduce the potential for negative impacts to wildlife. Such night lighting is expected to affect nesting plovers by leading to nest failure.

Anthropogenic lighting attracts migrating birds, especially during times of reduced visibility. Potential effects can range in intensity from collision with structures resulting in injury or mortality, to lesser effects including expenditure of energy or delay in arrival at breeding or wintering grounds (Gauthreaux and Belser 2006). The majority of Atlantic Coast piping plover migratory movements are thought to take place along a narrow flight corridor, including the outer beaches of the coastline, with rare offshore and inland observations (Service 1996). Plover visual acuity and maneuverability are known to be good (Burger et al. 2011), including night vision (Staine and Burger 1994), suggesting that plovers may be able to identify and avoid structures in their flight paths. Plover collisions with fixed structures in the coastal zone are rarely documented (Service 2008). The ability to avoid structures, such as the infrastructure on Wallops Island, could be reduced in poor visibility conditions (Burger et al. 2011). Migrating plovers may be attracted by the lighting on Wallops Island.

Migrating knots may be exposed to similar risks. Burger et al. (2011) report knot migration flights occurring at altitudes between 1,000 and 3,000 m AGL, well above the structures on Wallops Island. The most serious risk is likely to occur when northbound long-distance migrants make landfall at foraging areas. Wallops Island is a known stopover site for northerly migrating knots; however, the high-use areas are located well north of the Wallops Island infrastructure that may pose a risk to birds landing to rest or forage, resulting in a low likelihood of collision. Southbound migrants are at comparatively less risk due to their farther offshore flight paths. Although visual acuity and maneuverability of knots are known to be good (Burger et al. 2011, Cohen et al. 2011), inclement weather conditions could increase collision risk.

Lighting on Wallops Island may attract migrating plovers or knots and effects are expected to result in temporary diversion of flight or excess energy expenditure.

Loggerhead - Anthropogenic light sources have documented negative effects on sea turtles. Unshielded lights can deter females from crawling onto a beach to nest. Bright full-spectrum or white lighting within view from the beach can cause female sea turtles to abandon nest attempts (Witherington 1992). At hatching, juveniles emerge and seek the nearest available light source, which on an undeveloped beach is the horizon over the ocean. Bright full-spectrum or white lighting shining in the vicinity of a nest can disorient emerging hatchlings, leading them away from the ocean and leaving them more vulnerable to predation, desiccation, or crushing by vehicles (Witherington and Bjorndal 1991). Hatchlings that reach the surf can become disoriented by lighting and leave the surf (Witherington 1991, NMFS and Service 2007).

Amber LED and low-pressure sodium fixtures are considered to be “turtle friendly” lights (Witherington and Martin 2003), that reduce the potential for negative impacts. Night lighting at airstrips used are not in close proximity to areas used by loggerheads for nesting and effects are not expected. Effects on adult loggerheads from night lighting at facilities other than the launch complex are expected to be minor and may cause nesting loggerheads to avoid sections of the beach in proximity to the lighting. Hatchling loggerheads may be disoriented by the lights and effects may result in injury or death if they travel towards the lights and into the dunes rather than towards the surf. Loggerhead nests are not frequently laid in areas impacted by night-time lighting adjacent to launch facilities. During the 6 year survey period (2010 – 2015), 1 loggerhead nest was recorded near the launch pads (NASA 2010b, 2011, 2012b, 2013, 2014b, 2015b). Effects to hatchling loggerheads will be limited to nests in proximity of the launch pad in the process of hatching during the approximately 4 weeks/launch that night-time lighting is being implemented.

UAS flights are occasionally conducted at night in response to special circumstances or for hurricane monitoring. Safety lighting at the airstrip will be minimal intensity and downward shielded, and over flying UAS will not use running lights. We expect some behavioral effects on adult turtles and disorientation of young turtles to occur.

Disturbance

Effect on plover, knot, and loggerhead from facility security, recreational/ORV beach use, and miscellaneous activities on and education use of Wallops Island beach

WFF personnel and their families are allowed to use the north end of Wallops Island for recreation outside of NASA operations periods. Recreational use, miscellaneous maintenance activities and security patrols conducted on the beach have similar effects on listed species because they may involve operation of vehicles or heavy equipment on the beach, in addition to people on foot in areas where plovers, knots, or loggerheads may occur. Security patrols have been ongoing at WFF for a number of years, and have likely presented some level of disturbance to plovers and nesting loggerheads.

Plover - Effects of foot traffic to nesting plovers can range from relatively minor disturbance that temporarily interferes with normal breeding, feeding, and sheltering behavior to injury or death of chicks, destruction of an entire nest, or sustained disturbance resulting in nest abandonment. Vehicle use on the beach can crush nests, eggs, or hatchlings. Vehicles can also create ruts capable of trapping plover chicks.

Closure of a plover nesting area will avoid these effects to the extent that the closure is observed; however, plovers may nest outside of the established closure area. In these cases, monitoring, placing nest exclosures, and posting signage will minimize potential effects to the identified nests. After hatching, young plovers are likely to move away from nesting areas, making them vulnerable to these effects throughout a much larger area. Even with surveys and monitoring conducted at a high frequency, there is potential that undetected nests will be disturbed or young plovers may be killed or injured. Plovers that migrate along the barrier islands between wintering grounds and breeding grounds may also be impacted by human activity and vehicle use interfering with their ability to forage.

Loggerhead - Security patrols and recreational use may inadvertently disturb nesting females, crush eggs within the nest, or crush, entrap, or disturb hatchlings attempting to leave the nest. Vehicle use on the beaches may compact beach sand and/or disturb female turtles attempting to nest. Monitoring for turtle activity followed by erecting exclosures to protect nests will avoid adverse impacts due to the low level of nesting activity exhibited at Wallops Island.

Plover and loggerhead - Effects to plovers and loggerheads are likely to include an increased predation rate due to human activity. Human activity may result in trash on the ground, which could both attract predators and increase the carrying capacity of the predators due to increased food availability. The increased numbers of predators may increase risk of disturbance, nest loss, and adult mortality of plovers and increase losses of loggerhead eggs and nests. Plovers may expend more energy in predator surveillance and avoidance and that energy expenditure could decrease overall fitness. However, use of these sites for recreation and security patrols is generally light and not continuous; therefore effects to plovers and loggerheads are expected to be minimal.

Knot - Both recreational and operational uses of Wallops Island beach have the potential to disturb foraging and resting knots. The presence of vehicles on the beach has been shown to result in fewer individuals as compared to an area without the disturbance, as affected shorebirds shift their preferred habitat (Pfister et al. 1992). A study in Massachusetts suggests that knots may be more susceptible to human disturbance (based on pedestrian induced flight-initiation distance) than other species commonly found on the beach during spring migration (Koch and Paton 2014). In Virginia, Watts and Truitt (2015) demonstrated that the majority of knots are only present on the barrier islands for an approximately 4 to 5 week period in late spring.

Therefore, although knots could be exposed to beach use-induced stressors in the action area, impacts would be for a short duration. In addition, the majority of north Wallops Island is closed to recreational use (NASA 2015b) during the plover nesting season (April 15 to August 31), corresponding to the location on Wallops Island where a majority of knots have been observed in recent years. Additionally, Schlacher et al. (2008) demonstrated *Donax* spp. mortality when exposed to vehicle traffic; however, vehicle use at Wallops Island is far less than the area studied and impacts are not expected to be significant. Therefore, the knot is not expected to be adversely affected by alterations to its foraging base from facility security, recreational/ ORV beach use or miscellaneous activities on or education use of Wallops Island beach.

Effect on plover, and knot from protected species management and shoreline reconstruction monitoring

Monitoring activities involve conducting frequent surveys, implementing area closures and posting signage, placing plover nest enclosures, and similar actions. While the intent of monitoring activities is to reduce or avoid impacts to listed species by detecting them early, the increased human activity within beach habitats results in some adverse effects to listed species. Knots are generally disturbed to some degree during monitoring, causing them to temporarily cease normal behaviors. Plovers are generally disturbed to some degree during monitoring and efforts to locate nests, causing them to temporarily cease normal behaviors. This disturbance, while limited, may increase the likelihood of plover nest predation. Observers may inadvertently crush plover nests or young while accessing areas to conduct monitoring or management.

Effect on plover, knot, and loggerhead from seawall repair and beach renourishment

The operation of heavy equipment and presence of personnel on the beach in conjunction with seawall repair and sand placement will result in disturbance to plovers and knots using the area for foraging or passing through the area while moving among foraging areas. Any plovers or knots using these areas are expected to temporarily cease normal foraging, roosting, or flight behavior and fly to adjacent suitable areas where there is no disturbance, or alter their flight paths to avoid areas where activity is occurring. Similarly, during the nesting season loggerheads may be temporarily disturbed by onshore activities and move to other nearby areas where there is no disturbance. However, habitat quality for plovers and knots in degraded shoreline areas where seawall repair and sand placement will be occurring is low, so these species are not expected and these effects are expected to be insignificant and discountable. Habitat quality for loggerheads is also expected to be low, but loggerheads may attempt to nest in these locations. Loggerheads in the vicinity of the beach undergoing renourishment are likely to be disturbed by the activities; however, suitable nesting habitat is available on adjacent beaches and overall effects on nesting success are expected to be low.

Operation of the dredge is limited to offshore areas and will not affect the shoreline beyond delivery of sand; therefore, it will not affect the species considered in this opinion under the Service's jurisdiction. Effects to loggerheads at sea are addressed separately through NASA's section 7 consultation with NMFS.

In future renourishment efforts, NASA may obtain up to half of the sand for renourishment from the north Wallops Island borrow area instead of from offshore shoals. During plover and knot migration, operation of heavy equipment in the north Wallops Island borrow area is expected to result in frequent alteration of plover and knot feeding and sheltering behavior, causing physiological stress and increased vulnerability to predators. If sand removal is conducted during the nesting season, all aspects of plover breeding will be affected, resulting in lack of nesting, failure of nests, or mortality of chicks. Acquiring fill material from north Wallops Island will entail use of heavy equipment on the beach, which is expected to deter loggerhead nesting through frequent disturbance or result in reduced hatch success and hatchling survival by: increasing the chance of crushing nests, eggs, and hatchlings; compacting the sand in the nesting area; and trapping hatchling turtles in vehicle ruts. Equipment use on the beach at night may cause collisions that result in injury or death of female sea turtles attempting to nest and hatchling turtles on the beach.

After each renourishment cycle, shortly after construction of the beach and dune, beachgrass planting and sand fence installation will be conducted on the seaward side of the dune adjacent to the new beach. Depending on timing of installation, the increased presence of people on the beach may result in disturbance to plovers and knots. This disturbance is expected to cause plovers and knots to flush and move to other areas. However, because habitat quality for plovers and knots is low directly after beach renourishment, these species are not expected and effects are expected to be insignificant and discountable. The installation of sand fencing and planting are not expected to affect loggerheads because these activities will be conducted during the day and loggerheads are expected to be in close proximity to the beach during the night hours.

Once installed, the presence of sand fence may deter plover nesting close to the sand fence and may increase the risk of depredation by providing cover for predators in close proximity to plover nests. Migrating knots generally do not use the renourished beach for feeding and do not nest in Virginia; therefore, the presence of sand fence is not expected to affect knots. The sand fence is expected to allow movement of adult loggerheads above the berm and into the dune area and will not prevent them from returning to sea. If nests are located landward of the sand fence a small fraction of hatchling turtles may become trapped, particularly if the sand fence is not maintained or if debris entangled in the sand fence prevents hatchling movements.

Habitat Loss/Suitability

Effect from beach renourishment

Plover - The operation of heavy earthmoving equipment and other equipment involved in pumping and moving sand is expected to result in small amounts of fuel, oil, lubricants, and other contaminants entering the water. Small quantities of these substances may result in death or impairment of invertebrate prey of plovers within limited areas. While toxicity to plovers is unlikely, reduction in prey may reduce the suitability of habitat for plovers in affected areas of the nourished beach.

The addition of sand dredged from offshore shoal A or B may result in a beach similar in appearance to a natural beach, but significantly different in sand density and compaction, grain size and assortment, and beach-associated fauna, including invertebrates, and nutrients and chemical characteristics of the sand. Immediately following sand placement, the suitability of the renourished beach for plovers is expected to be significantly less than a natural beach of similar size and configuration due to loss of invertebrate prey.

Over time, the faunal characteristics of a natural beach are expected to return as the created beach is recolonized by beach-associated fauna and plants, and as wave action, wind, rain, and other natural forces weather the beach (National Research Council 1995). After recolonization of the beach by invertebrates, the beach may become higher quality foraging habitat for plovers than surrounding natural beaches because the beach will remain free from vegetation for a period of time (Melvin et al. 1991) and may be higher and wider than nearby eroding beaches.

NASA monitoring data (NASA 2012b, 2013, 2014b, 2015b) shows that the number of plover nests is fairly consistent from year-to-year, suggesting that beach renourishment does not cause a decrease in the number of plover breeding territories on Wallops Island but that plovers may preferentially nest on north Wallops Island. Monitoring data shows that plovers nested on the renourished beach after 2 years (NASA 2014b, 2015b). Renourishment of the beach is not expected to result in a significant reduction in nesting success and survival on Wallops Island, although plovers may experience a decrease in their ability to rest or forage on the renourished beach and a temporary excess energy expenditure. Beach renourishment is expected to occur approximately once every 2 – 7 years. Based on the information provided by NASA, we are analyzing effects of the proposed action assuming a renourishment frequency of every 5 years. When renourishment is conducted, the beach and berm are expected to have eroded to the point where nesting by plovers is unlikely within the area identified to receive renourishment. Consequently, the effects of renourishment are expected to be limited to loss of habitat for migrant plovers that may use the area for feeding and sheltering.

In future renourishment efforts, NASA may obtain up to half of the sand for renourishment from the north Wallops Island borrow area instead of from offshore shoals. The delineated borrow area either includes or is immediately adjacent to areas used by plovers. The removal of sand from this area may result in a temporary decrease in habitat suitability or in temporary habitat

loss as sand is physically removed from the area. If the activity is conducted during the nesting season, it is expected to interfere with all aspects of breeding including territory establishment, courtship, nesting, egg-laying, incubation, brooding, and feeding. This is expected to result in lack of nesting, failure of nests, or mortality of chicks. If borrow from North Wallops Island is conducted during the breeding season and all plover nests are located in proximity to the borrow site, complete reproductive failure may occur during that breeding season.
Knot - The area of Wallops Island beach that historically hosted the greatest number of knots during the northern migration – the north "curve" – is rapidly accreting and is outside the beach renourishment area (King et al. 2011). It is expected that this area of the beach will continue to provide knot habitat, effectively dampening the effects of beach renourishment when the fill material is sourced from offshore shoal A or B. If sand is obtained from offshore shoal A or B, beach renourishment is not likely to adversely affect knots.

The operation of heavy earthmoving equipment and other equipment involved in pumping and moving sand is expected to result in small amounts of fuel, oil, lubricants, and other contaminants entering the water. Small quantities of these substances may result in death or impairment of invertebrate prey of knots within limited areas. While toxicity to knots is unlikely, reduction in prey may reduce the suitability of habitat for knots in affected areas of the nourished beach.

Acquiring sand from north Wallops Island will affect the knot foraging base. Although the action will be conducted outside of peak spring avian activity, it could take several seasons for the excavated area to biologically recover, depending on the size and specific location of the removal action. In particular, *Donax* spp., a primary knot food source, could be suppressed if material were systematically removed from the intertidal zone. Conversely, should the material be removed only from the upper part of the seaward beach, the primary effect would be the displacement of wrack, another source of forage that would be expected to more rapidly regenerate as compared to *Donax*. As a result of removal of fill material from north Wallops Island, a majority of knots using this area are expected to shift their foraging requirements to other nearby barrier islands, which will provide sufficient resources to fulfill their foraging needs. Knots commonly use north Wallops Island beaches during migration, rather than the renourished beach. Therefore, effects to knots will be limited to migrant knots using the renourished area for feeding and sheltering and are expected to be insignificant and discountable.

Loggerhead - Loggerhead nesting occurred on Wallops Island beach following the initial beach fill cycle (NASA 2012b, 2013), which occurred prior to the 2012 nesting season. This suggests that the elevated beach can provide suitable nesting habitat after renourishment given time for conditions to return to suitable levels. However, Crain et al. (1995) concluded that effects of a beach renourishment on sea turtle nesting is not predictable based on other renourishments and potential effects should be considered on a case-by-case basis. The sand characteristics following beach and dune reconstruction are unlikely to be similar to those that occur on natural beaches in the area, especially shortly after deposition. The characteristics that may be important to loggerhead nesting and are likely to differ from those of natural beach include: gas exchange, moisture characteristics (drainage, desiccation, water potential), temperature, soil cohesion/shear characteristics, compaction, and others (Crain et al. 1995, Byrd 2004). Because of the relatively extensive beach following reconstruction and the relatively high elevation of the proposed berm compared to many natural beaches in the area, we expect loggerhead nesting to occur on the newly created beach after the physical characteristics of the sand return to a suitable condition.

Based on the large grain size of the sand from shoals A and B, the relatively long distance from the water line to the berm/dune interface where turtles would be expected to nest, and the placement of sand over and around the rock seawall for most of the project area, desiccation of the beach is expected because the sand will likely drain quickly, the rock seawall will interfere with maintaining a natural moisture gradient, and the area may be infrequently affected by waves. The sand color is expected to be similar to that which occurs on the beaches of the area because the material that occurs in the offshore shoals is eventually transported to the beaches and likely originates from the same material as that which occurs on the beach.

Differences in color, grain size, and moisture content affect sand temperatures. The gender of sea turtles is determined by incubation temperatures; as a result, even relatively slight changes in sand temperature may alter the sex ratio of hatchlings. The sand is expected to show less cohesiveness and lower shear strength than sand found on natural beaches, which may reduce the ability of nestlings to emerge from the egg chamber under some conditions.

Compaction of the sand is expected to occur as a result of the use of heavy equipment and pumping of heavy slurry during sand placement. The amount of equipment use and the associated degree of compaction is not known, but due to the need to place sand over the seawall and contour the beach to design specifications, compaction is expected to occur. This compaction can reduce the ability of females to excavate an egg chamber, and can also reduce gas exchange, drainage, and other sand characteristics.

Crain et al. (1995) and Byrd (2004) noted that differences in turtle use and nest success between nourished and natural beaches was reduced over time. As wave action weathers the beach profile and re-sorts the sediments, the suitability for turtle nesting changes. It is not possible to accurately predict the success of loggerhead nesting attempts that may occur within the area following beach and dune reconstruction because the characteristics and the relative suitability of the beaches in the area for loggerhead nesting are not well known. It is possible that the beach will be more suitable for loggerhead nesting than other beaches in the area due to its relatively high elevation and different sand characteristics, and nest attempts may be successful; however, nest failure and reduced rates of hatchling emergence are expected to occur on this beach for up to 2 years after sand placement due to one or more of the factors described above.

NASA expects to avoid sand placement that may affect nests, and monitoring is expected to determine location of nests prior to sand placement. If nests are buried by sand, they may be subject to reduced hatch success as a result of changes in the moisture regime, gas exchange, and physical characteristics of the beach that result from adjacent sand placement and operation of heavy equipment in the general vicinity of the nests.

Plover, knot, and loggerhead - Following placement of sand on the beach and dune, some portion of this material will be transported onto natural beaches adjacent to the project area. Natural wind and current patterns are likely to transport sand to the north and deposit it on north Wallops Island and portions of CNWR, and also to the south, where it will be deposited on Assawoman Island. The amount and degree of deposition on these islands is dependent on environmental conditions (e.g., storms, wave action) and other factors that may affect littoral sand transport. Over time, the deposition of the relatively large sand grains will affect mean sand grain size and other physical characteristics of these beaches. These changes may either improve or reduce the suitability of unnourished beaches for plover nesting and foraging, knot foraging, and loggerhead nesting. These changes may shift the areas that plovers and knots use for foraging, or that plovers and loggerheads use for nesting but total area used by these species is not likely to change.

Acquiring fill material from north Wallops Island will decrease habitat suitability of north Wallops Island for all listed species. Movement of sand material from the borrow area will result in beach compaction. Additionally, the borrow area is the most seaward portion of the beach; as a result, the remaining beach will have a steeper initial profile, be more vegetated, and have different physical properties (e.g., sand grain characteristics, drainage) than a natural beach. Movement of sand material using heavy equipment will result in extensive sand compaction in the renourished area. These characteristics will make it less suitable for use by plovers, knots, and loggerheads. As wave action and weathering affect the beach position and profile, vegetation will be killed or uprooted and the beach contour, sediment stratification, and other characteristics return, the beach suitability and amount of available habitat is expected to improve.

The sand placed on the renourished beach will initially be unsuitable for use by invertebrates and plants characteristic of natural beaches and much of the fauna on the beach will be killed or negatively impacted by the renourishment. The beach conditions are expected to be completely unsuitable for use by migrating knots, and nesting plovers and loggerheads during the first year following sand placement, with limited amounts of suitable habitat available 1 year following placement, and returning to conditions similar to those that existed prior to placement by 3 years following placement. Use of the north Wallops Island borrow area may allow some faster recovery of flora and fauna if seeds or fauna in the sand survive transportation and placement, but because at least half of the renourishment material will originate from offshore shoals the difference is not expected to significantly improve the recovery time of beach-associated flora and fauna.

Additive Effects of Proposed Activities

In addition to the effects of the proposed actions considered and described above, the additive effects of the different types of activities result in greater impacts than each activity conducted independently. For example, operations of UAS within the parameters described may result in infrequent disturbance and some launch operations, rocket tests, and monitoring may have similar effects. The combination of all of these activities, when considered together, results in more frequent disturbance and as a result we expect plovers and loggerheads to experience low levels of disturbance in the action area on a regular basis.

Frequent disturbance to plovers, knots, and loggerheads resulting from mission preparation and support may disturb the species to the extent that they avoid use of the south end of Wallops Island where mission related activities are concentrated. If they avoid use of the area, listed species may not be subjected to the most intense and severe effects expected to occur during rocket launches. In addition, because the suitability of the newly created beaches is expected to be relatively low for a period following sand placement, use by plovers and loggerheads may be reduced and as a result some of the most severe effects resulting from launches may be reduced. However, because some nesting loggerheads and migrant plovers and knots use the beach only for limited periods of time, frequent disturbance and/or low habitat suitability is not expected to completely prevent the most severe effects from occurring.

Interrelated and Interdependent Actions – An interrelated activity is an activity that is part of the proposed action and depends on the proposed action for its justification. An interdependent activity is an activity that has no independent utility apart from the action under consultation. The Service is not aware of activities interrelated to or interdependent with the proposed action at this time.

Beneficial Actions – Shoreline restoration is a useful tool to reverse shoreline habitat loss and expand habitat availability for coastal species in a dynamic system. Following a short period of lower habitat suitability when sand is initially placed, the larger area of restored beach is expected to support feeding, sheltering, and nesting plovers; nesting loggerheads; and feeding and sheltering knots. Shoreline restoration may provide habitat to support larger populations of these listed species than currently exist and may contribute to increased productivity.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. The Service is not aware of any future State, tribal, local, or private actions within the action area at this time.

CONCLUSION

The combined effects of a variety of different activities on plovers and loggerheads are expected to result in reduction in either reproductive output or success. Although not common, nesting by plovers that occurs close to launch pads is most likely to be disturbed. Exposure to launch exhaust and extreme noise, or collision with UAVs or piloted aircraft may cause injury or death of a small number of plover or knots. Recreational use, security patrols, and species monitoring are expected to pose some risk to plovers, knots, and loggerheads because they occur within the habitats these species occupy and may directly and indirectly affect the species. Effects to loggerhead nests as a result of operational activities are expected to be minimal as a result of extensive monitoring for turtle crawls and marking of nests.

Sand placement on the renourished beach will result in temporary disturbance to plovers, knots, and loggerheads due to additional activity. Sand placement may also cause injury to loggerhead nests if they are buried. Sand placement will also result in temporary habitat loss for plovers, and knots due to the reduction of prey base, and for loggerheads due to changing physical characteristics of the sand. Sand removal from north Wallops Island may cause collision with equipment to nesting loggerheads or disturbance from increased activity to nesting or migrating plovers, migrating knots, and nesting loggerheads. Sand removal from north Wallops Island will also result in temporary habitat loss for plovers, knots, and loggerheads as sand will be removed adjacent to areas used by these species. Sand removal from shoal A or B is not expected to result in effects to plovers, knots, or loggerheads. Because of the amount of listed species habitat available, the listed species management and monitoring proposed, and the relatively low intensity effects anticipated, we expect only a small portion of the occurrences of each of these species will be affected, and none of the activities are expected to significantly reduce the suitability of the habitats for these species.

After reviewing the status of the plover, knot, and loggerhead, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is the Service's biological opinion that the proposed and ongoing launch operations and SRIPP at the WFF, as proposed, is not likely to jeopardize the continued existence of the plover, knot, or loggerhead, and is not likely to destroy or adversely modify designated critical habitat. Critical habitat for the plover and loggerhead has been designated; however, this action does not affect that area and therefore no destruction or adverse modification of critical habitat is anticipated. Critical habitat has not been proposed for the knot at this time.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns, which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are nondiscretionary, and must be undertaken by NASA so that they become binding conditions of any grant or permit issued to any applicant/contractor, as appropriate, for the exemption in section 7(o)(2) to apply. NASA has a continuing duty to regulate the activity covered by this incidental take statement. If NASA (1) fails to assume and implement the terms and conditions or (2) fails to require any applicant/contractor to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, NASA must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement [50 CFR 402.14(i)(3)].

AMOUNT AND EXTENT OF TAKE

The Service anticipates incidental take of plovers, knots, and loggerheads will be difficult to detect and take may be masked by seasonal fluctuations in numbers and other environmental factors. Detecting mortality or injury of plovers (especially chicks), particularly on beaches where vehicles are being operated, is extremely difficult. Cryptic coloration is the species' primary defense mechanism, evolved to cope with natural predators, and nests, adults, and chicks blend with beach surroundings. Newly hatched chicks stand 2.5 inches high, weigh less than a quarter ounce, blend with the beach substrate, and often respond to approaching vehicles, pedestrians, and perceived predators by "freezing" in place to take advantage of their natural camouflage. Dead chicks may be covered by wind-blown sand, ground into the sand by other passing vehicles, washed away by high tides, or consumed by scavengers. Knots will be similarly difficult to detect, although their larger size and less cryptic coloration is likely to lead to higher detectability than plovers. Loggerhead nests are generally detected by observing crawl marks on the beach and nest locations are recorded and marked. If nests are not detected by crawl marks, it is unlikely that they, along with their success or failure, will be documented.

Plover - The average plover productivity from 2012 to 2015 on Wallops Island, 1.33 chicks/pair, is the best estimate of productivity (NASA 2015a). The Service anticipates incidental take of 2 plover nests (2 x 1.33 = 2.66) (3 eggs or chicks) in the first breeding season following each 5-year beach renourishment cycle. Additionally, incidental take of 1 plover nest (1 x 1.33 = 1.33) (2 eggs or chicks), through either adults failing to nest or nest failure, in the second year of each renourishment cycle. This take will be in the form of harass, harm, injury, or death.

Incidental take of 1 plover pair, resulting in loss of 1 nest (1 x 1.33 = 1.33) (2 eggs or chicks), is anticipated per year from disturbance associated with ongoing operations, including rocket launches, recreational use of the beach, UAVs and piloted aircraft. This take will be in the form of harass.

Incidental take of 2 plovers (adult or post-fledging) is anticipated per year from the effects of launch-related activities immediately adjacent to the beach, resulting from intense sound, exposure to rocket exhaust and contaminants, collision with aircraft, and similar launch activities. This take will be in the form of injury or death.

Knot – Aerial surveys conducted from 2005 through 2014 (Watts and Truitt 2014) documented an average of 276 knots using Wallops Island. The Service anticipates incidental take of 28 knots per year (10 percent of the average observations of knots on Wallops Island) over 2 years during each 5-year beach renourishment cycle resulting from borrowing sand from the north Wallops Island borrow area, as a result of disturbance from heavy equipment and decreased habitat suitability for foraging during spring migration. This take will be in the form of harass or harm.

Incidental take of 2 adult knots is anticipated per year from the effects of launch-related activities immediately adjacent to the beach, resulting from intense sound, exposure to rocket exhaust and contaminants, collision with aircraft and similar launch activities. This take will be in the form of injury or death.

Loggerhead - The Service anticipates incidental take of hatchlings from 1 loggerhead nest (1 nest = 128 hatchling turtles) every 5 years as a result of beach renourishment that may bury nests or place sand of a grain size that does not support loggerhead nesting attempts. This take will be in the form of harass, injury or death.

Incidental take of 1 adult loggerhead is anticipated every 5-year beach renourishment cycle from beach renourishment and associated activities, including disturbance of a nesting female that prevents her from nesting successfully. This take will be in the form of harass, injury, or death.

Incidental take of hatchlings from 1 loggerhead nest (128 hatchling turtles) is anticipated every 5 years resulting from exposure to night-time lighting, vibration, and exhaust during launch of rockets. This take will be in the form of injury or death.

Incidental take of 1 adult loggerhead is anticipated every 5 years resulting from exposure to intense sound or exhaust gases released during launch of rockets. This take will be in the form of injury or death.

Table 4. Summary of anticipated incidental take.

Amount of Anticipated Take	Cause of Anticipated Take	Form of Anticipated Take	Frequency of Anticipated Take	Length of Biological Opinion	Total Anticipated Take
Plover					
5 eggs or chicks	beach nourishment	harass, harm, injury, or death	every 5 years	15 years	15 eggs or chicks
2 eggs or chicks	ongoing operations, including rocket launches, recreational use of the beach, UAVs and piloted aircraft	harass	every year	15 years	30 eggs or chicks
2 individuals (adult or post-fledging)	launch-related activities immediately adjacent to the beach, resulting from intense sound, exposure to rocket exhaust and contaminants, collision with aircraft, and similar launch activities	injury or death	every year	15 years	30 individuals

Plover total					**75**
		Knot			
56 individuals	borrowing sand from the north Wallops Island borrow area, as a result of disturbance from heavy equipment and decreased habitat suitability for foraging during spring migration	harass or harm	every 5 years	15 years	168 individuals
2 adults	launch-related activities immediately adjacent to the beach, resulting from intense sound, exposure to rocket exhaust and contaminants, collision with aircraft and similar launch activities	injury or death	every year	15 years	30 individuals
Knot total					**198**
		Loggerhead			
128 hatchlings	beach renourishment	harass, injury, or death	every 5 years	15 years	384 hatchlings
1 adult	beach renourishment and associated activities	harass, injury, or death	every 5 years	15 years	3 adults
128 hatchlings	exposure to night-time lighting, vibration and exhaust during launch of rockets	injury or death	every 5 years	15 years	384 hatchlings
1 adult	exposure to exhaust gases released during launch of rockets	injury or death	every 5 years	15 years	3 adults
Loggerhead total					**774**

EFFECT OF THE TAKE

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

REASONABLE AND PRUDENT MEASURES

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of listed species:

1. Conduct routine surveys and monitoring for the species addressed in this biological opinion and implement measures to avoid potential impacts whenever possible.

2. Conduct surveys and monitoring to determine the effects of the proposed action on listed species and their habitat.

3. Actively manage habitats and human activity on the beaches to avoid and minimize potential impacts to listed species.

TERMS AND CONDITIONS

To be exempt from the prohibitions of section 9 of the ESA, NASA must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are nondiscretionary.

1. Implement the Wallops Island Protected Species Management Plan for the duration of the proposed action and provide an annual report summarizing the survey and monitoring efforts, location and status of all occurrences of listed species recorded, and any additional relevant information. Reports should be provided to the Service in digital format, at the email address provided below by December 31 of each year.

2. Report any evidence of previously undocumented listed species located on Wallops Island to the Service at the email address provided below within 5 business days of observation.

3. Develop a training and familiarization program for all security personnel conducting patrols in areas where listed species may occur. This training program shall include basic biological information about all listed species and be sufficient to allow personnel to tentatively identify the species and its likely habitat to allow them to incorporate appropriate avoidance and minimization measures into their activities.

4. Excavate sand from the north Wallops Island borrow area for beach renourishment outside of plover and sea turtle nesting season (March 15 through November 30 or the last date of potential sea turtle hatchling emergence based on laying dates of all nests). Stockpile sand outside the north Wallops Island borrow area, and outside potential nesting habitat for plovers and sea turtles prior to placement for renourishment.

5. Following launches of rockets, conduct surveys for injured, dead, or impaired birds and sea turtles. These surveys must be conducted as soon as safety permits following launches. The survey protocols are outlined in the WFF protected Species Management Plan. Post-launch beach surveys will be conducted between March 15 and November 30 of every year to coincide with plover and sea turtle nesting seasons. The survey area will include the beach within 1,000 feet, to the north and south, of the respective launch pad for sounding and orbital-class (ELV) rocket launches. Provide reports of survey results to the Service in digital format, at the email address below, within 15 business days of each launch event.

6. Care must be taken handling any dead specimens of proposed or listed species that are found to preserve biological material in the best possible state. In conjunction with the preservation of any dead specimens, the finder has the responsibility to ensure that evidence intrinsic to determining the cause of death of the specimen is not unnecessarily disturbed. The finding of dead specimens does not imply enforcement proceedings pursuant to the ESA. The reporting of dead specimens is required to enable the Service to determine if take is reached or exceeded and to ensure that the terms and conditions are appropriate and effective. Upon locating a dead specimen, notify the Service's Virginia Law Enforcement Office at [redacted] 7721 South Laburnum Avenue, Richmond, Virginia 23231, and the Service's Virginia Field Office at [redacted] at the address provided on the letterhead above.

The Service believes that no more than 75 plovers, 198 knots, and 774 loggerheads will be incidentally taken as a result of the proposed action over the 15-year term of the biological opinion. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to further minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. NASA is encouraged to develop an integrated habitat conservation and management plan for Wallops Island. Due to the significance of the area for the conservation of migratory birds and other species, nearly all habitats that occur on WFF provide value to these species. Active efforts to manage habitat, including activities such as control of non-native invasive plants, may significantly improve the value of these areas as habitat.

2. NASA is encouraged to collect data on the characteristics of beaches and habitat where sea turtle nests and plover nests occur and share this information with the Service and VDGIF, or work with other interested parties to develop protocols for data collection and analysis throughout Virginia to improve our understanding of plover and sea turtle habitat characteristics.

3. NASA is encouraged to transition security from the current system of frequent roving patrols to a closed circuit television system to reduce beach access to the minimum required to augment the cameras in providing facility security.

For the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the actions outlined in the request. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

If you have any questions, please contact Sarah Nystrom of this office at [redacted] or [redacted]

Sincerely,

Troy M. Andersen

For Cindy Schulz
Field Supervisor
Virginia Ecological Services

cc: Corps, Norfolk, VA (Attn: William T. Walker)
FAA, Washington, DC (Attn: Daniel Czelusniak)
NMFS, Gloucester, VA (Attn: David O'Brian)
Service, Chincoteague Island, VA (Attn: Kevin Holcomb)
Service, Chincoteague Island, VA (Attn: Kevin Sloan)
VDCR, DNH, Richmond, VA (Attn: René Hypes)
VDGIF, Machipongo, VA (Attn: Ruth Boettcher)
VDGIF, Richmond, VA (Attn: Ernie Aschenbach)

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From: Marc Ochsner <[redacted]
Sent: Monday, November 1, 2021 9:01 AM
To: SpaceXBocaChica
Subject: SpaceX - Endangered Species Act - No Cutting Corners

Hi there,

I wanted to reach out as I have concern with SpaceX's plans to launch this coming month, when a section 7 opinion under the endangered species act is required first -- a process that normally takes 135 days.

How do you intend to keep SpaceX in line with the standard regulations? This is very concerning.

Marc Ochsner
M: +[redacted]
W: +[redacted]

Sent with ProtonMail Secure Email.

From: Matthew Sober <[redacted]
Sent: Monday, November 1, 2021 3:36 PM
To: SpaceXBocaChica
Subject: Spacex & Boca Chica

The accomplishments & future goals of SpaceX are among the most inspiring developments in the world.

They must be allowed to continue as needed!

Elon is using his resources to help humanity in the ways he feels most capable. I trust SpaceX will take as much care as reasonably possible to develop the Starship program safely with minimal detrimental effects.

The engineering problems are extremely difficult, please ensure that they don't have to deal with extra governmental restrictions that make those problems even harder to solve.

Almost all negative public commentary received is from misinformed people. They will benefit from Starship's success in ways they don't yet understand.

Thanks,
Matthew Sober
[redacted]

18099

From: Greg Hostiuck <[redacted]
Sent: Monday, November 1, 2021 1:14 PM
To: SpaceXBocaChica
Subject: SpaceX Boca Chica public comment

My name is Gregory Hostiuck of Cincinnati Ohio. I am writing in support of SpaceX's planned developments at Boca Chica, Texas. I believe SpaceX has the environment in mind and will mitigate any losses to the surrounding environment. SpaceX is trying to create multi-planetary life and I believe Boca Chica is the best location for their Starbase. Thank you very much for your consideration.

Sincerely

Gregory Hostiuck
[redacted]

--
Greg Hostiuck
IT Engineer
PC Wizards
Networking|Repair|Cybersecurity|Consulting
[redacted]

18100

From: [redacted] <[redacted]
Sent: Monday, November 1, 2021 10:28 AM
To: SpaceXBocaChica
Subject: SpaceX draft PEA comment

(Please redact personally-identifiable information.)

I am writing in support of SpaceX's efforts at Boca Chica.

The Starship/Superheavy system is critical enabling technology for the exploitation of space on a large scale. As the draft PEA makes clear, the benefits to the nation and to the world far outweigh the drawbacks. While launches on a production basis may migrate offshore (for noise and other reasons), the use of a land-based facility for initial prove-out will materially advance the timeline.

I encourage the FAA to provide the needed authorizations without delay.

Sincerely,
[redacted]

(Please redact personally-identifiable information.)

18101

From: [redacted] <[redacted]
Sent: Monday, November 1, 2021 3:16 PM
To: SpaceXBocaChica
Subject: SpaceX Draft PEA Comments
Attachments: Draft PEA SpaceX Comments_Sea Turtle Inc.pdf

Please find attached Sea Turtle Inc's comments regarding the FAA Draft PEA for the SpaceX Starship/Super Heavy launch program

Amy Bonka, Ph.D.
Chief Conservation Officer, Sea Turtle, Inc.
[redacted]

Sea Turtle Incorporated

Education, Conservation, Rehabilitation

November 1, 2021

Ms. Stacey Zee
SpaceX PEA c/o ICF
9300 Lee Highway
Fairfax, VA 22031

Public Comment regarding the Federal Aviation Administration (FAA) Draft Programmatic Environmental Assessment (PEA) for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas

Stranding Numbers

Sea Turtle, Inc. is responsible for all sea turtle nesting and stranding responses along Boca Chica and South Padre Island. Sea Turtle Inc has been responding to sea turtle strandings on Boca Chica beach and South Padre Island for over 20 years, starting in 2000. During that time, a total of 2368 turtles have been recovered from both beaches. Of these, 21.5% (n = 508 turtles) were recovered from Boca Chica (see 'Stranded Sea Turtles by Year from South Padre Island and Boca Chica'). This response covers the geographic area of Barracuda Cove, the full length of jetty rocks, and the approximate six mile length of beach from the jetties to the Rio Grande river. Turtles recovered alive within this geographic range of Boca Chica and transported to the rehabilitation facility at Sea Turtle Inc accounted for 4.2% of the total. Turtles that were deceased prior to recovery accounted for 17.3% of the total. Of those turtles that were deceased prior to recovery, 2021 saw the lowest percentage of deceased stranded turtles with an unknown stranding cause (i.e. strandings unrelated to boat strikes, jetty rock interactions, etc.) from Boca Chica since 2010 (2021: 70.1%, 2010: 63.6%). During 2010-2020, 85-100% of strandings were attributed to an unknown cause.

Sea Turtle, Inc. observed and documented factors that may have contributed to the influx in stranded sea turtles during the 2019 and 2021 years. For example, during 2019, there was a noted increase in illegal fisheries interaction and multiple live turtles were found stranded in a manner that may have been suggestive of a predator avoidance behavior. An intense freeze during February 2021 resulted in a large cold-stunning event, and following this event there was an increase in the number of deceased turtles documented (note: these numbers do not include any turtles that were part of the mass cold-stunning event from February 2021, or any prior year cold-stunning events).

During 2000-2009, Sea Turtle, Inc. recovered a mean (± SD) of 33.8 ± 19.4 turtles per year. Since 2010, there were only two years (2012, 2014) when Sea Turtle, Inc. recovered fewer than

100 stranded sea turtles, with all other years within that time period ranging from 126-348 stranded turtles recovered. When focusing on 2016-2021, the years in which the patrol efforts were standardized across Boca Chica and South Padre Island (see Patrol Efforts section for a full description), the mean (± SD) stranded turtles per year for all beaches was 211 ± 74.4. When focusing on each beach separately, during this same time period a mean (± SD) of 58.7 ± 41.6 turtles per year were recovered from Boca Chica, and a mean (± SD) of 152.3 ± 35.0 turtles per year were recovered from South Padre Island. Overall, Sea Turtle, Inc. has observed a change in the 10 year mean (± SD) number of stranded turtles across all beaches, from 42.2 ± 32.3 for 2000-2010 to 173.1 ± 67.9 for 2011-2021.

In summary:

- Since 2010, Sea Turtle, Inc. has recovered approximately 40 turtles per year from Boca Chica and approximately 130 turtles per year from South Padre Island.
- An increase in the number of strandings has been observed every other year; i.e. a low year is typically followed by a high year. This pattern has been relatively consistent since 2010.
- When focusing solely on the data collected by Sea Turtle, Inc. over the last 21 years regarding strandings at Boca Chica, 2021 saw the lowest percentage of deceased stranded turtles due to unknown causes.

Patrol Efforts

Sea Turtle, Inc. began conducting standardized patrols for live and deceased sea turtles on South Padre Island and Boca Chica beaches in 2016. These standardized patrols are currently on-going. During this time period (2016-present), the total number of miles covered while actively searching for sick, injured, or nesting sea turtles totaled 117,551. Overall, a total of 12,767.5 hours were spent covering these 117,551 miles. Throughout this six year period, a mean (± SD) of 19,591.8 ± 9,022.6 miles were covered per year, and a mean (± SD) of 2,127.9 ± 1,019 hours were dedicated to this task. Focusing solely on Boca Chica, this accounts for a mean (± SD) of 1,742.1 ± 939.6 miles per year and a mean (± SD) of 209.1 ± 128.2 hours per year. This includes several months during which patrol efforts were greatly reduced due to limitations of COVID-19 regulations. Additionally, this includes data from 2021, which is still ongoing. These factors may be reducing the mean and inflating the standard deviation for this time period. As a percentage of the total beach miles, Boca Chica, accounts for approximately 20% of the total distance Sea Turtle Inc is responsible for monitoring. This correlates with the percentage of strandings recovered from Boca Chica, at 27.8% of the total during the time period of 2016-2021, and at 21.5% across all years monitored.

During 2021 alone, a total of 2819 hours were spent actively patrolling the beaches for sea turtles, resulting in coverage of 28,274.5 miles. Boca Chica accounted for 14.1% (n = 396.5) of these hours and 11.3% of these miles (n = 3206). The total number of miles and the total hours spent actively searching and responding to sea turtles was the highest during 2021, and the year is not yet complete. Therefore, Sea Turtle Inc will end 2021 having completed the highest number of patrol hours and patrol miles since standardizing and recording patrol efforts in 2016. Sea Turtle Inc will continue this pattern, and conduct similar patrol efforts going forward into 2022, 2023, etc.

In Summary:

- The number of stranded sea turtles recovered from Boca Chica appears to be correlated with the the percentage of beach monitored (i.e. about 20% of strandings come from Boca Chica, and Boca Chica accounts for about 20% of the nesting beach patrolled by Sea Turtle, Inc.)
- Sea Turtle Inc has increased the number of patrol hours and covered the largest number of patrol miles in 2021 since standardizing their patrol process in 2016.

Nesting

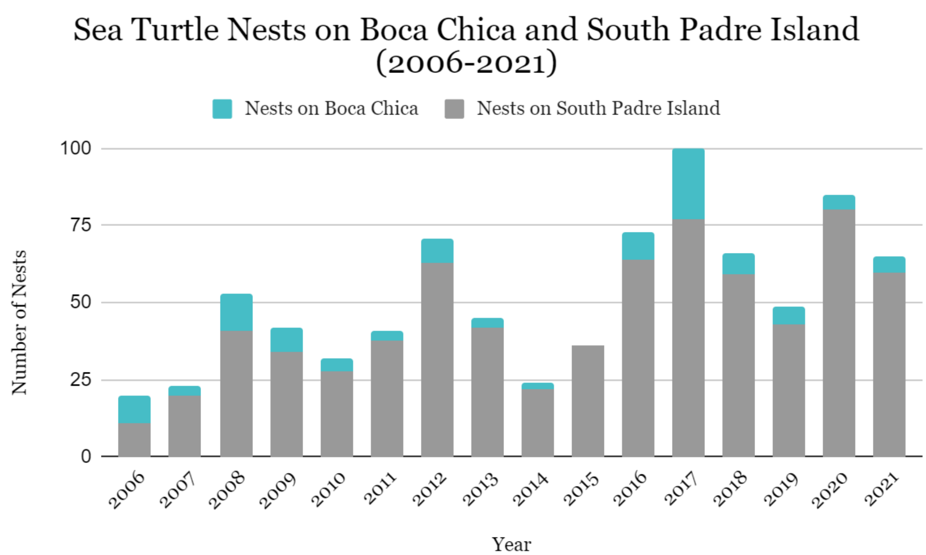
Sea Turtle, Inc. has monitored nesting on South Padre Island and Boca Chica beach since 2006. During this time Sea Turtle, Inc. has documented and protected 825 sea turtle nests. From 2008-2016 Sea Turtle, Inc. observed a peak in nesting numbers every three years. Starting in 2017 through 2021, Sea Turtle, Inc. has seen a peak in nesting numbers every two years (see: “Sea turtle nests on Boca Chica and South Padre Island 2006-2021”). This may be due to various factors, including increased recruitment to the nesting beaches of South Padre Island and Boca Chica, however a longer time period of sampling is needed to better understand this nesting pattern. Across all years (2006-2021), 13.6% ± 10.3% (mean ± SD) of nests were laid on Boca Chica, with the remaining nests laid on South Padre Island (range: 45% in 2006, 0% in 2015). Sea Turtle, Inc. monitors, documents, and protects all sea turtle nesting on South Padre Island and Boca Chica beaches. This includes investigating and documenting any ‘false crawl’ behaviors (i.e. female sea turtle comes ashore but does not successfully nest). False crawl behavior can occur for a variety of reasons, including the inability to find a suitable nesting location, something startling or disturbing the sea turtle, as well as other unknown factors. Since 2006, 10.1% ± 17.1% (mean ± SD) of false crawls have occurred at Boca Chica (range: 0%-50%). Additionally, during the 2006-2021 time period, there were 10 years during which no false crawls were documented on Boca Chica, with at least two false crawls per year documented on South Padre Island (see: “South Padre Island and Boca Chica False Crawl Behaviors”).

Sea Turtle Incorporated

Education, Conservation, Rehabilitation

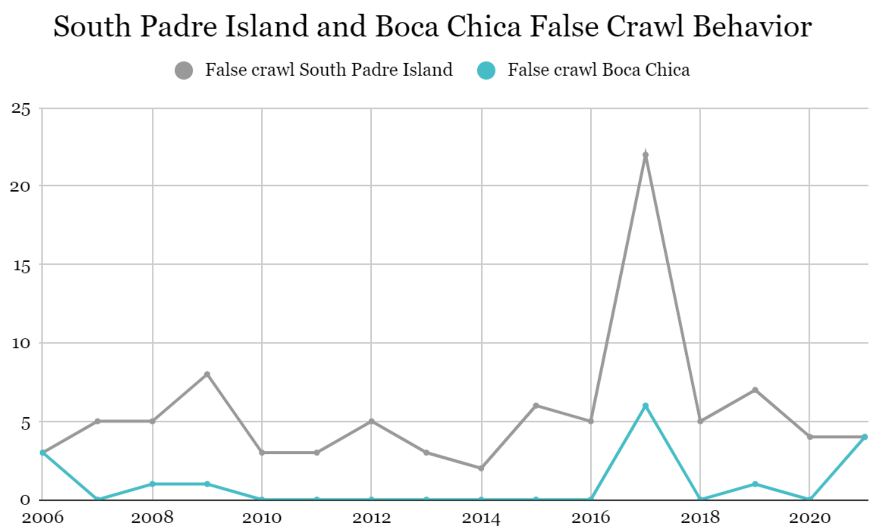
<u>In Summary:</u>

- Sea Turtle Inc has monitored nesting activity for over 15 years, and as seen in the graphs, sea turtle nesting on Boca Chica has generally followed a similar pattern to nesting on South Padre Island (i.e. high years, low years, etc.).
- Nest numbers on Boca Chica remained consistent during the 2020 and 2021 nesting seasons. Additional data is needed to determine if this is a pattern, or a single-year event. Therefore, it is critical Sea Turtle, Inc. can continue to monitor nesting on Boca Chica
- Given the limited number of years that SpaceX has been present on Boca Chica, Sea Turtle Inc is not currently seeing any significant changes in the nesting data. Sea Turtle Inc will continue to monitor nesting activity on Boca Chica.



Sea Turtle Incorporated

Education, Conservation, Rehabilitation



Interactions with SpaceX

SpaceX has provided Sea Turtle, Inc. with advanced notice of road and beach closures, which allows patrol efforts to be maintained and modified as needed. Sea Turtle Inc fully expects this advance notice to continue, and even improve with use of technology, into 2022, 2023, etc. During the 2021 nesting season, a Sea Turtle Inc biologist encountered evidence of nesting on the beach at Boca Chica on the morning of a road closure. SpaceX worked with Sea Turtle Inc staff to ensure this area could be investigated prior to the launch activities occurring. SpaceX provided the use of their vehicles for Sea Turtle Inc staff to utilize for patrolling and monitoring nesting activity on Boca Chica during the 2021 nesting season, and has agreed to provide vehicle use for the 2022 nesting season. Sea Turtle, Inc. has requested SpaceX provide UAV footage of the nesting beach during time periods when nesting may be occurring and Sea Turtle, Inc. staff are unable to access the beach due to road/beach closures. Sea Turtle, Inc. expects to have access to this footage in an efficient and timely manner during the 2022 nesting season. Sea Turtle, Inc. feels this data would allow biologists to continue to monitor the beach closely for any activity, and respond accordingly, even if access is temporarily interrupted due to a road/beach closure. Further, Sea Turtle, Inc. expects to continue to be informed of road and beach closures prior to the closure event to ensure patrol efforts can continue.

[redacted]

Final Conclusions

Overall, the current data at this time is not suggestive of a detrimental impact to nesting sea turtles at Boca Chica, nor is the data suggestive of a marked and/or continuous increase in sea turtle strandings occurring at Boca Chica. However, as with any trend, it is critical to continue to collect data regarding any and all nesting and stranding activity at Boca Chica to better understand potential trends in nesting and stranding activity and how this could be impacted by activities at Boca Chica beach.

Sea Turtle, Inc. will continue to expect a clear and transparent partnership with SpaceX, in which Sea Turtle, Inc. will continue to collect vital data regarding sea turtle activities on and near Boca Chica beach, respond to strandings throughout the year, and improve our processes of protecting all sea turtle activity on Boca Chica and South Padre Island. Sea Turtle, Inc. expects this transparency to continue and improve, allowing Sea Turtle, Inc. to focus on their core mission of conservation, education, and rehabilitation of all sea turtles species.

Amy Bonka, Ph.D.
Chief Conservation Officer, Sea Turtle, Inc.
[redacted]

18102

From: Neal Nations <[redacted]
Sent: Monday, November 1, 2021 8:38 PM
To: SpaceXBocaChica
Subject: SpaceX Environmental Stud

In reading and analyzing the documents provided to the FAA I do not see any significant environmental or any danger to any endangered species that could not be mitigated by adjacent wet lands. I support giving SpaceX's Starship/Super Heavy launch operations from the Boca Chica Launch Site in Cameron County, Texas. SpaceX an experimental permit(s) and/or a vehicle operator license from the FAA Office of Commercial Space Transportation. In my opinion there is nothing that could happen that would be irreversible given enough time.

Neal Nations

Sent from Mail for Windows

18103

From: [redacted]
Sent: Monday, November 1, 2021 7:20 AM
To: SpaceXBocaChica
Subject: SpaceX FAA Approval

To whom it may concern,

I am in full support of the SpaceX Starship program in Boca Chica. While I do believe that SapceX should be held to a high standard when it comes to an environmental impact, the work they are conducting is extremely important for the future of the human race and should be allowed to continue without further delay.

Please grant SpaceX the licensing they need to continue Starship Development immediately. Our children's futures rely on it.

Thank you,

Logan Aardrup
[redacted]

Sent from my iPhone

18104

From: Dobbs,Regan <[redacted]
Sent: Monday, November 1, 2021 1:02 PM
To: SpaceXBocaChica
Cc: Letter of Support Requests
Subject: SpaceX Letter of Support 11.1.21
Attachments: LOS__Space_X_11.1.21pm_signed.pdf

Good afternoon,
Please see attached for the signed letter.

Thank you,

Regan Dobbs, CTCM, CTCD
Texas Workforce Commission
Program Specialist
Strategic Workforce Initiatives and Federal Grants
[redacted]
T: [redacted]
E: [redacted]

Texas Workforce Commission
A Member of Texas Workforce Solutions

Bryan Daniel, Chairman
Commissioner Representing the Public

Julian Alvarez
Commissioner Representing Labor

Aaron Demerson
Commissioner Representing Employers

Edward Serna
Executive Director

November 1, 2021

Ms. Stacey Zee
Environmental Specialist
Federal Aviation Administration (FAA) c/o ICF
9300 Lee Highway, Fairfax, VA 22031

Subject: Letter of Support re: FAA comment period on Starship orbital launch

Dear Ms. Zee,

TWC is pleased to support SpaceX's application to the FAA to conduct Starship-Super Heavy orbital launch operations from its Starbase facility in Cameron County, Texas. SpaceX is working to enable sustainable human exploration of space, including crewed missions to the Moon on behalf of NASA by 2024.

SpaceX has had direct positive economic impact in Texas. Since first breaking ground in Cameron County in 2014, SpaceX has considerably expanded economic opportunities for the people of Texas, specifically in the Rio Grande Valley. SpaceX has grown its employees at Starbase from 100 people in January 2020 to more than 1,500, while investing $1.5B into Texas facilities, including Starbase infrastructure and operations, and Texas suppliers statewide. SpaceX's small business suppliers in Texas employ more than 15,900 people.

Additionally, Space X has contributed to the community and the local natural environment, including:

- helping to facilitate restoration of power to the Military Highway Water Supply Corporation, making potable water available to more than 6,000 people in Los Indios;
- hosting quarterly cleanups at Boca Chica Beach and State Hwy 4 and contributing to building a state water reef 13 miles north of Boca Chica;
- maintaining a six-year partnership with Sea Turtle Inc. (STI), and during the 2021 winter storm, as SpaceX carried out a campaign to assist in rescuing more than 850 sea turtles that were cold-stunned on local beaches and provided a large generator to restore STI's rehabilitation center.

FAA approval of SpaceX's application will provide even greater benefits for South Texas. Routine orbital launches with Starship will drive new capital, personnel, community investments, and tourism at Starbase and enable South Texas to become a gateway to the Moon and Mars. Thank you for your consideration.

Sincerely,

Edward Serna
Executive Director

18105

From: Janie Velasquez <[redacted]
Sent: Monday, November 1, 2021 7:01 AM
To: SpaceXBocaChica
Cc: Eduardo Campirano; Melinda Rodriguez
Subject: SpaceX PEA
Attachments: 2021 11 01 SpaceX PEA.pdf

Good Morning,

Please receive the attached letter from Mr. Campirano, Port Director & CEO. The original will be mailed via USPS Priority Mail.

Regards,

Janie Velasquez / Executive Assistant – Port Director's Office / Port of Brownsville
[redacted]
O: ([redacted] **M:** ([redacted] **F:** ([redacted]
[redacted]

PORT OF BROWNSVILLE
the port that *works*

November 1, 2021

Ms. Stacey Zee, SpaceX PEA,
c/o ICF
9300 Lee Highway, Fairfax, VA 2203

Re: Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas

Dear Ms. Zee,

The Port of Brownsville is concerned with the recent Programmatic Environmental Assessment (PEA) which was submitted for review pursuant to the following: Section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321, et seq.); Council on Environmental Quality NEPA-implementing regulations (40 CFR Parts 1500 to 1508); Section 4(f) of the Department of Transportation Act (49 U.S.C. § 303); Section 106 of the National Historic Preservation Act (16 U.S.C. § 470); Executive Order 11988, Floodplain Management; DOT Order 5650.2, Floodplain Management and Protection; Executive Order 11990, Protection of Wetlands; DOT Order 5660.1A, Preservation of the Nation's Wetlands; and FAA Order 1050.1F, Environmental Impacts: Policies and Procedures.

Our concerns stem from the proposed ground closures in the following: Section 2.1.6.5 Nominal Closures, 2.13.5.1 Ground Closures, Section 3.8.3.2, Launch Operations, 3.8.3.2.1 Nominal Closures, and 3.8.3.3 Anomalies. The areas of land that would be closed to public access, referred to as, *closure area* (Figure 2-4), include the waterway and land at the Brownsville Ship Channel. The proposed closures would place a temporary restriction on vessel traffic in the Brownsville Ship Channel and public access to Port property during orbital launches and some suborbital launches. Moreover, the planned closure hours, 500 for nominal operations and up to 300 hours for anomaly response could bring additional disruption to Port operations.

Disruption to vessel navigation in the Brownsville Ship Channel and restricting public access to land south of the ship channel could also be detrimental to cargo operators, as well as port tenants. Potential impacts include loss of wages for port personnel and commercial cargo providers, disruption of transportation and logistics operators, and additional operating costs for the Port, vessel operators, and cargo providers due to delayed access and disruption of operations.

BROWNSVILLE NAVIGATION DISTRICT • [redacted]

PORT OF BROWNSVILLE
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We recognize the tremendous economic benefit SpaceX brings to our community and region, but potential disruptions to Port operations, vessel movements, and tenant operations are a grave concern. We welcome the opportunity to discuss alternatives that are mutually beneficial to all parties involved.

Sincerely,

Eduardo A. Campirano
Port Director/CEO

18106

From: Brad Andres <[redacted]
Sent: Monday, November 1, 2021 9:56 AM
To: SpaceXBocaChica
Subject: SpaceX Programmatic EA Letter Attached
Attachments: USSCP SpaceX Letter 1 Nov 2021.pdf

The U.S. Shorebird Conservation Partnership

Building Collaborative Action for Shorebird Conservation

Ms. Stacey Zee
SpaceX PEA, c/o ICF
9300 Lee Highway
Fairfax, VA 22031
[redacted]

1 November 2021

Dear Ms. Zee,

On behalf of the U.S. Shorebird Conservation Partnership's Council, I am writing to express our deep concerns about the impacts of the SpaceX modifications proposed in the *Draft Programmatic Environmental Assessment for the SpaceX Starship/Super Heavy Launch Vehicle Program at the SpaceX Boca Chica Launch Site in Cameron County, Texas* (PEA). To address these concerns, we request completion of a full, detailed Environmental Impact Statement to evaluate immediate and cumulative effects of SpaceX activities on sensitive flora and fauna.

The U.S. Shorebird Conservation Partnership (USSCP) and its Council is a collective of individuals and organizations who are expert in the long-term conservation of Western Hemisphere shorebirds and their habitats. USSCP representatives have extensive experience in shorebird conservation and include federal agencies, state agencies and non-governmental organizations. We work collaboratively to address shorebird conservation issues and propose solutions. Accordingly, we are concerned about the loss of habitat, direct mortality (take), and contamination of wetlands vital to migratory shorebirds and other wildlife near the SpaceX launch site at Boca Chica. We have commented previously on the modifications to the wetlands permit issued to SpaceX.

At least 30 species of shorebirds have been recorded in the Boca Chica basin of the Lower Rio Grande Valley National Wildlife Refuge (Refuge) by professional biologists and volunteer observers, which represent nearly 60% of the shorebird species found in all of North America. This abundance of shorebird species present in the basin illustrates the biological diversity that the Refuge was designated to protect. Many of the species observed on the

Refuge rely on the site for winter habitat, and others depend on this unique area as a critical stopover site during migration from Central and South America to their breeding grounds in northern North America. Shorebirds from multiple flyways converge on the Boca Chica wetlands during the nonbreeding season. Adjacent to the Refuge, the Laguna Madre Western Hemisphere Reserve Network Site is recognized as being internationally important to shorebirds. Red Knots and Piping Plovers, which are listed under the U.S. Endangered Species Act, use the site during migration and winter. The saline shorelines near the current SpaceX site provide nesting habitat for Wilson's and Snowy Plovers, species of Birds of Conservation Concern in the U.S. (U.S. Fish and Wildlife Service 2021, https://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php).

We believe strongly that the mission of the Lower Rio Grande National Wildlife Refuge and the health of shorebirds and other wildlife dependent on the Refuge is being significantly compromised by the activities of the SpaceX testing and launching site, which is embedded on a private land in-holding surrounded by Refuge lands. We are particularly alarmed about the level of contamination anticipated from fuels, gasses, and toxic debris laid out across the Refuge. This launch-base area pollution could have long-term, ecosystem-wide impacts on all life of Boca Chica and near-shore Gulf of Mexico environments. It would have been difficult to choose a more biodiverse area surrounded by public lands accessible to state and U.S. citizens than the SpaceX site to undertake environmentally impactful activities.

Since the publication of the Environmental Impact Statement (EIS) and Record of Decision in 2014, the Federal Aviation Administration has issued eight Written Re-evaluations, all which determined that SpaceX's modifications to the launch site and operations fell within the scope of the original EIS. The infrastructure expansions proposed in the current PEA, including a power plant, natural gas pretreatment system and liquefier, desalination plant and solar farm, are not described in sufficient detail and continue a fragmented approach to understanding the environmental consequences of SpaceX's ever-changing plan for their Boca Chica operations. Particularly, impacts of launch failures and other "anomalies" are not adequately evaluated. Because of the lack of detail, mitigation to impacts cannot be determined adequately. Plans referenced in the PEA are filled with phrases like "to the extent practicable", which makes them meaningless and unenforceable (e.g., lighting plan). SpaceX has a history of not complying with permit conditions. Plans on how to pay for mitigation and permit violations should be specified.

Monitoring of sensitive wildlife is reported in Appendix D, although details on results are lacking. For Piping Plovers, we have information that populations in the vicinity of the SpaceX site have declined by 54% since 2018. Because Piping Plovers are highly site faithful on the nonbreeding grounds, expansion at Boca Chica could negatively affect a substantial portion of the Northern Great Plains breeding population (>6%).

As we previously recommended, a full, detailed Environmental Impact Statement should be prepared to evaluate the entire and cumulative effects of SpaceX activities on sensitive flora and fauna. The Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service should review the EIS and all documents associated with permitting. Until a rigorous EIS is completed, the FAA should halt all expansion of SpaceX's footprint and testing activities and ensure monitoring plans are being conducted and results transmitted to appropriate agencies and other stakeholders.

Thank you for the opportunity to comment.

Sincerely,

Catherine Hickey

Catherine Hickey, Vice Chair
U.S. Shorebird Conservation Partnership Council

18107

From: Max Weimer <[redacted]
Sent: Monday, November 1, 2021 7:52 AM
To: SpaceXBocaChica
Cc: [redacted]
Subject: SpaceX Public Comment

Greetings Ms. Zee,

I am writing to submit a public comment. I am for SpaceX's continued development of the Starship/Superheavy program in Boca Chica, Texas, due to its ideal location of the launch site in comparison to the equator, as well as the long term benefits it will provide to humanity through the research it will facilitate, through gaining materials from extraterrestrial bodies, and the benefits to the economy.

The location of the SpaceX launch site is ideal, and one of the best places in the united states, for sending objects into space. This is partially due to Boca Chica's distance to the equator while still being inside the US "SpaceX chose Boca Chica because… [Its] near the equator, closer to California," where SpaceX manufactures its rockets, "[A] critical factor is the proximity to the equator. A rocket that is closer to the equator gets more boost during launch" (ProvsCons.com) This shows that Boca Chica is the ideal location for the SpaceX launch site, due to its distance to the equator while still being located inside of the US, for easy transport of the rockets and the advantages of being a US-based company.

The location of Boca Chicha is also ideal due to the large body of water located next to the site, and the limited population, as well as the tax rebates offered by the Texas government. "SpaceX chose Boca Chica because it's near the shoreline, mostly inhabited." and the "FAA will never allow launching a rocket over land… and empty boosters crash on private property, causing damage." This makes the location ideal because of the fact that "Boca Chica is mostly inhabited. Though there is an unincorporated village, only 50 residents were living there." and "Texas state and local legislators offered tax incentives to build a rocket factory and launch site there." (ProvsCons.com) This shows that Boca Chica has a great number of distinct advantages, allowing for a more safe process to launch the rocket, as well as a more economical way.

To summarize these ideas, Boca Chica is one of the most ideal locations in the United States to launch a rocket due to its short distance to the equator, proximity to SpaceX's manufacturing facility in California, most uninhabited surrounding area, and nearby water source allowing for safer operations.

While space travel can be expensive, and harmful to the environment and ecosystems in the short term, the long-term benefits will outweigh the negatives, and improve humanity's overall way of life through better technology, improved economies, and save lives through early warning systems for natural disasters and improved medical technologies. "Science experiments performed on astronauts in space improve our understanding of medical conditions on Earth. This research has produced findings that can help people suffering from cardiovascular disorders, Type 2 diabetes, osteoporosis, and balance problems... Has allowed for innovations in the operating rooms" An example of this is the invention of the "NeuroArm, a highly precise robotic arm capable of performing brain surgeries that would otherwise be impossible." which was made possible via space travel.

We also improve daily life through the use of satellites, "Satellites provide crucial data about how our planet is changing. This information is invaluable to advance cutting-edge science, make climate projections and develop innovative solutions and services to mitigate or better adapt to the impacts of climate change." They can also be used via "save[ing] lives by gathering data that can be used to predict natural disasters such as hurricanes. This information helps people on the ground by giving them time to prepare or evacuate while enabling the quick deployment of adequate rescue teams." Some evidence of this helping is "Between 2012 and 2016, an average of six people per day were rescued by teams using this system."

Beyond that, we can also see the benefits that this provides to our everyday lives through research, the discovery of new materials, as well as the development of new equipment and items that we use every day. "Engineers in the space sector develop new cutting-edge technologies to accomplish seemingly impossible goals, and those technologies are often turned into products we use every day on Earth." This shows how space travel can really improve the general everyday life of average people here on earth through medical advances, satellites, new materials and equipment, and saved lives through early warning signs for natural disasters.

We can also see that space travel can be beneficial to the economy, and this is shown in "NASA Report Details How Agency Significantly Benefits US Economy" by NASA. "Through all NASA activities, the agency generated more than $64.3 billion [Despite only $21.5 billion being put in,] in total economic output during the fiscal year 2019, supported more than 312,000 jobs nationwide, and generated an estimated $7 billion in federal, state, and local taxes throughout the United States." This shows that while space exploration can be quite the investment; overall, it will significantly boost the economy.

In conclusion, we can conclude that space exploration, and the research being done through it, causes an overall extreme overall benefit to humanity. This is through new materials and technology being discovered, early warning systems for natural disasters, and advances in medical technology. We can also conclude that Boca Chica, Texas, is the most ideal place for SpaceX to set up a launch site, due to its proximity to the equator, distance to SpaceX's manufactiing site in California, and unihabbiting surrounding area. Please consider allowing SpaceX to continue its operations in Boca Chica, Texas, to allow for the benefit and improvement to humanity.

Thank you for your time and consideration.

-Max Weimer
A student at DSISD.

18108

From: Raymond DeLuna <[redacted]
Sent: Monday, November 1, 2021 8:09 AM
To: SpaceXBocaChica; Lauren Antonoff [she, her]
Subject: SpaceX Public Comment

Dear Ms. Zee,

I am writing to submit a public comment. I am for SpaceX's continued development of the Starship/Super heavy program in Boca Chica, Texas because I feel like colonizing another planet is crucial for humanity.

My subclaim is that Space Exploration is good for protecting our planet and our environment. “For example, the thinning of the **ozone layer** was discovered with the help of satellites, and governments from around the world took action by signing the Montreal Protocol to protect the ozone layer and tackle climate change”. The satellites protect the ozone layer and tackle climate change.6

Another one of my subclaims is Space Exploration is good for Enhancing safety on Earth. My claim is “During **earthquakes**, buildings and bridges undergo similar stress. That is why the same shock absorption technology used for spacecraft is now used to strengthen buildings and bridges in earthquake-prone regions”. With all the new technology they find it could make the world better.

I am for SpaceX counties development in Boca Chica because they Protect our planet and our environment. Reconsider Enhancing safety on Earth.

Sensorly,
Raymond De Luna

From: Malek Riche <[redacted]
Sent: Monday, November 1, 2021 1:05 PM
To: SpaceXBocaChica; [redacted]
Subject: SpaceX Public Comment

Dear Ms.
Zee,

I am writing to submit a public comment. I am for SpaceX's continued development of the Starship/Superheavy program in Boca Chica, Texas because I believe the future of humanity depends on the colonization of mars.

Part of SpaceX's mission is to position humankind to be able to travel to and live on Mars, which is great because the future of humanity depends on the colonization of mars for the resources and land. According to the article, *Why Exploring Space And Investing In Research Is Non-Negotiable* it says, "large areas of land could be utilized far better if efficient methods of watershed control, fertilizer use, weather forecasting, fertility assessment, plantation programming, field selection, planting habits, timing of cultivation, crop survey and harvest planning were applied."

It is a known fact that we can get resources from mars "The voyage to Mars will certainly not be a direct source of food for the hungry. However, it will lead to so many new technologies and capabilities that the spin-offs from this project alone will be worth many times the cost of its implementation." We could learn how to live life on Mars with the new technologies. And from the materials we get we will be able to make more of the things that are made by the materials that we can get more of on mars.

18111

From: Sean Ryan <[redacted]
Sent: Monday, November 1, 2021 1:05 PM
To: SpaceXBocaChica
Subject: SpaceX public Comment

Dear Miss Zee,

I'm for SpaceX’s continued development of the Starship/Superheavy program in Boca Chica Texas because I think the ends justify the means.

As you may know, SpaceX is set up in Boca Chica. I would like to go over what they doing there.
Let’s look at how is SpaceX affecting Boca Chicas wildlife. SpaceX has been testing rockets there and some of the failed tests and lanching debris into the marshlands. As a wildlife expert said, “local wildlife is being affected by SpaceX’s presence, Newstead said, but he’s already seen a change in the snowy plovers.” Anywhere that SpaceX sets up will have some form of damage to the wildlife so why should SpaceX have to move somewhere else just to spend more money to move again?

On a good note SpaceX has been bringing a lot of money into the small town nearby, “But SpaceX choosing to build here, that gave us tremendous validation. Other businesses finally started looking at us and seeing potential,” said a local business owner. Since there is so much more money going into the town and it has been really good for the people who live there.

Now that we have looked at how SpaceX has impacted Boca Chica let now turn our attention to what they trying to accomplish. SpaceX wants to send a rocket to Mars. As space becomes less and less expensive asteroid mining will become more viable. If we could mine one asteroid of normal size we could get a lot of rare metals that are not that rare in space. “The average asteroid is worth 4,500,000,000,000 in materials.” If we could start mining some of the asteroids we would not have to destroy so many natural areas for so little material. We could move most of the jobs that cause damage to our planet into space where we don’t need to worry about it.

The last thing I want to look at is how much we can learn by going to space. There is a lot that we don't know and going to space is a good way to learn more about how our universe works. I would like to talk about how “Our current understanding of physics is probably wrong.” One of the big things that we “know” about physics is that you can go faster than the speed of light. Now there could be something that we have not found out about yet or something that we can't think of without having knowledge of its existence before. So I think that the knowledge that we can gain can really outweigh the cons of damaging Boca Chicas environment.

Please take what I have said into account.

Thank you!
Oskar Ryan

From: Jacob Burgess Clark <[redacted]
Sent: Monday, November 1, 2021 1:05 PM
To: SpaceXBocaChica
Cc: Lauren Antonoff [she, her]
Subject: SpaceX Public Comment

Dear Ms. Zee,

I am writing to submit a public comment. I am for SpaceX's development of the starship/Superheavy in Boca chica Texas because the future of humanity depends on the colonization of Mars and because people leaving Earth can reduce pollution, thus helping the planet overall.

The future of humanity depends on the colonization of Mars. One reason is that we cannot survive on Earth forever because the population would get too big.“According to the United Nations, the population on Earth will reach approximately 9.8 billion by 2050 and 11.2 billion by 2100.” This increase in population proves that earth won't be able to hold a bunch of people forever. Additionally, the future of humanity depends on the colonization of Mars because when the population gets too big, there won’t be enough room for all the people to survive. “Colonizing Mars will help in leveraging this problem by distributing the Earth’s population to planet Mars.” When some of the population goes to Mars, then there may be room for people on earth.

Another reason that the future of humanity depends on the colonization of Mars is that people leaving Earth can reduce pollution because there will be less people using fossil fuels, and polluting the planet thus helping the planet overall. Next example is pollution would be reduced when the population decreases because less people would use things like cars, trains, plastic, etc. “The population of our planet has increased over the last few centuries.”

The last example is of how people leaving Earth can reduce pollution, thus helping the planet overall, is that earth’s resources would run out slower. “With this rapid growth of Earth’s population, there will be significant changes that our society will suffer from limited resources available on our planet.” This shows that the resources are running out slower if there are less people.

I am for SpaceX's development of the starship/Superheavy in Boca chica Texas because the future of humanity depends on the colonization of Mars and because people leaving Earth can reduce pollution, thus helping the planet overall. I believe that humanity won’t last long without Mars. Even though we are hurting animals in the process I think this is the best decision.

Sincerely,

Jake

From: Nicolas Mares-Gomez <[redacted]
Sent: Monday, November 1, 2021 1:08 PM
To: SpaceXBocaChica
Cc: [redacted]
Subject: SpaceX public Comment

Dear Ms. Zee,

I am writing to submit a public comment.
I am for SpaceX to continue development of the Starship/Superheavy Program in Boca Chica, Texas because I believe that Space Exploring is important to our world because we advance and achieve even more redundant things such as protecting wildlife and animals.

Using satellites to help access data that helps us world wide can be a really big help in protecting the wildlife."From space, astronauts have witnessed the world changing firsthand, such as the significant shrinking of the Aral Sea and the sharp decline in the Arctic sea ice extent. Satellites provide crucial data about how our planet is changing."Using satellites Worldwide can provide us with important data about our world. It gives us Data of the whole world from The geography of the world to providing weather information and how the world is shaping.

Climate change has damaged both Animals and humans too. ."This information is invaluable to advance cutting-edge science, make climate projections and develop innovative solutions and services to mitigate or better adapt to the impacts of **climate change**."
Information Valuable, Invaluable to advanced science to make climate projects to better the impacts of climate change.

Monitoring animals across the globe can be a really big help in protecting wildlife.
"From space, astronauts have witnessed the world changing firsthand, such as the significant shrinking of the Aral Sea and the sharp decline in the Arctic sea ice extent. Satellites provide crucial data about how our planet is changing."Using satellites world wide can provide us with important data about our world. It maps the lands and where the best places are to raise a species.

Improving knowledge and science to it's peak .One great benefit of space exploration is discovering new things. By using Space Probes, Rovers, and telescopes. "A great benefit of exploring space is new breakthroughs in science. Data collected by space probes, telescopes, rovers and more is continually challenging our assumptions."By using tools such as these we can collect data that is crucial to discovering data and learning more about space.

It is my own belief that I believe we should let Space exploration continue to progress further and further into the depths of the universe to help our planet and our humanity.

Sincerely,

Nicolas M

18114

From: Martin Romero-Valadez <[redacted]
Sent: Monday, November 1, 2021 1:10 PM
To: SpaceXBocaChica
Cc: [redacted]
Subject: SpaceX Public Comment

Greetings Ms. Zee,

I am writing to submit a public comment. I am against SpaceX´s continued development of the Starship/Superheavy Program in Boca Chica, Texas because it hurts vulnerable species and fragile ecosystems.

The Kemp Ridley turtle is an endangered species, and The Snowy Plover Species also is disappearing meaning going extinct."Sea turtles, known as Kemp's Ridley, deposit their eggs on beaches that SpaceX has been criticized for shutting". I am against SpaceX proofread because if and it's endangering the kemp ridley sea turtles and it's going extinct. And Proofread about Snowy plover disappearing. "The Pacific coast population of western snowy plovers has been in decline for several years, due to a loss of habitat". "The snowy plovers are important for the pacific coast because they are excellent indicators of the health and diversity of sandy beach ecosystems." The snowy plovers, a wading bird that is close to landing on the federal threatened species list. It would take a government agency to conduct the intensive rounds of ecological monitoring and study needed to understand how local wildlife is being affected by SpaceX's presence, Newstead said, but he's already seen a change in the snowy plovers. SpaceX is harming Fragile Ecosystem Coastal Dunes, SpaceX is hurting the fragile ecosystem with these tests with the explosions of the rockets and it's hurting the ecosystem and endangering endangered species.

Therefore, "there is usually an abundance of invertebrates in these coastal ecosystems and these serve as food for larger fish and a wealth of shorebirds and water birds". The coastal dunes that host a huge range of wildlife – with rocket debris. "I knew from the other explosions that the rocket would be scattered all over the refuge," Newstead said. Cleanup took three months, he added. The private space race is already causing concern about the potential climate impacts of the fuel needed to propel the rockets". But environmentalists on the ground in south Texas say SpaceX's testing site is having more immediate impacts. Lower Rio Grande wildlife refuge is full of discarded rockets, and The refuge is made of tidal flats, beaches, and sandy dunes which house the wildlife. If a rocket lands in the refuge it destroys the habitat of the animals who live there. I am against SpaceX´s continued development of the

Starship/Superheavy Program in Boca Chica, Texas because it hurts vulnerable species and fragile ecosystems. I cannot support efforts that have our future in mind, but not our present. Please, reconsider this site. The flora and fauna depend on you.
Sincerely,

Martin A Romero-Valdez

From: Finnegan Devitt <[redacted]
Sent: Monday, November 1, 2021 7:50 AM
To: SpaceXBocaChica
Cc: Lauren Antonoff [she, her]
Subject: SpaceX Public Comment

To Ms. Stacy Zee, Federal Aviation Administration

I am writing to submit a public comment regarding the location of the development of SpaceX's spacecraft in Boca Chica, Texas. I think that the development of the starship should be temporarily discontinued, but not permanently discontinued, due to environmental concerns. I think that there are more suitable and environmentally friendly places that the project could be moved to, without stopping it entirely.

First of all, the development of the spacecraft has been shown to harm the natural ecosystem in the area. In regards to the ecosystem, it is relatively well known that SpaceX's method of using prototypes of their rocket to test various flight conditions, leaves a substantial amount of debris and pollution around the area, which has apparently had adverse effects on the wildlife. Bryan Bird, a researcher with the National Environmental Nonprofit Defenders of Wildlife, says in regard to the endangered Snowy Plovers that nest in the area, that, "There used to be about a dozen nests dotting the tidal flats on the edge of Boca Chica where the refuge abuts SpaceX's property each spring, but last year the organization found just two pairs of the snowy plovers nesting, he said. This year they only spotted one." The data presented shows a drastic decrease in the population of endangered animals since SpaceX's rocket production began in 2019. If this trend continues, these already threatened animals could be seriously harmed by SpaceX's research in the area.

There is also the fact that harming Earth's environment defeats the purpose of the research SpaceX is conducting in the first place. Kathryn Denning, an anthropologist at York University in Canada, says that, "The tie to Earth does throw a wrench in dreams of shuffling off our terrestrial coil — dreams that can be an attractive alternative to the difficulty of tackling the challenges of life at home." This draws attention to the morals and ethics of SpaceX's project. The overarching goal of SpaceX's research is to allow humanity to live more sustainably and environmentally friendly, which includes the portion of humanity that is still on Earth. SpaceX also needs to consider the environmental sustainability of their rocket if they want to move humanity entirely to Mars. If we move to a new planet and can't sustain its ecosystem, then we'll just end up destroying planets as we move between them. If we can't sustain Earth's ecosystem, then we can't go to space so that we don't destroy other planet's ecosystems.

However, despite the environmental concerns, SpaceX's research is still important. Space travel will be invaluable once we have found a way to sustain a planetary ecosystem, and it can still provide benefits for the portion of humanity's population that has remained on Earth. Dr. Ernst Stuhlinger, a former NASA scientist, has said, "I even believe that by working for the space program I can make some contribution to the relief and eventual solution of such grave problems as poverty and hunger on earth. Basic to the hunger problem are two functions: the production of food and the distribution of food." In regards to solving the problem, Dr. Stuhlinger said, "The best tool for the improvement of all these functions, undoubtedly, is the artificial earth satellite. Circling the globe at a high altitude, it can screen wide areas of land within a short time; it can observe and measure a large variety of factors indicating the status and condition of crops, soil, droughts, rainfall, snow cover, etc." In this quote, Dr. Stuhlinger talks about how advances in aerospace research could improve agriculture. This is an example of why space travel is imperative to humanity's progress, and how we can't afford to discontinue SpaceX's starship program.

Because SpaceX's research is so important, but is also harmful to the environment, I propose that it be moved to another place. I think that an ideal location for a new launch site would be Slope County, North Dakota. According to data provided by the National Wildlife Refuge System, and the United States Census Bureau, Slope County has less than 1 person per square mile, and the only protected areas are White Lake, and Stewart Lake, neither of which are suitable spots for a launch site due to them being bodies of water. This makes it extremely unlikely that rocket debris would cause serious harm to either the human population, or endanger any unique or important species or natural resources. If SpaceX relocated their resources and research to Slope County, I believe they would be able to continue their research in a more environmentally friendly fashion.

While the experiments SpaceX is conducting could prove to be vital to the sustainability of the population, it threatens the ecological sustainability of the nature reserve in Boca Chica, and thus should not continue in that area specifically. If the project were not cancelled, but relocated to another area, the environmental concerns could be put to rest without hindering scientific progress. I hope that this has provided some, even slightly, valuable input to the Federal Aviation Association, thank you.

With respect.

Finnegan B. Devitt, Denver School of Innovation and Sustainable Design

From: Ned Cole <[redacted]
Sent: Monday, November 1, 2021 9:29 AM
To: SpaceXBocaChica
Subject: SpaceX Starship Super Heavy Project at the Boca Chica Launch Site and the environment

SpaceX Starship Super Heavy Project at the Boca Chica Launch Site and the environment

To The FAA From: Edward Cole

I would the environment where SpaceX is located and the aria around it to be protected. SpaceX should **at least** to be made to follow to the standards for protecting the environment that are now in place.

18117

From: colin blassingame <[redacted]
Sent: Monday, November 1, 2021 8:43 PM
To: SpaceXBocaChica
Subject: SpaceX Starship Super Heavy Project at the Boca Chica Launch Site
Attachments: SpaceX Super Heavy Programmatic Environmental Assessment.pdf

Commenter: Colin Blassingame

11/1/2021

Comments in regard to the SpaceX's Super Heavy/Starship Programmatic Environmental Assessment:

I would like to begin by thanking the FAA for the opportunity to give public comments on some of the issues that arose in an analysis of the PEA of SpaceX's Super Heavy/Starship. I am a current student at Grand Valley State University in Michigan and have been for the last two years following the Starship, Super Heavy and other programs that SpaceX has been generating. I of course have my own biases regarding the company and its specific projects including Super heavy/starship and will do my best during the main body of the these comment to not engage directly in those bias. I will go over specific chapters and section of the Assessment that I found lacking or in need of elaboration, then will continue with general comments about the overall PEA.

2.1 (Keywords: 'Infrastructure', 'Construction'.)

In this section the infrastructure being developed on Boca Chica is mentioned. This overview is based primarily on the 2014 EIS as mentioned after Table 2-1. Since the project is still in its earlier stages it is imperative that every significant period of growth involving infrastructure be analyzed with the current period in which development is occurring. Construction as cited later in the assessment (example: Section 3.3.4.) is in multiple sections concluded as one of the larger impacts of the program. Later comments will go further into the potential growth of this specific SpaceX program.

2.1.3. (Keywords: 'Radiosonde', 'negligible'.)

In this section one of many mentions of the term 'negligible' is given in reference to the impact of the Radiosonde weather data collection systems with the citation of NMFS 2017. I think that it would be prudent to quantify this impact within the larger context of the environmental impact of the program with a specific definition of the range of the impact these Radiosondes will have on the open marine waters in the region.

2.1.3.1., 2.1.3.2. & 2.1.3.3 (Keywords: 'Methane/LCH_4', 'Recycle', 'Unplanned Event'.)

In this section is mentioned Methane which has by far the largest GWP of 265 as cited later in section 3.4.1., however, I think it is also important to thoroughly layout the safety and regulatory protocols involved in housing LCH_4 and for there to be an overview of violations and consequence for negligence in the storing and significant release of this compound in case of an unplanned event. Later in section 2.1.3.3. it states that: 'SpaceX may recycle LCH_4', bring up a theme throughout the assessment that I will go further into later involving the ambiguity of the progression of the project and where it is headed. This is something that must be further investigated and understood in order to have a full and complete PEA of the SpaceX Super Heavy/Starship program.

2.1.3.4.

This section was not congruent to my understanding of the present strategy for the potential landing process of the Super Heavy. It is mentioned that it will land VLA, or on a floating platform off the coast. To my understand SpaceX was currently in the process of using a structure to grab hold of the

Super Heavy in a pincer-like action to assist in its vertical landing. Is this addressed with the infrastructure and landing process of the vessel?

2.1.4.

Construction is again mentioned within this section. Every expansion within the Boca Chica site should of course be assessed and the corresponding changes to the licensing and environmental impact should be update respectively.

3.2.

I would again push back on the 2014 EIS as the exponential growth of this program would influence 'the impact to the human environment' as the program progressed requiring action to the FAA license as quoted in the Chapter 1 introduction: 'The FAA is not licensing the entire Starship/Super Heavy program because SpaceX does not have the full details of all its planned operations at this time.'

3.3.1. (Keywords: 'negligible'.)

Again, the term negligible is used to describe the ambient pollutant emissions without giving an estimated or quantitative figure to the production generated.

Table 3.2

This is to me is the crux of the argument involving the need to reassess the environmental impact of SpaceX's Super Heavy/Starship program. Within this table and several other times throughout this document it is mentioned that the licensed number of launches for this program being 5. This may be congruent with the prototype and this specific launch site, however, SpaceX among its proposition for human operated missions in LEO(Low Earth Orbit) and potential future missions to the moon and specifically its claims of an attempt to send an anthropic mission to Mars has stated (or at least propagandized by a member of its executive team, Elon Musk; [Elon Musk says 'Building ~1,000 Starships to create a self-sustaining (tesmanian.com)]), that they are pushing for more frequent launches than 5 annual and has even mentioned a potential of multiple launches a day. I am unsure if this goal is meant to be reached on the Boca Chica site but this should be at least investigated for future PEA's throughout the life of this program.

- 3.4.1., 3.4.4. & Table 3-3 (Keywords: 'Methodology'.)

Within these sections it is mentioned that there is no methodology that exists to estimate the specific(if any) impacts to the GHG worldwide. This is based, as shown in Table 3-3, that the licensed Starship/Super Heavy annual launches is 5. This is equivalent to approximately 1/500,000th of the total annual CO_2 emissions generated by the United States. This I would agree is not a significant fraction of the countries environmental impact involving this particular GHG. However, as I stated in the previous paragraph the overall progression of the program in advancing meaning this impact will potentially increase to a significant fraction of the country's overall emissions impact. If the program were to grow to its published goal of 1000 launches a year its fraction impact annually in the U.S. would accordingly increase to ~1/2500th of total emissions.

Above are the specific sections that I believe need further analysis. But it must be stated that a majority of the document involved the environmental impact of the region, involving impacts on water supply, ecosystems, endangered animals, marine life, adolescents, historical structures and general possible degradation or damage to other infrastructure and natural structures in the region. This topic I have little to no expertise on and could not go into detail in the comments appropriate among those sections. I can only say that these forementioned topics that could be potentially impacted by SpaceX Starship/Super Heavy program should be thoroughly investigated, analyzed and data gathered to insure updates through the entirety of the program to insure that the environmental impact on the Boca Chica area remain as low as required for the continued flourishing of the regions ecosystems, and human inhabitances.

Lastly, I would like to overstep my honest attempt at an imperial analysis of this PEA to note a more biased opinion I had regarding some of the language used within this document. Specifically in section 2.1.3.4. a 'possible' mission is mentioned to Mars alongside, again, the proposed 5 launches a year. This possibility is so far beyond the scope of the SpaceX Superheavy/Starship program which would involve partnership with other organizations and technologies required that are far beyond the program's projection. Simply stated Starship/Super Heavy may have when fully operational the capacity to send an anthropic payload to Mars but lacks the technology or access to any technology capable of return the vessel and its inhabitants back to earth. As it cannot take enough essential resource along for a return journey and would have to synthesize them on the foreign regolith. Currently there is no technology available for such a mission especially since such an operation on Mars would require time meaning the window for a return mission would more than likely pass requiring a prolonged operation on the planet for an additional minimum of 18 months before the next return window occurs. This 'possible' mission is simply beyond the current potential of this program and should be mention thus or omitted entirely.

I hope to have been of some help with the FAA's PEA of SpaceX's Starship/Super Heavy program in contributing to the public comments. Thank you again for taking the time to do a thorough assessment and to review public responses. If you have any question about my comments, please don't hesitate to reach out to me via the email these comments were given.

18118

From: Sid Maddock <[redacted]
Sent: Monday, November 1, 2021 8:03 PM
To: SpaceXBocaChica
Subject: SpaceX: Zonick piping plover dissertation
Attachments: ZonickDissertation2000.pdf

Attached please find for submission to the administrative record for the SpaceX DPEA the dissertation of C.A. Zonick regarding piping plovers in TX.

Sidney Maddock

THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

A Dissertation
presented to
the Faculty of the Graduate School
University of Missouri - Columbia

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Philosophy

by
CURTIS A. ZONICK

Dr. Mark Ryan, Dissertation Supervisor

JULY 2000

The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

presented by Curtis A. Zonick

a candidate for the degree of Doctor of Philosophy

and hereby certify that in their opinion it is worthy of acceptance.

Dr. Mark Ryan

Dr. John Faaborg

Dr. Charles Nilon

Dr. Charles Rabeni

Gerald Summers

Dr. Gerald Summers

ACKNOWLEDGEMENTS

Never in my life have I spent so much time counting things. Birds, worms, beachcombers…I have a hard time looking at anything anymore without trying to count it. Few things, however, have been as challenging for me to count as the number of people that helped me with this project.

Let me begin by thanking my thesis advisor, Mark Ryan. Mark was a great facilitator, patient listener and inspiring mentor. One of my great regrets with this project was that I was in Texas most of the time and unable to benefit more often from Mark's wisdom and company. My other committee members, Drs. John Faaborg, Gerald Summers, Charles Nilon and Charles Rabeni were extremely helpful and supportive of the project, and I feel very fortunate to have benefited from the advice of such a distinguished group of scientists.

I was lucky to have the help of several fine field assistants. Keith Walsh, my first field assistant, endured the challenges of the hectic first field season, and became a good friend in the process. Tim Menard, Shawn Fairy, and John Hoffman also helped collect data on the project. I'm grateful for all of their dedication and camaraderie.

A most pleasant surprise was the large number of talented, and friendly biologists I came to know in Texas as they helped in one way or another with the project. Foremost among these was Lee Elliott, then with the Texas Parks and Wildlife Department (TPWD). Lee is a true naturalist and one of the finest people I've had the pleasure to know. I can't even begin to describe the number of ways Lee provided support during the project. I also owe Ted Eubanks (Piping Plover Recovery Team) a large debt of gratitude. The project simply would not have succeeded without Ted's initial support and enthusiasm. Others that provided expertise and moral support included Mary Ellen Vega, Lee Ann Linam, and Dick Harrington with TPWD, Robyn Cobb, Johnny French, Pat Clements, David Peterson, Phil Glass, Karen Myers, Claire Lee, and Theresa Barrera with the U.S. Fish and Wildlife Service Field Offices, Steve Thompson, Marie Fernandez, Linda Laack, and Dina, Freddie, Sam, Arturo, Rudy and the rest of the staff of Laguna Atascosa National Wildlife Refuge, Chris Pease with Matagorda Island National Wildlife Refuge, Mike Farmer and Rex Wahl with the National Audubon Society, Jake Dameron and Angela Deaton with Galveston Island State Park, and Dr. James Teer and the rest of the staff at the beautiful Rob and Bessie Welder Wildlife refuge.

At the Texas A&M University - Corpus Christi, Dr. Edward Jones provided valuable statistical advise and Dr. Kim Withers provided many interesting opportunities for discussion, and Tony Amos, at the University of Texas Marine Science Institute, was both informative and inspiring.

I would like to thank the Texas Parks and Wildlife Department, the U.S. Fish and Wildlife Service the National Fish and Wildlife Foundation, the Edward K. Love Foundation, the Rob and Bessie Welder Wildlife Foundation, and Ted Eubanks for their financial support of the project.

I would like to thank my family for their support during the project. My parents, Connie and Chuck Zonick, sister Michelle, grandfather Tony and grandmother Ruth, and in-laws Mary and Bill were always there to help me face the challenges of the project and ask me when I was going to finally get around to finishing.

Finally, I would like to dedicate the project, to my wonderful wife and friend Dr. Veronica Counihan, and to my new son Brett Anthony. They helped me realize that there are things that are actually more important than science, which, ironically motivated me to be a better scientist. Veronica helped me in so many ways, enduring the heat and other challenges of Texas and the long hours I had to dedicate to the project. I couldn't have finished this dissertation without her love and support.

THE WINTER ECOLOGY OF PIPING PLOVERS (*CHARADRIUS MELODUS*) ALONG THE TEXAS GULF COAST

Curtis A. Zonick
Dr. Mark Ryan, Dissertation Supervisor

ABSTRACT

Piping Plovers were monitored along the Texas Gulf Coast during the nonbreeding season (July – April) from 1991-1994. Groups of study sites were established within Texas' 2 coastal ecosystems (bay and lagoon ecosystems) and a coastal ecotone. Plovers were regularly counted at these sites and observed to determine habitat use patterns, diet, foraging effort, foraging efficiency, energy expenditure and factors influencing site abundance. Prey populations were sampled in areas used by foraging plovers for comparison to plover diets in different habitats and ecosystems.

Plovers were found to use bayshore tidal flats when bayshore tides were low and tidal flats were emergent. As bayshore tides inundated tidal flat habitat, plovers moved to beach habitat at most sites. Plovers density at beach and bayshore habitat varied in the 2 ecosystems and the ecotone. Plovers occurred at disproportionately high density at ecotone beaches and bay ecosystem tidal flats. In the lagoon ecosystem, where tides were controlled predominantly by winds, plovers used beaches less frequently, apparently also using mainland tidal flats and washover passes as secondary habitats.

Plover diet differed considerably in the 2 ecosystems. In the bay ecosystem, plovers fed predominantly on polychaetes, whereas plovers in the lagoon ecosystem were observed to feed largely on insects and other arthropods. Plovers in the ecotone exhibited a mixed diet of polychaetes and insects. Prey samples established that plover diets in these areas closely reflected the available prey communities. Plover flock size was

positively correlated with total benthic density and polychaete density in the bay ecosystem and the ecotone, but negatively correlated with these prey in the lagoon ecosystem, where plovers fed to a much greater extent on insects.

Plovers captured about 10 animals/minute in both ecosystems and the ecotone, and at beach and bayshore habitats. However, plovers foraging at beach habitat appeared to invest much more energy responding to human disturbance, territorial aggression, avoiding the swash. This additional energy investment likely resulted in a substantially lower energy intake rate for plovers foraging at beach habitat, and may explain why beaches were generally used only when bayshore flats were inundated. Plovers spent approximately 77% of their time foraging during daylight hours, and were more likely to roost during high bayshore tides and at beach and washover pass habitat.

Mean plover study site abundance was related to several environmental parameters (beach benthic density, bayshore benthic density, bayshore surface prey density, bayshore area, beach length, beach vehicular density). A stepwise multiple regression model selected beach length (positive) and beach vehicular density (negative) as the factors most strongly influencing plover site abundance. These results suggest that, although plovers may use beaches as a secondary habitat, degradation to this habitat may be limiting plover carrying capacity on Texas barrier islands. Given these findings, the large number of Piping Plovers wintering in Texas (~50% of the global population), and the extended length of the nonbreeding period (9-10 months), the protection of beach habitat should be among the highest priorities for Piping Plover recovery.

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CHAPTER I. INTRODUCTION AND STUDY AREA

INTRODUCTION

Few animals better symbolize the challenges associated with preserving biodiversity than the federally-protected Piping Plover (*Charadrius melodus* Ord). Like many other American species, the Piping Plover was reduced to near extinction in the late 1800's by unregulated hunting (Bent 1929). Plover populations recovered in the early 1900's after the establishment of the Migratory Bird Treaty Act and other laws designed to control the harvest of wildlife only to suffer another more recent decline caused by habitat loss and other impacts associated with human encroachment (U.S. Fish and Wildlife Service 1985).

In 1985, the Piping Plover was added to the group of plants and animals on the list of federally threatened and endangered species protected under the Endangered Species Act (ESA). There are now over 1,200 species on this list (U.S. Fish and Wildlife Service 2000), but in the 27 year history of the ESA, only 6 species have recovered to the point that they have been removed from the list (Mann and Plummer 1995). As is the case for most other species still on the federal list, the Piping Plover persists in the wild but continues to decline.

The federal agency responsible for enforcing the ESA for terrestrial species, the U.S. Fish and Wildlife Service (Service), admits on their worldwide web site that the ESA has succeeded in doing little more than preventing the extinction of listed species:

> "Of all the species listed between 1968 and 1995, only 7 -- or less than 1 percent — have been recognized as extinct and subsequently de-listed. The fact that almost 99 percent of listed species have not been lost speaks to the success of the Act as a mechanism for conservation of species that are at risk of extinction."

Millions of dollars have been spent toward Piping Plover recovery, no doubt greatly reducing the species' decline and improving its recovery potential. In this regard the Piping Plover is not typical of other listed species, most of which have received little or no funds for research or recovery efforts. More is known about the Piping Plover, and more protective measures have been undertaken on behalf its recovery, than for most of the other listed species combined. Despite such disproportionate investments, however, demographic models project the extinction of the Great Lakes/Great Plains populations sometime near the middle of the current century (Ryan et al. 1993, J. Plissner, pers. comm.)

The Piping Plover is one of about 650 species with an approved recovery plan. A recovery plan is essentially a set of goals and strategies, written by a group of biologists (i.e., a recovery team) with species-related expertise, and designed with the goal of recovering the listed species. The research described in this manuscript addresses many of the winter recovery goals set in the Piping Plover recovery plans.

Project Description

This dissertation details research I conducted between July 1991 and April 1994 describing the ecology of the federally - protected Piping Plover (*Charadrius melodus*) on wintering grounds along the Texas Gulf Coast (TGC). The northern and southern regions of the TGC present 2 different coastal ecosystems to nonbreeding Piping Plovers. One of the primary focuses of my research was to determine whether Piping Plover ecology differed substantially among these two coastal ecosystems. I approached this question by studying plover populations at 18 study sites along the TGC. I monitored plovers at 3 or more representative study sites within each coastal ecosystem, and within the ecotone region where the 2 ecosystems meet. I evaluated the effects of several habitat parameters and environmental variables on plover abundance and density, studied the diet and foraging ecology of plovers, and collected samples to describe the prey populations used by plovers at the 18 study sites. I used these measures to estimate and compare the resources available to plovers and the foraging success of plovers among the two coastal ecosystems.

The Focus of Piping Plover Recovery Efforts

On 11 December 1985, the Service issued a final rule recognizing 3 distinct breeding populations of Piping Plovers worldwide (U.S. Fish and Wildlife Service 1985). The larger 2 populations, breeding along the Atlantic Coast of North America and the North American Great Plains, were listed as threatened. A third population, much smaller than the others and breeding only along the shores of the North American Great Lakes, was listed as endangered. Two recovery teams were created by the Service, one to plan the recovery of the Atlantic Coast Population, and a second to do the same for both interior populations. Recognizing the link between species conservation and habitat conservation, both recovery teams placed a high priority on determining the habitat requirements of each population. Most research and management efforts focused on breeding populations (e.g., Prindiville-Gaines and Ryan 1988, MacIvor 1990, Nordstrom 1990, Mayer and Ryan 1991a, Mayer and Ryan 1991b), despite the fact that Piping Plovers spend the vast majority of their life cycle away from the breeding grounds (Bent 1929). The early bias toward breeding ecology was necessary to stem the species' steep decline (Ryan et al. 1993). The major causes for the decline of Piping Plovers were attributed primarily to the loss of breeding habitat (to development and water-control projects), increased depredation on eggs and juveniles, and the direct destruction of nests by human activities (Haig and Oring 1985).

More recently though, it has become apparent that the recovery of the Piping Plover may hinge on an understanding of the species non-breeding ecology and responsible stewardship of winter habitat. Recent events have focused increasing attention on the potential for a catastrophic loss of Piping Plovers during the 9-month nonbreeding period.

These include a series of hazardous material spills near Galveston Island and a persistent brown tide episode in the Texas Laguna Madre (Dunton 1994, Edwards 1995). Piping Plover winter habitat is threatened by hydrological changes associated with the Gulf Intracoastal Waterway (GIWW: Farmer 1991, Diaz and Kelly 1994), commercial development, and predicted sea level rises (Bildstein et al. 1991). These events pose less immediate, but potentially greater threats to the long-term population viability of the Piping Plover.

Research has begun to fill in the gaps in our understanding of the key aspects of Piping Plover winter ecology. Most work has focused on defining the species' winter range (Haig and Oring 1985, Nicholls and Baldassarre 1990a, Haig 1992). Early investigations have begun into such aspects of Piping Plover ecology as habitat associations (Nicholls and Baldassarre 1990b), movement patterns (Johnson and Baldassarre 1988), and activity budgets (Johnson and Baldassarre 1988). Most of these studies, however, have been limited by either time (a single field season; Nicholls and Baldassarre 1990b), or geography (a single study location; Johnson and Baldassarre 1988).

The winter distribution of Piping Plover populations is becoming clearer due to several recent census efforts (Haig and Oring 1985, Nicholls and Baldassarre 1990b, Haig and Plissner 1993, Eubanks 1994, Zonick and Ryan 1995, Elliott 1996). The first International Piping Plover Census (IPPC) was conducted in 1991. The winter portion of the 1991 IPPC accounted for a total of 3,451 Piping Plovers during a 2-week census of the presumed winter range of the species. The 1991 IPPC count represented approximately 63% (3,451 out of 5,482) of the number of breeding Piping Plovers recorded during the 1991 IPPC summer count of breeding Piping Plovers (not counting the number of young produced in 1991). Wintering Piping Plovers were observed along the Atlantic Coast from the southern tip of Florida to the upper portion of North Carolina.

Wintering birds also were recorded on the shores of the Bahamas and Cuba, but the majority of the winter population was observed along the Gulf Coast of the United States. Over 92% (3,206 out of 3,451) of all of the Piping Plovers observed during the non-breeding portion of the IPPC occurred along the Gulf Coast. Of these, nearly 60% (1,905 out of 3,206) were observed along the TGC. Several large regions of the TGC (e.g., the Land-Cut, Baffin Bay, and North Padre Island) received only partial coverage during the 1991 IPPC. Also, despite admirable efforts by a few individuals, the Gulf Coast of Mexico has yet to be surveyed to the extent of the United States Gulf Coast. It is very possible that a large portion of the birds unaccounted for on the winter portion of the IPPC occurred in these areas.

The second IPPC was conducted in 1996 (Elliott 1996). A total of 1333 Piping Plovers were recorded in Texas in 1996, down substantially from the 1991 count of 1905. Several factors varied between the 2 counts, however, and the 1996 count is almost certainly a less accurate count than was the 1991 IPPC. Whereas many sites that were missed in the 1991 IPPC were covered in the 1996 count, many areas that were covered in 1991 were omitted from the 1996 count. The difference in the coverage in 1996 was due in large part to an extended period of extremely low tides that made many areas inaccessible, and to a government furlough that greatly reduced the manpower available for the 1996 IPPC.

Piping Plover winter habitat requirements also have been recently investigated. Johnson and Baldassarre (1988) and Nicholls and Baldassarre (1990) described aspects of the major habitat types utilized by Piping Plovers, as well as some of the microhabitat characteristics that are predictive of Piping Plover presence. Johnson and Baldassarre (1988) observed Piping Plovers in the Mobile Bay complex of the Alabama Gulf Coast to use "sandflats," "mudflats," and "beaches" as winter habitats. Their research indicated that sandflats and mudflats were "used for feeding", and sandy beaches were used for "resting and probably roosting" (Johnson and Baldassarre 1988).

Nicholls and Baldassarre (1990b) used discriminant function analysis (DFA) to investigate the relationship between a number of microhabitat characteristics and the presence/absence of Piping Plovers throughout most of their winter range. Their analyses selected "...greater beach width, greater % mudflat, lower % beach and more small inlets ..." as the winter habitat characteristics predictive of Piping Plover presence/absence along the Gulf Coast of the United States. Along the Atlantic Coast, DFA selected "...the number of large inlets and passes, number of tide pools, % mudflat, beach width, and % sandflat as the major factors affecting (Piping Plover) presence or absence." (Nicholls and Baldassarre 1990b).

The nonbreeding behavior of Piping Plovers has been described for only selected locations. Piping Plovers wintering along the Alabama Gulf Coast were observed to spend the majority (76%) of their time foraging (Johnson and Baldassarre 1988). Tidal height was negatively correlated with plover foraging activity in Alabama. After resighting 12 of 19 plovers color-banded at Dauphin Island, Alabama, Johnson and Baldassarre (1988) concluded that Piping Plovers exhibit "relatively high site-fidelity...to wintering sites in coastal Alabama." Elliott and Teas (1996) described the behavior of plovers using beach habitat at 3 locations along the central Texas coast. Plovers at these 3 sites spent most of their time foraging (86.7%, 89.5%, and 96.2%). Elliott and Teas estimated levels of human disturbance at the sites based upon counts of vehicles and pedestrians and found pedestrian encounters caused plovers to shift from foraging behavior to some other activity. Vehicles did not have the same effect, suggesting plovers were less affected by this form of disturbance. However, Elliott and Teas found plover abundance to be negatively correlated with vehicle abundance.

Unanswered Questions

Most of the previous work done on nonbreeding *Piping Plovers* has been spatially or temporally restricted. For example, the conclusions by Nicholls and Baldassarre (1990a, 1990b) were founded primarily upon data collected from a collection of onetime visits to a large number of study sites throughout the winter range. Conversely, the research by Johnson and Baldassarre (1988) addressed specific aspects of Piping Plover ecology through multiple visits to a very small portion of the winter range. Whereas these approaches were appropriate for the scope of each project and provided a foundation toward an understanding of the winter requirements of Piping Plovers, they did not answer several key questions.

The habitat associations derived by Nicholls and Baldassarre (1990b) reflect only a portion of the parameters that might play a role in habitat selection by Piping Plovers. For instance, they did not consider such factors as tidal stage, prey density, and human disturbance in their analyses, yet these factors have been shown to significantly influence shorebird site-use and behavior (Burger et al. 1977, Connors et al. 1981, Hicklin and Smith 1984)

Johnson and Baldassarre (1988) provided new insight into the winter movements and winter activity of Piping Plovers. However, the limited spatial scale of their research constrains the degree to which their results can be used to describe general winter movements and behaviors of Piping Plovers, particularly within markedly different ecosystem types like the Laguna Madre systems in Texas and Mexico. Here also, the habitat descriptions were general in nature (e.g., sandflat, beaches) and were not related to proximate influences such as prey density or human disturbance.

Of central relevance to the recovery of the Piping Plover is the identification and protection of high quality winter sites. Generally, the quality of a particular habitat or location to Piping Plovers has been determined indirectly, based upon survey information or the presence of habitat features commonly associated with Piping Plover presence. In 1990, Nicholls and Baldassarre broadened the criteria for appraising a location's value to

Piping Plovers by ranking winter sites using a formula that incorporated judgments about the quality of local habitat features. According to their formula, sites having more than 40 plovers were ranked as "1" (i.e. most important sites). Sites were ranked as "2" (i.e. of secondary importance) if the site had between 20 and 40 plovers and met at least 2 of 3 criteria. The criteria were:

> "(1) habitat quality, i.e., excellent, with expansive mudflats adjacent to sandy beach; (2) historical data, i.e., presence on Christmas Bird Count at least once in previous five years; and (3) disturbance level, i.e. moderate to no disturbance at site (e.g., < 1.4 people and/or 0.2 off-road vehicles observed per km)."

Although the system's measure of habitat quality was subjective (by their own admission) and relied heavily on census data, the consideration of habitat features by Nicholls and Baldassarre resulted in a more credible ranking scheme by reducing the likelihood that a site might be given inflated stature based upon a single anomalous census. The consideration of human disturbance as one of the ranking criteria added another important dimension to the scheme. Nicholls and Baldassarre recognized that, when appraising a site's value to Piping Plovers, it was important to determine not only how many plovers occurred at a site, but also whether the habitat at that site was of sufficient quality to support the population (or an expanding population during the recovery process), and whether other environmental variables (e.g., human disturbance) were present that might compromise the site's apparent value.

Study Focus

In this study I present a site appraisal model predicting Piping Plovers abundance, and compare the quality of different habitat types and ecosystem types for Piping Plovers. I support these models by relating 3-year measures of Piping Plover site quality estimators (e.g., Piping Plover abundance, foraging efficiency) to an assemblage of simultaneously monitored habitat components (e.g., estimates of available habitat, prey population measures) and environmental variables (e.g., human disturbance measures) that are most likely to affect Piping Plover site quality.

My research focused on describing the effects of key habitat components and environmental variables on the abundance and foraging ecology of Piping Plovers in different habitats and ecosystem types along the TGC. I evaluated Piping Plover foraging success using several approaches and used these measures as a means of appraising the relative success of nonbreeding populations. I contend that, in addition to abundance, foraging success is one of the most appropriate means of appraising the quality of different habitats, sites and landscapes for Piping Plovers. Foraging activity has been shown to occupy the largest proportion of the diurnal activity of wintering Piping Plovers (Johnson and Baldassarre, Teas and Elliott unpublished data, pers. obs.). Maintaining fat stores is of primary importance to plovers and other migratory shorebirds (Evans 1976, Davidson 1981, Myers et al. 1987, Helmers 1992). Furthermore, because Piping Plovers are a federally-protected species, other means of appraising the relative condition of plovers (e.g., by direct measurement of fat stores from harvested birds) in different areas or habitats were not justifiable.

Research Objectives

The primary objectives of the research were as follows.

Objective 1. Characterize and compare the relative density of Piping Plovers among 2 coastal ecosystems and their ecotone.

Because Piping Plovers winter over a wide geographic range, encompassing several ecosystem types, this comparison is expected to guide Piping Plover recovery by determining how ecosystem type affects plover density.

Objective 2. Identify the spatial, temporal, and environmental factors that affect Piping Plover densities.

A specific goal associated with this objective was to determine whether differences in Piping Plover density can be explained by specific spatial, temporal or environmental parameters, or combinations of these conditions acting together. This will greatly extend the current knowledge associated with Piping Plover winter habitat use patterns.

Objective 3. Characterize the prey resources potentially available to Piping Plovers among the habitats and ecosystems used by Piping Plovers along the TGC.

These data will help determine the relationship between potential prey density and Piping Plover density and will support habitat quality appraisals.

4. Characterize the foraging ecology of Piping Plovers along the TGC, and identify the factors affecting foraging success.

Specific goals associated with this objective were to determine and compare:

a. The amount of time Piping Plovers spend foraging among major habitat types along the TGC;
b. Piping Plover diets among major habitat types and ecosystems along the TGC;
c. Estimated energy expenditures by Piping Plovers among major habitat types and ecosystems along the TGC;
d. Piping Plover foraging efficiency among major habitat types and ecosystems along the TGC;
e. Agonistic behavior by Piping Plovers among major habitat types and ecosystems along the TGC;

This information will provide additional knowledge about Piping Plover diets in different habitats and ecosystems and will allow for a comparison of the quality of the habitat types and ecosystems used by Piping Plovers along the TGC as appraised by the relative costs and benefits associated with foraging.

Objective 5. Identify the habitat components and environmental conditions that most strongly influence Piping Plover abundance at sites along the TGC.

Accomplishing this objective will help prioritize sites, or perhaps entire ecosystems, for conservation. This model will help direct the preservation or restoration of areas with quality habitat for wintering Piping Plovers by identifying the habitat components that are most likely to influence Piping Plover carrying capacity. With this knowledge, high quality habitat might be preserved in areas that are subject to development or other human modifications by guiding the design of future projects in a manner that is likely to minimize impacts to key habitat components. Similarly, this model will allow resource managers to more accurately predict the effects of changes associated with environmental conditions (e.g., bayshore tidal regimes, human disturbance), potentially leading to more effective habitat management for Piping Plovers during the nonbreeding season.

The research associated with these objectives is presented in 3 different, but interrelated chapters. Chapter 2 describes research addressing Piping Plover population density and the environmental factors affecting Piping Plover habitat use along the TGC (Objectives 1-3). Chapter 3 describes Piping Plover foraging ecology, and the factors that influence foraging success (Objective 4). Chapter 4 describes the factors influencing Piping Plover site abundance (Objective 5). In a summary chapter I discuss the implications of the findings on efforts to recover the Piping Plover, and recommend steps to improve the management of habitat along the TGC for plovers.

STUDY AREA

I selected the Texas coast as the geographic focus of this research because Texas supports the largest known portion of the Piping Plover winter population (Haig and Plissner 1993, Nicholls and Baldassarre 1990b). I examined the non-breeding ecology of Piping Plovers at 18 study sites along the Texas Gulf Coast (TGC). Three or more sites each were located within the 2 coastal ecosystems represented in Texas, the estuarine bay ecosystem, and the hypersaline lagoon ecosystem (Figure 1). Four more sites were located within the ecotonal transition between the 2 coastal ecosystems.

All sites but one (Laguna Atascosa National Wildlife Refuge) contained a stretch of ocean beach. Although site beaches differed somewhat with regard to prey population densities, levels of human disturbance, and beach width, beach habitat structure was similar at all study sites.

In contrast, bayshore habitat structure differed greatly among my study sites. Changes associated with a few key geomorphologic and environmental factors along the TGC have produced 2 markedly different coastal ecosystems, each characterized by very different bayshore habitats. Two factors, tidal regime and salinity, strongly influence the habitats that occur along the TGC.

Tidal amplitudes are attenuated along the entire TGC relative to other, less sheltered North American coastlines (Britton and Morton 1989). Tides affecting beach shore are similar along the Texas Gulf coastline. In contrast, the bayside tides vary markedly in different regions of the TGC, and often are not synchronized with beach tides.

The salinities of Texas bays also varies markedly. From Galveston Bay in the north to South Bay bordering Mexico, there is a progressive increase in salinity. Southern bays are saltier because they receive less freshwater from rains and riparian inflows, and lose greater relative volumes of freshwater to evaporation.

In the northern region of the TGC, extending from the Houston Ship Channel Pass south to Aransas Pass (Figure 1), tides are controlled predominantly by astronomical forces, baywater salinities are generally brackish (15 - 30 ppt), and the climax intertidal community is dominated by cordgrass (*Spartina alterniflora*). This region can most accurately be described as an estuarine bay ecosystem, and is referred to by this term, or by the term "bay ecosystem" hereafter in this report.

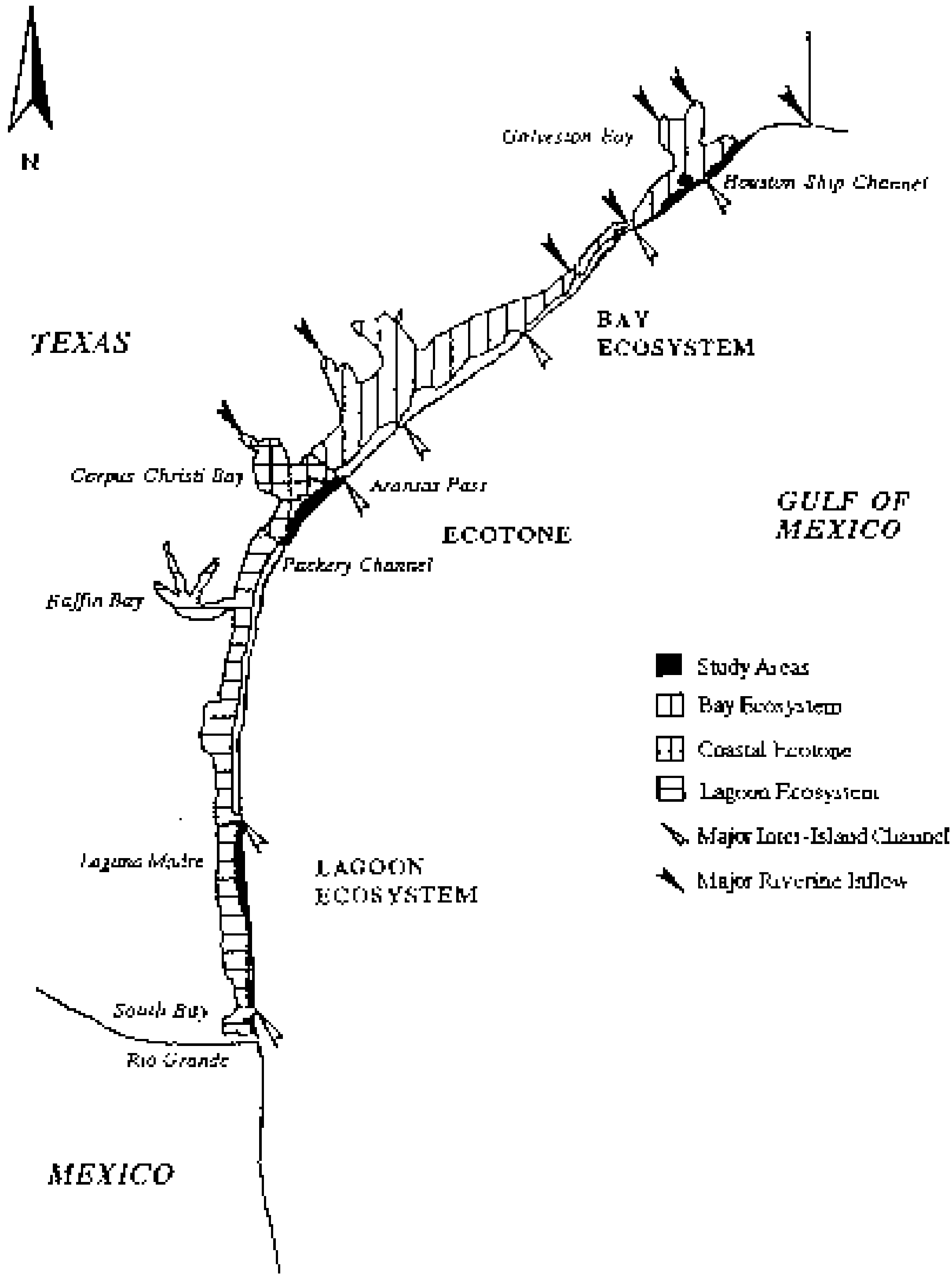

Figure 1. Schematic diagram of the Texas Gulf Coast illustrating the relative positions of the two major coastal ecosystems and the coastal ecotone.

About 50 km to the south, a different ecosystem becomes evident near Packery Channel and extends to the Rio Grande (Figure 1). In this region, tides are controlled mostly by shifts in winds and atmospheric pressure, particularly those accompanying winter cold fronts. Baywater salinities are often extreme (> 50 ppt), and the climax intertidal community is dominated by blue-green algal flats. This unique ecosystem is best described as a hypersaline lagoon ecosystem because it is characterized and maintained by recurrent periods of hypersalinity due to relative geographic isolation from other permanent bodies of water. This region is referred to as either the "hypersaline lagoon ecosystem" or the "lagoon ecosystem" hereafter.

Between these 2 ecosystems exists a transitional region where the tides are affected in mixed fashion by both winds and astronomical forces, salinities fluctuate between brackish and extreme, and the intertidal community is dominated neither by cordgrass, nor algal flats, but a mixture of both communities (Figure 1). This region can best be described as a coastal ecotone and is identified by this term, or by the term "ecotone" hereafter.

The Estuarine Bay Ecosystem and Study Sites.

The Galveston Bay system of the upper Texas Coast typifies the landscape and habitat features of the estuarine bay ecosystem. The climate in this ecosystem ranges from humid to subhumid with average annual rainfalls between 80 - 125 cm (Texas General Land Office 1994). Temperatures generally range from winter minimum lows near 7°C to average summer highs near 35°C (Texas General Land Office 1994). Baywaters within the estuarine bay ecosystem are deeper than those in the lagoon ecosystem. Maximum depths of primary bays in the estuarine bay ecosystem range from about 1.3 m (Galveston Bay) to 4.0 m (Matagorda Bay) compared to the hypersaline lagoon ecosystem's shallow primary bay (Laguna Madre) which reaches a maximum depth of only about 1 m (Britton and Morton 1989). Primary bay salinities range from about 18 ppt in Galveston Bay to 23 ppt in Matagorda Bay (Texas General Land Office 1994). The intertidal regions of the bayshore in the estuarine bay ecosystem are dominated by densely-vegetated cordgrass marshes. Other typical plant species that flourish within this ecosystem include Marshhay cordgrass (*Spartina patens*), Glasswort (annual: *Salicornia bigelovii*, perennial : *Salicornia virginica*), Saltwort (*Batis maratima*) and Gulf cordgrass (*Spartina spartinae*). Unvegetated sand and mud flats appear as a narrow fringe along the marsh's border during periods of low tide. A few large (> 20 ha) unvegetated sand and mud flats occur in the bay ecosystem, usually adjacent to large tidal channels, or on the accreting side of jetties, but these flats comprise only a small percentage of the total area of bayshore habitat, most of which occurs as cordgrass marsh. The tides occur at a diurnal to semi-diurnal frequency, so that the unvegetated flats become available to shorebirds once or twice every 24 hours. The 3 sites monitored in the bay ecosystem were Bolivar Flats, Big Reef, and San Luis Pass (Figure 2).

Bolivar Flats. This site, located at the southeastern tip of Bolivar Peninsula in Galveston County, was composed of a single muddy sand flat, sandwiched between the northern jetty along the Houston Ship Channel and a cordgrass marsh (Figure 3). The marsh and sand flats at this site were growing as a result of the accretion of sediment transported by the Gulf longshore current, and trapped by the north jetty. Bolivar Flats was accorded protection via a 100-year lease to the National Audubon Society in 1992.

Big Reef. This site, located on Galveston Island in Galveston County, was an accreting wetland situated along the northern edge of the Houston Ship Channel's southern jetty (Figure 3). This site contained a small lagoon surrounded by a vegetated sandy spit. However, salinities in the lagoon were usually well below that of seawater (i.e., < 35 ppt). The lagoon was bordered by several small muddy sand flats fringed by patches of cordgrass marsh. A small tidal channel at the site's west side maintained a constant tidal exchange between the lagoon and the Houston Ship Channel. The City of

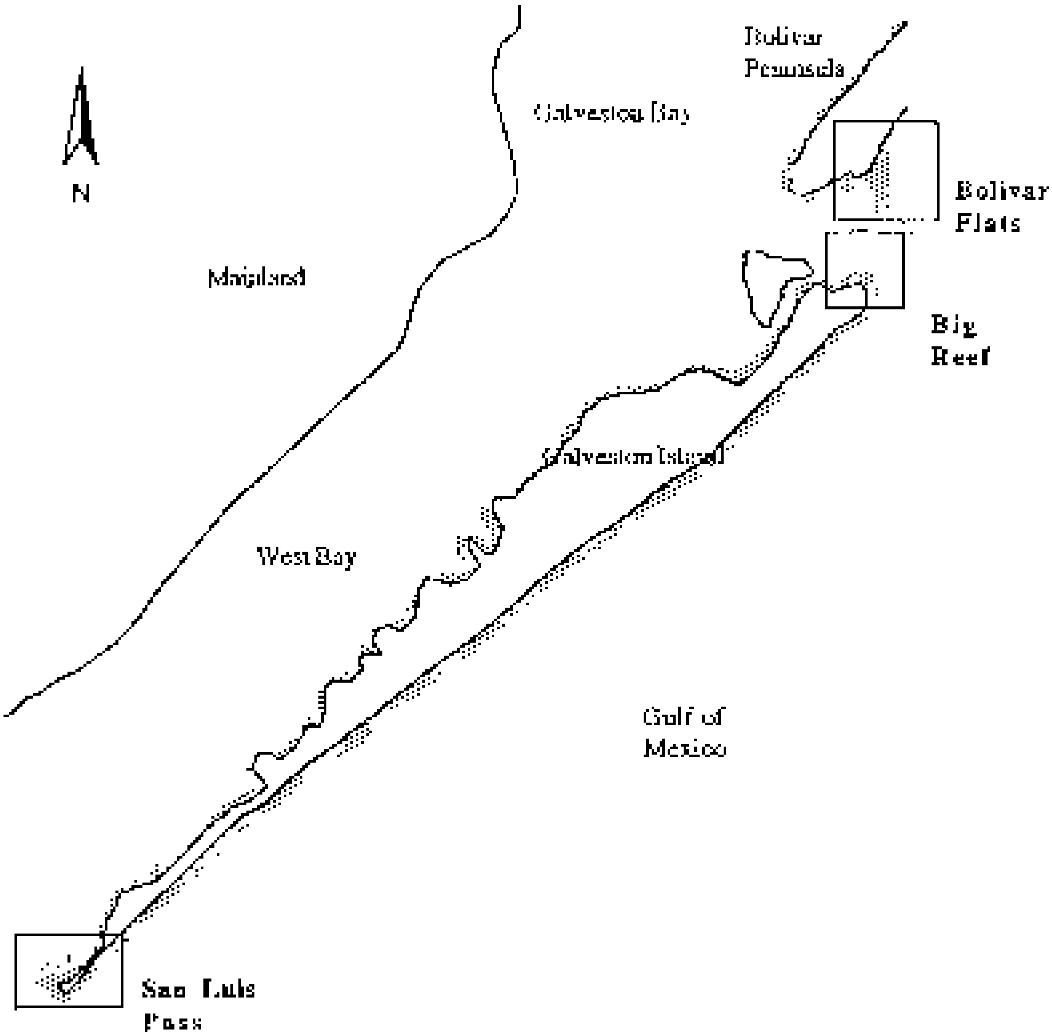

Figure 2. The relative locations of the study sites representing the bay ecosystem are illustrated. Bolivar Flats is located on Bolivar Peninsula. Big Reef and San Luis Pass are located on Galveston Island.

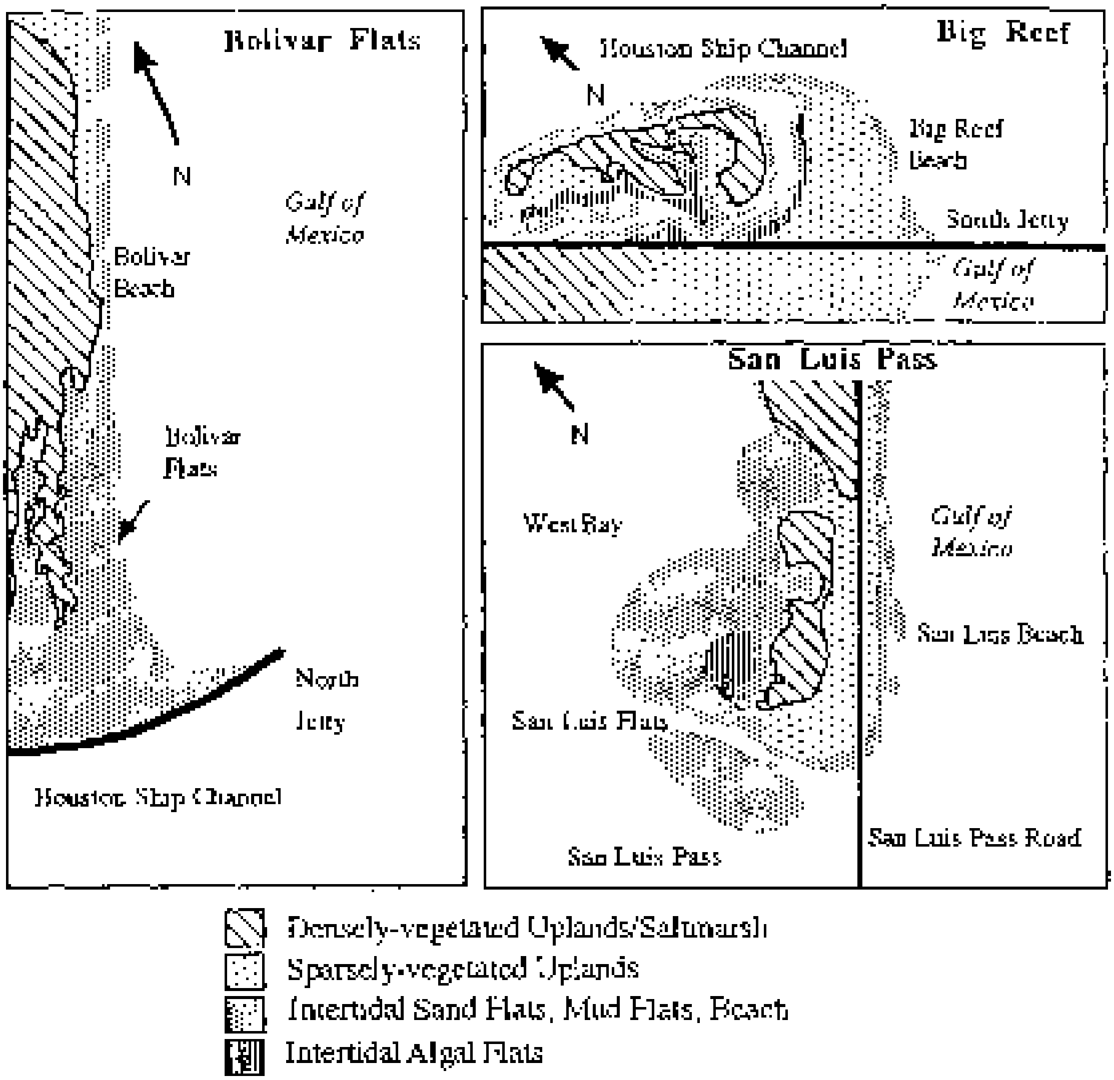

Figure 3. Schematic maps of the 3 Estuarine Bay Ecosystem Sites.

Galveston established the Big Reef study site as the Big Reef Nature Park soon after the conclusion of the study in 1994.

San Luis Flats. This site, located along San Luis Pass on the southwest tip of Galveston Island in Galveston County, was composed of several large sand flats bordered by coastal prairie (Figure 3). It was the only estuarine bay ecosystem study site that was not largely created by a man-made structure.

The Central Ecotone and Study Sites.

The ecotone exhibits habitat features diagnostic of each bordering ecosystem. Cordgrass marshes are present, but reduced in comparison to the bay ecosystem. The ecotone also is reflective of the lagoon ecosystem, as permanent algal flats occur in many locations. The vegetative community and baywater salinities are a blend of those typifying the 2 ecosystems, and tides are driven by both winds and astronomical forces. The 3 sites monitored in the ecotone were East Flats, Mustang Island State Park, and Packery Channel (Figure 4).

East Flats. This site, located near the northern tip of Mustang Island in Nueces County, was composed of a series of algal flats and mud flats separated by small patches of upland, and fingers of cordgrass and cattail (*Typha* spp.) marsh (Figure 5). A wastewater reclamation facility released a treated, low-salinity effluent into this wetland from its eastern border. Once sharing a broad tidal exchange with the waters of Corpus Christi Bay and Redfish Bay, this wetland had been surrounded to such a great extent by dredge spoil from the Corpus Christi Ship Channel and a residential access channel that the only remaining tidal exchange between the site's tidal flats and the surrounding baywater occurred through a few small channels along the site's southern border. The periodicity and magnitude of inundation experienced by the flats was erratic due to the restricted tidal flow.

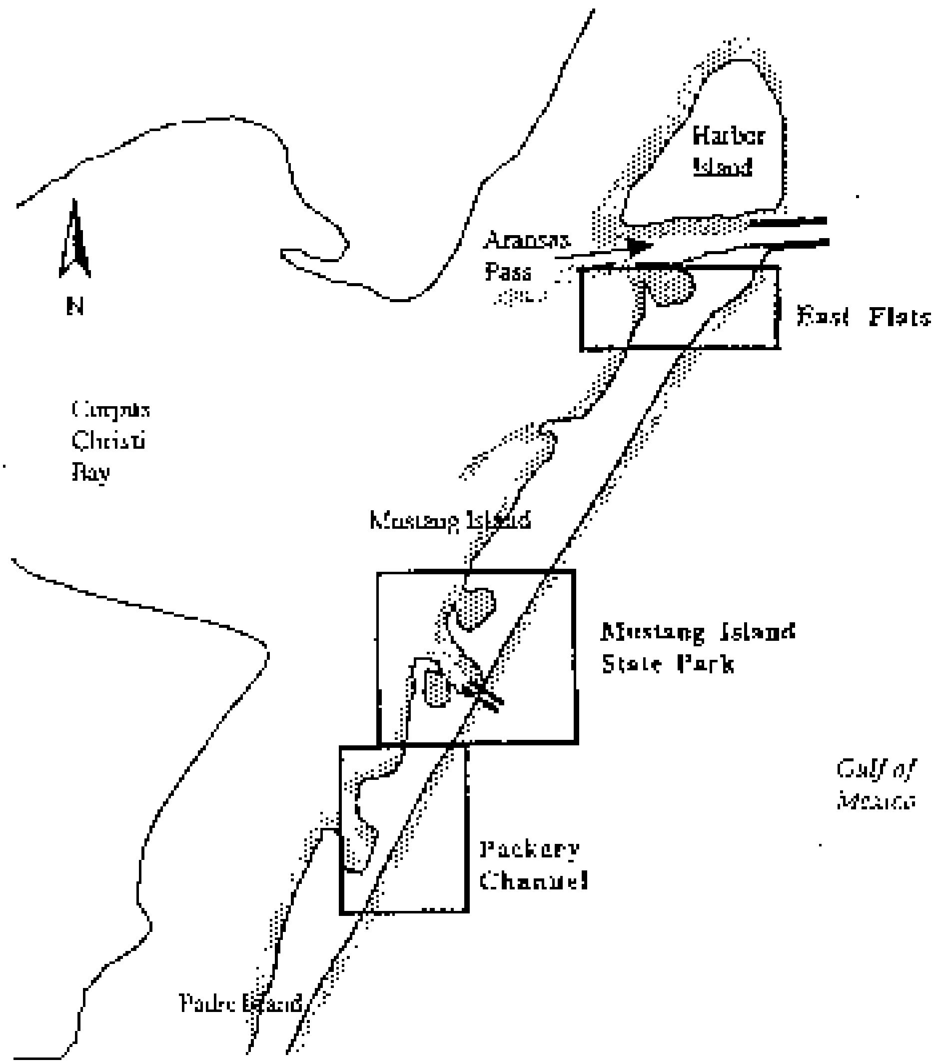

Figure 4. The locations of the study sites representing the Coastal Ecotone. All 3 sites are located on Mustang Island.

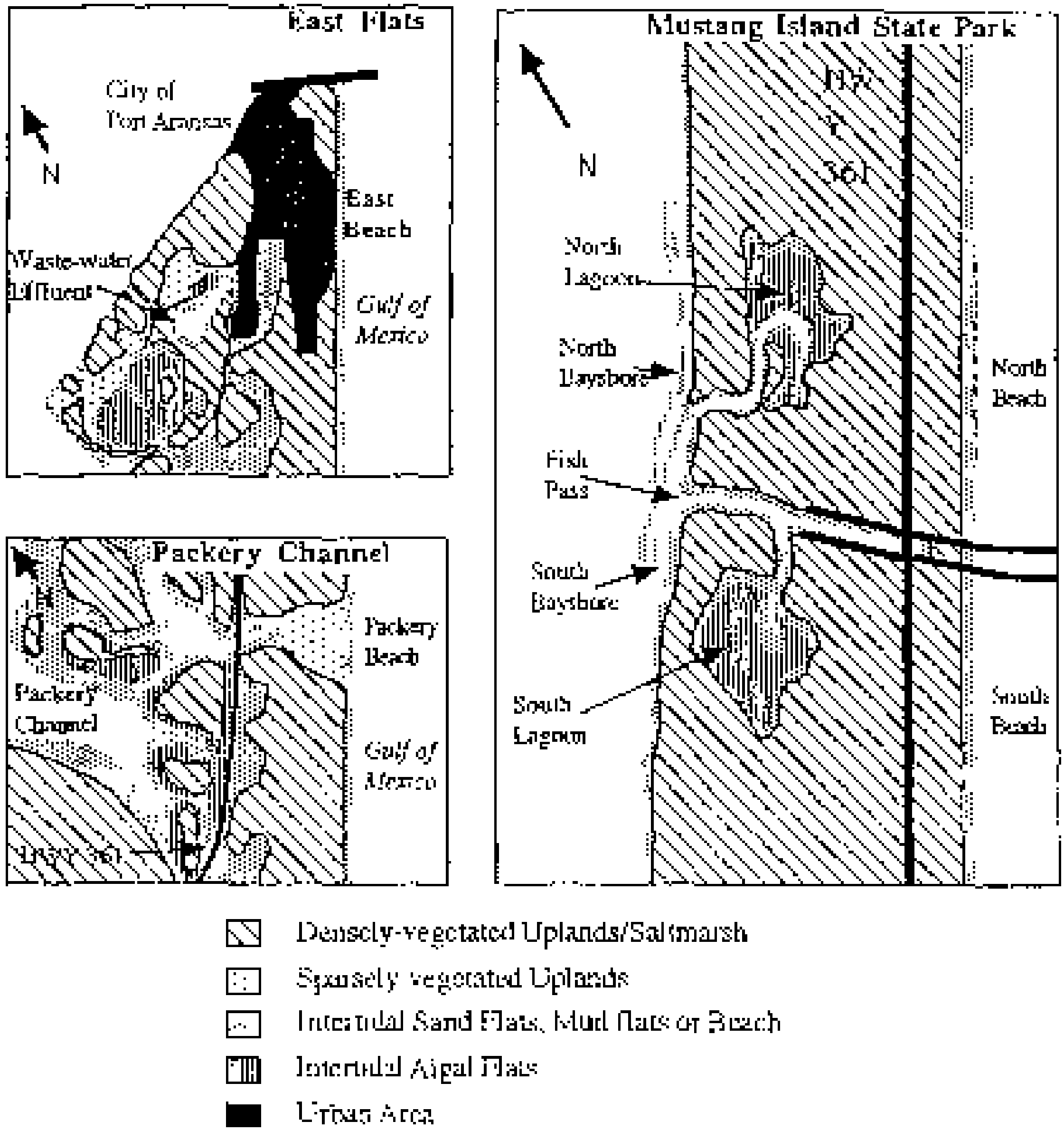

Figure 5. Schematic maps of the 3 Coastal Ecotone Sites.

Effluent released by the treatment facility into the wetlands probably contributed as much to the regular inundation of the wetland as did baywater swells.

Mustang Island State Park. This site, contained within the boundaries of the Mustang Island State Park (MISP), Nueces County, was divided by a man-made boat channel, identified on most maps as Fish Pass (Figure 5). The elevated banks along Fish Pass had eliminated most of the tidal exchange between the Park's tidal flats and the waters of Corpus Christi Bay, effectively splitting 1 large lagoon into 2 small lagoons, 1 each on the north (MISP - North) and south (MISP - South) side of the pass. An artificial channel re-established an effective tidal exchange between the northern lagoon and the bay, but the southern lagoon remained isolated from baywater tidal exchanges to a large extent during the study.

Packery Flats. This site, located along the northern shoreline of Packery Channel in Nueces County, was composed of sand flats and algal flats surrounded by coastal prairie (Figure 5). Due in part to its proximity to Corpus Christi, the beach at this site often experienced high levels of human disturbance.

The Hypersaline Lagoon Ecosystem and Study Sites.

The climate in this ecosystem ranges from subhumid to semiarid with average annual rainfalls between about 65 - 80 cm (Texas General Land Office 1994). Temperatures generally range from winter minimum lows near 9°C to average summer highs near 36°C (Texas General Land Office 1994). The lagoon ecosystem borders an extreme-saline lagoon, the Laguna Madre. The Laguna Madre has probably been without a significant riverine influence since the Rio Grande filled its estuary approximately 4,000 years ago (Rusnak 1960). The low relative amount of freshwater entering the Laguna Madre from rain or riverine inflow, coupled with a high evaporative rate, contributes to high local salinities (> 80 ppt) compared with those of the Gulf of Mexico (36 ppt), or the primary bays of the estuarine bay ecosystem (13 - 23 ppt; Britton and Morton 1989, Hedgpeth

1967). Smaller lagoons and tide pools associated with the Laguna Madre often exceeded 100 ppt during the study (pers. obs.). Few intertidal organisms flourish under these severe conditions (Copeland and Nixon 1974). The hypersaline environment of the Laguna Madre is probably most challenging to life at the lower trophic levels (e.g., plants, invertebrates), and it was at these levels that the hypersaline lagoon ecosystem appeared to differ most noticeably from the estuarine bay ecosystem (e.g., insects replacing polychaetes as the dominant intertidal macrofaunal groups). The life forms that are able to survive in this ecosystem, however, often occur in great numbers (Carpelan 1967, pers. obs.), presumably because they are released from competition with their saline-sensitive
counterparts in the estuarine ecosystem.

A considerable portion of the intertidal area in the lagoon ecosystem is covered by a sheet-like matrix described as a "blue-green algal mat" or "algal mat." Flats covered by algal mats are referred to as "algal flats" (regardless of the underlying substrate) and cover hundreds of square kilometers in the lagoon ecosystem (Pulich and Rabalais 1986, Tunnell 1989). Algal mats are composed of a mix of blue-green algae, dominated by *Lyngbya confervoides*. Algal mats also contain a variety of pennate diatoms (Pulich and Rabalais 1986, Sorensen and Conover 1962). Although most algal mats are only a few millimeters thick, algal flats have been shown to be 20-40% as productive as cordgrass marshes (Pulich and Rabalais 1986).

Plant species that flourish in the lagoon ecosystem include Glasswort (annual: *Salicornia bigelovii*, perennial: *Salicornia virginica*), Saltwort (*Batis maratima*), Sea lavender (*Limonium nashii*), Key Grass (*Monanthochloe littoralis*), and Sea Purslane (*Sesuvium portulacastrum*). Only a handful of hypersaline ecosystems exist world-wide, and the Laguna Madre is one of the largest and most extensively studied (Britton and Morton 1989).

Due to several unique characteristics of the wind-tidal flats along the Laguna Madre (e.g., hypersalinity, low-human population density), the bayshore margins of the mainland land mass also exhibit large areas of unvegetated intertidal flat habitat. In contrast, mainland shores in the bay ecosystem are generally narrow and are dominated by densely-vegetated cordgrass marsh habitat, or have been converted to human developments. Because Piping Plovers generally avoid densely-vegetated habitat (pers. obs., Brush 1995), much of the mainland intertidal habitat in the bay ecosystem is unsuitable for Piping Plovers, whereas the mainland flats in the lagoon ecosystem exhibit large areas of suitable habitat. Accordingly, both mainland and barrier landforms were represented by study sites within the lagoon ecosystem.

The 3 sites monitored in the lagoon ecosystem were Laguna Atascosa National Wildlife Refuge, South Padre Island, and South Bay (Figure 6). At 1 of the sites (South Bay), the mainland and the local barrier (Brazos Island) were connected by a land bridge formed by Highway 4, and there was no clear division between the 2 landforms. To clarify this situation, I defined all flats ≥ 5 km from the Gulf shoreline as "mainland" flats, and all flats < 5 km from the Gulf shoreline as "barrier" flats. Because the beach habitat was, by definition, always associated with the barrier landform (i.e., < 5 km from Gulf Coastline), this landform classification existed only for bayshore habitat. Furthermore, because none of the study sites in the bay ecosystem nor the ecotone were ≥ 5 km from the Gulf Coastline, mainland sites occurred only within the lagoon ecosystem, and comparisons between parameters among the mainland flats and barrier flats are restricted to those within this ecosystem

Laguna Atascosa National Wildlife Refuge. This site, located within the boundaries of Laguna Atascosa National Wildlife Refuge (LANWR) in Cameron County, was composed of a series of large algal flats and mud flats (Rincon Buena Vista Flats, Elephant Head Cove Flats, Horse Island Flats, Redhead Cove Flats and Yucca Flats)

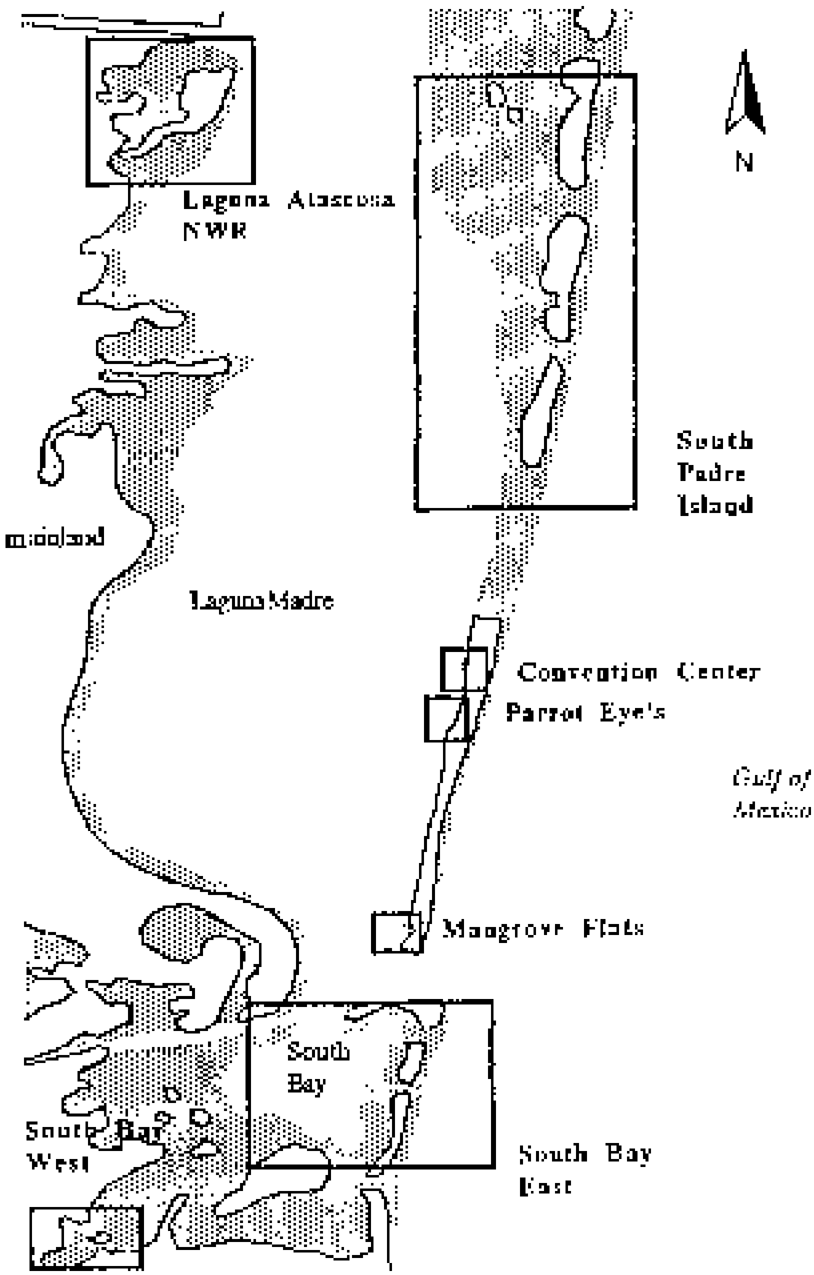

Figure 6. The locations of the study sites representing the Hypersaline Lagoon Ecosystem. Sites are located at Laguna Atascosa National Wildlife Refuge (mainland sites only), South Bay (mainland and barrier island site) and South Padre Island (barrier island sites only)

associated with a system of coves near Horse Island (Figure 7). All of the flats were $\geq$ 5 km from Gulf Coastline, and were thus classified as "mainland" flats. The flats were bordered by a dense coastal thicket of Tamaulipan thorn scrub elevated from the flats by a 1-3 m steep cliff-line. Like the East Flats study site, this site had been nearly removed from tidal exchange from the Laguna Madre by dredge spoil deposits and an elevated access road. This site occurred at roughly the same latitude as the South Padre Island site (Figure 6).

South Bay. This site, located along the shoreline of South Bay in Cameron County, was composed of 2 large algal flats and mud flats surrounded by an elevated coastal prairie/savanna (Figure 7). One of the flats, South Bay West, was located $\geq$ 5 km from the Gulf, and was classified as a "mainland" flat. The other flat, South Bay East, was located within the 5 km zone, and was classified as a "barrier island" flat. Dredge spoil deposits associated with the Brownsville Ship Channel had substantially reduced the natural tidal exchange between South Bay and the Laguna Madre.

South Padre Island. This site on South Padre Island in Cameron County, was composed of 1 large flat and a series of small, isolated flats (Figure 7). The smaller flats (Mangrove Flats, Parrot Eye's Flats and Convention Center Flats) were situated within the commercially-developed, southern tip of the island. The large flat (North Flat) was located immediately north of all development at the northern terminus of highway P100. All of the flats were within the 5 km zone of the Gulf and were classified as "barrier island" flats. Algal flats and sand flats were the dominant habitat types at all of the locations on South Padre Island

Wetland Classification of Study Sites

I classified the landscape and wetland habitat features at the sites (Table 1) using a slightly modified version of the wetland classification system developed by Cowardin et

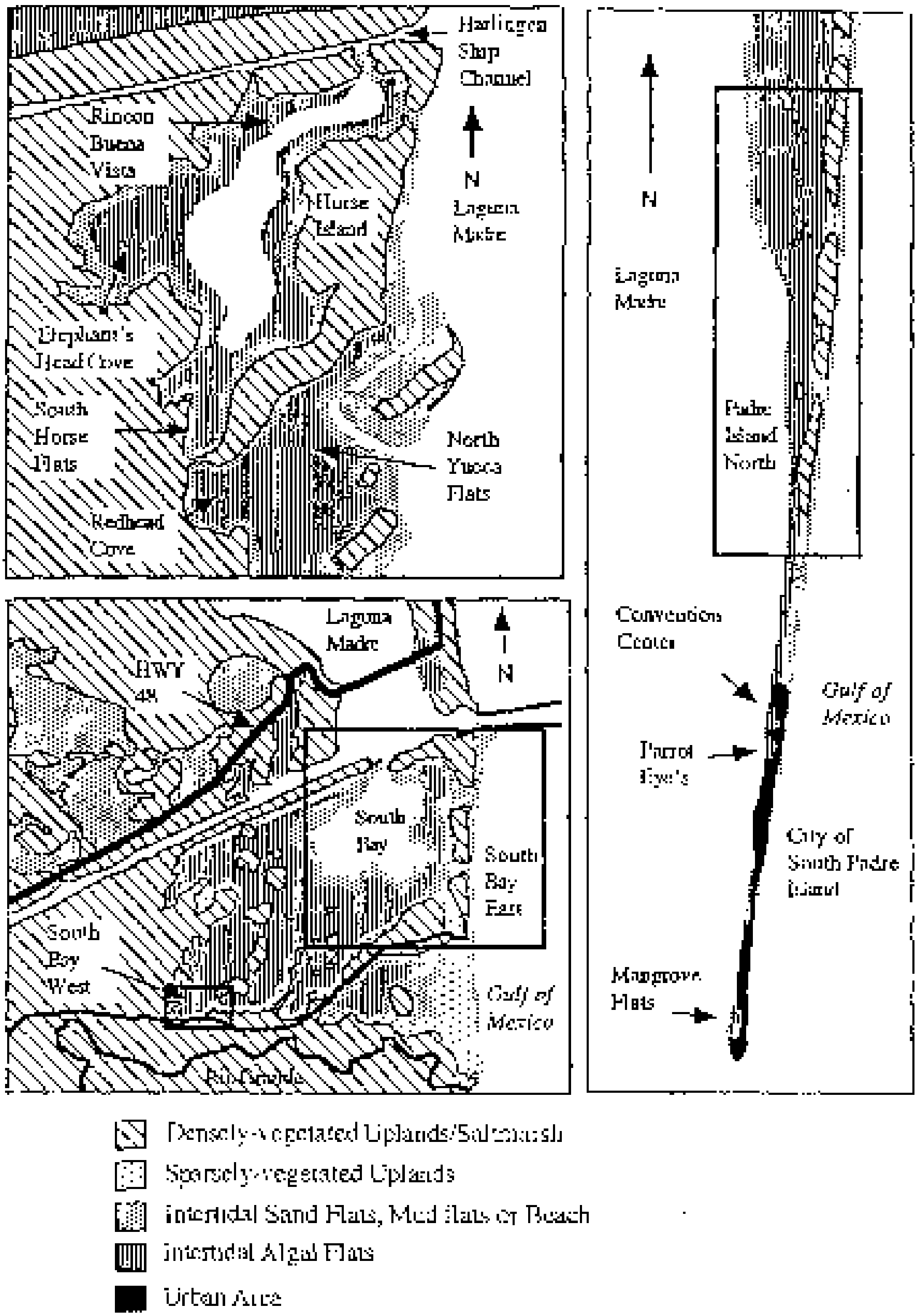

Figure 7. Schematic maps of the 3 Hypersaline Lagoon Study Sites

Table 1. Classification of beach and bayshore habitat among study sites based on a modification of the wetland classification system designed by Cowardin et al. (1979). Modifiers for such parameters as tidal regime and algal mat prevalence have been added to augment the wetland characteristics that provide distinction among study locations.

Study Site	System	Subsystem	Tidal Regime	Tidal Force	Substrate Subclass	Salinity Modifier	Algal Mat
Beaches							
Estuarine Bay Ecosystem							
Bolivar Flats	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Big Reef	Estuarine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
San Luis	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Coastal Ecotone							
East Flats	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
MISP	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
Packery	Marine	Intertidal	Regular	Astronomical	Sand	Polyhaline	Absent
Hypersaline Lagoon Ecosystem							
South Bay	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
South Padre	Marine	Intertidal	Regular	Astronomical	Sand	Euhaline	Absent
Tidal Flats							
Estuarine Bay Ecosystem							
Bolivar Flats	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Absent
Big Reef	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Ephemeral
San Luis	Estuarine	Intertidal	Regular	Astronomical	Sand/Mud	Polyhaline	Ephemeral
Coastal Ecotone							
East Flats	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Euhaline	Present
MISP	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Euhaline	Present
Packery Flats	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Polyhaline	Present
Hypersaline Lagoon Ecosystem							
LANWR	Marine	Intertidal	Irregular	Wind	Mud	Euhaline	Dominant
South Bay	Marine	Intertidal	Irregular	Wind	Mud	Hyperhaline	Dominant
South Padre	Marine	Intertidal	Irregular	Mixed	Sand/Mud	Hyperhaline	Dominant

al. (1979). Modifiers were added to the classification system to describe the tidal regime, tidal force, salinity and presence of algal mats at each site.

Site Visitation Schedule

The bay ecosystem, lagoon ecosystem, and the ecotone were visited in alternating fashion throughout the nonbreeding period, with visits to each area lasting approximately 1 month. In this way, each area was visited for approximately 3 months during each 9 month field season. During each of the 1 month visits, the sites within the site group were visited in alternating fashion. Because some sites were more difficult to access, and required the availability of an ATV, or relatively dry roads, some sites were visited more frequently than others. For example, the large, northern flat on South Padre Island (Figure 7) was accessible only with an ATV. Because ATVs were not always available, this site was visited less frequently than were the other 2 sites in the lagoon ecosystem. The East Flat site (Figure 5), located in the ecotone, was added to the study late in the second year, and was visited less frequently than were the other 2 sites in the ecotone.

Site Selection Criteria

I selected study sites that were reasonably accessible (e.g., by car, ATV or walking) and supported large numbers of Piping Plovers and Snowy Plovers (*Charadrius alexandrinus*) during either the 1991 IPPC, or during preliminary surveys I conducted between July 1991 - September 1991. In general, natural land formations were used to delineate site boundaries (e.g., habitat transitions, water boundaries, lomas [islands of upland prairie surrounded by tidal flats]). I selected sites that were representative of their respective ecosystems. The lagoon ecosystem study sites were larger than the sites within the bay ecosystem, reflecting the more expansive nature of the wind-tidal flats of the Laguna Madre. The bay ecosystem sites were composed predominantly of sparsely vegetated and unvegetated sand flats. The lagoon ecosystem sites were composed predominantly of sparsely vegetated and unvegetated mud flats, sand flats and algal flats.

The sites within the ecotone were intermediate in size compared to the sites in the 2 ecosystems, and contained a combination of sand flats and algal flats.

Human-engineered Alterations

To varying degrees, all of the study sites owe their present form to the influences of human-engineered manipulations. Bolivar Flats and Big Reef are supplied by sediment that is either trapped or redirected by the jetties erected to maintain the channel depth of the Houston Ship Channel. In contrast, the tidal flats at San Luis Pass may have been reduced by the presence of the jetties which trap sediment at Bolivar Flats and Big Reef that normally may have accreted at San Luis Pass. The flats associated with the East Flats, Mustang Island State Park, Laguna Atascosa National Wildlife Refuge, and South Bay study sites all appear to have been substantially affected by dredge spoil (pers. obs) Portions of Packery Channel are occasionally deepened by dredging.

Without question the large northern flat on South Padre Island has been less affected by human manipulation than any of the other study sites I monitored for this research. But this site too, was has been substantially altered by human design Spoil dredged from Mansfield Channel erodes onto the flats during periods of strong north winds associated with winter fronts. The foredunes along the flat's Gulf border, stripped of large tracts of stabilizing vegetation by ATVs, release large volumes of sand into the prevailing southeastern winds (F. Judd, pers comm.). The sand, in turn, has begun to swamp hundreds of hectares of intertidal habitat. Waters entering the Laguna Madre through the Mansfield Channel, the Harlingen Ship Channel, and the Land Cut (a section of the GIWW connecting the once isolated upper and lower Laguna Madre systems) have reduced the overall salinity of the Laguna Madre (Diaz and Kelly 1994). The Harlingen Ship Channel carries hazardous materials from the Rio Grande Valley agricultural industry into the lagoon.

Study Period

I collected these data over a period of 3 consecutive years incorporating large portions of 3 consecutive nonbreeding seasons beginning in July 1991 and ending in April 1994. Although I collected some data during very early (i.e., July) and very late (i.e., April) portions of the nonbreeding period, most of the data were collected between mid-August and late-March.

CHAPTER II. PIPING PLOVER DENSITY

INTRODUCTION

The largest concentrations of nonbreeding Piping Plovers occur along the western Gulf Coast, particularly in Texas (Nicholls and Baldassarre 1990b, Haig and Plissner 1993, Elliott 1996). The local distribution of nonbreeding Piping Plovers along the Gulf Coast has been linked to such habitat features as wide beaches, large mudflats and small inlets (Nicholls and Baldassarre 1990a). However, other habitat and environmental features that are known to affect shorebird abundance have not been studied in association with Piping Plover distribution. Climatic factors and tide cycles often strongly influence shorebird activity and habitat use patterns (Pienkowski 1983, Puttick 1984, Colwell 1993). Human disturbance also has been shown to alter shorebird behavior in ways that might affect population density (Burger and Gochfeld 1991, Pfister et al. 1992, Elliott and Teas 1996). Spatial and temporal factors, such as habitat interspersion (Connors et al. 1981, Handel and Gill 1992, Farmer and Parent 1997), time of day (Robert et al. 1989, Thibault and McNeil 1994, McNeil and Rompre 1995), and time of year (Baker and Baker 1973, Withers and Chapman 1993) also can affect shorebird behavior, habitat use, and population density.

Identifying the habitat and environmental parameters that most strongly influence Piping Plover habitat use patterns and population density will provide valuable insight for the process of preserving locations and habitat types important to Piping Plovers. To address this goal I monitored Piping Plover density and abundance in association with the factors described above. I monitored plovers at different times of the day during the winter period and both migratory periods (spring and fall) to address temporal variations in nonbreeding ecology. I focused my research within 4 nested spatial scales: 1) the ecosystem scale, 2) the site scale, 3) the habitat scale, and 4) the microhabitat scale.

METHODS

Objective 1. Piping Plover Density

In objective 1, I proposed to establish and compare the relative densities of Piping Plovers among the dominant habitat types and ecosystem types along the TGC. To accomplish this objective, I conducted regular censuses at the 2 dominant habitat types (beach and bayshore) at 18 study sites located within the 2 ecosystems and the ecotone zone between the 2 ecosystems.

I counted Piping Plover populations during each site visit (see Study Areas for site visitation schedule). Because beach and bayshore habitats were spatially disjunct at most of the sites, I counted these areas separately. However, within each of these 2 habitats, bird counts were of the entire site. In general, I conducted only 1 survey/habitat during each site visit, however when tide levels changed dramatically during a site visit, I occasionally conducted a second survey under the altered tidal condition.

Beach Piping Plover density was calculated by dividing plover beach by the length of beach surveyed. Bayshore Piping Plover density was calculated by dividing plover bayshore counts by the average area of bayshore habitat available at each site during the study. The average area of available bayshore habitat was estimated by multiplying the total potential area of bayshore habitat at each site by the average percent bayshore tidal amplitude (described below) recorded at that site during the study.

Objective 2. Factors affecting Piping Plover density.

In objective 2, I sought to identify the factors affecting Piping Plover density. To accomplish this objective, I monitored an array of environmental, temporal, and spatial variables.

Variables evaluated for their effects on Piping Plover density were 1) bayshore tidal amplitude, 2) beach tidal amplitude, 3) climatic conditions, 4) human disturbance,

5) season, 6) time of day, 7) habitat and microhabitat types, and 2 spatial variables: 8) landform and 9) ecosystem.

Bayshore tidal amplitude

During each site visit, I recorded the level of bayshore tidal inundation as one of 5 ranked values. The ranks corresponded to visual estimates of percent tidal inundation of the total available area of Piping Plover habitat at each site. The ranks (very low, low, moderate, high and very high) corresponded to estimated percent tidal inundation levels equal to 0, 1 - 24, 25 - 75, and 76 - 99, and 100, respectively. During very low tides (i.e., ~ 0% inundation) the tidal flats were judged to be emergent to the maximum extent possible. During very high tides (i.e., 100% inundation), the flats were completely submerged, and only upland habitat remained emergent. Very high tide conditions usually were associated with storm tides during the summer-fall hurricane season or strong north fronts during the winter period.

Visual estimates of tidal inundation were used instead of tide gauges because the substrate associated with most of the bayshore habitat was often unstable, preventing the use of permanently located tide gauges on many of the tidal flats. Initial attempts to place site-associated tide markers resulted in almost complete loss due to tidal erosion in some areas and vandalism in others. Whereas professional tide monitors are maintained in some locations along the Texas coast these gauges measure the tidal amplitude in areas that were often far removed from the study sites. These monitors were designed to measure tide levels within the deeper regions of the bays, and would have provided very poor estimates of tidal inundation of the broad wind tidal flats at many of the sites. For these reasons, I determined visual estimation to be the best method for accurately documenting the local bayshore tidal conditions.

For the purpose of data analyses, I ranked bayshore tidal conditions as either emergent or inundated. Bayshore conditions were considered emergent if the tide was either very low, low or moderate (i.e., if inundation was estimated to be < 75%). If the tide was estimated to be high or very high (i.e., ≥ 75% inundation) the bayshore tidal conditions were ranked as inundated.

I appraised the total potential area of bayshore habitat at each site by digitizing the boundaries of all intertidal and sparsely-vegetated supratidal habitat from U.S. Geological Survey Topographic Quadrangle Maps into a geographic information system (Atlas Geographic Information System, Strategic Mapping Inc., Santa Clara, California). I referred to aerial infrared photographs to guide the delineation of tidal boundaries. In many cases, man-made or natural structures (e.g., seagrass beds, upland vegetation transitions, duck blinds) helped locate the extreme low and high tide boundaries.

Beach Tidal Amplitude

I estimated beach tidal amplitude by measuring beach width. I measured beach width at 3 sites (Bolivar Flats, Mustang Island State Park North Beach, and Packery Channel). These were the only sites that had stable beach landmarks, such as beach mileage signs, that I was able to use as consistent reference points to collect comparable beach width measures. I defined beach width as the distance between the swash boundary and the vegetation line on the upper beach.

Climatic Conditions

During each site visit, I measured air temperature, wind speed, and precipitation and used these data to classify climatic conditions as either harsh or mild. All three of these variables have been shown to adversely affect the foraging effectiveness of plovers and other visually foraging shorebirds, often reducing their net energy intake rates (Goss-Custard 1984, Davidson 1981, Pienkowski 1981). Plovers and other visually foraging shorebirds have been observed to feed more slowly during cold periods and rainy periods, possibly due to reduced prey activity (Goss-Custard 1970, Pienkowski 1981).

Air temperatures ranged from near 0°C to greater than 30°C during the study (data not shown). Winter precipitation varied from very dry during drought periods to very wet during El Niño cycles, or during months when the coast experienced heavy rain in association with tropical storms or winter north fronts. Winds were generally most strong during storm events or winter north fronts, often topping 30 knots during these periods.

Rather than attempt to analyze the effects of individual climatic variables on Piping Plovers, my analyses focused on comparing the ecology of Piping Plovers during periods of severe climatic stress (i.e., those typical of winter storm events) against that during periods of more clement conditions (i.e. those between winter storm events).

I classified climatic conditions as harsh if the air temperature was $\leq$ the average associated with north fronts (10-14°C), and if the wind speed was also $\geq$ the average associated with north fronts (5 - 20 knots). Climatic conditions also were considered harsh if it was extremely cold (0 - 4°C), regardless of the wind speed or precipitation, or if it was raining, regardless of the air temperature or wind speed. Between 5 - 14°C, the wind speed-temperature combination determined my ranking. Harsh conditions were judged to have occurred if the air temperature was between 10 - 14°C, and the wind speed was > 20 knots, or if the air temperature was between 5 - 9°C, and the wind speed was above 5 knots.

Human Disturbance

I recorded the number of vehicles present during each of the plover surveys and used vehicular density (vehicles/ha at bayshore habitat and vehicles/km at beach habitat) as an estimate of human disturbance

Season and Time of Day

I classified seasons according to the migratory period and the winter period, which are the 2 major stages of the annual life cycle when Piping Plovers occur in Texas. The winter period was defined as 1 November - 20 February, and the migratory period was defined as 1 July - 30 October, and 21 February - 15 May. These periods closely reflect the boundaries of the migratory and winter periods reported by others (Eubanks 1994, Haig 1992). I classified surveys as either morning (<12:00) or afternoon (>12:00).

Habitats and Microhabitats

During bird counts, I classified habitat as either beach or bayshore habitat. I considered beach habitat to be that directly bordering the Gulf of Mexico. All other foraging habitat (i.e., that directly bordering baywater) was considered bayshore habitat. At locations where the two habitats meet, such as at the end of a barrier island (e.g., San Luis Beach and San Luis Flats), the point at which the shoreline bends away from the Gulf was considered the transition between the two habitats.

I distinguished 2 microhabitats on beaches, both occurring within the intertidal zone where the sand was still moist at the surface due to recent inundation. I classified the portion of the intertidal zone where the swash regularly wetted the substrate as the swash zone. The moist portion of the intertidal zone that lies adjacent to, but above, the swash zone was classified as the upper beach.

I recognized 2 microhabitats on bayshore flats. Flats with an algal mat were classified as algal flats, and those without an algal mat were classified as sand flats.

Data Analysis

All analyses were performed using JMP, version 3.1. JMP is a statistical program written by SAS Institute Inc., Cary, NC. Advanced statistical analyses (i.e., beyond the calculation of means, standard errors, etc.) consisted of one-way and multi-factor analyses of variance (ANOVA), linear regressions, and multiple regressions.

One-Way ANOVA

One-way ANOVAs were employed to compare numerous relationships, primarily the effects of habitat components, environmental variables, temporal variables and spatial variables on the density of Piping Plovers or prey populations. Where appropriate, one-way ANOVAs were accompanied by multi-factor ANOVAs to support the evaluation of a particular parameter's effect either alone, or in combination with other related parameters.

Multi-factor ANOVA

Multi-factor ANOVA models were constructed to investigate the relative influences of habitat components, environmental variables, temporal variables and spatial variables on the density of Piping Plovers, total benthic prey, polychaetes, crustaceans, and insects. To build models incorporating all of the relevant parameters, it was necessary to omit some of the sites with smaller data sets from some of the models. For example, a model investigating the full complement of environmental factors affecting Piping Plover bayshore densities must contain data collected at each site during each of the following 8 different sets of conditions:

1. Emergent bayshore habitat, migratory season, mild climate;
2. Emergent bayshore habitat, migratory season, harsh climate;
3. Emergent bayshore habitat, winter season, mild climate;
4. Emergent bayshore habitat, winter season, harsh climate;
5. Inundated bayshore habitat, migratory season, mild climate;
6. Inundated bayshore habitat, migratory season, harsh climate;
7. Inundated bayshore habitat, winter season, mild climate;
8. Inundated bayshore habitat, winter season, harsh climate:

In this particular example, all 8 condition sets did not occur at all of the sites during the study. Therefore, I developed a multi factor ANOVA model using data collected at a smaller group of sites (4 sites, in this example) where I had obtained data under all of the above conditions.

Nested Parameters

The study site variable was built into the multi-factor ANOVA model as a nested parameter. Each site contributing data to the model was nested within the ecosystem (or ecotone) in which it occurred. Nesting the study site parameter within the ecosystem parameter instructed the model to assess the contribution of intra-ecosystem (i.e., inter-site) variability as a component of the effect of the ecosystem parameter on the response variable.

Regression Analysis

Relationships between 2 continuous variables were investigated using linear regression (e.g., the relationship between Piping Plover beach density and beach vehicular density).

RESULTS

Objective 1. Piping Plover Density

Beach Density

Piping Plover beach density varied from about 0.4 birds/km to > 3.5 birds/km (Table 2). When only foraging birds were considered, the smallest average spacing between plovers ranged from about 1 bird every 50 m at the Mustang Island State Park - South site to about 1 bird every 840 m at the South Padre Island - North site. At most sites, plovers were spaced 100 - 200 m apart during the period of high abundance of foraging birds.

Mean Piping Plover density was below 3 birds/km at all but one of the sites within the bay and lagoon ecosystems, but exceeded 3 birds/km at all of the ecotone sites (Figure 8).

Bayshore Density

Piping Plover bayshore density varied from 0 birds/100 ha to almost 150 birds/100 ha (Table 3; Figure 9). The highest average densities throughout the study were observed at the 3 small flats on South Padre Island. Of the flats larger than 10 ha, high plover densities (> 49 birds/100 ha) were recorded at all 3 bay ecosystem sites, and at the South Padre Island - North site (Table 3; Figure 9).

Objective 2. Factors Affecting Piping Plover Density

Ecosystem Type and Bayshore Tidal Amplitude

Ecosystem type ($P < 0.0001$) and bayshore tidal amplitude ($P < 0.0001$) had a significant effect on Piping Plover beach density. Plover populations were significantly higher at ecotone beaches than at bay beaches ($P < 0.0001$; Table 4) or lagoon beaches ($P = 0.0002$; Table 4). There was no difference in plover density at bay and lagoon beaches ($P = 0.5787$, Table 4).

Ecosystem type ($P = 0.0448$) and bayshore tidal amplitude ($P < 0.0001$) had a significant effect on Piping Plover bayshore density. I performed this analysis using barrier island data only. Piping Plover density was significantly higher on barrier island

Table 2. Abundance, spacing, and density estimates of Piping Plovers at beach habitats at sites along the Texas Gulf Coast, 1991-1994. The length of beach (BL) monitored at each site is presented in kilometers. Abundance is presented as the mean and maximum (Max.) number of Piping Plovers recorded at each site. Spacing describes the minimum (Min.) average distance (m) between Piping Plovers as estimated by dividing the maximum abundance of foraging Piping Plovers only (data not shown) by the length of beach at each site. Mean and maximum density were estimated by dividing the mean and maximum abundance estimates by the length of the beach monitored at each study site.

Study Location	N	BL (km)	Abundance			Spacing	Density		
			Mean	SE	Max.	Min.	Mean	SE	Max.
Bay Ecosystem									
Bolivar Flats	35	4.8	15.3	3.96	83	177.8	3.19	0.81	17.3
Big Reef	17	3.2	1.2	5.63	12	237.5	0.37	0.22	3.8
San Luis Pass	64	6.3	12.3	4.47	32	240.0	1.87	0.21	5.1
Ecotone									
East Flats	7	2.8	9.9	8.78	24	133.3	3.54	1.27	8.6
Mustang Island State Park - North	66	3.2	10.3	2.86	38	88.9	3.22	0.49	11.9
Mustang Island State Park - South	32	2.6	8.5	4.11	55	47.3	3.26	1.00	21.2
Packery Channel	58	3.9	14.0	3.05	87	70.9	3.59	0.75	22.3
Lagoon Ecosystem									
South Bay East	25	7.6	22.6	4.65	254	233.3	2.97	1.54	33.4
South Padre Island North Area	27	25.1	12.3	4.47	171	836.7	0.49	0.26	6.8

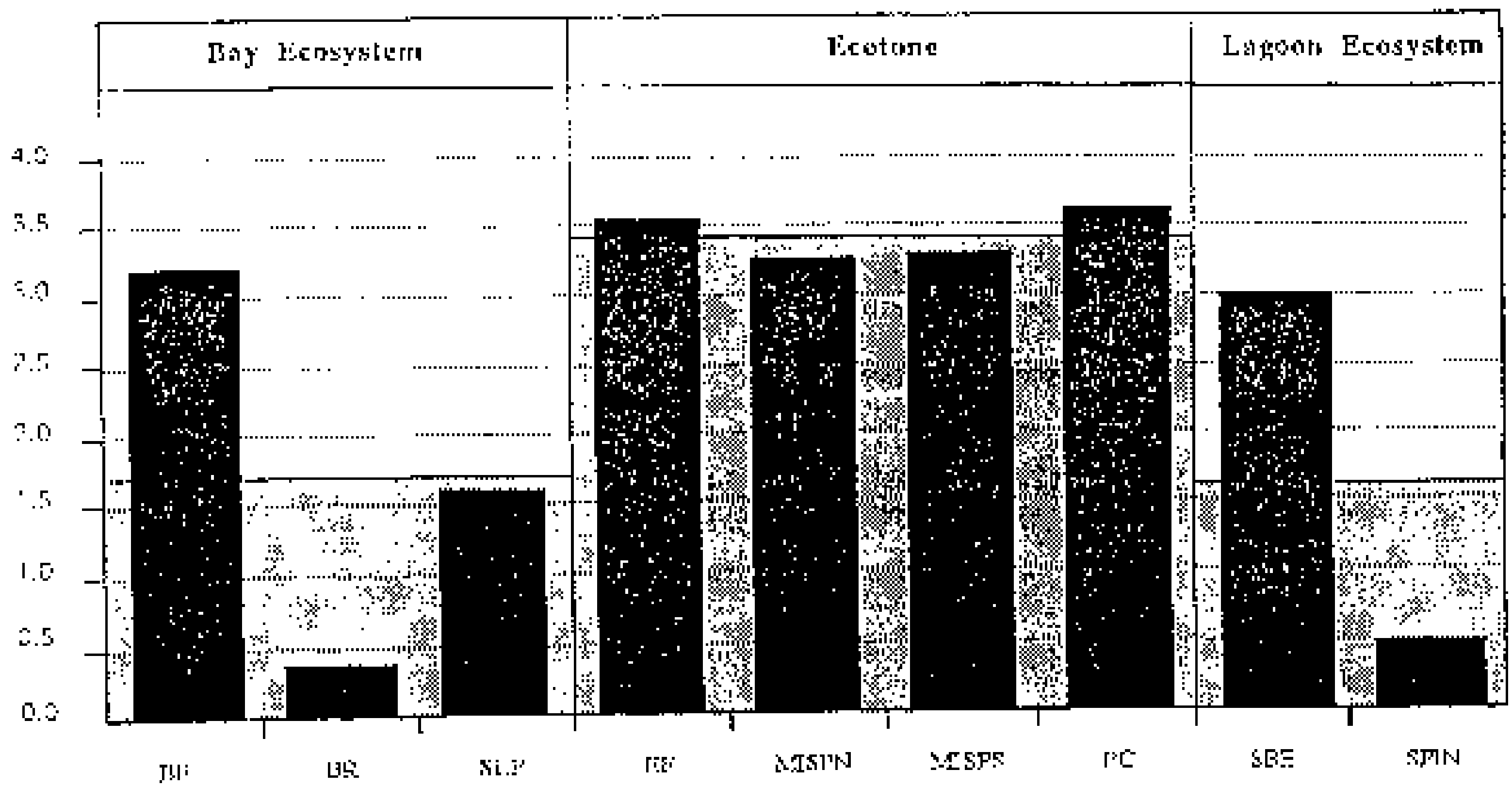

Figure 8. Mean site density and ecosystem density of Piping Plover at beach habitat along the Texas Gulf Coast, 1991 - 1994. Black bars represent site density estimates, gray bars illustrate mean density estimates for each ecosystem (calculated as the average of the mean density estimates for each site in each ecosystem).

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS - Mustang Island State Park - South, PC - Packery Channel, SBE = South Bay East, SPIN = South Padre Island - North

Table 3. Total abundance, highest study counts, and densities of Piping Plovers on bayshore tidal flats at sites along the Texas Gulf Coast, 1991 - 1994. Piping Plover (PIPL) density is expressed as the number of birds/100ha. The area of bayshore habitat at each site (BA) report the total potential area of bayshore habitat at each site (Max.) and the mean area of bayshore habitat at each site throughout the study (see page 27 for more information on this estimate).

Study Location	N	BA		Abundance			Density		
		Max.	Mean	Mean	SE	Max.	Mean	SE	Max.
Bay Ecosystem									
Bolivar Flats	40	188	102	50.2	4.26	119	49.2	5.2	116.7
Big Reef	23	58	29	19.7	6.78	54	68.1	13.2	203.4
San Luis Pass	65	72	42	23.4	4.03	75	56.3	6.3	192.3
Ecotone									
East Flats	7	246	136	49.3	12.29	189	36.2	19.8	139.0
Mustang Island State Park - North	30	61	33	7.4	4.79	39	22.3	5.1	118.2
Mustang Island State Park - South	13	69	40	0.0	0.0	0	0.0	0.0	0.0
Packery Channel	47	179	107	14.7	4.74	75	13.7	2.6	70.1
Lagoon Ecosystem									
LANWR - Rincon Buena Vista	31	161	95	17.4	5.37	100	18.5	5.5	112.4
LANWR - South Horse Flats	35	28	16	1.2	5.49	40	7.9	6.7	235.3
LANWR - Redhead Cove	37	36	27	5.7	5.34	130	21.0	13.7	500.0
LANWR - North Yucca Flats	43	91	50	17.1	4.96	97	34.4	7.4	167.2
South Bay - West	21	100	51	0.0	0.00	0	0.0	0.0	0.0
South Bay - East	29	642	270	19.1	3.17	202	7.8	3.4	82.8
SPI - North Area	6	812	508	355.3	13.27	543	69.9	11.5	106.9
SPI - Convention Center	19	4	2	2.9	3.91	18	144.7	65.3	900.0
SPI - Parrot Eye's	21	4	2	2.5	3.72	16	123.8	50.4	800.0
SPI - Mangrove Flats	25	8	4	3.1	3.41	17	78.0	25.1	425.0

Abbreviations LANWR = Laguna Atascosa National Wildlife Refuge, SPI = South Padre Island.

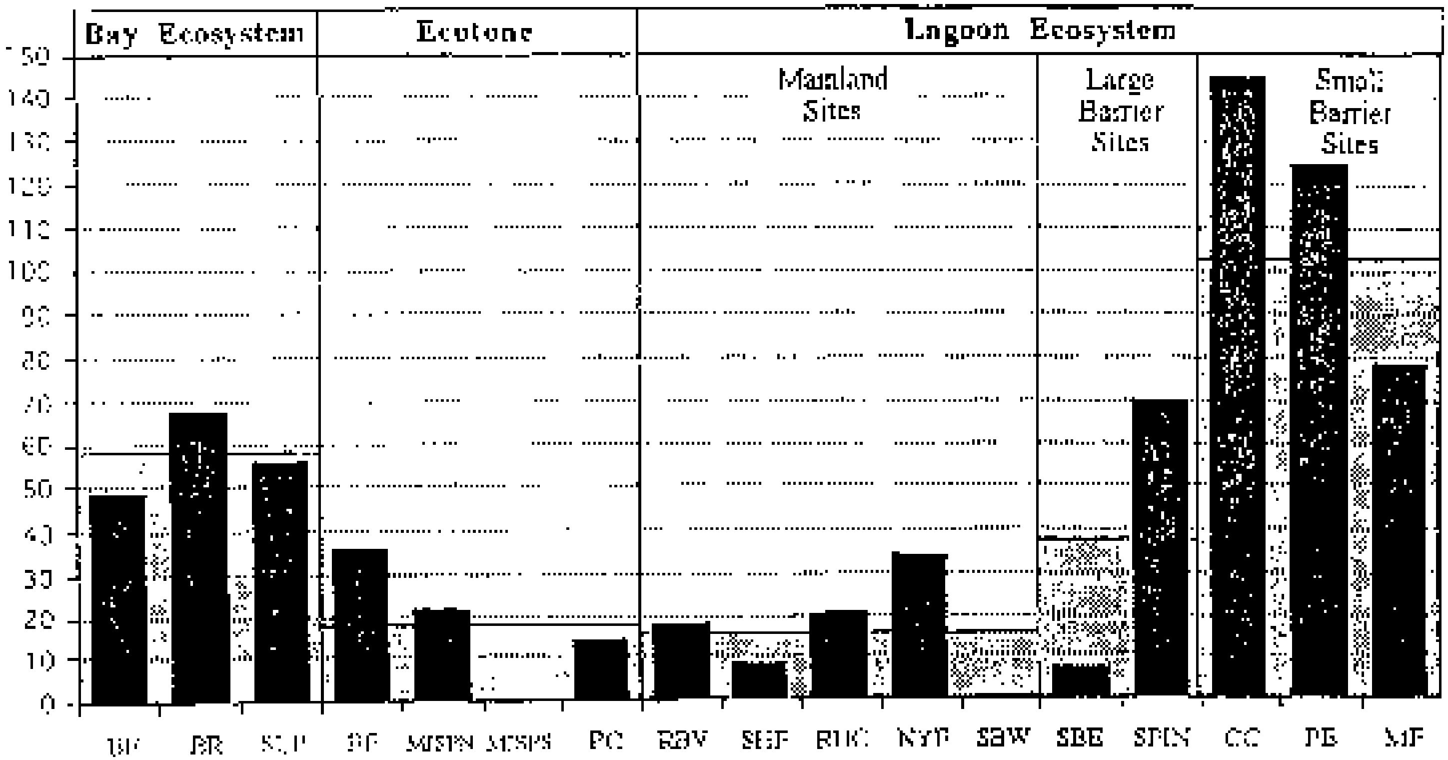

Figure 9. Mean site density and ecosystem density of Piping Plover at bayshore habitat along the Texas Gulf Coast, 1991 - 1994. Black bars represent site density estimates, gray bars represent ecosystem density estimates. Different lagoon ecosystem density estimates are presented for mainland sites, large barrier island sites and small barrier island sites.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, RBV = Rincon Buena Vista, SHF = South Horse Flats, RHC = Redhead Cove, NYF = North Yucca Flats, SBW - South Bay - West, SBE = South Bay East, SPIN = South Padre Island - North, CC = Convention Center, PE - Parrot Eye's, MF = Mangrove Flats

Table 4. Piping Plover population density and human disturbance at beach and bayshore habitat from the 2 ecosystems and the ecotone along the Texas Gulf Coast. Parameters are summarized as means for each location. Multi-factor ANOVA results of pair-wise comparisons between the ecosystems and the ecotone are presented in the last 3 columns. Piping Plover site density is represented as the number of plovers/km at beach habitat, and as the number of plovers/100ha at bayshore habitat. Human disturbance was estimated as the mean number of vehicles/km at beach habitat, and as the mean # vehicles/100ha at bayshore habitat.

Parameter	Bay Ecosystem			Ecotone			Lagoon Ecosystem			Bay	Bay	Eco.
	mean	N	SE	mean	N	SE	mean	N	SE	vs. Lag.	vs. Eco.	vs. Lag.
Beach Density	1.90	119	0.41	3.37	163	0.35	1.68	52	0.62	0.5787	< 0.0001	0.0002
Beach Disturbance	1.89	87	0.29	2.65	109	0.26	1.97	35	0.46	0.5045	0.4341	0.9413
Bayshore Density	58.2	127	7.1	42.0	135	8.4	69.5	100	8.1	0.0284	0.0304	0.7835
Bayshore Disturbance	8.8	69	1.9	4.8	90	1.6	2.3	81	1.7	0.0027	0.0834	0.3729

Bay = bay ecosystem, Eco = ecotone, Lag.= lagoon ecosystem.

+flats than on mainland flats within the lagoon ecosystem during emergent tide conditions ($P = 0.0139$). For this reason, data from the lagoon ecosystem mainland sites were excluded from other analyses to avoid compromising comparisons using data from sites in the bay ecosystem and ecotone which were located exclusively on barrier islands.

I observed a significantly higher mean density of Piping Plovers at bay ecosystem flats than at lagoon ecosystem flats ($P = 0.0284$; Table 4) or at ecotone flats ($P = 0.0304$; Table 4). I detected no difference in the density of Piping Plovers at lagoon ecosystem flats and ecotone flats ($P = 0.7835$; Table 4).

Piping Plovers used beaches when the bayshore tides were high and bayshore tidal flats were inundated. Bayshore tidal amplitude was strongly associated with Piping Plover density at beach habitat in both ecosystems and the ecotone (Table 5). As bayshore flats became inundated, the density of Piping Plovers at beaches increased significantly at the bay ecosystem ($P < 0.0001$), ecotone ($P < 0.0001$), and lagoon ecosystem ($P = 0.0021$).

Bayshore tidal amplitude also strongly influenced the density of Piping Plovers at bayshore habitat (Table 5). As bayshore flats became inundated, the total density of Piping Plovers using bayshore habitat decreased in the bay ecosystem ($P = 0.0011$; Table 5) and the lagoon ecosystem ($P = 0.0046$; Table 5). However, there was no detectable tide effect in the ecotone ($P = 0.3652$; Table 5).

<u>Climatic Conditions, Time of Day and Season</u>

With one exception, climatic conditions (Table 6), time of day (Table 7), and season (Table 8) were not related to Piping Plover density at beach habitat. Piping Plover density was higher at ecotone beaches during migration than during the winter period ($P = 0.0173$; Table 8). Human disturbance also did not significantly affect Piping Plover density at beach habitat ($P = 0.3817$; Figure 10).

Climatic conditions (Table 6), time of day (Table 7), season (Table 8) and bayshore

Table 5. The effects of bayshore tidal amplitude on Piping Plover density. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during emergent and inundated tidal conditions. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 tide ranks.

Ecosystem	**Emergent**			**Inundated**			***P*-value**
	mean	**N**	**SE**	**mean**	**N**	**SE**	
Beach Habitat							
Bay Ecosystem	0.60	89	0.26	3.91	46	0.36	< 0.0001
Ecotone	1.81	118	0.39	7.48	45	0.64	< 0.0001
Lagoon Ecosystem	0.35	40	0.79	6.12	12	1.44	0.0021
Bayshore Habitat							
Bay Ecosystem	71.5	85	4.9	31.4	42	7.0	0.0011
Ecotone	40.0	87	8.9	31.1	38	14.9	0.3652
Lagoon Ecosystem	46.6	211	8.5	23.7	74	14.9	0.0046

Table 6. The effects of climate on Piping Plover density along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during mild and harsh climatic conditions. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 climate ranks.

Ecosystem	Mild			Harsh			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.40	69	0.32	1.24	34	0.45	0.9169
Ecotone	3.54	94	0.53	3.38	53	0.71	0.5241
Lagoon	0.92	27	0.71	2.14	12	1.06	0.8601
Bayshore Habitat							
Bay Ecosystem	68.0	60	6.7	60.6	31	9.3	0.6845
Ecotone	31.7	93	9.2	28.7	47	13.0	0.6816
Lagoon Ecosystem	53.2	166	9.4	25.1	82	13.4	0.4427

Table 7. The effects of time of day on Piping Plover density along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during morning (0600 - 1200) and afternoon (1200 - 1800) periods. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 time of day ranks.

Ecosystem	Morning			Afternoon			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.75	86	0.32	2.50	23	0.62	0.5289
Ecotone	3.83	73	0.54	2.37	21	1.00	0.3657
Lagoon	0.67	26	1.13	3.61	19	1.33	0.1596
Bayshore Habitat							
Bay Ecosystem	53.2	75	5.3	56.7	29	8.5	0.9422
Ecotone	30.6	46	18.4	72.2	45	18.6	0.9724
Lagoon Ecosystem	45.6	131	10.9	48.2	122	11.3	0.5154

Table 8. Piping Plover densities during the winter and migratory periods at sites along the Texas Gulf Coast, 1991 - 1994. Mean Piping Plover beach and bayshore densities are presented for the bay ecosystem, lagoon ecosystem, and ecotone as they were recorded during migratory and winter periods. Beach densities are expressed as the number of plovers/kilometer. Bayshore densities are expressed as the number of plovers/100 hectares. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover densities between the 2 season ranks.

Ecosystem	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Bay Ecosystem	1.84	77	0.33	1.58	58	0.38	0.6149
Ecotone	4.61	58	0.64	2.69	105	0.48	0.0173
Lagoon Ecosystem	1.50	24	1.14	1.83	28	1.05	0.8314
Bayshore Habitat							
Bay Ecosystem	55.0	76	5.6	63.0	51	6.9	0.3724
Ecotone	38.3	70	11.7	37.2	94	10.1	0.9452
Lagoon Ecosystem	37.7	110	11.6	43.2	175	9.7	0.7163

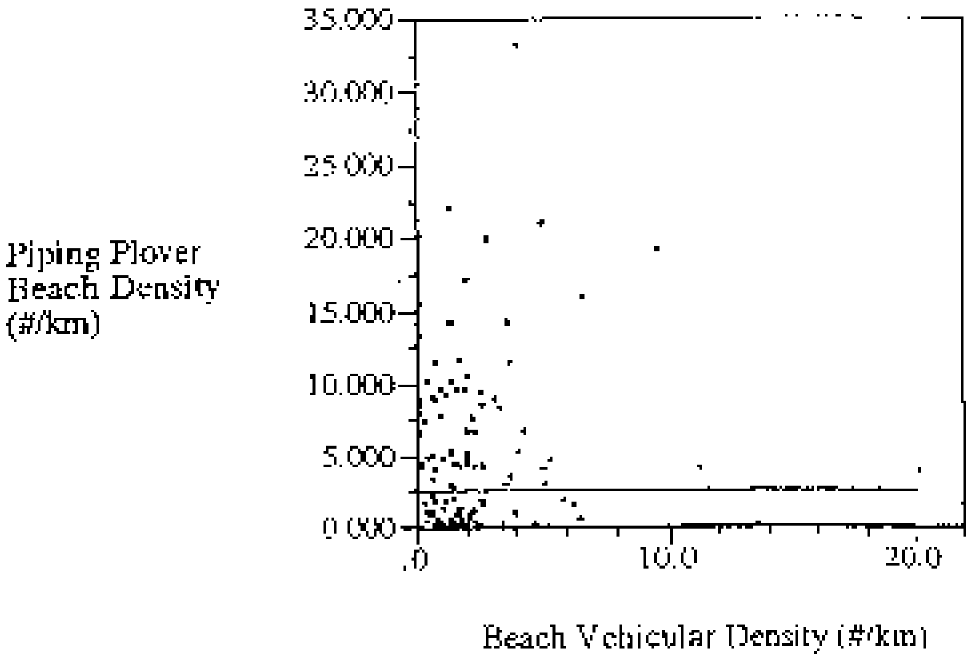

Figure 10. The effects of human disturbance on Piping Plover beach density at sites along the Texas Gulf Coast, 1991-1994. A solid regression line illustrates the relationship between human disturbance (estimated as the density of vehicles present at site beaches during the beach plover counts) and Piping Plover beach density. The analyses suggests that human disturbance had no direct effect on the use of beach habitat by Piping Plovers ($P = 0.3817$).

human disturbance (# vehicles/ha; Figure 11) seemingly were not related to Piping Plover density at bayshore habitat.

Beach Tidal Amplitude

I analyzed Piping Plover beach density in relation to beach tidal amplitudes at 3 sites where I was able to accurately monitor beach tidal amplitude during at least a portion of the study. As beach tidal amplitude increased, Piping Plover beach density also increased at Mustang Island State Park - North ($P = 0.0051$; Table 9). However, Piping Plover beach density was unrelated to beach tidal amplitude at Packery Channel ($P = 0.8764$; Table 9) and at San Luis Pass ($P = 0.6419$; Table 9). In comparison, bayshore tidal amplitude was significantly associated with Piping Plover beach density at Mustang Island State Park - North ($P = 0.0099$; Table 9) and Packery Channel ($P = 0.0017$; Table 9), but not San Luis Pass ($P = 0.3278$; Table 9).

Whereas the tidal regime influenced both beach and bayshore habitats, the most salient effect of the tides appeared to be how they affected the local availability of bayshore tidal flats. Distinguishing between the effects of the tidal regime on beach and bayshore was confounded by the fact that beach and bayshore tides were synchronous along many portions of the Texas coast (pers. obs.). That is, as tides rose and covered bayshore tidal flats, the high tide changed the level of the beach intertidal zone (i.e., swash zone) at many of the sites. This situation raises the possibility that plovers used beaches not because the tides made bayshore tides unavailable, but rather because high tides increased the availability of preferred habitat along the beach shoreline. This might result, for example, if the availability of prey populations residing within higher zones of the forebeach habitat increased significantly as high tides inundated these zones. If this were true, plovers should use beach habitat in response to beach tidal amplitude and not bayshore tidal amplitude at a site where the beach and bayshore tidal regimes are asynchronous. Fortunately, one of the sites I monitored exhibited asynchronous tides.

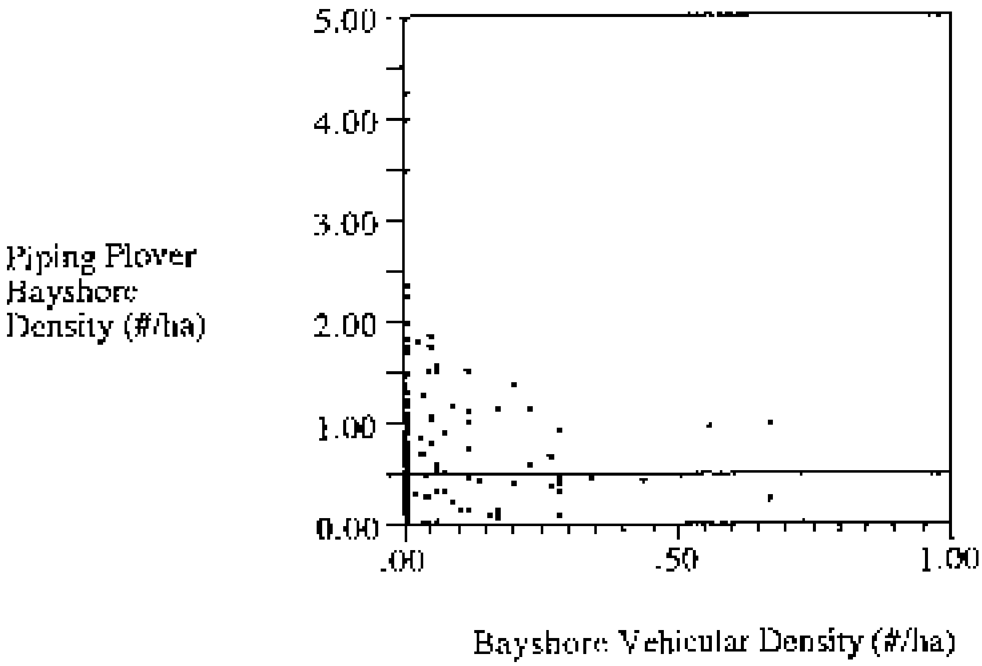

Figure 11. The effects of human disturbance on Piping Plover bayshore density at sites along the Texas Gulf Coast, 1991-1994. A solid regression line illustrates the relationship between human disturbance (estimated as the density of vehicles present at site bayshore habitat during the bayshore plover counts) and Piping Plover bayshore density. The analyses suggests that human disturbance had no direct effect on the use of bayshore habitat by Piping Plovers ($P = 0.9984$).

Table 9. The effects of beach tidal amplitude on Piping Plover density. Mean Piping Plover density at beach and bayshore habitats are presented for the 3 sites where beach tidal amplitude was measured. The proportional effect on Plover density caused by beach tidal amplitude is expressed as R^2. The significance of the effect is expressed as a *P*-value in the last column. Abbreviations: MISP = Mustang Island State Park.

Ecosystem	N	R^2	*P*-value
Beach Density			
MISP - North	22	0.2624	0.0051
Packery Channel	27	0.0008	0.8764
San Luis Pass	24	0.0148	0.6419
Bayshore Density			
MISP - North	22	0.2221	0.0099
Packery Channel	27	0.2916	0.0017
San Luis Pass	24	0.0638	0.3278

Among the 3 sites I monitored for beach tidal amplitude, beach and bayshore tides were synchronous at San Luis Pass ($P < 0.0001$, N = 17) and Mustang Island State Park - North ($P = 0.0170$, N = 29), but asynchronous at Packery Channel ($P = 0.8764$, N = 31). At Packery Channel, Piping Plover density was correlated with bayshore tides but not beach tides. Considered together, these data suggest that bayshore tidal amplitude was a better predictor of Piping Plover habitat use than was beach tidal amplitude.

DISCUSSION

Objective 1. Piping Plover Density

Beach Habitat

My estimates of Piping Plover density compare closely with most estimates from other studies in Texas. With 2 exceptions (Big Reef and South Padre Island), I found Piping Plovers to use beach habitat at a higher density than the 1.4 - 1.6 birds/km estimate reported for Texas by Nicholls and Baldassarre (1990b). Elliott and Teas (1996) reported beach densities of 1.11 birds/km, 3.13 birds/km and 4.51 birds/km at 3 Texas coastal sites. One of the sites monitored by Elliott and Teas (1996) was the same site I refer to as Packery Channel (the site was called Surfer Beach by Elliott and Teas). Their 2-year mean estimate of 3.13 plovers/km at Packery Channel beach compares closely with my 3-year mean of 3.59 plovers/km.

Lee (1995) reported a mean density of 3.41 Piping Plovers/km at the Mustang Island State Park - North site during portions of the nonbreeding season in 1990 and 1991. This estimate compares closely with my estimate of 3.22 plovers/km at the same site. Chapman (1984) reported a diurnal mean of 3.0 Piping Plovers/km along an 8.1 km stretch of beach located just south of the Packery Channel site. During surveys conducted between 1992 - 1995, Chaney et al. (1995) reported that the annual Piping Plover beach density on Padre Island National Seashore (located just south of the Packery

Channel site, and the same area counted by Chapman (1984)) varied from 0.48 plovers/km to 2.1 plovers/km. Their estimates were based upon counts made throughout the year, however, including the summer period when many Piping Plovers were at breeding sites away from Texas. For this reason, the density values reported by Chaney et al. (1995) almost certainly underestimated the mean beach density of plovers on North Padre Island during the winter period.

Whereas the southern portion of the Padre Island National Seashore can be accurately classified as belonging to the lagoon ecosystem, most of the density estimates described above were measured at ecotone beaches. My data suggest that Piping Plovers used beaches in the ecotone at greater densities than those located in the bay or lagoon ecosystem. Plovers occurred at an average density of about 1.75 plovers/km in the bay ecosystem and lagoon ecosystem. Whereas my density estimates for beach sites in the 2 ecosystems more closely approximate those by Nicholls and Baldassarre (1990b), the average beach density of Piping Plovers at all of the sites, 2.29 plovers/km, was appreciably higher than their estimate of 1.4 - 1.6 plovers/km.

Bayshore Habitat

Density estimates for Piping Plover use of bayshore habitat are rare, probably due to the difficulty associated with accessing bayshore sites, and accurately quantifying the area of tidal flat habitat being counted. Garza (1997) reported bayshore densities for Piping Plovers using 15 sites on South Padre Island in 1994. With a single exception (Site 9, which supported an average of about 48 plovers/100 ha), all of the sites monitored by Garza were estimated to support fewer than 20 plovers/100 ha. Surprisingly, these findings contrast starkly with my estimates of approximately 78 - 145 plovers/100 ha at many of the same locations.

In the Laguna Madre, the mainland sites I monitored supported a much lower density of Piping Plovers than did the barrier island sites. However, under certain conditions the mainland flats supported very large flocks (> 95 birds) of Piping Plovers. Peak use of mainland sites by Piping Plovers occurred during emergent conditions. On the mainland, these conditions were most common during the passage of winter north fronts. The strong winds accompanying these fronts often caused mainland flats to become emergent, and barrier island flats to become inundated. These conditions presumably caused plovers to migrate across the Laguna Madre from barrier islands flats to mainland flats. Until recently, such movement patterns were largely speculative. However, a radiotelemetry study investigating the movement patterns of Piping Plovers in the Lower Laguna Madre has confirmed that many Piping Plovers regularly migrate between the barrier island and mainland flats during the same winter period (Zonick et al. 1998).

Objective 2. Factors affecting Piping Plover density.

The local density of Piping Plovers at the beach and bayshore sites was most strongly influenced by 2 parameters, bayshore tidal amplitude and ecosystem type.

Bayshore Tidal Amplitude

Bayshore tidal amplitude affected density in a proximate fashion by directing the short-term movements of Piping Plovers between beach and bayshore habitat. As rising bayshore tides covered local bayshore feeding areas, plovers sought out alternative feeding habitat or suitable roost sites. Beach habitat was frequently used as a secondary habitat during periods of bayshore inundation, but washover passes and mainland tidal flats also appeared to provide important secondary habitats for Piping Plovers.

Lee (1995) found Piping Plover beach density to increase with falling beach tidal amplitude and decreasing availability of bayshore habitat (i.e., increasing bayshore tidal amplitude). My observations at the Mustang Island State Park and Packery Channel sites, which together encompass both of Lee's beach sites, suggest that bayshore tidal amplitude, and not beach tidal amplitude, directs the movements of plovers between beach and bayshore habitats. This finding suggests that plovers used beach habitat as a secondary feeding site, preferring bayshore habitat when available. Connors et al. (1981) reported a similar tidal response by Sanderlings (*Calidris alba*) and Snowy Plovers (*Charadrius alexandrinus*) along the California coast. There, Sanderlings and Snowy Plovers cycled between beach and bayshore habitat, using beaches during periods of bayshore tidal inundation.

Interestingly, Elliott and Teas (1996) reported no relationship between Piping Plover beach density and bayshore tidal amplitude at 7 ecotone beaches, but did find a positive relationship between bayshore tidal amplitude and Snowy Plover beach density. Furthermore, Withers (1994) reported a positive relationship between bayshore tidal amplitude and Piping Plover bayshore density at Corpus Christi Pass, a site situated between the Packery Channel and Mustang Island State Park - South sites. In fact, Withers observed all shorebird species but Snowy Plovers to increase in abundance at bayshore habitat with increasing bayshore tide height. Withers detected a decrease in Snowy Plover abundance with bayshore tidal inundation (Withers 1994). These findings contrast with my findings and with those reported by Lee (1995) regarding the response by Piping Plovers to bayshore tidal conditions.

Withers' observations were restricted to bayshore habitat, so I will limit comparisons of our findings to that habitat. My data suggest high bayshore tides caused Piping Plover bayshore density to drop in the bay and lagoon ecosystems, but not in the ecotone. In the ecotone, I observed plover bayshore abundance to decline somewhat during periods of tidal inundation relative to periods of emergence (by ~ 23%; Table 5), but the difference was not significant. Furthermore, Piping Plovers often declined at the ecotone sites as bayshore tide levels dropped from moderate - very low. I scored bayshore tidal amplitude into 1 of 5 ranks (very high, high, moderate, low and very low; ranks are described in the Methods section). At Packery Channel, the mean number of Piping Plovers using bayshore habitat during very high, high, moderate, low and very low bayshore tides was 2.3, 10.4, 18.9, 16.9, and 14.6, respectively. Therefore, plover bayshore abundance peaked near the moderate-low tide ranks, and declined somewhat if the tide dropped to a very low state. Presumably, during low and very low tides Piping Plovers moved to rarely-exposed off-site feeding areas.

The reduction in plover abundance at ecotone sites during extreme low tide episodes complicated the relationship between bayshore tidal amplitude and the use of bayshore habitat by plovers. However, my data suggest that plovers were much more common at bayshore habitat during emergent conditions (i.e., very low - moderate bayshore tides), even though they occasionally sought out off-site feeding areas during very low tide events. Plovers moved to beach habitat and washover pass habitat during periods of bayshore inundation (i.e., high-very high bayshore tides).

The Elliott and Teas (1996) study was restricted to beach habitat where they initially reported Piping Plover beach density to be unaffected by bayshore tidal conditions. My findings disagree with their reported findings and indicate bayshore tides strongly affect plover beach use. At Packery Channel, I recorded mean Piping Plover beach abundance during very high, high, moderate, low and very low bayshore tides of 44.1, 27.8, 9.9, 2.6, and 0, respectively. Furthermore, at Mustang Island State Park - North, a site lying just north of Elliott and Teas' Surfer Beach site (i.e., Packery Channel), the mean number of Piping Plovers using beach habitat during very high, high, moderate, low and very low bayshore tides was 16.7, 23.0, 5.3, 2.6, and 0, respectively. I never visited Mustang Island State Park - South during very high or high bayshore tides, and therefore have data only for moderate-very low tide ranks. However, during moderate, low and very low bayshore tides, I found 13.0, 1.0, and 0 Piping Plovers using beach habitat, respectively. Thus, at 3 south ecotone sites located near Elliott and Teas' Surfer Beach site, I observed a steady and significant (P < 0.0001 for Packery Channel and Mustang Island State Park - North, P = 0.0105 for Mustang Island State Park - South; data not shown) decline in the abundance and density of plovers on beaches as the bayshore habitat became emergent.

Based upon these findings, the authors (J. Elliott) conducted a revised analysis of their data and concluded that bayshore tides did correlate with Piping Plover beach density ($R^2 = 0.403$, $P < 0.0001$), and the contrary finding in Elliott and Teas (1996) was inaccurate (J. Elliott, pers. comm.).

The apparent preference by Piping Plovers for bayshore habitat is supported by another observation. Whereas beach use clearly appeared to be controlled by bayshore tidal amplitude, high bayshore tides did not always cause plovers to move to beach habitat. I was occasionally unable to locate Piping Plovers during periods of high bayshore tide. Such occurrences were most common in the lagoon ecosystem where bayshore tides were influenced to a much greater degree by wind forces and where mainland tidal flats were much more suitable as feeding areas than were those in the bay ecosystem and in the ecotone. Wind tides often had local effects, inundating one flat while exposing a neighboring flat (e.g., this would occur at 2 flats on opposing sides of a small lagoon). With the exception of those associated with tropical storms, wind tides in the lagoon ecosystem usually exposed new areas of bayshore habitat as others were becoming flooded. Therefore, plovers feeding in the lagoon ecosystem often had an alternative to beach habitat during periods of locally high bayshore tides. They were able move to alternative bayshore habitat sites that had become emergent by the same tide that inundated the site they were forced to abandon. Under this scenario, a plover being forced off of a tidal flat along a lagoon might fly into the wind to cross the lagoon and light on the opposite shoreline where baywaters were being blown off of the flats.

During the study, I observed several Piping Plovers that had been color banded by other biologists. Among those plovers that I was able to resight more than once during the study was an individual that used all 3 of the lagoon ecosystem sites during the same winter. These observations suggest that, in addition to crossing the Laguna Madre to move between mainland and barrier island sites, some Piping Plovers appeared to use a mosaic of many bayshore sites throughout the winter. Radiotelemetric tracking of Piping Plovers in the lagoon ecosystem has further supported this hypothesis (Zonick et al. 1998). Presumably, movements among these sites are directed to a great extent by the local availability and productivity of bayshore feeding areas.

Ecosystem Features and Landscape

Piping Plover density was also affected by ecosystem and landscape features along the Texas Gulf Coast. Plovers were more common at ecotone beaches than in either ecosystem. Whereas my data do not directly demonstrate why plover beach density was highest in the ecotone, I believe indirect inferences can be drawn from information presented in this chapter and that presented in the following chapter.

As previously demonstrated, one of the major features distinguishing the 3 coastal regions was the tidal regime, and the way the tides influenced local bayshore feeding areas. The discussion above describes clearly why plovers may have been less common at lagoon ecosystem beaches than at those in the ecotone throughout the tidal cycle. Plovers in the lagoon ecosystem were more likely to seek out alternative bayshore feeding areas in preference to beach habitat when local bayshore feeding sites became inundated.

However, tidal variations among the 2 ecosystems and the ecotone did not appear to explain all of the differences in local plover density. Multi-factor ANOVA models identified an ecosystem effect on plover density that was independent of the bayshore tidal effect, suggesting some other factor may affect the use of beach habitat. As I describe in the next chapter, the bayshore prey communities at the sites also differed markedly among 2 ecosystems and the ecotone. Bayshore habitat in the bay ecosystem supported a much higher mean prey density than did that in the ecotone or the lagoon ecosystem. Therefore, plovers wintering within the bay ecosystem may have been able to build sufficient fat stores to allow them to seek most refugia during many high tides rather than risk predation and other potential deleterious effects that might be incurred by periods of extended feeding. Bayshore flats in the ecotone may not have been sufficiently productive to allow resident plovers to avoid as many high tide foraging episodes as plovers in the bay ecosystem.

An alternative explanation may be that periods of bayshore inundation lasted longer in the ecotone than in the bay ecosystem, thereby forcing plovers in the ecotone to seek alternative feeding sites (e.g., beach habitat) more often. Unfortunately, my data allow for only a crude investigation of this hypothesis. I encountered inundating tides during 33.6% of all censuses in the bay ecosystem, but during only 26.9% and 25.5% of all censuses in the ecotone and lagoon ecosystem, respectively. These data suggest that ecotone tidal flats (and lagoon tidal flats) were not inundated longer than bay ecosystem tidal flats and probably were inundated for shorter periods of time. Tidal flats in the ecotone and lagoon ecosystem may often have been subject to only partial inundation. This, combined with higher baywater salinities relative to the bay ecosystem, may have limited the availability of productive bayshore habitat in the ecotone and forced plovers to use beach habitat to a greater extent.

Finally, Piping Plovers were more common on emergent barrier island tidal flats than on emergent mainland tidal flats. The prey density data I collected can be used to suggest an hypothesis as to why this might be so. As I discuss in Chapter III, benthic prey density was significantly higher at lagoon ecosystem barrier island flats than at mainland flats. Therefore, the observed higher use of barrier islands may simply reflect a preference by Piping Plovers for more productive feeding areas.

CHAPTER III. PREY DYNAMICS AND PIPING PLOVER BEHAVIOR

INTRODUCTION

Perhaps more than any other parameter, prey density has been associated with shorebird ecology and linked to local abundance and fitness (Goss-Custard 1984, Hicklin and Smith 1984, Wilson 1990, Colwell 1993). This is particularly true for wintering shorebirds (Duffy et al.1981, Myers and McCaffery 1984, Myers et al. 1987). Because of their demanding life strategy, involving long migratory journeys and the reliance upon numerous ephemeral staging sites, the winter period is considered critical for shorebirds (Myers et al. 1987). During winter, shorebirds must rebuild fat stores that have been depleted during fall migration to levels that will allow them to survive the winter period and help power a return migration to their breeding grounds in the spring (Blem 1990). Individuals that are best able to find and capture prey during the winter and maintain optimal fat stores are presumably most likely to arrive early and fit at their breeding grounds. Thus, shorebirds benefit reproductively by occupying winter sites with a reliable food supply. For this reason, estimating the availability of food to plovers among the different habitats and ecosystems of the Texas Coast was an important goal of my research.

The diet of wintering Piping Plovers had only been partially characterized at the time this study was initiated (Nicholls and Baldassarre 1990a). A better understanding of the species diet in Texas was required to evaluate what portions of the available prey community were available to the plovers. The task of describing and quantifying prey availability to plovers was complicated by observations indicating plovers fed in large part on surface prey populations (e.g., flies and other non-burrowing insects), particularly in the lagoon ecosystem (pers. obs, T. Eubanks pers. comm.). I addressed these problems by documenting the diet of plovers while concurrently sampling the prey community in areas where plovers were feeding using several different techniques.

Due to the rarity of the Piping Plover, some techniques commonly employed to evaluate bird diets (e.g., the evaluation of stomach contents from dissected birds or birds palpated to induce regurgitation) could not be used. The analysis of fecal dropping is a non-invasive technique that has been used to evaluate Piping Plover diet (Nicholls 1989, Shaffer and LaPorte 1994). Nicholls (1989) analyzed a small number of fecal samples from Piping Plovers wintering in Texas. From 4 samples collected from habitats at Bolivar Flats and 1 sample collected at San Luis Pass (all at bayshore habitat), Nicholls observed fragments of polychaetes in all samples, insects in 3 samples, and fragments of bivalves, ostracods, and copepods in 2 -3 samples each. In 2 samples collected at beach habitat on Mustang Island, Nicholls found polychaetes and crustaceans (Copepoda) in 1 sample, and insect fragments (Diptera) and amphipods (Haustoriidae) in another. From 2 samples collected at bayshore habitat in the lagoon ecosystem, Nicholls found insect fragments in 1 and polychaete fragments in the other.

Unfortunately, fecal sample analysis provides only a crude assessment of a shorebird's diet. Soft-bodied organisms are rapidly and nearly totally digested, resulting in an under-representation of annelids and other soft-bodied animals in the description of the diet (e.g., Shaffer and Laporte 1994). Additionally, shell and carapace fragments residing in the sediment can be ingested incidentally by foraging plovers leading to the inaccurate inclusion of non-prey taxa. I evaluated the Piping Plover diet among different habitats and ecosystem types by observing feeding plovers and directly characterizing the prey they captured into 2 categories (polychaetes and arthropods)

Another important aspect of Piping Plover foraging ecology is foraging success. The rate at which plovers capture prey (i.e., gross intake rate) and the energy plovers expend while feeding are both important factors in determining the net energy return (i.e., net intake rate; Goss-Custard 1984) plovers experience during foraging bouts. Plovers are visual foragers, relying upon visual cues to detect prey (Pienkowski 1979). Factors that reduce the surface activity of prey animals (e.g., soil desiccation, low air temperature, high winds, precipitation) can also reduce the rate at which plovers capture prey (Pienkowski 1981).

One of the primary focuses of my research involved evaluation of Piping Plover diet in the 2 ecosystems and the ecotone. I also analyzed foraging success to determine whether plovers were able to forage more efficiently in either ecosystem. Additionally, I compared prey populations and plover foraging success at bayshore tidal flats and beaches, the 2 major habitat types used by plovers along the TGC.

I addressed these goals by monitoring 1) the amount of time plovers spent foraging, 2) an index of the amount of energy plovers expended while foraging, and 3) the rate at which plovers captured prey among ecosystems and habitat types. Collectively, these data allowed me to describe the prey resources that were most available to Piping Plovers, as well as investigate how these prey resources differed in availability among habitat types, ecosystem types and landscape types along the TGC, and how well plovers were able to exploit these resources. These observations address large gaps in the current understanding of Piping Plover winter ecology.

Data from this section also were used in the development of the model predicting the factors that most strongly affected Piping Plover site abundance. This model is presented in Chapter IV.

METHODS

Prey Dynamics

I sampled potential prey populations from areas that were being used by foraging Piping Plovers at the time of sample collection. During preliminary observations, I found Piping Plovers to forage on prey animals occurring below the ground (benthic prey), and also on prey animals occurring at or above the ground surface (surface prey).

To address this, I sampled prey populations in several different ways. Sampling strategies consisted of the collection of soil cores (benthic prey), the deployment of sticky traps (surface prey), visual surveys of prey using a spotting scope (surface prey), and the collection of algal mat cores (benthic to surface prey, depending upon the developmental stage of the prey animal).

Transect Layout

All prey samples were collected along transects established within areas recently (within minutes) used by one or more foraging Piping Plovers (Figures 12 and 13). The dimensions of the transects were dictated by either the dimensions of the foraging flock being sampled, or the area used by an isolated plover subject (if the plover was foraging alone).

Plovers often fed in large flocks at bayshore habitat. Foraging flocks were sampled in order of size, beginning with the largest flock. The number of samples/day I collected was limited only by the number of foraging flocks of Piping Plovers observed, by the time required to collect and transport the samples back to research vehicles from the study area, and by the physical weight of the samples I was capable of carrying. Prey samples also were collected in areas where individual plovers were foraging alone, particularly at beach habitat where plovers aggressively defended foraging territories. Samples collected in association with solitary plovers using bayshore habitat were compared to those collected in association with foraging plover flocks.

My samples were specifically directed at appraising the prey community locally available to Piping Plovers during foraging episodes. They do not necessarily reflect the prey density available throughout the study site.

Benthic Prey Samples

Macroscopic benthic (i.e., subsurface) animals were sampled via a series of 5 soil cores/transect (Figures 12 and 13). Each core was 10 cm deep x 7.5 cm in diameter.

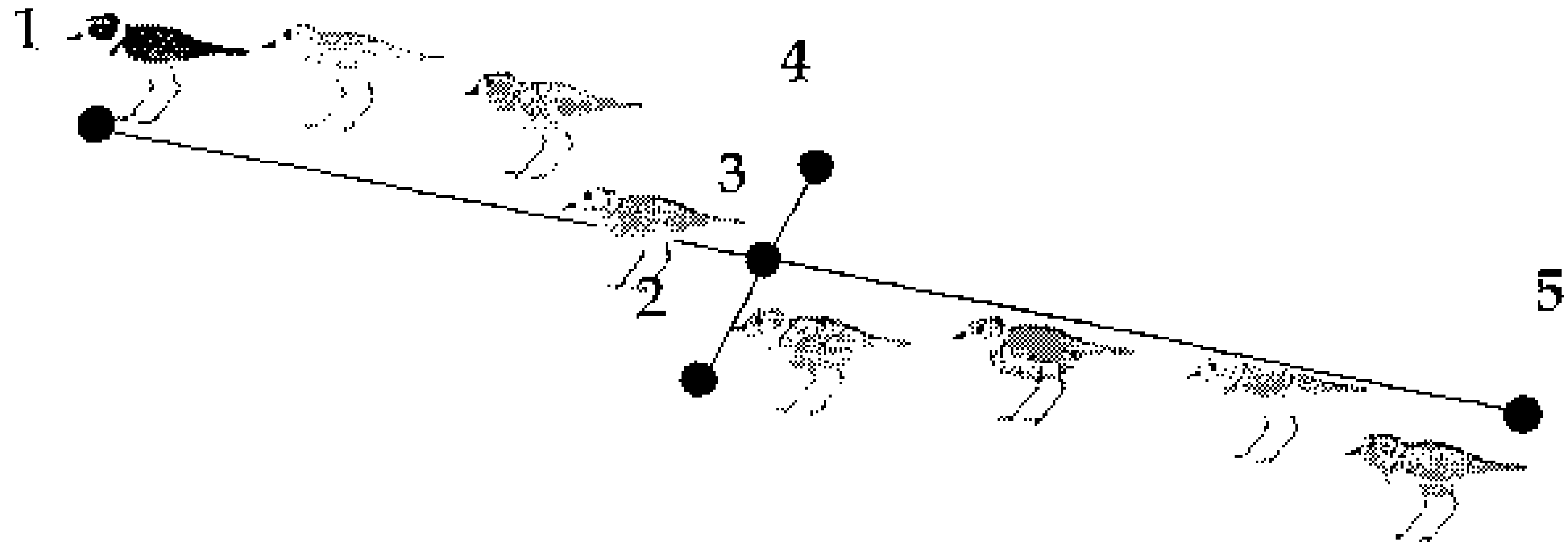

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Figure 12. Strategy used to collect prey samples in areas occupied by a single foraging Piping Plover. A +-shaped transect was positioned within the area used by the plover immediately preceeding sample collection. In this figure, the single foraging Piping Plover is represented by a darkly shaded figure on the extreme left. To its right, are several lightly shaded figures representing the hypothetical path of the plover immediately prior to sample collection. The sample locations are depicted by filled circles, labelled 1 - 5. I collected sample 3 from the center of the area covered by the plover. Samples 1 and 5 were collected from the outer limits of the area's long dimension. Samples 2 and 4 were collected 3 - 5 meters on each side of the center sample (sample 3) along an axis perpendicular to the area's long dimension.

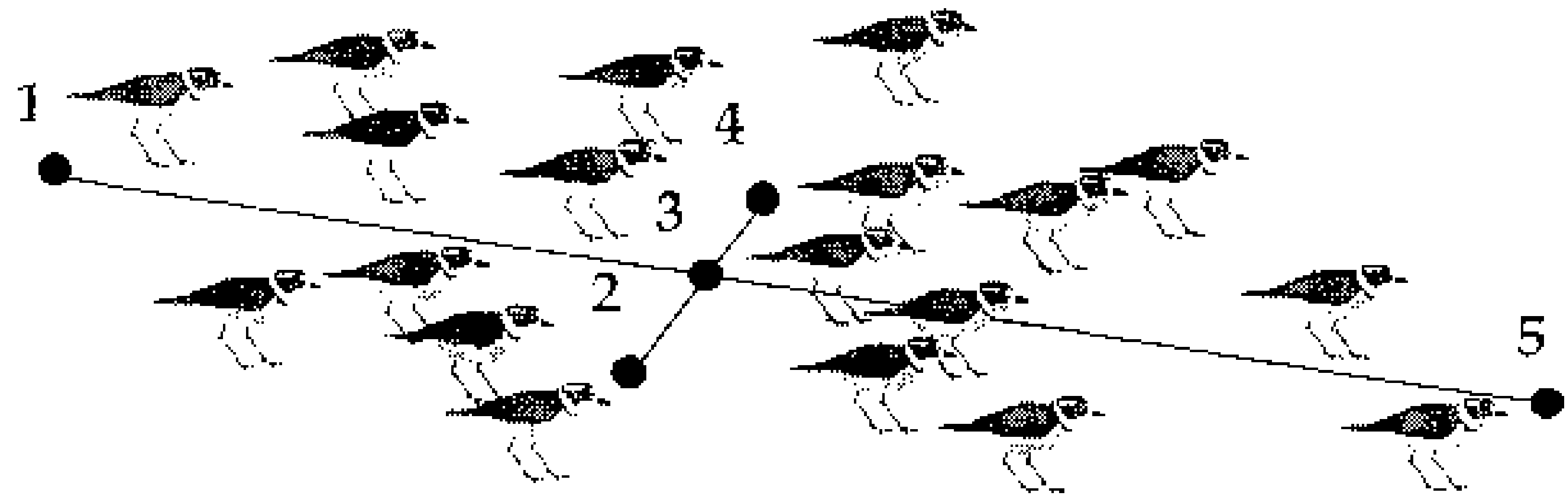


Figure 13. Strategy used to collect prey samples in areas occupied by a flock of foraging Piping Plovers. A +-shaped transect was positioned within the flock. The sample locations are represented by filled circles, labelled 1 - 5. I collected sample 3 from the center of the flock. Samples 1 and 5 were collected from the outer limits of the flock's long dimension. Samples 2 and 4 were collected 3 - 5 meters on each side of the center sample (sample #3) along an axis perpendicular to the flock's long dimension.

After retrieval, cores were placed in plastic bags and sieved (600 μm) and scored later the same day or early the next morning. Each prey item was classified into one of 4 prey groups (polychaetes, crustaceans, insects, other). Benthic prey were investigated in this way on both beach and bayshore habitat.

Surface Prey Samples

During the 1991 IPPC, I observed Piping Plovers foraging on flies and other prey located above the ground, especially on bayshore habitat. Because these animals (mostly adult insects and spiders) were highly mobile, and could not be accurately represented in core samples, I employed 2 additional techniques, sticky traps and spotting scope sampling, to obtain systematic samples of this portion of the prey community.

Sticky Trap Samples

To estimate surface insect abundance, I used modified sticky traps (Southwood 1996, MacLean and Pitelka 1971, Nordstrom 1990). Each foraging flock was sampled using five square flooring tile pieces (each ~ 2 mm x 15 cm x 15 cm) placed directly on the ground along the same transect used to sample benthic prey (Figure 13). Each tile was displaced approximately 1 m from the position where a soil core was retrieved. The tiles were coated with a 1-2 mm layer of Stickem Special™ (Seabrite Enterprises, Emeryville, CA 94608) filling a 12.5 cm diameter circle. These sticky traps were left in position along the transect for 60 minutes. During this period, small animals crawling onto, or landing within the layer of adhesive became trapped and were collected and scored later that night or early the next morning. Because sticky traps were "active" for a full hour, tallies could not be used to estimate above ground prey density, but were used only as relative measures of abundance.

Spotting Scope Samples

I developed and implemented a second technique during the final year of the study to collect instant counts of the above-ground fauna and allow for instantaneous density estimates of this portion of the prey community. A spotting scope was positioned at a consistent and reproducible height (tripod legs fully extended, center tripod support fully retracted) near the spot of each sampling position within the transect. The scope was then near-focused to its limit, and pointed down toward the surface until the ground became focused. The scope/tripod-head complex was spun and allowed to come to rest. The radius of ground that the scope was pointing to was "angled into focus" to reveal a 0.95 m^2 patch of ground that was surveyed (without moving the scope) for surface animals. Animals walking or flying into the field of view during the survey were not counted.

Algal Mat Samples

Where Piping Plovers were observed feeding on algal flats, a single core was taken of the mat near the center of the transect (i.e., sample location #3; Figure 1?). Each core was ~ 2 cm deep, and 7.5 cm in diameter. Each core was sealed in a separate Zip lock™ bag with trapped air, and incubated under a controlled light cycle of 12 hours light /12 hours dark. Each core was checked once per week, throughout a six week period. All emergent animals were collected and scored.

Behavior

I characterized the foraging ecology of Piping Plovers along the TGC, and identified the factors affecting foraging success. One of my goals under this objective was to describe the diets of Piping Plovers in the 2 ecosystems and the ecotone, and among the major habitat types. The other goals of this objective related to foraging effort and foraging success.

To estimate foraging effort and success, I identified Piping Plovers involved in foraging activity during daily bird counts. I approached foraging groups of plovers and monitored randomly selected subjects with regard to their style of locomotion and the efficiency with which they captured different types of prey. The parameters I monitored are described in more detail below under "Piping Plover Foraging Locomotion" and

"Piping Plover Foraging Efficiency".

I used multi-factor models to investigate the relative effects of habitat type, ecosystem type and season on each estimate of foraging success. Additionally, I evaluated the foraging effort of Piping Plovers in relation to the density of different benthic prey groups. Finally, I measured the frequency with which foraging Piping Plovers exhibited aggressive behavior and investigated its expression among the different habitats and microhabitats used by plovers.

Piping Plover Activity

During daily bird counts, I scored the activity of each Piping Plover as either "foraging" or "roosting." I considered foraging plovers to be those that were actively feeding, or that were nearby other foraging plovers during the same count, and were not bathing, roosting or preening (i.e., plovers that appeared to be momentarily pausing between foraging attempts). Plovers scored as "roosting" were birds that were either bathing, roosting, or preening during the count.

Piping Plover Diet

I evaluated the Piping Plover diet from observations of those individuals that I was able to approach closely enough during the foraging efficiency records to identify the types and frequencies of prey that were captured.

I scored prey captured into 1 of 3 classes: 1) polychaetes and other worm-like prey, 2) arthropods and other non-worm like prey, or 3) unknown. Polychaete captures were usually very obvious, as plovers often pull them out of the sand slowly to avoid breaking the worm.

Piping Plover Foraging Locomotion

I observed Piping Plovers to use 2 predominant styles of foraging motions. One motion, henceforth described as reserved foraging locomotion (RFL), consisted of repeated, short, conserved movements toward prey animals located within 1-2 body lengths of the plover. The second type of motion was more prolonged, and was often very rapid, and is henceforth described as prolonged foraging locomotion (PFL). Plovers engaged in PFL moved beyond the normal 1-2 body lengths typical of RFL, often not pausing until it reached an area far beyond its initial location.

Because plovers presumably expend more energy during PFL periods relative to RFL periods, I monitored this type of locomotion as a factor potentially affecting a foraging plover's energy costs, and thereby its net energy intake rate. To document PFL, I watched randomly selected, foraging Piping Plovers for a period of 120 seconds and recorded the amount of time the plover spent in PFL. I defined PFL as any movement beyond 2 plover body lengths, and I timed the duration of all such movements using a stopwatch. I recorded a maximum of 10 records/habitat during each site visit.

During the 120 second period, I also recorded 1) the number of times the plover took flight, 2) the number of aggressive interactions involving the plover, and 3) the number of noticeable human disturbances (e.g., passing vehicles, beachcombers walking by, low-flying airplanes).

Piping Plover Foraging Efficiency

To appraise foraging efficiency, I observed foraging Piping Plovers at close range with a high-resolution spotting scope. During foraging efficiency records, a single, randomly selected plover was observed until it made 50 attempts to capture prey (pecks). Occasionally plovers moved beyond the range necessary for accurate observation, and the record was discontinued before 50 attempts were observed. Among the data recorded during the record were 1) the number of animals captured, 2) the number of pecks [if < 50], 3) the time of record, 4) the number of each prey type captured, 5) the species of nearest shorebird neighbor and 6) the number of aggressive interactions involving the plover during the record. As many records as possible were collected, up to a maximum of 10/habitat/site visit.

To score captures with accuracy it was usually necessary to approach birds to ≤ 50 m. Rather than attempting to sequentially approach each bird present, I sampled plovers by moving in increments of about 100 m through or around foraging flocks. Records were collected by scanning the flock in a complete 360° circle, pausing throughout the scan to monitor each bird that was close enough to accurately monitor foraging efficiency. After all of the plovers within viewing range were monitored at one position, I moved another 100 m to the next position and waited a short period to allow the birds to become accustomed to my presence before data collection resumed.

Foraging Ecology and Prey Density

Foraging efficiency and foraging effort were compared to benthic prey density and surface prey abundance (prey density and abundance are described in Chapter IV). Foraging effort was estimated as the mean number of pecks/minute exhibited by foraging plovers. For these comparisons, the daily means for benthic prey density and surface prey abundance were regressed against the daily mean for foraging efficiency and foraging effort. All data were collected in areas occupied by foraging Piping Plovers.

Intraspecific and Interspecific Interactions

To investigate associations between foraging Piping Plovers and other nearby birds, I recorded the species identification of the bird located closest to the plovers I was monitoring during foraging efficiency and foraging locomotion records. I recorded all acts of aggression involving Piping Plovers (i.e., intraspecific and interspecific aggressions) that I observed during the foraging locomotion and foraging efficiency records.

Data Analysis

All analyses were performed using JMP, version 3.1. JMP is a statistical program written by SAS Institute Inc., Cary, NC. Advanced statistical analyses (i.e., beyond the calculation of means, standard errors, etc.) consisted of one-way and multi-factor

Table 10. Mean macrobenthic polychaete, crustaceans and total prey density collected at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Density represented as the mean number of animals per square meter based upon core samples collected along transects associated with foraging Piping Plovers. Abbreviations: MISP = Mustang Island State Park.

Study Location	N	Polychaetes		Crustaceans		Insects		All Prey	
		mean	SE	mean	SE	mean	SE	mean	SE
Bolivar Flat	100	1577.5	182.81	1710.8	228.28	13.8	2.73	3304.1	347.76
Big Reef	35	3383.5	420.16	490.7	93.34	0.0	7.05	3887.2	385.46
San Luis Pass	155	2140.4	229.62	1278.7	197.23	0.0	2.19	3425.0	343.51
East Flats	35	678.0	117.20	1607.8	297.32	0.0	4.62	2298.7	338.21
MISP - North	165	920.4	111.93	880.7	170.56	0.0	2.13	1845.0	222.03
MISP - South	52	1799.3	236.41	1303.9	259.97	0.0	3.79	3155.3	307.45
Packery Channel	175	732.2	70.84	2005.6	241.97	0.0	2.06	2783.0	250.83
South Bay - East	45	693.1	121.98	597.64	117.18	0.0	4.07	1295.7	166.04
South Padre Island	45	783.5	118.37	838.71	106.20	0.0	4.07	1622.2	174.66

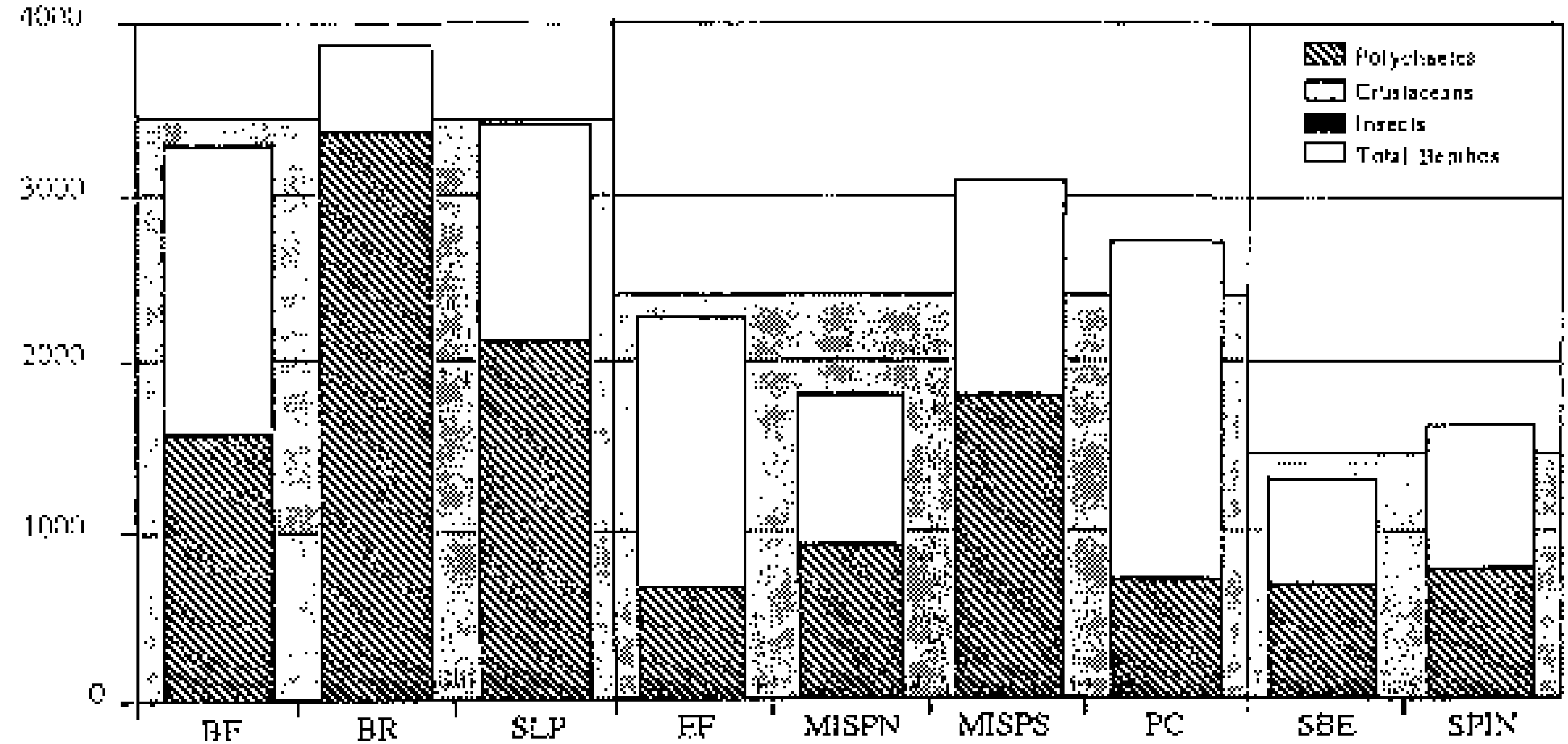


Figure 14. Macrobenthic density at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Stacked bars illustrate polychaete density, crustacean density, insect density, and (collectively) total mean benthic density recorded at locations occupied by foraging Piping Plovers. Wide gray bars in background illustrate mean total benthic density for both ecosystems and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, SBE = South Bay East, SPIN = South Padre Island - North

Total beach benthos differed significantly among both ecosystems and the ecotone (Table 11). Total benthic prey density was much higher in the bay ecosystem than the lagoon ecosystem ($P < 0.0001$) or the ecotone ($P < 0.0001$). Much of the variation in total benthos among the 3 regions was due to variation in polychaete populations. Polychaete densities were higher at bay beaches than at ecotone beaches ($P < 0.0001$) or lagoon beaches ($P < 0.0001$). I also recovered more polychaetes in samples from ecotone beaches relative to lagoon beaches ($P = 0.0020$). There were fewer crustaceans at lagoon ecosystem beaches than at those in the bay ecosystem ($P = 0.0210$) or the ecotone ($P = 0.0033$), however, crustacean density did not differ between the bay ecosystem and the ecotone ($P = 0.5893$). None of the 3 coastal regions differed with regard to benthic insect density at beach habitat.

There was no difference in total benthic density ($P = 0.3528$), polychaete density ($P = 0.1057$), or crustacean density ($P = 0.9846$) in the swash zone and upper beach zone (Table 12). There also was no detectable difference in the density of the dominant beach benthic prey groups in the winter and migratory periods (Table 13).

Bayshore Benthos

Benthic prey density ranged widely at bayshore habitats from just over 100 animals/m^2 to over 7000 animals/m^2 (Table 14; Figure 15). Total benthic prey varied significantly among the 3 coastal regions (Table 11). I detected higher benthic prey density in the bay ecosystem relative to the lagoon ecosystem ($P < 0.0001$) and the ecotone ($P < 0.0001$). Total benthic density also was greater in the ecotone than the lagoon ecosystem ($P = 0.0010$).

Polychaetes were often the most numerous prey group in samples, but polychaete density ranged widely from 0 to over 7,000 worms/m^2. Polychaete density was higher in the bay ecosystem than in either the lagoon ecosystem ($P < 0.0001$; Table 11) or the ecotone ($P < 0.0001$, Table 11) and was lower in the lagoon ecosystem than the ecotone

Table 11. Piping Plover bayshore flock size and prey population measures at beach and bayshore habitat from the 2 ecosystems and the ecotone along the Texas Gulf Coast. Parameters are summarized as study means for each location. Multi-factor ANOVA results of pair-wise comparisons between the ecosystems and the ecotone are presented in the last 3 columns. Bayshore flock size represents the mean number of Piping Plovers within foraging flocks as recorded during prey sampling periods at bayshore habitat. Benthic prey parameters are represented as the mean number of animals/m². Surface prey, as estimated by sticky traps (ST), and scope surveys (SS), are represented as the mean number of animals/100m². Insect larval density, as estimated by algal mat cores samples (AC) is represented as the mean number of larva/m².

Parameter	Bay Ecosystem			Ecotone			Lagoon Ecosystem			Bay	Bay	Eco.
	mean	N	SE	mean	N	SE	mean	N	SE	vs. Lag.	vs. Eco.	vs. Lag.
Bayshore Flock size	12.8	550	0.6	9.4	401	0.7	16.6	230	0.9	0.1945	0.2608	0.0714
Beach Total Benthos	3439.1	290	185.9	2426.2	427	153.2	1459.0	90	333.7	< 0.0001	< 0.0001	0.0010
Beach Polychaetes	2096.3	290	106.6	930.5	427	87.8	738.3	90	191.3	< 0.0001	< 0.0001	0.0020
Beach Crustaceans	1332.6	290	139.[illegible]	1452.9	427	114.6	718.2	90	249.6	0.0210	0.5893	0.0033
Beach Insects	4.7	290	1.6	0.0	427	1.3	0.0	90	2.9	0.1719	0.4369	0.3750
Bayshore Total Benthos	5067.7	550	168.0	1317.7	401	196.7	864.7	230	259.8	< 0.0001	< 0.0001	0.0010
Bayshore Polychaetes	5041.9	550	155.3	796.1	375	188.5	495.2	230	240.1	< 0.0001	< 0.0001	< 0.0001
Bayshore Crustaceans	18.9	550	59.0	604.1	370	71.9	211.3	230	91.2	0.0309	< 0.0001	< 0.0001
Bayshore Insects	6.2	550	5.0	15.9	370	6.1	158.2	230	7.7	< 0.0001	0.3925	< 0.0001
Surface Prey - ST	15.5	401	17.2	160.9	330	16.3	225.6	445	16.3	0.0082	0.0296	0.0142
Surface Prey - SS	0.6	206	8.0	81.4	95	11.8	58.1	205	8.0	0.0330	0.1638	0.4710
Insect Larva - AC	--	--	--	522.6	32	162.6	838.1	72	108.4	--	--	0.0865

Bay = bay ecosystem, Eco = ecotone, Lag = lagoon ecosystem

Table 12. Comparison between the swash zone and the upper beach, the 2 microhabitats used most frequently by Piping Plovers along the Texas Gulf Coast.. All numbers represent means for all sites and years. Piping Plover (PIPL) abundance is reported as the number of plovers/transect as measured during prey sampling. Benthic parameters are reported as the number of animals/m². Foraging efficiency estimates are reported as the number of captures/minute, and foraging locomotion is reported as the number of seconds/minute spent in prolonged locomotion.

Ecosystem	Swash Zone			Upper Beach			*P*-value
	mean	N	SE	mean	N	SE	
PIPL Abundance	1.42	315	0.10	1.20	346	0.09	0.0224
Total Benthos	2621.6	315	189.3	2641.5	346	180.6	0.1528
Benthic Polychaetes	1427.8	315	110.8	1224.7	346	105.8	0.1057
Benthic Crustaceans	1151.5	315	136.9	1401.1	346	130.6	0.9816
Benthic Insects	0.0	315	1.7	3.9	346	1.6	0.0558
Foraging Efficiency	13.7	66	0.8	7.0	38	1.1	< 0.0001
Foraging Locomotion	10.0	54	0.8	5.7	81	0.7	0.0002

Table 13. The effects of season on benthic prey density along the Texas Gulf Coast, 1991 - 1994. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing benthic prey density among the 2 seasons.

Ecosystem	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
Beach Habitat							
Total benthos	2468.9	397	161.7	2888.9	410	159.1	0.7602
Polychaetes	1247.8	397	95.4	1405.6	410	93.9	0.6069
Crustaceans	1186.4	397	119.1	1464.6	410	117.2	0.2898
Insects	3.4	397	1.4	0.0	410	1.4	0.0417
Bayshore Habitat							
Total benthos	2176.2	561	179.7	3186.4	725	158.1	0.3858
Polychaetes	2031.5	540	176.9	2905.4	720	153.2	0.7270
Crustaceans	182.9	540	58.0	261.4	715	50.4	0.8616
Insects	46.5	540	6.0	42.7	715	5.2	0.5662

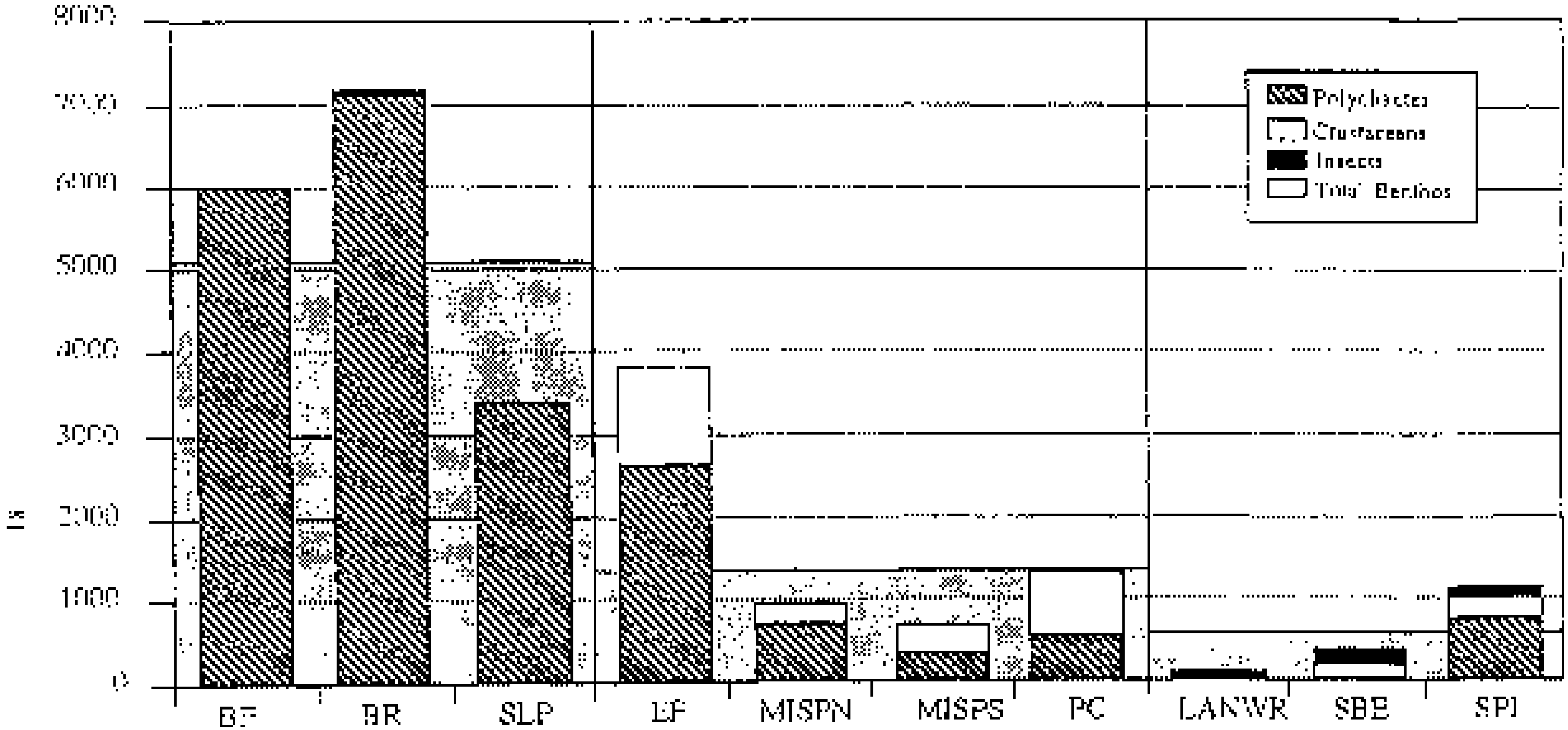


Figure 15. Mean site density and ecosystem density of Piping Plover at bayshore habitat along the Texas Gulf Coast, 1991 - 1994. Stacked bars illustrate polychaete density, crustacean density, insect density, and (collectively) total mean benthic density recorded at locations occupied by foraging Piping Plovers. Wide gray bars in background illustrate mean total benthic density for both ecosystems and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park - South, PC = Packery Channel, LANWR = Laguna Atascosa National Wildlife Refuge, SBE = South Bay East, SPI = South Padre Island

($P < 0.0001$; Table 11). Polychaete density in my samples from Bolivar Flats and Big Reef was similar to polychaete density estimates reported by Sears and Mueller (1989) for those 2 sites (Figure 16). Sears and Mueller sampled polychaetes along a fixed transect, and therefore their samples were not necessarily associated with areas recently used by foraging Piping Plovers. When the samples from both studies are compared on a monthly basis (as the data from Sears and Mueller (1989) were summarized) polychaete density was higher in my samples in 7 out of 8 months at Bolivar Flats, but just 3 out of 6 months at Big Reef. Both studies suggest that peak polychaete density occur in winter (January - February) in the bay ecosystem.

Crustacean density ranged from 0 to over 1,100 animals/m^2 at bayshore habitat (Table 14). Large crustacean counts were usually associated with local blooms of tanaids. Crustacean density was much higher in the ecotone ($P < 0.0001$; Table 11) and the lagoon ecosystem ($P = 0.0309$; Table 11) relative to the bay ecosystem. The highest crustacean density occurred in the ecotone, where I collected nearly 3 times as many crustaceans as in the lagoon ecosystem ($P < 0.0001$; Table 11).

Insects were much less common in bayshore benthic samples relative to polychaetes or crustaceans, and most insects collected in subsurface samples were fly larva. I recorded densities of < 100 insects/m^2 at most of my sites, however, insect density exceeded this amount at all 3 study areas in the lagoon ecosystem (Table 14; Figure 16).

Total benthic prey density was similar in areas used by flocks and individual plovers ($P = 0.4925$, Table 15). Crustacean density was greater in areas used by plover flocks ($P = 0.0015$; Table 15), but neither polychaete density ($P = 0.3829$; Table 15) nor benthic insect density ($P = 0.2408$; Table 15) differed among areas used by flocks or solitary plovers.

Total benthic prey density ($P < 0.0001$) and polychaete density ($P < 0.0001$) were higher at sand flats than at algal flats (Table 16). Benthic insect density was higher at

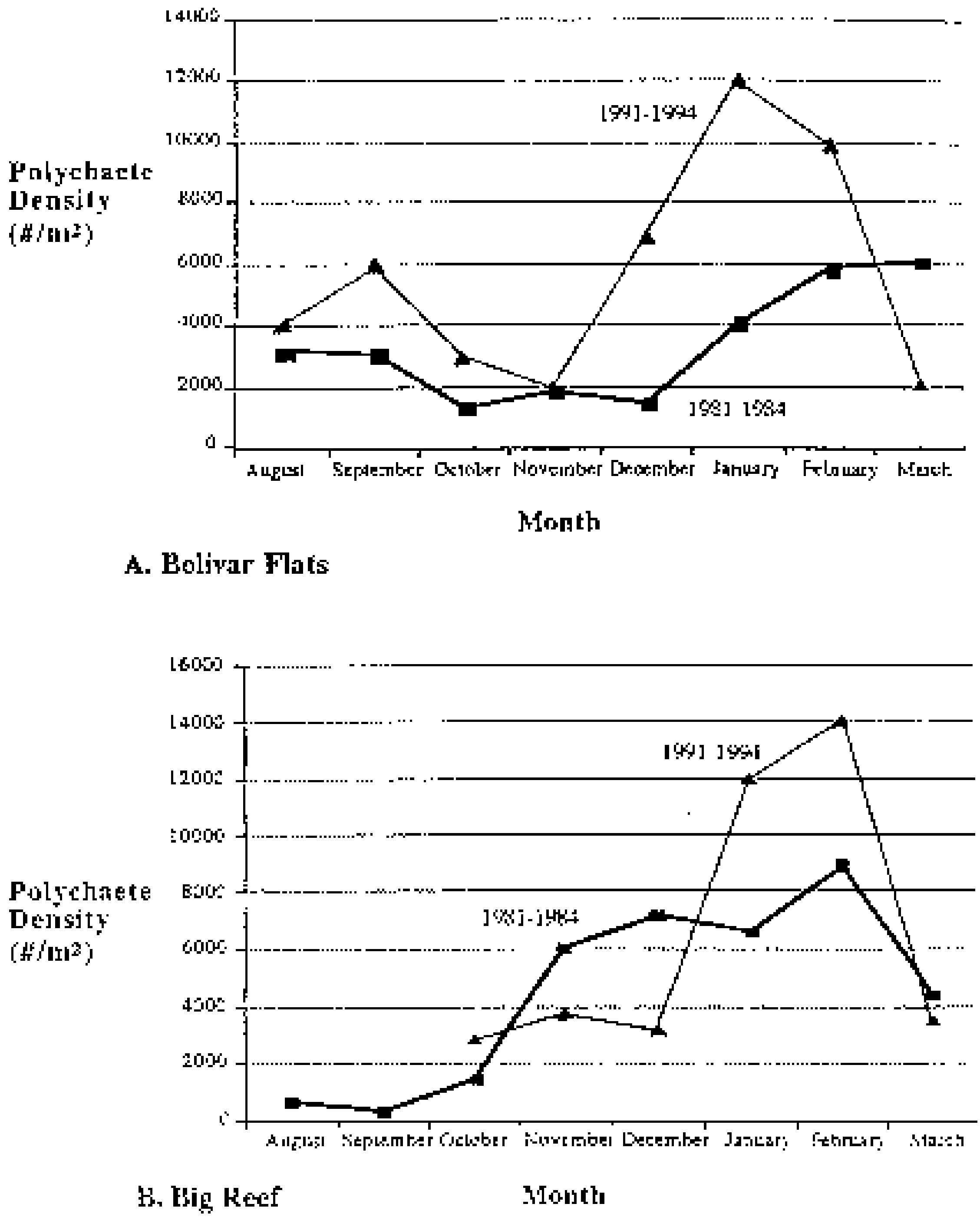


Figure 16. Polychaete density at Bolivar Flats (A) and Big Reef (B) as measured in 1981 - 1982 (thick line with rectangles) by Sears and Mueller (1989) and in 1991 - 1994 (thin line with triangles) for this study.

Table 15. Comparison of prey populations collected in association with flocks of Piping Plovers and solitary Piping Plovers. All numbers represent means for all sites throughout the study. Benthic parameters are reported as the number of animals/m². Sticky trap (ST) estimates of surface prey are reported as the number of insects captured/100 trap hours.

Ecosystem	Plover Flocks			Solitary Plovers			*P*-value
	mean	N	*SE*	mean	N	*SE*	
Total Benthic Prey	2895.8	1066	130.9	2018.6	220	288.2	0.4925
Benthic Polychaetes	2636.7	1048	127.5	2007.4	212	283.4	0.3829
Benthic Crustaceans	260.9	1048	41.6	59.0	207	93.6	0.0015
Benthic Insects	47.0	1048	4.3	30.6	207	9.7	0.2408
Surface Prey - ST	141.8	1028	11.1	94.6	148	29.2	0.9687

Table 16. Comparison between sand flat and algal flat habitat with regard to several study parameters. All numbers represent means for all sites throughout the study. Piping Plover (PIPL) abundance is reported as the number of plovers/transect during prey sampling. Benthic parameters and spotting scope survey (SS) estimates of surface prey are reported as the number of animals/m^2. Sticky trap estimates of surface prey are reported as the number of insects captured/100 trap hours. Foraging efficiency estimates are reported as the number of captures/minute, and foraging locomotion is reported as the number of seconds/minute spent in prolonged locomotion.

Ecosystem	Sand Flats			Algal Flats			*P*-value
	mean	N	SE	mean	N	SE	
PIPL Abundance	12.7	754	0.5	12.7	532	0.6	0.8373
Total Benthos	4316.5	754	140.5	519.6	532	167.2	< 0.0001
Benthic Polychaetes	4021.5	754	135.1	309.5	506	165.0	< 0.0001
Benthic Crustaceans	275.8	754	49.1	155.2	501	60.2	0.1037
Benthic Insects	18.6	754	5.0	83.0	501	6.1	< 0.0001
Surface Prey - ST	87.0	604	15.0	187.0	572	14.0	< 0.0001
Surface Prey - SS	0.27	336	0.6	0.71	140	0.1	0.0002
Foraging Efficiency	10.3	336	0.3	9.8	168	0.4	0.9114
Foraging Locomotion	1.25	167	0.22	1.54	118	0.26	0.0027

algal flats than at sand flats ($P < 0.0001$). Crustacean density did not differ among bayshore microhabitat types ($P = 0.1037$). All types of benthic prey were more abundant at barrier island sites relative to mainland sites (Table 17).

Bayshore Surface Prey as Estimated Using Sticky Traps

With the exceptions of a few spiders, all of the animals captured by the sticky traps were flies and other small adult insects. My samples suggest that surface prey density varied widely along the coast. The mean number of insects captured using sticky traps ranged from < 10 to nearly 1000 insects/100 trap hours (Table 18; Figure 17).

Surface prey abundance was lower in the bay ecosystem than the ecotone ($P = 0.0296$) or the lagoon ecosystem ($P = 0.0082$). The lagoon supported the highest abundance of surface prey, where levels exceeded those collected at sites in the ecotone ($P = 0.0142$). Total surface prey abundance was similar in areas used by flocks and individual plovers ($P = 0.9687$; Table 15).

Bayshore Surface Prey as Estimated Using Spotting Scope Surveys

Mean surface animal density, as estimated by spotting scope surveys, varied from 0 to over 200 animals/m^2 (Table 18; Figure 17). I observed significantly more surface prey in the lagoon ecosystem than in the bay ecosystem ($P = 0.0330$). However, surface prey density did not differ significantly between bay ecosystem and the ecotone ($P = 0.1638$) or the ecotone and the lagoon ecosystem ($P = 0.4710$).

Bayshore Emergent Prey Density as Estimated Using Algal Cores

I collected and monitored 104 algal mat core samples for emerging prey animals (Table 18; Figure 17). I did not collect any samples from the bay ecosystem because algal mats were extremely rare in this ecosystem and plovers were never observed to feed at algal flats during the 2 years algal cores were collected. Because there were no adult prey on the surface of the algal mat cores when they were collected, the insects scored from algal cores were mostly adult stages that had developed from eggs, larvae or pupae

Table 17. Mean prey population estimates on barrier island and mainland bayshore tidal flats in the lagoon ecosystem, 1991 - 1994 as estimated from samples collected in association with foraging Piping Plovers. Benthic prey density is expressed as the mean number of prey/m². Surface prey is expressed as the number of prey/100 trap hour for sticky traps, and the number of prey/m² for scope surveys and algal core samples. The *P*-values presented in the last column are associated with one way ANOVA analyses comparing benthic prey density among the 2 landform types.

Ecosystem	Barrier Island			Mainland			*P*-value
	mean	N	SE	mean	N	SE	
Benthos							
Total benthos	831.5	240	89.5	109.0	85	150.4	< 0.0001
Polychaetes	474.6	240	79.1	0.0	85	133.0	< 0.0001
Crustaceans	202.5	240	32.1	0.0	85	54.0	< 0.0001
Insects	154.4	240	14.5	109.0	85	24.4	0.0147
Surface Prey							
Sticky Traps	191.6	215	29.1	257.8	230	28.1	0.4906
Scope Surveys	0.40	180	0.07	1.66	25	0.21	< 0.0001
Algal Cores	1013.6	33	239.0	1321.2	39	219.8	0.7320

Table 18. Mean surface prey density collected at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Surface prey populations are represented as relative abundance (# animals/100 trap hours) as estimated by sticky traps, and prey density (# animals/100 m²) as estimated by spotting scope counts and incubated algal core samples. Abbreviations: LANWR = Laguna Atascosa National Wildlife Refuge, MISP = Mustang Island State Park.

Study Location	Sticky Traps			Spotting Scope			Algal Mat Cores		
	N	mean	SE	N	mean	SE	N	mean	SE
Bolivar Flats	150	60.0	22.7	75	0.0	12.2	0	--	--
Big Reef	90	42.2	29.3	55	0.0	14.2	0	--	--
San Luis Pass	161	9.3	21.9	99	28.8	10.6	0	--	--
East Flats	31	971.0	499.7	25	223.7	211.0	4	1299.5	658.5
MISP North Area	121	75.2	25.3	25	19.0	21.1	2	1356.0	931.2
Packery Flats	168	81.5	21.5	39	42.7	16.9	26	1451.6	258
LANWR	220	266.8	34.5	25	185.6	21.1	39	1321.2	210.9
South Bay East	50	78.0	39.3	35	23.8	17.8	13	851.9	365.2
South Padre Island	100	230.0	27.8	117	30.5	9.8	20	1118.7	294.5

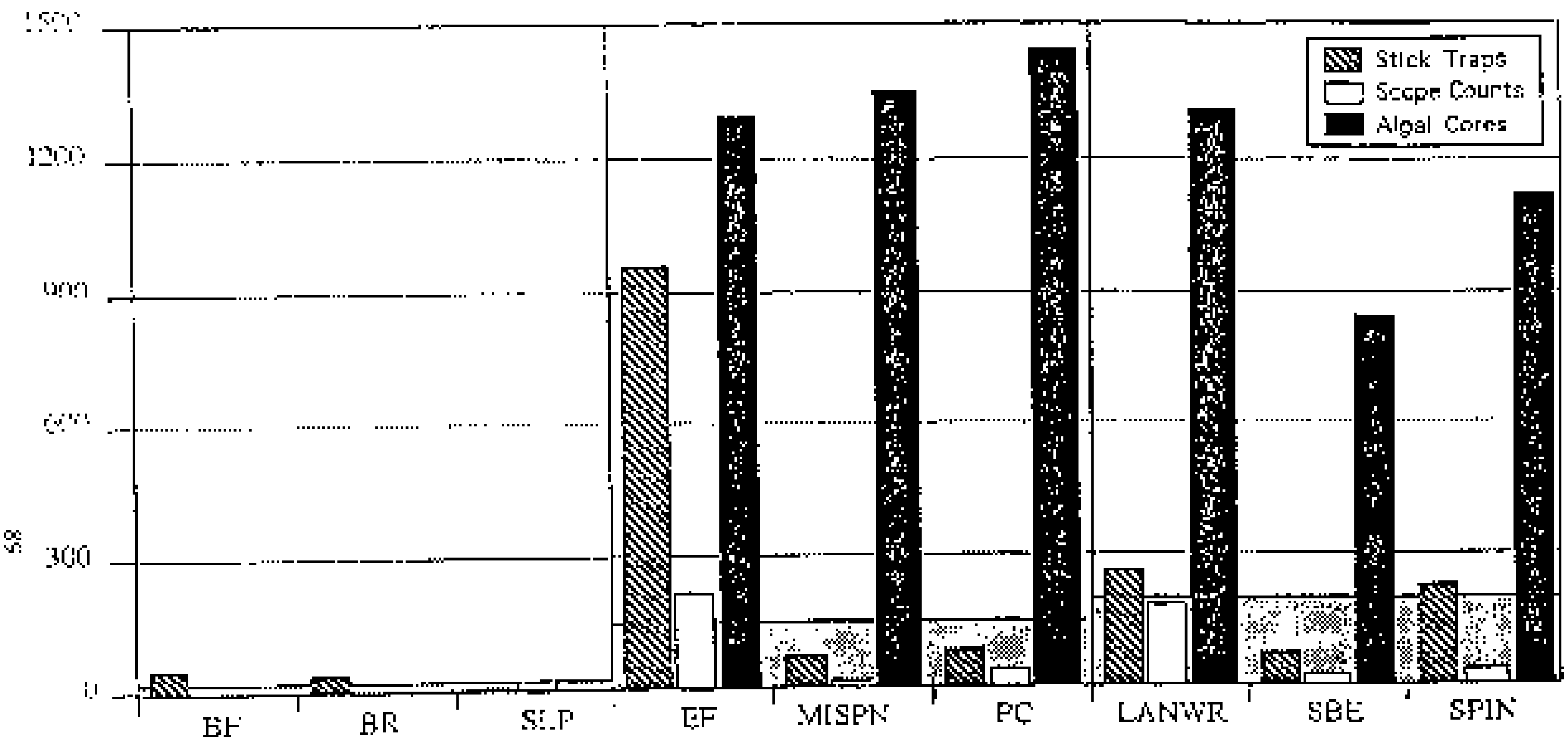


Figure 17. Mean surface prey density collected at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Surface prey populations are represented as relative abundance (striped bars # animals/100 trap hours) as estimated by sticky traps, and prey density (# animals/100 square meter) as estimated by spotting scope counts (white bars) and incubated algal core samples (black bars). Wide gray bars in background illustrate mean relative surface abundance from sticky traps at each ecosystem and the ecotone.

*Site Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN - Mustang Island State Park - North, MISPS = Mustang Island State Park South, PC = Packery Channel, LANWR = Laguna Atascosa National Wildlife Refuge, SBE = South Bay East, SPI = South Padre Island.

present in the mat. Therefore, these samples estimate the short-term (6 week) insect productivity potential of algal mats.

Emergent insect density ranged from about 850 to nearly 1,500 insects/m^2 (Table 18; Figure 16). Emergent insect density was somewhat lower in the ecotone than the lagoon ecosystem ($P = 0.0865$; Table 11).

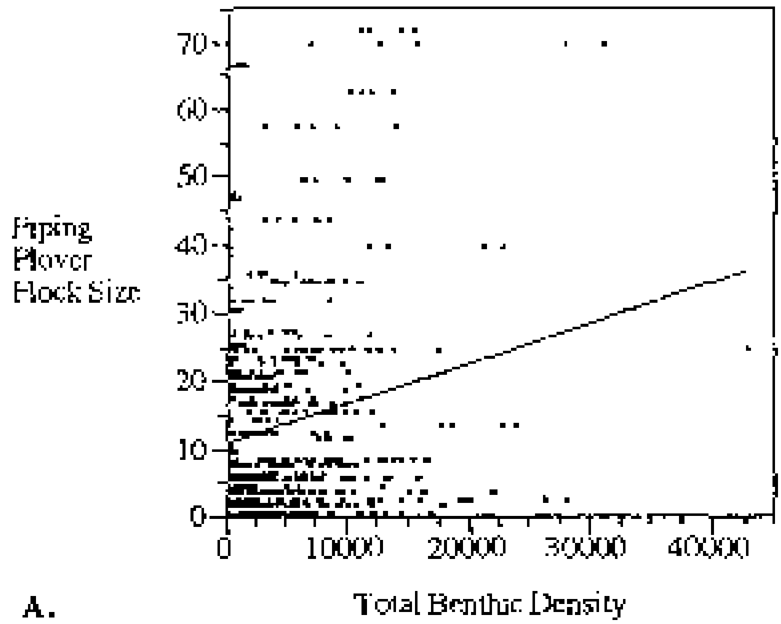
<u>Relationship Between Prey Density and Piping Plover Flock Size</u>

Whereas bayshore plover flock size did not differ significantly in the 2 ecosystems and the ecotone (Table 11), there was a strong relationship between Piping Plover foraging flock size and total benthic prey density. When I pooled data from both ecosystems and the ecotone I detected a positive relationship between the number of Piping Plovers feeding in an area and the density of total benthos ($P < 0.0001$; Figure 18A) and polychaetes ($P < 0.0001$; Figure 18B) within the area used by the flock. There was no such relationship between plover flock size and benthic crustacean density ($P = 0.0885$, Figure 19A) or benthic insect density ($P = 0.0594$; Figure 19B).

Different relationships become apparent when the data from each of the ecosystems and the ecotone were investigated independently. Within the bay ecosystem, Piping Plovers were attracted to concentrations of polychaetes. Flock size increased in areas with high total benthic density ($P < 0.0001$; Figure 20A), high benthic polychaete density ($P < 0.0001$; Figure 20B), and low benthic insect density ($P = 0.0035$; Figure 21B). There was no relationship between flock size and benthic crustacean density in the bay ecosystem ($P = 0.2420$, Figure 21A)

In the ecotone, plover flocks were associated with concentrations of total benthos ($P = 0.0003$; Figure 22A), polychaetes ($P = 0.0054$; Figure 22B) and crustaceans ($P = 0.0016$; Figure 23A). Benthic insect populations were not related to Piping Plover concentrations in the ecotone ($P = 0.1034$; Figure 23B).

In the lagoon ecosystem, the larger flocks of Piping Plovers were associated with



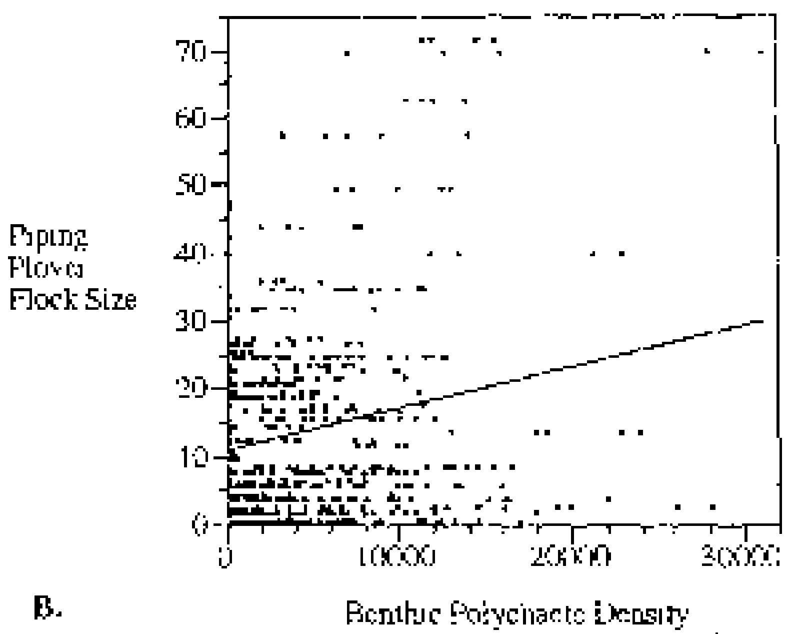
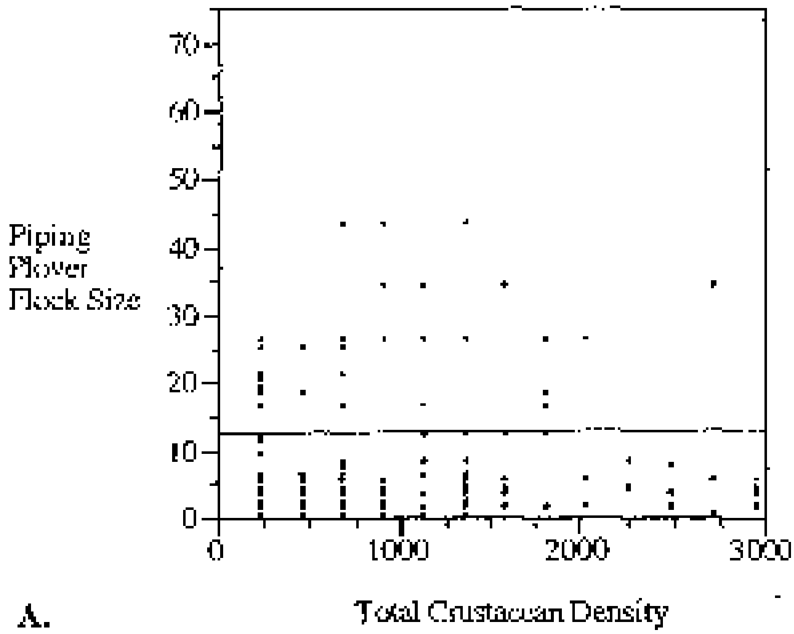
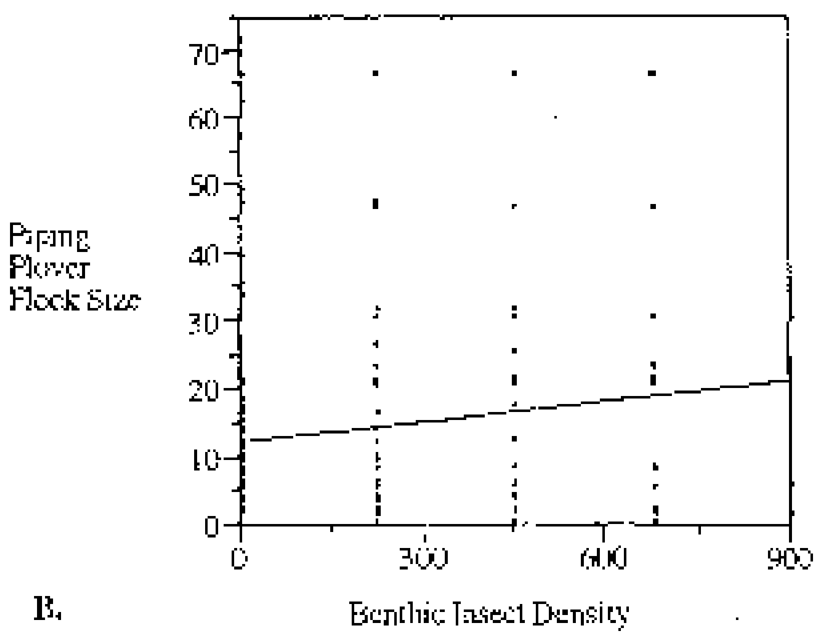


Figure 18. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (*A*; $P < 0.0001$) and benthic polychaete density (*B*; $P < 0.0001$). Data are pooled from all sites.



A.



B.

Figure 19. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0885$) and benthic insect density (B; $P = 0.0594$). Data are pooled from all sites.

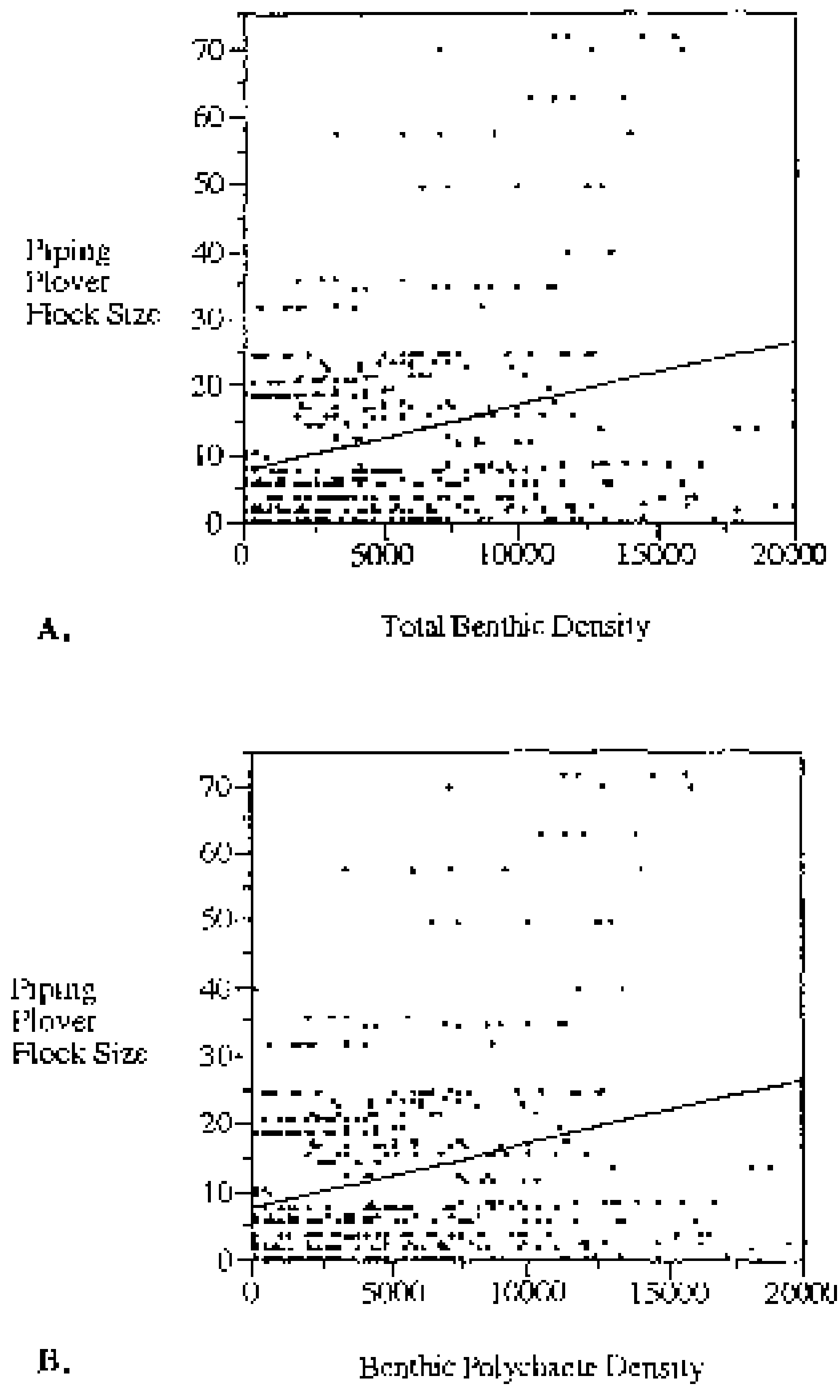


Figure 20. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P < 0.0001$) and benthic polychaete density (B; $P < 0.0001$). Data are from bay ecosystem sites only.

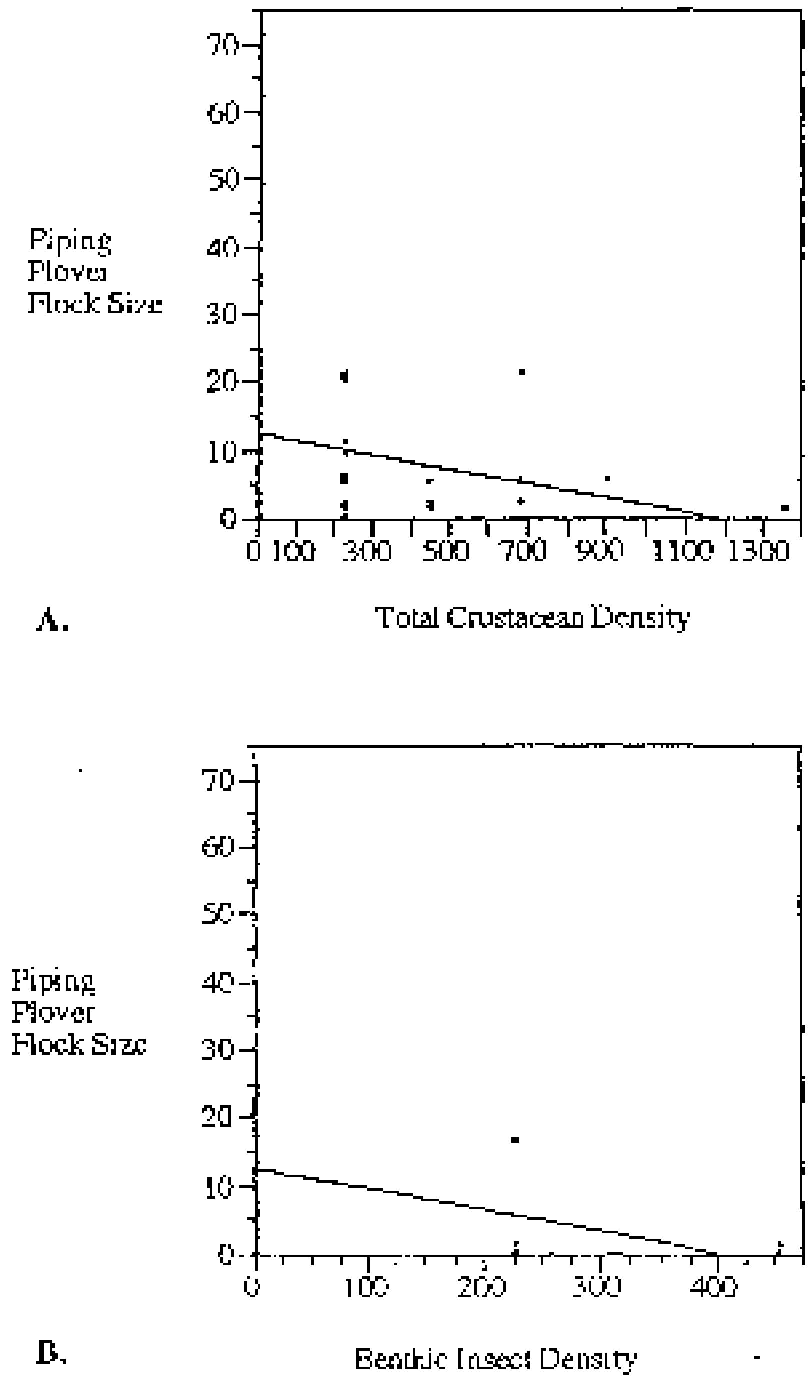
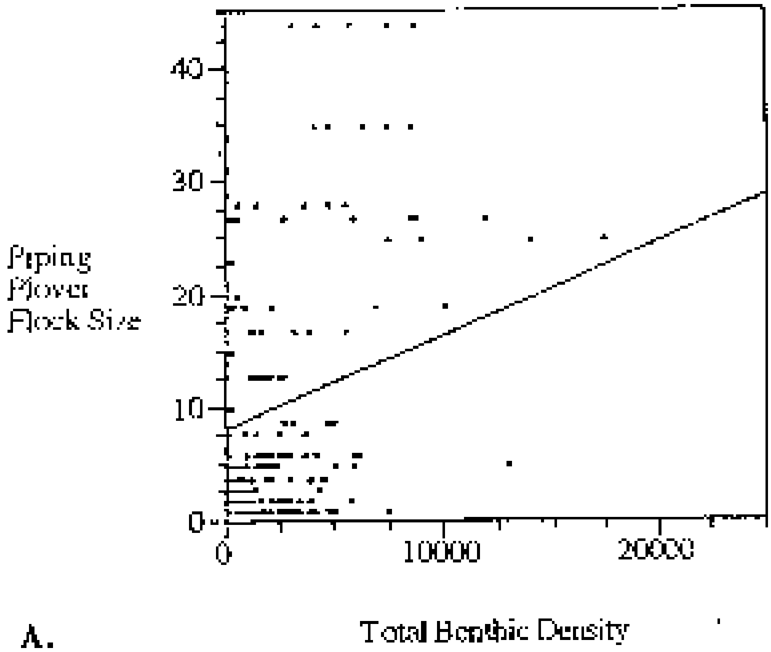
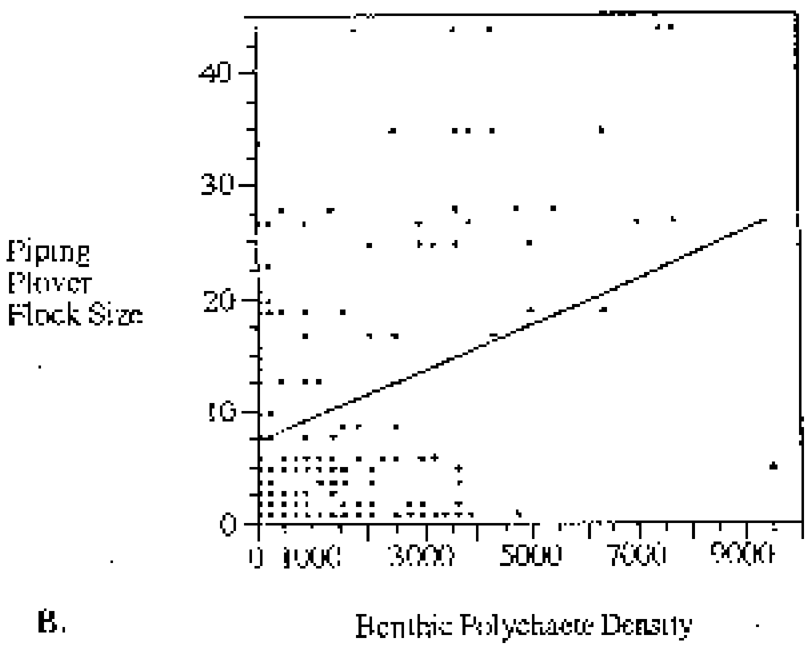


Figure 21. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.2420$) and benthic insect density (B; $P = 0.0035$). Data are from bay ecosystem sites only.

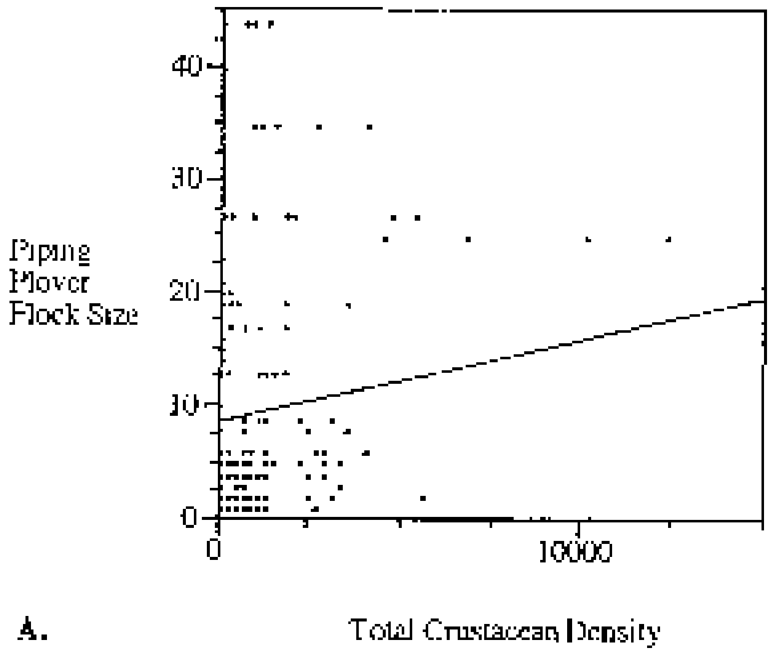


A.

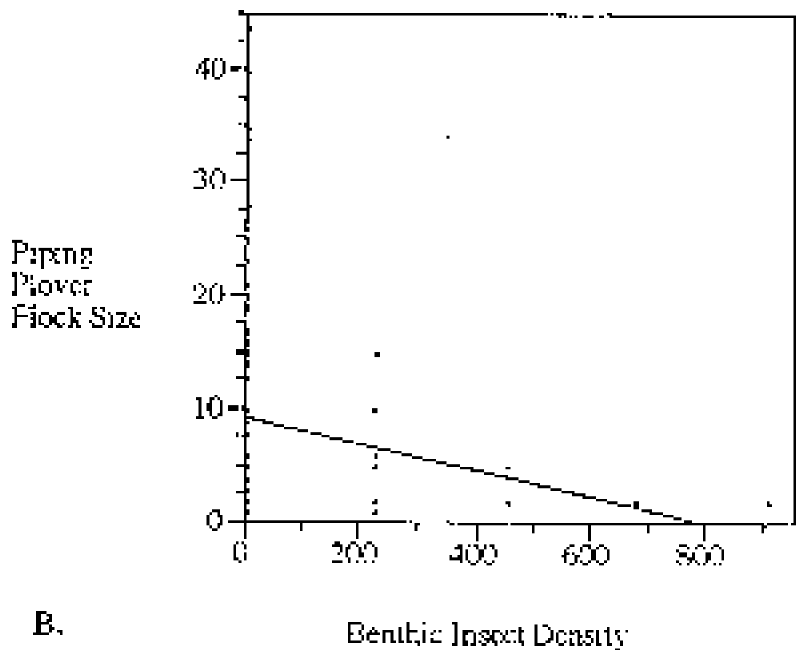


B.

Figure 22. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P = 0.0003$) and benthic polychaete density (B; $P = 0.0054$). Data are from the ecotone sites only.



A.



B.

Figure 23. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0016$) and benthic insect density (B; $P = 0.1034$). Data are from ecotone sites only.

areas of the flats that exhibited the lowest concentrations of total benthos ($P = 0.0004$; Figure 24A), polychaetes ($P = 0.0019$; Figure 24B) and crustaceans ($P = 0.0048$; Figure 25A). Benthic insect density did not significantly affect Piping Plover flock size in the lagoon ecosystem ($P = 0.2845$; Figure 25B).

There was no relationship between flock size and surface prey abundance at all sites combined ($P = 0.9568$; Figure 26A) or in the bay ecosystem ($P = 0.9568$; Figure 26B) or the ecotone ($P = 0.1402$; Figure 27A). Surprisingly, flock size was negatively associated with surface prey abundance in the lagoon ecosystem ($P < 0.0001$; Figure 26B).

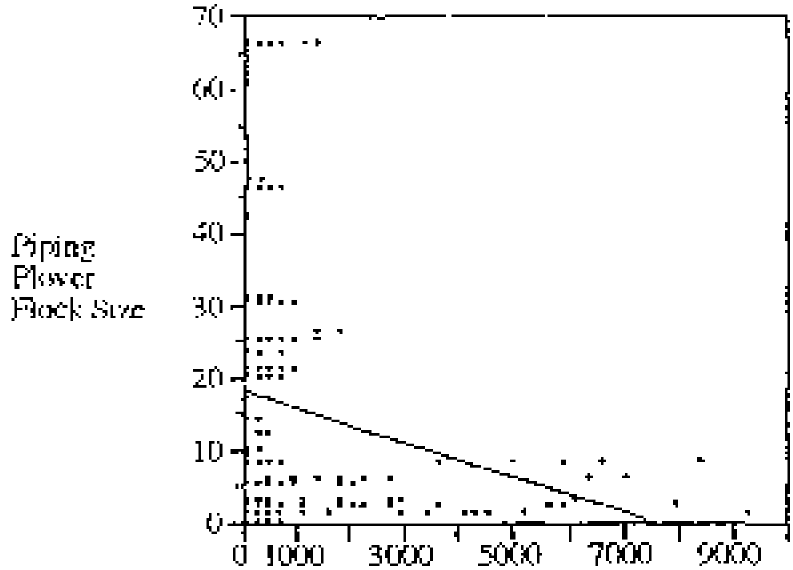
Behavior

Piping Plover Activity

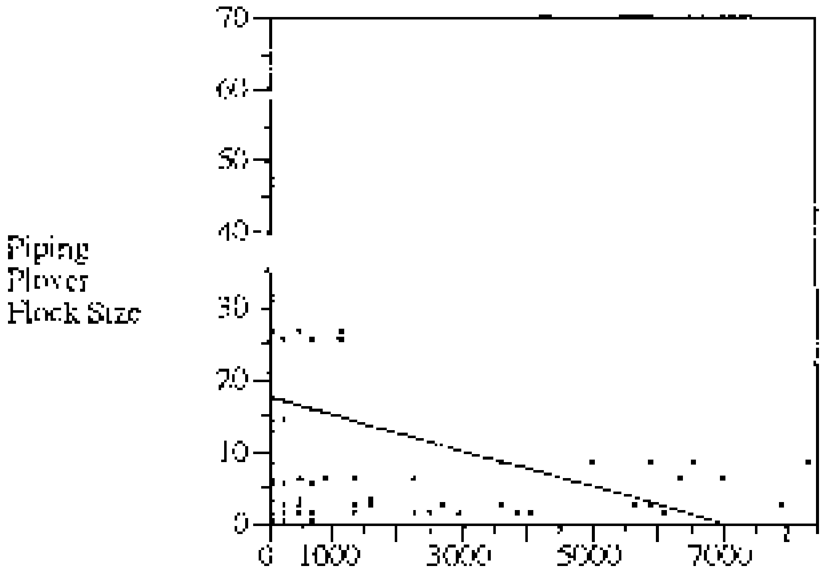
The majority of the Piping Plovers I encountered during shorebird counts were engaged in foraging activity (Figure 28). Plovers using beach habitat were more likely to be roosting than were plovers using bayshore habitat ($P < 0.0001$)

Most roosting activity by Piping Plovers at my sites occurred during high bayshore tide conditions ($P < 0.0001$). Piping Plovers roosted most commonly in washover pass regions of beach habitat and on high flat areas of bayshore habitat. Washover passes are broad, unvegetated barrier island landscapes that are formed and maintained by hurricanes and tropical storms. Because they occur at higher elevations than the forebeach, and receive less human disturbance, they provide ideal roost habitat for plovers. In washover passes, plovers often roosted along the front (Gulfward) margin of the pass in *Sargassum*-based coppice dune fields. Roosting in washover passes also occurred in areas where trash and other flotsam accumulated, and in tire tracks and other depressions. Unfortunately, these latter associations caused plovers to be more susceptible to disturbance as these areas were popular driving corridors for people seeking to access the bayshore areas for fishing, windsurfing, etc.

On bayshore flats, plovers often roosted in patches of dried algal mat and seagrass



A.



B.

Figure 24. Linear regressions illustrating the relationship between Piping Plover foraging flock size and total benthic prey density (A; $P = 0.0004$) and benthic polychaete density (B; $P = 0.0019$). Data are from lagoon ecosystem sites only.

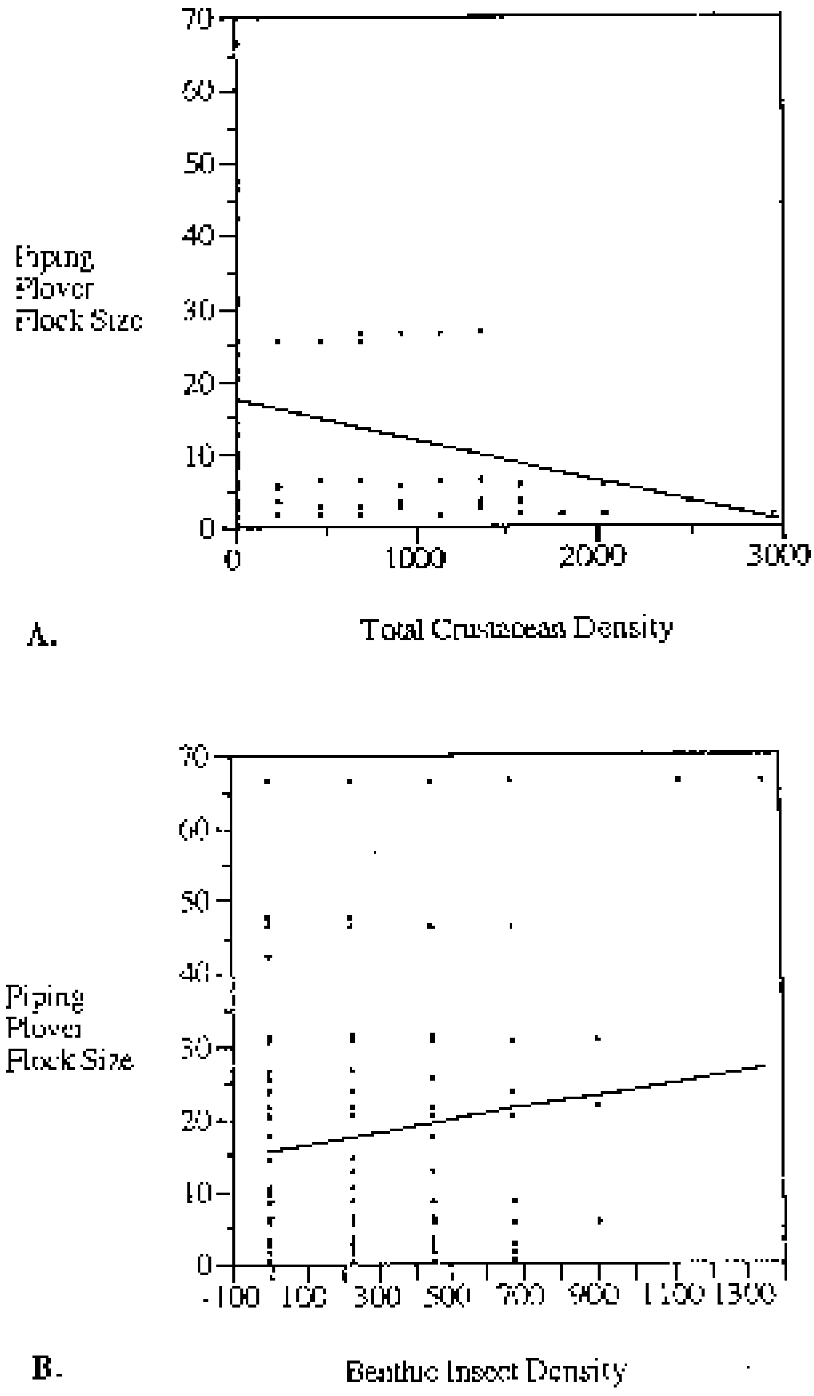


Figure 25. Linear regressions illustrating the relationship between Piping Plover foraging flock size and benthic crustacean density (A; $P = 0.0048$) and benthic insect density (B; $P = 0.2845$). Data are from lagoon ecosystem sites only

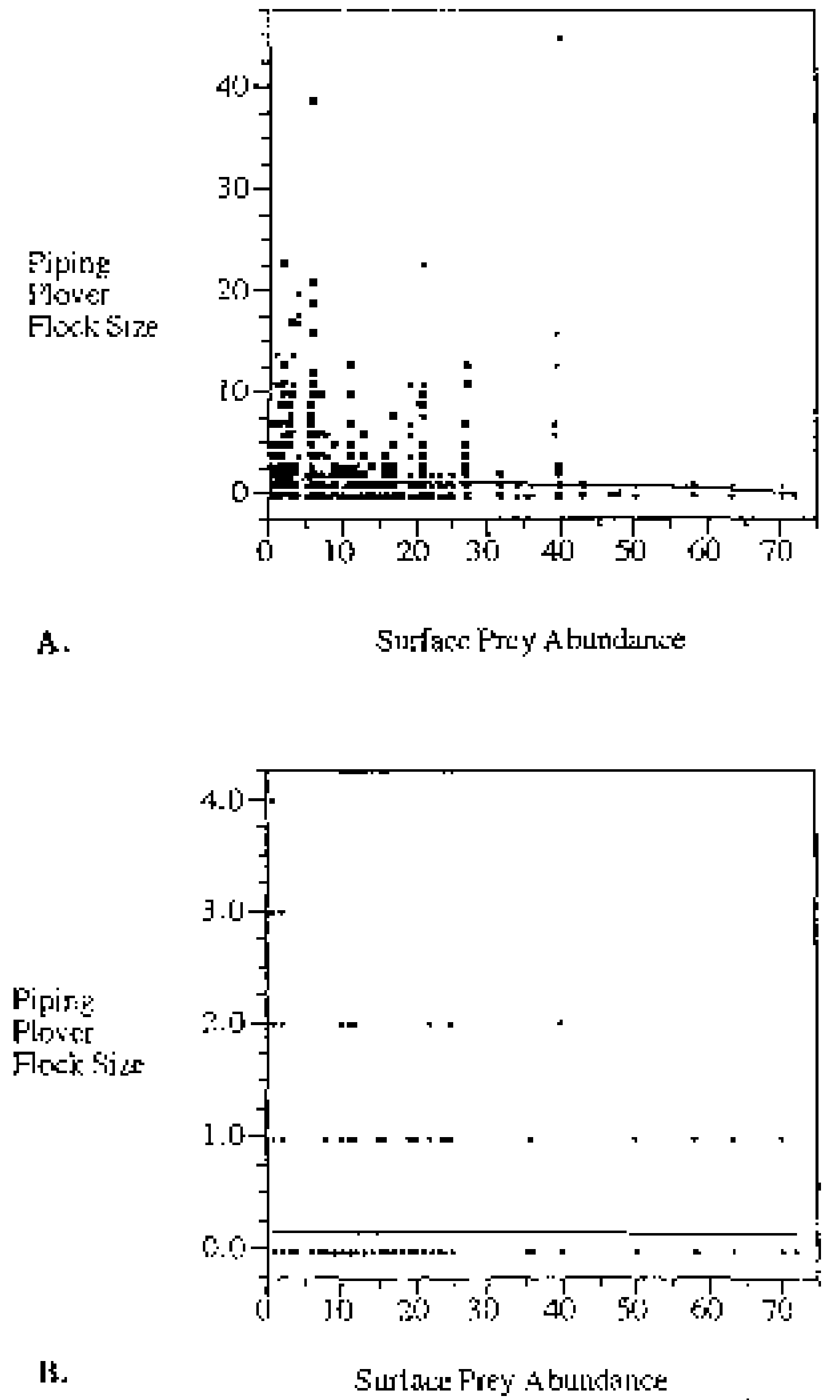


Figure 26. Linear regressions illustrating the relationship between Piping Plover foraging flock size and surface prey abundance at all sites (A; P = 0.0501) and at bay ecosystem sites (B; P = 0.4080).

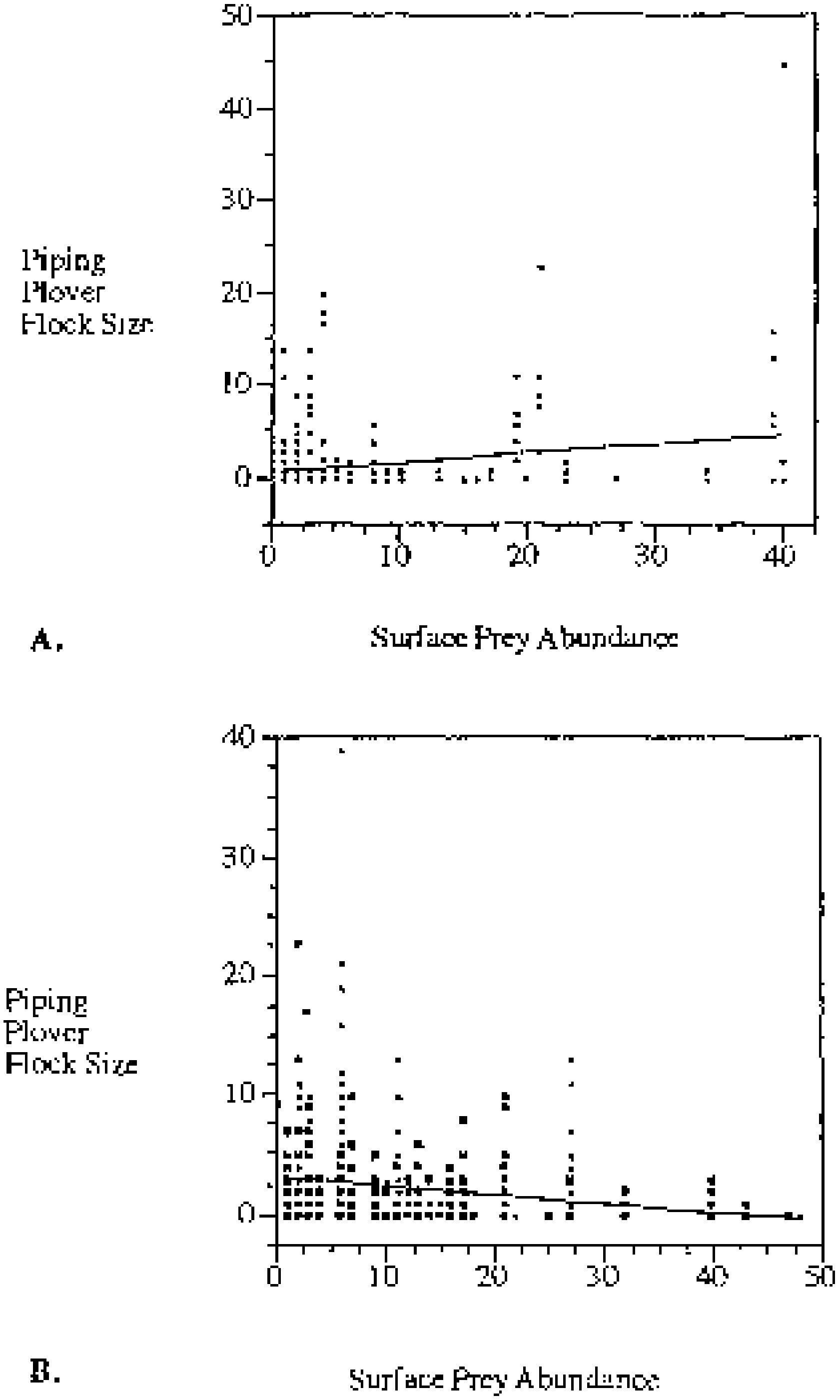


Figure 27. Linear regressions illustrating the relationship between Piping Plover foraging flock size and surface prey abundance at ecotone sites (A; $P = 0.1402$) and at lagoon ecosystem sites (B; $P < 0.0001$).

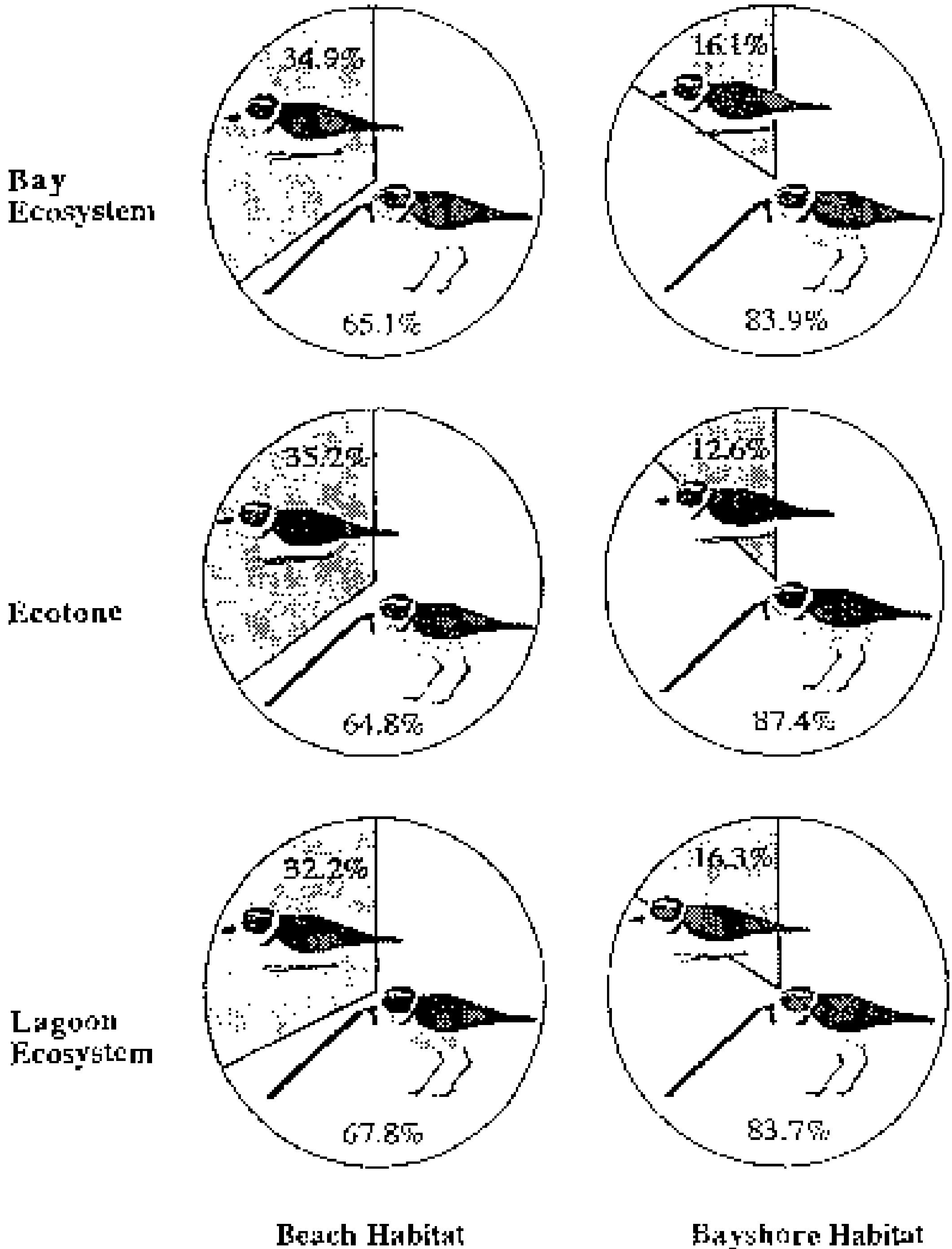


Figure 28. Mean Piping Plover activity for beach and bayshore habitat at the bay and lagoon ecosystem and the ecotone. Activity was assessed during daily, sites-wide shorebird counts. The area of each unshaded pie wedge is proportionate to the percentage of plovers that were foraging during the counts. Shaded pie wedges reflect the proportion of plovers that were roosting, preening or bathing during the counts.

wrack (primarily shoalgrass, *Halodule wrightii*). As higher areas of the algal mat became desiccated, the mat cracked and separated into pieces. As these pieces dried further, their corners curled upward creating small windbreaks behind which plovers often roosted. The colors of the Piping Plover nonbreeding plumage are ideally suited for all of these roosting environments. Despite great efforts, I often became aware of many roosting plovers only after one or more of the birds in the roosting flock moved into the open. Fortunately, in most cases, roosting plovers tolerated some disturbance, and often settled back into roosts if they were not unduly disturbed. The exception to this rule occurred in washover passes, where plovers were often more easily flushed. Plovers flushed from washover pass roost sites usually flew completely out of the pass to the bayshore.

Piping Plover Diet at Beach Habitat

Polychaetes were the dominant prey group captured by Piping Plovers at beach habitat. Nearly 70% of all identifiable prey captured by Piping Plovers at beach habitat were polychaetes (Table 19; Figure 29). At beach habitat, the polychaete group included all worm-like animals captured by plovers. I was able to identify most polychaete captures at beach habitat as *Scolelepis squamata* based on size and color characteristics.

Arthropods composed just under 30% of the known beach diet of Piping Plovers (Table 19; Figure 29). The arthropod prey group included amphipods, mole crabs and other crustaceans, as well as insects (larvae, pupae, and adults). The large majority of captures scored as arthropods at beach habitat appeared to be amphipods.

Plover diet at beach habitat in the 2 ecosystems and the ecotone was fairly similar (Figure 30). Polychaetes made up over half of the diet of plovers in all 3 regions. The higher proportion of polychaetes in the diet of plovers using lagoon ecosystem beaches may be an artifact of the small sample size (N = 9).

Piping Plover diet differed strongly at the 2 distinct beach microhabitats. Piping

Table 19. The relative proportions of polychaetes and arthropods in the diet of Piping Plovers at different locations and habitat types along the Texas Coast.

Parameter	Polychaetes			Arthropods		
	mean	N	SE	mean	N	SE
All sites and habitats	59.1	609	1.7	28.9	609	1.7
Bay Ecosystem - all habitats	77.7	308	1.9	7.6	308	1.3
Ecotone - all habitats	55.2	155	3.0	28.3	155	3.1
Lagoon Ecosystem - all habitats	23.9	146	3.3	74.7	146	3.4
Beach	68.7	123	2.9	18.9	123	2.8
Beach - swash zone	84.8	67	2.6	5.9	67	1.9
Beach - upper zone	38.1	32	5.9	39.3	32	7.4
Bayshore Flats	56.6	486	2.0	31.5	486	2.0
Sand Flats	75.0	340	2.0	13.1	340	1.7
Algal Flats	13.8	146	2.4	74.3	146	3.5

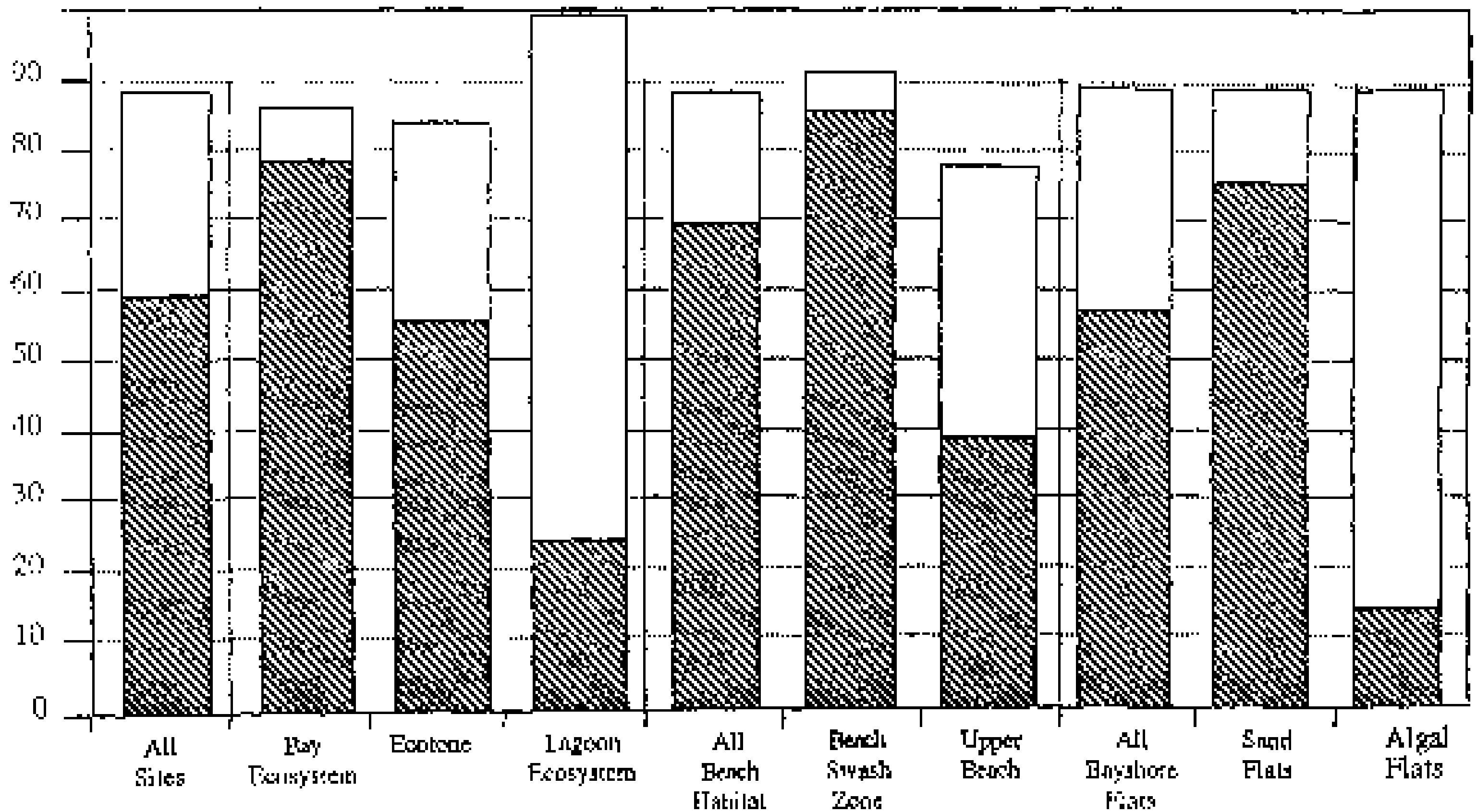


Figure 29. The proportion of polychaetes (▧) and arthropods (▭) in the diet of Piping Plovers along the Texas Coast. Bars illustrate the identifiable proportion of plover prey captures.

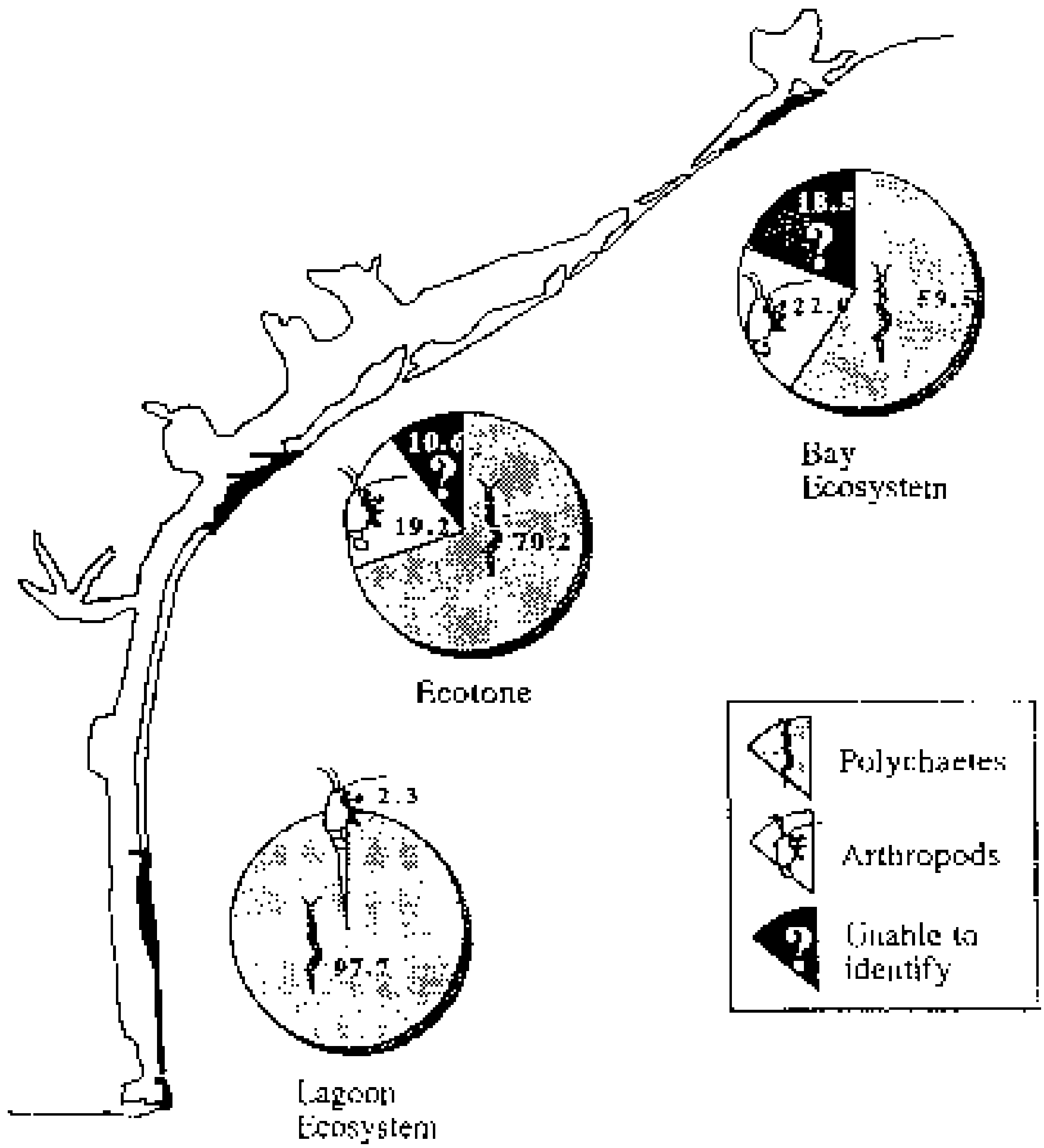


Figure 30. Piping Plover diet at beach habitat in the 2 ecosystems and the ecotone. Pie charts illustrate the proportion of polychaetes and arthropods captured by foraging plovers.

Plover captured mostly polychaetes in the lower beach swash zone ($P < 0.0001$; Table 19; Figure 29). Plovers foraging higher up on the beach captured a much greater proportion of arthropods ($P < 0.0001$). Above the swash, plovers captured a similar proportion of polychaetes and arthropods (Table 19; Figure 29).

Piping Plover Diet at Bayshore Habitat.

Piping Plovers captured more polychaetes than arthropods on bayshore flats. However, the ratio of these 2 prey types was not as pronounced as at beach habitat (Table 19; Figure 29). At bayshore habitat, the arthropod prey group was very broad including tanaids and all other types of crustaceans, spiders and insects (larvae, pupae, and adults). Strong dietary changes were observed when Piping Plovers moved among bayshore microhabitats. At sand flats, plovers fed mostly on polychaetes, capturing approximately 5 polychaetes for every arthropod (Table 19; Figure 29). At algal flats, the reverse was true, as plovers captured about 5 arthropods for every polychaete (Table 19; Figure 29).

Plover diet among the 2 ecosystems and the ecotone reflected the relative availability of sand flats and algal flats, the 2 dominant types of bayshore microhabitat used by Piping Plovers along the Texas Gulf Coast (Figure 31). In the bay ecosystem, where sand flats were much more common, polychaetes made up over 75% of the diet of Piping Plovers (Figure 31). In the lagoon ecosystem, where algal flats were much more common, arthropods comprised about 75% of the diet (Figure 31). At the ecotone sites, where a mosaic of sand flats and algal flats occurred, polychaetes and arthropods both comprised substantial portions of the Piping Plover diet (Figure 31).

Foraging Locomotion

Piping Plovers foraging at beach habitat spent > 12% of their time in prolonged foraging locomotion (PFL), compared to < 3% for plovers foraging on bayshore flats ($P = 0.0413$; Table 20). PFL bouts often occurred when plovers were engaged in territorial interactions with other Piping Plovers or when plover that were feeding in the beach

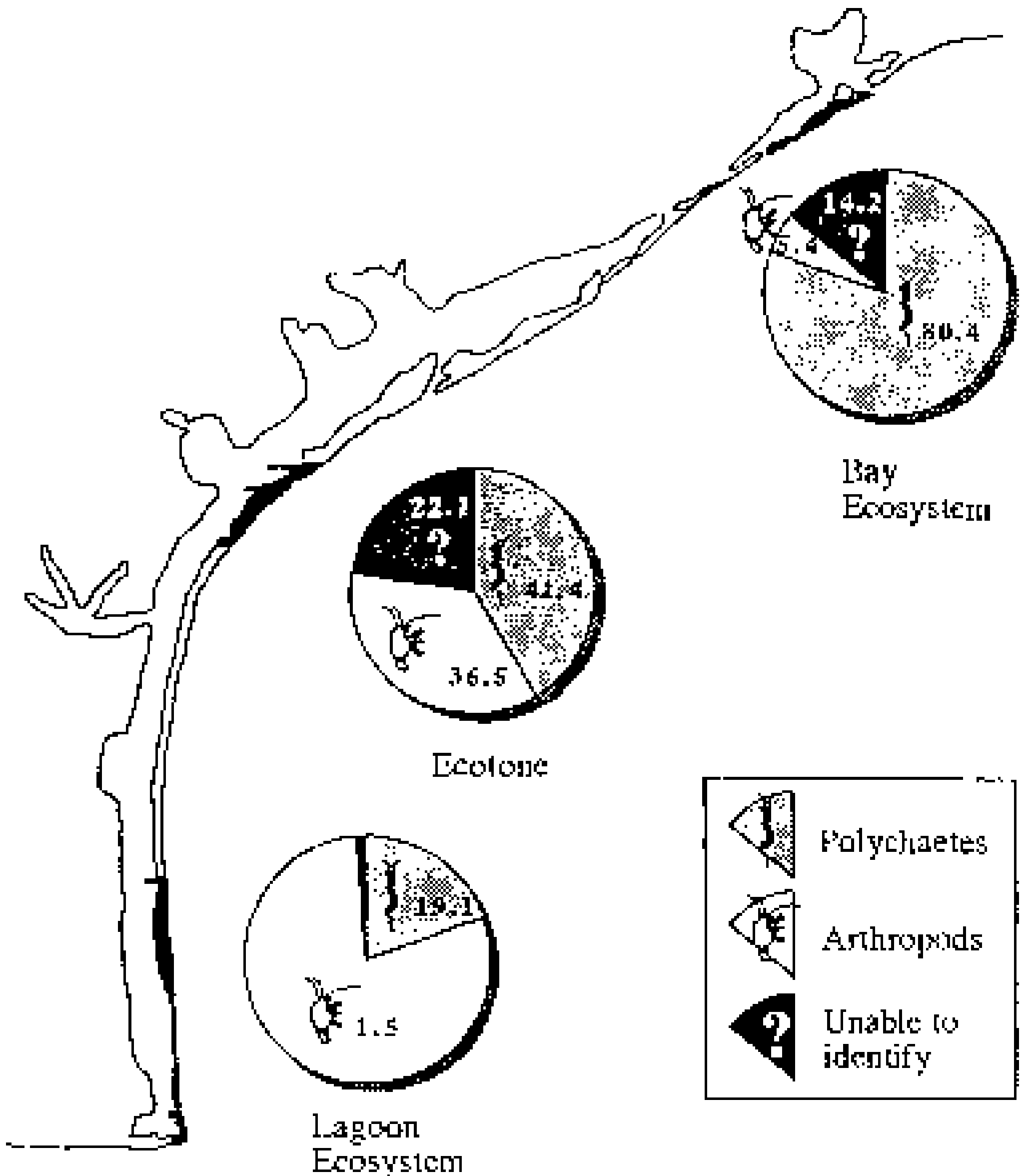


Figure 31. Piping Plover diet at bayshore habitat among the 2 ecosystems and the ecotone. Pie charts illustrate the proportion of polychaetes and arthropods captured by foraging plovers.

Table 20. Foraging efficiency (FE) and prolonged foraging locomotion (PFL) among different habitats and coastal regions of the Texas Gulf Coast, 1991 - 1994. All numbers represent means for all sites throughout the study. Foraging efficiency estimates are reported as the number of prey captured/minute, and foraging locomotion is reported as the % time plovers spent in PFL.

Parameter	FE				PFL			
	mean	N	SE	*P*	mean	N	SE	*P*
Beach	11.0	127	0.5		12.5	154	0.7	
Bayshore	10.1	504	0.2	0.3726	2.3	285	0.5	0.0413
Sand Flats	10.3	336	0.3		2.1	167	0.4	
Algal Flats	9.8	168	0.4	0.9114	2.6	118	0.4	0.0027
Beach Swash Zone	13.7	66	0.8		16.6	54	1.3	
Upper Beach Zone	7.0	38	1.1	< 0.0001	9.5	81	1.2	0.0002
All Beach:								
Bay Ecosystem	10.2	40	1.1		11.8	47	1.5	
Ecotone	10.9	78	0.8		13.5	90	1.1	
Lagoon Ecosystem	16.2	9	2.3	0.1285	9.2	17	2.6	0.1626
All Bayshore:								
Bay Ecosystem	10.8	272	0.3		1.9	141	0.4	
Ecotone	11.2	95	0.5		2.5	99	0.5	
Lagoon Ecosystem	8.0	137	0.4	0.2321	3.2	45	0.7	0.2454

swash zone were forced to retreat to the upper beach to avoid an incoming swell of water. I also observed PFL as a response to the approach of a beachcomber walking through a feeding territory. The effect of the swash on PFL is supported by the fact that plovers foraging in the swash zone spent nearly twice as much time in PFL as did plovers feeding on the upper beach ($P = 0.0002$; Table 20). However, movements to avoid the swash did not completely account for elevated PFL at beach habitat. Piping Plovers foraging on upper beach habitat (i.e., those plovers that were not forced to move to avoid the swash) still exhibited significantly greater PFL than did plovers foraging at bayshore tidal flats ($P < 0.0001$; Table 20). Territorial interactions ($P < 0.0001$) and human disturbance ($P = 0.0002$) also were important factors contributing to PFL. Plovers that exhibited at least 1 display of aggression toward another plover spent an average of 9.3% (N = 16, SE = 0.6) of their time in PFL compared to just 1.8 % (N = 269, SE = 0.2) for nonaggressive plovers. Plovers that experienced at least 1 encounter with a beachcomber or other type of pedestrian spent more time in PFL (mean = 11.8%, N = 16, SE = 1.3) than did plovers that did not encounter pedestrians (mean = 5.6%, N = 423, SE = 0.3).

Foraging locomotion did not differ significantly at beach habitat among the 2 ecosystems and the ecotone ($P = 0.1626$; Table 20). I detected no difference in foraging locomotion between the migratory and winter seasons at beach habitat ($P = 0.5584$; Table 20).

At bayshore habitats, plovers spent slightly more time in PFL on algal flats than on sand flats ($P = 0.0027$; Table 20). Territorial displays also affected foraging locomotion at bayshore habitat. Plovers that exhibited at least 1 display of aggression toward another plover during the record spent an average of 9.3% (N = 16, SE = 1.1) of their time in PFL compared to just 1.8% (N = 269, SE = 0.3) for nonaggressive plovers ($P < 0.0001$).

Plovers in both ecosystems and the ecotone spent similar amounts of time in PFL at bayshore habitat ($P = 0.2454$; Table 20). I detected no difference in foraging locomotion between the migratory and winter seasons at bayshore habitat ($P = 0.2672$)

Foraging Efficiency

Piping Plovers captured an average of about 10 animals/minute among all habitats at my study sites (Tables 21 and 22). Foraging efficiencies were similar at beach and bayshore habitats ($P = 0.3726$). Plovers also foraged with similar efficiency among the 2 ecosystems and the ecotone at beach habitat ($P = 0.1285$; Table 21). However, Piping Plovers foraged more efficiently within the swash zone of the beach habitat relative to the upper beach zone ($P < 0.0001$; Table 12).

Plovers foraged with similar efficiency among the 2 ecosystems and the ecotone at bayshore habitat ($P = 0.1626$; Table 22). Plovers captured prey at about the same rate on sand flats and algal flats ($P = 0.9114$; Table 18).

Piping Plovers were more efficient at capturing polychaetes than arthropods ($P < 0.0001$; Table 23). At beach habitat, plovers captured *Scolelepis squamata* and other polychaetes more efficiently than amphipods and other beach arthropods ($P = 0.0351$; Table 23). At bayshore habitat, plovers captured polychaetes more efficiently than insects and other types of arthropods ($P < 0.0001$; Table 23).

Foraging Ecology and Prey Density

Piping Plovers foraged more actively and efficiently in areas of high benthic prey density. At beach habitat, plover foraging effort increased from about 10 pecks/min in areas of low prey density (< 1000 animals/m^2) to about 20 pecks/min in areas of high prey density (> 5000 animals/m^2; $P = 0.0208$; Figure 32A). Foraging effort was positively related to polychaete density ($P = 0.0306$; Figure 32B) but was not related to crustacean density ($P = 0.1642$, Figure 33A) or insect density ($P = 0.5953$; Figure 33B). Plovers also captured more prey in areas of the beach with dense prey populations ($P = 0.0132$; Figure 34A).

Table 21. Mean foraging efficiency of Piping Plovers at beach habitat at sites along the Texas Gulf Coast, 1991 - 1994. Capture efficiency of all prey types, polychaetes, and arthropods are represented as the number of prey captured/minute. Abbreviations: MISP = Mustang Island State Park.

Study Location		All Prey			Polychaetes			Arthropods		
		mean	N	SE	mean	N	SE	mean	N	SE
Bolivar Flat		11.9	20	1.5	8.6	20	1.7	1.7	20	0.7
Big Reef		4.9	6	2.7	1.7	6	3.1	1.4	6	1.3
San Luis Pass		10.0	14	1.8	7.9	14	2.0	1.7	14	0.9
East Flats		5.2	2	4.8	4.0	2	5.4	0.0	2	2.3
MISP - North		10.5	28	1.3	7.8	24	1.5	1.9	24	0.7
MISP - South		11.8	20	1.5	9.7	20	1.7	1.0	20	0.7
Packery Channel		11.1	28	1.3	8.7	22	1.6	3.3	22	0.7
South Bay - East		14.9	2	4.8	13.9	2	5.4	1.0	2	2.3
South Padre Island		16.5	7	2.5	16.5	7	2.9	0.0	7	1.2

Table 22. Mean foraging efficiency of Piping Plovers at bayshore habitat at sites along the Texas Gulf Coast, 1991 - 1994. Capture efficiency of all prey types, polychaetes, and arthropods are represented as the number of prey captured/minute. Abbreviations: MISP = Mustang Island State Park.

Study Location	All Prey			Polychaetes			Arthropods		
	mean	N	SE	mean	N	SE	mean	N	SE
Bolivar Flat	11.9	143	0.4	9.9	142	0.5	0.7	142	0.3
Big Reef	8.7	42	0.8	6.5	41	1.0	1.2	41	0.5
San Luis Pass	10.0	127	0.5	8.5	121	0.6	0.1	121	0.3
East Flats	8.5	8	1.8	1.0	8	2.2	7.2	8	1.2
MISP - North	10.4	59	0.7	7.2	45	0.9	1.1	45	0.5
Packery Channel	11.6	86	0.6	5.7	67	0.8	3.3	67	0.4
South Bay - East	9.3	8	1.8	6.3	8	2.2	2.7	8	1.2
South Padre Island	9.9	64	0.7	3.3	64	0.8	6.6	64	0.4

Table 23. Comparison of foraging capture rate (number of prey captured/minute) among different prey groups. Data represented are from only those records in which each prey group represented at least 75% of the total captures. For example, arthropods comprised 75% or more of the prey captured at beach habitat for 16 foraging efficiency records, compared to 321 records at beach habitat in which polychaetes comprised 75% or more of the prey captured.

Parameter	Polychaetes			Arthropods			*P*-value
	mean	N	SE	mean	N	SE	
All Habitats	12.3	243	0.3	8.6	143	0.5	< 0.0001
Beach Habitat	11.7	321	0.3	8.8	16	1.5	0.0351
Bayshore Habitat	12.3	243	0.4	8.5	137	0.5	< 0.0001

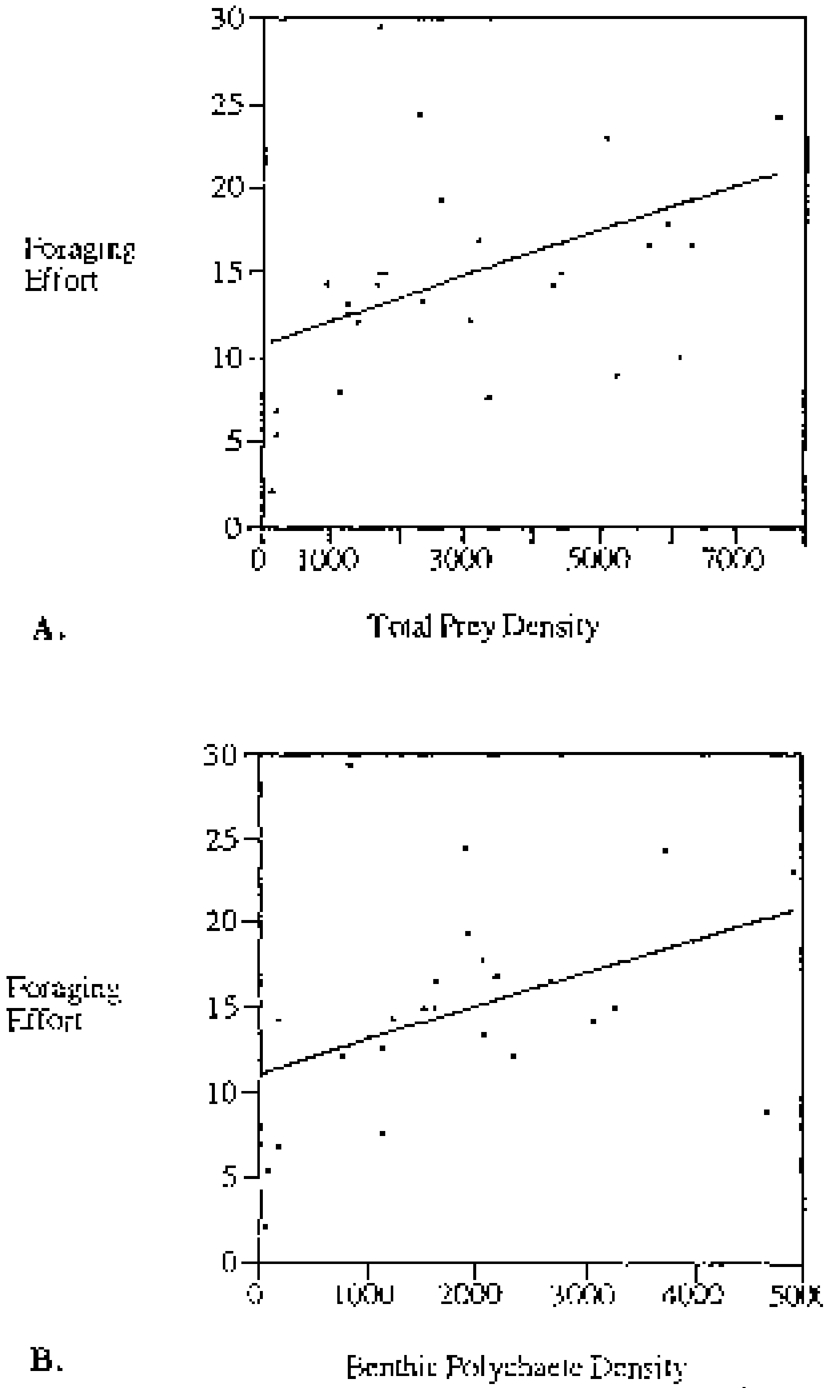


Figure 32. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A; $P = 0.0208$) and benthic polychaete density (B; $P = 0.0306$) at beach habitat. Data are from all sites.

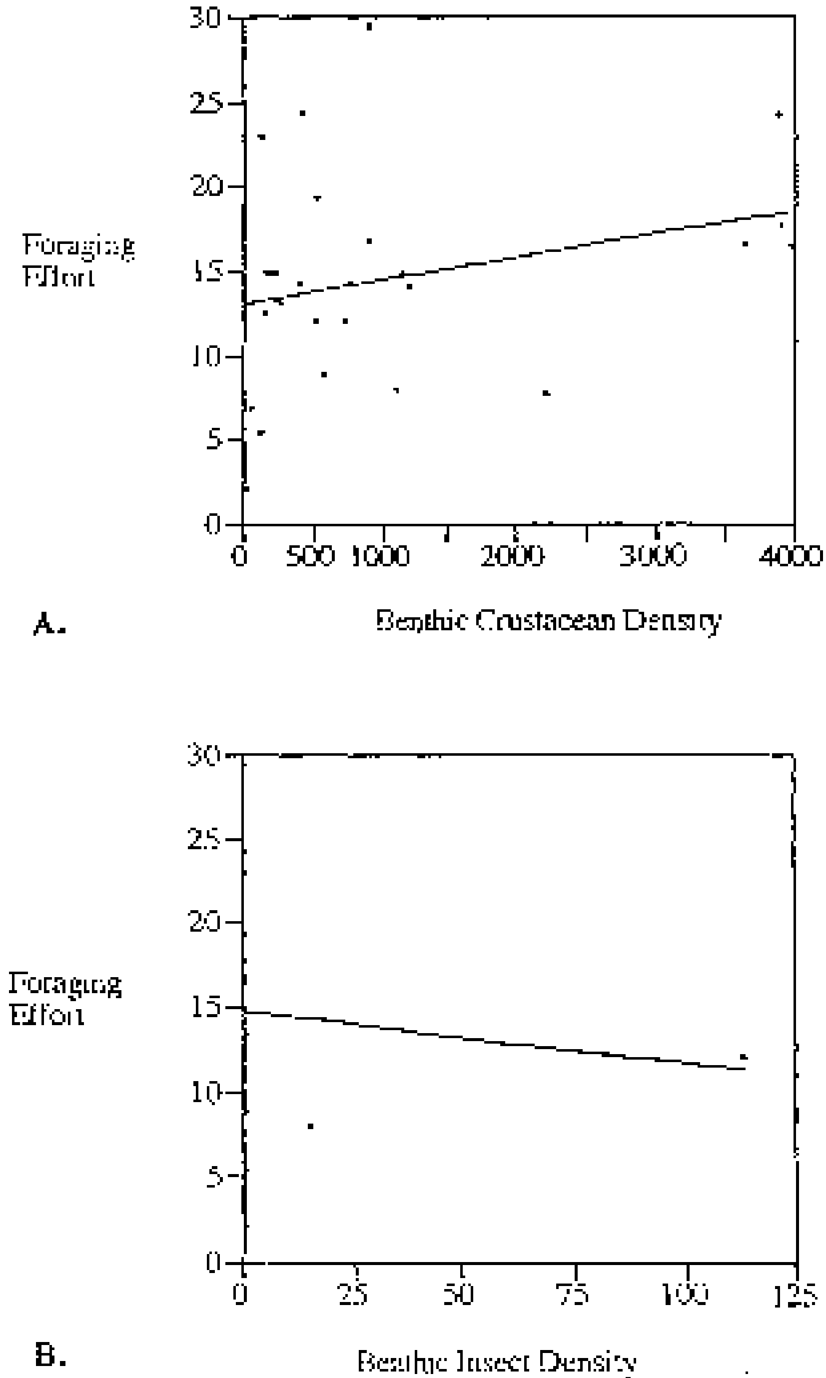


Figure 33. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to benthic crustacean density (A; P = 0.1642) and benthic insect density (B; P= 0.5953) at beach habitat. Data are from all sites.

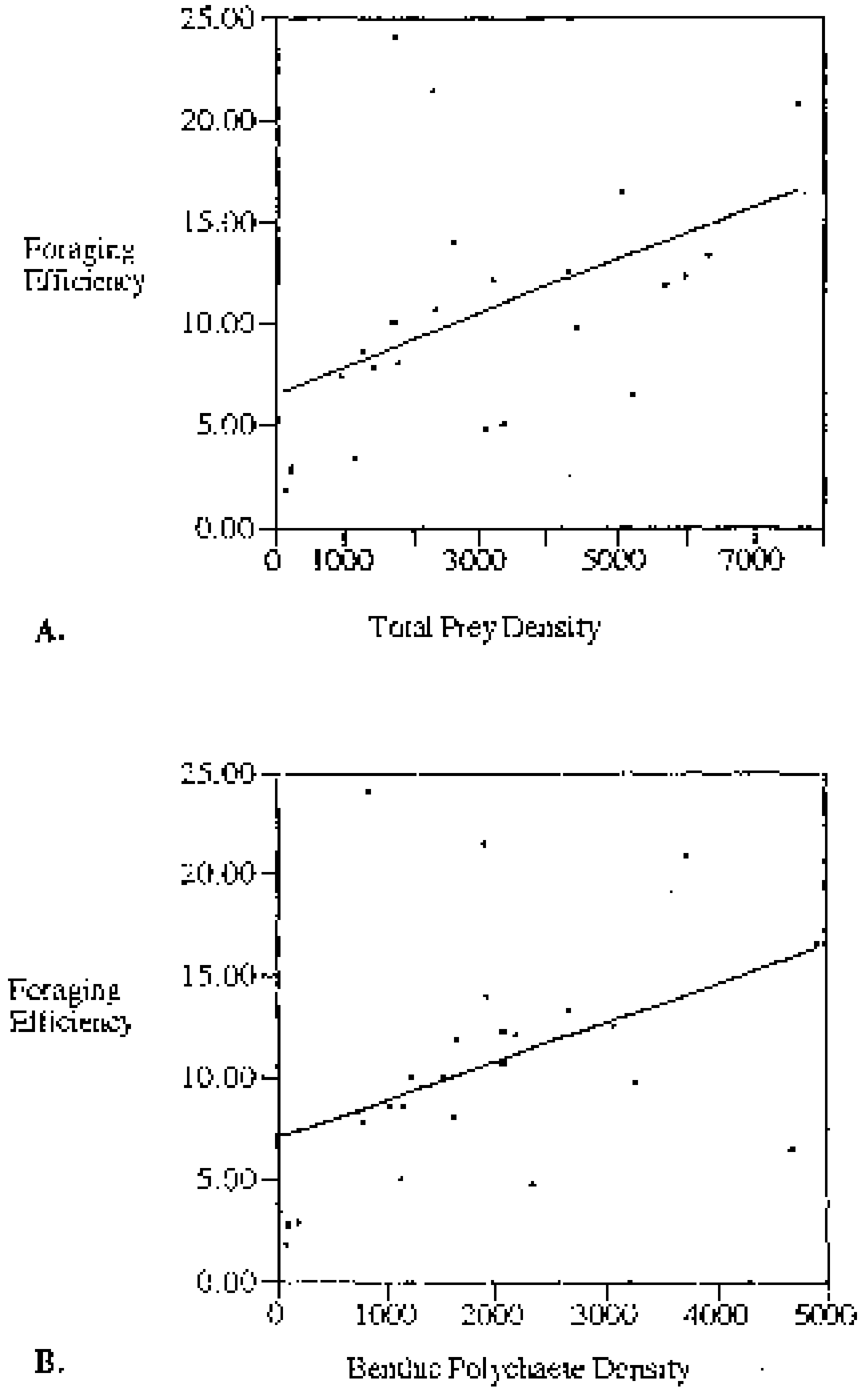


Figure 34. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A; $P = 0.0132$) and benthic polychaete density (B; $P = 0.0245$) at beach habitat. Data are from all sites.

Foraging efficiency was positively related to polychaete density ($P = 0.0245$; Figure 34B), but was not related to crustacean density ($P = 0.1206$; Figure 35A) or benthic insect density ($P = 0.5636$; Figure 35B).

At bayshore habitat, foraging effort also was positively related to total benthic prey density ($P < 0.0001$; Figure 36A) and polychaete density ($P < 0.0001$; Figure 36B), but was unrelated to benthic crustacean density ($P = 0.5222$; Figure 37A) or benthic insect density ($P = 0.2858$; Figure 37B). Plovers captured more prey on tidal flats with high total prey density ($P = 0.0094$; Figure 38A) and polychaete density ($P = 0.0109$; Figure 38B). Foraging efficiency on tidal flats was not affected by crustacean density ($P = 0.8491$; Figure 39A), or benthic insect density ($P = 0.9731$; Figure 39B).

Interestingly, plovers foraged less actively ($P = 0.0096$; Figure 40) and less efficiently ($P = 0.0183$; Figure 41) in areas of the tidal flat with high surface prey abundance. However, polynomial fits explained the greatest amount of variability among the data (e.g., quartic fit, $P = 0.0784$, $R^2 = 0.113$; Figure 41B) and suggest the existence of a threshold abundance of surface prey, above which plovers may have foraged less efficiently.

Intraspecific and Interspecific Interactions

Piping Plovers were more likely to occur in close proximity to another Piping Plover at bayshore habitat than at beach habitat ($P < 0.0001$; Figure 42). At beaches, the nearest species to Piping Plovers were Sanderlings (*Calidris alba*). Western Sandpipers (*C. mauri*) and other Piping Plovers were the most common nearest neighbors at sand flats, and *C. mauri*, Least Sandpipers (*C. minutilla*) and other Piping Plovers were the most common nearest neighbors at algal flats

The large majority of aggressive interactions I observed during the study were intraspecific. The majority of interspecific aggressions involving Piping Plovers were with another *Charadrius* spp., usually Snowy Plovers (*Charadrius alexandrinus*) or

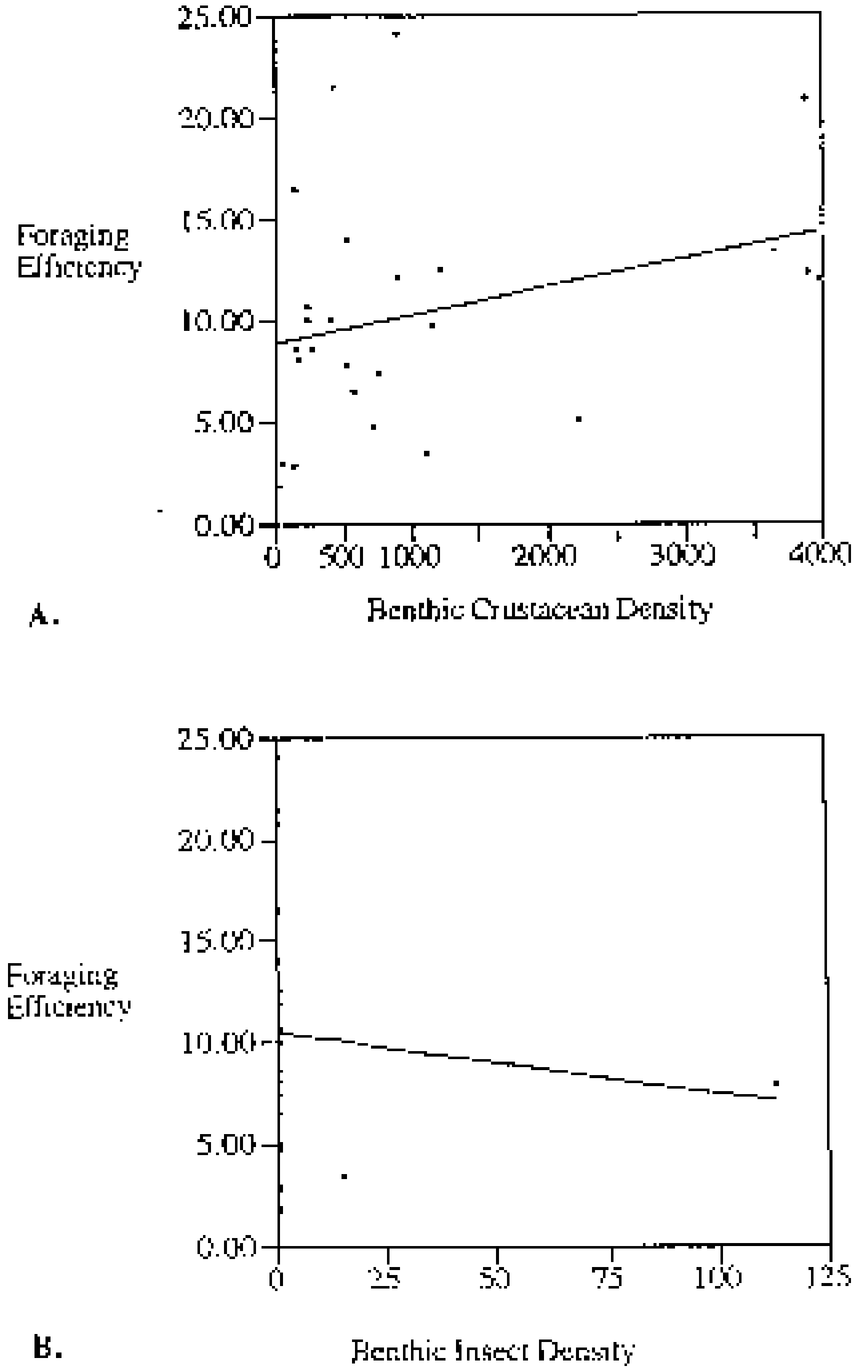
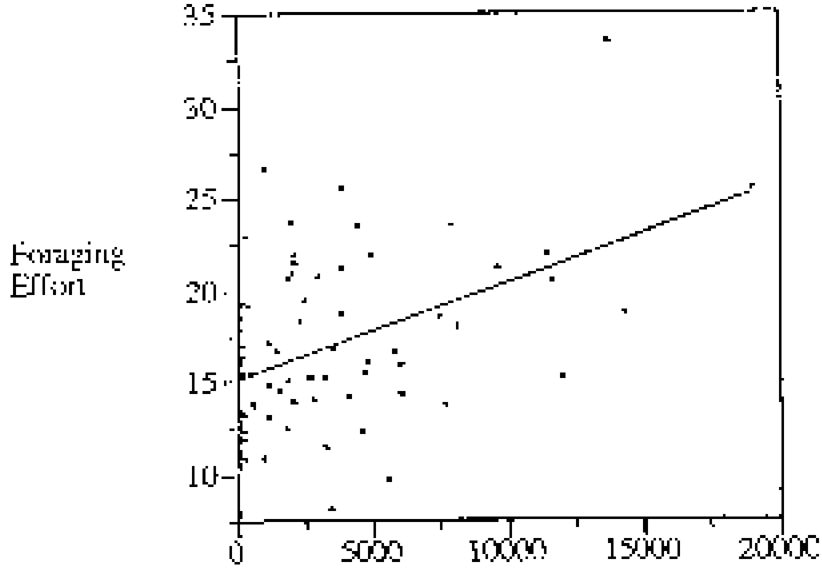
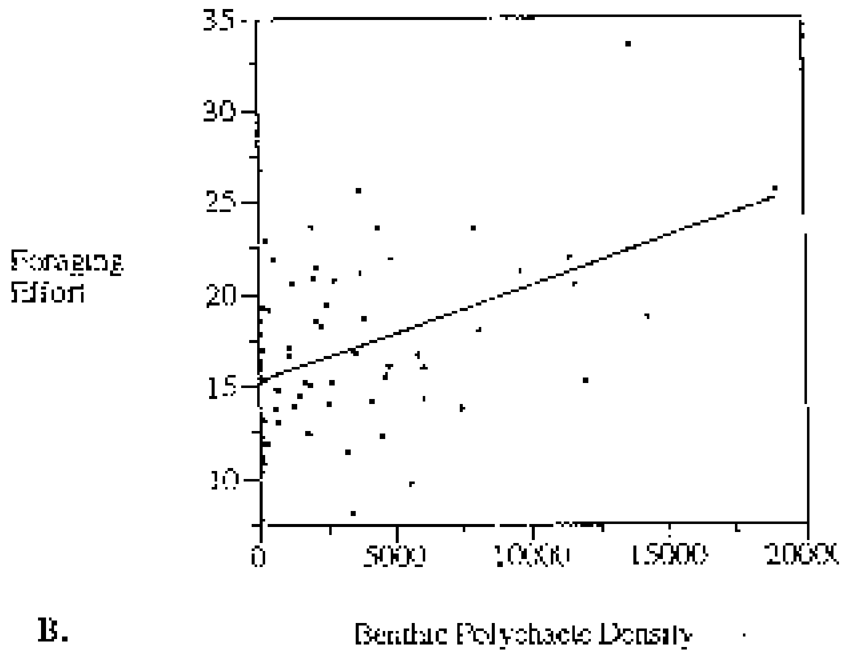


Figure 35. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to benthic crustacean density (A: $P = 0.1206$) and benthic insect density (B; $P = 0.5636$) at beach habitat. Data are from all sites.

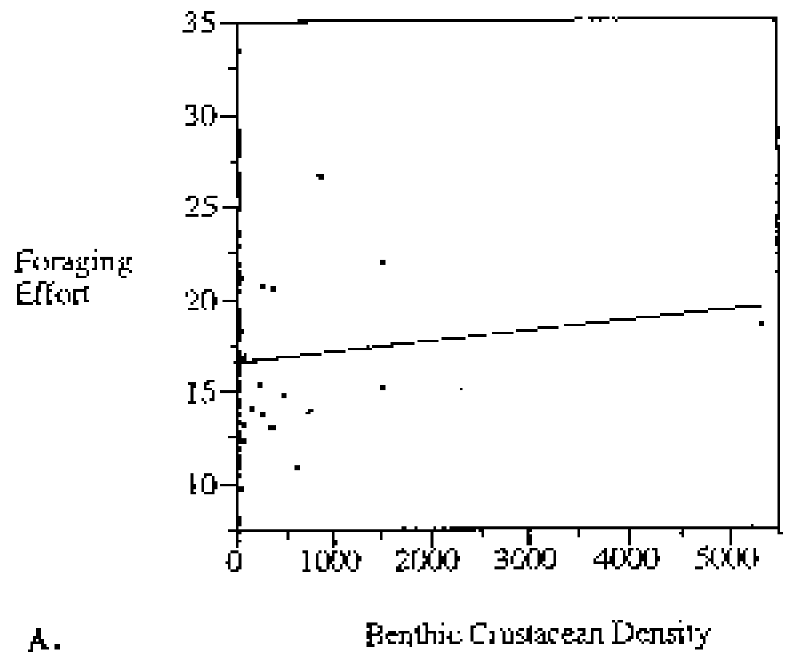


A.

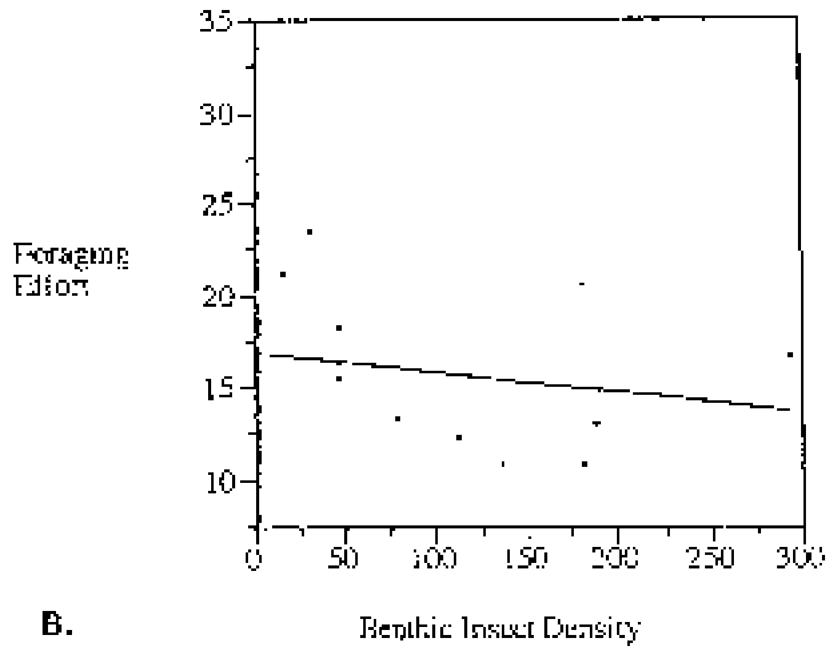


B.

Figure 36. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to total benthic density (A: $P < 0.0001$) and benthic polychaete density (B: $P < 0.0001$) at bayshore habitat. Data are from all sites.



A.



B.

Figure 37. Linear regressions illustrating Piping Plover foraging effort (number of pecks/minute) in relation to benthic crustacean density (A; P = 0.5222) and benthic insect density (B; P = 0.2858) at bayshore habitat. Data are from all sites.

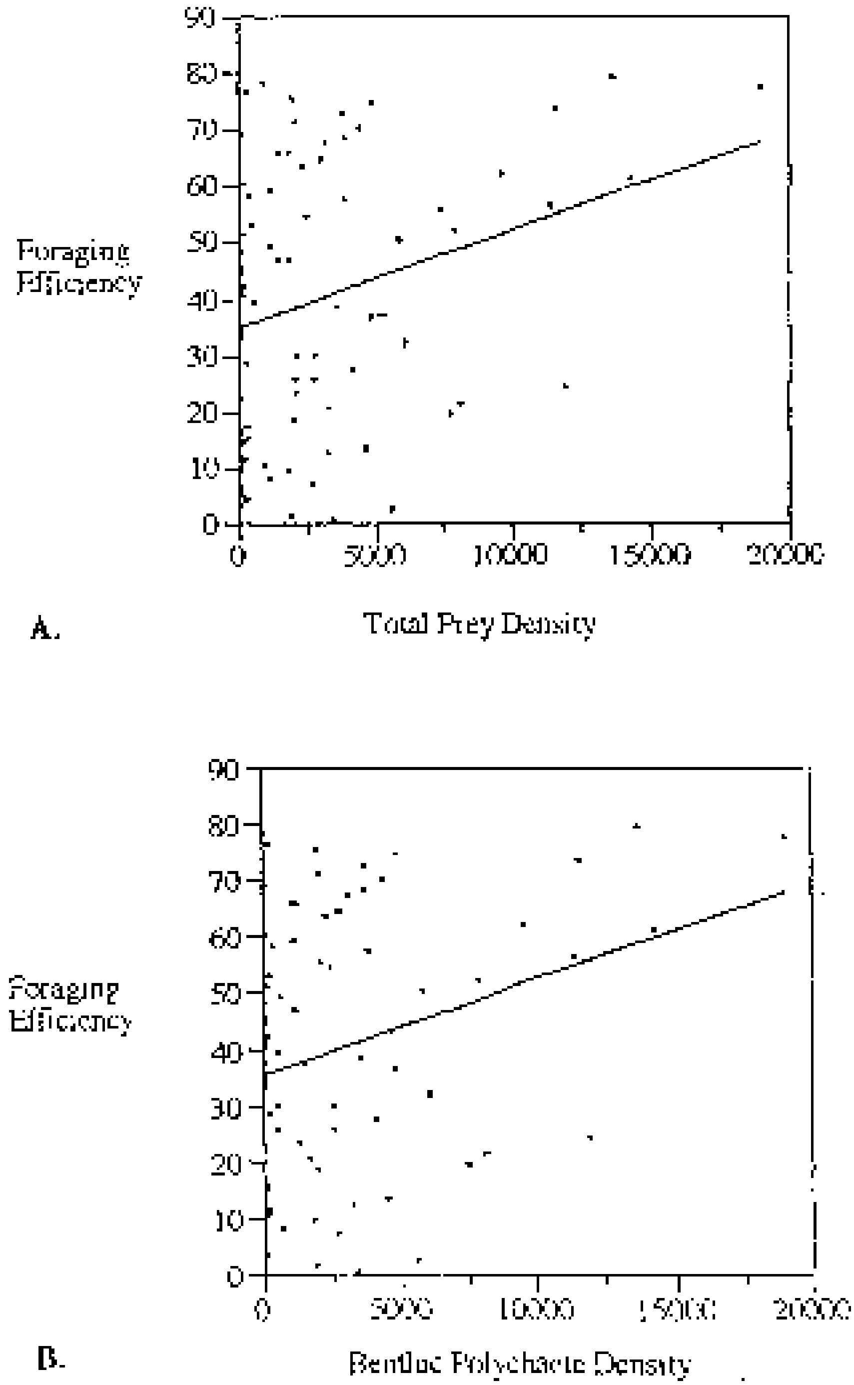


Figure 38. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to total benthic density (A: P = 0.0094) and benthic polychaete density (B, P= 0.0109) at bayshore habitat. Data are from all sites.

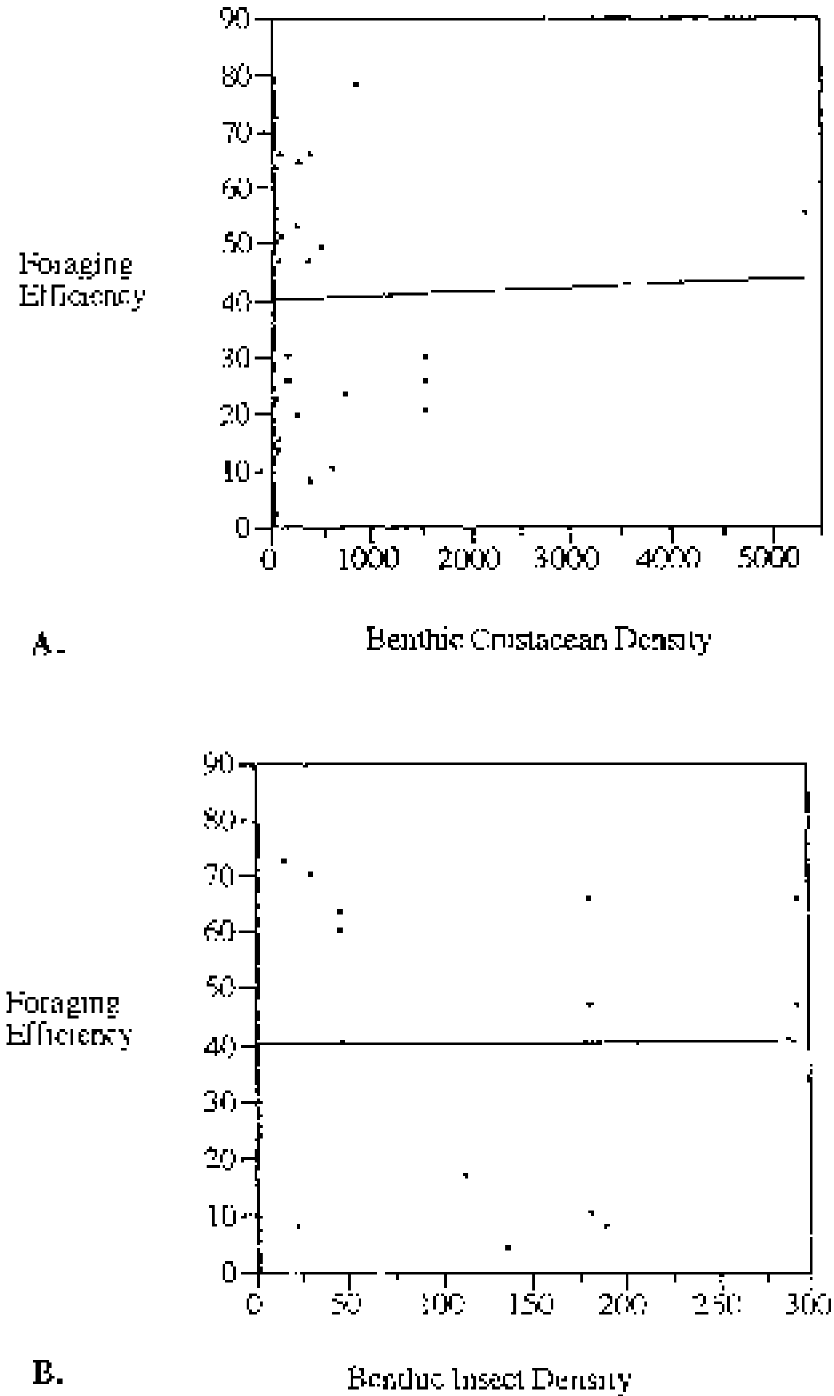


Figure 39. Linear regressions illustrating Piping Plover foraging efficiency (number of captures/minute) in relation to benthic crustacean density (A; r^2 = 0.8491) and benthic insect density (B; r^2 = 0.9731) at bayshore habitat. Data are from all sites.

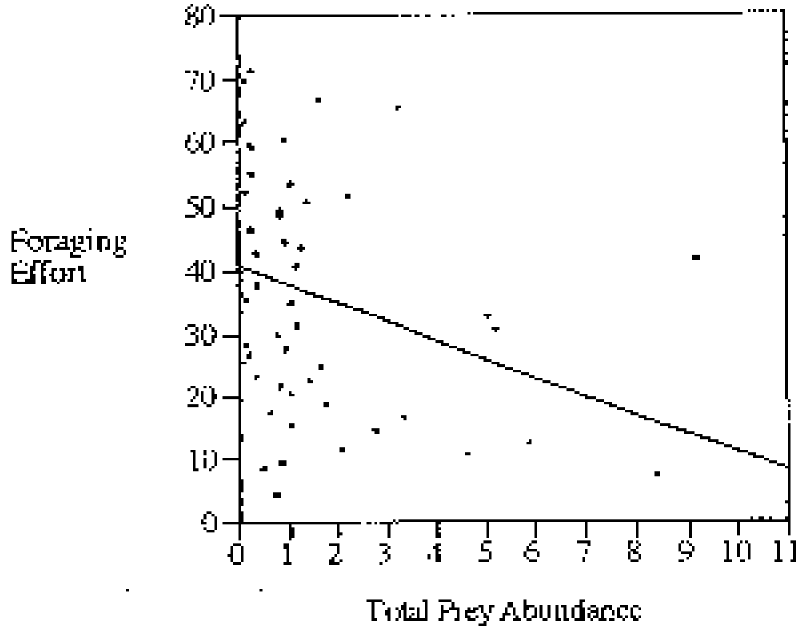


Figure 40. Linear regressions illustrating the relationship between Piping Plover foraging effort (number of pecks/minute) and total surface prey abundance at bayshore habitat (P . 0.0096). Data are from all sites as appraised by sticky trap prey assays.

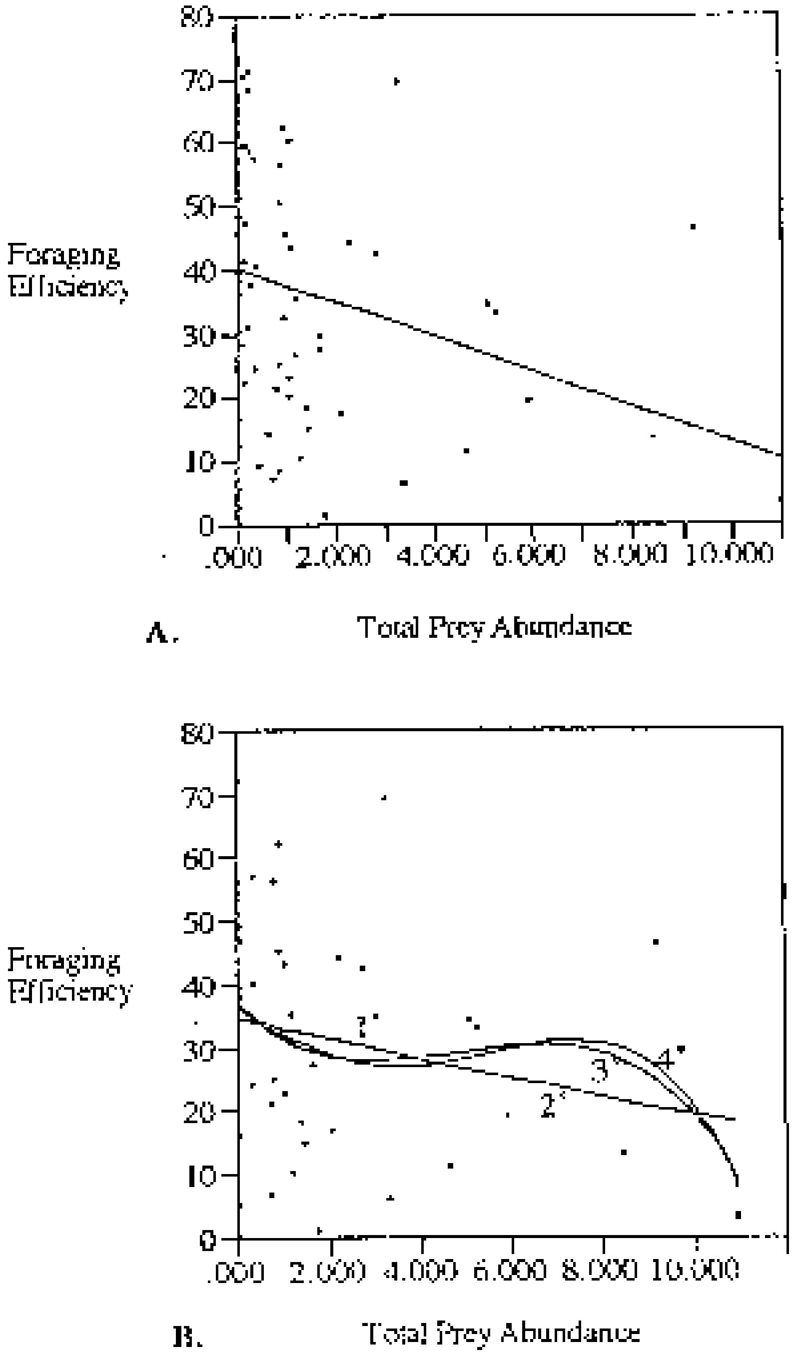


Figure 41. Linear regressions illustrating the relationship between Piping Plover foraging efficiency (number of captures/minute) and total surface prey abundance at bayshore habitat at all sites as appraised by sticky trap prey assays. Figure A illustrates a linear regression line ($P = 0.0303$, $r^2 = 0.064$), and (B) the linear fit in relation to various polynomial fits. The quartic fit (4°; $P = 0.0784$, $r^2 = 0.113$) and cubic fit (3°; $P = 0.0436$, $r^2 = 0.109$) explain a greater amount of variation in the data relative to the linear fit or quartic fit ($P = 0.0589$, $r^2 = 0.077$).

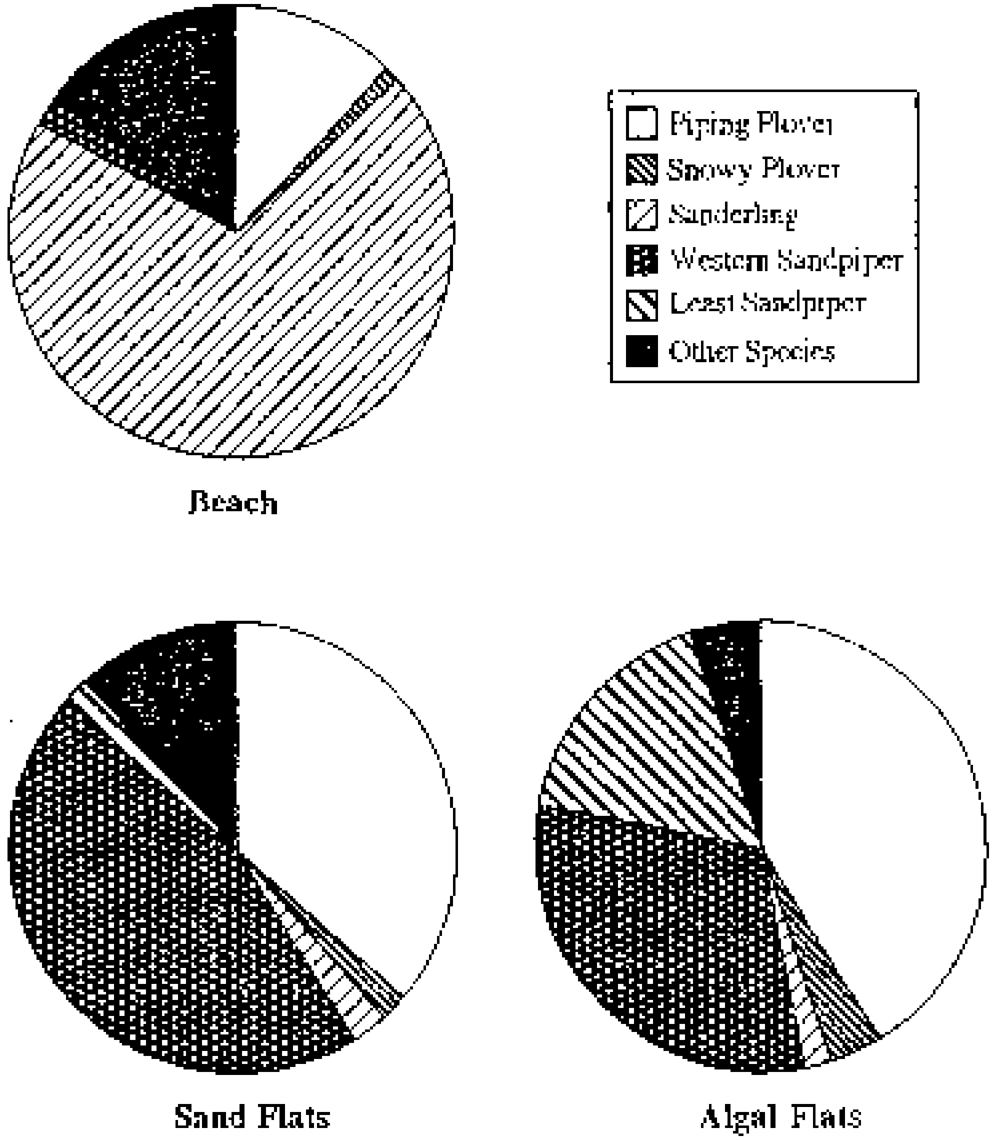


Figure 42. Species that were closest to Piping Plovers foraging at beach, sand flat, and algal flat habitat. Pie sections correspond to the 4 shorebird species most commonly associated with foraging Piping Plovers. The area of the pie wedge is proportional to the frequency with which each species occurred as the nearest neighbor to a Piping Plover as it was observed during a foraging efficiency record

Semipalmated Plovers (*C. semipalmatus*). Interspecific interactions were generally restricted to bayshore habitat, as *C. alexandrinus* and *C. semipalmatus* only rarely utilized beaches as foraging habitat at my study sites (pers. obs.). Interactions between Piping Plovers and Sanderlings (the other common shorebird utilizing beach intertidal habitat) occurred, but were rare (pers. obs.).

Foraging Piping Plovers were observed to exhibit some form of aggression about once every 8 minutes (mean = 0.119 acts of aggression/min., SE = 0.019, N = 533 records [1926.8 minutes of observation]) as appraised via FE records, and about once every 15 minutes (mean = 0.068 acts of aggression/min., SE = 0.014, N = 441 records [882 minutes of observation]) as appraised via PFL records.

Using FE data, I found Plovers to be no more aggressive at beach habitat (mean = 0.066 acts of aggression/min, SE = 0.044, N = 102) than at bayshore habitat (mean = 0.131 acts of aggression/min, SE = 0.021, N = 431; $P = 0.3065$). However plovers were significantly more aggressive during the migratory period than during the winter period ($P = 0.0018$; Table 24) at beach habitat. Season did not affect plover behavior at bayshore habitat (Table 24).

Using PFL data, I found Plovers to be no more aggressive at beach habitat (mean = 0.075 acts of aggression/min, SE = 0.025, N = 154) than at bayshore habitat (mean = 0.0645 acts of aggression/min, SE = 0.018, N = 287; $P = 0.1162$). Plovers were no more aggressive during the migratory period than during the winter period at beach or bayshore habitat based upon the PFL data (Table 24).

DISCUSSION

Prey Dynamics

Piping Plovers wintering in the bay and lagoon ecosystems of the TGC encountered very different bayshore prey communities. In the bay ecosystem plovers fed at tidal flats

Table 24. Seasonal variation in the frequency of aggressive displays by Piping Plovers along the Texas Gulf Coast, 1991 - 1994. The mean number of aggressive displays/minute as recorded during foraging efficiency (FE) and foraging locomotion (PFL) records is reported by season among different habitat types. The *P*-values presented in the last column are associated with one-way ANOVA analyses comparing plover aggression between the 2 seasons. N = the number of FE or PFL records supporting the estimates.

	Migration			Winter			*P*-value
	mean	N	SE	mean	N	SE	
FE Data							
Beach	0.124	54	0.030	0.000	48	0.032	0.0018
Bayshore	0.121	231	0.032	0.144	200	0.034	0.6281
Sand Flats	0.141	187	0.040	0.225	125	0.049	0.5958
Algal Flats	0.033	44	0.016	0.008	75	0.012	0.5607
PFL Data							
Beach	0.077	84	0.031	0.071	70	0.034	0.6413
Bayshore	0.034	119	0.030	0.086	168	0.025	0.3727
Sand Flats	0.024	83	0.042	0.157	86	0.041	0.1424
Algal Flats	0.056	36	0.032	0.012	82	0.021	0.8977

that supported an extremely rich benthic food base dominated by polychaetes but containing only a sparse population of insects and other types of surface prey. Conversely, plovers wintering in the lagoon ecosystem fed at tidal flats that were benthos-poor, but rich in surface prey relative to the bay ecosystem. Prey populations in the ecotone were mixed, offering both benthic and surface prey to plovers.

Withers (1994) also reported abundant populations of polychaetes, crustaceans, and insects (adults and larvae) between 1991 - 1993 at Corpus Christi Pass (a small tidal flat situated in the ecotone between my Packery Channel and Mustang Island State Park - South sites). Withers recorded between 225 polychaetes/m^2 and 1335 polychaetes/m^2 in 3 microhabitat types. In samples collected in association with foraging Piping Plovers I recovered an average of 339 polychaetes/m^2 at the Mustang Island State Park - North site and 557 polychaetes/m^2 at Packery Channel site. Although surface prey populations were not sampled, Withers found between 455 insects/m^2 and 729 insects/m^2 in benthic samples. Benthic insect density was much lower among samples collected in association with foraging Piping Plover flocks, ranging from 3 insects/m^2 at the Packery Channel site to 41 insects/m^2 at Mustang Island State Park - North site.

Diet

In general, I found the diet of Piping Plovers to reflect the relative availability of the major prey groups. Plovers in the bay ecosystem fed primarily on polychaetes, whereas plovers in the lagoon ecosystem relied more heavily on surface prey. Plovers wintering in the ecotone, where a mix of habitats and prey communities occurs, exhibited a mixed diet, incorporating more surface prey than the diet of plovers wintering in the bay ecosystem and more polychaetes than the diet of plovers wintering in the lagoon ecosystem.

On beaches, plovers fed primarily on the polychaete *Scolelepis squamata* and on small amphipods. These organisms, along with small clams (*Donax* spp.; not regularly eaten by plovers), dominated the beach invertebrate community at all of my sites. Polychaete densities were highest in the bay ecosystem, lowest in the lagoon ecosystem, and intermediate in the ecotone. Crustacean densities were also lower in the lagoon ecosystem than the bay ecosystem and the ecotone.

At McFaddin Beach (a site located in the bay ecosystem ~ 50 km north of Bolivar Flats) and Malaquite Beach (a site located in the ecotone ~ 10 km south of Packery Channel) Shelton and Robertson (1981) found *S. squamata* and haustoriid amphipods to be the most abundant fauna in random samples of the mid and upper intertidal zones These are the 2 zones I found plovers to use most frequently. They found *S. squamata* to be more abundant at their bay ecosystem site (McFaddin Beach), and amphipods to be more abundant at their ecotone site (Malachite Beach). They reported an average of 591 *S. squamata*/m^2 and 436 amphipods/m^2 at their bay ecosystem beach and ~ 313 *S. squamata*/m^2 and 2598 amphipods/m^2 at their ecotone beach (based upon 6 visits to eac7h site). These findings compare reasonably well with the data I gathered from samples collected in association with foraging plovers at beach habitat. The higher relative density of polychaetes in my samples at bay ecosystem and ecotone beach compared to the random samples collected by Shelton and Robertson (1981) may indicate a selection by plovers for areas where *S. squamata* were most abundant.

I rarely observed plovers feeding on any prey other than amphipods and polychaetes at beach habitat. Therefore, despite their abundance, bivalves appeared to comprise a very small part of the Piping Plover diet. The bivalve fragments Nicholls (1989) recovered from plover fecal pellets may have been incidentally ingested by plovers along with sand as they were capturing other prey. Shelton and Robertson (1981) found *Donax* sp. to be the most abundant prey at both of their sites, but found them to be concentrated at lower tidal zones, which are often not available to Piping Plovers.

Foraging Efficiency

Interestingly, plovers foraged with similar efficiency at both major habitats, and in both ecosystems and the ecotone. Piping Plovers captured about 10 animals/min. whether feeding at beach habitat or bayshore habitat, or whether feeding in the polychaete-rich bay ecosystem flats, the insect-rich lagoon ecosystem flats or the mixed community ecotone flat.

The only detectable shift in foraging efficiency occurred at beach habitat when plovers moved from the upper beach microhabitat into the lower swash zone. After such a move, the primary diet of plovers shifted from amphipods to polychaetes, and foraging efficiency nearly doubled from about 7 animals/min. to 14 animals/min. My prey samples suggest that *S. squamata* were present at equal densities in both microhabitats. By closely watching *S. squamata* feed, however, it seems likely that this polychaete is much more readily available to plovers in the swash zone. *S. squamata* appeared to actively forage at the surface only when they were covered with water. As the swash zone became covered, *S. squamata* extended palps into the thin film of water in the receding swash in order to trap food particles. Presumably, *S. squamata* became visually detectable to plovers under these conditions, for it was during the period when the swash was receding that plovers ran into the swash zone and switched from amphipods to *S. squamata*. Once in the swash zone, plovers collected as many *S. squamata* as they could before an incoming swell forced them to again move up into the upper beach zone and shift back to an amphipod diet.

Prolonged Foraging Locomotion

The repeated movement between the swash zone and the upper beach illustrates another distinguishing feature in Piping Plover behavior at beach habitat and bayshore habitat along the Texas coast. Plovers appeared to expend much greater energy on beach habitat than at bayshore habitat. Plovers spent about 12% of their time in prolonged foraging locomotion (PFL) at beaches compared to less than 3% at bayshore habitats. Much of the PFL appeared to be explained by movements in and out of the swash, territorial defense (which was much higher on beach habitat), and running to avoid people using the beach.

These results complement and perhaps partially explain my findings in Chapter II suggesting Piping Plovers preferred bayshore habitat over beach habitat in Texas. One hypothesis for this preference is that plovers suffered a lower net energy intake at beaches. The lower net energy intake may be due, not to a lower direct energy intake since plovers captured about the same number of prey in both habitats, but to an increased energy investment required to capture the same number of prey at both habitats.

Connors et al. (1981) demonstrated a directed response by Sanderlings to tides and prey availability along the California coast. They found Sanderlings to forage on beach habitat at high and mid-level tides but switch to protected bayshore sand flats as the tides receded. They related these movements to the availability of prey at different tide levels and found a strong correlation between prey availability and Sanderling density at both beach and bayshore habitats, suggesting birds were visiting each habitat type when it was most productive.

Because the beach and bayshore sites monitored by Connors et al. (1981) were closely situated and the tides synchronous, they were unable to evaluate whether Sanderlings shifted to beach habitat because bayshore flats were inundated, or because beach sites became more productive. In this way their study area was similar to my bay ecosystem sites and my 2 northern ecotone sites (East Flats and Mustang Island State Park), where bayshore tides and beach tides were synchronous. At these sites, Piping Plovers behaved like the Sanderlings in California, using beaches during high tides and bayshore flats at low tides. However, one of my ecotone sites (Packery Channel) experienced asynchronous beach and bayshore tides. At Packery Channel, Piping diet in the lagoon ecosystem.

A negative correlation between flock size and prey abundance might have occurred if plovers foraging in large flocks were able to rapidly deplete local surface prey populations. Therefore, an alternative hypothesis is that plovers were attracted by locally abundant surface prey populations, but harvested these populations to such an extent that my prolonged sampling technique (1 hour sticky traps) measured the depleted population rather than the initial population abundance that attracted the plover flock.

Another important feature to consider when comparing benthic and surface prey communities is prey mobility and the way it affects a plover's ability to detect and capture prey. Most of the benthic prey eaten by plovers (polychaetes and crustaceans) were sessile or sedentary. The detectability of these prey to Piping Plovers may have been governed simply by whether these organisms were present at the surface (when feeding or defecating) or were not (when burrowing or residing in a tube, etc.) Surface prey were probably more detectable to Piping Plovers than most benthic prey, but may have been more difficult to catch due to their mobility. The mobility feature of surface prey also may have reversed the effect of prey density on Piping Plover foraging efficiency. Perhaps, at some point, too many mobile surface prey caused a reduction in the intake rate by plovers. Plovers may have become confused about which prey to pursue, just as do predators foraging on schooling fish or flocking birds (Page and Whitacre 1975).

Could there have been a maximum surface prey density threshold above which foraging efficiency was compromised? Some support for this hypothesis is found in the negative relationship between foraging efficiency and surface prey abundance and the apparent existence of a threshold of foraging efficiency for plovers feeding on surface prey. The predicted threshold, 10 animals/sticky trap, was higher than I commonly observed among most of my samples, but suggests that a threshold might exist and may affect how plovers select local feeding areas in the lagoon ecosystem.

I did not assess the caloric value of different prey groups to Piping Plovers, but this measure clearly affects the net energy plovers realize and presumably governs their selection of prey from among the available population. Pienkowski (1981) found Ringed Plovers (*Charadrius hiaticula*) and Black-bellied Plovers (*Pluvialis squatarola*) to feed selectively on large lugworms (*Arenicola marina*) when environmental conditions increased the activity of this species. The plovers fed at greater rates on lugworms, even though a smaller polychaete species (*Notomastus latericeus*) was more common than *Arenicola*, and also became more available to plovers under the same conditions that increased *Arenicola* availability.

Withers (1994) measured both biomass and prey density at 2 ecotone sites. Withers found benthic density rather than biomass to most often affect shorebird abundance. However, the biomass measures reported by Withers provide a means of estimating the relative caloric potential of the major prey groups eaten by plovers. At Corpus Christi Pass, Withers found polychaetes to have a biomass of about 0.86 mg/animal. Adult insects and amphipods had about 1/2 the biomass of polychaetes (0.48 mg/animal and 0.36 mg/animal, respectively). Larval insects and tanaids had only a fraction of the biomass available from polychaetes (0.27 mg/animal and 0.07 mg/animal, respectively). Based upon the biomass estimates by Withers, polychaetes appear to offer a substantially higher relative energy return to plovers than do insects, amphipods and tanaids. This may explain the ability of plovers wintering in the bay ecosystem to spend less time at beach habitat relative to plovers wintering in the ecotone. Polychaetes comprised a much greater proportion of the bayshore diet of plovers wintering in the bay ecosystem relative to plovers wintering in the ecotone (Figure 31). Whereas the diet of plovers in the lagoon ecosystem contained an even smaller proportion of polychaetes, beach habitat may have offered a poor alternative to these birds. Beach benthic populations were apparently less dense in the lagoon ecosystem (Figure 14). The increased energy expenditures required of plovers foraging at beach habitat coupled with the reduced benthic populations occurring there may partially explain why lagoon plovers also used beaches less than ecotone plovers. However, my data suggest that when Piping Plovers did use lagoon beaches, they fed almost exclusively on polychaetes (Figure 30).

Roosting Behavior

I found Piping Plovers to spend about 34% of the diurnal period roosting or preening while at beach habitat and about 18% of the diurnal period roosting or preening while at bayshore habitat (i.e., foraging rates of 66% and 82% for beach and bayshore habitats, respectively). These estimates compare well with those reported for plovers wintering in Alabama (Johnson and Baldassarre 1988). Elliott and Teas (1996) reported a much higher estimate of foraging activity for Piping Plovers using 3 Texas beaches (86.7%, 89.5%, and 96.2%). This apparent incongruity may stem from the way in which beach habitat was delineated in both studies. I included all washover passes that occurred at my sites as a part of the beach habitat. Because they occur at higher elevations than the beach, and receive less human disturbance, washover passes provide ideal roost habitat and many of the plovers I found roosting at beach habitat at my sites occurred in washover passes. The foraging activity estimates developed by Elliott and Teas (1996) were for only those plovers using the forebeach habitat, and did not account for the activity of plovers using nearby washover passes, where roosting behavior was more common (L. Elliott, pers. comm.).

Human Disturbance

My data suggest human activity reduced the net foraging success of Piping Plovers at beach habitat by increasing the amount of energy plovers had to expend while foraging. Vega (1988) reported an apparent reduction in the abundance of *S. squamata* and *Haustorius* sp. at beaches experiencing vehicular traffic, suggesting human activity at beach habitat may be the source of both direct and indirect impacts to Piping Plovers.

Elliott and Teas (1996) reported a negative relationship between Piping Plover beach density and vehicular density at the Packery Channel site (referred to as Surfer Beach in Elliott and Teas 1996). Whereas Elliott and Teas (1996) detected no relationship between Piping Plover density and pedestrian density, they found pedestrian encounters reduced the amount of time plovers were able to spend foraging. Elliott and Teas (1996) concluded that "Reductions in time spent foraging may be sufficient to cause birds to move to habitats where time budgets are unaffected by human disturbance. This may entail moving to bayshore habitats or beaches occupied by fewer pedestrians." I found no relationship between Piping Plover density and vehicular density at beach habitat. In fact, the trend between plover density and beach vehicular density was positive at the Packery Channel site. My data indicate that plover movements between beach and bayshore habitat were predominantly controlled by bayshore tidal amplitude. However, in addition to disrupting foraging efforts, human disturbance appeared to have a significant effect on Piping Plover abundance at my sites. This relationship is described further in Chapter IV.

CHAPTER IV. PIPING PLOVER SITE ABUNDANCE

INTRODUCTION

The recovery of rare plants and animals must be founded on thorough knowledge of the features that define and threaten the species' niche. This knowledge guides both the preservation of sites that exhibit optimal habitat and the sound management of sites where habitat quality has been compromised. The final objective of my study was to identify the habitat components and environmental conditions that affect the abundance of Piping Plovers along the TGC. Accomplishing this objective will identify the environmental features that are most important to winter recovery throughout a major portion of the species nonbreeding range.

Nicholls and Baldassarre (1990b) used discriminant function analysis (DFA) to investigate the relationship between a number of microhabitat characteristics and the presence/absence of Piping Plovers throughout most of their winter range. Their analyses selected "...greater beach width, greater % mudflat, lower % beach and more small inlets..." as the winter habitat characteristics predictive of Piping Plover presence/absence along the Gulf Coast of the United States. Along the Atlantic Coast, DFA selected "...the number of large inlets and passes, number of tide pools, % mudflat, beach width, and % sandflat as the major factors affecting (Piping Plover) presence or absence." (Nicholls and Baldassarre 1990b).

However, Nicholls and Baldassarre's conclusions were founded primarily upon data collected during single visits to a large number of study sites throughout the winter range. Furthermore, the habitat associations evaluated by Nicholls and Baldassarre (1990b) include only a portion of the parameters that may play a role in habitat selection by Piping Plovers. For instance, such factors as tidal stage, prey density, and human disturbance were not considered in their analyses, yet these factors have been shown to significantly influence shorebird site-use and behavior (Burger et al. 1977, Connors et al. 1981, Hicklin and Smith 1984). I sought to build upon the foundation developed by Nicholls and Baldassarre. I did this by developing a site abundance model that incorporated several factors that were not considered by Nicholls and Baldassarre's model, and supported the new model with data collected from multiple visits to several sites.

METHODS

To address this objective I developed a multiple regression model predicting local Piping Plover abundance based upon the following 6 habitat and environmental parameters measured at each study site:

1. Available beach habitat area.
2. Available bayshore habitat area.
3. Macrobenthic prey density at beach habitat.
4. Macrobenthic prey density at bayshore habitat.
5. Surface prey abundance at bayshore habitat.
6. Human disturbance at beach habitat.

I employed a step-wise regression model to select, from among these 6 parameters, those that most significantly predicted variation in the number of Piping Plovers occurring at all of the barrier island study sites I monitored. Data collected at Laguna Atascosa National Wildlife Refuge, the 3 southern sites on South Padre Island and the South Bay -West site were omitted from this model because these sites either did not possess beach habitat, or because data were not collected at beaches for these sites. Including these sites would not have allowed the incorporation of beach-associated parameters in the model. Additionally, the Mustang Island State Park -South site was omitted from this analysis because this site was not representative of its geographic region (the ecotone), and Piping Plovers were never found at this site. This site was monitored only to support comparisons to the Mustang Island State Park - North site.

I selected the habitat parameters because they have all been associated with shorebird abundance or quality shorebird habitat (e.g., habitat area; Goss-Custard et al. 1995, prey abundance; Cullen 1994, Withers 1994, Connors et al. 1981, human disturbance; Staine and Burger 1994), and were variables that had the potential to vary substantially among my study sites.

To support the model, I monitored Piping Plover populations and the above 6 independent variables at my study sites from July - May in 1993 and 1994 (i.e., the last 2 years of the study). Whereas many of the above parameters were monitored during the study's first field season (July 1991- May 1992), human disturbance and surface prey were not measured until the second year of the study, and therefore data collected in the first year of the study are not incorporated into the model.

To maximize the number of samples used to support the model, I partitioned the study period into 4 temporal periods comprised of the migration season (fall and spring) and the winter season for each of the last 2 years of the study. Season and study year also were built into the model as independent variables to factor variability associated with these parameters into the analysis. Thus, each of the 8 barrier island study sites could potentially be represented by as many as 4 samples, yielding a potential maximum of 32 samples. However, because weather and other factors limited access to some of the sites during one or more of the 4 periods, most sites were represented in the model by fewer than 4 samples, and the model was supported by a total of 19 samples.

Piping Plover site abundance for each period was estimated as the sum of the mean number of Piping Plovers recorded during all beach and bayshore surveys conducted during each temporal sampling period at each site. For instance, during the 1993 fall migratory season at Bolivar Flats, I recorded an average of 46.0 plovers using bayshore habitat and 17.4 plovers using beach habitat, yielding an estimated site abundance for that period of 63.4 plovers

I selected the most robust model using backwards stepwise regression analysis. To investigate the effects of autocorrelation, I compared the relationships among the means of the 6 variables and Piping Plover abundance among the 19 samples using nonparametric correlation (Spearman Rho test).

Data Analysis

The analyses were performed using JMP, version 3.1 (SAS Institute Inc., Cary, NC). I programmed entry and exit criteria for the backward stepwise analyses to initially incorporate all 8 parameters (year, season, beach vehicular density, bay area, beach length, beach benthos, bayshore benthos, bayshore surface prey). Through backward stepwise regression, all parameters were removed from the model, beginning with the parameter that least affected plover abundance, and ending with the parameter than explained the greatest amount of variation in abundance. Akaike's Information Criterion was used to determine which parameters collectively constituted the model that best fit my data.

RESULTS

Mean abundance at beach habitats varied from < 1 birds/count to > 20 birds/count (Table 25). The highest single day counts at beach habitats were of roosting flocks and occurred at washover passes in the lagoon ecosystem or at the Packery Channel site, which was the only site outside of the lagoon ecosystem that had a washover pass (Table 26).

Mean abundance at bayshore habitats ranged from 0 plovers to > 355 plovers (Table 25). Nine of the 10 highest single day counts in bayshore habitat were in the lagoon ecosystem, most of these counts coming at the South Padre - North Area site (Table 26). In contrast to my observations of plovers at beach habitat, most plovers counted during

Table 25. Estimated mean site abundance of Piping Plovers on bayshore tidal flats and beach habitats at sites along the Texas Gulf Coast, 1991 - 1994. Mean site abundance was estimated as the sum of the mean bayshore flat abundance and the mean beach abundance at each site. Abbreviations: LANWR = Laguna Atascosa National Wildlife Refuge, MISP = Mustang Island State Park, NB = no beach at site, ND = no data, NYF = North Yucca Flats, RBV = Rincon Buena Vista, RHC = Redhead Cover, SHF = South Horse Flats, SPI = South Padre Island.

Study Location	Beach Abundance			Bayshore Abundance			Total
	N	mean	SE	N	mean	SE	
Bay Ecosystem							
Bolivar Flats	35	15.3	3.9	40	50.3	5.3	65.5
Big Reef	17	1.2	0.7	23	18.4	3.8	19.6
San Luis Pass	64	12.3	6.5	65	27.4	2.5	39.7
Ecotone							
East Flats	7	9.9	3.5	7	49.3	26.9	59.2
MISP - North	66	10.3	1.6	30	7.4	1.7	17.7
MISP - South	32	8.5	2.6	13	0.0	0.0	8.5
Packery Channel	58	14.0	2.9	47	14.7	2.8	28.7
Lagoon Ecosystem							
LANWR - RBV	NB	0.0	--	31	17.4	4.9	17.4
LANWR - SHF	NB	0.0	--	35	1.2	1.1	1.2
LANWR - RHC	NB	0.0	--	37	5.7	3.6	5.7
LANWR - NYF	NB	0.0	--	43	17.1	4.3	17.1
South Bay - West	NB	0.0	--	21	0.0	0.0	0.0
South Bay - East	25	22.6	11.7	29	19.1	8.2	41.7
SPI - North Area	27	12.3	6.5	6	355.3	58.3	367.6
SPI - Convention Center	ND	--	--	19	2.9	1.3	2.9
SPI - Parrot Eye's	ND	--	--	21	2.5	1.0	2.5
SPI - Mangrove Flats	ND	--	--	25	3.1	1.0	3.1

Table 26. High single day counts of Piping Plovers at beach and bayshore habitats along the Texas Gulf Coast, 1991 - 1994.

Location	Date	# Piping Plovers	
		Total	Roosting
Beach Habitat			
South Bay - East	2/10/93	254	254
South Padre Island - North	2/4/93	171	171
South Bay - East	2/26/93	153	121
Packery Channel	2/25/93	87	87
Bolivar Flats	2/18/93	83	56
Bolivar Flats	1/22/93	80	80
Packery Channel	11/2/92	76	76
South Bay - East	10/8/93	74	45
Packery Channel	2/11/93	63	63
Packery Channel	2/5/93	61	6
Bayshore Habitat			
South Padre Island - North	3/2/93	543	0
South Padre Island - North	1/27/94	489	223
South Padre Island - North	12/5/91	400	no data
South Padre Island - North	12/9/93	254	0
South Padre Island - North	10/15/93	251	13
Laguna Atascosa NWR - Yucca Flats	1/28/93	238	0
South Bay - East	3/3/92	202	no data
South Padre Island - North	3/1/92	195	no data
East Flats	3/26/93	189	0
Laguna Atascosa NWR - Redhead Cove	11/18/91	130	0

the high single day counts at bayshore habitats were engaged in foraging behavior.

Mean total site abundance (i.e., beach and bayshore counts combined) ranged from 0 plovers to over 350 plovers (Table 25). With one exception, all of the sites with small plover populations (< 10 plovers) were either very small (e.g., the 3 sites on the southern end of South Padre Island) or were situated away from the barrier island chain on the mainland coastline (e.g., the South Bay-West site and the Laguna Atascosa National Wildlife Refuge sites).

The exception to this rule was one of the Mustang Island State Park (MISP) sites. Whereas the MISP - South site was neither small (40 ha tidal flats, 2.6 km beach) nor on the mainland, it supported a site population of just 8.5 plovers. All of the plovers in this mean population estimate were observed at beach habitat. No Piping Plovers were observed using bayshore flats at this site during the study. The MISP - North site, which was similar in size (33 ha tidal flats, 3.2 km beach) and borders the south site, supported a much larger site population (17.7 plovers). Furthermore, Piping Plovers consistently used bayshore flats at the MISP - North site (Table 3).

The difference in plover site abundance at these 2 sites is less confounding when the habitat features of the sites are compared more closely. The bayshore portions of the MISP sites consist of 2 lagoons, one lagoon forms part of MISP - North, and a second lagoon forms part of MISP - South (Figure 5). The 2 lagoons were once part of a single large lagoon, but they were isolated by a man-made channel (Fish Pass). In addition to splitting the large lagoon into 2 smaller lagoons, the channel also interrupted tidal flow into both lagoons. A second artificial channel was dredged into the north lagoon to re-establish a tidal exchange between the MISP - North lagoon and Corpus Christi Bay, but the MISP - South lagoon remained relatively isolated from tidal influences throughout the study. The MISP - South site was drier and more heavily vegetated, and these factors appear to have affected the value of the site to Piping Plovers.

Factors Affecting Piping Plover Site Abundance

Data from 8 sites were evaluated to investigate the relationship between Piping Plover site abundance and habitat and environmental conditions occurring at the sites. Mean Piping Plover site abundance at the 8 sites varied from < 3 plovers to > 370 plovers (Table 27).

The habitat and environmental parameters also varied widely. Mean bayshore area at the sites varied from about 20 ha to > 500 ha (Table 27). Beach length for most of the sites ranged from about 3 km to about 7 km, with the long (> 25 km) South Padre Island - North site being the exception (Table 27). Human disturbance, estimated as beach vehicular density, ranged from 0 vehicles/km to almost 6 vehicles/km (Table 27). Bayshore benthic density ranged from 0 animals to > 12,000 animals/m^2 (Table 27). As expected, beach benthic populations were more consistent, ranging from about 560 to about 7,000 animals/m^2, with most samples ranging from about 1,000 to about 3,500 animals/m^2 (Table 26). Finally, insects and other surface prey ranged from 0 to nearly 1400 animals captured/100 trap hr. (Table 27).

Pairwise correlation analyses revealed that some of the independent parameters were significantly correlated with each other (Figure 43). Among these were bay area/beach vehicular density (P= 0.0007), bay surface prey/beach length (P= 0.0112), and bay surface prey abundance/bay benthic density (P= 0.0243). All of these correlations were negative.

The effects of each of the measured parameters on Piping Plover abundance were independently evaluated. The area of bayshore habitat (positive relationship; R^2 = 0.3770, P = 0.0052) explained the greatest amount of variability in plover abundance at my sites (Figure 44). Beach vehicular density (negative relationship; R^2 = 0.3277, P = 0.0104; Figure 44), and beach length (positive relationship; R^2 = 0.2259, P = 0.0397; Figure 45) also each explained over 20% of the variability in Piping Plover abundance at

Table 27. Mean values for the environmental and habitat variables used in the multiple regression models. Each figure represents the mean value of the variable over the 3 year study period.

Study Site	Yr.	Sea.	Beach Variables: BI.	Beach Variables: Benthic Density			Beach Variables: Vehicular Density			Bayshore Variables: Bayshore Area			Bayshore Variables: Benthic Density			Bayshore Variables: Surface Prey			Piping Plover Abundance		
				mean	N	SE	mean	N	SE	mean	N	SE	mean	N	SE	mean	N	SE	mean	N	SE
BF	Y2	Mig	4.8	1239	25	203	1.56	7	0.54	78.3	6	23.2	4765	35	697	0.07	30	0.05	63.4	7	18.0
BF	Y2	Wint	4.8	6418	40	564	0.83	7	0.30	100.7	7	15.5	11998	45	841	0.13	45	0.05	90.6	7	29.2
BF	Y3	Mig	4.8	1266	30	167	2.22	7	0.38	105.8	8	21.1	2757	30	469	0.03	30	0.02	59.0	7	14.7
BF	Y3	Wint	4.8	949	5	512	0.58	5	0.23	131.6	5	27.4	7110	35	843	0.00	10	0.00	55.2	5	21.3
BR	Y2	Wint	4.4	7142	5	361	3.65	3	0.83	34.8	5	5.3	12340	15	734	0.75	15	0.28	2.8	3	5.8
BR	Y2	Mig	4.4	3104	15	939	5.10	6	1.13	19.3	6	5.3	2260	15	669	1.00	15	0.20	7.1	6	7.9
SLP	Y2	Mig	6.3	3633	40	560	5.83	13	2.17	27.0	12	5.2	4076	30	670	0.35	20	0.15	30.8	13	5.4
SLP	Y2	Wint	6.3	3824	90	511	1.24	24	0.13	47.1	21	3.7	4294	90	322	0.12	66	0.05	29.7	24	6.3
SLP	Y3	Mig	6.3	1654	25	484	2.75	6	0.56	33.0	6	7.6	2296	25	470	0.00	25	0.00	32.5	6	7.2
EF	Y2	Mig	2.8	3345	10	559	0.00	2	0.00	123.0	2	0.0	0	6	0.0	13.83	6	2.52	34.5	2	61.5
EF	Y3	Mig	2.8	2140	15	437	0.00	2	0.00	123.0	2	35.5	0	25	0.0	8.72	25	0.99	74.0	2	38.9
MISPN	Y2	Wint	3.2	3464	55	531	1.21	25	0.26	25.9	20	17.4	329	55	102	0.54	80	0.15	16.2	20	11.0
MISPN	Y3	Wint	3.2	1695	10	324	4.06	2	2.19	44.8	2	13.2	1996	25	318	1.04	25	0.25	18.0	2	13.5
PC	Y2	Wint	3.9	563	45	90	1.73	30	0.39	102.0	25	10.5	600	125	132	0.68	125	0.37	32.1	25	8.3
PC	Y3	Mig	3.9	2066	35	341	2.91	3	1.51	29.8	3	16.7	0	5	375	5.00	5	0.46	43.0	3	15.2
PC	Y3	Wint	3.9	4447	35	317	2.65	3	1.37	89.5	3	25.8	3179	15	298	0.73	15	0.21	46.0	3	15.4
SBE	Y3	Mig	7.6	712	20	200	1.49	3	0.48	267.5	3	40.1	859	20	341	0.70	20	0.21	47.3	3	27.4
SBE	Y3	Wint	7.6	1808	20	238	2.57	2	0.59	120.4	4	76.8	181	5	132	0.00	5	0.00	4.5	4	4.5
SPIN	Y3	Wint	25.1	1740	40	185	0.00	3	0.00	507.5	2	101.5	663	45	107	1.09	45	0.35	372.8	3	118.8

Abbreviations: BF = Bolivar Flats, BR = Big Reef, SLP = San Luis Pass, EF = East Flats, MISPN = Mustang Island State Park, PC = Packery Channel, SBE = South Bay - East, SPIN = South Padre Island - North, Wint = Winter, Mig = Migration, Y = year

Variable	by Variable	Spearman Rho	Prob>|Rho|
Beach Veh	Year	0.1170	0.6334
Bay Area	Year	0.2629	0.2769
Bay Area	Beach Veh	-0.7086	0.0007
BL	Year	0.1474	0.5471
BL	Beach Veh	0.0444	0.8569
BL	Bay Area	0.2295	0.3445
Be Tot Benth	Year	-0.3892	0.0995
Be Tot Benth	Beach Veh	0.1160	0.6363
Be Tot Benth	Bay Area	-0.4142	0.0779
Be Tot Benth	BL	-0.2028	0.4049
Bay Tot Benth	Year	-0.2925	0.2244
Bay Tot Benth	Beach Veh	0.2095	0.3893
Bay Tot Benth	Bay Area	-0.1653	0.4989
Bay Tot Benth	BL	0.3461	0.1467
Bay Tot Benth	Be Tot Benth	0.2320	0.3392
Bay Surf Pry	Year	0.0683	0.7812
Bay Surf Pry	Beach Veh	-0.0872	0.7227
Bay Surf Pry	Bay Area	0.0325	0.8948
Bay Surf Pry	BL	-0.5677	0.0112
Bay Surf Pry	Be Tot Benth	0.2497	0.3026
Bay Surf Pry	Bay Tot Benth	-0.5143	0.0243

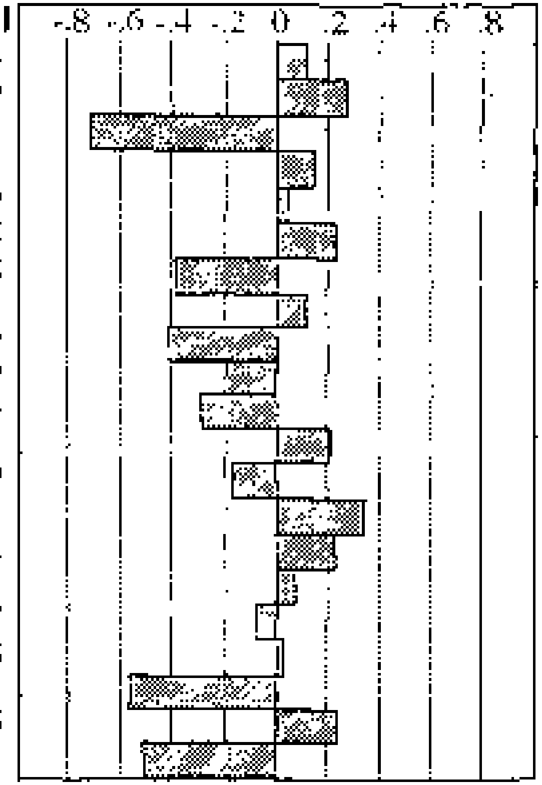
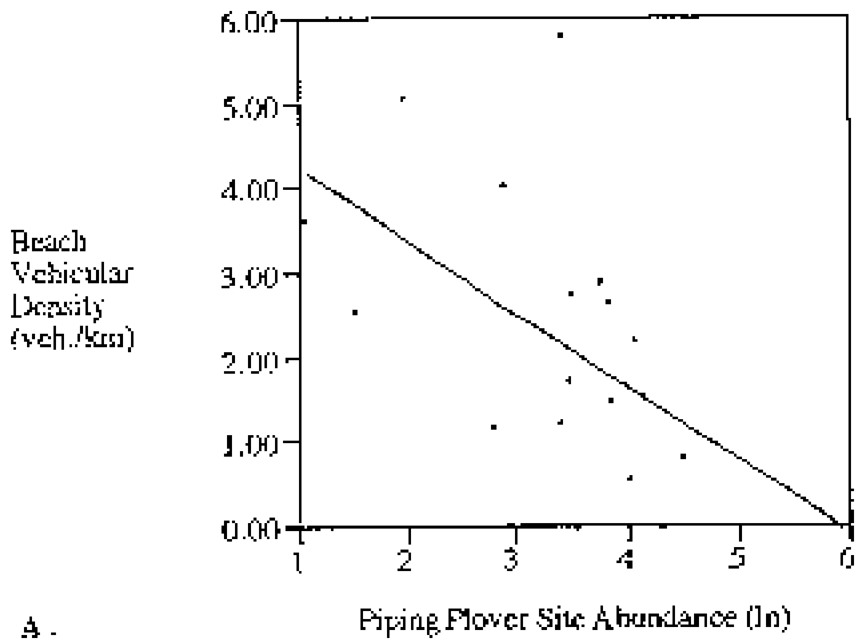
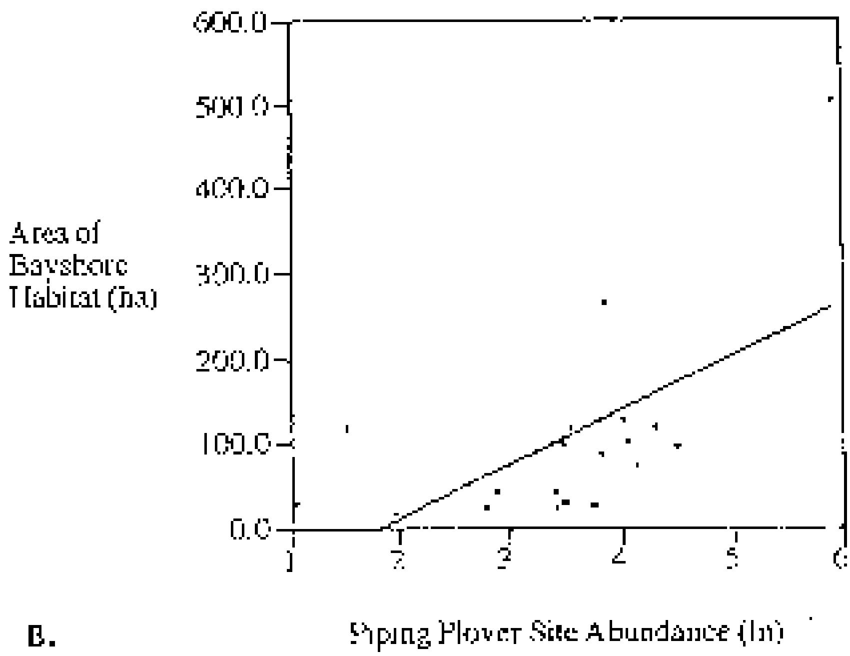


Figure 43. Nonparametric pairwise correlations between the 6 independent environmental parameters evaluated for thier effect on Piping Plover abundance. Year and season are also shown. Abbreviations: Veh = vehicle density, BL = beach length, Be Tot Benth = beach benthos density estimate, Bay Tot Benth = bayshore benthos density estimate, Bay Surf Pry = relative bayshore surface prey abundance estimate.

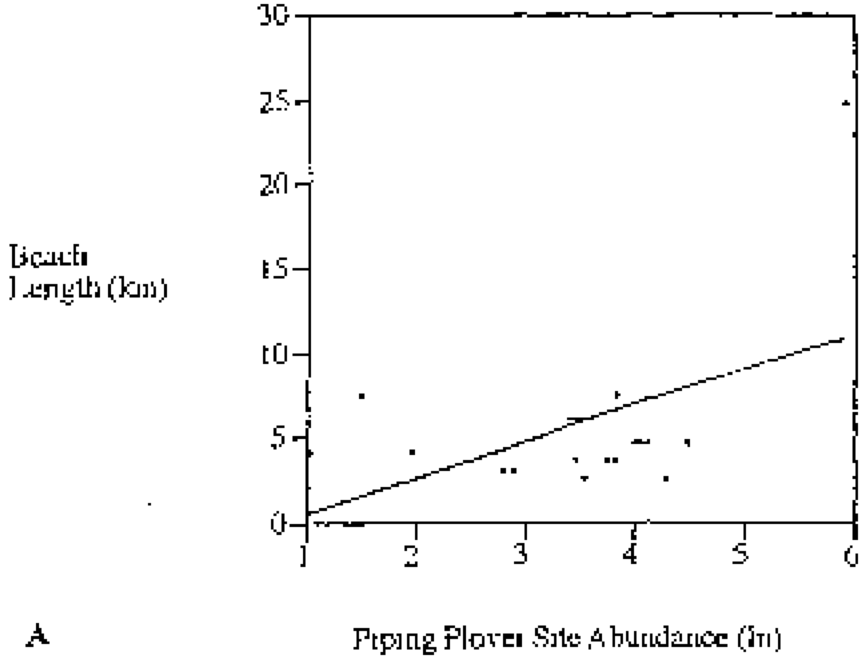


A.



B.

Figure 44. Simple regressions evaluating the effects of (A) beach vehicular density (vehicles/kilometer; $P = 0.0104$, $R^2 = 0.3277$) and (B) bayshore area (hectares; $P = 0.0052$, $R^2 = 0.3770$) on Piping Plover site abundance.



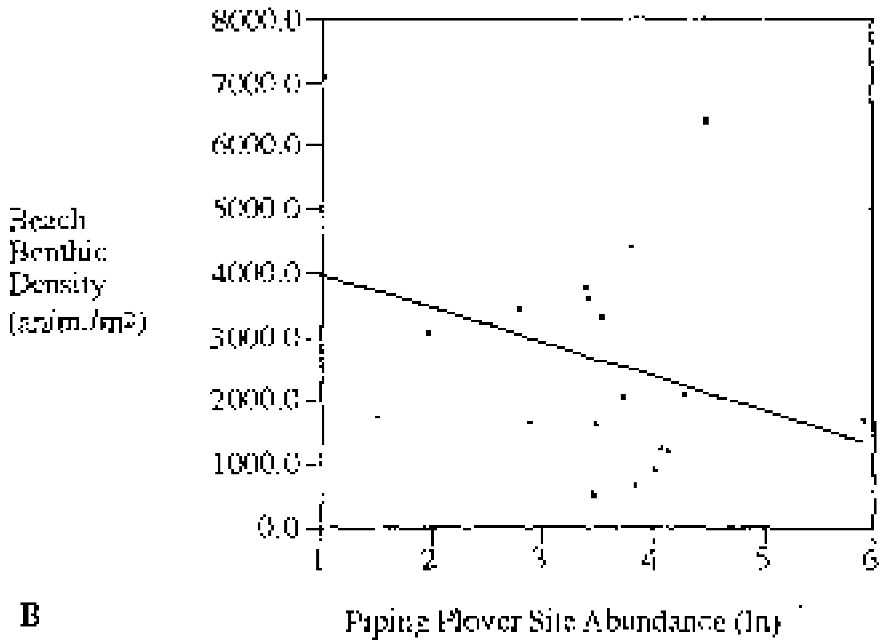


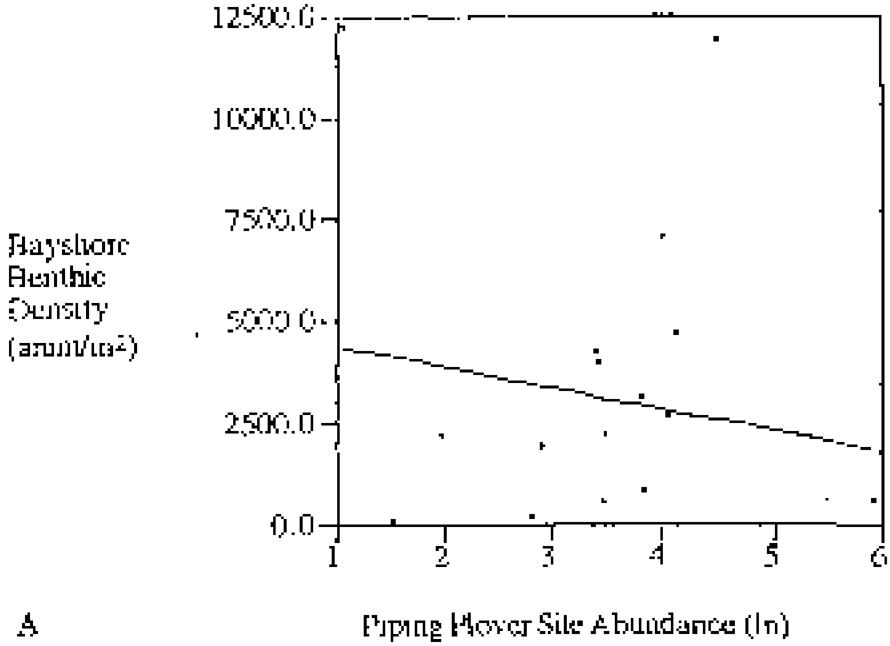
Figure 45. Simple regressions evaluating the effects of (A) beach length (kilometer; $P = 0.0397$, $R^2 = 0.2259$) and (B) beach benthic density (# animals/square meter; $P = 0.1762$, $R^2 = 0.1049$) on Piping Plover site abundance.

my sites.

None of the prey measures strongly or significantly influenced plover abundance (Figures 45 and 46). Beach benthic density (negative relationship; $R^2 = 0.1049$, $P = 0.1762$), bayshore benthic density (negative relationship; $R^2 = 0.0232$, $P = 0.5333$), and bayshore surface prey density (positive relationship; $R^2 = 0.0151$, $P = 0.6157$) all explained only a small amount of the variability in the abundance of Piping Plovers at my sites. The sites with the largest plover populations were those that had the largest area of bayshore flat, the largest area of beach habitat, and the lowest level of human disturbance.

The most robust multiple regression model selected by stepwise regression identified beach vehicular density ($P = 0.0106$), beach length ($P = 0.0396$), and season ($P = 0.1105$) as the most important factors explaining Piping Plover site abundance. This 3-factor model explained over half of the variability associated with Piping Plover abundance at my sites ($P = 0.0052$; $R^2 = 0.5396$). The regression formula describing the effect of these parameters on Piping Plover abundance was:

ln # Piping Plovers	=	3.69 (y - intercept)
	-	0.3525 (beach vehicular density [#/km])
	+	0.3309 (Season [Fall = 1, Winter = 2])
	+	0.0934 (beach length [km])



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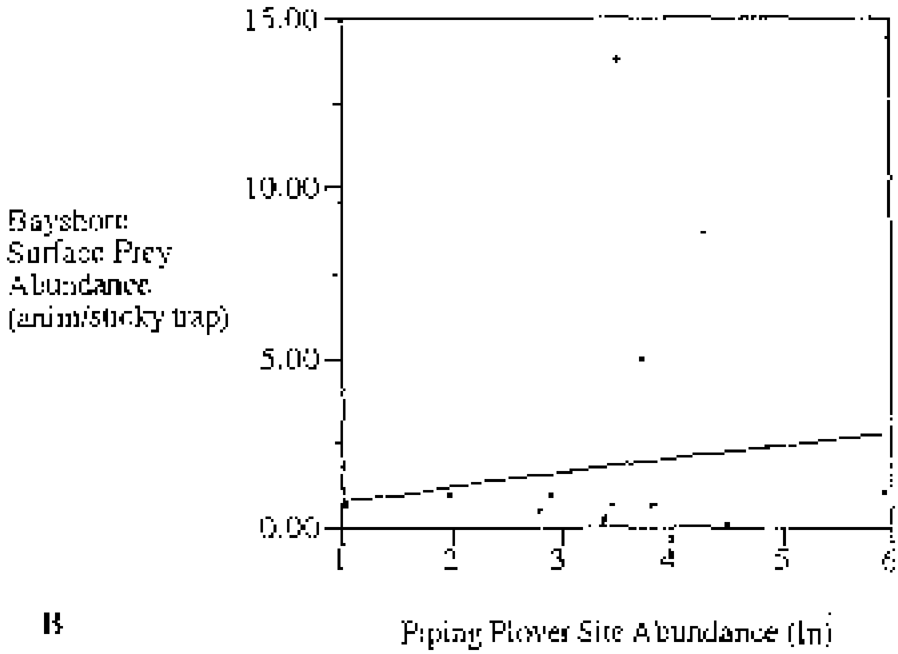

B

Figure 46. Simple regressions evaluating the effects of (A) bayshore benthic density (# animals/square meter; $P = 0.5333$, $R^2 = 0.0232$) and (B) bayshore surface prey abundance (# animals/sticky trap; $P = 0.6157$, $R^2 = 0.0151$) on Piping Plover site abundance.

The full model, incorporating all 6 habitat and environmental parameters and the seasonal effect into the analysis was only marginally better at predicted Piping Plover abundance (P= 0.2210; R^2 = 0.5714) than was the 3 parameter model:

ln # Piping Plovers	=	3.90 (y - intercept)
	-	0.3475 (beach vehicular density [#/km])
	+	0.3753 (season [Fall = 1, Winter = 2])
	+	0.0581 (beach length [km])
	+	0.0016 (bayshore habitat area [ha])
	+	0.000038 (bayshore benthic density [#/m^2])
	-	0.000074 (beach benthic density [#/m^2])
	-	0.0348 (bayshore surface prey density [#/sticky trap])

DISCUSSION

My site abundance estimates compare well with counts from the 1991 and 1996 International Piping Plover Censuses (IPPC). Piping Plover site abundance was estimated at Bolivar Flats, Big Reef and San Luis Pass during the 1991 and 1996 International Piping Plover Census. Seventy-three Piping Plovers were counted at Bolivar Flats in 1991 and 101 were counted in 1996 (mean = 87). Nicholls and Baldassarre (1990a) found 66 Piping Plovers at Bolivar Flats. I used data from the last 2 years of my study for the regression models presented in this chapter, resulting in an abundance estimate of 65.5 plovers at Bolivar Flats.

At Big Reef, 25 Piping Plovers were counted during the 1991 IPPC, while none were found there in 1996 (mean = 12.5). My 2-year estimate of plover abundance at Big Reef was 19.6. Bolivar Flats and Big Reef are separated only by the Houston Ship Channel, and plovers often move between these sites (pers. obs.). This probably explains why the number of plovers counted during the 1996 IPPC rose by 28 plovers at Bolivar Flats while it dropped by 25 at Big Reef. The cumulative 1991 and 1996 IPPC counts for both sites were very similar (98 and 101), and the mean of these 2 counts (99.5) was similar to my mean estimate for both sites (85.1).

Forty-one Piping Plovers were counted during the 1991 IPPC at San Luis Pass (beach and bayshore potions of the count), and 29 were counted in 1996 (mean = 35). Both IPPC counts were similar to my 2-year estimate of 39.7 Piping Plovers for the site. Nicholls and Baldassarre (1990a) found 39 Piping Plovers at San Luis Pass. Unfortunately, comparative site abundance data are not available from the 1991 or 1996 IPPC to support comparisons with my other study sites because the boundaries of those counts differed from the boundaries of my study sites.

The regression model I present in this chapter indicates Piping Plover recovery efforts may need to be reevaluated. In Texas, most recovery activity for the federally-listed Piping Plover has focused on preserving bayshore habitat on barrier islands. Examples of this trend include the establishment of the Mollie Beattie Sanctuary in 1997 (which includes the bayshore portion of the Packery Channel site), the 1992 establishment of a Western Hemispheric Shorebird Reserve Network (WHSRN) site at Bolivar Flats, the establishment of preserves at Big Reef in 1995 and San Luis Pass (in progress, P. Glass pers comm.), and the acquisition by the U.S. Fish and Wildlife Service of the eastern portion of South Bay in 1998. Preserving habitat for the Piping Plover was one of the primary goals of each of these actions. However, most of these sites include large tracts of barrier island bayshore tidal flat habitat, but contain very little of the other habitat types used by Piping Plovers (e.g., beaches, mainland tidal flats, washover passes).

Indeed, my data do strongly suggest barrier island tidal flats are the preferred habitat of Piping Plovers wintering in Texas. Beach habitat, washover passes and mainland tidal flats (in the lagoon ecosystem) clearly appeared to be secondary habitats that primarily were used by plovers during periods when barrier island tidal flats were unavailable due to tidal inundation. Clearly any site that supports Piping Plovers must have bayshore tidal flats. In fact, plover abundance and bayshore tidal flat area were positively correlated at my sites, indicating that a reduction in the amount of bayshore tidal flat habitat may reduce a site's plover population. By itself, bayshore area explained 38% of the variability in plover abundance.

The strong correlation between bayshore area and beach vehicular density further muddies an appraisal of the isolated effects of bayshore area on plover abundance. However, the 3-factor model presented above (that excluded bayshore area) was generated by backward stepwise regression analysis. Backward stepwise regression evaluates interactions among parameters before removing the parameters one at a time in reverse order of fit. This approach identifies those parameters that best explain plover abundance while also considering how these parameters interact. Whereas bayshore area explained a large amount of variation in plover abundance, when evaluated in combination with the other parameters, its effect was diminished, and it was omitted from the most robust model.

The fact that bayshore area was not incorporated into the best-fit model does not mean that protecting large areas of bayshore habitat is fruitless. However, my data suggest that the carrying capacity of barrier island sites is presently limited to a greater extent by the availability of protected beach habitat than bayshore habitat. Therefore, the present strategy of protecting barrier island tidal flats to the exclusion of beach habitat may prove ineffective in the long-term recovery of the Piping Plover.

There is recent evidence to suggest that mainland tidal flats and washover passes also function as important secondary habitats for Piping Plovers, particularly in the lagoon ecosystem (Zonick 1997, Zonick et al. 1998). Mainland tidal flats in the lagoon ecosystem are seriously threatened by human-induced alterations. Broad areas of mainland flats once experienced numerous flooding and drying cycles throughout the winter as winter fronts pushed Laguna Madre waters into and out of the mainland coastline (Farmer, 1991). Large tracts of mainland flats, however, have become extensively isolated from these waters by miles of continuous dredged spoil banks associated with Gulf Intracoastal Waterway (GIWW) and the Harlingen Ship Channel. Rincon Buena Vista, Elephant's Head Cove, South Horse Flats (Figure 7) and other mainland tidal flats used by Piping Plovers during my study have undergone an extensive and progressive encroachment by Glasswort (*Salicornia bigelovii*), Saltwort (*Batis maratima*), and other salt-tolerant plants. Whereas these plants are not unusual in the tidal flat landscape, tidal flats surrounded by dredged spoil appear to exhibit much higher levels of encroachment. These, and perhaps several other mainland tidal flats may require expeditious management (e.g., removal of dredged spoil banks blocking tidal waters) if they are to remain intertidal wetlands.

However, the trend associated with human influences on beach habitat is most alarming. The Texas Gulf Coast supports thriving petrochemical refining and offshore drilling industries. Texas beaches are exposed to small scale oil and tar exposure on a constant basis. Bolivar Flats and other sites situated nearby the mouths of ship channels are particularly vulnerable to catastrophic oil spills.

Human presence on beaches, however, may be a greater long-term threat to Piping Plovers in Texas. Piping Plovers primarily used beaches during periods when bayshore flats were flooded. The availability of high quality beach habitat to plovers during these periods may be critical to their survival. Human disturbance at beach habitat was identified by stepwise regression as the most important factor affecting the abundance of Piping Plovers at my sites. By itself, beach vehicular density explained 33% of the variability in Piping Plover abundance among my study sites. The area of beach habitat (i.e., beach length) also significantly affected plover abundance, independently explaining 23% of the variability in Piping Plover abundance among my study sites.

CHAPTER V. CONCLUSIONS & MANAGEMENT RECOMMENDATIONS

Along the TGC, Piping Plovers occupy sparsely-vegetated beach, and bayshore tidal flat habitat (e.g., sand flats and algal flats) throughout a 9-10 month non-breeding period (Haig 1992). At my study sites, plovers used both beach and bayshore habitat, but preferred bayshore habitat when both habitat types were emergent and thereby available to plovers. During periods of high bayshore tides, when tidal flats were inundated and were not available, Piping Plovers moved to beach habitat at most sites and foraged within the beach intertidal zone until bayshore tides receded and bayshore habitat was again available to plovers.

The preference for bayshore habitat could not directly be explained by differences in prey availability or plover foraging efficiency in the 2 habitat types. Whereas prey were more abundant at bayshore habitat than at beach habitat in the bay ecosystem, the relationship was reversed in the lagoon ecosystem and the ecotone. Furthermore, Piping Plovers foraged with similar efficiency at beach and bayshore habitats. Plovers also foraged with similar efficiency at bayshore tidal flats in the bay and lagoon ecosystems, even though these ecosystems supported starkly different bayshore prey communities.

The preference for bayshore habitat may have been due to factors that reduced net energy intake rates of plovers using beach habitat. Piping Plovers were much more territorial when feeding at beach habitat, often interacting aggressively to defend feeding areas along the forebeach from other Piping Plovers. Plovers also experienced greater levels of human disturbance at beach habitat than at bayshore habitat. Finally, to feed on their preferred prey at beach habitat, plovers had to repeatedly run into and out of the swash zone. These factors caused plovers to spend considerably more time in prolonged foraging locomotion (PFL), and presumably expend more energy to obtain a similar rate of prey intake. The result was probably a lower net energy intake rate on beaches relative to bayshore flats, resulting in the observed preference for bayshore habitat.

The importance of beach habitat to Piping Plovers

Although plovers preferred to feed at bayshore habitat, beaches provided alternative feeding and roosting habitat for plovers during periods when bayshore feeding areas were unavailable. Changes in atmospheric pressure and wind conditions accompanying winter cold fronts often created extremely high bayshore tides that covered all bayshore tidal habitat at many of my sites. A plover's ability to survive the harsh conditions accompanying these fronts may depend on its ability to find suitable roost sites or alternative feeding sites. In many parts of the Texas coast, beaches appeared to provide the only suitable alternative to bayshore tidal flats. The importance of beaches is underscored by the habitat model described in Chapter IV, which identified undisturbed beach habitat as the key component affecting local Piping Plover abundance at my study sites. Beaches appeared to be most critical in the ecotone, where plovers occurred at higher densities relative to the bay or lagoon beaches.

The importance of mainland habitat in the lagoon ecosystem

Plovers used beaches somewhat less frequently in the lagoon ecosystem, particularly along the long (25.4 km) South Padre Island study site. There is recent evidence to suggest that, in the lagoon ecosystem, mainland tidal flats may serve the same role for plovers as do beaches in the bay ecosystem and ecotone (Zonick et al. 1998). My mainland study sites had lower average densities of plovers throughout the year, but occasionally supported large plover flocks (> 90 birds). As described in the Study Area section, tides in the lagoon ecosystem were controlled to a much greater extent by wind forces which often created new emergent flats at mainland sites just as flats on the barrier island became flooded. Plovers in the lagoon ecosystem appeared to react to this tidal regime by moving among several barrier island and mainland tidal flats as they became emergent under the wind-tidal regime. This hypothesis is supported by my observations of what appeared to be the same color banded Piping Plover using all 3 of my lagoon ecosystem sites during the same non-breeding period (Zonick and Ryan 1994, 1995), and by a recent study demonstrating the use of both barrier island and mainland sites by radiofitted plovers (Zonick et al. 1998).

Large areas of mainland tidal flats in the lagoon ecosystem are threatened by indirect effects of maintenance operations on the Gulf Intracoastal Waterway (GIWW). Dredged material removed from the GIWW is placed on dredged material placement areas (DMPAs; also referred to as "spoil islands") that lie along the channel. DMPAs located near Laguna Atascosa National Wildlife Refuge and South Bay have formed barriers that have greatly altered the natural tidal inundation regime of neighboring mainland tidal flat systems (Farmer 1991, pers. obs.). These flats began exhibiting unusually dense blooms of *Salicornia bigelovii* and other vascular plant species in 1992 (Zonick and Ryan 1994). These blooms have persisted and may represent the first stage in the successional replacement of tidal flats by upland habitat (Zonick and Ryan 1994, Brush 1995). The importance of mainland tidal flats to Piping Plovers in the lagoon ecosystem underscores the need for remedial measures to restore a more natural tidal regime to these mainland systems (Zonick et al. 1998).

Washover pass habitat

The washover pass is another habitat that appeared to offer critical high tide refugia to Piping Plovers. Washover passes were used by Piping Plovers both as feeding and roosting areas during the study and also provide important roosting, feeding and nesting habitat for other plover species (e.g., Snowy Plovers and Wilson's Plovers: Zonick 1997). During tropical storm events, all tidal flat habitat in the lagoon ecosystem may be submerged for days or weeks. Such a phenomenon occurred in the fall of 1992 following Hurricane Andrew. Though Hurricane Andrew did not strike the Texas Coast directly, it caused extreme high tides in the Laguna Madre which inundated South Bay and other rarely submerged tidal flats for a period lasting several weeks. A similar episode occurred following Tropical Storm Josephine in 1997 (Zonick 1997). During these events, washover passes provided critical foraging and roosting habitat for Piping Plovers and other waterbirds. Newport Pass, one of the washover passes at the Packery Channel site, consistently supported large flocks of Piping Plovers during and beyond the study period (Zonick 1997).

Threats associated with the human use of Piping Plover habitat

The increasing human use of Texas beaches appears to be the greatest immediate threat to the long term recovery of Texas Piping Plover populations. For example, human use of Nueces County beaches (Nueces County includes Mustang Island, including all 3 ecotone sites, and the city of Corpus Christi) has increased at an annual rate of nearly 10% in the last decade. The rate of human use of Mustang Island may soon increase. Nueces County has recently announced its intent to elevate the causeway connecting Mustang Island to Corpus Christi, and reopen Packery Channel as a recreational waterway connecting Corpus Christi Bay with the Gulf of Mexico. These projects would clearly stimulate greater human use of the barrier island, further degrading the quality of beaches along the Texas coastal ecotone, where plovers are most dependent on protected beach habitat.

The Great Lakes and Northern Great Plains Piping Plover Recovery Plan requires that the 1998 interior population of Piping Plovers be nearly doubled (from ~ 2,500 breeding pairs to ~ 4,000 breeding pairs) before the Piping Plover interior population be delisted (U.S. Fish and Wildlife Service 1988). It is logical to expect that the Texas Gulf Coast will need to support many of these additional birds. The potential for the TGC to support an expanding Piping Plover population may hinge on the availability of protected beach habitat, particularly in the ecotone and the bay ecosystem where plovers have no