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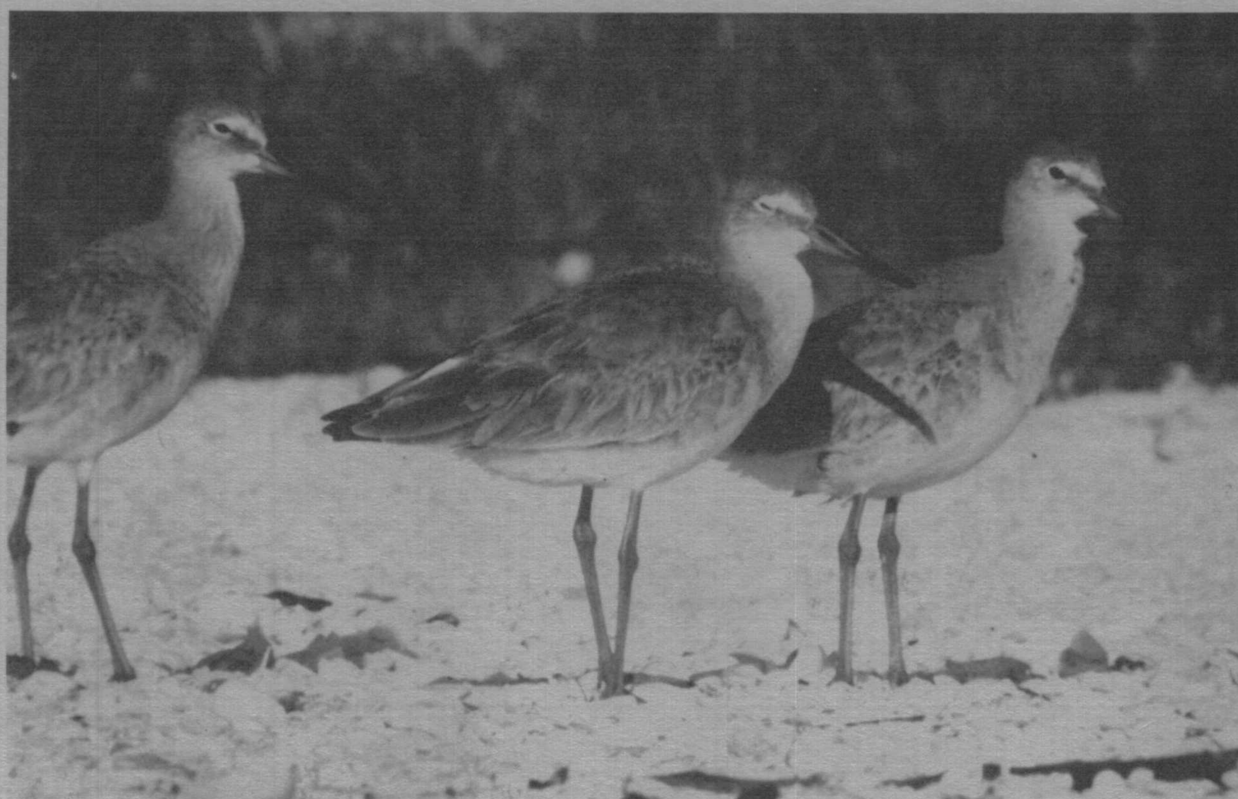

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Cover photo:

Willets (*Catoptrophorus semipalmatus*) in winter plumage. Photograph by Howard R. Spendelow, Jr.

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SEASONAL ABUNDANCE AND HABITAT-USE PATTERNS OF COASTAL BIRD POPULATIONS ON PADRE AND MUSTANG ISLAND BARRIER BEACHES [Following the Ixtoc I Oil Spill]

by

Brian R. Chapman
Department of Biology
Corpus Christi State University
Corpus Christi, TX 78142

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Project Officer
Ken Adams
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

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National Coastal Ecosystems Team
1010 Gause Boulevard
Slidell, LA 70458

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PREFACE

This report resulted from a continuation of studies begun just before oil slicks and tar balls from the Ixtoc I oil-well blowout began washing ashore on south Texas beaches. The purposes of this study were twofold: to assess the impact of the Ixtoc I oil spill on coastal bird populations and to provide baseline information about the distribution and seasonal abundance of the avian species that use south Texas beach and nearshore habitats. The report synthesizes all available data on waterbirds in the study area, including the results of censuses made from October 1979 through June 1981. The information is presented in two sections: a results and discussion section and individual species profiles. The results and discussion section describes the annual, seasonal, and daily cycles of avian abundance, distribution, and diversity. The species profiles provide distribution, status, seasonal abundance, habitat-use patterns, and oil vulnerability information for 26 species.

Suggestions or questions regarding this report or requests for copies should be directed to the following:

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

SUMMARY

Bird populations on the Gulf of Mexico beaches of Padre and Mustang Islands, Texas, varied seasonally. Peak abundances coincided with spring and fall migration. Maximum fall abundance exceeded 186 birds per km and was 1.5 times the maximum spring abundance. Minimum avian abundance in late December was less than 20 birds per km.

Avian populations on the beach were influenced by time of day, tidal stage and weather conditions. Most shorebirds such as Sanderlings, Piping Plovers, Red Knots, Willets, and Ruddy Turnstones were present throughout the day, but fed most actively during receding tides. Sanderlings, Red Knots, Black-bellied Plovers, and Piping Plovers also fed throughout the night. Blowing sand and blowing rain tended to reduce avian numbers on the beach.

Few pelagic species were observed during this study, but nearshore waters were used as feeding habitat by marine birds throughout the year. Nearshore numbers varied from 24.2 birds per km in October to 5.2 birds per km in January. Most birds fed inside of the third bar.

Birds were not uniformly distributed along the barrier island beaches. Three factors affected linear distribution patterns: composition of the beach substrate (coarse substrates attracted fewer birds); presence of storm-tidal passes (birds accumulated near the mouths of passes); and tar mats or dense concentrations of fresh tar balls (birds avoided oil).

Most birds were concentrated in the foreshore, the primary feeding habitat for shorebirds and loafing habitat for gulls and terns. Fewer birds fed or loafed on the drier habitats of the beach, the berm and the backshore. Avian abundance and distribution data from this study and data from pre- and post-Ixtoc I beach infauna studies suggest that the Ixtoc I oil spill lowered the carrying capacity of the foreshore. However, populations of most avian species have recovered and there is little evidence of permanent effects.

Seasonal abundance and distribution data were used to construct a series of profiles for species that are annually or seasonally abundant, prone to oil contamination, beach habitat dependent, and endangered or threatened. The information contained in the species profiles may be useful as baseline information in the advent of future perturbations.

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ACKNOWLEDGMENTS

Financial support for the initial portions of the study was provided by the National Oceanic and Atmospheric Administration (Contract NA-70RAC00149) and Padre Island National Seashore (Contract PX7490-9-0243). Financial support for the major portion of this study was provided by the Minerals Management Service (Contract AA851-MU9-14) and the National Coastal Ecosystems Team, U.S. Fish and Wildlife Serivce (Contract 14-16-0009-80-062). Greatly appreciated are the assistance and cooperation of Ken Adams and Dr. David M. Smith of the National Coastal Ecosystems Team, Robert P. Hannah and E. Glade Woods of the National Oceanic and Atmospheric Administration, and Robert G. Whistler of the Padre Island National Seashore.

Several people contributed significantly to the collection of field data. Gene W. Blacklock and Dr. Allan H. Chaney cooperated in the weekly avian censuses during the interim between research contracts. Dr. Pauline James, Christopher Pease, David W. Potter, and Dr. J.W. Tunnell, Jr., conducted avian censuses at various times during the study. Field data collection was made with the assistance of W.E. Bowles, Jr., Dr. Scott Holt, Roy L. Lehman, Rebecca Pease, Edna Rodriguez, and Kathy Tunnell. In addition to assisting with the avian censuses, Thomas L. Grantland designed a computer program to store and analyze the data.

The manuscript benefitted from the reviews of Dr. Eric G. Bolen, Texas Tech University; Dr. J.P. Myers, Philadelphia Academy of Natural Sciences; Dr. Robert Rogers, Minerals Management Service; Dr. James D. Brown, U.S. Fish and Wildlife Service; and Cherry Keller, Jill Parker, Dr. Jeffrey A. Spendelow, and Robin White of the National Coastal Ecosystems Team. Various drafts of the manuscript were typed by Donna M. Chapman and Frances D. Trevino.

INTRODUCTION

Although chronic minor spills (Liebow et al. 1980) and releases of oil from natural seeps (Geyer 1981) have washed ashore on the Texas coast for many years, no major oil spill affected the region prior to 1979. However, the Ixtoc I oil spill, followed within five months by the Burmah Agate oil spill, demonstrated the vulnerability of the Texas Gulf Coast to marine oil pollution. The Ixtoc I blowout resulted in the largest spill into marine environments ever documented (Woods and Hannah 1981).

In addition to being the largest oil spill in history, the Ixtoc I oil spill was unique in that Federal and State agencies had more than a month before the oil reached the Texas coast to prepare for the impact. During this period, an interagency team developed a "Damage Assessment Program" to evaluate the damage to the northwestern Gulf of Mexico resources resulting from the spill. Under the auspices of this program, a computer model was developed to predict when and where the oil would wash ashore on Texas beaches; environmentally sensitive habitats in areas of potential impact were protected by skimmers and booms, where possible, from oil intrusion; and biologists assembled pre-impact baseline data on biological populations and communities along the Texas coast. Because most marine oil spills have a devastating effect on marine bird populations (Bourne 1976), the wading and shorebird populations of the barrier island beaches of the south Texas coast were selected for detailed study (Woods and Hannah 1981).

The assessment of ecological damage depends upon adequate pre-incident population data (Fidell and DuBey 1978) and a knowledge of the distribution, habitat-use patterns, and trophic relationships of each species (Connors et al. 1979), but prior to the spill no analysis of seasonal avian population cycles or related behavioral parameters had ever been conducted on the species of the lower Texas coast. The checklists of McCamant and Whistler (1974) and Blacklock (1977) provided only subjective information on seasonal abundance of the species frequenting Padre Island. Therefore, the National Oceanic and Atmospheric Administration and Padre Island National Seashore awarded contracts to initiate a study of bird populations prior to the impact of Ixtoc I oil. The study censuses continued during the two-month period (August-September 1979) that oil contaminated the beaches.

The results of this study (Chapman 1981) showed that the Ixtoc I oil spill affected birds on the lower Texas coast. Several oil-soaked shorebirds and pelagic birds were found dead or dying on the beaches. During the period of peak contamination, most shorebirds were forced into suboptimum feeding habitats. Oiled Sanderlings (Calidris alba) and Willets (Catoptrophorus semipalmatus) exhibited altered behavioral patterns: they fed less and preened more. Specimens of Sanderlings taken during this period showed evidence of weight loss (G.W. Blacklock, pers. comm.) and kidney tissue damage resulting from oil ingestion (necropsy report provided by D.H. White, Patuxent Wildlife Research Center). However, the absence of adequate pre-impact population data and knowledge of seasonal trends precluded drawing conclusions about the impact of the spill on shorebird populations; further research was necessary to accomplish this goal.

To develop a knowledge of avian seasonal population fluctuations on Padre Island, weekly censuses were conducted with the cooperation of Gene W. Blacklock, Dr. Allan H. Chaney and Christopher Pease along an 8.1-km transect on Padre Island immediately north of the northern boundary of Padre Island National Seashore. These censuses were conducted from October 1979 to June 1981 and the resultant data were compared to those reported from Chapman (1981) to further assess the impact of the Ixtoc I oil spill on avian populations along the lower Texas coast.

In addition to providing information on seasonal avian population cycles, this study was designed to: (1) analyze the habitat-use patterns of the bird species using the Texas barrier island beaches; (2) examine the distribution of species along the beaches; (3) explore the relationship between time of day, tidal stage and species abundance on the beach; and (4) detail the daily cycle of behavior for several species. These data were used to assemble a species profile for many species of birds on the lower Texas coast.

STUDY AREA

GENERAL DESCRIPTION

Padre and Mustang Islands are two of the southernmost links in a chain of barrier islands that stretches along the Texas coastline from Galveston to the Rio Grande (Figure 1). The islands are bounded by a shallow lagoon, the Laguna Madre, and Corpus Christi Bay to the landward side, and by the Gulf of Mexico to the seaward side. Once separated by Corpus Christi Pass, the two islands have been joined since 1929 when the pass silted in (Price 1952). Two man-made channels currently bisect the island: the Port Mansfield Channel was dredged through Padre Island in 1957 (Hansen 1960) and the Corpus Christi Water Exchange Pass, locally known as the "Fish Pass," was dredged through Mustang Island in 1972 (Behrens and Watson 1973).

GEOMORPHOLOGY

Although there are disputes regarding the geological formation of barrier islands (Hoyt 1967, Fisher 1968, and others), most authors agree that the drift of sand in nearshore currents is of major importance in the development and maintenance of island structure (Bullard 1942, Otvos 1970). Lohse (1955) showed that longshore currents move sand southward from Mustang Island and from along the upper Texas coast to the Big Shell Beach in central Padre Island (Figure 1). Off Big Shell, sedimentary materials moving southward meet with sand and shell moving northward from the Rio Grande Delta. This convergence results in large beach deposits of sand and shell on the Big Shell area, and, to a lesser extent, slightly northward on Little Shell Beach. Thus, large volumes of sand are available for eolian transport inland; the remaining shell detritus is concentrated on the beach (Watson 1971).

Differences in the rates of sediment deposition result in distinctive beach profiles. The beaches on Padre and Mustang Islands usually are composed of fine sands and generally have flat profiles (Figure 2a). The Big Shell shoreface is characterized by excessive shell debris and a steep, sandy profile (Figure 2b). Little Shell beaches are composed of shell fragments that are smaller than those of the Big Shell beaches and the beach profile is not nearly as steep.

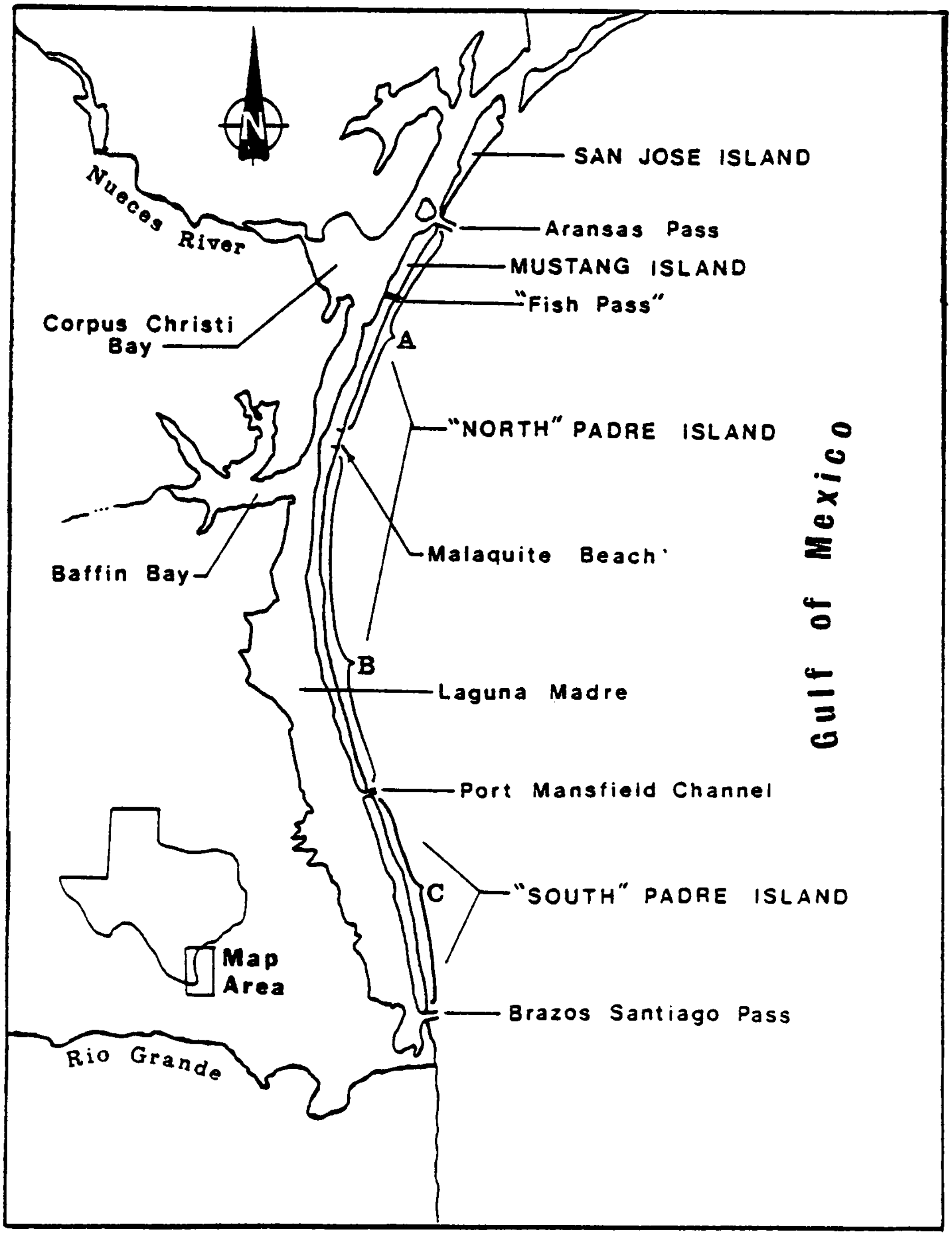

Figure 1. The study area. The three sections of the whole-island census transect are designated A, B, and C. The 8.1-km study transect is located north of Malaquite Beach.

Ecologically, the beach can be divided into three regions of varying widths (Chapman 1981). The "foreshore" region includes the area from the swash zone (the zone of wave impact) to the high tide drift line. This area

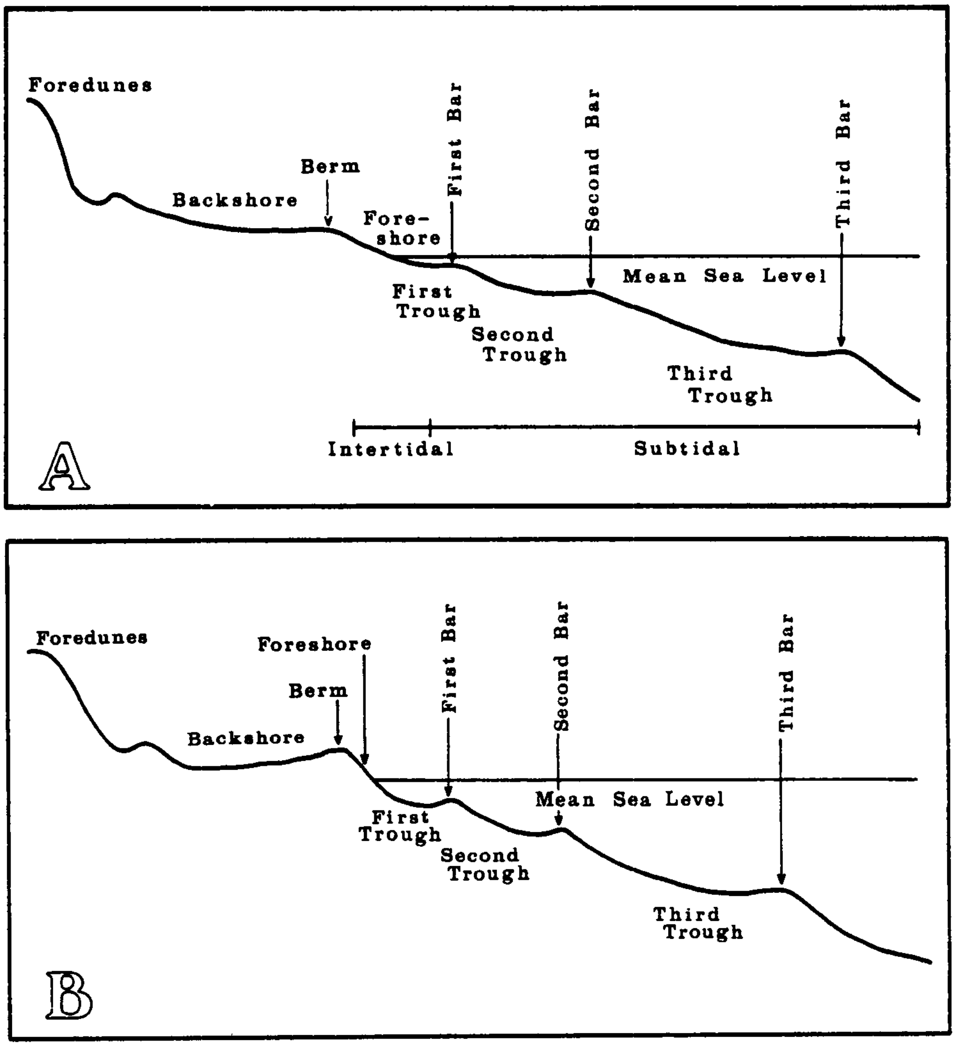

Figure 2. Profile of typical beach bar-trough system (A) and that found in the Big Shell area (B).

is usually damp and contains the greatest density of infaunal (invertebrate) species (Tunnell et al. 1981). The "berm" region is located above the foreshore in an area that is dry on the surface but damp within centimeters below the surface. This area is inundated during storm tides and typically is littered with detritus. In the Big Shell area the berm consists of the steep transition zone between the foreshore and the backshore. The "backshore" region consists of the loose, dry sand between the berm and foredune ridge (Figures 2a,b).

The nearshore typically consists of a series of three bars, sometimes called break-point bars because waves break while passing them, and intervening troughs (Figure 2a). The contours of the bars are nearly parallel to the shore throughout most of Padre Island's length, but the pattern breaks up toward the southern end and during certain weather conditions. The longshore current flows in the troughs (Hunter et al. 1972). Because longshore current direction is a function of wind direction (Weise and White 1980), longshore currents move predominately northward during most of the year, but switch to the south during the late fall and winter.

CLIMATE

The climate of Padre and Mustang Islands varies from dry subtropical at the northern end to semiarid at the southern end (Thornthwaite 1948). Average annual rainfall ranges from approximately 74 cm at the northern end of the island to 66 cm in the south. Evaporation rates increase southward along the island. As a result of the lower rainfall and higher evaporation, the southern end of the island has different environments from the northern end. The width of the backshore region is greater, the foredune ridge is smaller, and the grassland habitat characteristic of the middle portion of the island's northern end is absent or reduced in the southern end.

The average annual temperature is 22°C. During the summer temperatures on the mainland commonly exceed 37°C, but island temperatures are moderated by tropical maritime air coming off the Gulf of Mexico and rarely exceed 36°C. The tropical maritime air generally prevents the occurance of freezing temperatures on the island during the short winter (Dahl et al. 1975).

The prevailing winds are southeasterly, but from December through February wind direction fluctuates between northerly and southeasterly when polar cold fronts ("Northers") pass through the area (Weise and White 1980). Most of the cold fronts are accompanied by strong, gusty winds and rain. Prior to the passage of a cold front, strong southerly winds push water over the berm and backshore regions of the beach to the dunes. When the wind switches to a northerly direction with the passage of the front, the currents transport sand and beach sediments into the Gulf of Mexico (Brown et al. 1976). Thus, the beach profile is typically flatter during the winter months.

Hurricanes strike the Texas coast at an average rate of once every 2.3 years (Hayes 1967). Many of these storms produce tidal surges that erode the beach and dune systems. In August 1980, just prior to this study, Hurricane Allen passed over the Port Mansfield Channel area and cut more than 50 temporary passes through the islands. Six of the passes remained open until mid-February 1981, when a tidal surge of approximately 2.5 m severely eroded the beach and leveled most of the dunes in an area 32 km to either side of the channel.

Usually there is only one high tide and one low tide per day, although two tides occur at certain times of the month. Normal tidal changes along the Texas coast are small in comparison to the tidal ranges of the Atlantic and Pacific coasts (Weise and White 1980). Astronomical tides average about 0.4 m along Padre Island, but strong onshore winds preceeding a winter cold front may negate the astronomical tidal cycle and push water high onto the beach for long periods (Hunter et al. 1972).

IXTOC I OIL SPILL

CHRONOLOGY

On 3 June 1979 the Ixtoc I oil drilling rig in the Bay of Campeche, Mexico, blew out and began to release oil into the Gulf of Mexico. The initial rate of release was estimated to be 30,000 barrels per day. Released under pressure at the sea floor, much of the oil was thoroughly mixed with seawater to form a thick emulsion called "mousse" that floated in large masses ("pancakes") on the surface. The remainder of the oil formed thick, light slicks called "sheen."

Ixtoc I oil was first observed on south Texas beaches on 6 August when light swashes of tar balls came ashore on 27 km of shoreline (Gundlach et al. 1981c). There was no further impact until heavier oil concentrations began washing ashore on 13 August. By 18 August most of northern Padre Island was lightly oiled and scattered areas were heavily covered. During this period the area around the Port Mansfield Channel received the heaviest impact.

After a week without significant oil impact, thick patches of mousse began to wash ashore in the area from the Port Mansfield Channel north to Aransas Pass. By 28 August most foreshore areas of northern Padre Island were moderately covered by tar balls and mousse, and oil sheen was present on 30 to 40 percent of the offshore waters (Gundlach et al. 1981c).

The period of heaviest oil impact occurred from 29 August through 1 September 1979. During this period, oil coverage was light (10 to 24 percent surface coverage of a 10-m transect in the intertidal zone) to moderate (25-64 percent surface coverage) along the entire south Texas barrier island beachfront; heavy (65+ percent coverage) concentrations of oil were present in scattered locations (see Gundlach et al. 1981b for a description of methods used to estimate oil concentrations). Gundlach et al. (1981c) calculated that by 1 September, approximately 3500 metric tons of oil had accumulated on south Texas barrier island beaches. The maximum concentration of intertidal oil along the Padre Island shoreline, regardless of the day observed, is shown in Figure 3.

No new oil washed ashore after 2 September and during the following two weeks a series of tropical depressions moved into the area. The depressions generated an increase in tides of over 60 cm and the strong onshore winds

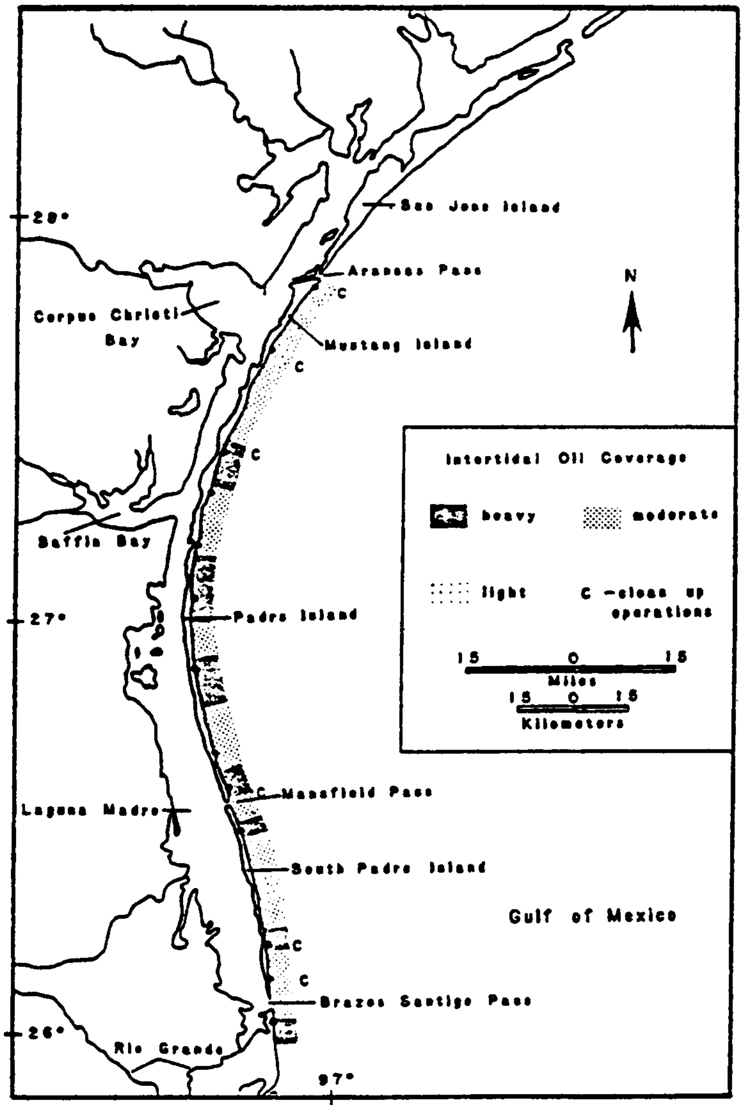

Figure 3. Maximum intertidal oil coverage along the south Texas coast during the Ixtoc I Oil spill from 15 August to 15 September 1979. Areas of cleanup activity also are indicated. Modified from Gundlach et al. (1981c) and Kindinger (1981).

produced 1- to 2-m waves. The wave action and associated currents pushed some of the oil deposits back to the base of the dunes, but about 90 percent of the oil was removed from the beach (Gundlach et al. 1981b). Shell beaches, however, retained large amounts of oil. The fine-sand beaches resisted oil penetration whereas oil readily percolated into the loosely packed and poorly sorted sediments of the shell beaches (Gundlach and Finkelstein 1981). As a result, surface oil deposits on compact, fine-sand beaches were more readily removed by wave action.

The flow from Ixtoc I gradually decreased during the early months of 1980 and, after the successful completion of a relief well, finally stopped on 23 March 1980. During the period of oil release, an estimated 3.3 million barrels of oil were released into the Gulf of Mexico (Woods and Hannah 1981).

IMPACTS

As expected, the beaches on the seaward side of the south Texas barrier islands received the brunt of the Ixtoc I oil spill impact. Small amounts of oil got past the booms and into the estuarine environments behind the barrier islands, but the oil did not go very far and damage to the wetlands habitat was negligible (Woods and Hannah 1981). Fortunately, only 0.8 percent of the oil released by Ixtoc I ever washed ashore in Texas (Gundlach et al. 1981c). The remainder degraded as a result of weathering (MacKay et al. 1981), was dispersed or sunk by aerially applied chemicals (Lindblom et al. 1981), or was confined to Mexican waters by seasonal currents and winds (Gundlach et al. 1981c).

It was difficult to determine the exact amount of oil present in any given area because waves and tides constantly redistributed the sand, tar and mousse. Gundlach et al. (1981c) concluded that most of the mousse and tar present in the beach-nearshore region was concentrated in the intertidal zone, but it was periodically buried and uncovered. Gundlach et al. (1981c) calculated the intertidal oil content at 15 sample stations and found that approximately 31 percent of the beached oil was on the surface, 53 percent was buried, and 16 percent remained within the swash zone and first trough. Along the shell beaches, oil was mixed with sediment as deep as 40 cm, whereas it reached a depth of only 7 cm on fine-grained beaches (Gundlach et al. 1981b).

After the passage of the tropical depressions in September 1979, at least 36 "tar mats" (asphalt-like deposits of mousse-sediment aggregation) were discovered, most within an area 16 km to either side of the Port Mansfield Channel. Most of the tar mats were large, covering areas of up to 72 m in length and 8 m in width, and penetrated to a depth of 25 cm. Although most tar mats were rapidly covered by sediments, many were periodically uncovered by storm tides.

When the tar mats are exposed, wave action breaks off chunks of the aggregate and releases volatile (i.e., aromatic and buoyant) oils that form small slicks. The chunks may wash up onto the beach and be melted by the sun to form sticky tar balls. Despite their tendency to break apart, all of the tar mats survived the waves and 4-m tides associated with Hurricane Allen in August 1980 and remained essentially intact to June 1981.

The mousse pancakes, tar balls, and tar mats that accumulated along the south Texas coastline came in direct contact with the infauna of the intertidal zone and may have been directly toxic or may have physically smothered some organisms (Kindinger 1981, Tunnell et al. 1981). As a result, a 70% reduction in the total number of infaunal organisms was observed when pre- and post-spill samples were compared (Kindinger 1981). Although other factors such as the wave action associated with the tropical depression may have contributed to the decline in infauna, both Kindinger (1981) and Tunnell et al. (1981) noted that the greatest population decreases occurred in areas of highest oil accumulation.

The decline in intertidal infauna may have contributed to the shifts in habitat and declines in bird populations observed by Chapman (1981). As the patches of oil washed ashore, the shorebirds avoided contaminated areas and concentrated in oil-free areas. When the entire coastline was coated with oil, most of the shorebirds avoided the intertidal zone and occupied backshore or estuarine habitats. Such habitat shifts could have been related to reduced food supplies because most shorebirds feed on intertidal infauna. Perhaps as a consequence of the habitat shifts, few birds (less than 10% of the total population) ever exhibited signs of conspicuous oiling.

Reduced infaunal populations may also explain the apparent avian population decline reported by Chapman (1981). In late September 1979 avian populations did not equal or surpass the totals observed prior to the oil impact, whereas an increase due to migration had been expected. Since migratory birds depend on an abundant and readily available food supply in stopover areas, the shorebirds that regularly stop in the fall to feed on south Texas beaches may have moved to other habitats or areas. If this was the case, then the avian population decline was artifactual. However, there were few coastal habitats south of the Rio Grande that were not heavily impacted by oil (H. Hildebrand, pers. comm.) and, thus, there may not have been suitable feeding habitat available for a great distance, a factor that may have contributed to population losses or displacement during migration.

CHRONIC OIL SPILLS

Although the Gulf Coast did not experience a major oil spill prior to 1979, the annual quantity of oil and petroleum products spilled into the Gulf of Mexico is high. Between 1972 and 1979, more than two million barrels of oil and other substances were reported spilled within the United States jurisdictional limits of the Gulf of Mexico (Liebow et al. 1980). The total amount of petroleum hydrocarbons released into the marine waters from unreported spills or runoff was probably much higher (National Academy of Sciences 1975).

Major oil spills can produce adverse effects for protracted periods (Blumer 1971), but low-level chronic oil pollution may be ecologically more serious (Armstrong et al. 1979). Continuous introduction of small petroleum quantities may result in hydrocarbon accumulations in sediments that become toxic to benthic organisms and thereby disrupt food chains. Furthermore, some infaunal species remove hydrocarbons from the water while feeding, but lack the enzymes to metabolize these compounds (Lee et al. 1972, Lee 1977). When birds feed on these species, petroleum hydrocarbons acquired through the diet may affect liver function (Hartung and Hunt 1966) and reduce reproductive success (Albers 1977). As a result of such dietary intake of petroleum, avian populations generally decline (Tanis and Mozer-Bruyns 1968, Bourne 1976, Vermeer 1976).

As a result of chronic oil spills, tar balls and, occasionally, sheen, wash ashore on the Texas coast continuously. During the period from 1 October 1979 to 30 June 1981, 26 fresh patches of tar balls were observed on Padre and Mustang Islands. While most of the patches were less than 0.5 km long and coverage was light (5%-20% intertidal surface coverage), several patches were over 10 km in length and coverage was "moderate" (25%-64% intertidal surface coverage).

METHODS

AVIAN CENSUSES

There was no "best" method for making a precise estimate of avian species abundance on an island having a beach as long as Padre Island's. It was too difficult and expensive to conduct daily or weekly censuses of the entire island. Such counts were likely to contain errors due to time of day; some species, such as gulls and terns, tended to remain away from the beach in the morning and gather in large flocks in late afternoon. Tidal stage also affected shorebird numbers. Contrariwise, censuses taken in shorter sample areas did not include counts of all species because such areas did not include all types of substrate and hence, all feeding areas. Therefore, censuses of both short sample areas and the entire island were conducted during this study to insure that all species utilizing the Gulf beaches of Padre Island were documented and that variations in avian numbers due to time of day, tidal stage, and oil concentration were noted.

General Census Methods

During each census all birds observed on the beach within the designated census area were counted from a four-wheel-drive vehicle. The vehicle was driven slowly along the middle portion of the beach and intermittent stops were made to verify species identifications. Each bird was identified to species using unaided vision, 7x or 10x binoculars, or a 25-45x zoom spotting telescope. Flying and swimming birds were not included in the beach counts and care was taken to avoid counting a bird twice.

The position of each bird on the beach was recorded with respect to the three ecologic zones (foreshore, berm, and backshore) previously described. Whenever flocks of birds were encountered, the individuals of each species were counted and the position of the flock was recorded as a unit.

Following each census the data from the three regions were added to obtain a total count for each species and for the entire census. These totals were divided by the length of the census transect to compute abundance for each species and for the census. Species diversity for each census was calculated using the formula of Menhinck (1964):

$$D = \frac{S}{\sqrt{N}}$$

where D represented species diversity, S represented the number of species, and N represented the total number of individuals. The percentage of the total population in each ecologic zone was also calculated. The total number of birds counted on each census during a month was added and divided by total distance censused to obtain a mean value for the month. Seasonal comparisons were made by combining data from three-month periods corresponding to winter (December to February), spring (March to May), summer (June to August), and fall (September to November).

On each census the location and extent of oil-contaminated areas were recorded. The type of contamination (i.e., oil sheen, tar balls, or mousse) and distribution of the oil in the habitat were noted. Oil density was estimated in the manner described by Hayes and Gundlach (1978). Individual birds (including each member of a flock) were observed for evidence of oil on their plumage, bills, and feet. A separate count of oiled birds was made by species and the extent and position of the oil on the body of each contaminated bird was noted.

Weekly Censuses

From 3 October 1979 to 30 June 1981, a weekly census was conducted on the beach along an 8.1-km (5-odometer mi) transect in a study area located immediately north of the Padre Island National Seashore northern boundary (Figure 1). Ninety weekly censuses were conducted; no census was taken during the first week of January 1980 because of high tides. The study area was censused daily at dawn, noon, and dusk. Each census took approximately one hour. These censuses had three purposes: (1) to record weekly changes in species abundance and species composition over a long period; (2) to compare the species abundance, composition, and diversity observed in the weekly censuses to similar data from whole-island censuses made during the same week; and (3) to determine the daily effects of time and tidal conditions on species abundance and species composition. The abundance data from the weekly census were compared to the data from the whole-island censuses (see below) using Kendall's coefficient of rank correlation (Sokal and Rohlf 1969).

For each census day, the morning total was used as a baseline and compared to the midday total for each species. Similarly, the midday total was used as a baseline for comparison with the evening total. Changes greater than 10% in numbers of birds were classified as positive (+), no change (0), and negative (-). Tidal cycles were determined from National Weather Service charts for the "Gulf Pier" at Port Aransas, Texas. The tidal cycle was divided into four stages: high and low occurred from one hour before to one hour after the times of dead high and dead low tides; rising and falling tides were the remaining, intervening periods (see Duffy et al. 1981). Calculations of chi-square and Cramer's V for nominal data by the CROSSTABS subprogram of the Statistical Package for the Social Sciences (SPSS) computer program (Nie et al. 1975) were used to determine overall correlations of tidal cycles with census counts.

Whole-Island Censuses

Censuses of all birds on the Gulf beaches of Padre and Mustang Islands were conducted twice each month from 1 October 1980 to 30 June 1981 (Total = 18). Each census was conducted by three teams of two observers working simultaneously in adjoining study regions. They were of unequal length and were delineated by barriers to continuous access: Region A (48.3 km) was from Brazos Santiago Pass (South Padre Island) to the Port Mansfield Channel; Region B (96.6 km) was from the Port Mansfield Channel to the south barricade of Malaquite Beach, a 7.9-km pedestrian-only beach within Padre Island National Seashore; and Region C (45.1 km) was from the north barricade of Malaquite Beach to the Port Aransas Ship Channel. Birds within the Malaquite beach barricades were not censused because foot censuses proved unreliable.

The odometer mileage was registered at the beginning of each census trip and the data were written on sheets that were changed at 3.2-km intervals (each 2-mi odometer revolution) to record the linear distribution of birds. Notes on the presence of oil sheen, mousse, tar balls, and tar mats; on the existence of passes; and on the composition of beach substrate were made on each sheet to permit the comparison of avian abundance with physical conditions. From this information inferences were made concerning beach productivity and avian abundance, and the impacts of future spills.

During each whole-island census, 15 min stops were made every 16 km to scan the nearshore area for birds. Individual birds within a 0.5-km radius were identified to species, whenever possible, using a 20-45x spotting scope. Data on activity, flight direction and approximate distance from shore were recorded for each individual or flock. These data were used to assess the abundance of birds using nearshore waters for feeding, swimming or migration on a seasonal basis. The data also were used to describe feeding habitat preferences of the species discussed in the "Species Profile" section.

AVIAN BEHAVIORAL STUDIES

Diurnal Behavior

Five shorebird species were selected for a quantitative behavioral study: Sanderling (*Calidris alba*); Red Knot (*Calidris canutus*); Willet (*Catoptrophorus semipalmatus*); Piping Plover (*Charadrius melodus*); and Black-bellied Plover (*Pluvialis squatarola*). These species were selected because of their abundance during all or part of the year and their almost exclusive use of the foreshore for feeding. Although few oiled birds were observed, the behavior patterns of oiled birds were compared with those of clean birds.

The method used for recording behavioral activities was similar to the time-budget methods of Dwyer (1975), Afton (1979), and Chapman (1981). Birds were observed weekly for 1 to 6 hours with binoculars (10x) from a parked vehicle. Activities of individual birds were observed and recorded for 5- to 15-min intervals using a portable tape recorder. Activities were divided into five categories: (1) feeding, (2) resting (loafing and sleeping),

(3) comfort movements, (4) locomotion (walking and flying), and (5) alert and social interactions (alert posture, threat displays, and pursuit). As a second measure of feeding activity, behavior of a feeding individual was watched for 2-10 min and the number of feeding attempts (pecks) was counted. Notes were taken on the ecological location and substrate upon which feeding occurred, but no attempt was made to determine feeding success. Behavioral observations were usually, but not always, conducted on the same day as the weekly censuses.

Nocturnal Behavior

Nocturnal censuses of birds along a 3.2-km stretch of beach just north of the northern Malaquite Beach barrier were conducted at two-hour intervals from 2200 h to 0400 h (inclusive) twice each month throughout the study period. Birds on the beach were counted from a vehicle with a 20,000-candlepower spotlight fitted with a red filter. In the interim between censuses feeding rates of active individuals were recorded using feeding attempt counts. Notes were taken on the general behavior and habitat use of each individual observed during the night. Few observations were made in areas other than the foreshore because the uneven topography obscured the birds.

SPECIES PROFILES

Because Connors et al. (1979) emphasized the importance of having species-specific information on distribution, habitat use, trophic relationships, and behavior, for many of the species observed the data obtained in this study were assembled into a series of Species Profiles. Criteria for selection were: (1) high annual or seasonal abundance, (2) habitat-use patterns that lead to vulnerability to oil contamination, (3) dependence upon use of the barrier island beach or nearshore habitat, and (4) endangered or threatened status. Thus, the Species Profiles section includes many species in addition to the five chosen for detailed behavioral study.

Nomenclature and taxonomic listings follow the order of the American Ornithologists' Union (AOU) Checklist (1957) or its Thirty-fourth Supplement (1982).

RESULTS AND DISCUSSION

SPECIES OCCURRENCE AND DIVERSITY

Table 1 lists all of the coastal species known to occur along the south Texas coast. The list was compiled from observations during this study, state records (Oberholser and Kincaid 1974), and observations reported by Lowery and Newmann (1954) Duncan and Havard (1980) and Fritts and Reynolds (1981). The table also provides an indication of habitat-use patterns, relative frequency of occurrence, and seasonality.

Monthly average species diversities are listed in Table 2. Avian species diversity remained relatively constant throughout the year, but declined during the spring. Diversity is a statistical parameter that is dependent upon two factors (Odum 1971): the number of species present (species richness) and the relative abundance of each species (species evenness). Species richness was greater during the spring, but few species were present in large numbers during these three months. Fewer species used the barrier islands beaches during other periods, but their populations tended to be more equal in size.

SEASONAL ABUNDANCE PATTERNS

Annual Cycle of Abundance

The abundance of birds fluctuated seasonally. Peak abundance coincided with spring and fall migrations (Figure 4). In both 1980 and 1981 the abundance of birds on barrier island beaches began to increase in late February as flocks of Sanderlings, Herring Gulls, Ring-billed Gulls, and Forster's Terns arrived. Abundance continued to increase throughout March and early April as the numbers of Sanderlings and gulls increased as flocks of Red Knots, Willets, Piping Plovers, Ruddy Turnstones, and Royal Terns gathered on the beach. Peak spring abundance was reached in late April.

Avian abundance declined in the late spring and early summer (Figure 4) as flocks of shorebirds, gulls, and terns departed for their breeding grounds. Minimum summer abundance was reached in mid-June when fewer than 20 birds per km were recorded in some weeks. Most of the birds present on the beach in the summer were gulls and terns (Table 3). Laughing Gulls, Royal Terns, and

Table 1. Checklist of species that utilize the beach (B), nearshore (N), and pelagic (P) habitats of the southern Texas coast. Occurrence in the above habitats is indicated by R (regular), I (irregular) and A (accidental). Seasonality is indicated by M (spring and fall migrant), S (summer resident), W (winter resident), A (annual resident), or U (unknown). Information on pelagic species is from Duncan and Havard (1980) and Fritts and Reynolds (1981). Species observed during this study are marked with an asterisk (*).

Common name	Scientific name	Habitat	Occurrence-Seasonality
Common Loon	*Gavia immer	N	R-W
Least Grebe	*Tachybaptus dominicus	N	I-A
Pied-billed Grebe	*Podilymbus podiceps	N	R-M
Eared Grebe	*Podiceps nigricollis	N	R-M
Yellow-nosed Albatross	Diomedea chlororhynchos	P	A-U
Cory's Shearwater	Calonectris diomedea	P	R-U
Greater Shearwater	Puffinus gravis	P	R-U
Sooty Shearwater	Puffinus griseus	P	A-U
Manx Shearwater	Puffinus puffinus	P	A-U
Audubon's Shearwater	Puffinus lherminieri	P	R-A
Wilson's Storm-Petrel	Oceanites oceanicus	P	R-S
Leach's Storm-Petrel	Oceanodroma leucorhoa	P	I-S
White-tailed Tropicbird	Phaethon lepturus	P	R-A
Masked Booby	*Sula dactylatra	P	R-A
Blue-footed Booby	Sula nebouxii	P	A-U
Brown Booby	Sula leucogaster	P	R-S
Red-footed Booby	Sula sula	P	A-U
Northern Gannet	Sula bassanus	P	R-W

(continued)

Table 1. Continued.

Common name	Scientific name	Habitat	Occurrence-Seasonality
American White Pelican	*Pelecanus erythrorhynchos	N	I-A
Brown Pelican	*Pelecanus occidentalis	N	R-M
Double-crested Cormorant	*Phalacrocorax auritus	N	R-W
Olivaceous Cormorant	*Phalacrocorax olivaceus	N	R-W
Magnificent Frigatebird	*Fregata magnificens	N	R-M
Great Blue Heron	*Ardea herodias	B	R-A
Great Egret	*Casmerodius albus	B	I-S
Snowy Egret	*Egretta thula	B	I-S
Tricolor Heron	*Egretta tricolor	B	I-S
Reddish Egret	*Egretta rufescens	B	I-S
Little Blue Heron	*Egretta caerula	B	I-S
Cattle Egret	*Bubulcus ibis	B	R-M
Black-crowned Night Heron	*Nycticorax nycticorax	B	R-S
Yellow-crowned Night Heron	*Nycticorax violaceus	B	R-S
White Ibis	*Eudocimus albus	N	I-M
White-faced Ibis	*Plegadis chihi	N	R-M
Roseate Spoonbill	*Ajaia ajaja	B	I-S
Mallard	*Anas platyrhynchos	N	R-M
Mottled Duck	*Anas fulvigula	B	I-S

(continued)

Table 1. Continued.

Common name	Scientific name	Habitat	Occurrence-Seasonality
Gadwall	*Anas strepera	N	R-M
Northern Pintail	*Anas acuta	N	R-M
Green-winged Teal	*Anas crecca	N	R-M
Blue-winged Teal	*Anas discors	N	R-M
American Wigeon	*Anas americana	N	R-M
Redhead	*Aythya americana	N	R-M
Canvasback	*Aythya valisineria	N	R-M
Lesser Scaup	*Aythya affinis	N	R-M
Bufflehead	*Bucephala albeola	N	R-M
Oldsquaw	*Clangula hyemalis	N	I-W
Surf Scoter	*Melanitta perspicillata	N	I-W
Red-breasted Merganser	*Mergus serrator	N	R-M
White-tailed Hawk	*Buteo albicaudatus	B	R-W
Northern Harrier	*Circus cyaneus	B	R-W
Osprey	*Pandion haliaetus	N	R-W
Peregrine Falcon	*Falco peregrinus	B	R-W
American Kestrel	*Falco sparverius	B	R-W
Northern Bobwhite	*Colinus virginianus	B	I-S
American Coot	*Fulica americana	N	I-M
American Oystercatcher	*Haematopus palliatus	B	R-A
Semipalmated Plover	*Charadrius semipalmatus	B	R-M

(continued)

Table 1. Continued.

Common name	Scientific name	Habitat	Occurrence-Seasonality
Piping Plover	**Charadrius melodus*	B	R-M
Snowy Plover	**Charadrius alexanderinus*	B	R-M
Wilson's Plover	**Charadrius wilsonia*	B	R-W
Killdeer	**Charadrius vociferus*	B	I-A
Lesser Golden Plover	**Pluvialis dominica*	B	R-M
Black-bellied Plover	**Pluvialis squatarola*	B	R-A
Ruddy Turnstone	**Arenaria interpres*	B	R-A
Long-billed Curlew	**Numenius americanus*	B	R-A
Upland Sandpiper	**Bartramia longicauda*	B	A-M
Spotted Sandpiper	**Actitis macularia*	B	I-M
Willet	**Catoptophorus semipalmatus*	B	I-M
Greater Yellowlegs	**Tringa melanoleuca*	B	I-M
Lesser Yellowlegs	**Tringa flavipes*	B	R-A
Solitary Sandpiper	**Tringa solitaria*	B	I-M
Red Knot	**Calidris canutus*	B	R-M
Pectoral Sandpiper	**Calidris melanotos*	B	I-M
Baird's Sandpiper	**Calidris bairdii*	B	I-M
Least Sandpiper	**Calidris minutilla*	B	R-M
Dunlin	**Calidris alpina*	B	R-M
Semipalmated Sandpiper	**Calidris pusilla*	B	I-M
Western Sandpiper	**Calidris mauri*	B	R-M

(continued)

Table 1. Continued.

Common name	Scientific name	Habitat	Occurrence-Seasonality
Sanderling	*Calidris alba	B	R-A
Short-billed Dowitcher	*Limnodromus griseus	B	I-M
Long-billed Dowitcher	*Limnodromus scolopaceus	B	I-M
Buff-breasted Sandpiper	*Tryngites subruficollis	B	I-M
Marbled Godwit	*Limosa fedoa	B	I-M
American Avocet	*Recurvirostra americana	B	R-M
Black-necked Stilt	*Himantopus mexicanus	B	I-M
Red Phalarope	Phalaropus fulicaria	P	I-U
Red-necked Phalarope	Phalaropus lobatus	N	I-U
Parasitic Jeager	*Stercorarius parasiticus	P	I-U
Long-tailed Jeager	Stercorarius longicaudus	P	I-U
Great Black-backed Gull	*Larus marinus	N	A-W
Herring Gull	*Larus argentatus	B	R-W
Ring-billed Gull	*Larus delawarensis	B,N	R-W
Laughing Gull	*Larus atricilla	B,N	R-W
Franklin's Gull	*Larus pipixcan	B	I-W
Bonaparte's Gull	*Larus philadelphia	B,N	R-W
Black-legged Kittiwake	Rissa tridactyla	P	R-W
Sabine's Gull	*Xema sabini	P	I-U

(continued)

Table 1. Concluded.

Common name	Scientific name	Habitat	Occurrence-Seasonality
Gull-billed Tern	*Sterna nilotica	B	I-A
Forster's Tern	*Sterna forsteri	B,N	R-M
Common Tern	*Sterna hirundo	B,N	R-M
Arctic Tern	Sterna paradisaea	P	A-U
Roseate Tern	*Sterna dougallii	P	I-S
Sooty Tern	*Sterna fuscata	B,P	I-S
Bridled Tern	Sterna anaethetus	P	R-S
Least Tern	*Sterna antillarum	B,N	R-M
Royal Tern	*Sterna maxima	B,N	R-A
Sandwich Tern	*Sterna sandvicensis	B,N	R-A
Caspian Tern	*Sterna caspia	B,N	R-A
Black Tern	*Chlidonias niger	B	R-M
Brown Noddy	*Anous stolidus	P	I-S
Black Skimmer	*Rynchops niger	B,N	I-S
Horned Lark	*Eremophila alpestris	B	R-A

Table 2. Monthly average abundance and species diversity of coastal birds observed on Padre and Mustang Islands, October 1979 - June 1981. Data represents mean birds per km (± standard deviation) from whole-island censuses.

	MONTH									
SPECIES	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
Sanderling	27.9 (2.2)	7.9 (2.3)	8.3 (3.3)	8.6 (3.2)	8.6 (0.9)	15.9 (2.8)	36.1 (9.1)	20.5 (4.7)	6.7 (2.3)	15.6
Willet	4.3 (1.6)	1.8 (0.5)	1.8 (1.3)	2.4 (0.7)	3.1 (1.4)	2.3 (1.2)	5.8 (0.4)	4.8 (3.8)	2.4 (1.4)	4.9
Red Knot	3.5 (2.6)	0.5 (0.4)	0.1 (0.1)	0.0	0.5 (0.2)	0.7 (0.7)	6.0 (5.8)	9.0 (4.3)	0.2 (0.2)	2.3
Black-bellied Plover	2.0 (0.2)	0.9 (0.3)	0.8 (0.6)	0.4 (0.0)	1.0 (1.0)	0.6 (0.5)	3.3 (1.1)	1.3 (1.2)	0.6 (0.2)	1.2
Ruddy Turnstone	2.5 (0.5)	0.6 (0.2)	0.3 (0.3)	0.2 (0.0)	0.3 (0.0)	0.8 (0.3)	6.5 (2.4)	5.4 (2.0)	0.2 (0.1)	1.9
Piping Plover	1.8 (1.2)	0.9 (0.8)	0.2 (0.1)	0.1 (0.0)	0.2 (0.2)	0.1 (0.1)	0.4 (0.4)	0.0	0.0	0.4
Snowy Plover	0.5 (0.2)	0.2 (0.1)	0.2 (0.1)	0.2 (0.0)	0.2 (0.2)	0.1 (0.1)	0.2 (0.2)	0.0	0.0	0.1
Royal Tern	1.4 (1.1)	2.4 (1.6)	1.5 (0.9)	1.1 (0.1)	3.6 (0.9)	1.6 (0.2)	7.8 (1.7)	4.5 (2.3)	3.4 (1.5)	3.6
Caspian Tern	1.0 (0.6)	1.8 (1.3)	0.2 (0.2)	0.0	0.0	0.2 (0.1)	0.1 (0.0)	0.0	0.1 (0.0)	1.5
Forster's Tern	0.8 (0.8)	1.8 (1.0)	1.0 (0.7)	1.7 (0.3)	4.4 (1.5)	0.3 (0.3)	0.1 (0.0)	0.0	0.0	2.0
Sandwich Tern	0.3 (0.1)	0.5 (0.5)	0.5 (0.5)	0.1 (0.1)	0.1 (0.1)	0.4 (0.3)	3.8 (1.4)	0.8 (0.5)	1.3 (1.2)	0.8
Least Tern	0.0	0.0	0.0	0.0	0.0	0.0	1.7 (0.5)	2.2 (0.6)	1.3 (0.2)	0.6
Black Tern	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9 (0.9)	2.2 (2.2)	0.3
Laughing Gull	7.1 (3.3	4.8 (1.9)	3.7 (1.8)	2.3 (0.8)	2.6 (0.8)	11.8 (5.8)	12.0 (0.4)	9.3 (0.5)	9.1 (2.8)	7.0
Herring Gull	0.2 (0.1)	0.9 (0.2)	1.1 (0.3)	1.1 (0.1)	2.0 (0.7)	1.7 (0.3)	1.5 (0.8)	0.1 (0.1)	0.0	0.9
Ring-billed Gull	2.4 (0.5)	5.0 (2.3)	4.5 (2.7)	4.3 (0.6)	6.2 (2.2)	5.0 (3.4)	1.0 (0.1)	0.1 (0.1)	0.0	3.1
Great Blue Heron	0.5 (0.3)	0.3 (0.0)	0.3 (0.1)	0.1 (0.1)	0.2 (0.1)	0.0	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)	0.2
Other Species	1.3 (0.3)	0.6 (0.1)	0.2 (0.0)	0.5 (0.2)	1.6 (0.7)	0.2 (0.1)	0.4 (0.3)	0.0	0.1 (0.1)	0.5
Mean Individuals	6447	4456	2555	3485	6538	5230	13,909	8033	4285	54,938
Number of Species	28	23	23	26	24	22	29	17	20	
Diversity	0.35	0.34	0.46	0.44	0.30	0.30	0.26	0.19	0.31	

Sandwich Terns nested in large colonies on islands in the Laguna Madre and flew across Padre Island to feed nearshore in the Gulf of Mexico. Between rounds of feeding, the birds loafed in large, mixed-species flocks on the beach. Few shorebirds remained on Gulf Coast beaches through the summer and most of those that did were in subadult plumage.

In early August avian abundance began to increase with the onset of fall migration (Figure 4). Maximum fall abundance, reached in late September, exceeded an average of 186 birds per km during some weeks and surpassed maximum spring density by a factor of 1.5. Although populations of most species increased during the fall, the greatest factor affecting the increase

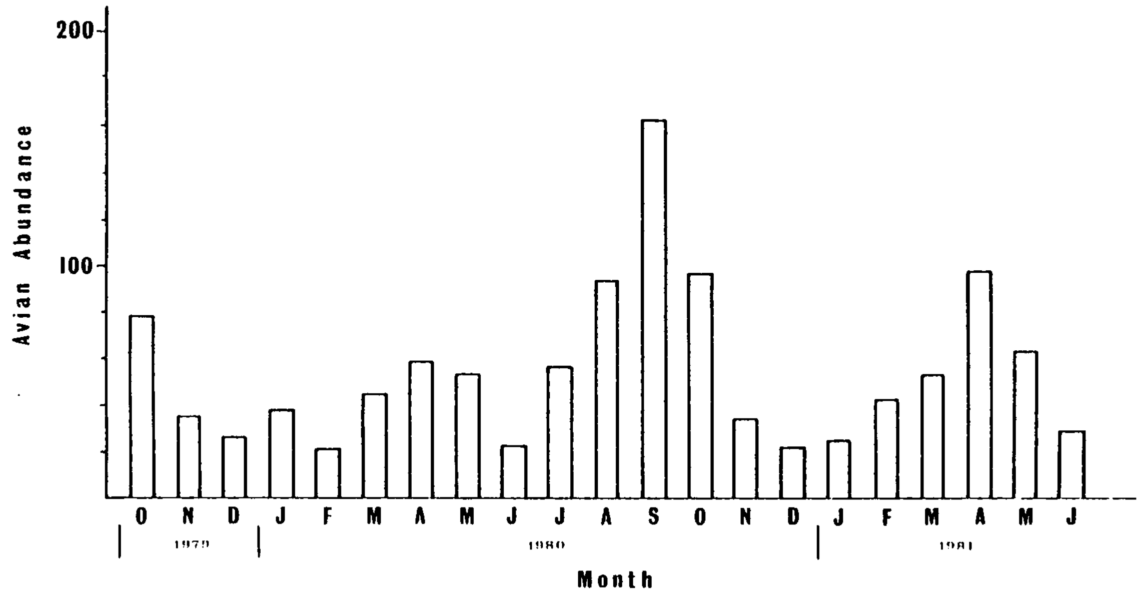

Figure 4. Average monthly total avian abundance (birds/km) along the 8.1-km transect from October 1979 to June 1981.

was an influx of terns (Table 3). Several species of terns that were seen only occasionally during the spring censuses were seen in large numbers on the beach during the fall; Least Terns and Black Terns showed the most noteworthy fall increases.

The abundance of birds began to decline in early October and the decline continued through December (Figure 4). Mass migrations were observed just prior to cold fronts. After each successive cold front fewer birds were counted on the beach. By late December avian abundance averaged less than 20 birds per km. During the winter shorebirds and gulls accounted for more than 86% of the birds on the beach (Table 3), but there were few species present. Sanderlings, Willets and Black-bellied Plovers were the most abundant winter shorebirds; Herring Gulls and Ring-billed Gulls were the predominant gulls.

Similar cycles of shorebird abundances have been observed in other areas that serve as wintering or staging areas (Storer 1951: Recher 1966; Gerstenberg 1972, 1979; Smith and Stiles 1979). However, most studies, including this one, have lasted one year or less. Page et al. (1979) pointed out that interpretations derived from such studies are limited because of the amount of natural variation in numbers that can be expected between different years and because most study sites have been only parts of larger wetland areas. As a result, it is difficult to distinguish between fluctuations in numbers of birds caused by local movements of the birds and fluctuations in seasonal abundance.

Table 3. Seasonal changes in percent composition of total birds on Gulf beaches by general type of bird. Data from 8.1 km weekly censuses.

Avian group	Percent of total census by season			
	Spring	Summer	Fall	Winter
Shorebirds	69.9	23.4	55.7	49.0
Gulls	12.9	46.1	14.3	37.5
Terns	16.2	30.2	29.9	10.4
Other birds	1.0	0.3	0.1	3.1

Comparison of Whole-Island and 8.1-km Censuses

There was a significant correlation (τ=0.88, m-64, $P < 0.01$) in mean monthly abundance rank values between the 8.1-km and whole-island censuses. However, whole-island abundances were generally lower than abundance values obtained in the 8.1-km study transect (Figure 5) because of the uneven distribution of birds along the length of the island (see Linear Distribution on the Beach - Effects of Substrate). Only in December did the abundance value from the whole-island census exceed that of the 8.1-km transect, and this may have resulted from the attraction of many gulls to the Port Mansfield Channel mouth when the channel was dredged and the effluent containing many fish and other small organisms was dumped in the foreshore north of the jetties.

Nocturnal Census Results

Most birds left the beach by nightfall (Table 4). All of the gulls and terns spent the night roosting on islands or sandbars in the Laguna Madre or associated bays. These birds left the beach at dusk and did not return until the following morning. Shorebird populations on the beach declined at night, but individuals of almost every species remained on the beach at night to roost or feed. Sanderling, Knots, Black-bellied Plovers and Piping Plovers actively fed throughout the night. Black-bellied Plovers are almost exclusively nocturnal feeders.

The abundance figures reported in Table 4 represent data from counts in the foreshore and berm only. Thus, they do not represent a complete count of birds present on the beach at night because some shorebirds occupied the backshore. It was impossible to count them because of irregularities in terrain and the presence of campers and beach debris.

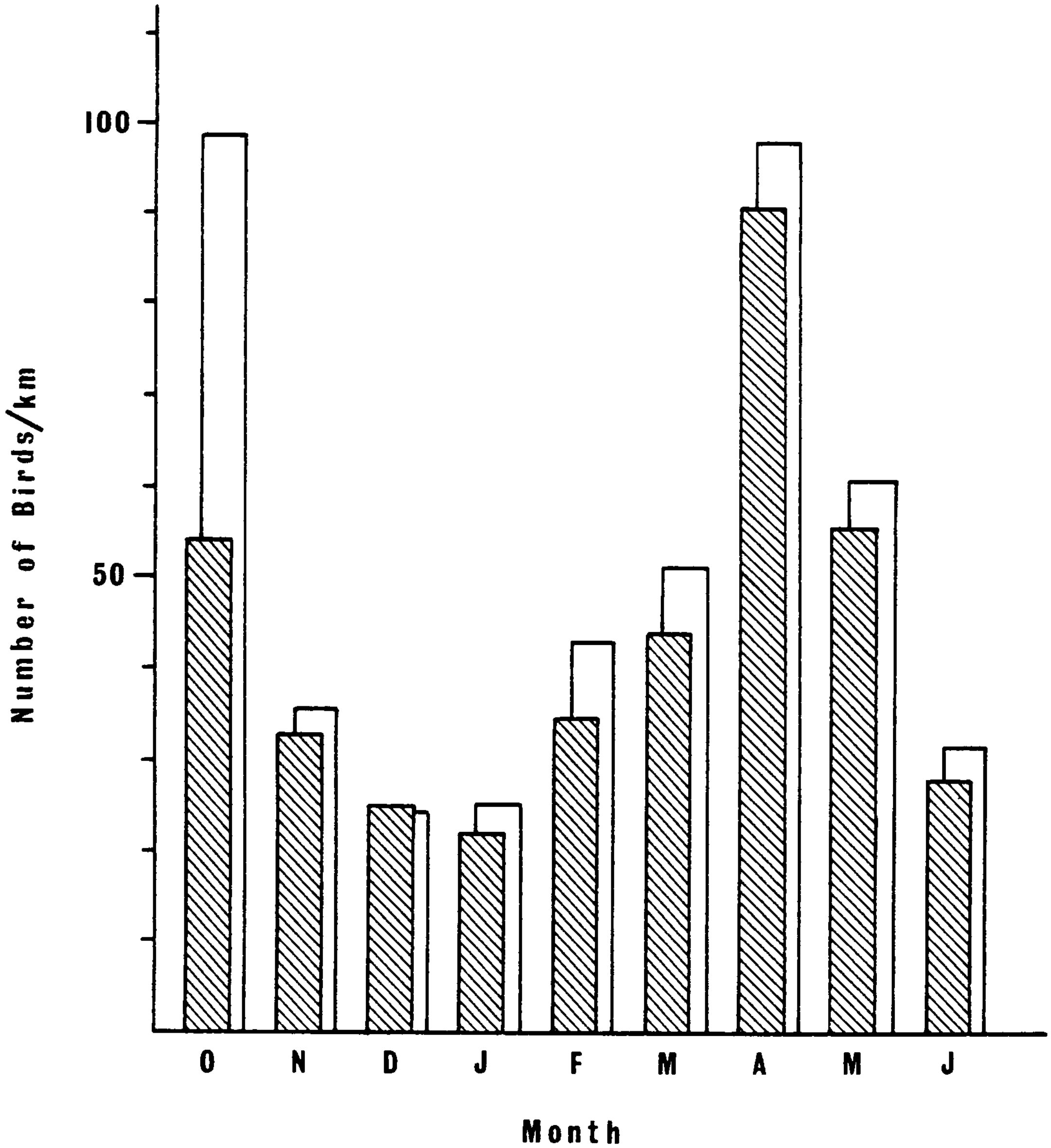

Figure 5. Comparison of avian abundance in the 8.1-km study transect (open) with that in the whole-island census (diagonal lines).

Nearshore Census Results

Most pelagic species occur beyond or at the margins of continental shelves and come to shore only as a consequence of tropical storms, hurricanes, or other weather disturbances (Lowery and Newman 1954, Williams 1965, DeBenedictis 1980). However, Magnificent Frigatebirds and Parasitic Jaegers regularly visit the Gulf Coast during certain seasons of the year (Lowery 1974, Oberholser and Kincaid 1974, Imhoff 1976) and were the only pelagic birds seen during the censuses.

Table 4. Percent change between mean noon and midnight abundances of various species in the 8.1-km study transect. Comparison is between abundances of birds in the foreshore and berm regions of the beach only.

	Mean abundance (birds/km)		Percent change
	Noon	Midnight	
Sanderling	30.5	12.6	-58.7
Willet	5.7	3.5	-38.6
Knot	15.6	15.0	- 3.8
Black-bellied Plover	2.1	2.0	- 4.8
Ruddy Turnstone	3.1	1.1	-64.5
Piping Plover	3.0	0.6	-80.0
Other species	2.4	0.5	-79.2
All shorebirds	62.4	35.3	-43.4
All terns	11.6	0.0	-100.0
All gulls	12.4	0.0	-100.0

During the Ixtoc I oil spill, eight Masked Boobies and one Brown Noddy were found, oil soaked, on the beach (Chapman 1981). These birds must have come in contact with the oil fairly close to shore because five of the boobies and the tern were found alive. Most oiled pelagic birds either sink or are consumed by predatory fish before they wash ashore (Bourne 1976).

The nearshore was used as feeding habitat throughout the year, but the greatest number of species and highest abundances occurred in the fall (Table 5) when many gulls and terns congregated on the beach following migration from northern breeding grounds, the breakup of local breeding colonies, and the addition of many juvenile birds. These birds loafed in large flocks in the foreshore and fed in the nearshore. Most feeding activity was confined to the surf zone, the area inside the third bar. Terns, gulls, cormorants, grebes, and pelicans concentrated in this area to feed on schools of fish. Only a few gulls and terns were observed feeding beyond the third bar.

Many flocks of ducks migrated over the third bar and beyond during the fall and spring months. Most ducks did not stop here during migration, but several species did so regularly. Red-breasted Mergansers, Buffleheads and Lesser Scaup (listed in declining order of occurrance) stopped to feed in the surf. Oldsquaws and Surf Scoters, both uncommon species on the south Texas coast, were also seen feeding, singly, in nearshore waters.

HABITAT-USE PATTERNS

Beach Zone Distribution

Most birds that used the barrier island beaches were concentrated in the foreshore region (Table 5). The foreshore was used as feeding habitat by most species of shorebirds and as loafing habitat by most gulls, terns, and wading birds. Several species were not observed in any other type of habitat: Red Knots, Dunlins, and Least Sandpipers. However, most species did leave the foreshore occasionally to feed or loaf in the berm or backshore. The majority of the loafing birds, particularly Royal Terns, tended to concentrate along the high-tide swash line.

The berm was used occasionally as feeding habitat by Sanderlings, Ruddy Turnstones, Willets, Piping Plovers, Snowy Plovers, Semipalmated Plovers, and other less abundant shorebirds. Here species rarely probed in the sand as when feeding on the foreshore. Instead, they mostly picked at debris and snapped at flying insects on the berm. Some species, such as the Laughing Gull and Black-bellied Plover, used the berm exclusively for loafing.

Of the beach zones, the dry backshore was the least used habitat. Most of the birds that frequented the backshore were attracted to food provided by the offal of human campers. Only the Semipalmated Plover used the area as a regular feeding habitat unassociated with human activity.

On occasion in some backshore areas, heavy rains created large temporary rain pools that attracted many species of birds. The pools were used for drinking and bathing, but rarely for feeding. The rain pools were usually too ephemeral for buildups of algal or invertebrate populations.

Nearshore Distribution

Although few pelagic species feed nearshore, many other species feed close to the shore and rest on inshore waters during migration. Based upon feeding habitat preferences, the nearshore waters could be divided into zones corresponding to the bar and trough system (Figure 2; Table 6).

Least Terns, Forster's Terns, Common Terns, and Bonaparte's Gulls fed most commonly in the zone between the foreshore and the first bar. Least Terns typically dove into the shallow water behind a dying wave near the foreshore. Forster's Terns and Common Terns fed by diving into the deeper water near midtrough. Bonaparte's Gulls fed by hovering above the water near the foreshore and dipping down to scoop up fish.

Table 5. Percent of birds counted in each beach region (FS = foreshore; B-berm; BS = backshore) in each month of the study.

SPECIES	ZONE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
		MONTH								
Sanderling	FS	94	77	81	74	75	94	80	97	93
	B	4	14	12	26	12	5	19	2	1
	BS	2	9	7	0	13	1	1	1	6
Willet	FS	96	100	88	99	95	94	84	100	92
	B	3	0	8	1	4	6	11	0	8
	BS	1	0	4	0	1	0	5	0	0
Red Knot	FS	100	-	-	-	100	100	100	100	-
	B	0	-	-	-	0	0	0	0	-
	BS	0	-	-	-	0	0	0	0	-
Black-bellied Plover	FS	78	68	36	50	79	95	82	98	97
	B	16	22	28	50	12	5	15	1	3
	BS	6	10	36	0	9	0	3	1	0
Ruddy Turnstone	FS	71	72	36	-	45	89	74	97	99
	F	25	20	36	-	35	8	26	2	1
	BS	4	8	28	-	20	3	0	1	0
ALL SPECIES	FS	72	92	86	88	90	90	84	98	94
	B	15	4	8	11	6	4	6	1	3
	BS	13	4	6	1	4	6	10	1	3

Table 6. Mean monthly number of species and abundance of birds feeding in the nearshore during whole-island censuses. Migratory species that flew over the census area but did not stop to feed are not included. Abundance is expressed as birds per km.

Year	Season	Month	Number of species	Abundance
1980	Fall	October	15	24.2
		November	12	13.6
1981	Winter	December	8	8.6
		January	6	5.2
		February	8	7.6
	Spring	March	11	10.9
		April	11	12.5
		May	12	13.1
	Summer	June	12	18.8

The zone between the first bar and the foreshore also was used by migratory Eared Grebes. Many flocks of 10 to 25 individuals floated and fed in this zone in late October and again in February and March.

The zone between the first and second bars was used as a feeding area by Sandwich Terns. However, almost all species that fed in the second trough also used the third trough as feeding habitat. Royal Terns, Caspian Terns, and to a lesser extent, Herring Gulls, Ring-billed Gulls, and Laughing Gulls, fed in the second and third troughs.

In winter and spring large rafts of Double-crested Cormorants accumulated in nearshore waters from the second bar outward. Raft size varied from approximately 20 to 2500 individuals. In many instances these birds engaged in leapfrog feeding. In contrast, Olivaceous Cormorants rarely were observed on the barrier island beaches or nearshore, even though a considerable winter population can be found in the Laguna Madre and associated bays (Oberholser and Kincaid 1974).

Many species of waterfowl, shorebirds, and wading birds migrate along the Padre Island shoreline. Mallards, Pintails, Gadwalls, American Wigeons, Blue-winged Teal, Green-winged Teal, Redheads, and Lesser Scaups were observed migrating over the third bar in fall and spring. Green-winged Teal and Pintails occasionally were seen resting in the foreshore areas or in storm pass waters.

Wading birds and shorebirds usually were observed flying close to shore. Cattle Egrets were more common in the fall and flew south over the first bar. Cattle Egret flocks frequently stopped to rest on the beach, often in association with a mixed flock of terns and gulls. Brown Pelicans migrated in small groups of from 3 to 6 individuals that stopped to feed or rest in the second trough.

LINEAR DISTRIBUTION ON THE BEACH

Birds were not uniformly distributed along the length of the barrier island beaches. Three factors affected the linear distribution of birds: (1) beach substrate composition; (2) the presence of storm-tidal passes; and (3) the location of tar mats, fresh tar balls, or mousse.

Effects of Substrate

Throughout the study there were fewer birds in the Big Shell and Little Shell areas than on finer sand substrates elsewhere. The abundance of birds along a 16.1-km (10-mi) stretch centered in Big Shell is compared to the abundance of birds for the entire census transect (Figure 6). Only twice did the abundance of birds in the Big Shell area exceed that observed on the entire island. On both occasions, the count of birds within the Big Shell area was elevated by the presence of large flocks of terns. The terns were part of a large feeding assemblage that was diving for fish in the nearshore. While most birds were feeding in the surf, many terns rested on the foreshore.

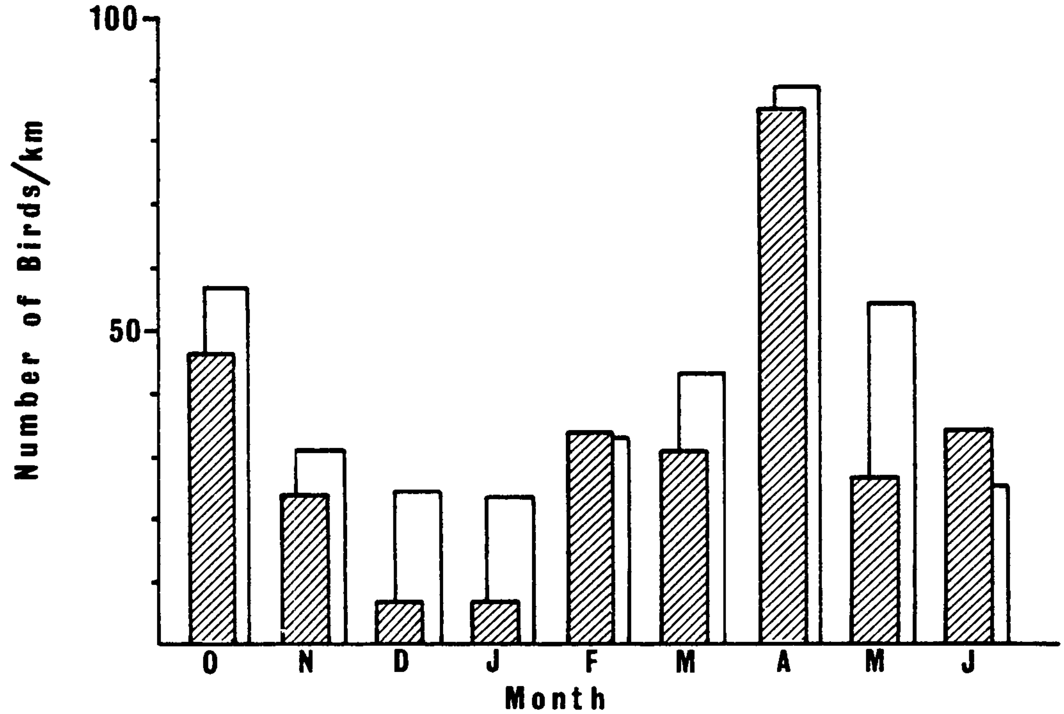

Figure 6. Monthly comparisons of average avian abundance on Big Shell (diagonal lines) and the whole island (open).

The shell-hash substrate characteristic of the Big Shell area contains lower densities of infaunal organisms than areas with fine-sand substrates. The density of shorebird prey may directly affect the abundance of shorebirds. Myers et al. (1979) found that territory size in wintering Sanderlings related inversely to food abundance: smaller territories occurred in areas of higher prey density. When territory size is reduced, more individual birds may occur in a given area. Thus, abundances of shorebirds were generally lower in areas of Padre Island with shelly substrates because of reduced prey density.

Effects of Passes

Many birds congregated near the mouth of storm-tidal passses. The storm surge of Hurricane Allen (11 August 1980) opened over 50 such passes in the island (Gundlach et al. 1981a). Most of the passes filled in rapidly with sediment, but six of the passes near the Port Mansfield Channel remained open, or were reopened by successive cold fronts, until February 1981. The abundance of birds in the 3.2-km segment containing a pass were usually 1.5-2.5 times greater than those in the adjacent 3.2 km segments (Table 7). Black-necked Stilts, American Avocets, Long-billed Dowitchers, and Lesser Yellowlegs congregated in large numbers to feed in the passes, especially during periods of tidal flow. These species rarely were observed elsewhere in beach habitats. Most gulls and terns were observed elsewhere on the beach, but were found in greater abundance near the mouth of storm-tidal passes. Bonaparte's Gulls fed in the shallow pass-outflow waters.

Table 7. Comparisons of avian abundance in 3.2-km segments with a flowing pass to abundances in 3.2-km segments without a pass to the north and south. Data from 4 October to 8 November 1980 censuses.

Flowing pass	Mean avian abundance (birds/km)		
	South segment	Pass segment	North segment
Coyote Pass	28.1	37.2	19.4
Rattlesnake Pass	19.4	58.4	48.8
Tractor Pass	25.0	55.0	22.2

Effects of the Presence of Oil

The presence of oil in any form reduced avian abundances in the immediate vicinity. Although 36 tar mats, semipermanent conglomerations of oil and sand, were identified in the months following the Ixtoc I oil spill, the tar mats were gradually covered by sandy sediments. Only 15 of the tar mats were located during this study. Most of these were found only after Hurricane Allen uncovered them; prior to the hurricane they had been covered by 0.25 to 1 m of sand. However, their location could be predicted because of the presence of (1) high densities of tar balls and (2) low densities of birds. Birds avoided areas in the immediate vicinity of both covered and uncovered tar mats.

Small oil spills washed ashore on Padre Island periodically throughout the study. For example, in March 1981 a spill contaminated approximately 50 km (30 mi) of beach with moderate to heavy concentrations of tar balls. Because of the wide distribution of the tar balls, it was difficult to assess their impact on avian abundance, but a drop in total abundance was noted on the 28 March 1981 census. This drop occurred when avian abundances were increasing because of spring migration.

DAILY ABUNDANCE PATTERNS

Most species of shorebirds can feed in several distinct habitat types (Palmer 1967, Johnsgard 1981). Recent studies of marked birds have shown that some birds regularly switch habitats in response to time of day, tidal cycle, wind changes, and season (Connors et al. 1979, 1981; Kelly and Cogswell 1979). The Gulf beaches of Padre and Mustang Islands are in close proximity to both extensive freshwater pond systems (down the center of the island) and saltwater estuaries (Laguna Madre and local embayments) and the birds undoubtedly shift between the beach and these areas. Chapman (1981) noted limited local movements and habitat shifts during the Ixtoc I oil spill.

Effects of Tide and Time of Day

Both time of day and tidal stage influenced the abundance of some species of birds on the beach. Shorebird abundances were independent of time of day but showed positive correlations to outgoing tides. When compared to abundances during the preceding high tide, the abundance of Willets (χ^2=22.4, df=6, $P<0.05$) and Piping Plovers (X^2=15.8, df=6, $P<0.05$) significantly increased during receding tides. Nonbreeding shorebirds regularily shift feeding sites to areas with high prey abundance when other feeding habitats are available (Gerstenberg 1979; Myers et al. 1979; Connors et al. 1981). These movements occur in response to spatial variations in prey density and the relative profitability of feeding at the different sites (Myers et al. 1979). Variations in prey density result from local variations in tidal cycle (Connors et al. 1981). Migratory movements out of the area, however, may be independent of prey density or other local factors (Schneider and Harrington 1981).

The density of gulls and terns was not related to tidal stages, but showed a slight tendency to increase in the afternoon. These birds congregate in large mixed-species flocks that loaf on the foreshore and berm. During the morning, most gulls and terns actively feed in the nearshore and do not often rest on the beach.

Effects of the Weather

During most weather conditions no differences were noted in abundance, distribution, or behavior of beach-inhabiting birds. Low temperatures and light rains did not affect the presence of birds on the beach. Only strong winds, blowing rain, and/or sand affected abundance. During a gusty thunderstorm, polar cold front, or tropical depression when the wind carried sheets of rain or sand, most of the birds left the beach. Many birds flew inland, presumably to the Laguna Madre. The large shorebirds, however, usually sought refuge in or near the foredune ridge. Sanderlings and Ruddy Turnstones would sometimes crouch on the lee side of a dunelet or piece of debris either singly or in groups.

BEHAVIORAL STUDIES

The five species chosen for behavioral study were observed during all daylight hours and tidal conditions. The data from these observations were combined so that comparisons could be made to the data reported by Chapman (1981) during the Ixtoc I oil spill. The results of the behavioral studies are presented in Table 8.

Sanderlings, Willets, Red Knots, and Piping Plovers spend most of their time feeding. These data were consistent with those reported by Chapman (1981) for oil-free birds during the spill. Black-bellied Plovers were not as active during the day and spent the majority of their time resting. Black-bellied Plovers fed during the night.

Table 8. Percent of time spent in various behaviors by birds observed during time-budget studies.

Species	Number of obser- vations	Total time observed (min)	Percent of time observed				
			Feeding	Resting	Comfort	Motion	Alert
Sanderling	94	426	64	6	8	11	11
Willet	76	382	53	24	8	10	5
Red Knot	53	281	71	6	2	21	0
Piping Plover	21	126	61	10	9	17	3
Black-bellied Plover	45	203	23	61	12	4	0

When feeding, all five species stayed in the foreshore and berm. All except the Willet fed almost exclusively by probing in the sand. Willets probed in the sand only half of the time; the remainder was spent in pursuit of epifaunal organisms in the surf.

EFFECTS OF IXTOC I

The effects of the Ixtoc I oil spill on the marine bird populations of south Texas proved difficult to assess. Only a small percentage of the avian population showed signs of extensive plumage contamination and few oiled carcasses were found. Chapman (1981) noted that during the period when oil from Ixtoc I contaminated the beaches, the abundance of birds on the island declined and most birds avoided the contaminated foreshore area. Following the removal of the oil by a series of storms, birds returned to the foreshore, but avian abundance did not increase as expected. However, lacking avian census data from previous years, Chapman could only hypothesize that population abundances were below normal. The data from this study provide a baseline, albeit post-impact, of seasonal trends that can be used for comparisons to the trends observed during and immediately after the Ixtoc I spill.

Chapman (1981) suggested that overall population abundance immediately after the spill was lower than expected. During that period increases due to migration should have caused abundances to exceed those noted prior to the spill. Census data from this study (Figure 7) confirmed this suggestion. Furthermore, when post-spill census data from 1979 were compared to the avian densities observed during the same period in 1980, the 1979 densities were much lower (Figure 7).

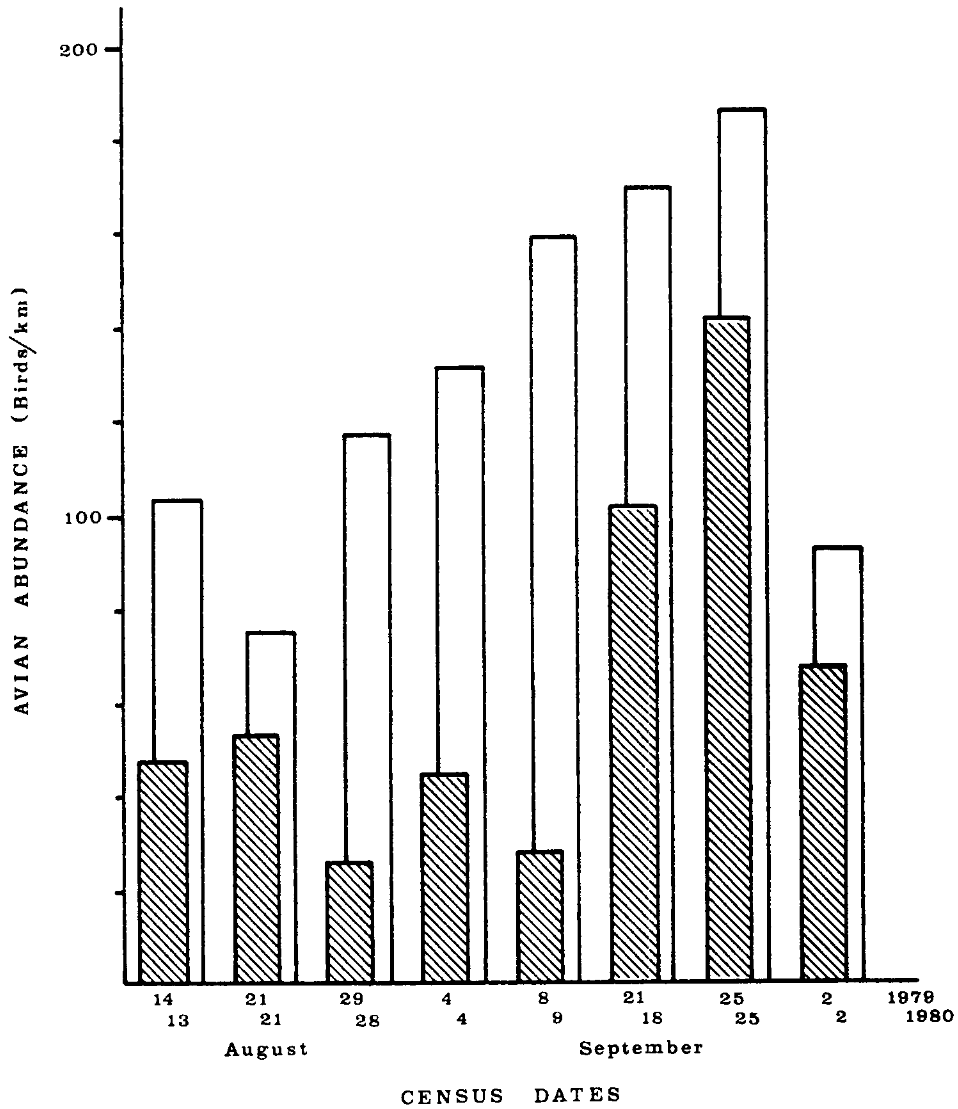

Figure 7. Comparison of avian abundance during Ixtoc I oil spill (diagonal lines) to avian abundance during the same period one year later (open).

Similarly, 1979 and 1980 Sanderling and Willet abundances were compared. These species were chosen for comparison because they both fed in the foreshore, the area most contaminated by the spill, and were the most abundant shorebirds on the beach. Following the Ixtoc I oil spill, the abundance of Sanderlings was barely equal to pre-impact abundances (Chapman 1981). However, in late September 1980 the abundance of Sanderlings was approximately 26% higher than that observed in August 1980. There also was a higher abundance of Sanderlings in late September 1980 (60 birds per km) than during the same period in 1979 (20 birds per km).

The abundance of Willets also declined from August to September 1979 following the Ixtoc I oil spill, and a similar decline was observed in 1980. Furthermore, Willet densities were approximately equal in both years.

There is little evidence to suggest that large numbers of Sanderlings were killed by the Ixtoc I oil spill while Willet numbers were unaffected or that Willets are more "site faithful." However, these data, coupled with the overall comparisons between years, may indicate that the carrying capacity of the habitat was altered. Birds that feed upon infaunal organisms, such as Sanderlings, were forced to go elsewhere for food while birds that feed on crabs or small fish, such as Willets, found enough food to exist in normal densities on the beaches.

The greatest biological impact of Ixtoc I may have been on infaunal organisms. Both Kindinger (1981) and Tunnell et al. (1981) found infaunal invertebrate populations to be reduced significantly following the spill. During the oil spill, approximately 3500 metric tons of oil washed ashore, where most of it accumulated in the intertidal zone (Gundlach et al. 1981). Kindinger (1981), after studying 13 transects spaced at regular intervals down the length of the island, found a 70% reduction in the total number of infaunal organisms in the intertidal zone.

The tendency to avoid contaminated habitats (Chapman 1981) and seek areas of greater prey density (Connors et al. 1981), may have prevented mass mortality of marine birds during the Ixtoc I spill. Doubtless, there was some avian loss because of toxicity or starvation, but the loss was probably insignificant.

Although the Ixtoc I oil spill was the "largest oil spill ever recorded" (Woods and Hannah 1981), only a small proportion of the oil released at the wellhead ever reached the south Texas beaches. Furthermore, the oil remained on the beaches only a short time before being washed away. Had more oil reached the south Texas coast and remained longer, the impact on birds would have been much more pronounced. Not only would more birds have been directly affected by the toxic effects of the oil, but also their food supply would have been further reduced.

SPECIES PROFILES

ORDER PODICIPEDIFORMES

Eared Grebe (*Podiceps nigricollis*)

Eared Grebes breed in western North America from southern Canada and Iowa to northern Baja California, Arizona, and Texas (Palmer 1962). The species winters from Washington southward through Mexico and as far south as Guatemala (Blake 1977). A portion of the Eared Grebe population migrates through southern Texas twice a year. Eared Grebes may migrate at night (Palmer 1962).

Status and seasonal abundance. Populations of the Eared Grebe were once reduced by market hunting (Bent 1919). At present the status of the Eared Grebe populations is unknown, although in some parts of the country they may be declining. It was included on the 1980 Blue List as a marginal species: a species thought to be declining in numbers but for which an accurate assessment cannot be made due to insufficient data (Arbib 1979).

Scattered individuals began to appear in our census in early August. Numbers gradually increased to a peak in mid-October, but by mid-November all Eared Grebes had disappeared. Some were first sighted again in late January and numbers increased through mid-April. Eared Grebes were more abundant in early spring than in fall (Figure 8).

Habitat-use patterns. No flying birds were observed during daylight hours. Eared Grebes were always found in small flocks (4-40 individuals, mean = 12.6) located between the first bar and the foreshore. Individuals in the flocks alternately floated on the surface and dove underneath the water, presumably to feed on marine organisms in the trough system. The flocks appeared to be carried by the longshore currents. Since these currents flow south in the fall and winter and in the opposite direction during the spring and summer, Eared Grebes may utilize them for some of their migratory movement.

Vulnerability to oil spills. The flocks that migrate along the southern Texas coast nearshore are extremely vulnerable to oil spills. These birds spend most of their lives on the surface of the ocean, dive

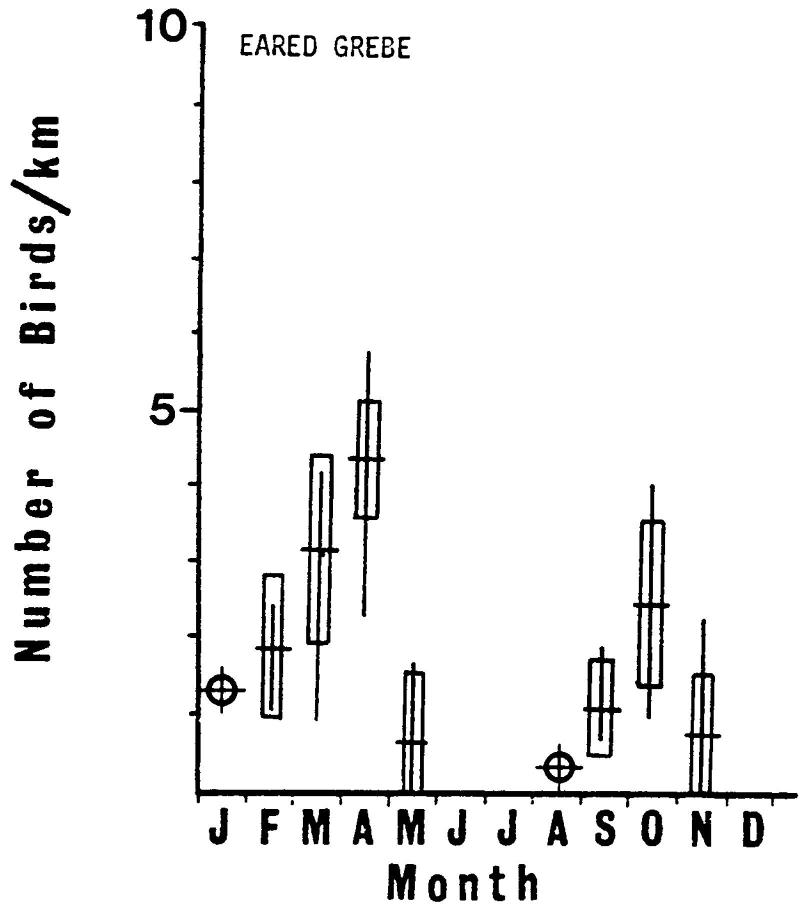

Figure 8. Seasonal abundance patterns of Eared Grebes. The vertical line represents the range, horizontal line the mean, open rectangle one standard deviation of the mean, and circle a single observation during the month. Figures 9-16 are similarly constructed.

to collect their food and are weak fliers. In response to a disturbance they dive rather than fly; if they dive on encountering floating oil or if they surface within an oil slick, they become coated with oil. Since these birds are also highly gregarious, it is possible for a small oil slick to cause high casualties.

The proportion of the total population using the nearshore waters is unknown. Eared Grebes also use the protected waters of the Laguna Madre and coastal bays (Oberholser and Kincaid 1974, DeSante and Ainley 1980). Within the lagoon and bay system, Eared Grebes are vulnerable to local oil spills and to slicks that enter through the passes to the Gulf of Mexico. Vulnerability of this species is limited to the spring (February to April) and fall (August to October); peak vulnerability occurs in mid-April and mid-October.

Pied-billed Grebe (Podilymbus podiceps)

Status and seasonal abundance. Pied-billed Grebes breed from southern Canada and the western United States to central Mexico (Palmer 1962). They have been known to make long migratory flights over oceanic waters (Oberholser and Kincaid 1974). The species winters in the southern half of the breeding range, and in the extreme southern portions, it may not migrate at all (Blake 1977).

Habitat-use patterns. Pied-billed Grebes can be found on freshwater ponds and in quiet estuarine waters in south Texas throughout the year. Although it is uncommon for this species to occur on the ocean (Bent 1919, Oberholser and Kincaid 1974), several oiled individuals washed ashore on south Texas Gulf beaches in August 1979 during the Ixtoc I oil spill (Chapman 1981). Two captured individuals were immobilized completely by a coat of sticky mousse. When first observed, both individuals were floating toward the shore from the vicinity of the third bar, suggesting that they must have landed on the surface of the Gulf and contacted the oil offshore. Small patches of the Ixtoc I mousse resembled patches of Sargassum which often support dense populations of invertebrates and provide shade for schools of fish. Therefore, these birds may have landed mistakenly in or near mousse pancakes to feed.

Vulnerability to oil spills. Little is known concerning the overseas movements of Pied-billed Grebes. Therefore, no accurate assessment of the vulnerability of this species to offshore oil spills can be made. However, some individuals may become oiled during the fall migration.

ORDER PELECANIFORMES

Brown Pelican (Pelecanus occidentalis)

Status and seasonal abundance. There are two recognized subspecies of Brown Pelican in the United States (AOU 1957). Only the eastern subspecies (P. occidentalis carolinensis) occurs in Texas, where its breeding population declined from approximately 5,000 birds in Texas prior to 1920 to only about 100 birds in 1963 (King et al. 1977). Consequently, the subspecies was placed on the Endangered Species List of the U.S. Department of Interior in 1971 (U.S. Code of Federal Regulations, Title 50, Part 17).

Significant breeding populations of the Eastern Brown Pelican are presently limited to southeastern Mexico, Florida, and South Carolina, but a small breeding population occurs in southern Texas (Williams et al. 1976). The Texas population migrates south to spend the winter along the eastern Mexico coast south as far as Panama (Oberholser and Kincaid 1974). The timing of migration varies from year to year and from colony to colony (Palmer 1962).

Habitat-use patterns. Small numbers of Brown Pelicans were observed flying over nearshore waters during migration in January and February and again in October and November (Figure 9). They usually flew just above the waves inside the third bar. Brown Pelicans usually migrate in small groups of from 3 to 8 birds, but single birds were seen on two occasions. The birds frequently stop during migration to float upon the water's surface. Such stops are usually near the mouth of a pass or between the breakwaters of a channel. On one occasion 22 Brown Pelicans were counted near the mouth of the Port Mansfield Channel.

Brown Pelicans rarely fed in the nearshore waters. However, a pair was seen diving into Gulf waters approximately 0.5 km from shore in March 1980. Both birds appeared to be in adult plumage, but it was not known whether or not they were from a local breeding colony.

Vulnerability to oil spills. Because of their endangered status and their habit of resting upon Gulf of Mexico nearshore waters during migration, Eastern Brown Pelicans in Texas are extremely vulnerable to oil spills. They are most vulnerable to spills in nearshore waters during the migratory seasons (January-February and October-November).

Double-crested Cormorant (*Phalacrocorax auritus*)

Status and seasonal abundance. The breeding range of the species includes most of the northern United States and southern Canada east of the Great Lakes and along most coasts except for that of Texas. Birds from central North America migrate to the Gulf coast to spend

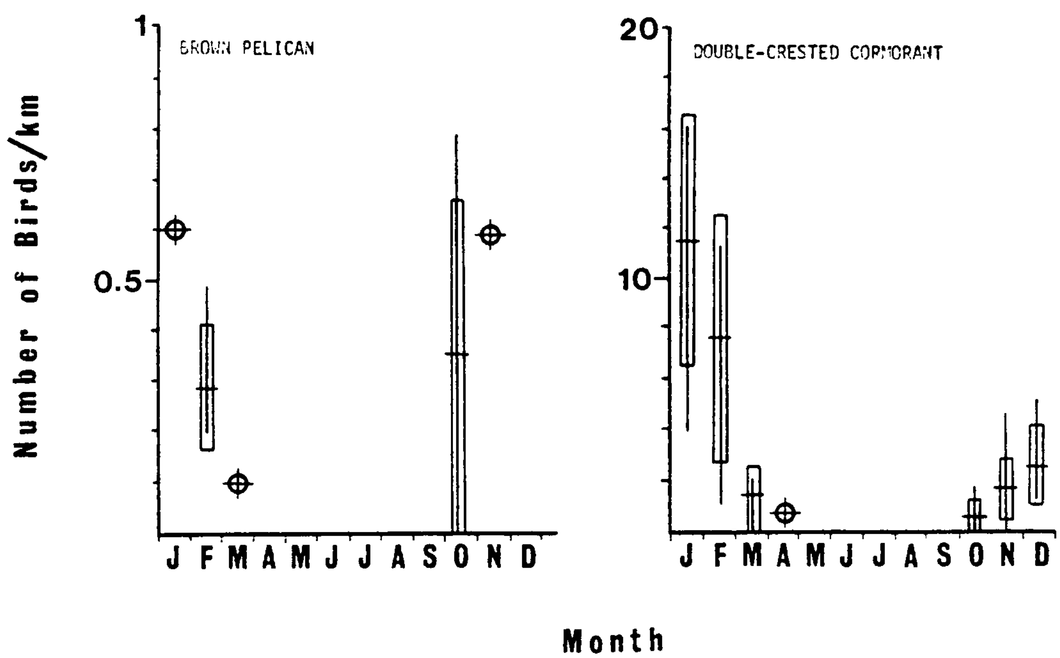

Figure 9. Seasonal abundance patterns of Brown Pelicans and Double-crested Cormorants. See Figure 8 for explanation of symbols.

the winter. Double-crested Cormorants occur in large flocks along the Texas coast from October to March (Figure 9). The Double-crested Cormorant is on the Blue List because of continued population declines in some areas (Arbib 1979).

Habitat-use patterns. Double-crested Cormorants concentrate in large flocks, sometimes exceeding 1,000 individuals per flock, throughout the winter. Occasionally, the flocks leave the lagoons and bays behind the barrier islands and move to the nearshore to feed. The feeding flocks observed in this study were concentrated between the third and second bar. Periodically, groups broke away from the feeding flocks to sit on the beach and dry their plumage.

Vulnerability to oil spills. An oil spill during the winter would pose a considerable threat to Double-crested Cormorant populations. Periods of peak vulnerability are from November to February.

ORDER CICONIIFORMES

Great Blue Heron (*Ardea herodias*)

Status and seasonal abundance. Populations of the Great Blue Heron declined slightly in Texas from 1970 to 1980 (Blacklock et al. 1978, Chapman, 1980) although suitable habitat for migrant and wintering birds has increased (Oberholser and Kincaid 1974). Because many breeding colonies have been destroyed in all parts of its range, the Great Blue Heron was included on the Blue List (Arbib 1979).

Great Blue Herons were present year round on the beaches of the lower Texas coast, but their numbers increased in winter (Figure 10). During the spring and summer, Great Blue Herons were seen often feeding on the beach and flying to breeding colonies located in the Laguna Madre.

Habitat use patterns. Great Blue Herons fed by standing still in the first trough or in the swash zone and seizing fish with their bills. Dead fish on the beach were also eaten and Great Blue Herons often were seen in the proximity of fishermen who were discarding unwanted fish.

Vulnerability to oil spills. Only a small proportion of the resident and wintering Great Blue Heron populations feed on the beaches; therefore few individuals are vulnerable at any time. However, during the breeding season oil might be transfered from a contaminated bird's plumage to the eggs or young and might, therefore, cause some mortality (Eastin and Hoffman 1978).

Cattle Egret (*Bubulcus ibis*)

Status and seasonal abundance. Cattle Egrets first appeared in the United States in 1941 or 1942 (Palmer 1962). Since that time they have expanded their range along the Gulf and Atlantic coasts and in most

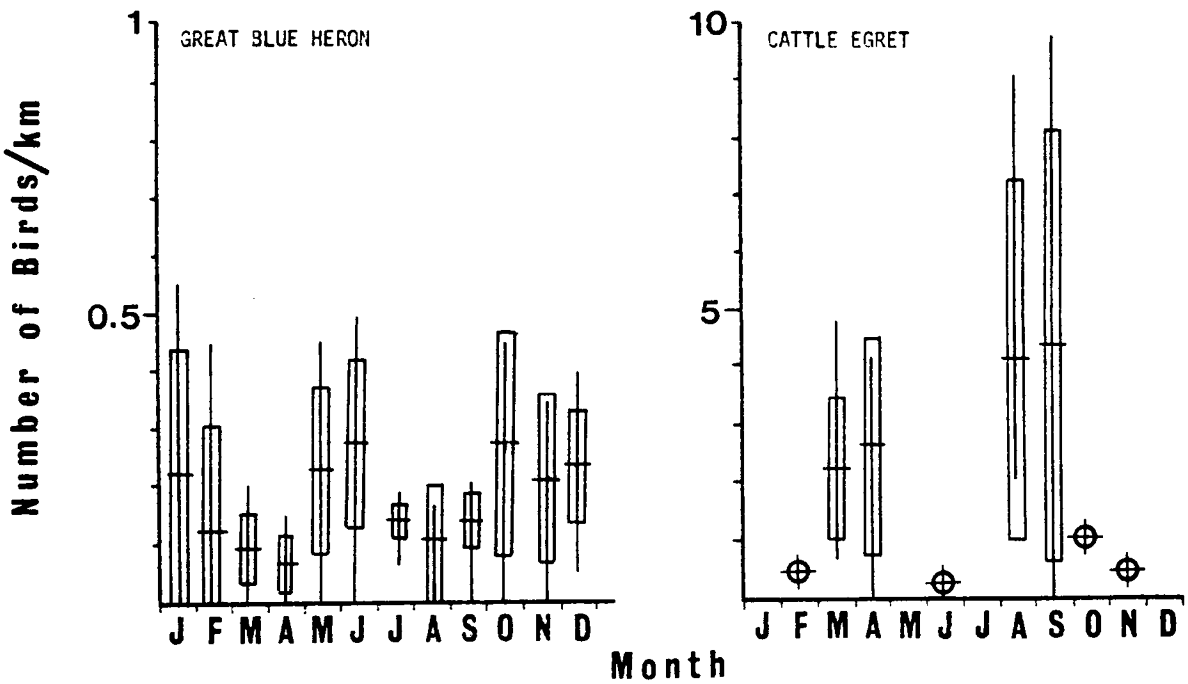

Figure 10. Seasonal abundance patterns of Great Blue Herons and Cattle Egrets. See Figure 8 for explanation of symbols.

southeastern states (Rice 1956). Cattle Egrets were first seen in Texas in 1955, and the first breeding colony was observed in 1958 (Oberholser and Kincaid 1974). Since that time the breeding population in Texas has increased to more than 103,000 breeding pairs (Mullins and Roberts 1981). Populations from the Atlantic coast migrate to and from Cuba and southern Mexico via the Florida Keys (Palmer 1962), but the migratory routes and destinations of the Texas populations are unknown.

Large flocks of Cattle Egrets were observed on the beach and in flight during August-September and March-April (Figure 10). During the fall, all flocks were flying south, whereas during the spring, all flocks flew north.

Habitat-use patterns. Cattle Egret flocks were observed flying in tight groups between the third bar and the foredune ridge. The flocks usually flew less than 10 km before landing on the foreshore for rest stops; feeding was not observed during such stops. Cattle Egret flocks often landed in the midst of large mixed-species groups of terns that occupied the foreshore.

Vulnerability to oil spills. Because of their habit of landing in the foreshore during migration, Cattle Egrets are susceptible to oil spills on barrier island beaches. Chapman (1981) observed many Cattle Egrets with large clumps of tar on their feet during the Ixtoc I oil spill. These birds picked up the oil when they rested in the foreshore.

Because the clumps of tar were heavy, these birds had difficulty flying, and may have sustained high rates of energy loss, thereby affecting survival. Cattle Egrets are most vulnerable during spring (March-April) and fall (August-September) migration.

ORDER FALCONIFORMES

Northern Harrier (Circus cyaneus)

Status and seasonal abundance. Northern Harriers breed throughout most of central North America south of central Canada and north of Mexico (AOU 1957). Most Northern Harriers winter in the southern states and northern Mexico. In some years, many Northern Harriers spend the winter on Padre and Mustang Islands; 128 Northern Harriers were counted on the 1980 Christmas Bird Count centered at Padre Island National Seashore (Heilbrun 1981). Northern Harrier populations throughout the United States have been declining steadily in recent years as a result of habitat destruction, and the species was included on the Blue List for 1980 (Arbib 1979).

Northern Harriers first appeared on Padre Island in early September. Numbers increased throughout the fall, then began to decline in midspring. All Northern Harriers left the area by early April.

Habitat-use patterns. Northern Harriers usually forage over wetlands and grasslands (Bent 1937), but they occasionally prey on shorebirds along the foreshore of Padre and Mustang Islands. Four successful attacks were witnessed during this study. After killing the prey (3 Sanderlings, 1 Ruddy Turnstone), the hawks remained on the foreshore to eat.

Vulnerability to oil spills. Only a small proportion of the Northern Harriers wintering in Texas feed on Gulf beaches, but those that feed on shorebirds are vulnerable to oil spills. The hawks may ingest oil from oiled prey and may contaminate their plumage while feeding in an oiled habitat. Furthermore, after a spill Northern Harriers may be attracted to the contaminated habitat by the abundance of oiled, and less mobile (and therefore easily captured), shorebirds. The period of vulnerability for Northern Harrier is from August to March.

Peregrine Falcon (Falco peregrinus)

Status and seasonal abundance. The Peregrine Falcon is a nearly cosmopolitan species, the North American subspecies of which are considered endangered (OES 1980). Peregrine Falcons breed in tundra areas throughout arctic Alaska, Canada, and western Greenland (Bent 1938). They migrate along the Atlantic coast and winter along the entire Gulf coast and south as far as central South America (AOU 1957). Peregrine Falcons are common winter inhabitants of southern Padre Island, although they are never present in large numbers. The falcons begin arriving in south Texas in early September and depart by mid-May (Oberholser and Kincaid 1974).

Habitat-use patterns. Peregrine Falcons spend part of the day and probably all night perched on sand dunes. Peregrines attack small passerines, shorebirds, and waterfowl in flight, although sometimes birds on the ground are taken. On two occasions during this study, Peregrine Falcons attacked shorebirds on the beach (one Sanderling in the foreshore, one small plover in the backshore).

Vulnerability to oil spills. An oil spill on the beach in winter may result in the contamination or loss of some Peregrine Falcons on Padre Island. Total impact cannot be assessed because of the lack of adequate census data. The period of greatest vulnerability is from September to April.

ORDER CHARADRIIFORMES (SHOREBIRDS: PLOVERS AND SANDPIPERS)

Semipalmated Plover (*Charadrius semipalmatus*)

Status and seasonal abundance. Semipalmated Plovers nest along the Arctic, Pacific, and Atlantic coasts of Canada (Terres 1980), and winter coastally from central California to Ecuador and Chile and from South Carolina to Patagonia, including the entire Gulf coast (Oberholser and Kincaid 1974).

Either very few Semipalmated Plovers migrate along the lower Texas coast in the spring or they pass rapidly through the area. They were recorded on only four spring censuses and the largest number of individuals in the 16.1-km study transect was recorded 24 April 1981, when 16 were seen. However, Semipalmated Plovers were counted on 8 of 10 censuses from 31 July to 2 October 1981 (Figure 11). According to Oberholser and Kincaid (1974), stragglers have been recorded on the Texas coast year round.

Habitat-use patterns. Semipalmated Plovers fed from the backshore to the swash zone. They were observed most commonly (86% of observations) on the berm or backshore and appeared to feed on beach flies and organic debris deposited by the wind. On two occasions Semipalmated Plovers were observed feeding at night. In both instances the individuals were found in the debris line at the high-tide mark.

Vulnerability to oil spills. Because of their low density and preference for the high beach, Semipalmated Plovers are not very vulnerable to oil spills. Periods of peak abundance occur in April and September.

Piping Plover (*Charadrius melodus*)

Status and seasonal abundance. Although there are two subspecies in North America, only one (*C. melodus circumcinctus*) winters on the Texas Gulf coast (Oberholser and Kincaid 1974, Johnsgard 1981). This subspecies breeds in the prairie provinces of Canada, the Dakotas, and Nebraska and around all the Great Lakes except for Lake Michigan.

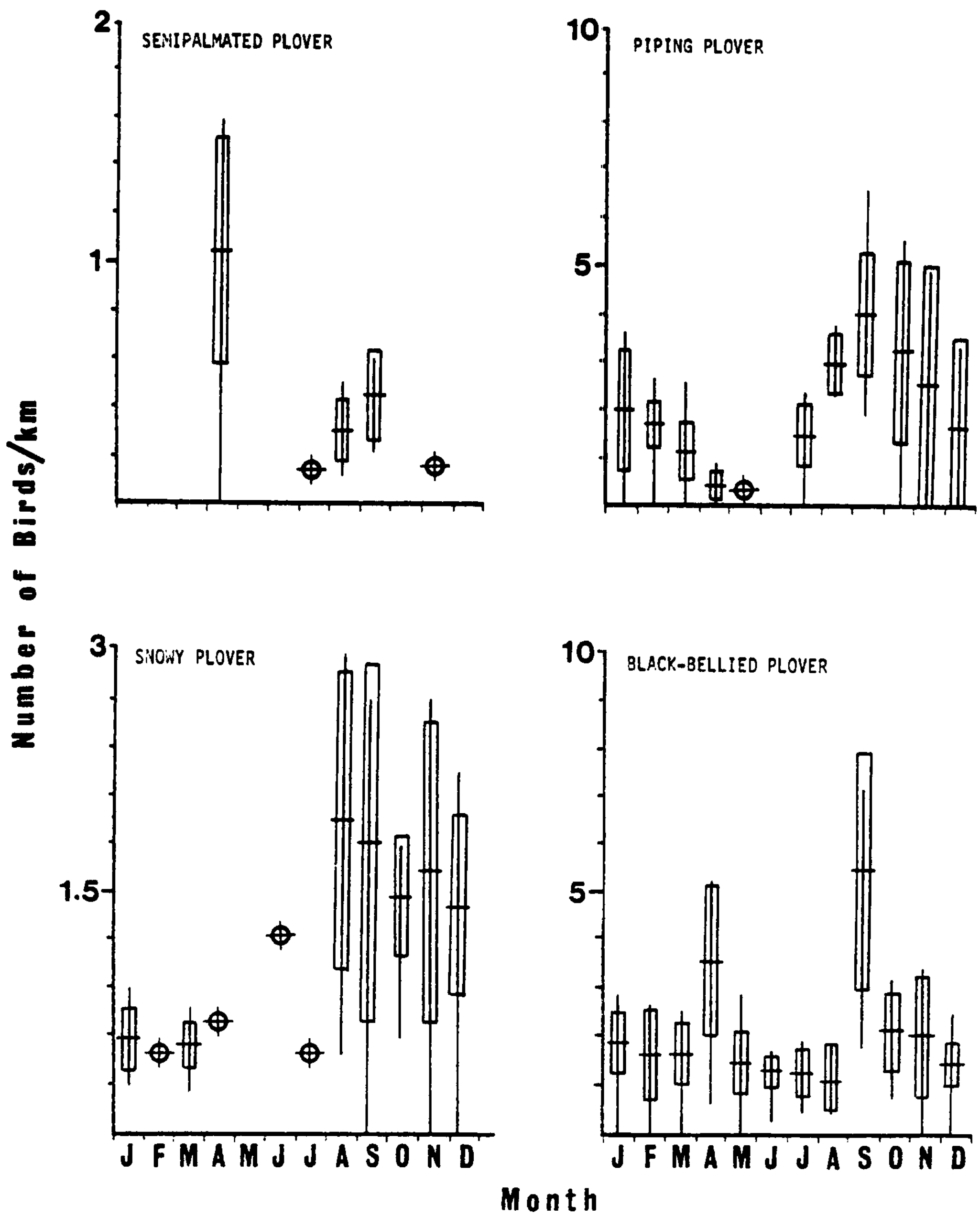

Figure 11. Seasonal abundance patterns of Semipalmated Plovers, Piping Plovers, Snowy Plovers, and Black-bellied Plovers. See Figure 8 for explanation of symbols.

Because of habitat destruction and disturbance by man throughout their range, the Piping Plover has been declining in numbers since the 1930's. As a result, this species is included on the 1980 Blue List of threatened species (Arbib 1979).

Scattered individuals were observed year round, but Piping Plovers were most common in fall and winter (Figure 11). Numbers of Piping Plovers began to increase in mid-July and peaked in August and September. During these months, abundances averaged 2.4 birds per km. In early September 5.6 birds per km were counted. During the summer, fewer than 4 Piping Plovers were counted on the whole-beach censuses and they were usually not observed on the 8.1-km censuses.

Habitat-use patterns. Piping Plovers spent most of their diurnal hours in the foreshore: 86% of all Piping Plovers counted on all censuses were found in this area. All of the remaining birds (14%) were counted in the berm area. No Piping Plovers were observed in the backshore under normal census conditions, although several individuals were observed crouching on the lee side of beach debris (large pieces of driftwood) during a windy rainstorm.

All feeding activities were confined to moist-sand substrates. During daylight hours Piping Plovers spent 61.5% of their time feeding (Table 8). Some Piping Plovers were observed feeding nocturnally. The birds stand still until they (apparently) sight a prey organism, and then run quickly to it. Occasionally, Piping Plovers will extend one leg and vibrate the foot in damp sand during pauses between pecking. The vibrations produced by this activity may cause prey to come to the surface. Piping Plovers obtain almost all food from the surface and rarely probe beneath the sand.

Piping Plovers regularly flew up and down the beach in pairs or small flocks. However, upon alighting the individuals quickly dispersed. During feeding activities, intraspecific aggression occurred when individuals approached within 3 m of one another. As a result, Piping Plovers were distributed uniformly along most areas of the beach during the fall and winter. Few Piping Plovers were counted in the Big Shell and Little Shell regions. This may indicate a preference for sandy substrates with few shells.

Vulnerability to oil spills. Piping Plovers use the habitat that is most likely to be contaminated by an oil spill and, therefore, are highly vulnerable to any such spill. However, during the period that Ixtoc I oil was on the beach, few severely oiled Piping Plovers were seen. Although most Piping Plovers got oil on their feet, there was little evidence of transfer to the plumage. Apparently they were able to adjust their habits in such a way as to avoid extensive exposure to oil. A more severe or extended oil spill might be more damaging to this species because of its dependence on foreshore and berm. The period of peak vulnerability is from early August to mid-December.

Snowy Plover (*Charadrius alexandrinus*)

Status and seasonal abundance. There are two distinct breeding areas for Snowy Plovers in North America: along the Pacific coast from Oregon south to Baja California and as far east as New Mexico and along the Gulf coast from southern Texas to Florida (Johnsgard 1981).

Prior to 1950 the Snowy Plover may have nested on the backshore of Padre Island (Louis Rawalt, pers. comm.), but, as a consequence of increased vehicle traffic on the beach, it no longer does so. Because they breed in the study area, a few Snowy Plovers occur intermittently on the beach throughout the summer, but the greatest abundance is attained during the fall and winter (Figure 11). The highest abundance recorded during the study was 1.5 birds per km on 13 August 1980 (8.1-km census). Because the Snowy Plover is beset by the same problems as the Piping Plover, it is included on the 1980 Blue List (Arbib 1979).

Habitat-use patterns. Snowy Plovers used the dry portions of the beach. Of all Snowy Plovers observed during the censuses, 8% were counted in the foreshore, 36% in the berm and 56% in the backshore. Snowy Plovers were found on all portions of the beach, but were most common on the southern end of Padre Island.

Vulnerability to oil spills. Because of their low abundance and their use of the backshore, Snowy Plovers are not highly vulnerable to oil spills.

Black-bellied Plover (Pluvialis squatarola)

Status and seasonal abundance. Black-bellied Plovers breed in the Arctic tundra of North America from Alaska to Greenland (Johnsgard 1981), and winter over a widespread area of North, Central, and South America (Blake 1977). Because of the widespread distribution of the species, little is known of its population status.

Black-bellied Plovers were common on south Texas beaches throughout the year (Figure 11). The greatest abundance occurred in April and September, probably as a result of migratory movements. The highest abundance was 4.4 birds per km, recorded on 25 September 1980 (8.1-km census area). During the summer all of the Black-bellied Plovers on the beach lacked complete breeding plumage.

Habitat-use patterns. Few Black-bellied Plovers engaged in feeding activity during daylight hours (Table 8). Most were observed standing in the berm (63% of all observations) or in the backshore (24%). Those that were observed feeding did so at the upper portion of the swash zone. Foraging methods included alternate pecking and running, and pausing.

Throughout the night Black-bellied Plovers commonly fed on the beach by probing in the sand at the swash line. The rate of probing appeared to be much greater at night than during the day, and there were fewer pauses and movements between probing attempts.

Black-bellied Plovers were distributed uniformly down the length of the beach. During the late fall and early spring, concentrations increased slightly on the southern portions of the island. Sometimes large groups (15-30 birds) were seen in the backshore.

Vulnerability to oil spills. Although oil-stained Black-bellied Plovers were never observed, such stains were difficult to discern on adult birds. Because of their feeding habits, local populations of this species may be very vulnerable to oil spills. However, the world-wide population is so dispersed that cosmopolitan declines because of a single spill are unlikely. On the Texas coast the periods of greatest vulnerability are from early April to mid-May and from early August to late November.

Ruddy Turnstone (*Arenaria interpres*)

Status and seasonal abundance. Ruddy Turnstones breed in North America from northeastern Alaska east across arctic Canada to Southampton and the Baffin Islands (Johnsgard 1981). Migration begins in July and by early August migrants appear on most of the coasts of the United States (Cooke 1910). The species winters primarily on the Gulf and Atlantic coasts (AOU 1957) and may occur on the Texas coast throughout the year (Oberholser and Kincaid 1974).

The abundance of Ruddy Turnstones was greatest from April to May (Figure 12). Many Ruddy Turnstones (presumably nonbreeding subadults or stragglers) remained on south Texas beaches throughout the summer months (Oberholser and Kincaid 1974). The abundance of Ruddy Turnstones increased again in August, September, and October, but declined greatly during the winter months. In both years of the study only one bird was counted during all of the January censuses.

Habitat-use patterns. Ruddy Turnstones are scavengers (Bent 1929). They feed by turning over shells, stones and other debris to uncover sand fleas, worms, insects, and other organisms (Oberholser and Kincaid 1974). They have been observed "rooting like a pig" (Bent 1929) in piles of seaweed and frequently turn over large objects by pushing them with their breast.

As a consequence of their feeding behavior, most Ruddy Turnstones were observed in the foreshore (47% of all observations) and berm (45%). Their distribution coincided with availability of beach wrack, and they exhibited no preference for sand or shell beaches.

Vulnerability to oil spills. Ruddy Turnstones appear to be highly vulnerable to oil spills. Their habit of feeding in and around beach debris in the foreshore and berm limits them to the habitats most affected by oil spills. Their habit of picking food from the midst of seaweed and other debris which may become oil soaked insures exposure to oil. The period of maximum vulnerability is from April to May and from September to October.

Willet (*Catoptrophorus semipalmatus*)

Status and seasonal abundance. There are two subspecies of Willets that breed in the United States. The eastern subspecies (*C. s. semipalmatus*)

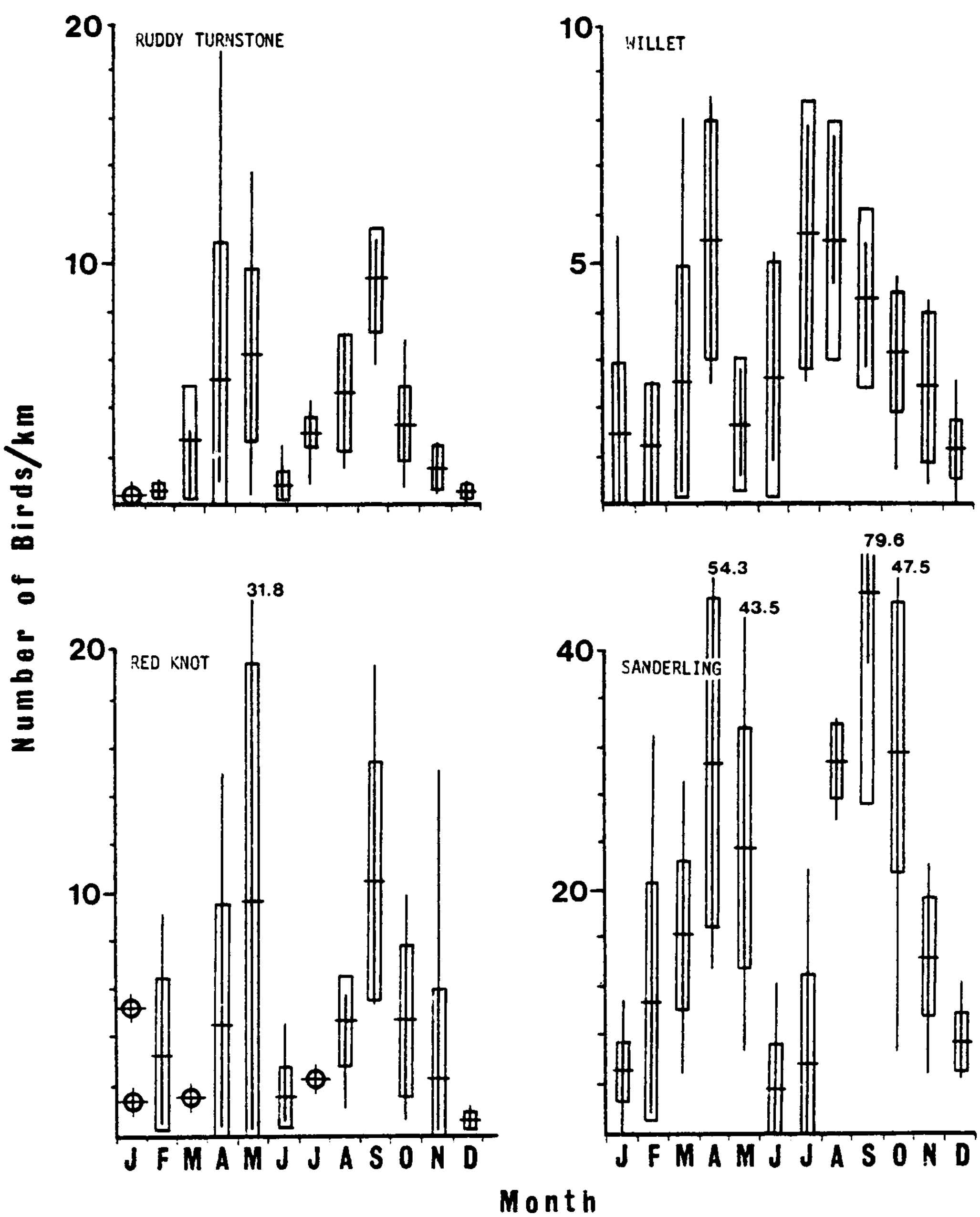

Figure 12. Seasonal abundance patterns of Ruddy Turnstones, Willets, Red Knots, and Sanderlings. See Figure 8 for explanation of symbols.

breeds in southwestern Nova Scotia, from southern New Jersey and Delaware south along the Atlantic coast to Florida, and from southern Texas eastward along the Gulf coast to western Florida (AOU 1957). The western subspecies (C.s. inornatus) breeds westward from South Dakota and southern Manitoba to Oregon, and southward along the Pacific coast.

Both subspecies winter on the Texas coast (Oberholser and Kincaid 1974).

Willets occurred along the south Texas coast throughout the year (Figure 12), but were never very numerous. Willet abundance never exceeded an average of 8 birds per km, but flocks of up to 20 individuals were observed during migration. Numbers increased in late March and early April as flocks of migrants moved through the area. The population declined in the early summer and began to increase again in mid-July. The numbers of Willets remained high throughout August but began to decrease by September. By January and February there were few Willets on the beach.

Habitat-use patterns. Willets spent most of their diurnal hours either feeding or resting (Table 8). Almost all of their activities were centered on the foreshore (94% of all observations). Willets fed by wading in the swash zone, sometimes belly-deep, and probing for infaunal organisms. Loafing usually occurred in the drier portions of the foreshore, but some Willets (5% of all observations) rested on the berm.

While no pattern of feeding activity was discernable, there was a slight preference for feeding on a falling tide. Willets were observed feeding at night, but few apparently do so. The numbers of Willets observed were much lower during the night than during the day.

Vulnerability to oil spills. After the Ixtoc I oil spill, 6% of the Willets had oiled plumage. Most of these were heavily oiled. Willets on the beach seemed to avoid the oiled areas, but because of their feeding habitats, Willets in the swash zone may not be able to avoid patches of floating oil. Periods of peak vulnerability are March through April and July through August.

Red Knot (*Calidris canutus*)

Status and seasonal abundance. The Red Knot has a circumpolar breeding range. The individuals that migrate to the Gulf coast nest in the arctic region north and east of the Great Lakes and in Greenland (Cooke 1910, AOU 1957). Because of hunting, numbers declined during the early part of this century, but have increased slowly since then (Bent 1927).

Red Knots occurred on south Texas beaches from March to May and from August to November (Figure 12). Throughout the remainder of the year, they were virtually absent, although small groups were sighted in all months except June and December 1980 and January 1981. When present, Red Knots always were found in flocks. Flock sizes ranged from 10 to 350 individuals. The flocks were spaced irregularly up and down the beach so that although many individuals might be present on a given census date, abundance figures were low. Maximum abundance was 13.3 birds per km on the 9 May 1981 whole-island census.

Habitat-use patterns. Of all the Red Knots counted, only four individuals were not in the foreshore. The flocks feed together in the upper portions of the swash zone. An average of 71% (Table 8) of a Red Knot's time budget was devoted to feeding activity. Most of the remainder of the time is spent in locomotion. No aggressive behavior between individuals in the flocks was recorded.

Few Red Knots were observed on the beach at night. Most flocks left the beach at dusk and returned at dawn. None of the Red Knots observed on the beach at night were feeding. They appeared to be sleeping near the berm edge of the foreshore.

Vulnerability to oil spills. Red Knots are dependant upon the foreshore for feeding habitat. As a result, they are highly vulnerable to oil spills. An oil spill not only may contaminate a large number of birds, but also may reduce the food supply that may be critical for a migrating species. The periods of greatest vulnerability are from March to May and from August to November.

Sanderling (*Calidris alba*)

Status and seasonal abundance. Sanderlings breed on the northern arctic islands and in northern Alaska (Bent 1927, Johnsgard 1981), and winter from British Columbia and Massachusetts south to southern South America (Blake 1977). As a consequence of its broad range, the Sanderling has maintained a stable population (Johnsgard 1981).

The annual cycle of Sanderling abundance on Padre Island followed the overall pattern of avian abundance on the beach (Figure 12). Peak densities were recorded in April and September as migratory flocks moved through the area. A few birds remained on the beach in the summer, but summer densities declined to fewer than 3 Sanderlings per km. While winter numbers were lower than fall numbers, they rarely fell below 10 birds per km.

Habitat-use patterns. Sanderlings typically feed by probing in the damp sand behind retreating waves. They follow the drainage flow of a retreating wave down the foreshore, probing as they go, and then rush up the foreshore towards the berm just ahead of the next oncoming wave. Sanderlings also feed by pecking at beach debris, including carrion.

Seventy-four percent of all Sanderlings observed were counted in the foreshore where most feeding occurred. Feeding occupied over 64% of a Sanderling's diurnal time budget (Table 8). However, there is a bias in these data: time-budget studies were conducted only on active

(=feeding) Sanderlings. Thus, the loafing or resting component is underestimated.

Most resting Sanderlings were observed on the berm (81% of all resting observations) or backshore (18%), although limited foraging activity occurred in these habitats. Sanderlings rarely stood like most shorebirds when resting. Instead, they squatted in depressions or on the lee side of large items such as logs. As a result, most Sanderlings that got oil on their feet transferred the oil to their belly plumage.

Sanderlings are among the few species that remained on the beach at night in high numbers. Feeding occurred throughout the night. Although feeding attempt rates (pecks per minute) were similar for nocturnal and diurnal feeding, feeding behavior was different. During the daytime, most Sanderlings appeared to be territorial. Individuals were spaced at regular intervals and aggressive behavior occurred when one bird encroached upon another's area. At night, however, Sanderlings were almost always seen feeding in groups ranging in size from 3 to 16 individuals. The birds were closely grouped, approximately 10 to 30 cm apart, and walked together in the same direction down the length of the foreshore. Feeding orientation was independent of wave action.

Vulnerability to oil spills. The feeding habits of Sanderlings make them extremely vulnerable to oil spills. After the Ixtoc I oil spill, all observed Sanderlings had oil on their feet and 40% had oil on their breast plumage. During this period, several Sanderlings taken by Gene W. Blacklock (Welder Wildlife Foundation, pers. comm.) showed signs of malnutrition. One Sanderling, autopsied by personnel in the Fish and Wildlife Service, showed signs of liver and kidney tissue damage (D.W. White, pers. Comm.). The period of peak vulnerability is from February through May and from August through October.

ORDER CHARADRIIFORMES (GULLS)

Herring Gull (*Larus argentatus*)

Status and seasonal abundance. The Herring Gull, the most widely distributed gull of the Northern Hemisphere, has a circumpolar breeding range. It nests in colonies from Ellesmere Land, British Columbia to Manitoba and Maine (Bent 1921), and winters from the southern parts of its breeding range south along all United States coasts to Panama, Bermuda, and the West Indies (AOU 1957).

Herring Gulls were present on the Texas coast from late October to mid-April (Figure 13). During that period they were common, but never numerous. Maximum density was less than three birds per km, and the species was distributed uniformly down the beach. Herring Gulls were not seen in summer.

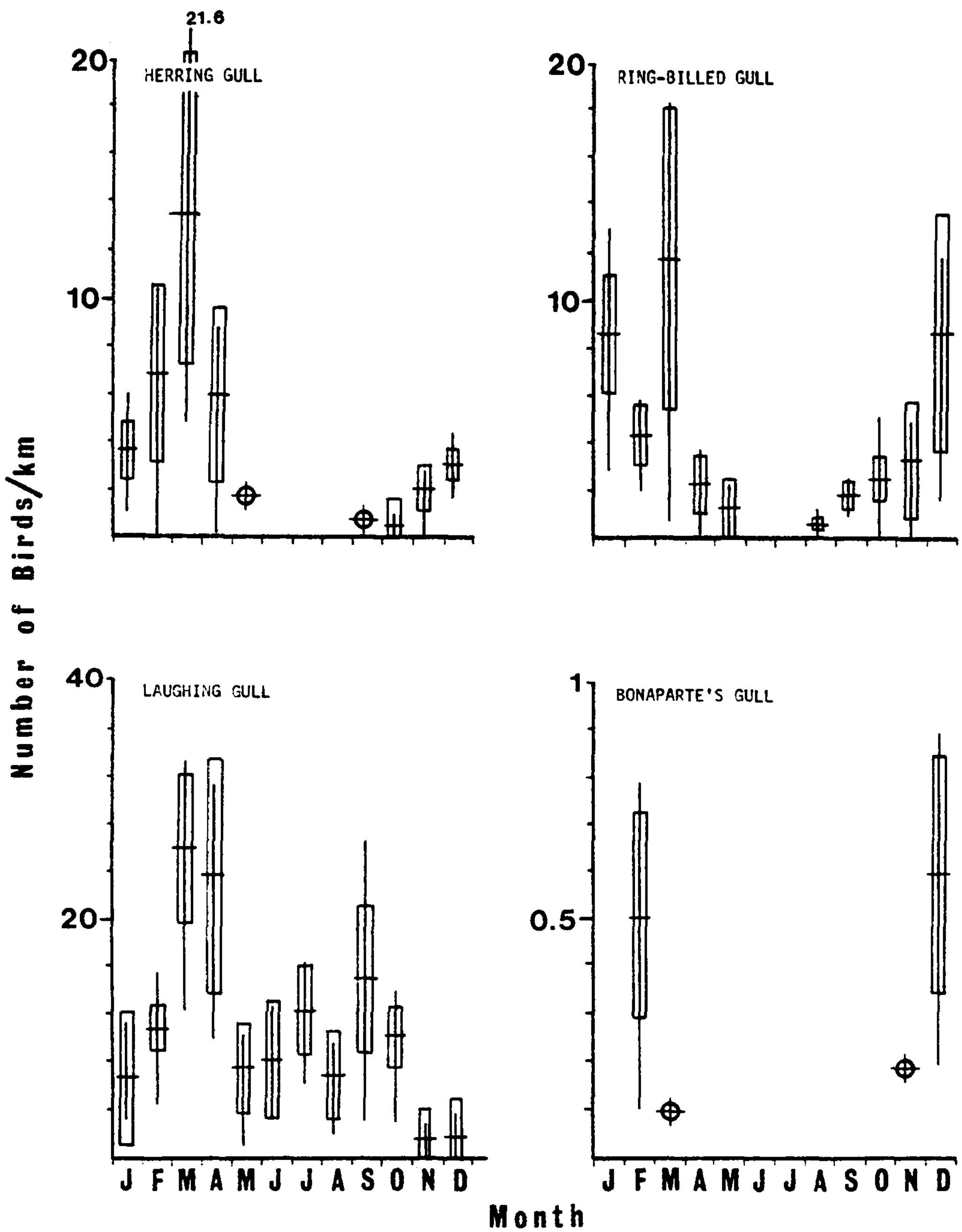

Figure 13. Seasonal abundance patterns of Herring Gulls, Ring-billed Gulls, Laughing Gulls, and Bonaparte's Gulls. See Figure 8 for explanation of symbols.

Habitat-use patterns. Herring Gulls fed by scavenging upon dead organisms on the beach. When not feeding, they usually were observed standing at the upper part of the foreshore in mixed gull and tern flocks. On a few occasions Herring Gulls were seen swimming in nearshore waters, usually in the vicinity of a pass.

Although the abundance of Herring Gulls on the beach was low during the winter, there were many Herring Gulls on the Laguna Madre. These birds fed by diving in shallow water for scallops (Pecten sp). It is unknown to what extent birds from the Laguna Madre use the Gulf beaches and vice versa.

Vulnerability to oil spills. The individuals that inhabit the Texas Gulf Coast are vulnerable to oil spills because of their concentration in the foreshore. However, these individuals represent a small portion of the species' national population. The period of peak vulnerability is from December through March.

Ring-billed Gull (*Larus delawarensis*)

Status and seasonal abundance. Ring-billed Gulls nest in colonies throughout the northern United States and Canada (Bent 1921), and winter from the southern portions of their breeding range south to Central America (AOU 1957). The population of Ring-billed Gulls has increased since the 1930's, 3-to 5-fold in certain western states (Conover et al. 1979, Conover and Conover 1981).

Ring-billed Gulls were common along the Texas coast from September to April (Figure 13). A few early migrants were seen in August and the population increased to a maximum abundance of more than 10 birds per km in March. The population declined as migrants departed; by May only a few individuals remained.

Habitat-use patterns. Ring-billed Gulls fed by picking fish or organic debris from the surface of the water. They also scavenged among beach wrack at the high tide line. Ring-billed Gulls often congregated in the foreshore near passes or channels in large, mixed-species flocks of gulls and terns.

Vulnerability to oil spills. Although a large proportion of the wintering population remains inland (Oberholser and Kincaid 1974), those Ring-billed Gulls that winter along the coast are vulnerable to oil spills because of their feeding habits and choice of resting habitats. Peak vulnerability occurs from December to March.

Laughing Gull (*Larus atricilla*)

Status and seasonal abundance. Laughing Gulls breed along the Atlantic coast from Nova Scotia south to Florida and along the Gulf coast from Florida westward to Texas and south to the Yucatan (AOU 1957). They winter along the south Atlantic coast, the Gulf coast, the Pacific coast of southern Mexico south to northern South America (Oberholser and Kincaid 1974). The Texas breeding population of Laughing Gulls has declined slightly in recent years (Blacklock et al. 1978, Chapman 1980).

Laughing Gulls were present on the beach throughout the year (Figure 13). Few birds were counted during December and January, but the population increased to a peak abundance of 18.6 birds per km by late April. Most of these birds were in breeding plumage. Numbers decreased through the summer but began to increase again in late August. Peak fall abundance was reached in mid-September (10.4 birds per km).

Habitat-use patterns. Large colonies of Laughing Gulls nest on islands in the Laguna Madre and associated bays. In March and April, Laughing Gulls assembled on the Gulf beaches to carry on courtship rituals. Most displays took place in the foreshore although the backshore was also used. Laughing Gulls accumulated in large flocks in the foreshore when not displaying.

Few Laughing Gulls fed on or near the beach although they sometimes scavenged along the high-tide line. Laughing Gulls congregated in the vicinity of campers, picnickers, and fishermen. Many Laughing Gulls flew offshore to feed on the discarded organisms from shrimp boats.

Vulnerability to oil spills. The abundance of Laughing Gulls on the beach throughout the year makes a large proportion of the Texas population extremely vulnerable to oil spills. During the breeding season, the gulls that contaminate their plumage on the beach may also cause high mortality in young and eggs (Hartung 1965). Peak vulnerability may be interpreted in two ways: the greatest number of Laughing Gulls is at risk in April and May and in September and October, but the breeding success of Laughing Gulls may be most affected by an oil spill in early summer.

Bonaparte's Gull (*Larus philadelphia*)

Status and seasonal abundance. Bonaparte's Gulls, the smallest and most tern-like North American gulls, range widely throughout the Western Hemisphere. They breed from western Alaska and northeastern Manitoba south to central British Columbia and east to Ontario (AOU 1957). They winter from southwestern British Columbia to southern Baja California along the Pacific coast, from Ohio to Massachusetts and south to Florida along the Atlantic coast, and in the Gulf States from Florida to southeastern Mexico. Their occurrence along the Gulf coast in the winter is sporadic. In some years they are common or even abundant, but in other years none are observed (Lowery 1974, Oberholser and Kincaid 1974, Imhoff 1976).

Bonaparte's Gulls were never numerous during this study. Individuals and small groups were observed from mid-October to late March (Figure 13). The greatest numbers were observed in February 1981, when 125 were counted in a 16-km stretch of beach approximately 20 km north of the Port Mansfield Channel. These birds were feeding in the surf and in the openings of several temporary, storm-produced passes. In February 1981, an average of 1.2 Bonaparte's Gulls per km of census were observed, the highest abundance recorded for the species during the study.

Habitat-use patterns. Bonaparte's Gulls feed by hovering just above the water surface and picking food items from the surface during quick swoops, or by swimming on the water surface. When hovering, Bonaparte's Gulls usually fly above rough water at the swash line or at the break-point bars. When swimming, the gulls prefer calmer water between the bars or in passes. Several Bonaparte's Gulls were observed far offshore during the pelagic census.

This species is not dependent upon the marine environment for its food. It is often seen feeding in plowed fields or on freshwater ponds and rivers (Oberholser and Kincaid 1974, Cogswell 1977). Such diversity of feeding habits may account for its sporadic occurrences in coastal habitats.

Vulnerability to oil spills. Bonaparte's Gull is the most pelagic North American gull during the winter (Lowery 1974), and little is known of the distribution and abundance of most pelagic species in the Gulf of Mexico. Because this species is only an occasional visitor to coastal habitats, it is not highly vulnerable to oil spills. However, in some years large numbers of this species might be exposed to a spill if they were to concentrate in a contaminated region. The period of peak vulnerability is from November to February.

ORDER CHARADRIIFORMES (TERNS)

Forster's Tern (*Sterna forsteri*)

Status and seasonal abundance. Forster's Terns breed from south-central Alberta to Manitoba and east of the Cascade Mountains in Washington and Oregon south to southwestern California, Utah, and Colorado, and east to Wisconsin (Cogswell 1977). They also breed along the Atlantic and Gulf coasts from Maryland to northeastern Mexico. The greatest number of nests in Texas are found on the central portion of the coast (Blacklock et al. 1978). Most of the nests are situated within mixed-species tern colonies on sparsely vegetated dredged material islands in the bays and lagoons behind the barrier island chain (Chaney et al. 1978). The species winters along the coasts from central California and Virginia to Florida and Guatemala (Cogswell 1977).

The status of the Forster's Tern is uncertain. Although it is not listed as a threatened species, populations in Texas have been declining (Oberholser and Kincaid 1974, Blacklock et al. 1978). This species is particularly sensitive to disturbance during the breeding season.

Forster's Terns were rarely seen along the barrier island beaches during the summer (Figure 14). When feeding young, Forster's Terns foraged in the bays and lagoons and rarely ventured into Gulf waters. After the breeding season, Forster's Terns joined most of the other locally common species of terns in large mixed-species flocks on the Gulf beaches. Forster's Terns began to arrive on the beaches in early August and increased in numbers until late October. During the fall, as many as 100 Forster's Terns were counted feeding in a 200-km transect. Abundance declined through the winter months, presumably

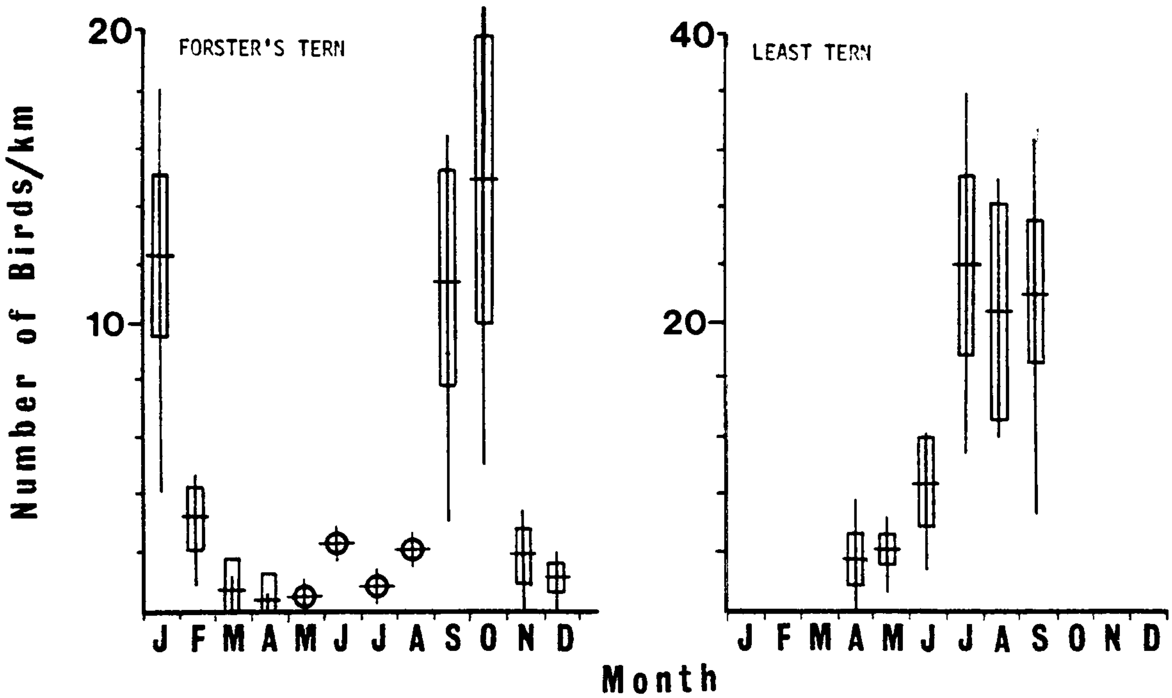

Figure 14. Seasonal abundance patterns of Forster's Terns and Least Terns. See Figure 8 for explanation of symbols.

as a result of southward migrations, but began to increase again in mid-January. By mid-March, few Forster's Terns were found on the beach.

Habitat-use patterns. When feeding, a Forster's Tern flies into the wind parallel to the beach over the center of the first trough. When prey is sighted, the tern comes to an abrupt stop in midair, followed by a steep dive or plunge into the water. The bird usually disappears from sight below the water surface for a brief period, then emerges immediately into flight.

When not feeding, Forster's Tern flocked with other species of terns in large aggregations centered about the high-tide line. Many individuals in these flocks folded their legs into their plumage and rested with their bellies directly on the sand. All terns left the beach at dusk and usually did not return until midday. They apparently roosted on sandbars in the Laguna Madre during the night.

Vulnerability to oil spills. Forster's Terns are highly vulnerable to oil spills during the spring and fall. Their habit of sitting at the high-tide line where tar balls and oil slicks accumulate increases the chances of getting oil on their plumage. The periods of peak vulnerability are from August to October and from February to March.

Least Tern (*Sterna antillarum*)

Status and seasonal abundance. Least Terns breed in small colonies located along the coast from California to Baja California and from

Massachusetts to Florida. They also breed along the Gulf coast from Texas south to Brazil and inland along the Mississippi River and its tributaries (AOU 1957). In past years Least Terns nested on the barrier island beaches, but increased human activity on these beaches since the early 1940's have forced the terns to move to more isolated locations on dredged material islands (Louis Rawalt, pers. comm.). Today most Least Terns nest on shell banks or dredged material islands in the bays and lagoons behind the Texas barrier island chain (Chaney et al. 1978). Least Terns winter along all coasts in the southern portions of their range.

The Least Tern was recommended for inclusion on the Blue List of threatened species throughout its range because of widespread population declines (Tate 1981). The annual Texas Colonial Waterbird Censuses have indicated a significant decline in Texas Least Tern breeding populations: 380 nesting pairs were counted in 1978 compared to 4,300 pairs in 1973 (Blacklock et al. 1978).

In this study no Least Terns were observed from mid-October through March. Small groups of Least Terns, usually pairs, were seen in early April and the number seen on each census increased until late July (Figure 14). On the 31 July 1980 census, 356 Least Terns were counted in the 8.1-km study for a maximum abundance of 44.0 birds per km. This was a much higher abundance than previously indicated by the few ornithologists that have studied Least Terns in Texas. It may indicate that Padre Island is a major gathering area for Least Terns during southward migrations.

Habitat-use patterns. Least Terns feed in a manner similar to Forster's Terns. Least Terns also dive into the shallow water behind the crest of a dying wave at the upper end of the swash zone. Although the birds dive from heights exceeding 3 m, they rarely go below the surface.

When resting on the beach, Least Terns usually were found in pairs or in groups that were some multiple of two. The birds rested from the high-tide line to the midbackshore, but most often they were found near the top of the berm. Least Terns rarely associated with flocks of other species of terns, but, like other terns, they left the beach at dusk.

Vulnerability to oil spills. Least Terns are extremely vulnerable to oil spills. Birds that feed in the surf or rest on the foreshore might be killed by an oil spill during the late spring, summer, and fall months. The period of peak vulnerability is from June through October.

During the Ixtoc I oil spill many Least Terns with oil spots on their breast plumage were seen. Even more common were Least Terns with oil stains around the cloacal opening. Unfortunately, no specimens in this condition were collected and, therefore, evidence of oil ingestion is lacking.

Royal Tern (*Sterna maxima*)

Status and seasonal abundance. Royal Terns nest along the Gulf coast from Florida to northeastern Mexico, along the Atlantic coast from Maryland to northern Venezuela, and in Baja California. The species winters throughout the southern portions of its breeding range south to Peru and Argentina (AOU 1957).

Although the Royal Tern has been included on the Blue List several times in the past ten years (Arbib 1973, 1979), its current status is uncertain (Tate 1981). Royal Tern populations have declined slightly on the Texas coast in recent years but this species remains the most numerous tern in the state (Blacklock et al. 1978). They breed in large colonies along the Texas coast, often in association with Forster's Terns and Caspian Terns. Royal Tern colonies typically are found on open sand or shell substrates that occur on natural or dredged material islands (Chaney et al. 1978). Such colonies are located in every bay system along the coast (Oberholser and Kincaid 1974).

Royal Terns were counted on every census in this study. During the nesting season, Royal Terns that nested on islands in the Laguna Madre and Corpus Christi Bay flew across Mustang and Padre Islands to feed in the Gulf. During this period few birds loafed on the beach. The greatest numbers of Royal Terns were counted in March, prior to the onset of the breeding season, and in October during fall migration (Figure 15). In October, as many as 60 birds per km were counted.

Habitat-use patterns. Feeding Royal Terns preyed on fish in the second trough, although some feeding in the first and third troughs also was seen. Royal Terns dove for fish in the manner described for Forster's Terns. Loafing terns sat in mixed-species flocks at the high-tide line. During the fall such flocks regularly contained more than 200 individuals.

Vulnerability to oil spills. Because of their seasonal abundance and habit of sitting at the high-tide line, Royal Terns are extremely vulnerable to oil spills. The periods of peak vulnerability are from February to April and from August to November, but oil spills in late spring and early summer could seriously affect reproductive success of the Texas population. Oil-stained plumage acquired during fishing expeditions could contaminate and kill eggs and young (Hartung 1965).

The susceptibility of Royal Terns to oil contamination was demonstrated during the Ixtoc I spill. Approximately 70% of the Royal Terns on the beach during the first week of oil impact had oil stains on their plumage. The stains were concentrated on the breast, indicating that the terns sat in pools of oil or in tar balls at the high-tide line. After the first week, few Royal Terns exhibited oiled plumage. They either had learned to avoid contaminated areas (Chapman 1981), had moved further south and were replaced by clean birds, or had died.

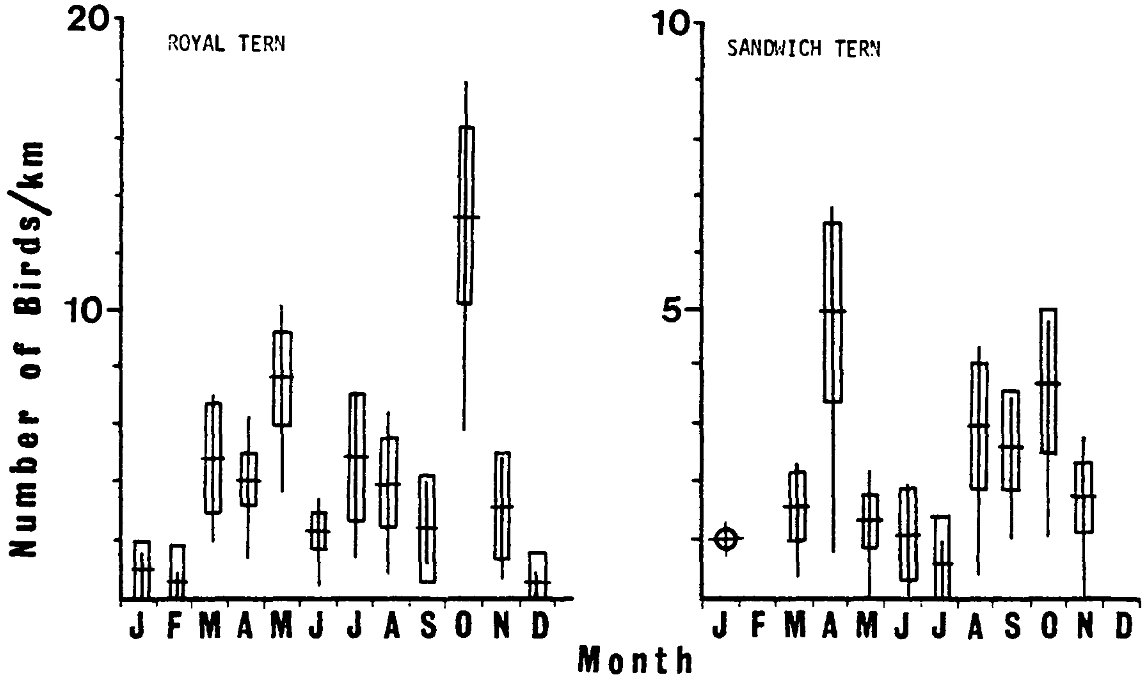

Figure 15. Seasonal abundance patterns of Royal Terns and Sandwich Terns. See Figure 8 for explanation of symbols.

Sandwich Tern (Sterna sandvicensis)

Status and seasonal distribution. Sandwich Terns breed from Virginia to South Carolina, from Louisiana to southern Texas, and on several coral reefs off Yucatan. There also are breeding populations on the Atlantic Coast of Europe and in the Mediterranean. In the Western Hemisphere they winter in the Pacific from southern Mexico to Panama. They are rare winter residents along the northern Gulf coast (Lowery 1974); the main portion of the population winters from southern Florida and the Caribbean area to southern Brazil.

No information indicating a population decline for this species has been published. In fact, the Texas population has increased slightly in recent years (Blacklock et al. 1978). Most of the Texas breeding population breeds along the central and southern parts of the coast.

Only isolated individuals or small flocks of Sandwich Terns were counted in winter in this study. Larger numbers of these terns began to arrive in early April (Figure 15). The main concentration of Sandwich Terns in the spring was on south Padre Island. Few Sandwich Terns were seen on the beach in the summer even though thousands nested on islands in the Laguna Madre. Large numbers of these terns began to appear again in mid-August and remained on the beach until late October.

Habitat-use patterns. During the spring and fall Sandwich Terns rested at the high-tide line in large, mixed-species flocks. Individuals or small groups occasionally broke away from these large flocks and fed in the nearshore waters. Sandwich Terns dove for fish in the manner described for Forster's Terns except that they feed in deeper waters. Most Sandwich Terns were seen feeding out from the second bar and many were observed diving for food beyond the third bar.

Although few Sandwich Terns were counted on the beach during the summer, many were seen flying to and from the Laguna Madre to obtain fish from the nearshore waters. Sandwich Terns nest on natural and dredged material islands in the Laguna Madre and associated bays (Chaney et al. 1978). Probably a large percentage of food given to the young is taken from the Gulf.

Vulnerability to oil spills. Sandwich Terns are vulnerable to oil spills along the Texas coast in the spring, summer, and fall. During the summer, oil could be transferred to the eggs and young and thus reduce reproductive success for a season (Hartung 1965). The period of peak vulnerability is from April through October.

Caspian Tern (*Sterna caspia*)

Status and seasonal abundance. Caspian Terns breed in scattered locations throughout the northern hemisphere and Africa (Cogswell 1977). Breeding colonies in North America occur from Manitoba south to Baja California, along the Atlantic coast from Virginia to Florida, and along the Gulf coast from Florida to southern Texas. At one time the species may have nested on the sandy beaches of the Texas barrier islands (Oberholser and Kincaid 1974). Nowadays it nests on natural and dredged material islands in the bays and lagoons behind the barrier island chain; no inland Texas colonies are known (Chaney et al. 1978). Caspian Terns winter in California (Pacific coast birds) and in Central and South America.

Oberholser and Kincaid (1974) suggested that the breeding population of Caspian Terns in Texas started to decline after 1950. Since 1973, however, Caspian Terns have maintained a stable population in Texas (Blacklock et al. 1978). The Texas population may have future difficulties as a result of environmental pollution. King et al. (1978) found that Caspian Tern eggs had the highest PCB residues (16.5 ppm) and the second highest concentration of DDT (15.1 ppm) of all the waterbirds breeding in Texas.

Caspian Terns were absent from the southern Texas coast in winter (Figure 16). The earliest arrival date for the species was 2 April 1981, but few individuals were seen until the first of June. The species was regularly seen on the beach, although in small numbers, through October. The numbers dwindled throughout November and by the end of the month, all Caspian Terns were gone.

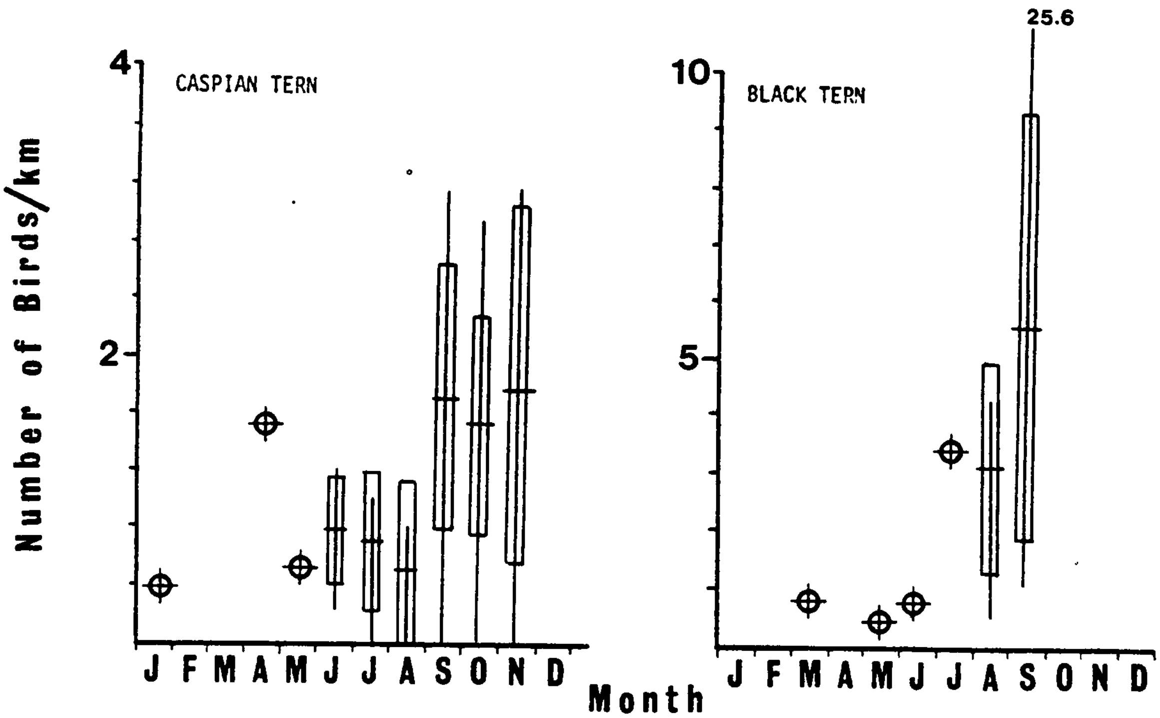

Figure 16. Seasonal abundance patterns of Caspian Terns and Black Terns. See Figure 8 for explanation of symbols.

Habitat-use patterns. Caspian Terns were seen regularly in groups of two or four; larger groups were rare. Most of the time these small groups were independent of the large tern flocks seen along the beach, but were also found resting at the high-tide line. Feeding Caspian Terns hunted between the first and second bars and dove from a greater height than other terns.

Vulnerability to oil spills. Caspian Terns are vulnerable to oil spills because they loaf on the beach in the same manner as other terns and because they feed in nearshore waters. They are vulnerable throughout the spring, summer, and fall, but the period of peak vulnerability is during September and October.

Black Tern (Chlidonias niger)

Status and seasonal abundance. Black Terns breed across much of the north-central United States and from southeastern British Columbia to California, Nevada, Utah, and Colorado (AOU 1957). They nest in small colonies located in marshes or on the margins of lakes or ponds and winter on rivers in South America and on the ocean from the Gulf of Mexico southward to northern South America (Bent 1921).

The Black Tern was placed on the Blue List in 1978 (Arbib 1977). The species has been declining at the eastern end of its breeding range as a result of habitat loss and nesting disturbance (Arbib 1979, Tate 1981).

Occasionally small flocks were seen in spring, but Black Terns appeared in large numbers on south Texas barrier beaches only during the fall (Figure 16). Most Black Terns that migrate through south Texas during the spring remain inland, feeding in plowed fields (Oberholser and Kincaid 1974). During August and September, large flocks of Black Terns were common on the beach. Maximum abundance exceeded 25 birds per km in mid-September.

Habitat-use patterns. Black Terns intermingled with the mixed-species tern flocks that occupied the foreshore. Feeding Black Terns flew over the grasslands or ponds on the interior of the islands or directly above the foredune ridge and apparently fed on flying insects. Some birds flew above the second bar and pecked at the water's surface just behind a breaking wave.

Vulnerability to oil spills. Black Terns loaf in the foreshore during fall migration, thus exposing themselves to accumulations of tar and oil on the beach. Because large numbers of Black Terns migrate through the area, a large spill could reduce already declining populations of this species. The period of peak vulnerability is during August and September.

CONCLUSIONS

Although the Ixtoc I oil spill was the largest spill ever recorded in a marine environment (Woods and Hannah 1981), it apparently did not cause mass mortality of marine birds as have many other recent spills. For example, thousands of birds were killed as a result of the Torrey Canyon spill (Bourne et al. 1967, Bourne 1970), and many hundreds of birds were lost in other spills (Hope-Jones et al. 1970, Smail et al. 1972, Cooper 1978, Veitch 1978).

Most spill-related avain mortality is caused directly by plumage fouling or toxicity, but indirect effects can also reduce bird populations. Oil pollution can reduce avian food supplies (Bellamy et al. 1967), forcing birds to use less nutritious foods (Burnett and Snyder 1954) or occupy less productive feeding habitats (Aldrich 1938, Eastin and Hoffman 1978). However, the relationships between such food or habitat shifts and mortality are unknown.

The marine birds on the southern Texas coast may have shifted their habitat to noncontaminated areas during the Ixtoc I oil spill. As a result, only a small percentage of the population was oiled (Chapman 1981). Presumably most of the birds found adequate food in the Laguna Madre or other nearby estuarine habitats, since the numbers the next year were apparently normal.

Although the effects of the Ixtoc I oil spill on marine birds were minor, the spill should be regarded as a special case for two reasons. First, the actual spill site was hundreds of kilometers from the impact site. During the time that the oil floated from the spill site to the south Texas beaches, it underwent a great deal of weathering (MacKay et al. 1981) which reduced its volume, toxicity, and viscosity. Secondly, the oil was present on the beaches for only a short time before being removed by a series of tropical storms (Gundlach et al. 1981). Both of these factors substantially reduced the exposure of birds to oil contamination and the impact of the spill.

The likelihood of future spills in the Gulf of Mexico is substantial. Within the next 15-25 years offshore petroleum may account for 40%-50% of all domestic production, and the Gulf of Mexico represents a major source of such production (Clark et al. 1978). Therefore, this study may be important in providing a base for future impact studies in the event of future spills.

Marine bird populations along the southern Texas coast are threatened most seriously by spills that impact the beach in spring or in fall. The impact of a widespread, prolonged spill on bird populations might be great because marine birds from most of the prairie provinces and northern tundra regions migrate through south Texas and congregate on the beaches. On Padre Island, the foreshore-dependent species are more likely to be affected by plumage contamination and prey population declines than are species that use the backshore. Gulls and terns, on the other hand, must avoid floating patches of oil while feeding (Moffitt and Orr 1968, Bourne 1968).

During all oil spills, passes should be boomed to prevent oil contamination of environmentally sensitive estuarine habitats in the Laguna Madre and associated bays. Many migratory birds, most notably waterfowl (Weller 1964), winter in the Laguna Madre or feed there during migration. Many species nest in the Laguna during the spring and summer months (Chaney et al. 1978).

The beaches of Padre Island serve as important feeding and roosting habitats for many species of shorebirds. The greatest number of shorebirds occur on Padre Island in the spring and fall as a result of migrations. Gulls and terns feed in the Gulf of Mexico nearshore year round, but their numbers are also greatest during the spring and fall. Any oil spill that contaminates the beaches and/or nearshore or reduces the food supply during the spring and fall will likely cause high mortality to shorebirds, gulls, and terns.

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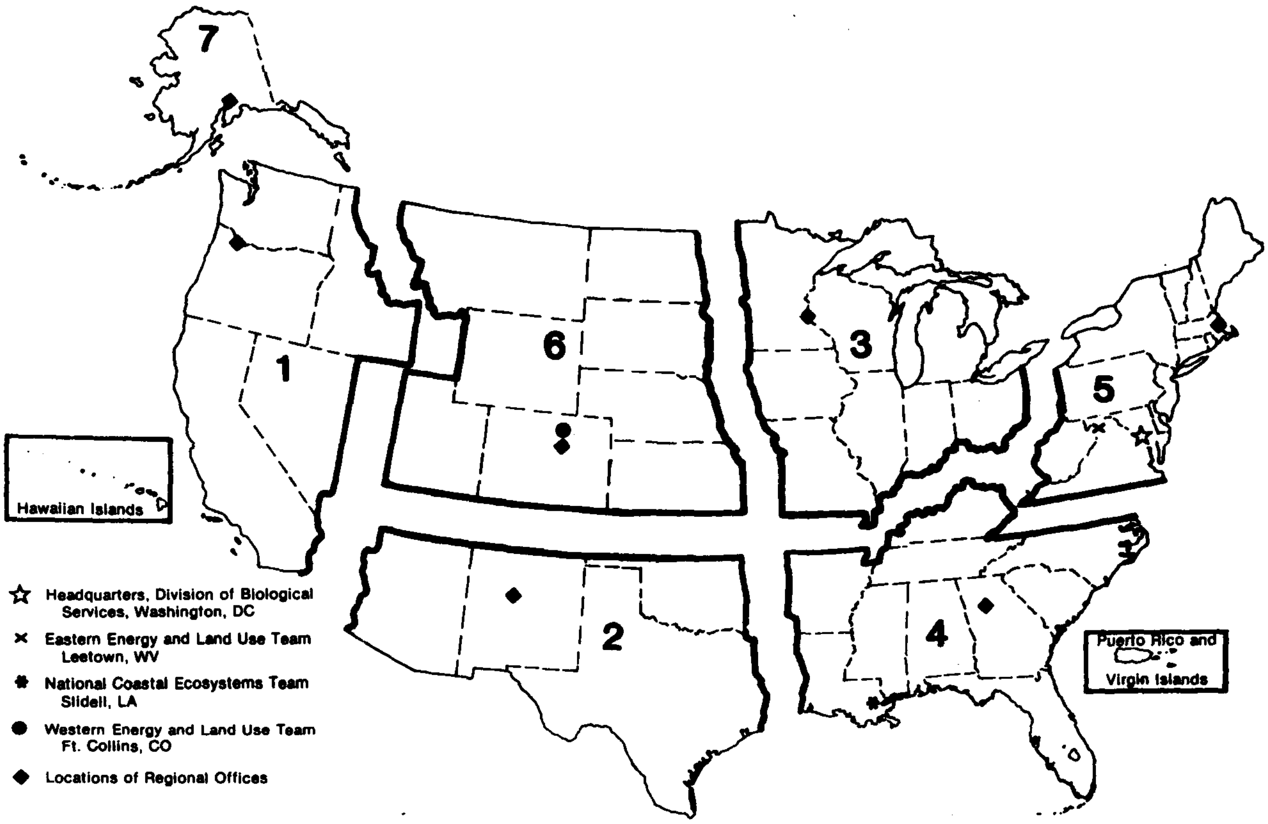

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

DEPARTMENT OF THE INTERIOR
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