Disturbance and Roosting Ecology of California Brown Pelicans (*Pelecanus occidentalis californicus*) on East Sand Island in the Columbia River Estuary

by
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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

DISTURBANCE AND ROOSTING ECOLOGY OF CALIFORNIA BROWN PELICANS (*Pelecanus occidentalis californicus*) ON EAST SAND ISLAND IN THE COLUMBIA RIVER ESTUARY

Chapter 1

GENERAL INTRODUCTION

Sadie K. Wright

This study was designed to determine the effects of potential disturbance, both anthropogenic and natural, on the numbers, distribution, movements, and behavior of California brown pelicans (*Pelecanus occidentalis californicus*) roosting on East Sand Island in the Columbia River estuary. California brown pelicans are listed as endangered under the U.S. Endangered Species Act, which prohibits take of listed species by humans. Flushing California brown pelicans (forcing them to fly) is considered take under the law. The California Brown Pelican Recovery Plan (1983) describes the importance of suitable roost sites to the well-being and survival of California brown pelicans, and recommends minimizing human disturbance at these sites. East Sand Island is the largest known roost for brown pelicans in the Pacific Northwest, and it is one of a few sites used as a night-roost in this region. It is important to understand the factors that could potentially negatively affect pelican use of this roost site or degrade its quality as a roost.

The California brown pelican is one of six subspecies of brown pelicans, and ranges from temperate North America to mid-South America along both coasts. The brown pelican has many of the distinctive traits of the family Pelecanidae, including large size; elongated bill; a large, distensible gular pouch; and totipalmate feet. It is the only pelican species, however, that primarily inhabits marine waters (Shields 2002), plunge-dives for food (Bent 1964, Carl 1987, Johnsgard 1993), and has predominately brown plumage and a black and brown gular pouch (Johnsgard 1993).

The six subspecies of brown pelican differ slightly from each other in size, plumage, and bare skin coloration. The California brown pelican is the third largest in size (culmen, tarsus, and wing length) and displays sexual size dimorphism

(Palacios 2001, Shields 2002). Sexual dimorphism differs among subspecies, with females larger than males in *P. o. occidentalis* and *P. o. urinator*, and males larger than females by 38-44% in *P. o. murphyi* and *P. o. californicus* (Palacios 2001). The proximal end of the gular pouch of the California brown pelican is reddish orange in the non-breeding season and poppy red during the breeding season, considerably different from other subspecies. In general, the plumages of the six subspecies are similar (Shields 2002).

Brown pelicans are socially gregarious and travel and roost in large flocks year round. They breed in large colonies of up to several thousand pairs on offshore or estuarine islands free from mammalian predators. They are monogamous within a breeding season, typically lay 3-egg clutches (range 2-4 eggs), and begin breeding at 3-5 years of age (Shields 2002). California brown pelicans nest on islands off the Pacific coast of Baja California (Everett and Anderson 1991) and the Channel Islands of southern California (Gress 1995). Many pelicans migrate north from these areas post-breeding in search of food along the coast of Oregon and Washington (Jaques 1994; Ulrich Wilson, pers. comm.), with smaller numbers migrating to the southern coast of British Columbia (Shepard 1999; Ulrich Wilson, pers. comm.). Most of these migrants return to southern California by December (Briggs et al. 1983, Shepard 1999, Tweit et al. 1999).

The California brown pelican was designated as endangered by both the state (California State Endangered Species Act of 1970) and the federal government (35 Federal Register 16047, October 13, 1970) when the segment of the subspecies that nests on the Channel Islands, California experienced catastrophic reproductive failure in the late 1960's and early 1970's. The reproductive failure was primarily attributed to eggshell thinning (Keith et al. 1971, Risebrough et al. 1971, Jehl 1973, USFWS 1983). Considerable evidence has been gathered that indicates a strong relationship between body burdens of DDE, a metabolite of DDT, and the degree of eggshell thinning (Schreiber and Risebrough 1972). The shells of most eggs, highly deficient in calcium carbonate, were crushed during incubation (Jehl 1973, USFWS 1983). Eggshells from Anacapa Island, the site of the largest breeding colony of California brown pelicans in the United States, averaged 53% thinner in 1969 compared to those collected prior to 1943. Of 1,272 nests observed on the Channel Islands in 1969, only two successfully fledged one young apiece (Risebrough et al. 1971).

DDT input into the Pacific Ocean (via wastewater) along southern California dropped dramatically beginning in 1970 (USFWS 1983). Shortly thereafter, mean pelican eggshell thickness began to slowly increase and the nesting success of pelicans on Anacapa Island began increasing as well (USFWS 1983). The increase in reproductive rate began to level off in 1974 (Anderson et al. 1977), while the breeding population increased dramatically until 1980. Since then the population has increased slowly (D. Anderson, UC Davis, pers. comm.), allowing scientists to identify other factors limiting population growth and recovery of California brown pelicans.

Food availability has been identified as a primary factor limiting the reproductive success of California brown pelicans (USFWS 1983). Brown pelicans breeding in the Southern California Bight are highly dependent on northern anchovy (*Engraulis mordax*; Anderson et al. 1980, 1982) and Pacific sardine (*Sardinops sagax*; F. Gress, pers. comm., cited in Shields 2002) during the breeding season. Breeding adults are known to abandon nests and chicks in years of low food availability (Schreiber 1979, Anderson et al. 1982) and migrate to areas of higher prey density (Anderson and Gress 1984).

Human disturbance is another factor limiting the reproductive success of brown pelicans; disturbance at breeding colonies has been linked to lower productivity at the colony (Anderson and Keith 1980, Anderson 1988). The presence of humans on breeding colonies can cause panic flush events by parents, during which nestlings and eggs are crushed (Schreiber and Risebrough 1972, Kushlan and Frohling 1985), larger nestlings leave nests and became entangled in vegetation (Schreiber 1979, Anderson and Keith 1980), and eggs and nestlings are exposed to predators and weather (Anderson and Keith 1980). Repeated human disturbance at breeding colonies has caused complete colony abandonment for multiple years (Anderson and Keith 1980, Stiles 1984).

The California Brown Pelican Recovery Plan (1983) not only describes the importance of protecting breeding colony sites, it also explains the need to designate major roost sites as 'critical habitat' throughout the entire range of the subspecies. Although most, if not all, of the breeding colony sites are now protected, very little has been done to monitor and protect roosting habitat for California brown pelicans. It is difficult to measure the effects of human disturbance on non-breeding pelicans. To determine sensitivity of non-breeding California brown pelicans and other birds to human disturbance, researchers have measured flush response rate and distance (Madsen 1985, Jaques and Anderson 1988, Holmes et al. 1993, Jaques et al. 1996, Stiedl and Anthony 1996). Jaques et al. (1996) developed a protocol for scoring behavioral responses of California brown pelicans to human disturbances to quantify intensity of pelican flush responses. We used a similar method to measure intensity of pelican flush responses on East Sand Island.

East Sand Island (46°15'45"N, 123°57'45"W) is owned by the U.S. Army, Corps of Engineers. It is approximately 2 km in length and is located at river kilometer 8 in the Columbia River estuary. East Sand Island is part of what was once a natural shifting-sand shoal documented by Lewis and Clark in 1805 as "three small islands off the mouth of the river" (Brooke 1942). What became known as Sand Island shifted northeast into Baker Bay and, in 1931, it split into two islands, East Sand Island and West Sand Island (Brooke 1942). Boulder rip-rap was later added to the west end of East Sand Island to prevent further erosion, while the shoreline of the eastern end of the island is primarily sand. The inland areas of the island, including the Tidal Pond area, are vegetated mostly by grasses, small shrubs (Scotch broom, *Cytisus scoparius*; gorse, *Ulex europaeus*; twinberry, *Lonicera involucrata*), and low-lying deciduous trees (willow, *Salix* spp.; alder, *Alnus* spp.).

Coastal estuaries have been identified as important foraging habitat for non-breeding brown pelicans (USFWS 1983, Jaques et al. 1996). Estuaries often support high concentrations of young, schooling fishes, and brackish waters seem to be preferred bathing areas for pelicans, possibly because freshwater reduces salt-water adapted parasites in the gular pouch and esophageal region (Jaques et al. 1996). Islands are preferred by pelicans as roost sites because the deep water around the island provides a barrier for land-based predators (Briggs et al. 1981, Anderson et al. 1982, USFWS 1983, Jaques and Anderson 1988, Shields 2002). Brown pelicans have wettable feathers that will become water-logged and hinder thermoregulation if they can not rest out of the water after feeding, when they dry and preen their plumage (Rijke 1970, Schreiber and Schreiber 1982).

East Sand Island is also the site of the largest breeding colony of Caspian terns (*Sterna caspia*) in the world, the largest breeding colony of double-crested cormorants (*Phalacrocorax auritus*) on the west coast of North America (Roby et al. 1998, Collis et al. 1999), and a large breeding colony of western/glaucous-winged gulls (*Larus occidentalis x L. glaucescens*; ca. 6,000 pairs; D. Roby, USGS, unpubl. data). Researchers have monitored the double-crested cormorant and Caspian tern colonies from 1997 through 2004 to determine diet composition, consumption of salmonid smolts, and the size and productivity of these colonies. Resource managers seek information on foraging patterns, distribution, and habitat selection of double-crested cormorants and Caspian terns to develop sound management plans to help restore endangered and threatened runs of Columbia Basin salmonids (NPPC 1994, NMFS 1995, CRITFC 1995). Research activities have included night-time entry onto the cormorant colony to radio-tag adults and collect chick regurgitations, day- and night-time monitoring of nesting cormorants and Caspian terns from blinds, experiments to measure cormorant energy expenditure rates, lethal collection of cormorants and Caspian terns for food habits analysis, and habitat management to maintain the Caspian tern colony site. An upland area (4-6 acres) of mixed herbaceous and woody vegetation on the east end of the island was scraped free of vegetation and woody debris in 1999 to provide nesting habitat for Caspian terns (Roby et al. 2002), and scarification is required annually to prevent encroaching vegetation from covering the site.

When I conducted this study I attempted to record all pelican disturbances caused by my research activities in order to account for the effects of this study on pelican numbers and behavior on East Sand Island. I attempted to minimize the effects of my presence on pelicans by maintaining a distance of 150 m (or greater if pelicans began to 'startle' or fly) during boat-based censuses, accessing the observation tower (blinds) only within 2 hours of low tide (in order to put as much distance as possible between myself and roosting pelicans) using an aboveground tunnels to access the blinds, installing one-way glass in the observation blinds, padding the floor of the tower, and speaking in hushed tones while in the tunnels and blinds. In an effort to avoid anthropomorphic bias in the classification of pelican activities (Ristau 1996), I used detailed drawings from Schreiber (1977) to categorize activities.

Although public access to East Sand Island is not permitted, sturgeon, salmon, and crab fishermen frequent the waters in close proximity to the island. Local residents gather driftwood from the shores of the island, windsurfers rest on the island, and boaters have been observed to feed birds close to East Sand Island.

There are many potential natural causes of disturbance to California brown pelicans on East Sand Island. Bald eagles (*Haliaeetus leucocephalus*) are common in the Columbia River estuary, with peak abundance during February-May (Isaacs et al. 1983, Garrett et al. 1988, Jenkins et al. 1999), the period when colonial waterbirds are arriving and beginning to nest on East Sand Island. Other raptors hunt on or near

East Sand Island, including red-tailed hawks (*Buteo jamaicensis*), osprey (*Pandion haliaetus*), peregrine falcons (*Falco peregrinus*), and turkey vultures (*Cathartes aura*). Harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and river otters (*Lutra canadensis*) swim in the waters near East Sand Island.

This study was designed to determine how all of these potential anthropogenic and natural disturbance factors affect California brown pelicans roosting on East Sand Island, while accounting for environmental variables such as weather, tide stage, and date. The objectives of this study were to (1) determine the effects of potential anthropogenic and natural disturbances on the numbers and distribution of California brown pelicans roosting on East Sand Island, (2) determine the effects of potential anthropogenic and natural disturbances on the behavior of California brown pelicans roosting on East Sand Island, and (3) examine how other extrinsic factors influence the numbers, distribution, and behavior of California brown pelicans roosting on East Sand Island, including date, time of day, tide stage, and weather (e.g., wind speed and direction, precipitation, cloud cover, and temperature).

Chapter 2

FACTORS AFFECTING THE NUMBERS AND DISTRIBUTION OF CALIFORNIA BROWN PELICANS ROOSTING ON EAST SAND ISLAND IN THE COLUMBIA RIVER ESTUARY

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ABSTRACT

We examined factors that potentially influence the numbers and distribution of California brown pelicans (*Pelecanus occidentalis californicus*) roosting on East Sand Island, Oregon in the Columbia River estuary during 2001 and 2002. Numbers of pelicans roosting on East Sand Island have increased sharply in recent years, from less than 100 during 1979-1986 to a high count of 10,852 in 2002. The East Sand Island roost is currently the largest known non-breeding aggregation of this endangered subspecies throughout its range. Total numbers of pelicans roosting on East Sand Island increased seasonally from April to September or October, and then declined sharply with the onset of winter storms. Pelican numbers on the island were positively associated with tide height in both years. Wind direction and speed influenced where pelicans roosted on the island; roosting pelicans favored the lee side of the island during windy conditions. Natural disturbances and anthropogenic disturbances not related to research on colonial waterbirds had no detectable effect on the total number of pelicans on the island. Recreational boaters affected the distribution of pelicans on the island, causing pelicans to move away from an area of high boater traffic to sections of the island's shoreline less frequented by boaters. In 2001 pelican numbers were negatively associated with the magnitude of daytime research-related disturbance on the island. Numbers of pelicans roosting on East Sand Island were apparently not affected by research-related disturbance in 2002, when new restrictions on research activities reduced the magnitude of disturbance to roosting pelicans.

INTRODUCTION

The California brown pelican (*Pelecanus occidentalis californicus*) was listed as endangered by both the state of California (California State Endangered Species Act of 1970) and the U.S. (35 Federal Register 16047, October 13, 1970) in 1970. The California Brown Pelican Recovery Plan (USFWS 1983) outlined the steps needed to ensure recovery for this subspecies. Protection of major roost sites throughout the range of the California brown pelican was specified as an important conservation action in the recovery plan. The negative effects of human disturbance on nesting success at brown pelican breeding colonies are well documented (Schreiber and Risebrough 1972, Schreiber 1979, Anderson and Keith 1980, Stiles 1984, Kushlan and Frohling 1985, Anderson 1988). The effects of human disturbance at roost sites are less well known, and no published studies have examined the effects of disturbance at California brown pelican roosts in Oregon or Washington.

East Sand Island at river km 8 in the Columbia River estuary is currently the largest known brown pelican roost site in the Pacific Northwest. It is one of the few suitable sites for a night-roost in this region, and the only known night-roost in the Columbia River estuary. Understanding the factors that affect pelican usage of the island or potentially degrade the quality of the roost site is important for achieving the goals of the recovery plan. Although East Sand Island is closed to the public to minimize disturbance to nesting colonial waterbirds, waterbird researchers have been accessing the island since 1997 as part of a study of food habits and breeding ecology of double-crested cormorants (*Phalacrocorax auritus*) and Caspian terns (*Sterna caspia*) in the Columbia River estuary in order to develop sound management recommendations to help recover endangered runs of Columbia Basin salmonids (NPPC 1994, NMFS 1995, CRITFC 1995). Concern arose over the potential effects of these research activities on brown pelicans roosting on East Sand Island.

Human disturbance to birds has led to decreased numbers of roosting and feeding birds at previously preferred sites (Batten 1977, Bell and Austin 1985, Madsen 1985, Bélanger and Bédard 1989), including roost sites frequented by California brown pelicans (Jaques and Anderson 1988). In 2001 we initiated a two-year study to better understand how various disturbance factors, both anthropogenic and natural, and other extrinsic variables (date, time of day, tide stage, and weather) influenced the numbers and distribution of brown pelicans roosting on East Sand Island. The results of this study should help in the design of science-based guidelines for managing roost sites used by this endangered species.

METHODS

Study Area

East Sand Island (46º15'45"N, 123º57'45"W), located 8 km upriver of the mouth in the Columbia River estuary (Figure 2.1), was the focus of this study. The island is approximately 2 km long on an east-west axis, ranges from 10 to 300 m wide, and has an area of approximately 21 hectares (Figure 2.2). The shore of East Sand Island consists of either large boulders (i.e., West Jetty, North Spit, and South Shore), sandy beach (i.e., North, East, and West beaches), or wooden pilings (Figure 2.2).

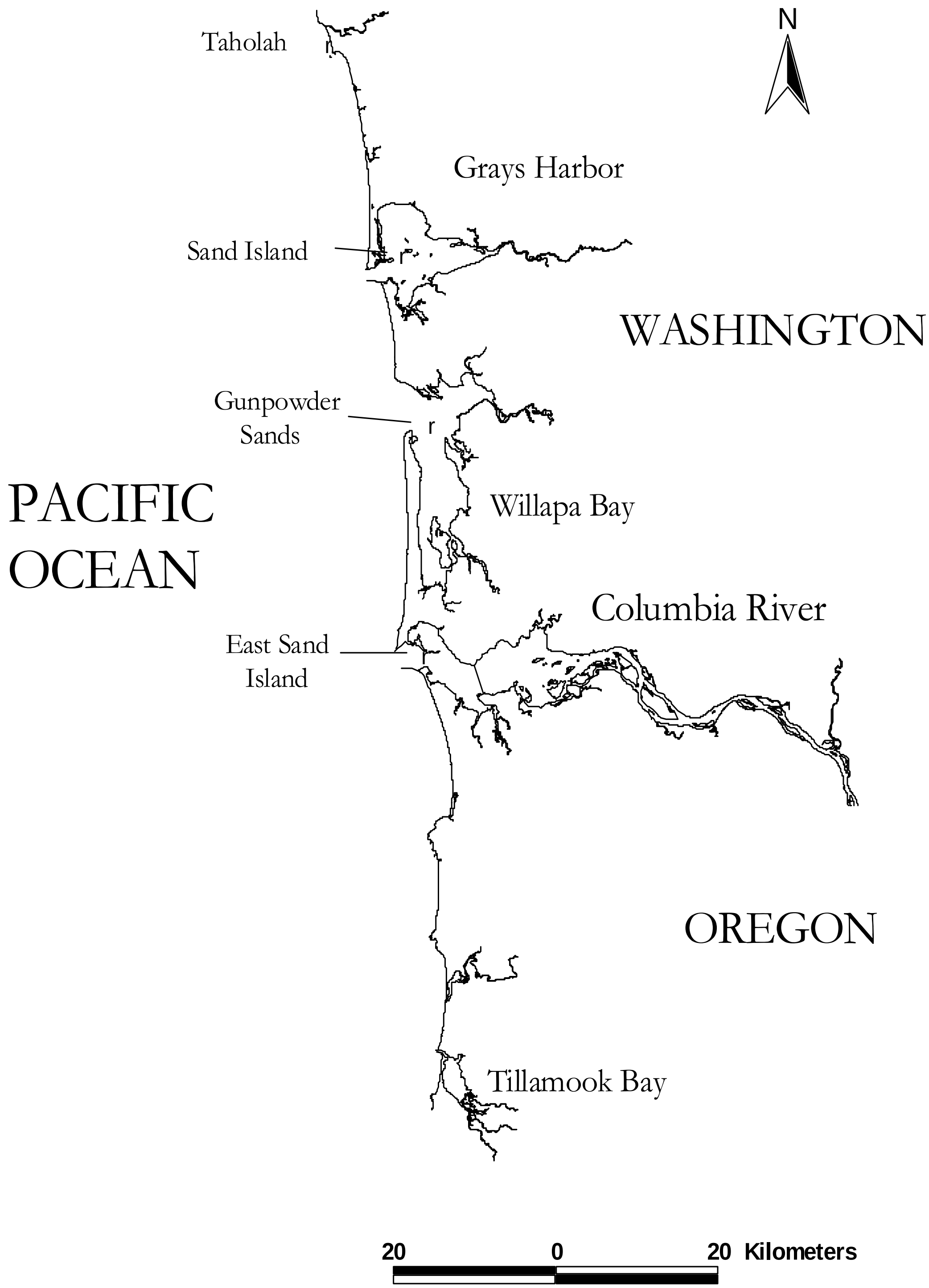


Figure 2.1 Map of northern Oregon and southern Washington coastlines where aerial surveys of roosting California brown pelicans were conducted.

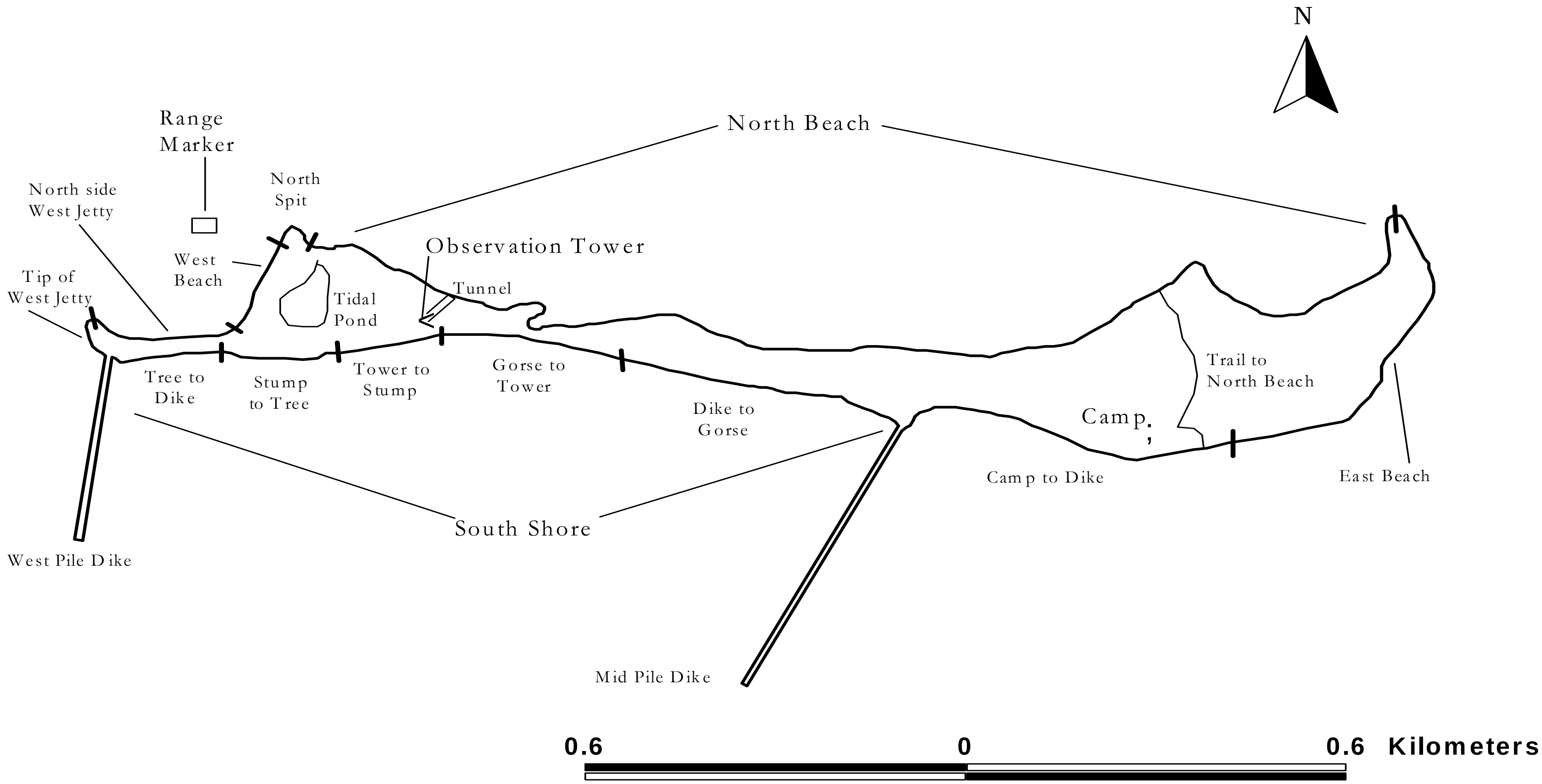


Figure 2.2 Map of East Sand Island showing pelican census section delineations.

The inland areas of the island are mostly vegetated in grasses and low-lying shrubs.

About 6,000 pairs of glaucous-winged/western gulls (*Larus glaucescens* x *L. occidentalis*) nest in grassy upland areas, primarily on the west end of the island. There is a large and increasing breeding colony of double-crested cormorants on the western half of the island (ca. 12,000 pairs; D. Roby, USGS, unpubl. data), mostly on the large boulders from the western tip of the West Jetty eastward to the Mid Pile Dike. The majority of pelicans that roost on East Sand Island are associated with the large cormorant colony.

The large numbers of nesting and roosting waterbirds on East Sand Island attract avian predators, such as bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*), which hunt birds and, in the case of the eagles, are known to kill adult brown pelicans on occasion (B. Winn, pers. comm., in Shields 2002). Both raptor species nest in the estuary near East Sand Island (Isaacs and Anthony 2002; J. Pagel, pers. comm.) and are frequent visitors to the island.

The study area included the coastline from Tillamook, OR north to Taholah, WA, including the large estuaries of Willapa Bay and Grays Harbor (Figure 2.1), areas that were periodically surveyed from the air.

Pelican Census Techniques

We conducted censuses of all brown pelicans roosting on East Sand Island from just offshore of the island using either a 20-foot Boston Whaler or 19-foot Alumaweld skiff. An experienced boat operator piloted the skiff slowly around the island approximately 150 m from shore. Censuses typically began at the northeastern tip of the island, and progressed westward along the south shore (Figure 2.2). After completing the count of pelicans on the south shore to the tip of the West Jetty, an observer was dropped off on a U.S. Coast Guard range marker and, from this elevated and stable vantage point, pelicans were counted on upland areas and the remaining shoreline along the north side of the island (Figure 2.2).

Pelicans were counted individually using 10 x 30 mm Canon image-stabilizing binoculars. Pelicans were counted approximately 6 times per week between June 1 and September 30 in 2001 and 2002; during May, October, and the first half of November censuses were conducted 1-2 times per week in both years. Counts occurred either early in the morning, starting at 05:00 to 07:00 Pacific Daylight Time (as early as light would allow), or late in the evening, starting at 19:00 to 21:00 PDT (as late as light would allow).

Five weather variables were recorded during each census: temperature (°C), percent cloud cover (estimated in increments of 5%), wind direction (degrees converted to Cartesian coordinates), wind speed (Beaufort Scale), precipitation (index of 0-7 ranging from no rain to constant rain).

We gathered data on two tide variables; tide height (meters of water from mean low tide), and tide speed (rate of water movement in meters per hour) at the start of the census. These data were from the NOAA tide gauge at Tongue Point, OR, 17 km up-river from East Sand Island.

We also conducted aerial surveys for roosting brown pelicans along the northern coast of Oregon and the southern coast of Washington, near the Columbia River estuary. In 2001, we conducted aerial surveys approximately twice a week between April 25 and July 18 along the southern Washington coast from the mouth of the Columbia River to the northern channel entrance of Grays Harbor and including Willapa Bay. In 2002, we flew approximately 2 surveys per month from June 15 to September 4. The track of the first three aerial surveys was the same as in 2001, whereas the next three included an additional track along the northern coast of Oregon from Tillamook Bay to the mouth of the Columbia River, including the bays and offshore stacks along this coastline (Figure 2.1).

Aerial surveys were flown in a Cessna 205 at ca. 85 knots air speed and at an altitude of ca. 200 m, just offshore so we could inspect the shoreline and near-shore waters. We never observed pelicans react to the plane during our aerial censuses. The pilot circled offshore stacks as many times as necessary for the observer to obtain a count of any pelicans present. Each aerial survey began at the southern end of the survey route and progressed northward. We used either 10 x 50 mm Leica binoculars or 10 x 30 mm Canon image stabilizing binoculars to count pelicans from the aircraft.

Disturbance Rate

For the purposes of this study, disturbance was defined as any stimulus that caused one or more pelicans to flush (to take flight). We monitored disturbances to pelicans roosting on East Sand Island from an observation tower near the west end of the island (Figure 2.2). From the elevated vantage of this converted U.S. Army Corps of Engineers range marker tower, most of the west end of the island could be easily viewed. Our view of the beaches at the eastern end of the island, however, was obscured by willows (*Salix* spp.) and alders (*Alnus* spp.) growing on upland areas near the center of the island. When disturbed into flight, pelicans leap up and fly away from the disturbance without losing altitude (Schreiber 1977), so we were able to detect pelicans when flushed from most areas of the island from the observation tower. Pelicans often circled high above the source of disturbance before re-landing, or leaving the island, enhancing our ability to detect disturbance events throughout the island.

Observation time blocks were categorized as either morning (04:00-13:00 PDT) or evening (13:00-22:00 PDT); duration of observation bouts was dictated by available light. We randomly selected three observation time blocks per week (alternating one morning and two evening time blocks per week with two morning and one evening time blocks per week) using a random numbers table. We began monitoring disturbance rates to pelicans as soon as daylight allowed, even if this was hours in advance of the selected evening observation time block. In addition, disturbance was monitored until we exited the observation tower, regardless of when the observation time block ended. Observation blocks that were missed due to stormy weather or precluded due to too many pelicans roosting along the access route to the observation tower were completed at the next available opportunity.

We grouped known-cause disturbances into three main categories: (1) Natural, including any non-domestic animal or driftwood; (2) Research, including any activities associated with waterbird research on East Sand Island; and (3) Non-research Anthropogenic, including any human activity exclusive of those associated with waterbird research.

Within an observation block, all natural and non-research anthropogenic disturbances to pelicans, as defined by 1 or more pelicans flushing, were recorded. When a disturbing stimulus occurred, we noted the time, the type of stimulus, distance of the stimulus from the nearest pelicans, and location of the stimulus relative to East Sand Island. We calculated rates of disturbance to brown pelicans by dividing the total observed number of pelicans flushed by the total number of observation hours for each category of disturbance.

We kept track of all pelicans flushed by research activities with the cooperation and assistance of all individuals associated with waterbird research on East Sand Island. In order to compare rates of pelican disturbance caused by research activities with disturbance rates caused by other anthropogenic disturbances and natural factors, we calculated the number of pelicans flushed per daylight hour by each factor. We divided the total number of pelicans flushed by research activities during the period when we collected disturbance rate data for other anthropogenic and natural disturbances (June 1 – September 4, 2001 and June 4 – August 21, 2002, from sunrise to civil evening twilight) by the total number of daylight hours during this period. To quantify the intensity of a disturbance, we recorded the number of pelicans flushed, and the fate of flushed pelicans. Fate was quantified as number that re-landed < 200 meters from the initial roosting place, number that re-landed > 200 meters from the roosting place, and number that left East Sand Island.

Statistical Analysis

We used multiple linear regression to examine factors that potentially influenced the number of pelicans roosting in various sections of East Sand Island. The factors included year (2001 or 2002), date, time of day (morning versus evening census), tide height, tide speed, temperature, precipitation, cloud cover, wind speed, and wind direction.

We examined quadratic functions of these variables and interactions between the variables. Some of the independent variables were correlated, but none of the correlations exceeded 0.4. We used step-wise removal of non-significant (P-value > 0.05) variables to determine models that identified factors that explained a significant proportion of the variation in the number of pelicans roosting on East Sand Island. We also examined factors affecting numbers of pelicans in six sections of shoreline of East Sand Island where disturbances were concentrated (North Spit, Tip of Jetty, Camp to Dike, North Beach, East Beach, Dike to Gorse; see Figure 2.2).

We sought to examine in more detail the potential effects of research-related disturbance on pelican numbers by comparing the proportional change in pelican numbers for paired evening or morning censuses recorded before and after a disturbance caused by research activities. These paired before and after censuses were taken either 24, 48, or 72 hours apart. The magnitude of diurnal research-related disturbance that occurred between the paired censuses was defined as the number of pelicans flushed by research activities divided by the average number of pelicans counted in the two censuses. The interval between the paired censuses used to assess potential effects from diurnal research-related disturbance did not include nights when night-time research occurred on the west end of the island, which might have confounded the results. To determine potential effects of night-time research activities on pelican numbers, we analyzed paired censuses before and after each night-time research activity. We were concerned that the analysis might fail to detect small differences in pelican numbers caused by research-related disturbance, so we set the level of significance at $\alpha = 0.10$.

In addition, we wanted to examine the potential effects of natural disturbances and anthropogenic disturbances (not related to research) on numbers of pelicans roosting on East Sand Island. We used the same paired, before and after census method used in analysis of potential effects of research-related disturbance. We calculated the proportional rate of disturbance by these two categories of disturbance (number of pelicans flushed per daylight hour/average number of pelicans on the island) and ran linear regression models with the response as the proportional change in the number of pelicans between the paired censuses.

RESULTS

Pelican Numbers

We completed 108 censuses of all brown pelicans roosting on East Sand Island during the 2001 field season and 106 censuses during the 2002 field season. The first brown pelicans of the season were observed on East Sand Island on April 7 in 2001 and on April 28 in 2002. In both years no more than 10 pelicans were

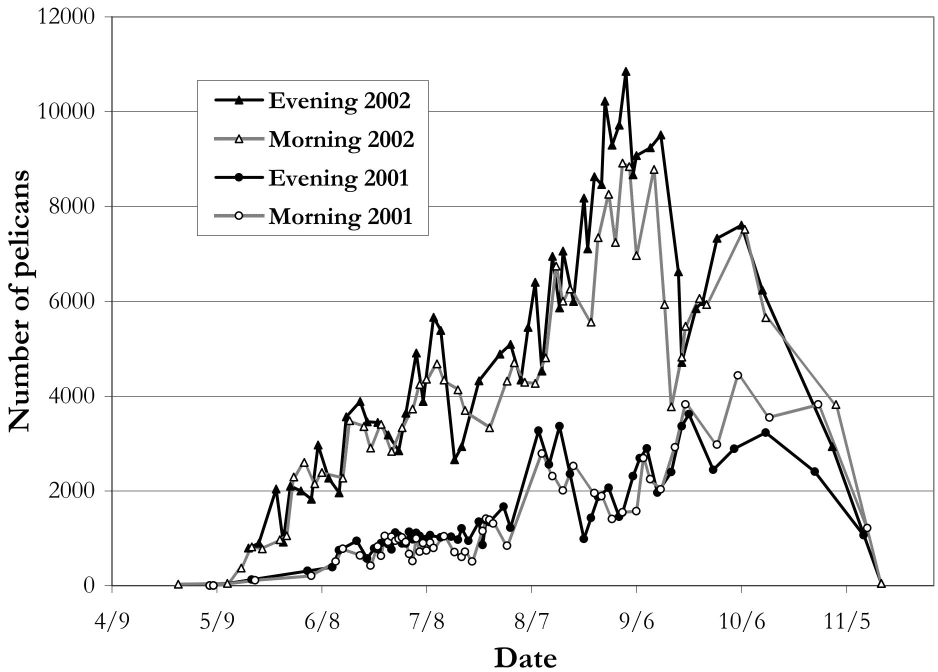
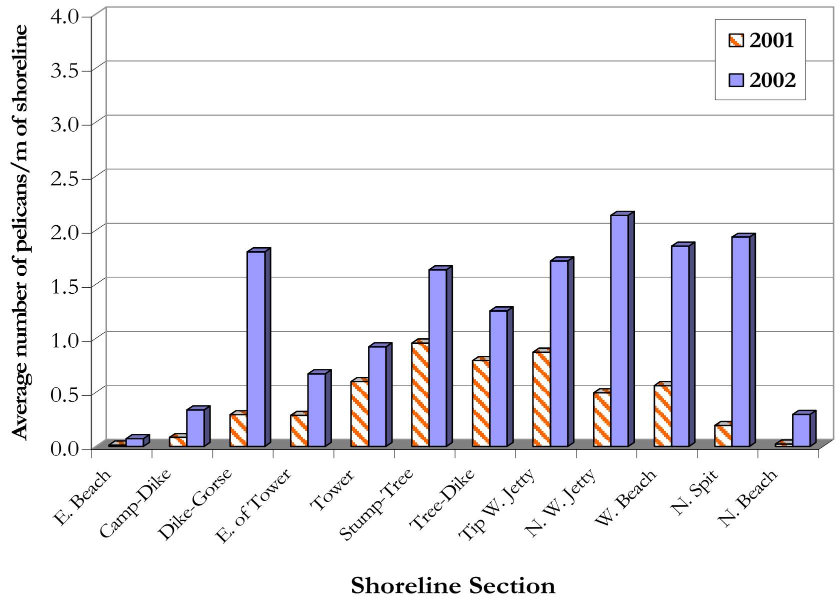


Figure 2.3 Number of California brown pelicans roosting on East Sand Island during evening and early morning island-wide censuses as a function of date (month/day) in 2001 and 2002.

observed on East Sand Island following December 1. Peak numbers of pelicans counted on the island were 4,434 on October 5 in 2001 and 10,852 on September 3 in 2002 (Figure 2.3). Numbers of brown pelicans on East Sand Island were much higher on average in 2002 compared to 2001 ($F_{5, 204} = 371.94$, $R^2 = 0.9012$, $P < 0.0001$). Numbers of pelicans counted on the island averaged 6% higher during evening censuses than during the following early morning census. This difference was significant in 2002 (one-sample t-test of proportional difference between paired evening and morning censuses, 95% CI: 0.2% to 11.6%, P = 0.0419), but not in 2001 (P = 0.115). Densities of roosting pelicans were highest on rocky sections of the shoreline on the west end of East Sand Island, ranging from 0.45 to 1.24 pelicans/m shoreline in 2001 and 1.26 to 2.86 pelicans/m shoreline in 2002. Densities of roosting pelicans were lowest on the sandy North and East beaches, ranging from 0.07 to 0.08 pelicans/m shoreline in 2001 and 0.31 to 0.77 pelicans/m shoreline in 2002 (Figures 2.4A and B).

No brown pelicans were detected outside the Columbia River estuary during aerial surveys in 2001 until the last survey on July 18, when 50 pelicans were counted near Sand Island in Grays Harbor, WA, about 80 km north of East Sand Island. In 2002, less than 200 pelicans were counted outside the Columbia River estuary during each aerial survey in late June and early July. Numbers of pelicans counted in Grays Harbor and on offshore stacks along the north Oregon coast increased markedly during late July through early September (Figures 2.5A and B). We saw no brown pelicans on offshore stacks along the southern Washington coast between July 30 and September 4, 2002.

(A)



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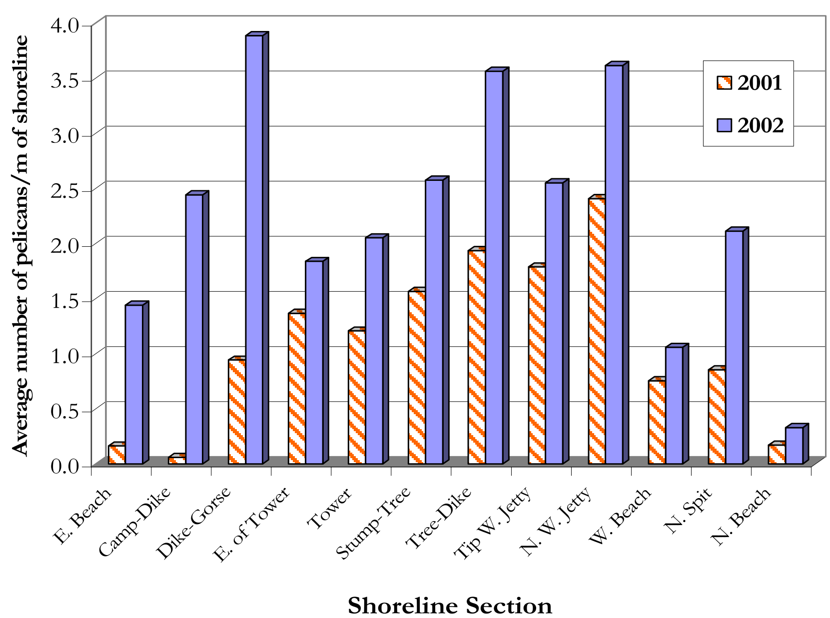
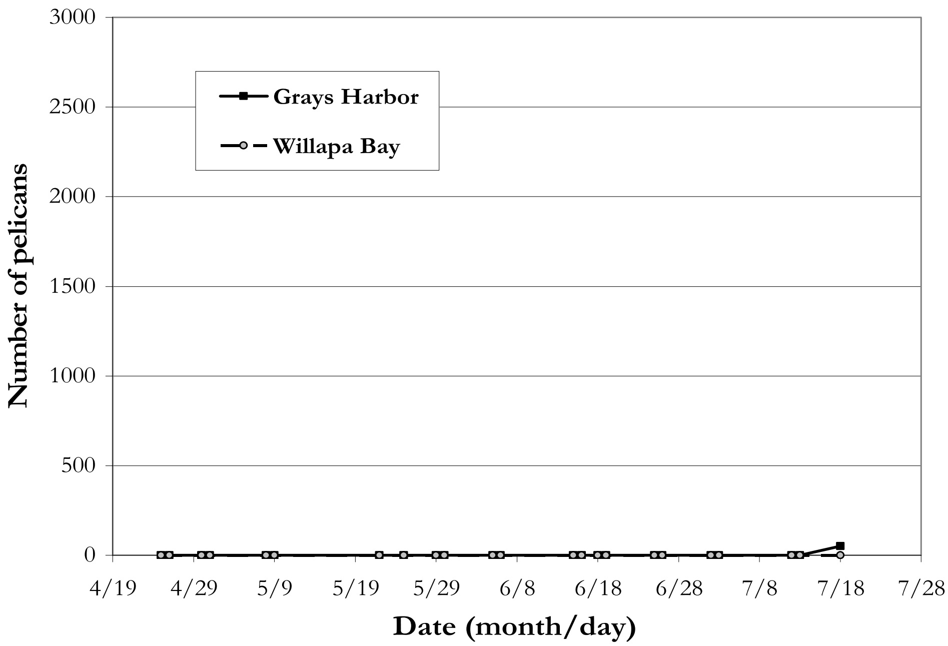


Figure 2.4 Density of California brown pelicans roosting on sections of the shoreline of East Sand Island during (A) the early season (May 7 – July 31, 2001 and April 28 – July 31, 2002) and (B) the late season (August 1 – November 11, 2001 and August 1 – November 15, 2002).

(A)



(B)

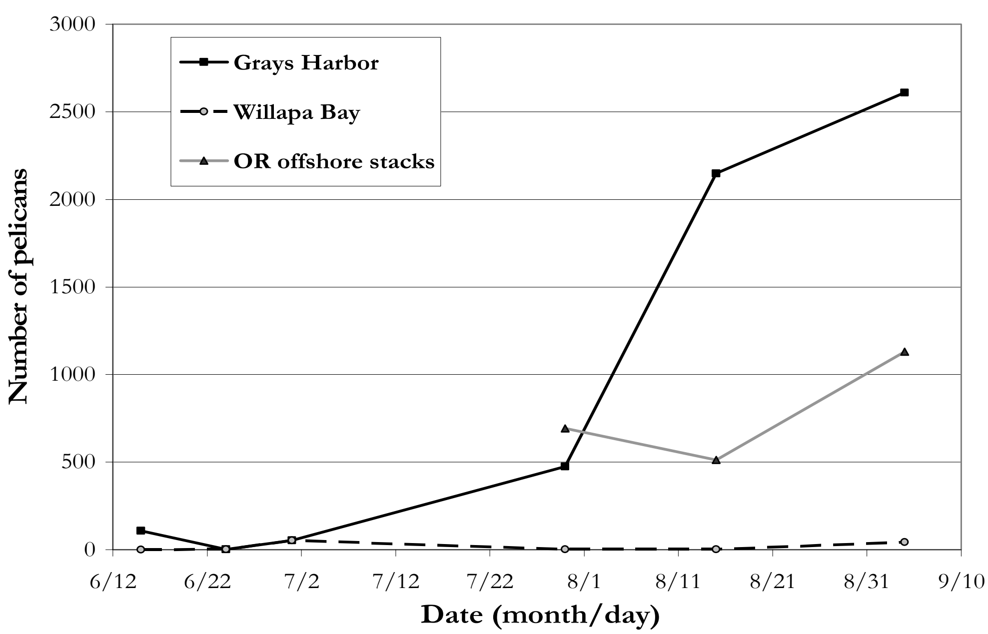


Figure 2.5 Number of California brown pelicans counted during aerial surveys along the coastline of northern Oregon and southern Washington during (A) April 25 – July 18, 2001 and (B) June 18 – September 4, 2002.

Disturbance Rate

In both 2001 and 2002, the greatest source of disturbance to brown pelicans roosting on East Sand Island was bald eagles, accounting for 83% of observed pelicans flushed due to natural disturbances in 2001 and 89% in 2002 (Table 2.1). There was a large increase in the number of pelicans disturbed during observation periods by bald eagles in 2002 (11,647 pelicans flushed) compared to 2001 (1,439 pelicans flushed). This was equivalent to disturbance rates of 37.6 and 5.2 pelicans flushed/daylight hour in 2002 and 2001, respectively, due to bald eagles. The much higher bald eagle disturbance rate in 2002 was due to increases in both the number of flush events and the number of pelicans flushed per flush event.

In 2001, natural disturbances caused more pelicans to flush from East Sand Island than either research-related disturbance or all other human-related disturbance (Table 2.1). In 2002, natural disturbances caused more pelicans to flush than all human disturbance combined (Table 2.1).

Pelicans appeared to react more intensely to all three categories of disturbance in 2001 than in 2002. In 2002 pelicans were less likely to leave East Sand Island (the strongest reaction to disturbance) than in 2001 in response to natural disturbance (Pearson $\chi^2_2 = 1169.01$, $P < 0.0001$), research-related activities (Pearson $\chi^2_2 = 617.18$, $P < 0.0001$), or non-research anthropogenic disturbance (Pearson $\chi^2_2 = 31.09$, $P < 0.0001$; Table 2.2). The decrease in intensity of the reaction of pelicans to disturbance may be indicative of habituation by pelicans returning to the roost from 2001 to 2002.

Table 2.1 Disturbance rates for California brown pelicans (number of individuals flushed per hour of observation) roosting on East Sand Island in 2001 and 2002.

Disturbance Factor	Flushes During Observation Periods 2001 (n=347.5 hours)	Flushes During Observation Periods 2002 (n=309.5 hours)	Flushing Rate (Flushes/Hour) 2001	Flushing Rate (Flushes/Hour) 2002
RESEARCH				
Research TOTAL	**1,881**[a]	**3,068**[a]	**1.36**[b]	**2.02**[b]
HUMAN/NON-RESEARCH				
USCG activities	14	120	0.04	0.39
Recreational vessels	1,213	374	3.49	1.21
Human/Non-Research TOTAL	**1,227**	**494**	**3.53**	**1.60**
NATURAL				
Bald Eagles	1,439	11,647	4.14	37.63
Peregrine Falcons	85	831	0.24	2.68
Gull Fights	0	190	0.00	0.61
Flotsam	26	381	0.07	1.23
Other[c]	181	15	0.53	0.05
Natural TOTAL	**1,731**	**13,064**	**4.98**	**42.21**
Unknown	1,306	2,416	3.16	7.81
GRAND TOTAL	**6,145**	**19,042**	**17.68**	**53.64**

[a]Observed number of pelicans flushed by research activities from June 1 to September 4, 2001, or May 18 to August 21, 2002, the same periods when natural and human/non-research disturbances were sampled.

[b]Research disturbance rate calculated by dividing observed number of pelicans flushed by total number of daylight hours (sunrise to civil evening twilight) during June 1 - September 4, 2001, or during May 18 - August 21, 2002.

[c]Other category included osprey (*Pandion haliaetus*), great blue herons (*Ardea herodias*), nutria (*Myocastor coypus*), river otters (*Lutra canadensis*), harbor seals (*Phoca vitulina*), sea lions (*Zalophus californianus*), turkey vultures (*Cathartes aura*), orca (*Orcinus orca*), and red-tailed hawks (*Buteo jamaicensis*).

Table 2.2 Observed fates of California brown pelicans flushed by various disturbance factors on East Sand Island in 2001 and 2002.

Disturbance Factor	Year	% Re-land within 200 m	% Re-land > 200 m	% Leave ESI
Natural	2001	34.4	54.0	9.4
Non-Research Anthropogenic	2001	37.7	54.3	5.5
Research Activities	2001	30.9	52.0	5.9
Natural	2002	43.8	56.3	0.1
Non-Research Anthropogenic	2002	37.0	63.0	0.0
Research Activities	2002	60.4	35.8	0.0

Factors Influencing Numbers

Approximately 90% of the variation in the number of pelicans roosting on East Sand Island during this study was explained by year, date, and tide height ($F_{5, 204}$ = 371.94, $P < 0.0001$). The mean number of roosting pelicans increased from 1,472 in 2001 to 4,758 in 2002. There was a concordant increase in the mean number of pelicans roosting in all sections of the island's shoreline (Figure 2.6).

In both years of the study, pelican numbers on East Sand Island increased gradually during May through August, and decreased rapidly during October and November (Figure 2.3). Date and quadratic function of date were included in multiple linear regression models to account for this large seasonal variability.

Tide height was positively associated with total number of pelicans on East Sand Island ($r = 0.07$, $P = 0.01$, $n = 210$). The model predicts a multiplicative increase in the median number of pelicans of 6.1% (95% CI: 1 to 11%) for every meter increase in tide height, after accounting for other variables. The multiple linear regression model predicts that 20% more pelicans roosted on East Sand Island during extreme high tides compared to extreme low tides. We observed changes in pelican numbers of this magnitude on several occasions when we conducted evening censuses at moderate high tide and censuses the following morning at extreme low tide. Tide speed did not significantly influence the total number of pelicans roosting on East Sand Island ($r = -0.03$, $P = 0.39$, $n = 210$).

Although wind speed ($r = -0.11$, $P = 0.12$, $n = 210$) and wind direction ($r = -0.06$, $P = 0.12$, $n = 210$) did not significantly influence total number of pelicans

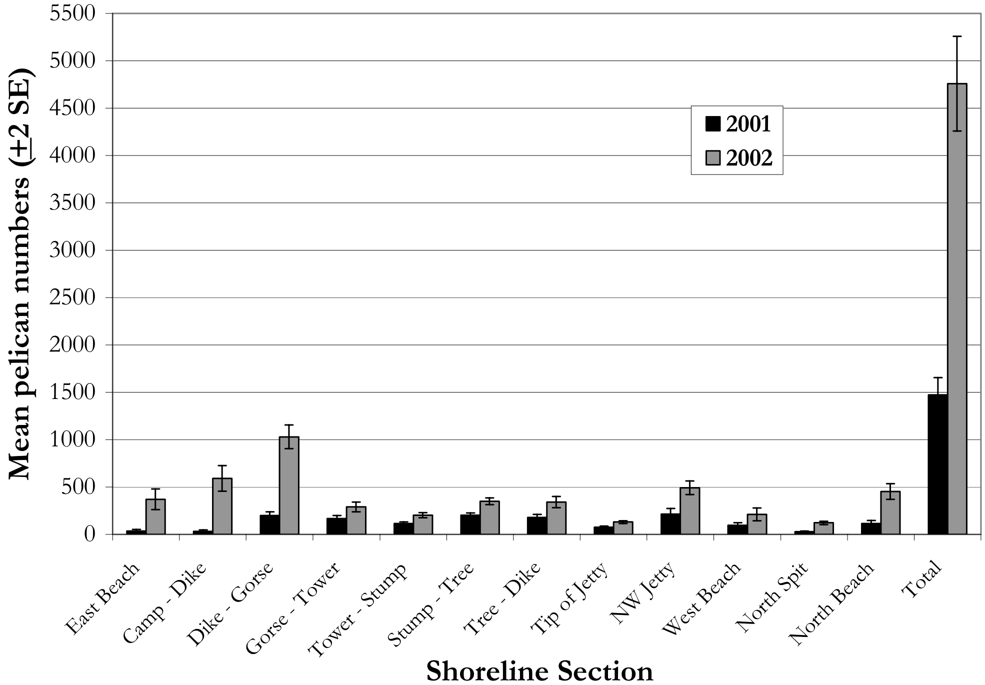


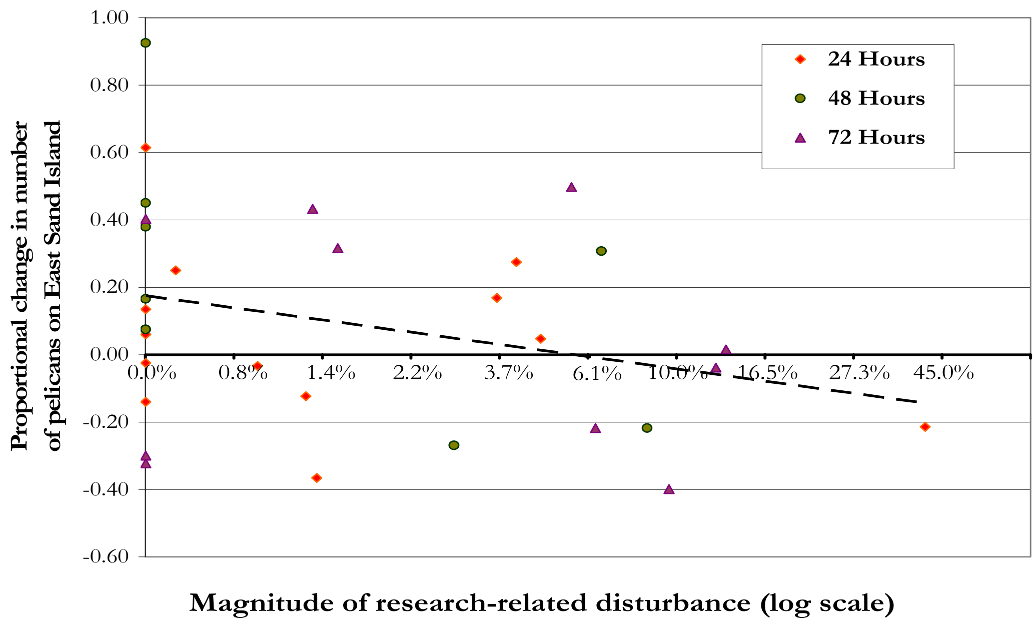
Figure 2.6 Average number of California brown pelicans counted in sections of shoreline of East Sand Island in 2001 (n = 108 counts) and 2002 (n = 106 counts).

roosting on East Sand Island, these factors did influence numbers of pelicans roosting on specific sections of the shoreline. Higher wind speeds from a northerly direction were negatively associated with number of pelicans roosting on the North Beach ($r = -0.29$, $P = 0.01$, $n = 210$) and north side of the West Jetty ($r = -0.42$, $P < 0.0001$, $n = 210$), and positively associated with the number of pelicans on the South Shore ($r = 0.28$, $P = 0.0001$, $n = 210$).

Disturbances

A majority of the pelicans flushed by research factors were flushed by land-based research activities (71% in 2001, 94% in 2002). The remaining disturbances were caused by boat-based activities (e.g., pelican censuses, collection of specimens using shotguns, surveys of waterbird use of pile dikes). Diurnal research-related activities had a slightly significant effect on total pelican numbers in 2001 ($F_{1, 30} = 3.04$, $P = 0.09$) based on the *a priori* decision to set $\alpha = 0.10$. Between one set of paired censuses 40% of the pelicans roosting on East Sand Island were flushed by researchers shooting 3 cormorants with a .22 rifle and exiting the blind on 3 occasions to retrieve the carcasses from the colony, and total number of pelicans on the island after the disturbance was 21% lower than before the disturbance (Figure 2.7A). The model predicted a 5% decrease in the total number of pelicans with a doubling in the magnitude of research-related disturbance, although the 95% confidence interval of the change in number of pelicans included zero. Other research-related disturbances caused less than 15% of pelicans on the island to flush. After removal of the data point where 40% of the pelicans on the island were flushed,

(A)



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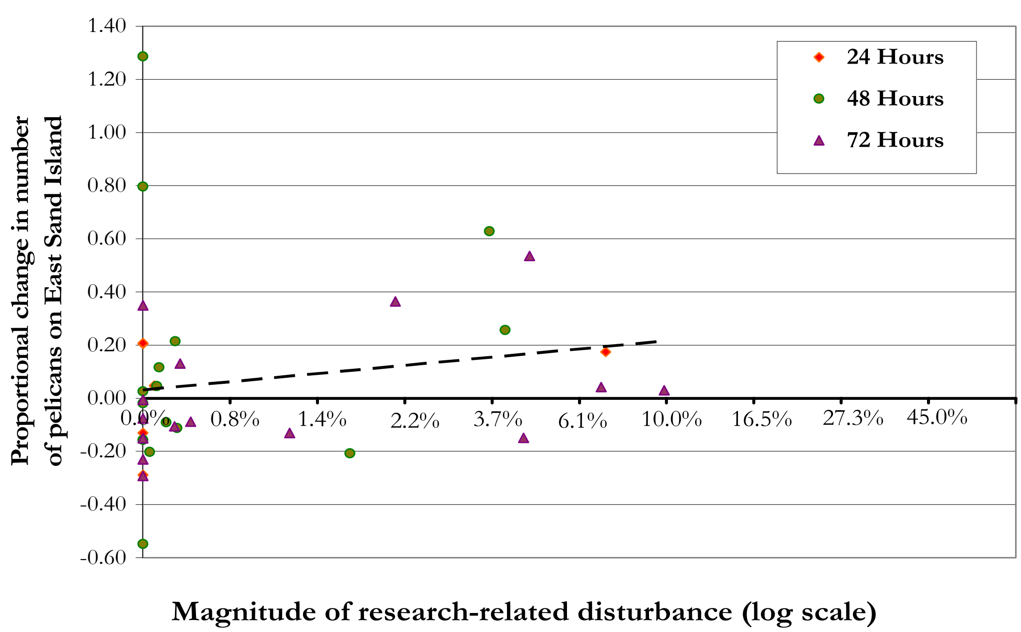

Figure 2.7 Proportional change in number of California brown pelicans roosting on East Sand Island (counted 24, 48, or 72 hours apart) in response to varying magnitudes of research-related disturbance on the island in (A) 2001, and (B) 2002.

the negative correlation between the proportional change in pelican numbers and the magnitude of research-related disturbance was no longer significant ($F_{1, 29} = 2.01$, $P = 0.17$). This suggests that only very large research-related disturbances that flushed greater than 15% of the pelicans roosting on the island had a significant negative effect on the total number of pelicans on the island. Total number of pelicans roosting on East Sand Island was not significantly influenced by research activities in 2002 ($F_{1, 34} = 1.05$, $P = 0.31$: Figure 2.7B). No research-related disturbance events in 2002 caused 15% or more of the pelicans roosting on the island to flush.

Number of pelicans roosting on the Tower to Stump section of the shoreline, the section where the majority of research disturbances occurred, was negatively associated with the magnitude of day-time research-related disturbance in that section during 2001 ($r = -0.2913$, $P = 0.0414$, $n = 40$). The model predicted a 5% decrease in pelican numbers (95% CI: -2.4 to -8.7%) with a doubling in the magnitude of researcher-related disturbance in this section.

Night-time research-related activities on the west end of East Sand Island did not significantly affect the total number of pelicans roosting on the island ($r = -0.19$, $P = 0.13$, $n = 210$). We also examined the number of pelicans in several sections of the island's shoreline where night-time research occurred and in sections that researchers traversed at night to access the sections where research occurred. Pelican numbers generally did not change in these sections following night-time research; the only significant difference was a negative association between the number of pelicans in the Tower to Stump section and occurrence of night-time research in 2001 ($r = -0.34$, $P = 0.03$, $n = 40$). This suggests that in 2001, the year when night-time research-related activities occurred on several occasions in the Tower to Stump section, pelicans avoided roosting in close proximity to the area of night-time disturbance. In 2002, night-time research was limited to accessing the above-ground tunnels, conducting repairs to the tunnels, and one night of research-related activity in an area of the cormorant colony where pelicans did not roost.

In 2001, 82% of the pelicans flushed by non-research anthropogenic disturbance were flushed by boat-based activities (e.g., fishing, sight-seeing near the island), while in 2002 only 32% were flushed by boat-based activities. Approximately 44% of the pelicans flushed by non-research anthropogenic disturbance in 2002 were flushed by windsurfers landing on the beaches after surfing over from the mainland. Anthropogenic disturbances not associated with research and natural disturbances did not appear to affect the total number of brown pelicans roosting on East Sand Island.

We examined pelican numbers in shoreline sections where pelicans were most frequently exposed to natural and non-research anthropogenic sources of disturbance. The magnitude of natural disturbance (average rate of pelicans flushed/number of pelicans on the island) did not significantly influence pelican numbers in any of the shoreline sections. The magnitude of anthropogenic disturbance not associated with research was negatively associated with the number of pelicans roosting on the Tip of West Jetty section in both 2001 and 2002 ($r = -0.4459$, $P = 0.0093$). This suggests a decrease in the number of pelicans roosting on this exposed section of the island's shoreline during times of high recreational boating activity. The effects of both natural and non-research anthropogenic disturbances were based on samples;

therefore, some high-magnitude natural and non-research anthropogenic disturbances may have been missed, along with their effects on pelican numbers.

DISCUSSION

Our examination of the roosting ecology of California brown pelicans on East Sand Island has identified several factors that influence numbers and distribution of pelicans on a major night-time roost. Controlling for these influential variables enabled us to assess the effects of human disturbance on numbers and distribution of roosting pelicans, and will aid managers in deciding the level of human access to allow at California brown pelican roosts.

Time of day was an important factor influencing the number of non-breeding brown pelicans at roost sites in California (Jaques and Anderson 1988, Jaques et al. 1996) and Florida (Herbert and Schreiber 1975). At night roosts in California, pelican numbers were greatest in the morning and evening and lowest at midday (Jaques and Anderson 1988, Jaques et al. 1996). At a diurnal roost near a fish-cleaning station in Florida, pelicans arrived during late morning, loafed in large numbers throughout the day, and departed in the evening (Herbert and Schreiber 1975). These observations indicate that pelicans leave night roosts in the morning for foraging areas and return to night roosts in the evening. Evening counts on East Sand Island averaged 6% higher than morning counts, suggesting that some pelicans had departed the roost before we could complete morning censuses. We began morning counts as soon as light would allow, but often the dim outlines of pelicans were detected leaving the roost in the semi-darkness before dawn, when counting pelicans on the island was not possible. Pelican census efforts at night roosts should include a second observer who monitors the number of pelicans arriving and departing the roost while the census is conducted to achieve a more accurate count. Our results also suggest that evening counts at pelican roost sites are more inclusive.

Brown pelican numbers at night roosts in California varied seasonally and among years (Jaques and Anderson 1988, Jaques et al. 1996). We expected pelican numbers on East Sand Island to peak in August, based on previous counts conducted by the U.S. Fish and Wildlife Service from 1987- 2000 (D. Pitkin, USFWS, unpubl. data) and counts conducted by Oregon State University researchers in 2000 (D. Roby, USGS, unpubl. data). In 2000, there were peaks in numbers of pelicans on East Sand Island on July 20 (3,103 pelicans) and August 16 (2,840 pelicans; D. Roby, USGS, unpubl. data). The peak pelican count in 2001 on October 5 was much later than expected, and the number (4,434 pelicans) was higher than expected. The peak number of pelicans in 2002 on September 3 (10,852 pelicans) was much greater than expected based on previous maximum counts of pelicans on East Sand Island. In comparison, peak counts at major roost sites in California were 1,404 pelicans at Mugu Lagoon (Jaques et al. 1996) and 4,355 at Moss Landing (Jaques and Anderson 1988). The roost at East Sand Island has become the largest known aggregation of non-breeding California brown pelicans throughout the range of this subspecies (Shields 2002, Palacios et al. 2003).

The peak number of 10,852 pelicans roosting on East Sand Island in 2002 has not been equaled in the two subsequent seasons. In 2003, pelican numbers on East

Sand Island peaked twice; 6,708 pelicans counted on July 19 and 6,541 pelicans counted on September 5 (Fischer 2004). In 2004 numbers peaked at 7,786 pelicans on August 13 and then rapidly declined (Fischer et. al. 2004). Thus the magnitude and timing of peak pelican numbers on East Sand Island appears to be highly variable among years. Disturbance rates to pelicans on East Sand Island have increased from the levels observed in 2001. The rate of disturbance from research activities was 1.36 pelicans flushed/hour in 2001, 2.02 pelicans flushed/hour in 2002 (Table 2.1), and 3.8 pelicans flushed/hour in 2003 (Fischer 2004). The rate of disturbance from natural factors was 4.98 pelicans flushed/hour in 2001, 42.21 pelicans flushed/hour in 2002 (Table 2.1), and 52 pelicans flushed/hour in 2003 (Fischer 2004). Bald eagles were the primary source of natural disturbance in all three years; 83% in 2001, 89% in 2002 (Table 2.1), and 95% in 2003 (Fischer 2004). The number of bald eagle nests in the Columbia River estuary has not increased from 2001 to 2004 (R. Anthony, USGS, pers. comm.). The majority of bald eagles that flushed pelicans from East Sand Island, however, were nomadic sub-adults that do not maintain breeding territories. In 2002, 68.5% of the eagles that we were able to identify as adults or sub-adults after they caused a disturbance to pelicans were sub-adults. High attendance of East Sand Island by nomadic sub-adult bald eagles could cause a large increase in the number of pelican flush events. It is possible that the increase in disturbance from research activities and natural factors in 2002 contributed to lower annual peaks in pelican numbers on East Sand Island in 2003 and 2004. Given the high inter-annual variability in the magnitude and timing of peak pelican numbers, however, the causes of lower and earlier peaks in pelican attendance in 2003 and 2004 are difficult to ascertain.

The rate of non-research anthropogenic disturbance dropped following the 2001 field season: 3.53 pelicans flushed/hour in 2001, 1.6 pelicans flushed/ hour in 2002 (Table 2.1), and 1.4 pelicans flushed/hour in 2003 (Fischer 2004). This suggests that the presence of researchers on East Sand Island, and our efforts to approach and educate people who landed on the island were successful in lowering the incidence of human disturbance not associated with research.

The number of brown pelicans at the Moss Landing roost site in California was negatively associated with the combined incidence of natural and human disturbances (Jaques and Anderson 1988). We examined the potential effects of human and natural disturbances separately in an effort to determine whether specific types of disturbance had more of a negative effect on pelican numbers. Disturbance from research-related activities appeared to be negatively associated with pelican numbers when pelican numbers were relatively low (in 2001 compared to 2002) and disturbance magnitude was high (greater than 15% of pelicans on the island were flushed). Although natural disturbances flushed a far greater number of pelicans from East Sand Island, this category of disturbance did not appear to affect numbers of pelicans using the roost within a season, possibly because pelicans were more habituated to frequent disturbance from avian predators.

At the Moss Landing roost in California, brown pelicans flushed in response to shotguns fired within 600 m of the roost (Jaques and Anderson 1988). During this study, researchers observed pelicans flush from East Sand Island in response to a shotgun fired at an approximate distance of 400 m. In both years of this study, researchers used shotguns to collect cormorants and terns near the Mid Pile Dike for diet studies. The number of brown pelicans roosting on the shoreline where the Mid Pile Dike connects to the island increased dramatically from 2001 to 2002. Consequently, the same research activity in the two years resulted in a 10-fold greater number of pelicans flushed in 2002 (922) compared to 2001 (94). The largest research disturbances to pelicans occurred when shotguns were fired within 400 m of East Sand Island during cormorant and tern collection, and when researchers accessed the cormorant colony to collect cormorants or examine potential pelican nests. Comparatively few pelicans were flushed when researchers shot cormorants on the colony with a .22 rifle. The sound level of a .22 rifle report is much lower than a shotgun and only flushed the pelicans closest to the fired rifle and the cormorant that was shot.

It was difficult to determine the number and, therefore, the rate of pelican flushes during night-time research activities. We used night-vision video to monitor the behavior of pelicans within 35 m of night-time research activities. In addition, pelicans were observed silhouetted by moonlight flushing from the roost > 200 m from night-time research activities. Total numbers of pelicans on East Sand Island were not negatively associated with the magnitude of night-time research activities in either 2001 or 2002; however, the number of pelicans in the Tower to Stump section was negatively associated with night-time research in 2001. This is the shoreline section where researchers, under the cover of darkness, captured double-crested cormorants for a separate study. This study was not conducted in 2002, and researchers did not access the Tower to Stump section during the night in that year. These results suggest that night-time research activity, while deterring some pelicans from roosting in this section of the island, did not significantly affect the total number of pelicans roosting on East Sand Island. Researchers took several precautions during night-time activities to limit their impact on roosting pelicans, including wearing dark clothing, speaking softly, covering lights with red cellophane, minimizing use of voice and light, and conducting as much of the research as possible from blinds. Effects on numbers of pelicans using the roost by night-time research in the absence of these precautions are unknown, but presumably much greater than observed in this study.

Natural disturbance and anthropogenic sources of disturbance not related to research did not significantly influence the number of pelicans roosting on East Sand Island, but not all natural and non-research anthropogenic disturbances were observed. It is possible that high-magnitude disturbances in both these categories may have had an undetected negative effect on the numbers of pelicans roosting on East Sand Island. In both 2001 and 2002, pelican numbers on the Tip of West Jetty section were negatively associated with the magnitude of non-research anthropogenic disturbance. This section extends into a channel used by many recreational vessels, some of which pass close to the island. There are large surges in numbers of recreational or commercial fishing vessels during holiday weekends, or during sport or commercial fishing season opening days. At these times, pelicans may avoid this exposed section of East Sand Island.

We did not detect an effect of natural disturbances on the number of pelicans on the island, or numbers on any of the shoreline sections. Although the rate of pelican flushes due to natural disturbances was far greater than that due to research-related disturbance in both years of the study (Table 2.1), the effect of natural disturbances on pelican numbers appeared to be less. Pelicans have apparently acclimated to more frequent or recognizable sources of disturbance, such as bald eagles flying over the island.

The large increase in the number of pelicans roosting on East Sand Island between 2001 and 2002 allowed us to investigate potential differences in pelican response to disturbances related to different densities of roosting pelicans. In 2002, fewer pelicans left the island after flushing due to a disturbance (Table 2.2). The higher density of roosting pelicans may have aided predator detection (Ward and Zahavi 1973) and resulted in a less intense response by pelicans to disturbance.

Although this study has identified several factors that affect pelican numbers and distribution on East Sand Island, it can not explain the large increase in numbers of California brown pelicans utilizing this roost since 1999, when only 50 pelicans were counted in the annual fall aerial census (USFWS, unpubl. data). The total population of California brown pelicans has been increasing slowly and steadily since the early 1980s (D. Anderson, UC Davis, pers. comm.), following large scale protective measures in response to DDE-induced reproductive failures. There have not, however, been any recent surges in population numbers.

The increased use of East Sand Island by brown pelicans may be partly a reflection of the loss of a roost site 35 km to the north at the mouth of Willapa Bay, Washington, referred to as Gunpowder Island (Speich and Wahl 1989), which has been largely eliminated due to erosion. This site had a high count of 5,875 pelicans on September 16, 1991, during the annual U.S. Fish and Wildlife Service fall aerial census, which were conducted during 1987-2001. The next highest count on Gunpowder Island was 2,100 pelicans in 1988. Other counts for this island roost between 1987 and 2001 were under 2,000 pelicans. While it is likely that the loss of this roost site contributed to the increase in numbers of pelicans roosting on East Sand Island, this factor alone can not explain the magnitude of the increase observed in 2002.

The apparent shift in the Pacific Decadal Oscillation in 1999 (Peterson and Schwing 2003) is another potential explanation for the recent increase in brown pelican numbers in the Columbia River estuary. This ocean regime shift was associated with an increase in coastal upwelling along the coast of Oregon and Washington and increases in the abundance of marine forage fishes near shore (Peterson and Schwing 2003). Abundance of anchovy (*Engraulis mordax*), a major component of the California brown pelican diet in California, has recently increased by an order of magnitude off the coast of Oregon and Washington (Emmett 2002). The dramatic increase in brown pelican numbers along the coast of the Pacific Northwest follows this shift in ocean conditions. Previously documented surges in pelican numbers along the coast of Oregon and Washington corresponded with El Niño events in 1976 and 1982-83 (Jaques 1994).

MANAGEMENT IMPLICATIONS

Researchers on East Sand Island gained access to the aboveground tunnels to the observation tower at the west end of the island only within two hours of low tide in order to walk lower on the beach and minimize flushing of roosting and nesting seabirds. In addition, this practice minimized flushing of pelicans by research activity because there were generally fewer pelicans present at the roost during low tide.

Efforts were made in the latter part of the 2002 field season to conduct tern and cormorant collections using shotguns at a sufficient distance from East Sand Island (> 400 m) to preclude flushing pelicans. This strategy was successful; researchers were able to collect specimens approximately 900 m west of East Sand Island (on West Sand Island) without flushing any brown pelicans. Brown pelicans sometimes roost on West Sand Island as well, so researchers will need to continue being flexible on collection sites and times in order to limit disturbance to brown pelicans.

We observed a few occasions when recreational boaters flushed pelicans by landing on East Sand Island or fishing/crabbing very near the island. Following these occasions, we attempted to make contact with the boaters and explain the protected status of nesting birds on the island, and the special status of brown pelicans. In general, people were receptive, interested to learn more about the birds, and did not know that East Sand Island was closed to the public. Only a few vessels ignored our requests. In addition, on several occasions we observed lines of crab pot buoys within 100 m of sections of shoreline where large numbers of pelicans roost, suggesting frequent undetected pelican flush events from this factor. Due to the positive response of most people approached after flushing pelicans, increased outreach and education of boaters in the area (possibly signs at nearby harbors) should result in reduced disturbance of pelicans roosting on East Sand Island by non-research anthropogenic sources. At levels observed in 2001 and 2002, however, non-research anthropogenic disturbance did not appear have an impact on pelican numbers on East Sand Island, and a limited impact on the distribution of pelicans roosting on the island.

Research activities on East Sand Island had a limited but significant effect on pelican numbers in 2001, when a disturbance event caused more than 15% of the pelicans on East Sand Island to flush. This indicates that unrestricted research activity has the potential to drive pelicans away from this roost. Researchers should continue to follow protocols designed to preclude major disturbances to roosting pelicans and take further precautions to minimize disturbance to pelicans.

Researchers should continue to access the west end of East Sand Island only within 2 hours of low tide, use the aboveground tunnels to access the blinds, and restrict activities to sections of shoreline with low densities of roosting pelicans (Camp to Dike section, North, and East Beaches: Figure 2.4A and 2.4B), unless permitted to access sections with higher average pelican densities by the USFWS. Research activities should be postponed or cancelled if greater than 15% of the pelicans roosting on East Sand Island might be flushed by the activity.

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Chapter 3

FACTORS AFFECTING THE BEHAVIOR OF ENDANGERED CALIFORNIA BROWN PELICANS AT A LARGE POST-BREEDING ROOST SITE

Sadie K. Wright, Daniel D. Roby, and Robert G. Anthony

ABSTRACT

Our primary objective was to determine how potential disturbance factors influence the behavior of endangered California brown pelicans (*Pelecanus occidentalis californicus*) at the largest known post-breeding aggregation site for the subspecies. We studied time-activity budgets of pelicans roosting at a representative study plot on East Sand Island in the Columbia River estuary during June – August in 2001 and 2002. We investigated the effects of several extrinsic explanatory variables on time-activity budgets of roosting pelicans, including year, date, time of day, weather, tide stage, natural and anthropogenic disturbances, and the number of pelicans on the plot. During daylight, pelicans spent the vast majority of time either resting (44%) or preening (41%). Time of day, number of pelicans, wind speed, precipitation, and disturbance accounted for 34% of the variation in the incidence of resting among pelicans; year, date, time of day, number of pelicans, and disturbance accounted for 27% of the variation in the incidence of attentive behavior. All three categories of disturbance (natural, research-related, non-research anthropogenic) were associated with significant decreases in the proportion of pelicans attentive and increases in the proportion of pelicans resting. Research-related disturbance had a larger positive association with the proportion of pelicans attentive than did natural disturbance, and it took longer for pelicans to recover to baseline behavior following a research disturbance than for non-research anthropogenic disturbance or natural disturbance. Permitted land-based human activities need to be restricted to minimize disturbance to pelicans roosting on East Sand Island, and the public needs to be notified that East

Sand Island is closed. The potential exists for humans to have a major negative impact on this major roost site of endangered California brown pelicans; therefore, human activities need to be regulated on East Sand Island to provide the habitat and conditions necessary for the continued recovery of this subspecies.

INTRODUCTION

Physiological condition has been shown to limit overwinter survival and subsequent breeding success in some bird species (Drent and Daan 1980, Krapu 1981). Disturbance can increase energy expenditure, and thereby affect physiological condition and the allocation of resources toward reproduction (Burton and Hudson 1978, Stalmaster 1983, Morton et al. 1989). Time-activity budgets have been used to identify vulnerable stages or limiting factors in both annual and life cycles of birds (Inglis 1977, Hickey and Titman 1983, Maxon and Pace 1992, Adams et al. 2000, Fischer and Griffin 2000). Some studies have used time-activity budgets to assess behavioral effects of potential disturbances, particularly as it relates to higher energy expenditure for activity (Burger 1981, Bélanger and Bédard 1989, Burger and Gochfield 1991, Steidl and Anthony 2000).

The California brown pelican (*Pelecanus occidentalis californicus*) was listed as endangered by the U.S. government (35 Federal Register, 16047, October 13, 1970) and the State of California (California State Endangered Species Act 1970) following severe reproductive failure in the late 1960s (Schreiber and Risebrough 1972, Jehl 1973, USFWS 1983). One of the three main objectives listed in the California Brown

Pelican Recovery Plan (USFWS 1983) is to "assure long-term protection of adequate food supplies and essential nesting, *roosting* and offshore habitat throughout the range" (italics added).

Several studies have investigated the impact of disturbance at brown pelican roosting sites in southern California by measuring the number and frequency of flush events, flush distances, and the fate of flushed pelicans (Jaques and Anderson 1988, Jaques et al. 1996). Published time-activity budgets for brown pelicans are scant (Croll et al. 1986), and no published studies have quantified the effects of various types of potential disturbance on brown pelican behavior by scanning large flocks. This study focused on the time-activity budgets of brown pelicans in an effort to determine those factors influencing behavior of pelicans roosting on East Sand Island, near the mouth of the Columbia River estuary. East Sand Island is currently the largest known post-breeding roost site for California brown pelicans, with over 10,000 pelicans counted on the island at one time (see Chapter 2). By collecting and analyzing data on time-activity budgets and the movements of brown pelicans to and from East Sand Island, we sought to better understand how disturbances affect the behavior of pelicans at this major roost site.

Concern has arisen regarding the potential effects of several disturbance factors on California brown pelicans roosting on East Sand Island. The waters surrounding East Sand Island are subject to heavy recreational boat traffic. Bald eagles (*Haliaeetus leucocephalus*), a known predator of brown pelicans (B. Winn, pers. comm., in Shields 2002), nest in the Columbia River estuary in increasing numbers and frequent East Sand Island. In addition, East Sand Island has been the site of colonial waterbird research since 1997, as part of an on-going study of food habits and breeding ecology of double-crested cormorants (*Phalacrocorax auritus*) and Caspian terns (*Sterna caspia*) in the Columbia River estuary (NPPC 1994). We hypothesized that the magnitude of the effects of disturbance on time-activity budgets would help us assess the relative impact of various disturbance factors on the energy budgets of California brown pelicans at their largest known post-breeding roost site. We hypothesized that disturbance to pelicans on East Sand Island would cause the incidence of attentive behavior to increase and the incidence of resting behavior to decrease. This assessment might prove useful for managers' efforts to identify significant sources of disturbance and to assure continued recovery of this endangered species.

METHODS

Study Area

East Sand Island (46º15'45"N, 123º57'45"W) is located 8 km east of the mouth of the Columbia River, in the Columbia River estuary (Figure 3.1). In the 1930s government engineers built pile dikes on the south side of the island to reduce shoreline erosion (Brooke 1942), and large boulder rip-rap was added later on the west end of East Sand Island to form a westward-pointing jetty (Figure 3.2). The island is approximately 2 km long on an east-west axis, ranges from 10 to 300 m wide, and has an area of approximately 21 hectares (Figure 3.2).

We recorded the behavior of pelicans roosting on a study plot on the south

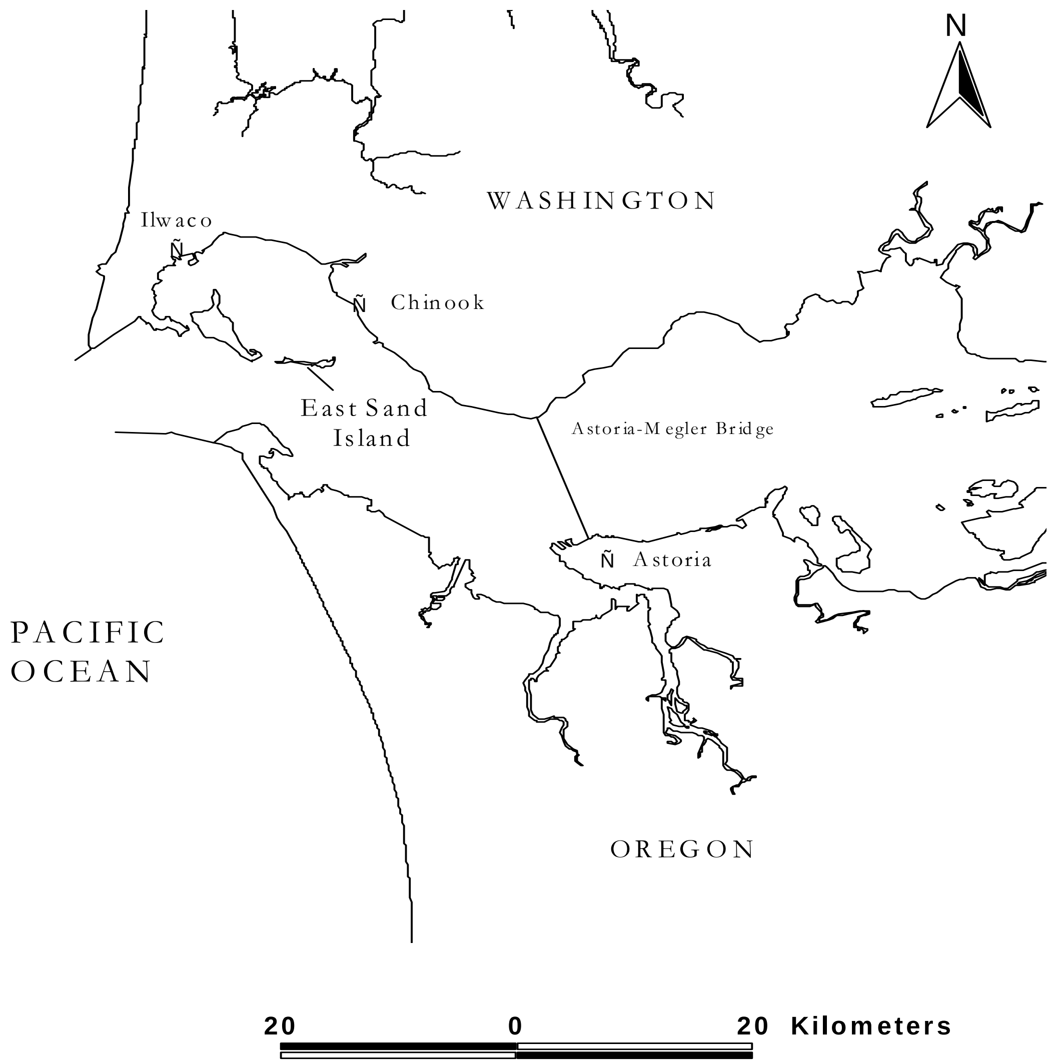


Figure 3.1 Location of East Sand Island in the Columbia River estuary, between the states of Oregon and Washington, USA.

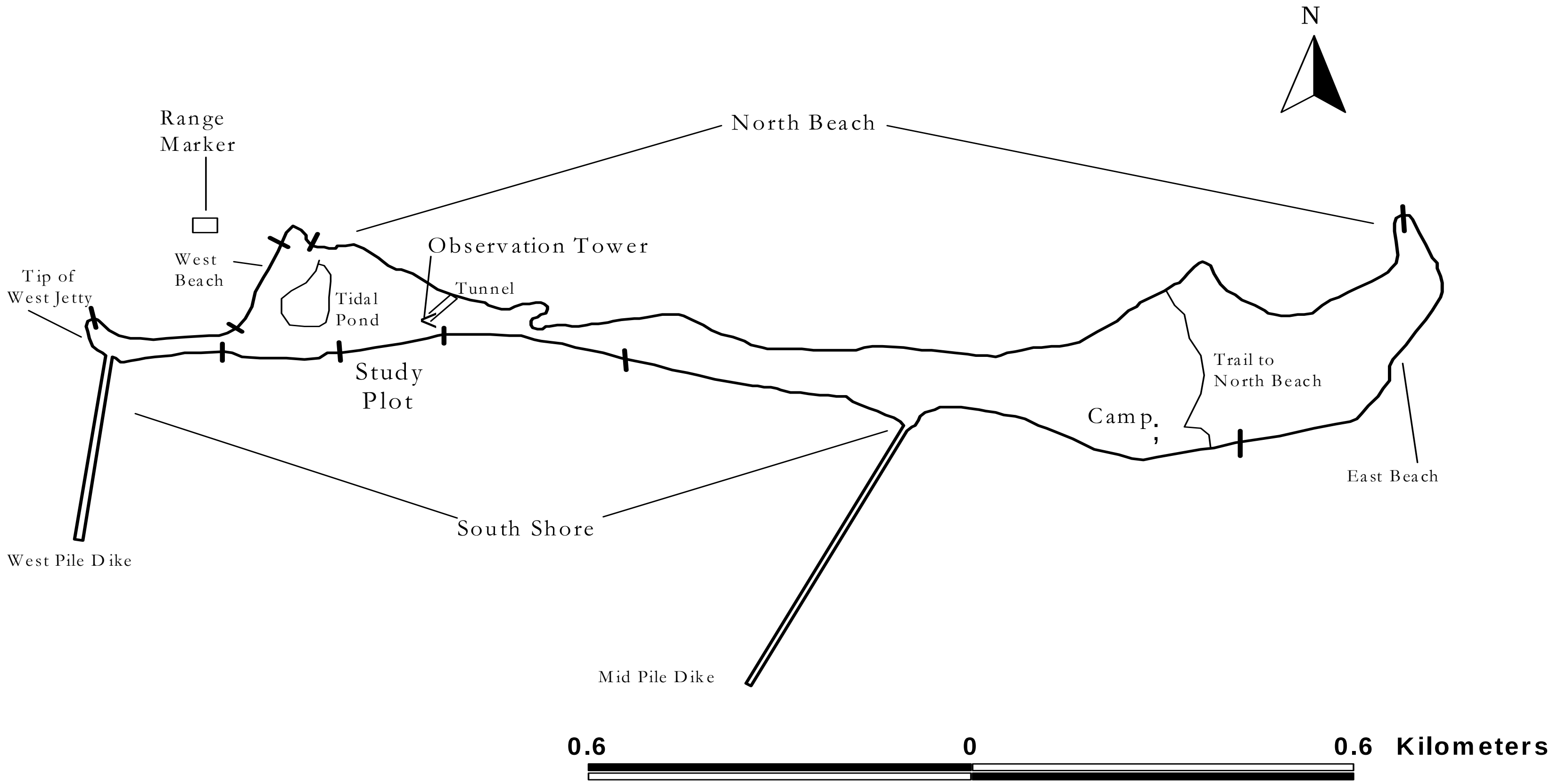


Figure 3.2 East Sand Island, Columbia River estuary, showing the location of the observation tower and study plot near the west end of the island.

shore of the island that was heavily used by roosting pelicans and visible from a nearby 5-m high, enclosed observation tower (Figure 3.2). The plot extended from directly to the south of the observation tower for 136 m along the shore to the west, where a large, clearly visible driftwood stump was lodged high on the beach. This long, narrow plot was bounded by the water's edge to the south and a grassy meadow to the north, which was not used by roosting pelicans. The plot ranged from 10-20 m wide, depending on tide height. Pelicans on the water within 50 m of shore directly off the study plot were included in behavioral observations.

The substrate of the study plot consisted of large piles of flotsam and jetsam (mostly wood) on rip-rap boulders. During inclement weather, when most pelicans were resting, we could not see from the tower as many as 10% of the pelicans on the study plot because they were obscured from view by driftwood, based on comparisons with boat-based censuses. The total number of pelicans on the study plot was more accurately determined by counting from a skiff about 150 m offshore of the plot using image-stabilizing binoculars (see Chapter 2). Consequently, boat-based counts of pelicans on the plot in the evening were used to assess seasonal trends in use of the plot by roosting pelicans.

We devised a method to access the blind on the observation tower without disturbing pelicans on the plot. Observers were dropped off by boat on the south shore beach near camp, walked across the island to the North Beach, then west along the North Beach as close to the water's edge as possible, and, using the sand dune as visual cover, approached the entrance to an above-ground tunnel system that led to the tower (Figure 3.2). We approached the tunnel entrance from the North Beach only within 2 hours of low tide, when the beach was widest, or at night in order to minimize the possibility of disturbance to pelicans roosting on the upland portions of the island.

Pelicans roosting on East Sand Island are subject to disturbance from both natural and anthropogenic factors, in addition to research-related activities. Located just north of the main Columbia River shipping channel and between the harbors of Chinook and Ilwaco, Washington, the waters around the island are subject to heavy traffic from recreational fishing boats, commercial fishing boats, and water sports enthusiasts (jet skiers, wind surfers, canoeists). The Columbia River estuary is also used by the U.S. Coast Guard for helicopter and boat rescue training, and Coast Guard helicopters occasionally fly low over East Sand Island.

Bald eagles and peregrine falcons (*Falco peregrinus*) are two large avian predators that nest in the Columbia River estuary and frequent East Sand Island (Isaacs and Anthony 2002; J. Pagel, USFWS, pers. comm.). Both species kill and/or scavenge waterbirds nesting on East Sand Island. Although we know of no evidence that peregrine falcons prey on brown pelicans, we observed bald eagles stooping on brown pelicans that were roosting on East Sand Island, and bald eagles have been documented to kill incubating adult brown pelicans in Georgia (B. Winn, pers. comm., in Shields 2002). Both of these raptors can elicit flight responses from pelicans, although in the case of peregrine falcons, the pelicans may be reacting to gull alarm calls rather than a direct predator threat.

Time-Activity Budgets

We collected time-activity data from June 1 to September 9 in 2001 and from June 4 to August 21 in 2002. We used scan sampling techniques (Altmann 1974) to quantify proportion of time spent in several categories of activity by California brown pelicans roosting on East Sand Island. Each day was divided into 2 equal time blocks: morning (05:30-13:29) and evening (13:30-21:30). We used a random numbers table to select 6 time blocks in each two-week period during the field season, with either 2 morning blocks and one evening block the first week, and 2 evening blocks and one morning block the second week, or vice versa. If scan sampling could not occur in a selected block due to weather or logistics, scan samples were collected during the next available time block.

During each 8-hour time block, an activity scan was conducted of all the visible pelicans on the study plot every 30 minutes. Thirty minutes was selected as the sampling interval in an attempt to avoid serial autocorrelation among time-activity budget data (Schreiber 1977). We used 10 x 50 mm binoculars to aid in classifying the activity of each pelican on the plot during scans, and pelican activity was assigned to one of the following six categories: (1) active; walking, agonistic behavior, stretching, picking up sticks, mounting, (2) attentive; standing and alert, neck extended, (3) preening; plumage maintenance, (4) resting; sitting or standing with neck not extended, not alert, (5) startled; standing, wings raised or flapping, flight intention movements, or (6) swimming; in water near shore, within 50 m of study plot. Sketches from Schreiber (1977) were used as a reference for these activity categories. Although scan samples are intended to be instantaneous (Altmann 1974), scans in this study required from 15 seconds to 13 minutes, depending on the number of pelicans roosting on the study plot.

Before each scan, the following weather variables were recorded: temperature (ºC), percent cloud cover (increments of 5%), wind direction (in degrees, converted to Cartesian coordinates), wind speed (Beaufort Scale), and precipitation (0-7, ranging from no rain to steady heavy rain). These variables were used as covariates in the analysis in order to account for variability in the data due to weather conditions. We were also interested in learning how weather conditions affected pelican behavior.

Movements To and From the Study Plot

Our objective was to measure potential differences in the flux rate (proportion of pelicans roosting in the study plot arriving or departing/minute) of pelicans on East Sand Island due to weather conditions and disturbance. Before each flux rate observation period, we recorded the same weather variables described above.

During the time interval between completing one scan sample and beginning the next, we monitored the number of brown pelicans that arrived on or departed from the study plot. We used the number of pelicans counted during the previous scan to determine the number of pelicans present at the beginning of each flux observation. We divided the number of pelicans that arrived or departed by the number of pelicans present on the study plot, and divided this by the number of minutes of observation to calculate a flux rate.

Disturbance Monitoring

We monitored disturbance to pelicans on the study plot between sunrise and civil evening twilight (approximately 40 minutes after sunset), the daylight hours when disturbance factors and pelican reactions could be clearly observed. Starting and ending times were recorded for all observation periods. When a disturbance occurred that caused one or more pelicans to flush from the study plot, we recorded date, time of day (Pacific Daylight Time), cause of disturbance (if discernible), and whether or not the disturbance occurred during a scan sample. We used these data to compare brown pelican behavior before and after a disturbance to pelicans on the study plot.

Statistical Analysis

We used multivariate linear regression to determine which variables influenced time-activity budgets and movements of pelicans on the study plot. We selected the two activity categories "resting" and "attentive" as the response variables in these analyses because they were common activities that clearly changed in response to disturbance. Attentive behavior was sometimes a precursor to flushing from the roost, whereas resting was the most inactive activity category that we used. We included the following variables in the analysis of factors influencing the proportions of resting and attentive pelicans, and the movement of pelicans to and from the study plot: year, date, time of day (Pacific Daylight Time), number of pelicans on the study plot, wind direction, wind speed, temperature, percent cloud cover, precipitation, tide height (meters of water from mean low tide), tide speed (tide data from the NOAA tide gauge at Tongue Point, OR, 46°11'N, 123°46'W, 17 km up-river from East Sand Island), disturbance variables (time elapsed since a disturbance when one or more pelicans were flushed from the study plot, and disturbance magnitude). Disturbance magnitude was defined as the proportion of pelicans flushed from the study plot.

In addition, we examined quadratic functions of these variables and interactions between these variables. Some of the variables were correlated; however, correlations among explanatory variables did not exceed the correlation coefficient of 0.4. We used step-wise removal of non-significant variables (P-value > 0.05) to identify variables that explained a significant proportion of the variation in the proportion of pelicans resting or attentive, and the rate of pelicans arriving or departing from the study plot.

To meet the assumptions of parametric statistical tests, the response variables (proportions of pelicans on the plot) were logit transformed (log(Y/(1-Y))). Due to the many 0 values in the response variables, 0.5 times the minimum non-zero value was added to the response variable to avoid zero in the denominator or numerator of the logit transformed values. We removed from the analysis all scans and flux rate observations when less than 10 pelicans were present on the study plot in an effort to avoid undue influence from single birds on the results. We examined graphs of residuals to ensure that autocorrelation or a lack of independence in the data did not confound the results.

Multiple linear regression models of logit transformed response variables tend to exaggerate predicted odds ratios greater than 2.5 or less than 0.5 (Hosmer and Lemeshow 2000). We present means from actual data (not accounting for other variables) to document changes in behavior when we thought this exaggeration might occur. The P-values presented are from the multiple linear regression models, unless stated otherwise.

To determine if there were immediate effects of disturbance on pelican behavior we examined the difference in the proportion of resting or attentive pelicans in the half hour following a disturbance in the study plot compared to the overall mean proportion of pelicans engaged in resting or attentive behaviors.

We examined the recovery times for each disturbance category separately to determine whether the three types of disturbance affected pelican behavior differently. We treated each disturbance to pelicans in the study plot as an independent event and examined pelican behavior over time following the disturbance by using the slope estimate of the linear trend-line fit to the scan data. Each event was weighted based on the number of scans we conducted following the disturbance. Disturbance events followed by less than 2 behavior scans were discarded from the analysis.

We were concerned that the analysis might fail to detect small differences in pelican behavior caused by disturbance, so we set the level of significance at $\alpha = 0.10$.

RESULTS

Number of Pelicans on the Plot

The mean number of pelicans on the study plot during boat-based censuses was 110 (SD = 48, n = 41) in 2001 and 202 (SD = 94, n = 35) in 2002. The average number of pelicans on the plot during June – August of 2002 was consistently higher than during the same period in 2001, regardless of time of day (Figure 3.3). The number of pelicans on the plot was lowest during early morning, increased until late morning, and declined again in late evening (Figure 3.3). In general, the number of pelicans roosting on East Sand Island increased throughout each field season when behavioral data were collected (June – August; see Chapter 2).

Time-Activity Budgets

The time-activity data set included 522 scans of pelicans on the study plot during the summer of 2001, with 10 - 197 pelicans/scan (mean = 68 pelicans); we recorded 455 scans during the summer of 2002, with 10 - 273 pelicans/scan (mean = 118 pelicans). Time-activity budgets of pelicans roosting on the study plot were similar between 2001 and 2002 (Table 3.1), although the proportion of attentive pelicans was significantly greater in 2001. Resting and preening were the two most prevalent activities of pelicans roosting on the study plot in both 2001 and 2002 (Figure 3.4). The activity category "startled" was recorded infrequently (Table 3.1), so we eliminated it from further analysis.

Strong correlations existed between some activities, particularly the negative correlation between resting and preening (Table 3.2). These correlations make it difficult to separate effects of disturbance on time-activity budgets from a change in the proportion of pelicans engaged in other activities. Resting and attentive activity categories were not strongly correlated and clearly reflected whether pelicans were relaxed or agitated (Table 3.2), so these two activities were used as response variables

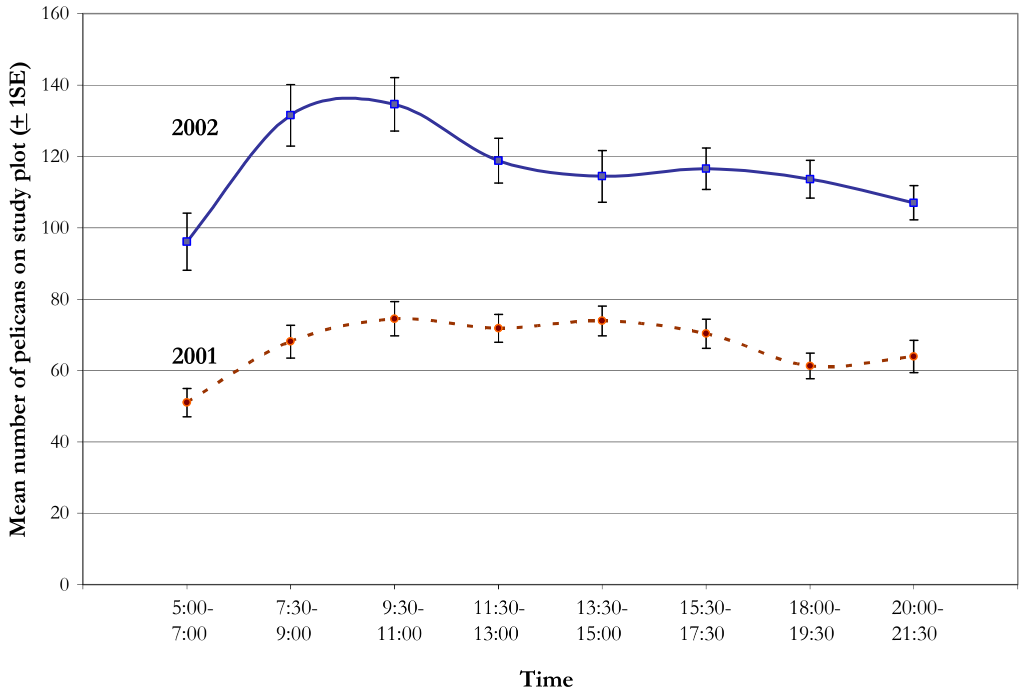


Figure 3.3 Mean number of pelicans roosting throughout the day on the study plot on East Sand Island in 2001 and 2002.

Table 3.1 Average time-activity budget of brown pelicans roosting on the study plot at East Sand Island in 2001 and 2002. P-values are based on two-sample t-tests for differences between years ($P \leq 0.05$ = significant difference).

	2001	2002
Active	11.5%	11.1%
SE	0.4	0.4
P-value		0.4955
Attentive	3.5%	2.4%
SE	0.2	0.2
P-value		**0.0001**
Preening	40.9%	40.4%
SE	0.7	0.8
P-value		0.6266
Resting	43.1%	45.0%
SE	0.8	0.9
P-value		0.1376
Startled	0.00032%	0.000025%
SE	0.00011	0.000025
P-value		0.0578
Swimming	1.0%	1.2%
SE	0.1	0.1
P-value		0.2893

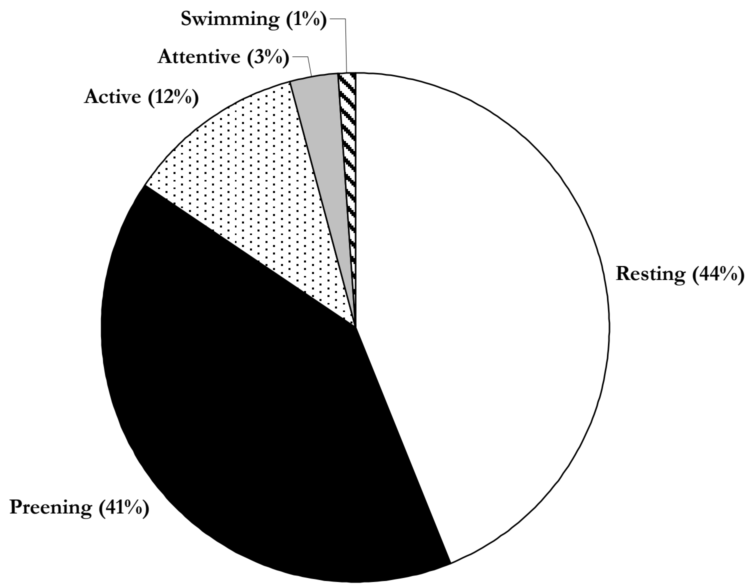


Figure 3.4 The average proportion of time California brown pelicans engaged in the top 5 observed activities on the study plot at East Sand Island in 2001 and 2002. The activity "startled" accounted for < 1% of time.

Table 3.2 Correlations among the activities of California brown pelicans on the study plot at East Sand Island in the Columbia River estuary during 2001 and 2002.

	Active	Attentive	Preening	Resting	Startled	Swimming
Active	1.000	0.201	-0.017	-0.464	0.027	-0.016
Attentive	0.201	1.000	-0.035	-0.303	0.113	0.112
Preening	-0.017	-0.035	1.000	-0.835	-0.002	-0.095
Resting	-0.464	-0.303	-0.835	1.000	-0.046	-0.064
Startled	0.027	0.113	-0.002	-0.046	1.000	0.005
Swimming	-0.016	0.112	-0.095	-0.064	0.005	1.000

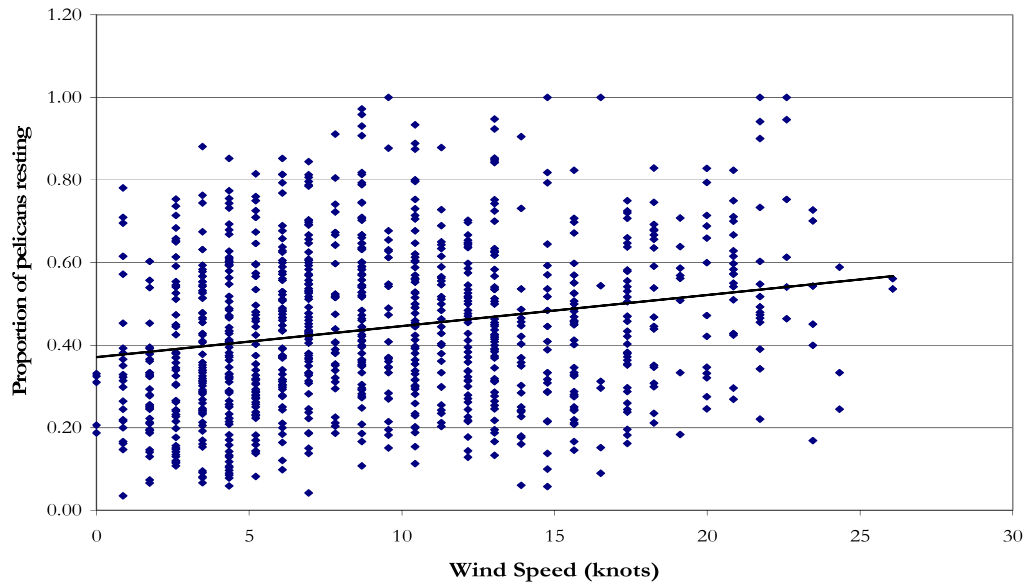
in further analyses of the effects of disturbance on time-activity budgets.

Factors Affecting Time-Activity Budgets

Brown pelicans roosting on the study plot at East Sand Island on average spent 44% (95% CI: 42.2% to 45.8%) of the day resting. Approximately 33% of the variation in proportion of resting pelicans was explained by time of day, number of pelicans on the plot, wind speed, precipitation, research activity disturbance, other anthropogenic disturbance, and natural disturbance to pelicans on the plot ($F_{8, 887}$ = 55.56, $P < 0.0001$). Date did not explain a significant amount of the variation in proportion of pelicans resting.

The proportion of resting pelicans was positively associated with wind speed (Figure 3.5A) and increased by a factor of 1.22 (95% CI: 1.15 to 1.33) with each 10-knot increase in wind speed. The proportion of resting pelicans was also positively associated with precipitation (Figure 3.5B) and increased by a factor of 1.51 (95% CI: 1.41 to 1.61) with each incremental increase in precipitation intensity. The positive associations between resting and these two weather variables indicate that pelicans spent more time resting during inclement weather. The temperatures in this study ranged from 7.2 ºC to 28.9 ºC with a mean of 16 ºC; however, temperature did not affect the proportion of resting pelicans ($P = 0.9689$). The proportion of resting pelicans was negatively associated with number of pelicans on the plot and decreased by a factor of 1.13 (95% CI: 1.01 to 1.25) with an increase of 100 pelicans. The proportion of resting pelicans increased from early morning (05:30) to midday (11:30-13:00: $P < 0.0001$) and then decreased late in the evening ($P < 0.0001$: Figure 3.6A).

(A)



(B)

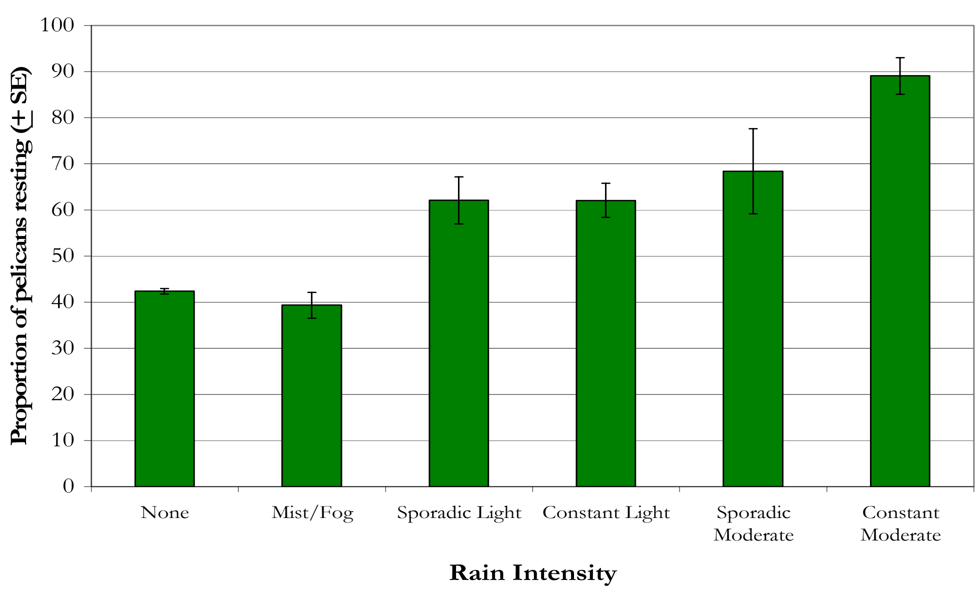
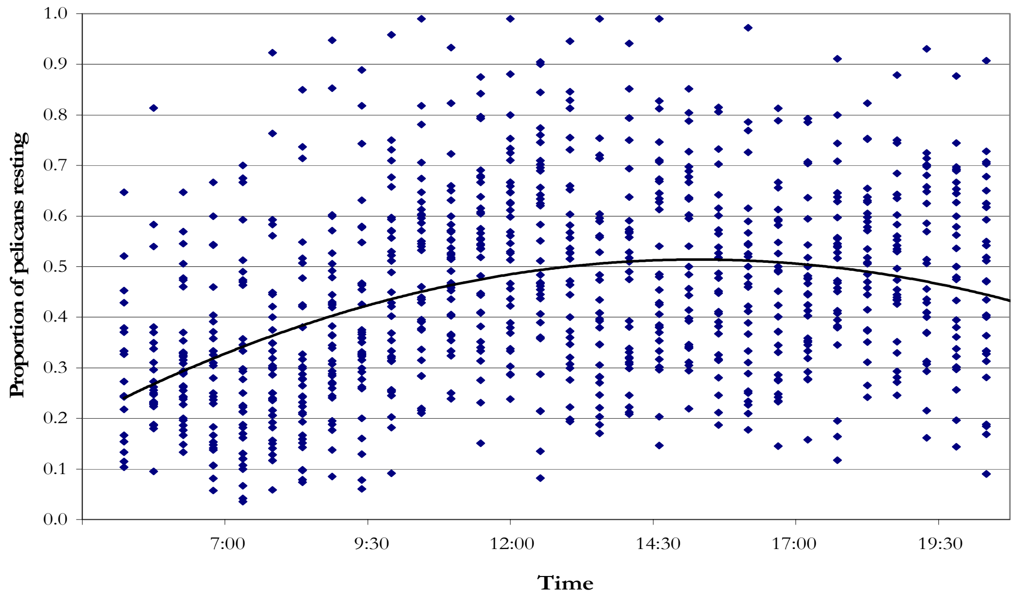


Figure 3.5 Proportion of resting California brown pelicans as a function of (A) wind speed and (B) rain intensity (average proportion ± 1SE) on the East Sand Island study plot during June 1 – September 4 in 2001 and 2002.

(A)



(B)

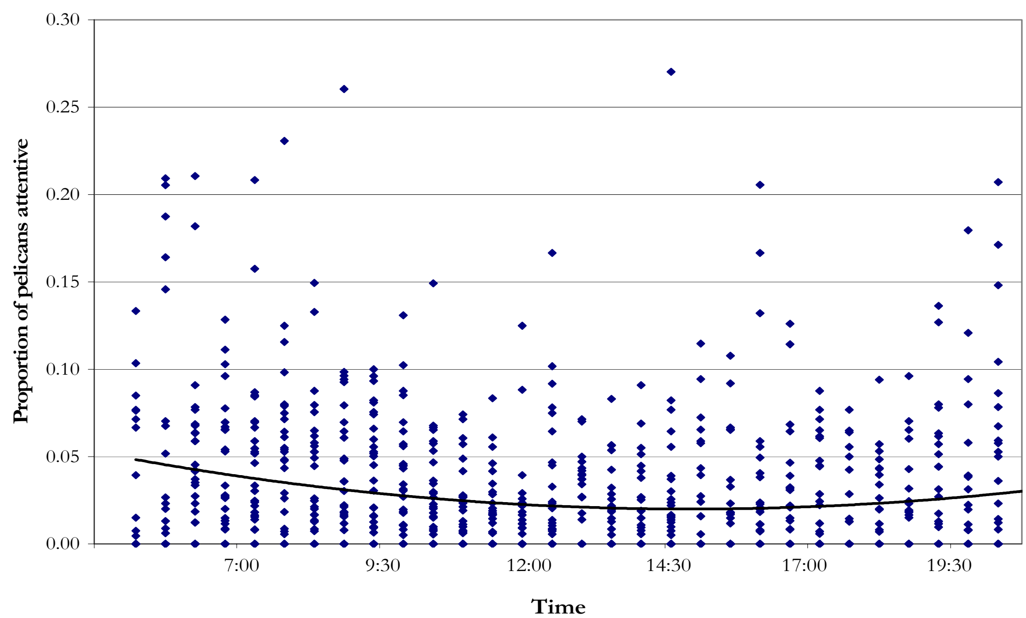


Figure 3.6 Proportion of California brown pelicans (A) resting, and (B) attentive throughout the day on the study plot at East Sand Island during June 1 – September 4 in 2001 and 2002.

Pelicans roosting on the East Sand Island study plot on average spent 3.5% (95% CI: 3.1 to 3.9) of the day attentive in 2001 and 2.4% (95% CI: 2.0 to 2.8) of the day attentive in 2002. There was a significant decrease in the proportion of time spent attentive from 2001 to 2002 (two-sample t-test, P = 0.0001; Table 3.1). The odds of a pelican engaging in attentive behavior in 2002 decreased by a factor of 2.05 (95% CI: 1.74 to 2.42) compared to 2001. Year, date, time of day, number of pelicans on the study plot, research activity disturbance, other anthropogenic disturbance, and natural disturbance together accounted for 27% of the variation in proportion of attentive pelicans ($F_{9, 893} = 36.71$, $P < 0.0001$).

Unlike the proportion of pelicans resting, the proportion of pelicans attentive was not related to any of the measured weather variables. The prevalence of attentive pelicans increased slightly with date. The proportion of attentive pelicans decreased from early morning (05:30) to midday (11:30-13:00; $P < 0.0001$), and then increased through the evening ($P < 0.0001$; Figure 3.6B). The proportion of attentive pelicans was positively influenced by the number of pelicans on the study plot. The proportion of attentive pelicans increased by a factor of 1.71 (95% CI: 1.45 to 2.01) with an increase of 100 pelicans on the study plot.

Disturbances to Pelicans on the Plot

Natural disturbance caused more pelicans to flush from East Sand Island than the two anthropogenic types of disturbance combined (see Chapter 2). During behavioral observations, natural factors caused more disturbance events to pelicans roosting on the study plot (17 events) than research-related disturbances (4 events) and anthropogenic disturbances not related to research (6 events).

Research-related disturbances flushed an average of 9.9% (median) of the pelicans on the study plot per disturbance event (range = 2 –56%: n = 4). Anthropogenic disturbances not associated with research flushed an average of 5.3% (median) of the pelicans on the study plot (range = 1 – 25%: n = 6: Figure 3.7). Natural disturbances flushed an average of 20.5% (median) of the pelicans on the study plot per disturbance event (range = 1 – 100%: n = 17: Figure 3.7). Bald eagles were responsible for 75% of the total number of pelicans flushed from the study plot due to natural disturbances in 2001 and 2002.

Effects of Disturbance on Time-Activity Budgets

All three types of disturbance (research, non-research anthropogenic, and natural) were associated with a significant increase in attentive behavior (two-sided t-test, $P = 0.015, 0.045, 0.015$, respectively) and a decrease in resting behavior (two-sided t-test, $P = 0.015, 0.007, < 0.0001$, respectively) in the 30 minutes following a disturbance. The magnitude of the decrease in resting behavior in the 30 minutes following a disturbance differed marginally among disturbance categories (one-way analysis of variance, $P = 0.062$), and the magnitude of the increase in attentive behavior also differed among disturbance categories (one-way analysis of variance, $P = 0.054$). There was a clear difference in pelican response between research disturbances and natural disturbances, with a greater proportion of pelicans attentive and a smaller proportion of pelicans resting immediately following research

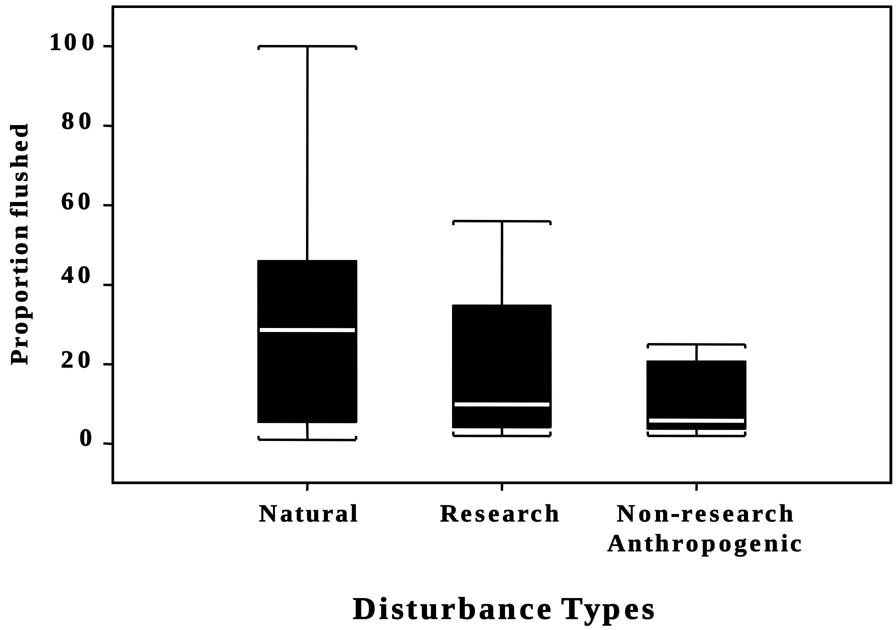
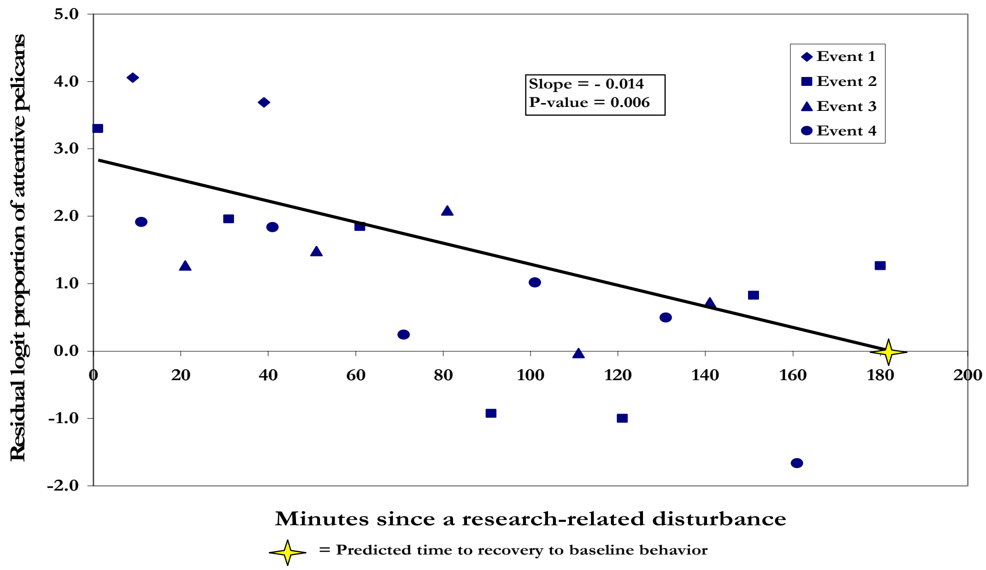


Figure 3.7 Proportion of pelicans on the study plot flushed per disturbance event by disturbances caused by research activities (N = 4 events), non-research anthropogenic factors (N = 6 events), and natural factors (N = 17 events) during behavior observations on East Sand Island in 2001 and 2002. Line within the box plot represents the median proportion of pelicans flushed by each disturbance type, the top and bottom edges of the box are the upper and lower quartiles, respectively, and the whiskers encompass the entire range of the data.

disturbances compared to natural disturbances. Following a research disturbance in the study plot, the ratio of the proportion of attentive pelicans to non-attentive pelicans was 6.9 times greater (Tukey-Kramer; 95% CI: 1.1 to 45.4 times greater) than following a natural disturbance. Additionally, the ratio of the proportion of resting pelicans to non-resting pelicans following a research disturbance was less than following a natural disturbance by a factor of 1.1 (Tukey-Kramer; 95% CI: 0.99 to 2.7 times less).

Following disturbance to pelicans in the study plot from research activities, the predicted time to recover to baseline attentive behavior was 181 minutes (95% CI: 79 to 283 minutes; Figure 3.8A), and to baseline resting behavior was 187 minutes (95% CI: 134 to 241 minutes; Figure 3.8B). Following disturbance from non-research anthropogenic factors the predicted time to recover to baseline attentive behavior was 57 minutes (95% CI: -89 to 202 minutes; Figure 3.9A), and to baseline resting behavior was 132 minutes (95% CI: 27 to 237 minutes; Figure 3.9B). Following disturbance from natural factors the predicted time to recover to baseline attentive behavior was 28 minutes (95% CI: -323 to 379 minutes; Figure 3.10A), and to baseline resting behavior was 82.5 minutes (95% CI: 34 to 131 minutes; Figure 3.10B). Thus, predicted times for pelicans to recover to baseline (average) incidence of attentive and resting behaviors were greater for anthropogenic disturbances than for natural disturbances. Differences in recovery times were particularly pronounced for resting behavior, where recovery times were much greater for disturbances caused by research activities than for natural disturbances.

(A)



(B)

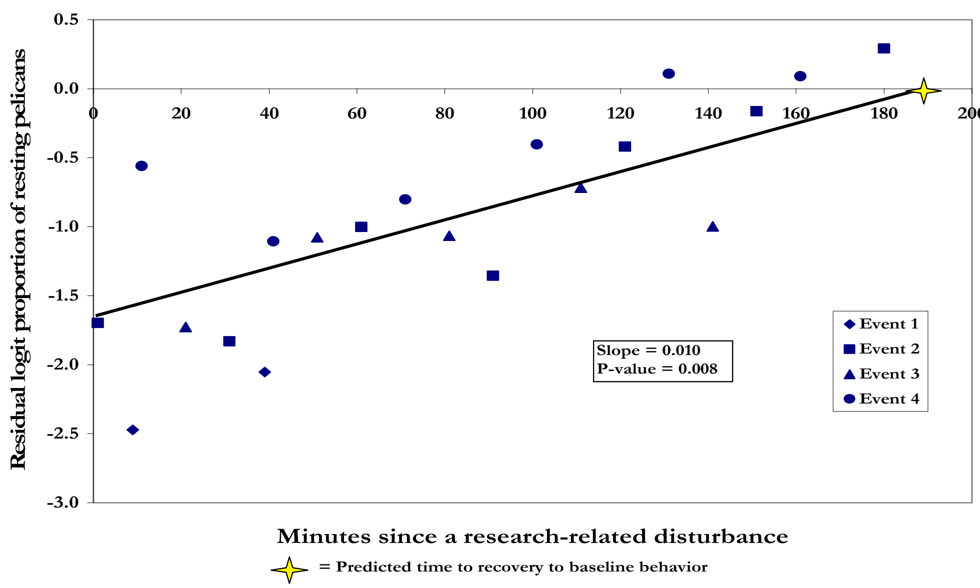
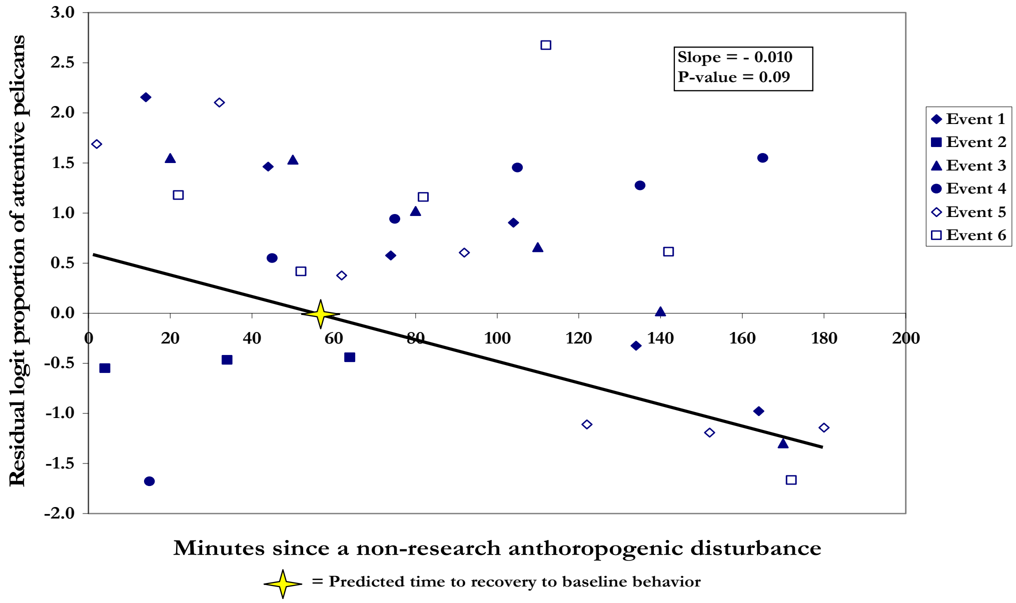


Figure 3.8 The proportion of pelicans on the study plot that were attentive (A) and resting (B) during the first three hours following a research disturbance that caused pelicans to flush from the study plot, after accounting for other factors, on East Sand Island in 2001 and 2002. The line is the average slope of the events weighted by the number of observations following each event.

(A)



(B)

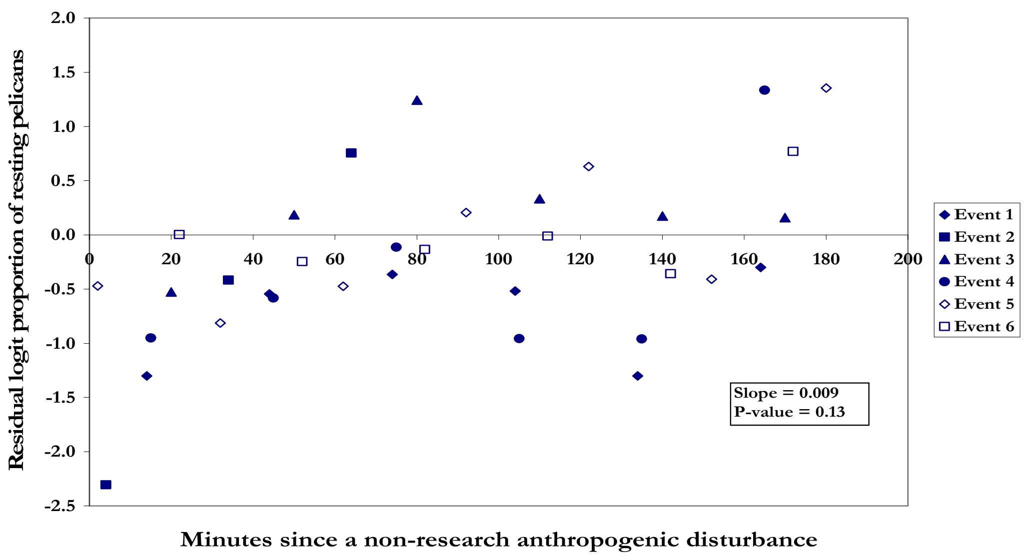
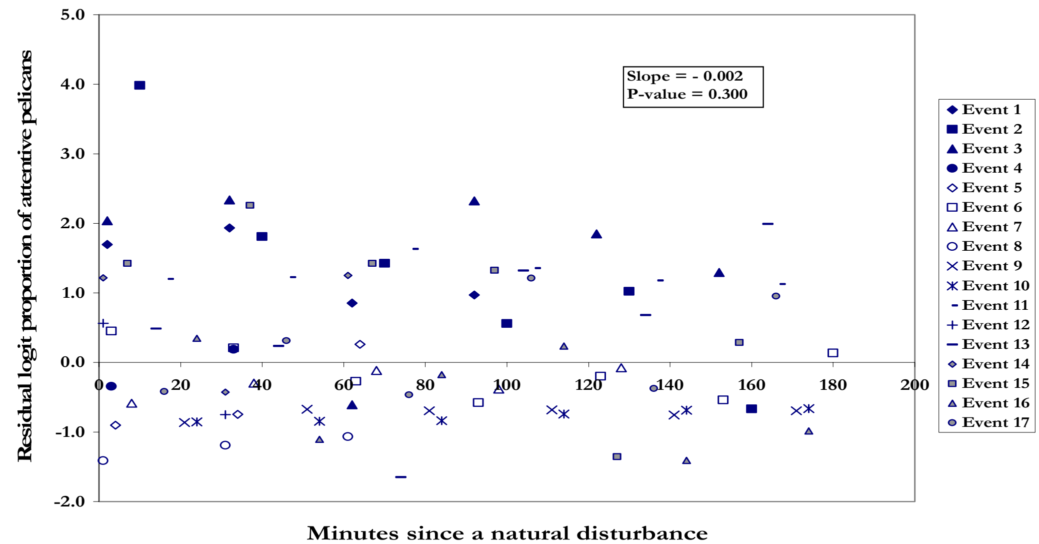


Figure 3.9 The proportion of pelicans on the study plot that were attentive (A) and resting (B) during the first three hours following a non-research anthropogenic disturbance that caused pelicans to flush from the study plot, after accounting for other factors, on East Sand Island in 2001 and 2002. The line (A) is the average slope of the events weighted by the number of observations following each event. The slope of the return to baseline resting behavior (predicted time to recovery = 132 minutes) was not significant (P = 0.13).

(A)



(B)

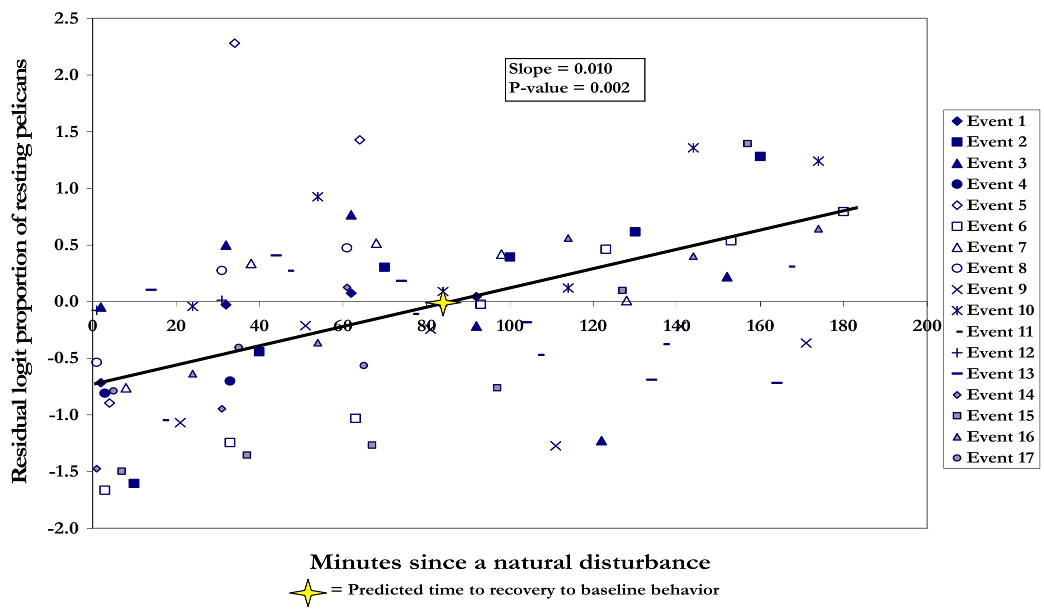


Figure 3.10 The proportion of pelicans on the study plot that were attentive (A) and resting (B) during the first three hours following a natural disturbance that caused pelicans to flush from the study plot, after accounting for other factors, on East Sand Island in 2001 and 2002. The line (B) is the average slope of the events weighted by the number of observations following each event. The slope of the return to baseline attentive behavior (predicted time to recovery = 28 minutes) was not significant (P = 0.3).

Movements To and From the Study Plot

We recorded pelican movements to and from the study plot during 520 observation periods from June 1 to September 4 in 2001, and during 441 observation periods from June 4 to August 21 in 2002. Observation periods ranged in length from 5 to 25 minutes, with a mean length of 16 minutes. The length of the observation period was not significantly correlated with the rate of pelicans arriving or departing the study plot. Pelican arrival rates ranged from 0 to 11.7% of the pelicans on the study plot per minute, with a median arrival rate of 0.41%. Pelican departure rates ranged from 0 to 7.3% per minute with a median departure rate of 0.34%. The lower rates of departure indicate that during periods when the plot was not observed (i.e., nighttime) more pelican departures from the plot occurred than arrivals, probably due to an exodus of pelicans from the night roost in the early morning hours before our observations began.

Date, time of day, wind direction, and wind speed accounted for 26% of the variation in the departure rate of pelicans from the study plot. Year, in addition to the four previous explanatory variables, accounted for 29% of the variation in the arrival rate of pelicans to the plot. However, the three types of disturbance (human activities not associated with research, research activities, and natural factors) did not significantly affect the arrival rate ($P = 0.1308$, 0.0833, and 0.4268, respectively) or the departure rate ($P = 0.9428$, 0.7301, and 0.4269, respectively) of pelicans to or from the study plot. Consequently, the observed disturbances to pelicans roosting on the study plot did not cause a detectable change in the rates of pelicans moving to or from the plot.

DISCUSSION

Brown pelicans have wettable plumage that will become waterlogged if pelicans are prevented from roosting on land to dry and maintain their plumage following feeding bouts (Rijke 1970). California brown pelicans roosting on East Sand Island during the day spent 85% of the time either resting or preening. Non-breeding American white pelicans (*Pelecanus erythrorhynchos*) in Mississippi and Louisiana spent 72 to 96% of daylight hours (06:00 to 17:30) loafing and the remaining proportion of the day foraging (King and Werner 2001). It may be necessary for pelicans to rest between feeding bouts to recover, particularly in brown pelicans, the only pelican species that plunge dives for food (Bent 1964, Schreiber et al. 1975, Shields 2002). Seabird plunge-diving is evidently costly, requiring at least 5 times the energy expenditure rate of flapping flight in one seabird species, the black-legged kittiwake (*Rissa tridactyla*; Jodice et al. 2003).

The daily patterns of pelican movements and time-activity budgets on the East Sand Island roost indicate higher activity in the early morning and late evening, with less activity around mid-day. The rates of pelicans arriving at the study plot were consistently highest early and late in the day. The proportion of resting pelicans was lowest in the morning and evening, and peaked in the middle of the day. Correspondingly, the proportion of attentive pelicans was highest in the morning and evening and lowest in the middle of the day. A sub-adult California brown pelican fitted with a radio transmitter spent less than 10% of the time inactive (not flying) from 04:30 to 07:30 and from 16:30 to 19:30, while spending approximately equal time active and inactive from 07:30 to 16:30 (Croll et al. 1986). This is consistent with our hypothesis of early morning departure to foraging areas, periodic return to rest throughout the day, and a late evening increase in activity associated with the return of large numbers of pelicans to the roost. Herbert and Schreiber (1975) observed that brown pelicans roosted at a Florida boat marina in large numbers during the middle of the day, but were present in only small numbers during the mornings and evenings. They concluded that pelicans foraged early in the morning and utilized the marina as a mid-day loafing area, spending the time sleeping and preening.

Disturbances on East Sand Island could degrade the quality of the roost site for California brown pelicans and potentially result in less pelican use of the site. Flight is the most energetically-expensive activity for pelicans that we observed in response to disturbance (Norberg 1996, Jodice et al. 2003). Each time a pelican is flushed from a roost due to disturbance, an energetic cost is incurred that requires compensation. If the cost of disturbances is not compensated for through increased food intake or reduced energy expenditure, subsequent survival and/or productivity may be compromised.

Another more subtle cost of disturbance is potentially reflected in changes in pelican time-activity budgets. Disturbances from research-related activity and natural sources led to significant declines in resting behavior and increases in attentive behavior among pelicans on the plot. A change in activity from relaxed or resting to alert or attentive has been shown to double the energy expenditure rate of captive birds (Buttemer et al. 1986) and increase the metabolic rate of free-living American black ducks (*Anas rubripes*) by a factor of 1.45 to 1.94 (Wooley and Owen 1978). Alert behavior in response to human presence can significantly increase avian heart rate above normal levels for walking, preening, and resting (Ely et al. 1999). In addition, wild birds may act normally in the presence of humans, but other physiological indicators, such as heart rate, may change dramatically (Bell and Amlanger 1980, Culik et al. 1990). Changes in avian behavior due to human disturbance can lead to increased exposure to natural predators (Keller 1991) and reduced foraging time (Owens 1977, Flemming et al. 1988, Bélanger and Bédard 1989, Burger and Gochfeld 1991, Riddington 1996), enhancing the fitness costs of disturbance.

The four observed disturbance events caused by research activities that occurred in the study plot were land-based activities, and the six non-research anthropogenic disturbances that occurred were water-based activities. It appears that pelican behavior was more affected by human activities on the island than by human activities on the water near the island, based on the significant difference between research and natural disturbance, but no significant difference between non-research anthropogenic and natural disturbances. Also the median magnitude of non-research anthropogenic disturbances in the study plot (5.3% of pelicans in the study plot flushed) was smaller than the median magnitude for research disturbances (9.9% of pelicans in the study plot flushed) which potentially contributed to the smaller effect on pelican behavior from observed non-research anthropogenic disturbances.

Conversely, the median magnitude of natural disturbances in the study plot (20.5% of pelicans in the study plot flushed) was much higher than the two categories of human disturbance, yet had a smaller effect than research disturbance on pelican behavior in the half hour following disturbance. This suggests that natural disturbance events, although more frequent, did not influence the time-activity budgets of pelicans on the study plot as much as research (land-based human) activities. Additionally, following a natural disturbance resting behavior recovered to baseline (average) levels in much less time than following a research-related disturbance.

It is difficult to determine the disturbance threshold above which California brown pelican fitness is negatively affected. Conomy et al. (1998) observed that waterfowl spent 1.4% of the time swimming, flying, and alert in response to human disturbance, and concluded that this energy investment was too low to have a significant effect on fitness. California brown pelicans are listed as endangered under the U.S. Endangered Species Act, however, and protected under law from any disturbance that causes them to flush. East Sand Island is the only suitable night-time roost for California brown pelicans in the Columbia River estuary and efforts to ensure that this roost is not degraded by human disturbance are warranted.

MANAGEMENT IMPLICATIONS

East Sand Island has become an important roost site for endangered California brown pelicans in part because it is closed to the public and free of mammalian predators, unlike other islands in the lower Columbia River estuary.

These two features offer a relatively disturbance-free site where pelicans can rest between feeding bouts.

Despite precautions taken by researchers to avoid disturbance to California brown pelicans roosting on East Sand Island in both 2001 and 2002, research-related disturbances did have a significant effect on time-activity budgets of pelicans on the study plot. The frequency, magnitude, and spatial-scale of research-related disturbances to pelicans on East Sand Island need to be limited in order to minimize potential effects on pelican fitness. The portion of East Sand Island west of the observation tower, which includes some of the highest densities of roosting pelicans (see Chapter 1), should be entirely off-limits to research activities from May 1 to November 15. Standard protocols to minimize disturbance to pelicans on the island should continue to be followed, including use of aboveground tunnels to conceal researcher access to the observation tower and accessing the tunnels from the North Beach only within two hours of low tide or at night to reduce disturbance to waterbirds from research activities. Researchers should be familiar with the protocol to minimize disturbance to pelicans developed in consultation with the U.S. Fish and Wildlife Service, as well as page 74 of the California Brown Pelican Recovery Plan (USFWS 1983), which outlines the importance of essential roosting habitat for recovery of this species. This information will assist researchers in understanding the necessity of precautions, and why it is important to follow these guidelines. The effect on roosting pelicans of unrestricted access to East Sand Island by researchers and the general public is not known, but it is likely that this increase in disturbance would eventually result in the abandonment of the island as a roost site.

Natural disturbance to brown pelicans on the study plot did not influence pelican time-activity budgets to the same extent as research-related disturbance, but increased use of East Sand Island by avian predators, particularly bald eagles, has the potential to greatly affect pelican behavior. Any human activities on East Sand Island that attract avian predators or coyotes (e.g., garbage, decoys, roost structures) should be closely monitored and regulated. Any coyotes or other terrestrial mammalian predators that manage to reach East Sand Island should be removed immediately. East Sand Island should be designated as critical roosting habitat for endangered California brown pelicans and monitored frequently during the months of highest pelican use (June – October).

ACKNOWLEDGMENTS

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Chapter 4

SUMMARY AND SYNOPSIS

Sadie K. Wright

The results of this study demonstrated significant effects of disturbance on the time-activity budgets, distribution, and number of California brown pelicans roosting on East Sand Island in the Columbia River estuary. Year, date, and tide height accounted for 90% of the variation in total numbers of California brown pelicans roosting on East Sand Island, indicating that these factors must be accounted for in order to detect effects of disturbance on pelican numbers. Research disturbance apparently had a negative effect on number of brown pelicans roosting on East Sand Island when the magnitude of disturbance caused at least 15% of the total number of roosting pelicans to fly from the roost. Investigation of the distribution of pelicans roosting on East Sand Island indicated that in the section of shoreline where the majority of pelicans were flushed due to research activities, pelican numbers were negatively associated with research activity. This suggests that pelicans moved away from this area of high researcher activity to roost on other parts of the island, or possibly left the island altogether.

The marginally significant negative association between the magnitude of research disturbance and pelican numbers on East Sand Island was detected only in 2001, not in 2002. Additional precautions that were taken by researchers in 2002 to avoid flushing pelicans, including reduced number of researcher forays on parts of the island where pelicans tended to congregate, apparently reduced the magnitude of disturbance. Research can be conducted on East Sand Island in the presence of roosting California brown pelicans without causing significant declines in numbers of roosting pelicans, if researchers take certain precautions. These precautions include restricted researcher access to the west end of the island, use of aboveground tunnels to access the observation tower, and curtailing research activities that could potentially cause large numbers of roosting pelicans (more than 15%) to flush.

Although anthropogenic disturbance not associated with research had no detectable effect on the number of pelicans roosting on East Sand Island, most of this type of disturbance event were not witnessed and the reactions of brown pelicans not recorded. Also, the magnitude of this source of disturbance was negatively associated with numbers of pelicans roosting on the western tip of the island, where recreational boats frequently passed within 150 m of the shoreline. The localized effect of non-research anthropogenic disturbance on pelican numbers suggests that pelicans were moving from an area of high human activity to a different part of the island. Pelican avoidance of areas with relatively high human activity indicates that the quality of this roost site can be compromised by human disturbance, and pelican use of East Sand Island would be greatly reduced if the public (e.g., beach combers, campers) were permitted access to the island.

I did not detect a significant effect of natural disturbance on total numbers of pelicans roosting on East Sand Island or on numbers of pelicans using sections of the shoreline with frequent natural disturbances. As with non-research anthropogenic disturbance, however, most of this type of disturbance event were not witnessed and reactions of pelicans not documented. Although natural disturbances were responsible for flushing far more pelicans than anthropogenic disturbances, anthropogenic disturbances appear to have had a greater influence on the numbers, distribution, and time-activity budgets of pelicans roosting on East Sand Island. California brown pelicans may be more acclimated to natural disturbances than to anthropogenic disturbances, perhaps due to habituation to frequent natural disturbances as an adaptation to reduce energy expenditure. In addition, the main source of natural disturbance to pelicans on East Sand Island is bald eagles, which rarely attack pelicans; only two unsuccessful attacks (no contact made) by juvenile eagles on juvenile pelicans were observed in 657 hours of observation. Brown pelicans flushing from East Sand Island due to eagle disturbance appeared to be reacting more to the alarm response of other waterbirds nesting on the island, rather than the eagles *per se*.

The presence of mammalian predators large enough to prey upon pelicans is more likely to cause roost abandonment by brown pelicans than the current levels of disturbance from avian predators. No coyotes were observed on East Sand Island during this study, although they have been sighted repeatedly on West Sand Island. Although the two islands are separated by a 600-m open water channel, elk and deer are known to have reached East Sand Island in recent years. It is possible that coyotes will reach East Sand Island in the future. In order to maintain the high quality of the roost site on East Sand Island, the island should be monitored between April and December, and any coyotes or other large mammalian predators that are detected on the island should be removed immediately.

The use of East Sand Island by California brown pelicans in future decades may change dramatically in response to global warming and increasing pelican population numbers. Northward range expansion by brown pelicans is occurring on both the East and West coasts of the United States. Although the breeding range of the eastern brown pelican (*P. o. carolinensis*) has expanded northward in recent years, the same has not yet been observed for California brown pelicans. We observed California brown pelicans on East Sand Island engage in courtship displays, nest building, copulations, and broodiness. These behaviors occurred at roost sites in southern California in the years prior to the roost becoming an active breeding colony. It is possible that with continued, consistent use of East Sand Island by pelicans during the breeding season, that breeding by California brown pelicans could occur at this site, a 1,500 km northward expansion of their current breeding range.

All three categories of disturbance, natural, research-related, and non-research anthropogenic, influenced the time-activity budgets of pelicans roosting on East Sand Island. Immediately following a disturbance that flushed pelicans from our study plot, the proportion of resting pelicans decreased, while the proportion of attentive pelicans increased. Switching from resting to attentive activity could lead to a significant increase in heart rate, and a doubling in resting metabolic rate of brown pelicans, two responses observed in other avian species. Based on immediate changes in pelican activity and average recovery times to baseline time-activity budgets, disturbance events related to research had a greater effect on pelican behavior compared to either non-research anthropogenic or natural disturbances. Larger natural predators (e.g., coyotes) and greater recreational disturbances (e.g., beach combers on the island) would have a much greater influence on the time-activity budgets of pelicans than observed during this study.

This study sought to identify potential threats to the quality of the East Sand Island roost site for California brown pelicans and may be used by resource managers to control the potential impacts of disturbance at this and other pelican roosts.

Research activity on East Sand Island can negatively affect the number and distribution of pelicans using the roost site, but precautions taken in 2002 to reduce research-related disturbance were shown to be effective. Research activities negatively influenced the time-activity budgets of roosting brown pelicans in both years. Researchers can minimize their effects on pelican behavior by reducing overall disturbance (e.g., use of aboveground tunnels to access blinds, fewer forays to the west end of East Sand Island) and restricting disturbances to small sections of the island's shoreline.

Studies of the physiological response (e.g., heart rate, baseline corticosterone levels, fitness response) of California brown pelicans to human disturbance would help to quantify the cost of the response. This information would validate the behavioral data presented here and allow me to extend my conclusions, but this type of invasive research is unlikely as long as California brown pelicans remain listed as endangered under the U.S. Endangered Species Act.

Humans continue to encroach on coastal wildlife habitat by building houses, beach combing, camping, and fishing. Pelicans are sensitive to human disturbance throughout their annual cycle and need undisturbed habitat for nesting and roosting. The restricted access status of East Sand Island will become increasingly important to the protection of California brown pelicans as the human population grows. The U.S. Army Corps of Engineers (or future managers of East Sand Island) should continue to keep East Sand Island closed to the public, at least during the period of the year when colonial waterbirds nest and pelicans roost on the island (April – November). Also, the island should be monitored for coyotes and other large predators, and any detected predators should be removed immediately to limit their impact on nesting and roosting seabirds.

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