Responses of California Brown Pelicans to Disturbances at a Large Oregon Roost

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Abstract.—Numbers of California Brown Pelicans (*Pelecanus occidentalis californicus*) along the coast of Oregon and Washington have increased sharply in recent years. We identified East Sand Island in the Columbia River estuary as the site of the largest pelican roost within this region. Numbers of pelicans roosting on East Sand Island have increased from less than 100 during 1979-1986 to a high count of 10,852 in 2002. The East Sand Island roost is currently the site of a major non-breeding aggregation of this endangered subspecies. 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. Pelicans appeared to forage more during low tides, and return to the roost during high tides; therefore, pelican numbers on the island were positively associated with tide height. Land-based human disturbance was negatively associated with total pelican numbers, whereas water-based human disturbance had no significant effect on total pelican numbers on the island. Natural disturbances, although more frequent than human disturbances, apparently did not influence the total number of pelicans on the island. *Received 18 October 2006, accepted 21 March 2007.*

Key words.—California Brown Pelicans, Columbia River estuary, disturbance, *Pelecanus occidentalis californicus*, roost.

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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 United States (35 Federal Register 16047, 13 October 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). Although humans have been observed disturbing pelicans at roost sites (Jaques 1994) and impacting roosting ecology (Jaques and Anderson 1988), the effects of human disturbance at roost sites are less well known than at breeding colonies. Because both human and pelican numbers are increasing along the coastline it is important to understand the effects of increased interactions between humans and pelicans.

East Sand Island at river km eight in the Columbia River estuary is a major California Brown Pelican post-breeding roost site, one of few suitable sites for a night-roost in the Pacific Northwest, 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 currently closed to the public to minimize disturbance to nesting colonial waterbirds, recreational boats occasionally land on the island, and pass close enough to the island when fishing to disturb pelicans. Additionally, 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 (*Hydroprogne caspia*) in order to develop sound management recommendations to help recover endangered runs of Columbia Basin salmonids (NPPC 1994; NMFS 1995; CRITFC 1995). This gave us the opportunity to study the effects of human disturbance on pelican numbers at a major roost site.

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 seabird roost sites.

METHODS

Study Area

East Sand Island (46°15'45"N, 123°57'45"W; Fig. 1) was the focus of this study. The island is approximately two km long on an east-west axis, ranges from ten to 300 m wide, and has an area of approximately 21 ha (Fig. 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 (Fig. 2). The inland areas of the island are mostly vegetated in grasses and low-lying shrubs.

There is a large and increasing breeding colony of Double-crested Cormorants on the western half of the island (ca. 13,000 pairs; D. Roby, USGS, unpubl. data), mostly on the large boulders from the West Beach eastward to the Mid Pile Dike (Fig. 2). 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 (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 (Fig. 1), areas that were periodically surveyed from the air.

Pelican Census Techniques

Counts of all Brown Pelicans roosting on East Sand Island were conducted from the deck of a skiff motoring slowly, approximately 150 m from shore. The shoreline was divided into 15 sections (Fig. 2) and pelicans were counted individually within the sections using 10 × 30 mm Canon image-stabilizing binoculars. Pelicans were counted approximately six times per week between 1 June and 30 September in 2001 and 2002; during May, October, and the first half of November, counts were conducted one or two times per week in both years. Counts occurred either early in the morning, starting at 05.00 to 07.00 h Pacific Daylight Time (as early as light would allow), or late in the evening, starting at 19.00 to 21.00 h PDT (as late as light would allow). Approximately once every two weeks two observers counted the pelicans concurrently and compared numbers to insure over 90% of the pelicans were counted.

Five weather variables were recorded during each boat census: temperature (°C), percent cloud cover (5% increments), wind direction (Cartesian coordinates), wind speed (Beaufort Scale), precipitation (index of 0-7; no rain to constant rain). Data on two tide variables were gathered: tide height (m of water from mean low tide), and tide speed (rate of water movement in m/h) at the start of the count. These data were from the NOAA tide gauge at Tongue Point, OR, 17 km upriver from East Sand Island.

Aerial surveys for roosting Brown Pelicans were conducted along the northern coast of Oregon and the southern coast of Washington, near the Columbia River estuary, to determine the location of roost sites. In 2001, a flight was flown from the mouth of the Columbia River north along the Washington coast, scanning Willapa Bay and Grays Harbor approximately twice per week between 25 April and 18 July. In 2002, approximately two surveys per month were flown from 15 June to 4 September. The track of the first three aerial surveys was the same as in 2001, whereas the next three included an

Figure 1. Map of northern Oregon and southern Washington coastlines where aerial surveys of roosting California Brown Pelicans were conducted.

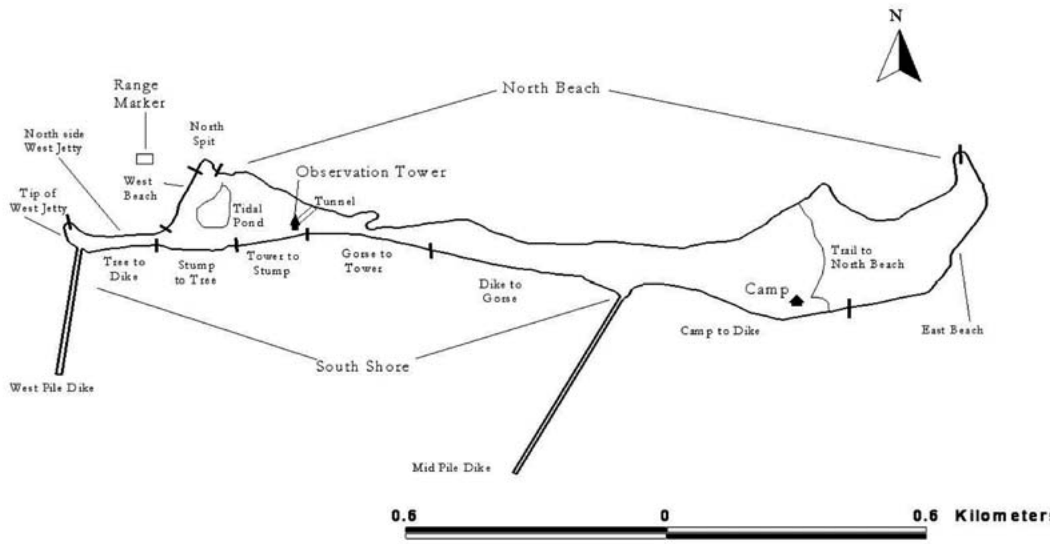

Figure 2. Map of East Sand Island showing pelican census section delineations.

additional track along the northern coast of Oregon from Tillamook Bay to the mouth of the Columbia River (Fig. 1).

Aerial surveys were flown in a Cessna 205 at ca. 85 knots air speed and at an altitude of ca. 200 m. Either 10 × 50 mm Leica binoculars or 10 × 30 mm Canon image stabilizing binoculars were used to count pelicans from the aircraft.

Disturbance Rate

Disturbance was defined as any stimulus that caused one or more pelicans to flush (to take flight) from the island. Disturbances to pelicans roosting on East Sand Island were monitored from an observation tower near the west end of the island (Fig. 2). Although most of the west end of the island could be easily viewed from this elevated vantage, the view of the beaches at the eastern end of the island 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 it was possible to detect pelicans when flushed from most areas of the island from the vantage on the observation tower. Pelicans often circled high above the source of disturbance before re-landing, or leaving the island, enhancing the ability to detect disturbance events throughout the island.

Observation time blocks were categorized as either morning (04.00-13.00 h PDT) or evening (13.00-22.00 h PDT); duration of observation bouts was half of the daylight period (dictated by available light). Disturbance rates to pelicans were monitored for morning time blocks as soon as daylight allowed and ended at 13.00 h; evening observation blocks began at 13.00 h and lasted as late as daylight allowed. Three observation time blocks per week were randomly selected (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. 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.

Known-cause disturbances were grouped into three main categories: (1) Natural, including any non-domestic animal or driftwood, (2) land-based human disturbance, and (3) water-based human disturbance. When a disturbing stimulus occurred, the time, the type, and location of the stimulus were noted. Rates of disturbance to Brown Pelicans were calculated by dividing the total observed number of pelicans flushed by the total number of observation hours for each category of disturbance.

All pelicans flushed by research activities were recorded 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 types of disturbance, disturbance rates were converted into the number of pelicans flushed per daylight hour by each factor. Accordingly, the total number of pelicans flushed by research activities during the period when disturbance rate data were collected for other types of disturbance (1 June-4 September 2001 and 4 June-21 August 2002, from sunrise to civil evening twilight) was divided by the total number of daylight hours during this period. Research disturbance was sub-divided into land-based and water-based disturbance to determine if human disturbance had a greater effect on pelican numbers if it occurred on the land or water. Land-based research disturbances, such as walking between bird blinds, recovering bird carcasses, and firing shotguns, were assumed to have similar effects on pelican numbers as land-based recreational activities, such as beachcombing, picnicking, and duck hunting. Water-based research disturbances, such as bird censuses, diet collection, and crew drop-offs on the island were assumed to have similar effects on pelican numbers as water-based recreation activities, such as fishing, crabbing, feeding the birds, hunting, and driftwood collection.

Statistical Analysis

Multiple linear regression was used to examine factors that potentially influenced the total number of pelicans roosting on East Sand Island. The factors included year, date, time of day (morning versus evening census), tide height, tide speed, temperature, precipitation, cloud cover, wind speed, and wind direction. Quadratic functions of these variables and interactions between the variables were examined. Some of the independent variables were correlated, but none of the correlations exceeded 0.4. Step-wise removal of non-significant (P-value > 0.05) variables was used to determine models that identified factors that explained a significant proportion of the variation in the total number of pelicans roosting on East Sand Island.

The potential effects of day-time land-based and water-based human disturbances on pelican numbers were examined in more detail by comparing the proportional change in pelican numbers for paired evening or morning pelican counts recorded before and after day-time disturbances caused by human activities. These paired before and after counts were taken either 24 or 48 h apart. The magnitude of day-time human disturbance that occurred between the paired counts was defined as the number of pelicans flushed by either land-based or water-based human activities, divided by the average number of pelicans counted in the two counts. Linear regression models were run with the response as the proportional change in the number of pelicans between paired counts.

To determine potential effects of night-time land-based human activities on pelican numbers, paired counts before and after each night of human activity were analyzed. In order to avoid having the effects of night-time human activities confound the effects of day-time human disturbance, intervals between paired day-time counts were excluded if night-time human activity occurred during the interval.

In addition, the potential effects of natural disturbances on numbers of pelicans roosting on East Sand Island were examined. The proportional rate of disturbance (number of pelicans flushed per daylight h/average number of pelicans on the island) was calculated and the same paired, before and after pelican count method used in analysis of potential effects of day-time human disturbance was used.

Due to concern that the analyses might fail to detect small differences in pelican numbers caused by day-time or night-time human disturbance (Type II error), the level of significance was set at $\alpha = 0.10$.

RESULTS

Pelican Numbers

One hundred and eight censuses of all Brown Pelicans roosting on East Sand Island were completed 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 7 April in 2001 and on 28 April in 2002. In both years no more than ten pelicans were observed on East Sand Island after 1 December. Peak numbers of pelicans counted on the island were 4,434 on 5 October in 2001 and 10,852 on 3 September in 2002 (Fig. 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). Pelicans appeared to favor the rocky sections of the island's shoreline. Densities of pelicans were highest on rocky sections of the shoreline on the west end of East Sand Island; 0.45 to 1.24 pelicans/m shoreline in 2001 and 1.26 to 2.86 pelicans/m shoreline in 2002. Densities of pelicans were lowest on the sandy North and East beaches; 0.07 to 0.08 pelicans/m shoreline in 2001 and 0.31 to 0.77 pelicans/m shoreline in 2002 (Figs. 4A, B).

East Sand Island was the site of by far the largest Brown Pelican roost detected during this study. No Brown Pelicans were observed outside the Columbia River estuary during aerial surveys in 2001 until the last survey on 18 July, 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 Colum-

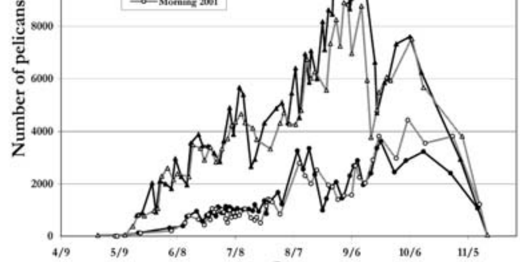

Figure 3. Number of California Brown Pelicans roosting on East Sand Island during evening and early morning island-wide counts as a function of date (month/day) in 2001 and 2002.

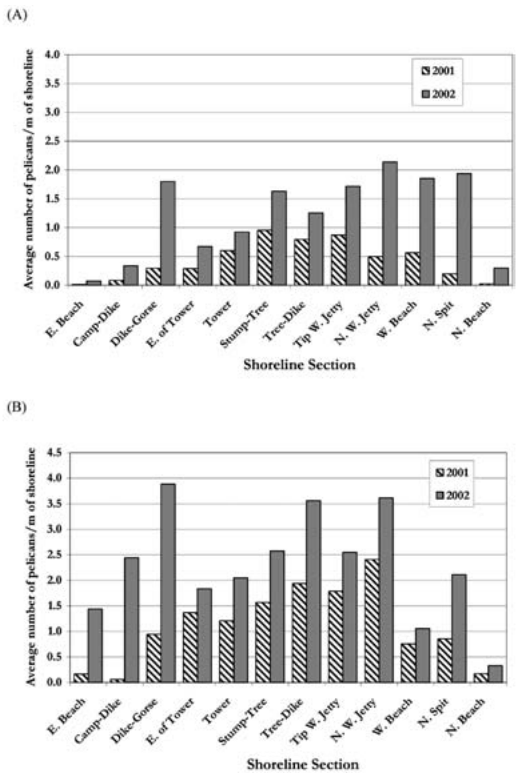

Figure 4. Density of California Brown Pelicans roosting on sections of the shoreline of East Sand Island during (A) the early season (7 May-31 July 2001 and 28 April-31 July 2002) and (B) the late season (1 August-11 November 2001 and 1 August-15 November 2002).

bia River estuary during each aerial survey in late June and early July. Numbers observed outside of the estuary increased to a peak of approximately 2,500 pelicans in Grays Harbor and 1,100 pelicans on offshore stacks along the north Oregon coast in early September, 2002. No Brown Pelicans were seen on offshore stacks along the southern Washington coast between 30 July and 4 September 2002.

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.

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 (Fig. 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 predicted a multiplicative increase in the median number of pelicans of 6.1% (95% CI: 1 to 11%) for every m increase in tide height, after accounting for other variables. The multiple linear regression model predicted that 20% more pelicans roosted on East Sand Island during extreme high tides compared to extreme low tides. Tide speed ($r = -0.03$, $P = 0.39$, $N = 210$), 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 roosting on East Sand Island.

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 1). There was a large increase in the number of pelicans disturbed by Bald Eagles during observation periods in 2002 (11,647 pelicans flushed) compared to 2001 (1,439 pelicans flushed). This was equivalent to disturbance rates of 37.6 and 4.1 pelicans flushed/daylight h 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 and 2002, natural disturbances caused more pelicans to flush than all human disturbances combined (Table 1).

Disturbances

A majority of the pelicans flushed by research activities were flushed by land-based research activities (71% in 2001, 94% in

Table 1. Disturbance rates for California Brown Pelicans (number of individuals flushed per hour of observation) roosting on East Sand Island in 2001 and 2002.

	Flushes during observation periods		Flushing rate (flushes/hour)	
Disturbance factor	2001 (n = 347.5 hours)	2002 (n = 309.5 hours)	2001	2002
Research				
Land-based Research	1,336[a]	2,884[a]	0.97[b]	1.90[b]
Water-based Research	545[a]	184[a]	0.39[b]	0.12[b]
Research total	1,881[a]	3,068[a]	1.36[b]	2.02[b]
Human/non-research				
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 1 June to 4 September 2001, or 18 May to 21 August 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 1 June-4 September 2001, or during 18 May-21 August 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*).

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 land-based human activities had a significant effect on total pelican numbers in 2001 ($F_{1, 20} = 4.08$, $P = 0.057$) 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 land-based human disturbance, and total number of pelicans on the island after the disturbance was 21% lower than before the disturbance (Fig. 5). Water-based human disturbance did not have a significant effect on total pelican numbers in 2001 ($F_{2,19} = 1.94$, $P = 0.95$) or 2002 ($F_{1,19} = 0.14$, $P = 0.71$), but the largest water-based human disturbance observed flushed only 3.6% of the total number of pelicans roosting on East Sand Island.

Night-time human land-based activities on the west end of East Sand Island did not significantly affect the total number of pelicans roosting on the island ($r = -0.19$, $P = 0.13$, $N = 210$). However, nearly complete evacuation by pelicans of the area within 50 m of the observation blinds was observed when researchers used a noose-pole for night-time capture of cormorants. Additionally, although natural disturbance did not significantly affect the total number of pelicans on East Sand Island, pelicans did avoid the area of the shoreline near some large driftwood stumps where Bald Eagles often perched.

DISCUSSION

Increases in the human population, particularly along the coast, have led to increased overlap between seabirds and humans. A better understanding of the impacts of human/seabird interactions will enable managers to make sound decisions regarding seabird protection. Our study has identified major pelican roost sites along sections of the Oregon and Washington coasts, and identified natural and anthropogenic factors that influence numbers of pelicans at a

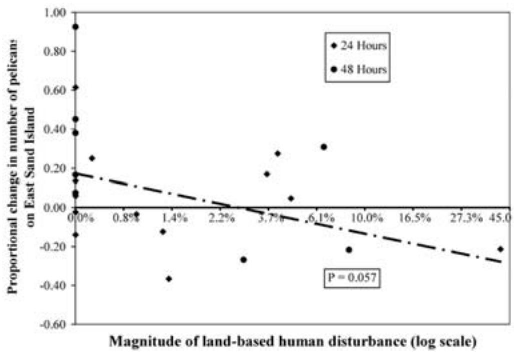

Figure 5. Proportional change in number of California Brown Pelicans roosting on East Sand Island (counted 24 or 48 h apart) in response to varying magnitudes of land-based human disturbance on the island in 2001.

major night-roost. Controlling for the influential natural factors enabled us to assess the effects of human disturbance on pelican numbers, and will aid managers in deciding what boundaries may be necessary near California Brown Pelican roosts to meet the requirements of the Recovery Plan.

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 as they left the roost in the semi-darkness before dawn. Counting pelicans on the island before dawn 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 suggest that evening counts at pelican roost sites are more inclusive.

The multiple linear regression model predicted 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. Counts of roosting California Brown Pelicans conducted during high tide will generally be more inclusive.

Number of Brown Pelicans 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 20 July (3,103 pelicans) and 16 August (2,840 pelicans; D. Roby, USGS, unpubl. data). The peak pelican count in 2001 was on 5 October, much later than expected, and the count (4,434 pelicans) was higher than expected. The peak number of pelicans in 2002 on 3 September (10,852 pelicans) was much greater than expected based on previous maximum counts of pelicans on East Sand Island.

To examine the effects of land and water-based human disturbance while minimizing confounding variables, we compared census numbers within the same year, conducted at the same time of day (morning or evening), and separated by a short time period (24 or 48 h) so tide height changes would be negligible.

We did not detect an effect of diurnal natural disturbances on the number of pelicans on the island. Although the rate of pelican flushes due to natural disturbances was far greater than that due to human disturbances in both years of the study (Table 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, and returned to the island to roost after being flushed.

Although there was no detectable change in the total number of pelicans roosting on East Sand Island due to natural disturbance, we observed local abandonment near favored Bald Eagle perches. The large increase in number of pelicans flushed by Bald Eagles in 2002 was primarily due to greater numbers of pelicans flushed per disturbance event. In 2002, 68.5% of the eagles that we were able to identify by age class after they caused a disturbance were sub-adults and 31.5% were adults. The number of Bald Eagle nests in the Columbia River estuary did not increase from 2001 to 2002 (R. Anthony, USGS, unpubl. data). Higher attendance of East Sand Island by nomadic sub-adult Bald Eagles could cause an even greater number of pelican flush events in the future.

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). There have not been any recent surges in total population numbers of California Brown Pelicans (D. Anderson, UC Davis, pers. comm.). The increased use of East Sand Island by Brown Pelicans may be partly a reflection of the loss of the Gunpowder Island roost site 35 km to the north at the mouth of Willapa Bay, Washington (Speich and Wahl 1989), which has been largely eliminated due to erosion following a nearby construction project to stabilize the shoreline. Continued human development of the coastline may cause pelicans to become concentrated at fewer roost sites. While it is likely that the loss of the Gunpowder Island roost site (high count of 5,875 pelicans in 1991; USFWS) 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 from 2001 to 2002.

Human development of coastlines may result in fewer roost sites for Brown Pelicans, causing pelicans to roost in higher densities at fewer sites. More pelicans are flushed with each disturbance event when pelican densities are high. As disturbance rates increase, pelicans may be forced to roost at lower quality sites that are more exposed to inclement weather and further from foraging areas. It is important to determine which roost sites pelicans prefer and protect those sites.

The apparent shift in the Pacific Decadal Oscillation in 1999 (Peterson and Schwing 2003) is a potential contributing factor 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 numbers of post-breeding Brown Pelicans along the coast of the Pacific Northwest coincides with 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).

Pelicans may depend on different roosts in different years based on ocean conditions and food availability. Roost sites should not lose protected status if pelican numbers drop for a couple of years. Managers may have to use adaptive methods to restrict human access to pelican roosts in years with high pelican numbers.

Land-based human activity and, in particular, shotguns fired within 400 m of the roost had the greatest effect on numbers of pelicans roosting on East Sand Island during this study. These human activities need to be managed along the coast to create quality roosting habitat for seabirds, particularly for cormorants and pelicans which have wettable plumage and require dry, undisturbed habitat at which to dry their plumage.

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