FACTORS AFFECTING THE BEHAVIOR OF BROWN PELICANS AT A POST-BREEDING ROOST

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ABSTRACT: We sought to determine how disturbance may influence the behavior of California Brown Pelicans (*Pelecanus occidentalis californicus*) at a major post-breeding roost. In addition to assessing the effects of natural and anthropogenic disturbance on Brown Pelican behavior, we investigated the effects of other potential explanatory variables, including year, date, time of day, weather, tide stage, and density of pelicans on time-activity budgets of pelicans roosting on East Sand Island in the Columbia River estuary from June to August, 2001 and 2002. We found that during the day, pelicans spent the great majority of time either resting (44%) or preening (41%). Time of day, density of pelicans, wind speed, precipitation, and disturbance accounted for 34% of the variation in resting behavior among pelicans; year, date, time of day, number of pelicans, and disturbance accounted for 27% of the variation in vigilant behavior. All three categories of disturbance (natural, research-related human, other human) were associated with significant increases in the proportion of vigilant behavior and reductions in the proportion of resting behavior. It took longer for pelicans to recover to baseline behavior following a research-related disturbance than after other types of disturbance. This is likely because research-related disturbances involved human activity on the island (i.e., land-based), whereas most other human disturbances were water- or air-based. The potential exists for human disturbance to significantly alter pelican behavior at roost sites. Therefore, restriction of human access to the pelican's major roost sites and regulation of human activities at roosts should be considered to ensure that available sites support the continued recovery of this subspecies.

Physiological condition has been shown to limit the over-winter survival and subsequent success of breeding by some bird species (Drent and Daan 1980, Krapu 1981). Disturbance can increase energy expenditure, affecting physiological condition and the allocation of resources toward survival and 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 the 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 the behavioral effects of potential disturbances, particularly as they relate to higher energy expenditure for activity (Burger 1981, Bélanger and Bédard 1989, Burger and Gochfield 1991, Steidl and Anthony 2000). Disturbance is identified as a potential threat to the California Brown Pelican (*Pelecanus occidentalis californicus*) in the recovery plan (Gress and Anderson 1983) for this subspecies.

In 1970, the U.S. Fish and Wildlife Service (USFWS: 35 Federal Register, 16047, 13 October 1970) listed the California Brown Pelican as endangered under the U.S. Endangered Species Act, following severe reproductive failure due to DDT contamination in the late 1960s (Schreiber and Risebrough 1972, Jehl 1973, Gress and Anderson 1983). One of the three main objectives listed in the recovery plan (Gress and Anderson 1983) is to "assure long-term protection of adequate food supplies and essential nesting, roosting and offshore habitat throughout the range." Protection of roosting habitat will contribute to the health and conservation of this now delisted subspecies.

Several studies have investigated the effect of disturbance at Brown Pelican roosts in southern California by measuring the number and frequency of instances of flushing, distances at which the birds flush, and the fate of flushed pelicans (Jaques and Anderson 1988, Jaques et al. 1996, Jaques and Strong 2002). A study concurrent with ours examined changes in pelican numbers and distribution on East Sand Island in response to disturbance (Wright et al. 2007), but time-activity budgets for the Brown Pelican are scarce (Croll et al. 1986). No published studies have quantified the effects of various types of potential disturbance on Brown Pelican behavior at major post-breeding roosts.

East Sand Island in the Columbia River estuary (between the states of Oregon and Washington) is now a major post-breeding roost site for the California Brown Pelican, with over 10,000 pelicans counted on the island at one time (Wright et al. 2007). The USFWS expressed concern regarding the potential effects of research-related disturbance on Brown Pelicans roosting on East Sand Island (USFWS 2001). By recording and analyzing their time-activity budgets, we sought to better understand how various types of disturbance affect the behavior of roosting pelicans.

We investigated several sources of potential disturbance of pelicans roosting on East Sand Island, including natural, research-related human, and other human disturbances. Bald Eagles (*Haliaeetus leucocephalus*) 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). Both species kill and/or scavenge waterbirds nesting on the island. Although we know of no evidence that Peregrine Falcons prey on Brown Pelicans, we observed Bald Eagles killing Double-crested Cormorants (*Phalacrocorax auritus*) on their nests and stooping on Brown Pelicans that were roosting on East Sand Island; there is at least one account of a Bald Eagle killing incubating an adult Brown Pelican in Georgia (Shields 2002). At East Sand Island, pelicans respond to both of these raptors by taking flight, although in the case of the Peregrine Falcon, the pelicans may be reacting to the alarm calls and predator-avoidance behavior of nesting gulls rather than perceiving a threat of predation.

Located just north of the main Columbia River shipping channel and between the harbors of Chinook and Ilwaco, Washington, the waters around the East Sand Island are subject to heavy traffic of recreational and commercial boats. The Columbia River estuary is also used by the U.S. Coast Guard for helicopter and boat-rescue training, and the helicopters occasionally fly low over the island. Although public access to the island is not allowed, we did observe infrequent visits by beachcombers and birdwatchers.

In addition, East Sand Island has been the site of continuing research on the colonial waterbirds that nest on the island. This research is focused on two large breeding colonies, one of the Caspian Tern (*Hydroprogne caspia*) and one of the Double-crested Cormorant (Roby et al. 2005b). The Caspian Tern colony is at the east end of the island, whereas the Double-crested Cormorant colony is at the west end of the island. Our plot for the pelican study was immediately adjacent to the Double-crested Cormorant colony, and hybrid Glaucous-winged × Western Gulls (*Larus glaucescens* × *L. occidentalis*) nest all around the cormorant colony and adjacent to the pelican study plot. Activities of researchers on East Sand Island occasionally disturb roosting pelicans. Human disturbance due to researchers differed from disturbance caused by other human activities in that researcher disturbance was generally land-based, whereas other human disturbances were typically water- or air-based.

We hypothesized that the magnitude of effects of disturbance on time-activity budgets should predict the relative effect of various disturbance factors on Brown Pelicans at roost sites. This assessment will prove useful in efforts by resource managers to limit and regulate significant sources of disturbance around such roosts.

METHODS

Study Area

East Sand Island (46° 15′ 45″ N, 123° 57′ 45″ W) lies 8 km east of the mouth of the Columbia River. In the 1930s, government engineers built pile dikes on the south side of the island to reduce shoreline erosion (Brooke 1942), and rip-rap consisting of large boulders was added later on the west end of the island to form a jetty pointing west (Figure 1). 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 ha (Figure 1).

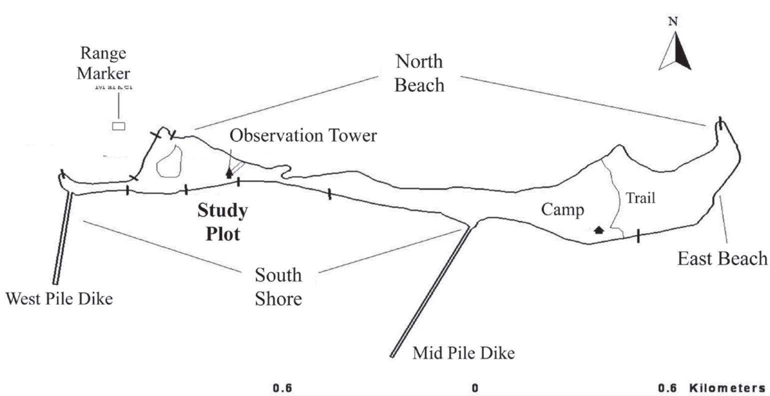

Figure 1. East Sand Island, Columbia River estuary, showing the location of the observation tower and study plot near the west end of the island.

We recorded the behavior of pelicans in a plot on the south shore of the island that was heavily used by roosting pelicans and visible from a nearby observation blind (Figure 1) with an elevated (5 m high) vantage point. In order to access the blind without disturbing pelicans on the plot, observers were dropped off by boat on the south shore of the island near the east end. They then walked across the island to the north shore, then west along the north shore to the entrance of an above-ground tunnel system (plastic fabric draped over a wooden framework) that led to the blind (Figure 1). We accessed the tunnel entrance only within 2 hours of low tide, when the beach was widest, or at night in order to minimize the possibility of disturbing pelicans roosting on the upland portions of the island.

The study plot extended from directly to the south of the observation blind for 136 m along the shore to the west, where a large and clearly visible driftwood stump was lodged high on the beach. This long, narrow plot was bounded to the south by the water's edge and to the north by a grassy meadow, which was not used by roosting pelicans. The plot ranged from 10 to 20 m wide, depending on tide height. We categorized pelicans on the water within 50 m of shore directly off the study plot as "swimming."

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

Time-Activity Budgets

We recorded time-activity data for Brown Pelicans from 1 June to 9 September 2001 and 4 June to 21 August 2002. We used scan-sampling techniques (Altmann 1974) to quantify the proportion of time the pelicans spent in several categories of activity. We divided each day into two equal blocks: morning (05:30–13:29 PDT) and evening (13:30–21:30 PDT). We used a random-number table to select six blocks in each 2-week period during the field season, with either two morning blocks and one evening block the first week, and two evening blocks and one morning block the second week, or vice versa. If weather or logistics precluded scan sampling in a selected block, we scanned during the next available block. During each 8-hr block, using 10 × 50 binoculars, we recorded the activity of all the visible pelicans on the study plot every 30 min. Although scan samples are intended to be instantaneous (Altmann 1974), ours required from 15 sec to 13 min, depending on the number of pelicans roosting in the study plot. We selected 30 min as the interval between samples in an attempt to avoid serial autocorrelation (Schreiber 1977). Using sketches from Schreiber (1977) as a reference, we categorized pelican activity as follows: (1) active (i.e., walking, agonistic behavior, stretching, picking up sticks, mounting), (2) vigilant (i.e., standing and alert, neck extended), (3) preening (i.e., plumage maintenance), (4) resting (i.e., sitting or standing with neck not extended, not alert), (5) startled (i.e., standing, wings raised or flapping, flight-intention movements), or (6) swimming (i.e., in water within 50 m of study plot).

Before each scan, we recorded temperature (°C), percent cloud cover (increments of 5%), wind direction (in degrees, converted to Cartesian coordinates), wind speed (Beaufort scale), and precipitation (on a scale from 0 to 7, ranging from no rain to steady heavy rain). We used these variables as covariates in the analyses in order to account for variability in the data due to weather conditions.

Disturbance Monitoring

Within each 8-hr time block we monitored disturbance of the pelicans on the study plot between sunrise and civil evening twilight (approximately 40 min after sunset). We recorded the times of the start and end of all observations of potential disturbances. We defined a disturbance as any event when one or more pelicans were flushed from the study plot. When a disturbance caused pelicans to flush, we recorded the date, time of day (PDT), cause of disturbance (if discernible), and whether or not the disturbance occurred during a scan sample of pelican activity.

Statistical Analyses

We used S-Plus to run multiple linear regression to determine which variables predicted the time-activity budgets of pelicans on the study plot. In these analyses, we selected the two activity categories "resting" and "vigilant" as the response variables because they were common activities that we observed to change in response to disturbance. Vigilant behavior was sometimes a precursor to flushing from the roost, whereas resting was the most relaxed and least vigilant activity that we recorded. We included the following variables in the selection of factors potentially influencing the proportions of resting and vigilant pelicans: year, date, time of day (PDT), number of pelicans in 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, Oregon, 46° 11′ N, 123° 46′ W, 17 km up-river from East Sand Island), time since last disturbance when one or more pelicans flushed from the study plot, and magnitude of response (defined as the proportion of pelicans in the study plot that flushed in response to a disturbance).

In addition, when determining the best model, we considered quadratic functions of explanatory variables and interactions between these variables because we expected some variables, such as time of day, to have a significant nonlinear effect on pelican behavior. The explanatory variables were not strongly correlated ($r \geq 0.4$). We used stepwise removal of nonsignificant variables ($P > 0.05$) to identify variables that explained a significant proportion of the variation in the proportion of pelicans in the plot that were resting or vigilant.

To meet the assumptions of parametric statistical tests, the response variables (proportions of pelicans on the plot) were logit transformed ($\log[Y/(1 - Y])$). Because of the many zero values in the response variables, to avoid zero in the denominator or numerator of the logit-transformed values, we added 0.5 times the minimum nonzero value to the response variable. In an effort to avoid undue influence from single birds on the results, we excluded from analyses scans during which fewer than 10 pelicans were on the study plot. We examined graphs of residuals to ensure that autocorrelation or a lack of independence in the data did not confound the results (Ramsey and Schafer 1997).

We used odds ratios to compare the proportion of vigilant pelicans in 2001 and 2002. Multiple-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. We also used odds ratios to compare pelican response to the type of disturbance.

To determine if there were immediate effects of disturbance on pelican behavior we compared the proportion of resting or vigilant pelicans in the study plot in the first 30-min scan following a disturbance to the overall mean proportion of resting or vigilant pelicans. We evaluated 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 estimated slope of the linear trendline fit to the scan data. We weighted each event by the number of scans we made following the disturbance and discarded from the analysis disturbances followed by fewer than two behavior scans. 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 $\alpha = 0.10$ in order to avoid type II statistical errors.

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 from June to August of 2002 was consistently higher than during the same period in 2001, regardless of time of day (Figure 2). The number of pelicans on the plot was lowest during early morning, increased until late morning, and declined again in late afternoon (Figure 2). In general, the number of pelicans roosting on East Sand Island increased through each summer of the study.

Time-Activity Budgets

In 2001 we recorded 522 scans of pelicans on the study plot, with 10–197 pelicans/scan (mean = 68 pelicans); in 2002 we recorded 455 scans, with 10–273 pelicans/scan (mean = 118 pelicans). The time-activity budgets of pelicans roosting in the study plot in the two years were similar (Table 1), although the proportion of vigilant pelicans was significantly greater in 2001. In both years resting and preening were the two most prevalent activities

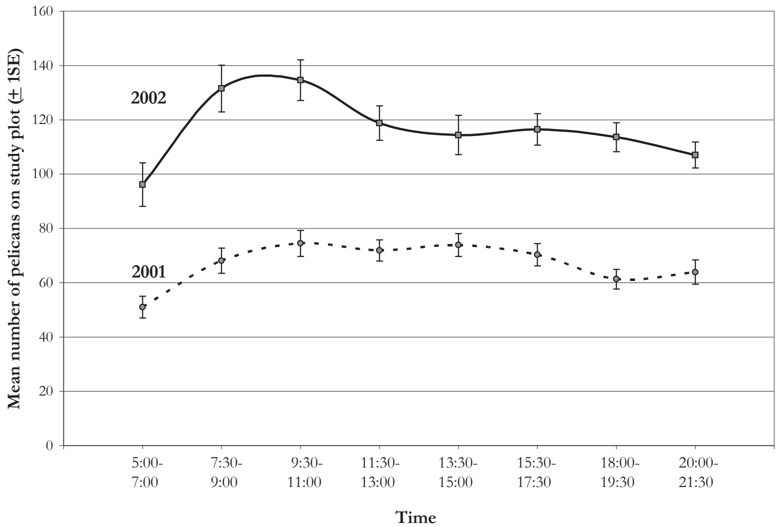

Figure 2. Mean number of pelicans roosting during daylight in the study plot on East Sand Island during 2001 and 2002.

Table 1 Average Time-Activity Budget of Brown Pelicans Roosting in the Study Plot at East Sand Island, Oregon, 2001 and 2002

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

[a]Based on two-sample t-tests for differences between years. Significant difference ($P \leq 0.05$) highlighted in **bold**.

of pelicans roosting in the study plot (Figure 3). We recorded the behavior "startled" infrequently (Table 1) so eliminated it from further analysis.

Resting and preening were strongly correlated ($r = -0.84$), making it difficult to separate effects of disturbance on time-activity budgets from a change in the proportion of pelicans engaged in other activities. The proportions of resting and vigilant pelicans were not strongly correlated ($r = -0.30$) and clearly reflected whether pelicans were relaxed or alert, so we used these two activities as response variables in analyses of the effects of disturbance on time-activity budgets.

Factors Affecting Time-Activity Budgets

Brown Pelicans in the study plot at East Sand Island spent on average 44% (95% confidence interval [CI]: 42% to 46%) of the day resting. Approximately 33% of the variation in the proportion of resting pelicans was explained by time of day, number of pelicans on the plot, wind speed, precipitation, disturbance from research, other human disturbance, and natural disturbance ($F_{8, 887} = 55.56$, $P < 0.0001$). The proportion of resting pelicans was positively associated with wind speed ($r = 0.22$, $P < 0.0001$) 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 ($r = 0.94$, $P < 0.0001$) and increased by a factor of 1.51 (95%

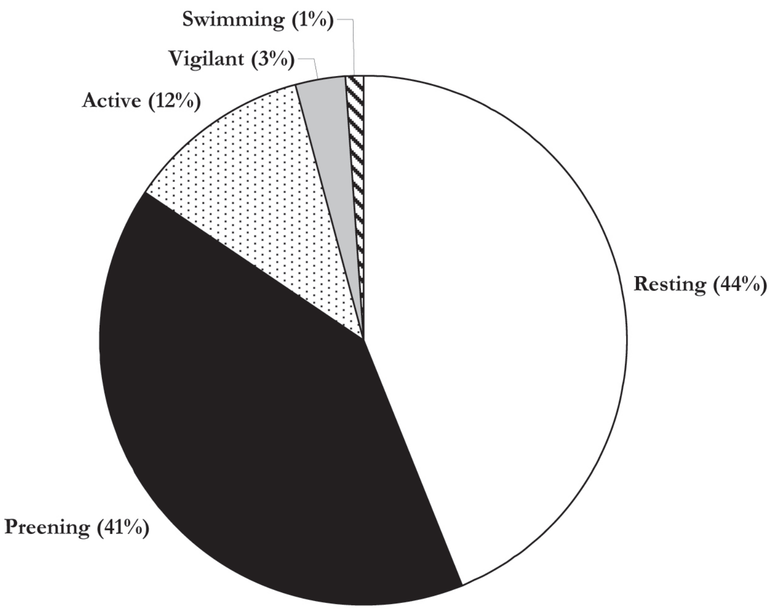

Figure 3. The average proportion of time Brown Pelicans engaged in the top five categories of behavior in the study plot at East Sand Island during 2001 and 2002. The behavior "startled" accounted for <1% of time.

CI: 1.41 to 1.61) with each incremental increase in precipitation intensity. Thus the pelicans spent more time resting during inclement weather. The ambient temperatures during this study ranged from 7.2 °C to 28.9 °C, with a mean of 16 °C; however, temperature did not significantly affect the proportion of resting pelicans (r = 0.09, P = 0.9689). The proportion of resting pelicans was negatively associated with the number of pelicans on the plot (r = –0.12, P < 0.0001) 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 PDT) to midday (11:30–13:00 PDT: P < 0.0001), then decreased late in the evening (P < 0.0001).

Pelicans roosting on East Sand Island spent on average 3.5% (95% CI: 3.1 to 3.9) of the day vigilant in 2001 and 2.4% (95% CI: 2.0 to 2.8) of the day vigilant in 2002, a significant decrease from 2001 to 2002 (t = 3.8; P = 0.0001; Table 1). The odds of a pelican being vigilant in 2002 decreased by a factor of 2.05 (95% CI: 1.74 to 2.42) from those in 2001. Year, date, time of day, number of pelicans on the study plot, research-activity disturbance, other human disturbance, and natural disturbance together accounted for 27% of the variation in proportion of vigilant pelicans ($F_{9,\ 893}$ = 36.71, P < 0.0001).

Unlike the proportion of pelicans resting, the proportion of pelicans vigilant was not related to any of the measured weather variables. The prevalence of vigilant pelicans increased slightly with date (r = 0.19, P < 0.0001). The proportion of vigilant pelicans was positively influenced (r = 0.32, P < 0.0001) by the number of pelicans in the study plot. The proportion of vigilant pelicans increased by a factor of 1.71 (95% CI: 1.45 to 2.01) with an increase of 100 pelicans in the study plot. The proportion of vigilant pelicans decreased from early morning (05:30 PDT) to midday (11:30–13:00 PDT; P < 0.0001), then increased through the evening (P < 0.0001).

Disturbances to Pelicans on the Plot

During behavioral observations, natural factors disturbed pelicans roosting in the study plot (17 instances) more frequently than did research (4 instances) or human activity not related to research (6 instances). Research-related disturbances flushed 9.9% (median) of the pelicans in the study plot per disturbance (range 2 –56%, n = 4). Human disturbances not associated with research flushed 5.3% (median) of the pelicans in the study plot (range 1–25%, n = 6). Natural disturbances flushed 20.5% (median) of the pelicans in the study plot per disturbance (range 1–100%, n = 17; Figure 4). Bald Eagles were responsible for 75% of the total number of pelicans flushed from the study plot by natural disturbances in 2001 and 2002.

Effects of Disturbance on Time-Activity Budgets

All three types of disturbance (research, nonresearch human, and natural) were associated with a significant increase in vigilant behavior (t = 4.2, 1.9, 2.4; P = 0.015, 0.045, 0.015, respectively) and a decrease in resting behavior (t = –4.1, –3.2, –6.9; P = 0.015, 0.007, <0.0001, respectively) within the 30 minutes following a disturbance. There was a clear difference in the pelicans' responses to research disturbances and natural disturbances, with a greater proportion of pelicans vigilant and a smaller proportion of

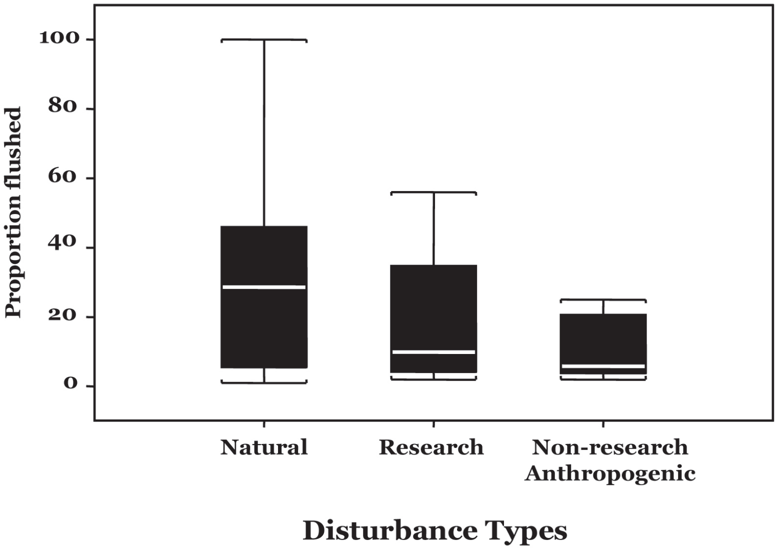

Figure 4. Proportion of pelicans on the study plot flushed per disturbance by research activities (4 instances), non-research human disturbances (6 instances), and natural factors (17 instances) during behavior observations on East Sand Island in 2001 and 2002. Lines within the box plots represent the 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.

pelicans resting immediately after research disturbances than after natural disturbances. After a research disturbance in the study plot, the ratio of vigilant pelicans to nonvigilant pelicans was 6.9 times greater (Tukey–Kramer; 95% CI: 1.1 to 45.4 times greater) than after a natural disturbance.

After research disturbance of pelicans, the predicted time to recover to baseline vigilant behavior was 181 min (95% CI: 79 to 283 min; Figure 5A), to baseline resting behavior, 187 min (95% CI: 134 to 241 min; Figure 5B). After disturbance from nonresearch anthropogenic factors, the predicted time to recover to baseline vigilant behavior was 57 min (95% CI: –89 to 202 min; Figure 5C), to baseline resting behavior, 132 min (95% CI: 27 to 237 min; Figure 5D). After disturbance from natural factors the predicted time to recover to baseline vigilant behavior was 28 min (95% CI: –323 to 379 min; Figure 5E), to baseline resting behavior, 82.5 min (95% CI: 34 to 131 min; Figure 5F). Thus the predicted times for pelicans to recover to baseline (average) incidence of vigilant and resting behaviors were greater for anthropogenic disturbances than for natural disturbances. Differences in recovery times were particularly pronounced for resting, for which recovery to baseline behavior was much greater for disturbances caused by research than by natural causes.

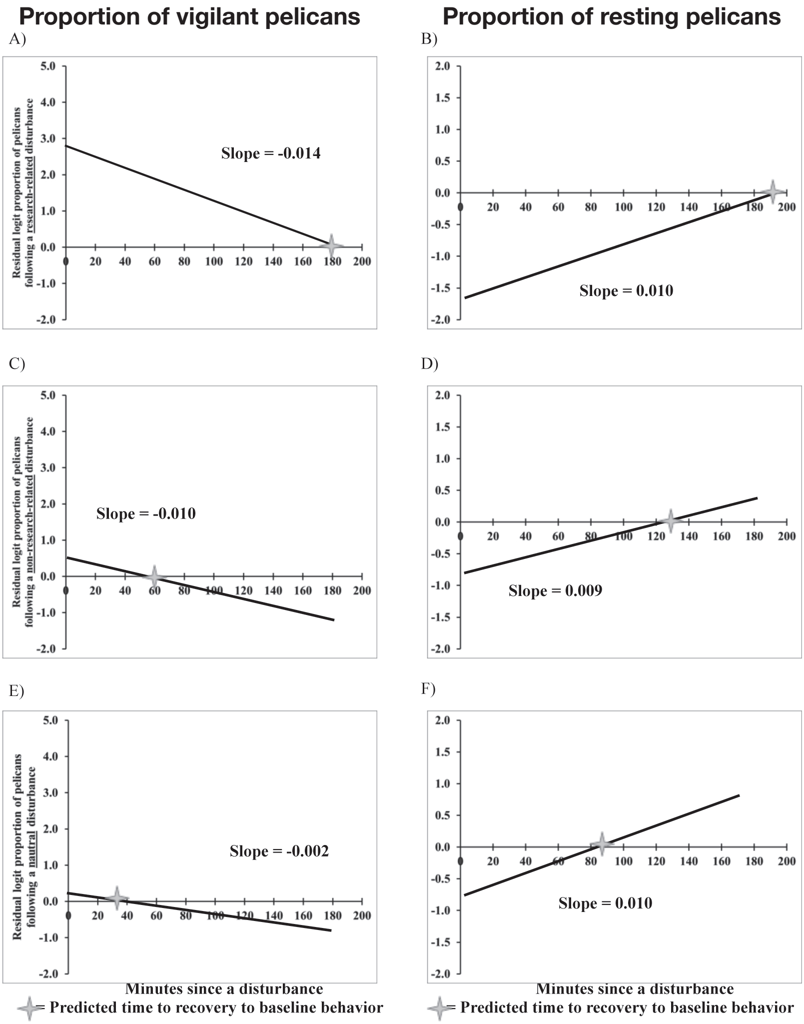

Figure 5. Proportion of pelicans on the study plot that were vigilant or resting during the first 3 hours after a disturbance caused by research-related activities (A, B), nonresearch human disturbance (C, D), and natural disturbance (E, F) that caused pelicans to flush from the study plot on East Sand Island in 2001 and 2002 (after other factors were accounted for). The lines in A, B, C, and F represent the average slope of the response weighted by the number of observations following each disturbance. The slopes of the response in D and E were not significant.

DISCUSSION

At the East Sand Island roost, Brown Pelicans were more active in the early morning and late evening, less active around mid-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 vigilant pelicans was highest in the morning and evening and lowest in the middle of the day. We interpreted this pattern as reflecting early morning departure to forage, periodic return to rest through the day, and a late afternoon increase in activity associated with the return of large numbers of pelicans to the roost for the night—a pattern consistent with past observational studies of pelican behavior. A subadult California Brown Pelican fitted with a radio transmitter was inactive (not flying) less than 10% of the time from 04:30 to 07:30 and from 16:30 to 19:30, but spent approximately half its time active and inactive from 07:30 to 16:30 (Croll et al. 1986). At a Florida boat marina Brown Pelicans roosted in large numbers during the middle of the day, but were present in only small numbers during the mornings and evenings (Herbert and Schreiber 1975), indicating that the birds foraged early in the morning and used the marina for mid-day loafing.

Disturbance poses a risk to Brown Pelicans at their roost sites by adding an energetic cost and interrupting plumage drying. Pelicans have wettable plumage that becomes waterlogged if the birds are prevented from roosting on land to dry and maintain their plumage after feeding (Rijke 1970). Brown Pelicans roosting on East Sand Island during the day spent 85% of their time either resting or preening. Similarly, in Mississippi and Louisiana King and Werner (2001) found that nonbreeding American White Pelicans (*Pelecanus erythrorhynchos*) spent 72 to 96% of daylight hours (06:00 to 17:30) loafing and the remainder of the day foraging. In addition, for seabirds, plunge-diving is very costly; Black-legged Kittiwakes (*Rissa tridactyla*) spend energy at a rate at least 5 times that of flapping flight (Jodice et al. 2003). Between forays to feed, pelicans may need to rest—particularly the Brown Pelican, the only pelican that plunge-dives for food (Bent 1964, Schreiber et al. 1975, Shields 2002).

Disturbance of Brown Pelicans could translate into undue stress and associated physiological displacement, as evidenced by changes in their time-activity budgets. Disturbances from research activity and natural sources led to significant declines in resting behavior and increases in vigilant behavior among pelicans on our study plot, which was consistent with our original hypothesis. A change in activity from relaxed or resting to alert or vigilant 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 birds' heart rate above levels normal 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 Amlaner 1980, Culik et al. 1990). Changes in avian behavior due to human disturbance can also lead to increased exposure to natural predators (Keller 1991) and reduced time spent foraging (Owens 1977, Bélanger and Bédard 1989, Burger and Gochfeld 1991, Riddington et al. 1996).

The median magnitude of natural disturbances in the study plot (20.5% of pelicans flushed) was much higher than that of the two categories of human disturbance, yet its effect on pelican behavior in the half hour after disturbance was smaller than that of research disturbance. This suggests that natural disturbances, although more frequent, did not influence the time-activity budgets of pelicans as much as research (land-based human) activities. Additionally, after a natural disturbance, resting behavior recovered to baseline levels in much less time than after a research-related disturbance. At East Sand Island pelicans may be more habituated to raptors than to humans.

While there was a significant difference between research and natural disturbance, there was no significant difference between nonresearch human and natural disturbance, suggesting that pelican behavior is more affected by human activities on the island than by human activities on the water near the island. The median magnitude of nonresearch human disturbances in the study plot (5.3% of pelicans flushed) was smaller than that of research disturbances (9.9% of pelicans in the study plot flushed), which may have contributed to the effect on pelican behavior of nonresearch human disturbances being smaller. Additionally, pelicans may have been able to see or hear (i.e., through gulls' alarm calls) nonresearch and natural disturbance factors approaching from a considerable distance. Initiation of research disturbances was typically abrupt, with researchers emerging from hidden tunnels or blinds. The sudden appearance and disappearance of researchers nearby may have resulted in pelicans remaining vigilant after the disturbance longer.

Disturbance could degrade the quality of the Brown Pelican's roost sites and result in the birds abandoning an otherwise suitable site. Flight is the most energetically expensive activity we observed in response to disturbance (Norberg 1996, Jodice et al. 2003). Each time a pelican is flushed from a roost due to disturbance, it spends energy that requires compensation. Energy deficits in the nonbreeding season could result in a less productive breeding season.

It is difficult to determine the disturbance threshold above which the pelican's fitness is reduced. Conomy et al. (1998) observed that waterfowl spent 1.4% of their time swimming, flying, and alert in response to human disturbance, and they concluded that this energy investment was too low to have a significant effect on fitness. Our study indicates that human disturbance at roost sites is associated with significant and potentially detrimental changes in the time-activity budgets of roosting pelicans, which might result in abandonment of roost sites and lower fitness if left unchecked. Consequently, we recommend restrictions of human activity on islands that serve as Brown Pelican roost sites for so that roost-site availability will not be a factor limiting the species' further recovery.

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