

# Mitigation of Traffic Mortality of Endangered Brown Pelicans on Coastal Bridges

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Since the initial 1984 mortality, brown pelican mortalities on the P100 bridge have corresponded to a recovering brown pelican population that has increased markedly. The population in the vicinity of the bridge peaks in the late summer and early fall, but wintering populations in the vicinity of the bridge have also shown a steady increase in recent years. The majority of the brown pelicans forage south of the bridge during the day and cross to the north of the bridge in the later afternoon and early evening. Strong north winds, especially when accompanied by rain or mist, often result in brown pelicans being forced down on the deck where they are struck by cars. On the basis of observed pelican behavior and limited wind tunnel testing, turbulence above the bridge roadway is suspected as a causal factor in the observed mortality, although the actual significance of the turbulence cannot be inferred without somewhat speculative observation of the flight and behavior of brown pelicans in the vicinity of the bridge. Brown pelican mortalities are likely to occur during any strong north winds, and the passage of cold fronts accompanied by rain increases the probability that brown pelicans will be killed on the bridge. Age, experience, and physical condition of the individuals being killed are apparently not related. Few brown pelicans fly under the bridge even without strong north winds. There are still undetermined factors related to turbulence under the bridge, or possibly related to sound, that deter brown pelicans from flying under the bridge. Traffic control measures, including better warning signs and, in particular, decreasing the speed limit during weather conditions are most likely to result in the decrease of brown pelican mortalities; placing telephones at each end of the bridge allows motorists to report birds or accidents on the bridge. This simple and economical approach should result in a mitigation of brown pelican traffic mortalities. Should these measures prove inadequate, further research will be necessary to determine whether brown pelicans can be induced to fly over the bridge to avoid air turbulence close to the deck, to fly higher under the bridge, or to roost south of the bridge. Bird count data indicate that the Texas brown pelican population is increasing. Although an increasing brown pelican population may result in the eventual delisting of this subspecies, the hazard to motorists may increase.

The eastern brown pelican is a large bird weighing about 7.5 lb with average body length of 4 ft and average wingspan of 6.5 ft. Figure 1 shows a sketch of a brown pelican. It is a coastal resident seldom straying inland from its preferred salt-water shores. The brown pelican is capable of flight speeds of 14 to 35 mph and usually flies with slow wing beats close to the water. It forages by diving and, while capable of lifting off from a horizontal surface without a headwind, it commonly takes off into the wind to increase airspeed and to gain lift.

The Texas eastern brown pelican population once numbered in the thousands. A recent study (1) provides some details about the history of the Texas population. As many as 5,000 pairs have been reported nesting on the Texas coast from the late 1800s until about 1920 (2). An early decline in the 1930s was a result of persecution by fishermen (3–5). Although legislation was enacted in 1939 to protect brown pelicans from being shot and from the destruction of their nests and eggs, another serious decline became apparent in the early 1950s. By 1962, no brown pelicans were reported in former areas of concentrations of wintering birds, and they had disappeared from former breeding areas. This second serious decline has been attributed to severe weather conditions, disease, and especially to exposure to chlorinated hydrocarbon pesticides (6). The Texas subspecies (*Pelicanus occidentalis carolinensis*) was placed on the endangered species list of the U.S. Department of the Interior in 1971.

Historically, the brown pelican has nested along the Texas coast from Galveston Bay to Cameron County, but from 1985 to 1988 brown pelicans nested only on Pelican Island in Corpus Christi Bay. In 1989, breeding colonies expanded to six sites. Brown pelicans winter along the Texas coast from Galveston to Cameron County. It has been estimated that 96 percent of the Texas brown pelican population use the lower Laguna Madre in winter.

The P100 bridge, or Queen Isabella Causeway, is a 2.4-mile-long, four-lane bridge connecting Port Isabel with South Padre Island, Texas. The bridge has a center span rising approximately 84 ft above the Intracoastal Waterway. The bridge was completed in 1974. One study conducted in 1984 and 1985 in the lower Laguna Madre in connection with a proposed transmission line to cross the lower Laguna Madre indicated the area of greatest brown pelican activity was in the vicinity of the causeway with a majority of the observations in the August to October period when the Texas population is supplemented by immature brown pelicans from Mexico. It is thought that these Mexican brown pelicans initiated the recovery of the Texas population.

In September 1984, the first brown pelican mortality on the bridge was recorded. Considerable public concern, already sensitized by the threat to brown pelicans by the proposed transmission line, was expressed after subsequent and increasingly frequent brown pelican mortalities occurred on the bridge.

Several causal factors were initially suggested. In conjunction with the increasing population size, the brown pelicans'



**FIGURE 1** Brown pelican (*Pelicanus occidentalis carolinensis*).

foraging and roosting habits in relation to the bridge were implicated. Also, the apparent connection between the passage of cold fronts accompanied by strong north winds possibly resulting in air turbulence around the bridge was proposed as a precipitating factor in the brown pelican mortalities on the P100 bridge.

It is the recovering brown pelican population wintering in the lower Laguna Madre that has come into conflict with the P100 bridge. A growing brown pelican population with an increasing number of nest sites potentially expanding into the lower Laguna Madre will increase the likelihood of fatal encounters on the P100 bridge year round.

## OBJECTIVES

The objectives of this study were to (a) identify the factors influencing the presence and resulting deaths of the brown pelican on the P100 bridge, and (b) suggest ways to mitigate those factors.

## METHODS

General background information was gathered from a variety of sources, including the following:

1. Letters, memorandums, etc., from correspondence leading up to the funding of this project. These included com-

munications from Texas State Department of Highways and Public Transportation, Texas Parks and Wildlife, U.S. Fish and Wildlife Service, Sierra Club, Bird Rescue, concerned citizens, and newspaper articles.

2. Literature searches, including two computer searches. The initial search explored the literature for information on brown pelicans and their behavior, flight, and aerodynamics, and road kills of birds on bridges and highways. The second search explored the literature with reference to the reaction of birds and wildlife to sound, including auditory perception, hearing, noise, ultrasound, and infrasound.

3. Other information about the brown pelican population was obtained from Audubon Christmas bird counts, breeding bird surveys, ornithological newsletters, bird rescue records, National Oceanographic and Atmospheric Administration weather data, and unpublished reports from Texas Parks and Wildlife.

4. Collection of dead brown pelicans for necropsy.

5. Behavioral observations at the bridge—brown pelican counts were made during four trips to the study site. These visits included an initial survey of the study site (January 12 to 14, 1989) and visits timed with the passage of strong cold fronts (February 2 to 17, 1989, October 19 to 22, 1989, and December 6 to 13, 1989). A brief visit was made to the study site on April 6, 1989, after the Area I Research Committee Meeting in Brownsville to determine if any brown pelicans were present. Another brief trip was made to Port Isabel for a meeting called by Gary Waggener with the brown pelican volunteers. Observations included several counts of brown pelicans in the general vicinity of the P100 bridge. These observations were made from several vantage points north and south of the bridge on South Padre Island including the state fishing pier and Isla Blanca Park. Observations were also made at Queen's Point Marina, Port Isabel channel, and Long Island. Counts were made of brown pelicans in Laguna Madre, the Brownsville ship channel, and the Gulf of Mexico. Brown pelicans were observed crossing the bridge in late afternoon and early evening. Most observations of brown pelicans crossing the bridge during strong north winds were made from Queen's Point or by driving back and forth across the bridge. One videotaping session was done on the north side of the west end of the bridge.

6. Videotaping of brown pelicans at the bridge.

7. Wind tunnel tests, including videotaping, conducted on two scale models (72:1 and 16:1) of the bridge July 31 and August 1, 1989.

8. Correspondence with personnel in other brown pelican states.

## RESULTS AND DISCUSSION

### Literature Search

There is little information in the published literature concerning the Texas brown pelican population. Some information was obtained concerning the results of banding studies on brown pelicans in general and some information on flight speeds. There was no information in the literature on road kills of brown pelicans, or even birds in general, on highways or bridges.

The literature search on bird responses to sound yielded little information, as the key words used retrieved papers concerning sound produced by birds and the use of sounds, i.e., bird distress calls and propane cannons, for animal damage control. Only two papers recording bird reactions to sound levels were located. This research involved investigations of the acoustic irritation thresholds of Peking ducks, other domestic and wild fowl (7), and ringbilled gulls (8). It was found that hungry Peking ducks were discouraged from taking food placed in a low-frequency sound field at 100-db intensity. Additionally, in a report prepared by LGL Limited, environmental research associates for Arctic Gas, it was demonstrated that snow geese were disturbed by sounds made by gas compressors (9).

### Status of the Brown Pelican Breeding Population

Figure 2 shows the decline and recovery of the brown pelican breeding population, the date of completion of the P100 bridge, and the time of the first recorded brown pelican mortality on the span. The breeding population had risen from nonexistence in 1964 to 230 in summer 1984 just before the first recorded mortality in September 1984. In the 1989 breeding season, six colony sites were used and the population increased markedly as a result of successful nests on five of these sites. Pelican Island in Corpus Christi Bay had 565 nesting pairs that produced about 900 young. This is an increase from the summer 1988 nesting season which had 350 nesting pairs producing 575 young. Other sites included Sundown Island (50 adults and 25 young), Second Chain (10 adults, 10 young), Steamboat Island (12 adults, 6 young), and Dressing Point (25 adults, 22 young). Flooding caused by a hurricane aborted nesting attempts by 14 adults at Cedar Lakes. This new nest site was the result of an attempt to establish a nest colony of brown pelicans at San Bernard National Wildlife Refuge. Thus, a total of 676 nesting pairs produced about 963 young in Texas during the 1989 breeding season.

Although these colony expansions were northward along the coast from Pelican Island, there were indications (Mike Farmer, Audubon Society warden, personal communication) that brown pelicans may have been nesting in Laguna Madre in summer 1990, because adults were seen carrying sticks, a

behavior that may be associated with nesting intentions. Two historical sites mentioned by Oberholser (10) included a mud dump at Port Isabel and Brazos Santiago Pass, both used in 1927. Steamboat Island used in summer 1989 was last used for nesting by brown pelicans in 1931. Recolonization of historical nesting sites could result in a breeding population in the vicinity of the P100 bridge.

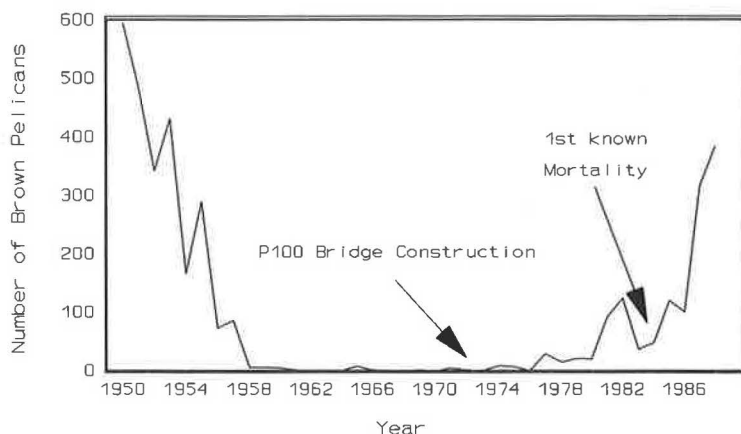
### Status of the Brown Pelican Wintering Population

Figure 3 shows the recovery of the brown pelican wintering population along the Texas coast as indicated by the Audubon Christmas bird counts (CBC) from 1950 to 1988 (11). The results of all of the Audubon Christmas bird counts for Texas for Christmas 1989 (90th CBC) will not be accumulated until April or May. However, there was an early report of 104 brown pelicans counted in the coastal tip of Texas count, which includes the area around the study site in a 15-mi-diameter count circle centered (26 deg 02 min N, 97 deg 14 min W) on the Brownsville ship channel. The coastal tip of Texas count was initiated during the Christmas 1986 (87th CBC) count and a total of 12 brown pelicans were seen. Subsequent count totals were 55 in 1987 (88th CBC) and 88 in 1988 (89th CBC), indicating a continuing trend of an increasing winter population.

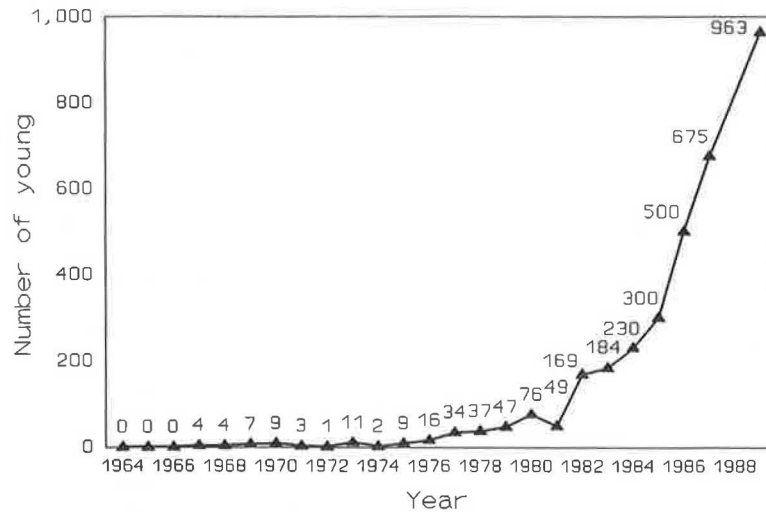
Thus, there was an increase in the total number of brown pelicans in spite of the severe cold weather in December 1989 when a number of pelicans died. Necropsies were done by the Texas Veterinary Medical Diagnostic Laboratory on 3 of the 18 dead brown pelicans found on Dressing Point. Necropsy results indicated that the pelicans had frozen to death. Another seven brown pelicans carcasses were found on Aransas NWR and at least two others were found along with a dead white pelican along the coast.

### Chronology of Brown Pelican Mortalities on the P100 Bridge

Table 1 presents the brown pelican mortalities that were documented in various correspondence and in the course of this study. These deaths have occurred from September through



**FIGURE 2** Decline and recovery of Texas brown pelican population—Audubon Christmas bird counts, 1950–1988.



**FIGURE 3** Recent historical data for Texas brown pelican wintering population—numbers of young produced, 1964–1989.

**TABLE 1** CHRONOLOGY OF KNOWN BROWN PELICAN MORTALITIES ON THE P100 BRIDGE

Date	Number	North Wind (Yes or No)	Wet/Dry	Bridge Lane (North or South)
<b>1984</b>				
19 September <sup>1</sup>	1	Y	W	S
<b>1986</b>				
12 October	3	Y	W	S
13 October	2	Y	W	-
12 November	2	Y	W	S
25 November	1	Y	W	S
<b>1987</b>				
21 January <sup>2</sup>	1	Y	W	N
15 December	2	Y	D	-
<b>1988</b>				
5 February	3	Y	W	-
<b>1989</b>				
6 January <sup>3</sup>	1	N	D	-
18 October <sup>4</sup>	1	Y	D	-
16 November	1	Y	D	S
29 November	2			S
2 December	2			S
7 December	2	Y	D	S

<sup>1</sup> Tropical Storm Edouard; 19 inches of rain on this date.

<sup>2</sup> Upper air disturbance in Northern Mexico.

<sup>3</sup> Strong winds but not from the north.

<sup>4</sup> An injured Brown Pelican also recovered.

early February. Nine pelicans were killed in the 1986–1987 fall and winter season. Another five pelicans were killed during the 1987–1988 winter season. Only one brown pelican was reported killed during winter 1988–1989 because of the mildness of the winter, which had few fronts with strong north winds passing through the area. Eight brown pelicans were killed from October to December 1989. One recovered alive from the bridge had an irreparably broken wing. After December 1989, no brown pelicans were reported killed on the P100 bridge because the remainder of the winter was mild with few strong fronts.

All but one of the documented deaths occurred during strong north winds, although all of these winds were not associated with the passage of cold fronts. Tropical disturbances, upper air disturbances, or other causes resulted in strong north winds on at least three occasions. Cold fronts accompanied by rain increased the probability of occurrence of brown pelican deaths. Thirteen brown pelican deaths occurred during wet fronts (seven dates) and seven deaths occurred during dry fronts (five dates). All but one of the documented deaths occurred in the eastbound (south) lanes of the bridge.

An examination of the bird rescue reports to the U.S. Fish and Wildlife Service (FWS) from 1983 to April 1988 revealed only four records of brown pelicans hit on the causeway in 1987. There were no other references to brown pelicans that were recovered by bird rescue, dead or alive, from the P100 bridge. These four records included two brown pelicans received from the Coastal Studies Laboratory on August 2, 1987, but which were killed on the causeway in October 1986. Two carcasses were given to Dr. Pauline James in the Biology Department at Pan American University for study skins. The other two brown pelican carcasses were received from Ann Grefke in December 1987, but there was no notation of the disposition of these carcasses. There was also a reference to the brown pelican that broke its wing in a collision with the transmission line and that was later acquired by Bird Rescue from Colley's Fishing Service. This brown pelican was sent to the Victoria Zoo, because it could not be rehabilitated to the wild. Although the Victoria Zoo later lost all its brown pelicans to disease, the injured brown pelican recovered from the P100 bridge on October 18, 1989, initially treated by Bird Rescue, had been transported to the Gladys Porter Zoo in Brownsville where the wing was amputated.

It is virtually impossible to recover carcasses from the bridge in good condition, unless they are picked up immediately after being struck by a car. The birds are struck almost immediately after they land on the bridge and following traffic renders the carcasses damaged beyond usefulness to the study. A coast guardsman reported seeing a live brown pelican and a dead brown pelican in the opposite lane, but by the time he could turn around and get back to the birds, the live pelican had also been killed.

#### **Necropsies of Brown Pelicans Killed on the P100 Bridge**

Only one of the brown pelican carcasses removed from the P100 bridge before the initiation of this study was recovered for necropsy. This carcass had been stored in a freezer at the Pan American University Coastal Studies Laboratory on South

Padre Island. This bird had been killed on the P100 bridge, probably sometime during winter 1988–1989, but there was no other information on this individual.

Another brown pelican was found dead on the jetty at the Brownsville ship channel on February 6, 1989. This bird had an injured wing that may have been the result of collision with a power line or the result of a gunshot wound. Although this was not a bridge mortality, it was sent for necropsy to get information about the general condition of brown pelicans in the area. Along with the carcass from the Pan American Laboratory, this carcass was sent to Dr. Nancy Thomas of the National Wildlife Health Center Resource Health Team in Wisconsin in February 1989. (We still do not have the results of these necropsies).

Two brown pelicans were retrieved from the south lane at the curve in the causeway on December 7, 1989. One was an adult in winter plumage, and the other was a first-year immature. The carcasses appeared to be fresh, having probably been killed between 7:30 and 10:00 p.m. These two were sent by Continental Airlines to the Texas Veterinary Medical Diagnostic Laboratory at Texas A&M University the next morning. The final necropsy reports indicated that one of these was male and one was female. The birds were in good flesh, and no lesions were noted except those that were the result of trauma. Numerous flukes were found in the small intestine, but there was no indication that these could be a contributing cause of death. Insecticide screens of both livers were negative, and lead levels were less than 1 ppm.

Four other brown pelicans that had been killed on the bridge in earlier cold fronts and that had been stored in the freezer at PAU Coastal Studies Laboratory were also necropsied by the Texas Veterinary Medical Diagnostic Lab. These carcasses were badly smashed. Consequently, there was little information gained from these carcasses other than the observation that they had numerous parasitic worms. The insecticide screens were also negative, and lead levels were less than 1 ppm.

#### **Observations of Banded Brown Pelicans**

Bird Rescue listed only one of the brown pelican carcasses they disposed of as having an FWS aluminum leg band. Only two brown pelicans having leg bands were observed during this study. On February 3, 1989, there was a winter adult on the breakwater at Queen's Point with a band on its right leg that consisted of a top narrow black stripe followed by a yellow band, another black stripe, and a lower yellow band that was wider than the top yellow band.

On December 7, 1989, leg bands were observed on a winter adult brown pelican perched on the transmission lines south of the state fishing pier. There was an aluminum band on the right leg and a colored band on the left leg. The band appeared greenish with no stripes or other markings. This band may have been one of the red bands put on brown pelicans in Mexico, as these bands tended to fade and could appear greenish. This bird exhibited a bright orange-red color at the base of the pouch on the neck and reddish bill. This coloration was not observed on any of the other pelicans with it on the transmission lines, nor was it noted on any other brown pelicans during the course of this study.



## Wind Tunnel Testing

Two series of wind tunnel tests were accomplished in the low-speed wind tunnel at Texas A&M University's Easterwood Airport research facility. The objective of the tests was to document the flow regimes around the roadway to support explanations of the observed pelican behavior in the vicinity of the bridge in times of strong north winds. Some fundamental questions that stimulated the wind tunnel studies were the following:

- Does turbulence below the deck cause pelicans to try to fly over the bridge, rather than under it, in times of strong north winds?
- Does turbulence above the deck affect the pelican's flight above the deck?
- Is turbulence above the deck caused by the railing, the median barrier, or the superstructure and roadway?
- Is there aerodynamic evidence to support a theory that the pelicans might be seeking shelter behind the safety shape median barrier?

Testing of the 72:1 scale model of Spans 36 to 39 took place July 31, 1989, beginning at approximately 8:30 a.m. with installation of the model into the test section and with removal of the model in the afternoon. The larger 16:1 model was installed at approximately 4:00 p.m. Videotape records were made by tunnel staff during the morning and in the afternoon, videotape records were made with the TTI camera, also. Still photographs, including both prints and slides were taken. Smoke tests were conducted at 0 degrees (perpendicular to the centerline of the model) and at various angles simulating N-NE winds at angles up to 45° to visually observe the flow pattern and the presence of regions of turbulence. Dynamic pressure probe measurements were obtained, sweeping the probe along vertical lines just behind the downwind railing (approximately 1.5 in.), which is a continuous trace, and at the median barrier and near the upwind railing, resulting in interrupted traces. These measurements are made in both Spans 36 and 38 at a free field dynamic pressure of 5.0 pounds per square foot (psf). In addition, there is a sweep at 3.0 psf on the record for Span 36 (for checkout only).

Testing of the 16:1 scale model of Span 38 began at approximately 4:00 p.m. on July 31, 1989, and was concluded by approximately 2:00 p.m. on August 1, 1989. Video records were made with both the tunnel camera and the TTI camera. Still photographs were also taken. Smoke tests were conducted at 0 deg and at various angles up to approximately 45 degrees, simulating NE winds. NW winds were not simulated, and because the deck has a downward grade to the east in the region modeled, some difference could be expected between NE and NW winds. NE winds have a negative angle of attack, while NW winds have a positive angle of attack. This effect was not thought to be significant, however. Dynamic pressure probe data were taken along a vertical line just behind the downwind railing, and along a vertical line through the median barrier.

In the afternoon, smoke tests were conducted after removal of a portion of the upstream railing to determine the role played by the upwind railing in the presence of turbulence on the deck. Later a V-shaped leading edge fairing was fabricated to modify the leading edge, and further smoke tests were conducted.

A zone of turbulence and reversed flow was observed above the bridge deck. It is visualized in the smoke tests and may be inferred from the dynamic pressure data. The extent of this zone is estimated best from the dynamic pressure measurements. On the 72:1 model, the deck height is approximately 12.25 in. from the datum (floor), and the zone of turbulence extends up to approximately 14.5, 15.5, and 16 in., respectively, over the upwind railing, the median barrier, and the downwind railing in Span 38. In Span 36, where the deeper steel girders are present, the respective heights are 15.5, 15.75, and 16.75 in. Subtracting the deck height of 12.25 in. from these distances and multiplying by the scale factor of 72 (or 6 ft = 1 in.), it is concluded that height of the turbulent zone above the deck is from 13.5 to 27 ft above the deck on the full-scale bridge. From tests of the 16:1 model, a value of approximately 12 ft is obtained with somewhat higher confidence. This latter number is more consistent with the smoke test observations. Within this region the smoke does not exhibit a static trail but is buffeted significantly. At the level of the deck, the smoke is generally blown upwind in a flow reversal, possibly suggesting horizontally oriented vortices above the deck caused by the bluff leading edge of the bridge—the girders and parapet wall. At 45 degree angles simulating a NE wind, the smoke is blown generally parallel to the traffic flow at the deck level.

This observed zone of turbulent flow extends some considerable distance downstream of the bridge. The horizontal extent of the region of turbulence was not quantified, but it would appear to be at least one deckwidth downstream of the structure, and it probably extends much further than this. It is possible that the pelicans search out this region, as the headwind effect is considerably reduced—a theory which might help to explain why the birds do not fly beneath the bridge during strong winds. However, this theory is at odds with the theory that the pelicans have difficulty flying in the turbulence above the bridge deck and are forced to land on the deck. This second theory appears to be more in line with the observed pelican behavior. Approaching from the south, the pelicans try to climb to an altitude sufficient to clear the bridge and traffic—approximately at the levels of the tops of the light standards. Upon reaching a point of sufficient height above the bridge, the pelicans appear to try to glide or fly across the bridge. It is then theorized, on the basis of reported observations, that the pelicans glide or fly into the region of turbulence above the deck, and disoriented or buffeted by the turbulence, light on the bridge deck rather than flying clear of it. While this theory still cannot be supported by more than observation and knowledgeable interpretation, it still is believed to offer the best explanation of the observed behavior.

The space beneath the spans is observed to be largely free of turbulence. While some turbulence undoubtedly exists near the bottom surface of the deck and near the planes of the piers, there appears to be no obvious aerodynamic explanation for the perceived reluctance of the pelicans to fly beneath the bridge during high winds perpendicular to the bridge. One related question that may not have been resolved is whether winds at angles to the bridge produce such turbulence. The models were tested at beta angles up to approximately 45 degrees, but a comprehensive survey of the air beneath the bridge was not attempted for such configurations.

It is also clear that the size of the region of turbulent flow is only partly influenced by the concrete median barrier. Smoke

tests clearly indicate strong reverse flow behind the barrier in the downwind lane. The differences in the flow pattern around the steel girders and concrete girders are observable, but not thought to be significant. In the presence of such a strong flow, it seems unlikely that the pelicans would be attempting to seek shelter behind the barrier.

In an attempt to determine how much of the turbulence was caused by the presence of the parapet wall and railing, a section of the parapet wall and railing was removed from the model. In subsequent smoke tests, it appeared that the size of the turbulent region was visibly reduced, indicating that a significant fraction of the turbulence in the upwind lane is caused by the presence of the parapet wall and railing. However, a region of turbulent flow still remains. It must be concluded that the region of flow reversal and turbulent flow cannot be eliminated even by removal of the median barrier and railing. The flow is, to a large extent, associated with the roadway.

Finally, a modification was made to the shape of the bluff leading edge of the bridge by fabricating a foam fairing, having a 90 deg nose angle and approximately 2.75-in.-long sides, which was then glued to the outer girder of the 16:1 model. It was difficult to assess the effects of the fairing; however, it appeared that the size of the zone of turbulent flow was reduced somewhat in the upwind lane, especially in that portion of the model where the parapet wall and railing had been removed. In the region where the railing and parapet wall had not been removed, the fairing appeared to reduce the height of the turbulent region slightly, but not as noticeably as in that portion of the model where the parapet wall and railing had been removed.

The region of flow reversal, when penetrated by a brown pelican flying upwind, would be perceived by the bird as a wind shear, a suddenly encountered change in airspeed, along with a suddenly decreased angle of attack. The result will be a sudden and rapidly increased rate of descent. Field observations indicate that the birds approaching this region will approach in an orderly formation that degenerates into a confused group at a certain, clearly defined point downwind of the bridge. It may be inferred that the birds are encountering this wind shear and are making large corrections to the right or left to try to avoid the suddenly encountered downdraft. Subsequently, they climb to a higher altitude by a series of parallel traverses downwind of the bridge until they again try to fly above the bridge. Speculatively, the birds that are killed on the deck have probably been forced down onto the deck by this wind shear when they enter the region of flow reversal and turbulence at too low an altitude or when they fail to turn back to gain further altitude. This hypothesis raises the question of whether age of the bird, and in particular flight experience, might correlate with the mortality, with younger, less experienced birds suffering higher mortality rates. Because of the difficulty of collecting physical specimens, this question has not been resolved.

### Correspondence With Other Brown Pelican States

A form letter describing the research on the brown pelican problem on the P100 bridge and asking for information on similar problems with birds on bridges was sent to state wildlife agencies and to conservation organizations in the 10

coastal states having brown pelican populations and Puerto Rico. These states included Alabama, California, Georgia, Florida, Louisiana, Mississippi, North Carolina, Oregon, South Carolina, and Washington. No response was received from either state agencies or conservation organizations in California, Washington, Puerto Rico, and South Carolina. Only two responses came directly from the original contact. A number of the original contacts referred our inquiry to 13 other people and 8 of these referees responded. I subsequently wrote three additional contacts suggested by responders, none of whom have responded to my inquiry. A total of 46 contacts have been made directly or indirectly with a total of 10 responses.

The following is a summary of responses:

- **Alabama:** There is a large nesting colony of brown pelicans in Mobile Bay but they have not noticed any problems with bridges. However, 10 percent of those recovered have been killed as a result of accidents with cars. There was no other information on these traffic mortalities.

- **Georgia:** They know of no problem with brown pelicans being killed on bridges in Georgia. They have lost some pelicans to collisions with transmission lines.

- **Louisiana:** They are not aware of any problems with brown pelicans, which are restricted to coastal barrier islands removed from transportation corridors.

- **Mississippi:** They are not aware of any problems with brown pelicans on bridges. The potential exists, however, because U.S. Highway 90 runs along the coast.

- **Oregon:** They are not aware of any problems with avian species on highways or bridges, although the South Slough Bridge of Coos Estuary parallels a Pacific Power and Light power transmission line on the southern Oregon coast. A persistent seabird and waterfowl (brown pelicans were not mentioned) mortality is associated with this site, but the mortality is thought to be caused by collision with the power lines after gaining altitude necessary to clear the more visible bridge. This persistent mortality has apparently increased since the power lines were relocated, evidence that the mortality is associated with the power lines rather than the bridges.

- **Florida:** We received three responses from Florida. (a) There is a problem with royal terns being killed on the causeway bridges between the mainland and Sanibel Island. A year-long study of road kills by the Sanibel-Captiva Conservation Association yielded an estimate of two brown pelicans having been killed along with 102 royal terns, 24 seagulls, 4 anhinga, and 2 cormorants. Brown pelicans commonly fly under the bridge and also feed directly under the spans. (b) A response from the Florida Audubon Society indicated they were not aware of any problems with brown pelican mortalities on bridges. (c) A response from the Florida Game and Fresh Water Fish Commission describes a problem with Least terns and black skimmers being killed on a causeway to St. George Island near Apalachicola. The only breeding colony of brown pelicans in northwest Florida is located 1 km south of the bridge, but it was estimated that no more than 10 pelicans have been killed on the bridge since 1986. However, there have been no consistent surveys for brown pelicans on bridges. They have initiated some traffic control measures; however, results of traffic control measures are difficult to assess because the nesting population increased by 70 percent as a result of habitat manipulations. The percentage of

the adult tern population killed decreased from 18 to 9 percent but the absolute numbers of adults and chicks killed increased. This year, they will reduce the speed limit during the nesting season, install flashing lights and new speed limit signs, and toll booth operators will pass out informational leaflets.

- **North Carolina:** A response from the North Carolina Wildlife Resources Commission (Charles Fullwood) indicated they were not aware of a problem with brown pelican mortalities on bridges. However, as a result of a response from the State of North Carolina Department of Transportation, it was determined that there have been a number of brown pelican mortalities on the Bonner Bridge across Oregon Inlet between Pea Island and Hatteras Island. The limited information on their problem and the descriptions of the Bonner Bridge indicate that there may be strong similarities to the brown pelican problem on the P100 bridge. This information about the Bonner Bridge problem was conveyed to the North Carolina Wildlife Resources Commission. The Coastal Endangered Species Project leader, Thomas Henson, was instructed to investigate and document brown pelican mortalities on the Bonner Bridge. It would be worthwhile to maintain contact with North Carolina to find out the results of their investigation.

A parallel survey of transportation officials in states having brown pelican populations was also conducted. The following is a summary of the responses:

- **Alaska:** Karl F. Mielke, Chief Bridge Engineer for Alaska Department of Transportation and Public Facilities, reports that brown pelicans are not thought to live in Alaska. There have been no reports of brown or white pelicans being involved in road kill incidents. They have had some reported road kill problems with bald eagles, but their most serious wildlife-traffic problem is with moose.

- **Alabama:** No response was received.

- **California:** James E. Roberts, Chief of Structures Division at California Department of Transportation, responded that no known incidents of pelican-automobile conflicts were known to him. In Southern California, brown pelicans nest on Channel Islands off the coast and feed along the coastline. There are no highway bridges between the coast and the Channel Islands. In Northern California, there is a major population of pelicans along the remote cliffs of Northern Mendocino County where there are no roads. Another population of brown pelicans occurs in the heavily developed Huntington Beach area but does not come into conflict with highway traffic.

- **Florida:** No response was received.

- **Georgia:** Mr. Paul V. Liles, Jr., State Bridge Engineer for the Georgia Department of Transportation, responded that their maintenance personnel, bridge personnel, and area engineers have not observed problems with brown pelican traffic mortality.

- **Louisiana:** Mr. W. L. Haymon, District Administrator in Lake Charles, and Vincent Pizzoloto, Public Hearings and Environmental Engineer for Louisiana Department of Transportation and Development, report no known instances of automobile-pelican collisions.

- **Mississippi:** Mr. W. K. Magee, Environmental Design Engineer, Mississippi State Highway Department, reports that

neither he nor the district engineer responsible for coastal counties has any knowledge about incidences of traffic mortality of brown pelicans.

- **North Carolina:** Mr. L. J. Ward, Manager of the Planning and Research Branch, Department of Transportation, reported that collisions with automobiles do cause some brown pelican deaths on the Hebert C. Bonner Bridge across Oregon Inlet, the NC 12 link between Pea Island and Hatteras Island. Followup discussions with various NC DOT personnel revealed that the extent of the mortality at that site, while not formally documented, may exceed the mortality rate observed at the study site in Texas. The brown pelican population in North Carolina is not endangered, and the mortality, even if more severe than in Texas, is not so significant because the higher population of brown pelicans in North Carolina is not listed as endangered. The Bonner Bridge constructed in 1962 is 2.44 mi long with three 180-ft-long main spans providing a 66-ft vertical navigation clearance. The two-lane roadway is 33.3 ft wide with 31 ft between railings. The superstructure is constructed of prestressed concrete girders in the minor spans and plate girders in the main spans and a 7.25-in.-thick reinforced-concrete deck. In many of these respects, the bridge is similar to the P100 bridge. The bridge is oriented generally north-south, whereas the P100 bridge is oriented east-west. Prevailing winds, however, may generally have similar relationship to the two bridges in spite of their different orientations. In summary, a similar mortality situation with similar causes cannot be ruled out.

- **Oregon:** No response was received.

- **South Carolina:** Mr. Ed Frierson, a biologist with South Carolina Highway Department, had no record of traffic mortality of brown pelicans.

- **Washington:** No response was received.

### **Chronology of Brown Pelican Presence Near the P100 Bridge**

There is some evidence that some brown pelicans remain south of the bridge at night at least some of the time. During an aerial survey on October 26, 1988, Gary Waggerman of TP&WD observed 46 brown pelicans roosting on the CP&L transmission lines next to the west end of the old causeway. Initial observation was at 6:57 p.m. Ten min later, there were 32 brown pelicans on the wires; at 7:20 there were 45 brown pelicans on the wires. Roosting on the wires was later confirmed by storm troopers, a group of volunteer brown pelican observers organized by Waggerman, after dark and before daylight in the same 24-hr period. Similar observations were made October 20–21, 1989. Forty-two brown pelicans were seen perched on the transmission lines on the south side of the west end of the old causeway after dark (7:20 to 7:45 p.m.); 18 brown pelicans were perched on the transmission lines south of the state fishing pier. Before sunrise the next morning, there were still nine brown pelicans roosting on the wires by the state fishing pier, and five were roosting on the wires at the west end of the old causeway. Brown pelicans were not observed roosting on the wires during other trips to the study site.

Brown pelicans began nesting in late February or March. Brown pelicans summering in the vicinity of the P100 bridge



are mostly immature or young of the year. On April 6, 1989, only 12 first-year immatures, those hatched in summer 1988, were observed foraging at Isla Blanca Park north of the Brownsville Ship Channel jetty.

#### Observations of Brown Pelicans at the P100 Bridge

A total of 313 observations of 1,287 individual brown pelicans were made at the bridge. Notation was made when possible of the age class, height of passage over the bridge with relation to the height of the light standards, whether individuals flew over or under the bridge, and the section of the bridge flown over or under. Poor visibility caused by weather conditions and distance limited the amount of information obtained; thus, all information is not available on all observations. This was particularly true of those crossings observed while driving across the bridge. Table 2 presents the information on age class observations and the height at which the brown pelicans flew across the bridge. Seventy-five percent of adults and 67 percent of immature brown pelicans (71 percent of all observations) crossed at or above the height of the light standards.

Table 3 presents the numbers of brown pelicans flying over or under the bridge according to the location along the length of the bridge. The extreme west end of the bridge is denoted Section 1, the west slope denoted Section 2, the main span over the Intercoastal Waterway denoted Section 3, the east

slope denoted Section 4, the curve at the bottom of the east slope denoted Section 5, and the east end of the bridge after the curve was denoted Section 6. The majority of the brown pelicans crossed the bridge at the east slope (29 percent), the center span (29 percent), or the west slope (24 percent). All crossings made from the beginning of the west slope to the bottom of the east slope included 84 percent of all observations. Some bias was introduced by observations being made at the west end. The view from Queen's Point allowed maximum visibility of most bridge sections. Consequently, a number of crossings made at Section 5 or Section 6 were probably missed. However, it was apparent that most of the brown pelicans approached the bridge from the south generally heading for the center span. Crossings over other sections were generally a result of the birds turning to fly parallel to the bridge in order to gain altitude after an initial approach from the south.

Only 16 observations (7.5 percent) of brown pelicans flying under the bridge were recorded. All occurred under Sections 1, 2, or 3. Distance and visibility limited observations of brown pelicans crossing under the other sections. An apparent reluctance to fly under the bridge was demonstrated by brown pelicans occasionally flying low toward the bridge as if to fly under the center span, only to turn back, gain altitude, and fly over the bridge. When flying under the bridge during strong north winds, both brown pelicans and cormorants flew just above the water. During southerly winds, birds flew higher

TABLE 2 SUMMARY OF OBSERVATIONS OF BROWN PELICANS CROSSING THE P100 BRIDGE AT HEIGHTS ABOVE OR BELOW THE HEIGHT OF THE LIGHT STANDARDS

Age Class	Number of Observations	Number of Individuals	Height	
			At/or above	below
Total adult	49	89	6	2
Adult	5	9	4	1
Winter	36	69	2	1
Breeding	8	11	0	0
Total immature	36	71	2	1
Immature	16	24	2	0
1st year	12	28	0	1
2nd year	8	19	0	0
Unknown	228	1127	155	63
Total	313	1287	163	66

TABLE 3 SUMMARY OF OBSERVATIONS OF BROWN PELICANS CROSSING OVER OR UNDER THE P100 BRIDGE ACCORDING TO SECTION OF THE BRIDGE CROSSED

Bridge section	Number of observations	Number of individuals	Flew over	Flew under	Unknown
1	6	20	18	1	1
1/2	4	5	3	2	0
2	38	73	56	3	14
2/3	1	2	0	2	0
3	27	109	57	8	44
3/4	1	1	1	0	0
4	7	48	47	0	1
4/5	1	1	1	0	1
5	4	6	6	0	0
5/6	1	1	0	0	0
6	3	7	7	0	0
Unknown	220	1014			
Total	313	1287	196	16	61

under the bridge, halfway between the water and the bridge deck or higher. Sharp tilting maneuvers by brown pelicans flying under the bridge were noted, both just as an individual began passage under the bridge from the south side and just as an individual cleared the bridge on the north side. This observation suggests turbulence at the surface of the water on both sides of the bridge, although the wind tunnel studies did not reveal any turbulence below the bridge between piers.

## RECOMMENDATIONS

No evidence has been obtained indicating that brown pelicans may be intentionally landing on the bridge to seek shelter or to roost. Consequently, measures to discourage brown pelicans from landing on the bridge such as by flashing lights, propane cannons, or other noise makers are not recommended. Nor would alternative roosting structures, such as platforms or additional railings on the bridge, be useful because it is believed that the birds are not intentionally landing on the bridge roadway. On the basis of the information gathered in this study, the actions most likely to reduce mortality involve using traffic control measures to reduce the possibility of birds being hit once they are on the bridge deck, allowing additional time for the birds to safely depart the bridge. There is no evidence that the existing railings and median barrier present insurmountable obstacles to brown pelicans, but further observation of pelican behavior after adoption of traffic control measures is recommended. Should these traffic measures fail to satisfactorily mitigate the problem, further study of more radical alternatives is recommended.

### Traffic Control Measures

Records of brown pelican mortality on the Queen Isabella Causeway indicate that the mortality most frequently occurs during the months of September through February which coincides with both the peak wintering population of brown pelicans and the presence of inclement winter weather conditions. Traffic control measures could be used during this time span to reduce the probability that a pelican would be hit once it is on the causeway, allowing the bird time to egress the roadway. Limited observations have not allowed assessment of the degree to which the existing railing represents an obstacle to a brown pelican on the roadway, but it appears that the birds that are killed, are killed before having much time to negotiate the railing. Birds on the roadway in the downwind lane may be faced with a more difficult problem unless they choose to depart through the downwind railing. The reverse airflow near the deck in the vicinity of the median barrier may serve to confuse birds on the roadway also. With these observations in mind, the following traffic control measures are recommended for consideration by the department:

1. The speed limit on the causeway should be reduced during the months of peak pelican wintering populations when the weather conditions known to be associated with pelican mortality exist. Basically, the significant weather variables include strong northerly winds. The presence of rain or mist makes the weather conditions more critical. Because these

conditions only occur a few times a year at the P100 bridge site, special signing would be required; and since these conditions do not occur in a regular, programmable pattern, manually activated signing is recommended. Attention-getting signs, flashing lights, and appropriate enforcement are recommended. It may not be necessary to restrict speeds except on the main spans and the adjacent sloping approaches to the main spans because approximately 85 percent of the pelicans observed crossing the bridge flew over these portions. Studies to determine an optimum or recommended reduced speed have not been accomplished, but the objective should be to allow a driver in poor weather conditions to avoid collisions with birds already on the roadway.

2. The circuits that automatically actuate the causeway lighting should be adjusted so that the lighting is turned on 15 to 30 min earlier in the evenings. Cloudy, rainy, and foggy conditions reduce the likelihood that a motorist can see a brown pelican on the deck soon enough to avoid hitting it under natural lighting at dusk. Furthermore, even though there is no evidence to support a theory that the pelicans cannot see the bridge clearly enough at present, increased lighting might reduce mortality by providing the pelicans better visibility of the structure, especially a better altitude reference.

3. The warning signs that are presently posted at the approaches to the P100 probably have had little effect. The wording of the warning is not sufficiently detailed to properly convey to drivers that there is a potentially dangerous situation. The visibility of those warning signs could be increased by using a more noticeable design. The design using the pelican silhouette, which was originally rejected, would probably be more eye-catching. Wording of the warning should be changed to more accurately reflect the potential danger of hitting the pelicans. Motorists using the bridge daily may become habituated to the signs. Additionally, the high turnover in a temporary winter visitor population results in numerous people crossing the bridge who are unfamiliar with the brown pelican problem and who might miss seeing the warning signs under bad road conditions. The use of flashing lights on the signs connected with a reduced speed warning during periods of severe weather would increase the awareness of both locals and winter visitors. The lights on the sign could be activated remotely via telephone lines. In addition to these recommendations, consideration should be given to the installation of emergency telephones at each end of the bridge to help reduce the risk of motorists who stop on the bridge to aid birds or other motorists. These telephones would be valuable not only for reporting birds on the bridge, but for reporting traffic accidents or disabled vehicles as well. Direct-line emergency telephones would be preferable to pay phones. Telephones in a highly visible area would reduce the likelihood of vandals' disabling them. Additional signs on the bridge warning motorists not to stop on the bridge should be installed.

Should traffic control allow the birds that land on the deck to survive longer, they may be able to effect safe egress from the deck. The possibility that the strong reverse flow at the deck disorients the birds may explain the mortality rates. Once traffic control measures are enacted, the behavior of the birds should be monitored to determine whether the confusing reverse flow or the railing geometry prevents the grounded birds

from safely departing the bridge. In the former case, other measures must be also used. In the latter case, railing modifications, which will allow easier egress, can be considered. The need to consider these two possibilities cannot be determined until traffic control measures are enacted and the subsequent effects on the mortality rates are observed.

#### Aiding Brown Pelicans in Flying over the Bridge

Because the brown pelicans usually begin to gain altitude several hundred yards before reaching the bridge, it seems evident that they are aware of the bridge and how to cross it. However, they frequently arrive at the bridge at too low an altitude to successfully cross because of strong north winds and possibly the presence of turbulence above the deck. It may be that they are taking aim on the bridge railing. One technique that could be explored involves giving the birds a higher visual reference point so that they arrive at the bridge at a higher altitude. They need to be at or above the height of the light standards when they arrive at the bridge in order to make it across. No other instance is known where something like this has been attempted. One correspondent from Florida mentioned using orange balls on transmission lines to reduce brown pelican strikes. Some modification of this technique, possibly using streamers, could be attempted experimentally. Another possibility is to string a lightweight but visible plastic line between the tops of the light standards. In addition to giving the birds a visual reference, they may be reluctant to fly under the line and thereby avoid the region of turbulence and reverse flow. Careful monitoring of the brown pelican behavior would be necessary to make sure that the solution is not doing more damage than the original problem. The actuation of existing causeway lighting during inclement weather as recommended may give the birds a better visual reference.

#### Aiding Brown Pelicans in Flying Under the Bridge

Additional research would be required to determine why brown pelicans are apparently reluctant to fly under the bridge. This research could explore the possibilities that sound, including infrasound, or turbulence near the water's surface may be factors. The marked similarities between the structures of Bonner Bridge in North Carolina and the Queen Isabella Causeway suggest the overall configurations of these two bridges may be influencing brown pelican bridge mortalities. Such additional research should be planned if the recommended traffic control procedures do not mitigate the mortality problem.

#### Alternative Roost Sites South of the Bridge

Roost sites could be provided by the use of floating artificial islands such as Schwimmkampen. These artificial islands were developed by Lothar Bestmann of Bestmann Ingenieur Biologie in Germany and are being distributed by Sven Hoeger of Wetland Habitat by Design in New York. The design of the triangular modules is based on nautical engineering and

ship building expertise. They have been used in Germany for 10 years for waterfowl habitat and other purposes and have survived strong winds in service. Artificial islands would also be used as nesting sites by waterbirds and possibly by brown pelicans as well. On the basis of a cursory study, probably the best location to place these would be in the cove formed by the west end of the old causeway and Long Island, south of the old causeway. This area is out of the way of most boat traffic, which could be a problem if the islands were placed between the two causeways. From behavioral observations it appeared that brown pelicans prefer to fly to and from the Gulf of Mexico via the Brownsville Ship Channel rather than flying across South Padre Island. Focusing both winter and summer populations south of the bridge would give them easy access to the Gulf for feeding and might keep them away from the bridge. Obviously, further research would be necessary to ascertain the feasibility of this approach. It might be possible to cosponsor research on artificial islands along with TP&WD and the FWS, as there is some interest in enhancing colonial waterbird habitat as the spoil islands degenerate.

The Texas brown pelican population appears to be increasing at present. Should brown pelican mortality rates increase to the point where a significant threat to the population exists or if the hazards to motorists increase unacceptably, it may be necessary to seriously examine modifications to the bridge structure such as a baffle on the north side of the bridge to deflect the wind currents, changing the design of the railing or changing the design of the center barrier. The findings of this study cannot support major modifications to the bridge structure. Even if much more detailed wind tunnel results were available to allow predictable reductions in the region of turbulence above the deck, the effects of such changes could only be evaluated by field trials.

The findings of this study should be carefully reviewed by designers of other major bridges over waters frequented by the Texas brown pelican. A major new bridge design in areas frequented by the brown pelican should include wind tunnel testing to evaluate the turbulence and potential risk to the brown pelican population.

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