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16. Abstract

A field study of the Texas Brown Pelican population and the behavior of the Brown Pelican population in the vicinity of the P100 Bridge between Port Isabel and South Padre Island, Texas was prompted by increasing traffic mortality of the endangered birds. The findings of the field studies, supplemented with wind tunnel studies of the airflow around models of the bridge, led to the conclusions that the mortalities result from a combination of several factors: the greatly increased numbers of birds in the population, the flight patterns of the birds as they fly to roosting sites in the evenings, the occasional presence of strong northerly winds and inclement weather, and the air flow patterns above the bridge deck. It is concluded that the birds are not intentionally landing on the deck, rather a region of pronounced reverse flow, downwash, and turbulence above the deck, similar to the "wind shear" phenomena which has contributed to airplane crashes, causes the birds to land unintentionally on the deck if they attempt to fly over the bridge without sufficient initial altitude. Because of the uncertain effectiveness and expense of aerodynamic modification, several other strategies are recommended for mitigation of the problem. Traffic control, including reduced speed limits during certain critical times and weather conditions, is recommended. Activation of roadway lighting earlier in the evenings is also recommended. Other recommendations are offered for evaluation should traffic control measures alone not provide acceptable mitigation of traffic mortalities.

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by

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and

R. Douglas Slack

Research Report 1226-1F
Research Study Number 2-5-88/9-1226

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SUMMARY

A field study of the Texas Brown Pelican population and the behavior of the Brown Pelican population in the vicinity of the Park Road 100 (P100) bridge between Port Isabel and South Padre Island, Texas was prompted by increasing traffic mortality of the endangered birds. The findings of the field studies, supplemented with wind tunnel studies of the airflow around models of the bridge, led to the conclusions that the mortalities result from a combination of several factors: the greatly increased numbers of birds in the population, the flight patterns of the birds as they fly to roosting sites in the evenings, the occasional presence of strong northerly winds and inclement weather, and the air flow patterns above the bridge deck. It is concluded that the birds are not intentionally landing on the deck, rather a region of pronounced reverse flow, downwash, and turbulence above the deck, similar to the "wind shear" phenomena which has contributed to airplane crashes, causes the birds to land unintentionally on the deck if they attempt to fly over the bridge without sufficient initial altitude. Because of the uncertain effectiveness and expense of aerodynamic modification, several other strategies are recommended for mitigation of the problem. Traffic control, including reduced speed limits during certain critical times and weather conditions, is recommended. Activation of roadway lighting earlier in the evenings is also recommended. Other recommendations are offered for evaluation should traffic control measures alone not provide acceptable mitigation of traffic mortalities.

SUMMARY STATEMENT ON RESEARCH IMPLEMENTATION

Implementation of the recommended traffic control strategies should be coordinated by the local district office with cooperation of appropriate law enforcement personnel. Lighting changes should be initiated by the state and/or local district administration. Mortality rates should be observed for one or more seasons to detect reductions in mortality rate. Consideration must be given to the weather--in good years such as 1988, few northers reached the vicinity of the P100 bridge during the months when the Brown Pelican population was summering in the vicinity of the bridge. Consequently, no bird mortalities were observed. Because of this inherent variability in mortality, an accurate assessment of mortality rates can require more than one season's observational data. If the Brown Pelican population continues to grow as it has during the past decade, increased mortalities can be expected if no action is taken. This factor should also be considered in assessment of effectiveness of recommended traffic control measures.

ACKNOWLEDGEMENTS

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MITIGATION OF TRAFFIC MORTALITY OF ENDANGERED BROWN PELICANS ON COASTAL BRIDGES

INTRODUCTION

The Eastern Brown Pelican is a large bird weighing about 7.5 pounds with an average body length of 4 feet and an average wingspan of 6.5 feet. Figure 1 shows a sketch of a Brown Pelican (B. Pelican). It is a coastal resident seldom straying inland from its preferred saltwater shores. The B. Pelican is capable of flight speeds of 14 to 35 miles per hour and usually flies with slow wing beats close to the water. They forage by diving and, while capable of lifting off from a horizontal surface without a headwind, they commonly take off into the wind to increase airspeed and to gain lift.

Figure 1.--Brown Pelican (*Pelicanus occidentalis carolinensis*)

The Texas Eastern B. Pelican population once numbered in the thousands. A recent study (Mabie, 1986) provides some details about the history of the Texas population. As many as 5000 pairs had been reported as having nested on the Texas coast from the late 1800's until about 1920 (Pearson 1920). An early marked decline in the 1930's was a result of persecution by fishermen (Allen, 1935; Gustafson, et al., 1939; Henny, 1972). Although legislation was enacted in 1939 to protect B. Pelicans from shooting and from the destruction of nests and eggs, another serious decline became apparent in the early 1950's. By 1962 no B. 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, exposure to chlorinated hydrocarbon pesticides (Paul, 1977). 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 B. Pelican has nested along the Texas Coast from Galveston Bay to Cameron County, but from 1985-1988 B. Pelicans nested only on Pelican Island in Corpus Christi Bay. In 1989 breeding colonies expanded to six sites. B. Pelicans winter along the Texas Coast from Galveston to Cameron County. It has been estimated that 96% of the Texas B. Pelican population use the Lower Laguna Madre in winter.

The Park Road 100 (P100) bridge, or Queen Isabella Causeway, is a 2.4 mile-long 4-lane bridge connecting Port Isabel with South Padre Island, Texas. The bridge has a center span rising approximately 84 feet above the Gulf 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 B. Pelican activity was in the vicinity of the causeway with a majority of the observations in the August-October period when the Texas population is supplemented by immature B. Pelicans from Mexico. It is thought that these Mexican B. Pelicans initiated the recovery of the Texas population.

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

Several causal factors were initially suggested. In conjunction with the increasing population size, the B. Pelicans' 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 B. Pelican mortalities on the P100 bridge.

It is the recovering B. Pelican population wintering in the lower Laguna Madre which has come into conflict with the P100 bridge. A growing B. 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:

(1) To identify the factors influencing the presence and resulting deaths of the B. Pelican on the P100 bridge, and

(2) To suggest ways to mitigate those factors.

METHODS

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

(1) Letters, memos, etc., from correspondence leading to the funding of this project. These included communications from 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 B. 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 B. Pelican population was obtained from Audubon Christmas Bird Counts, breeding bird surveys, ornithological newsletters, Bird Rescue records, NOAA weather data, and from unpublished reports from Texas Parks and Wildlife.

(4) Collection of dead B. Pelicans for necropsy.

(5) Behavioral observations at the bridge--B. Pelican counts were made during four trips to the study site. These visits included an initial survey of the study site (12-14 January 1989) and visits timed with the passage of strong cold fronts (2-17 February 1989, 19-22 October 1989, and 6-13 December 1989). A brief visit was made to the study site on 6 April 1989 after the Area I Research Committee Meeting in Brownsville to determine if any B. Pelicans were present. Another brief trip was made to Port Isabel for a meeting called by Gary Waggerman with the B. Pelican volunteers. Observations included several counts of B. 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 B. Pelicans in the Laguna Madre, the Brownsville Ship Channel, and the Gulf of Mexico. B. Pelicans were observed crossing the bridge in late afternoon and early evening. Most observations of B. 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 B. Pelicans at the bridge.

(7) Wind tunnel tests, including videotaping, conducted on 2 scale models (72:1 and 16:1) of the bridge 31 July and 1 August 1989.

(8) Correspondence with personnel in other Brown Pelican states.

FINDINGS AND DISCUSSION

Literature Search

There is little information in the published literature concerning the Texas B. Pelican population. Some information was obtained concerning results of banding studies on B. Pelicans in general and some information on flight speeds. There was no information in the literature on road kills of B. 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 (Thiessen, et al., 1957), and Ringbilled Gulls (Thiessen and Shaw, 1957). It was shown 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 (Gollop and Davis, 1974).

Status of the Brown Pelican Breeding Population

Figure 2 illustrates the decline and recovery of the B. Pelican breeding population, the date of completion of the P100 bridge, and the time of the first recorded B. Pelican mortality on the span. The breeding population had risen from nonexistence in 1964 to 230 in summer 1984 just prior to 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 which 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 due to a hurricane aborted nesting attempts by 14 adults at Cedar Lakes. This is a new nest site which is the result of an attempt to establish a nest colony of B. Pelicans at San Bernard National Wildlife Refuge. Thus, there were a total of 676 nesting pairs producing about 963 young in Texas during the 1989 breeding season.

While these colony expansions were northward along the coast from Pelican Island, there are indications (Mike Farmer, Audubon Society Warden, pers. comm.) that B. Pelicans may be nesting in the Laguna Madre in summer 1990, as adults were seen carrying sticks, a behavior which may be associated with nesting intentions. Two historical sites mentioned by Oberholser (1974) 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 B.

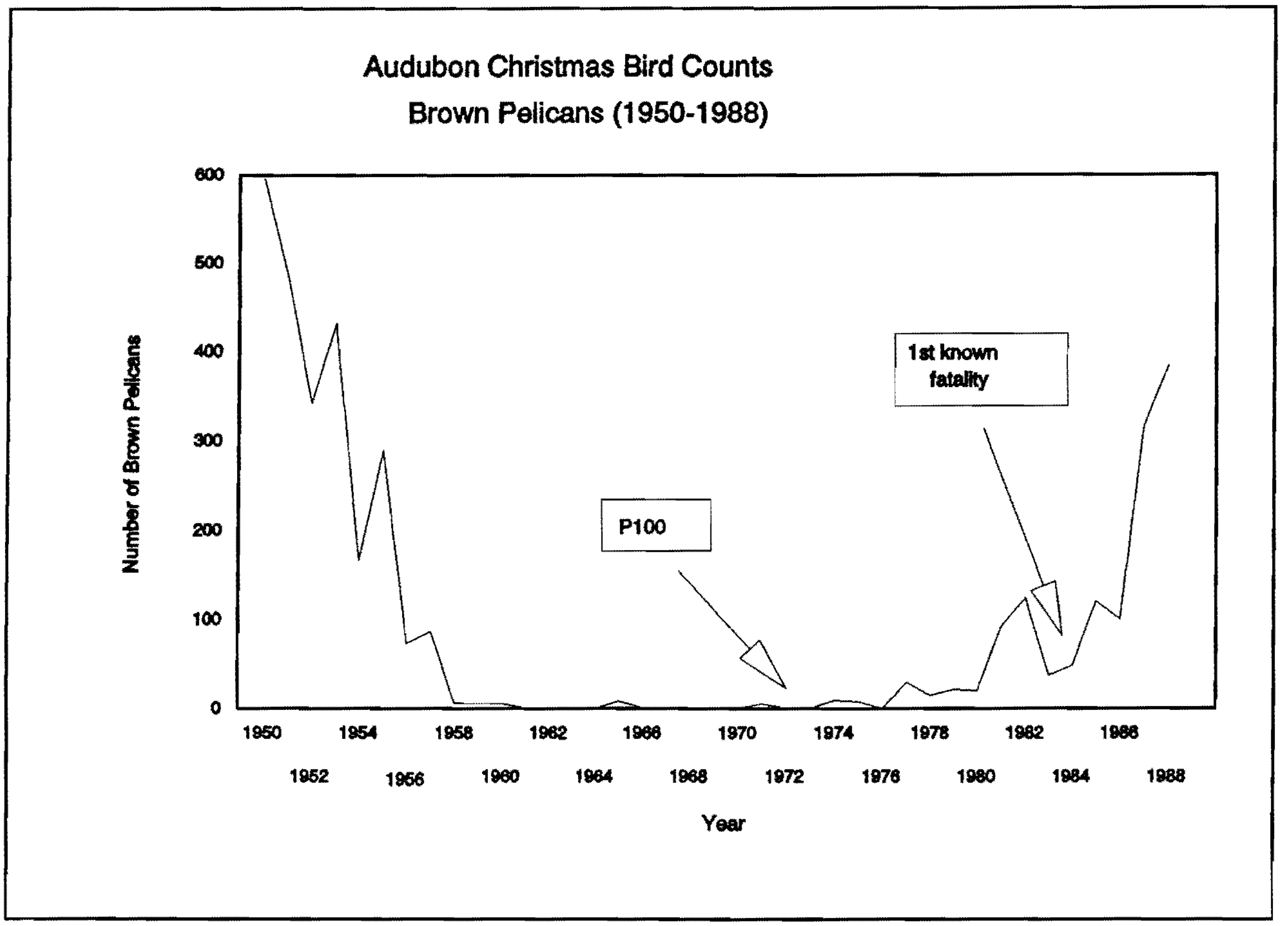

Figure 2.--Decline and Recovery of Texas Brown Pelican Population

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 illustrates the recovery of the B. Pelican wintering population along the Texas coast as indicated by the Audubon Christmas Bird Counts from 1950 to 1988. 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 B. Pelicans counted in the coastal tip of Texas count which includes the area around the study site in a 15 mile diameter count circle centered (26°02'N 97°14'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 B. Pelicans were seen. Subsequent count totals were 55 in

1987 (88th CBC) and 88 in 1988 (89th CBC). This indicates a continuing trend of an increasing winter population.

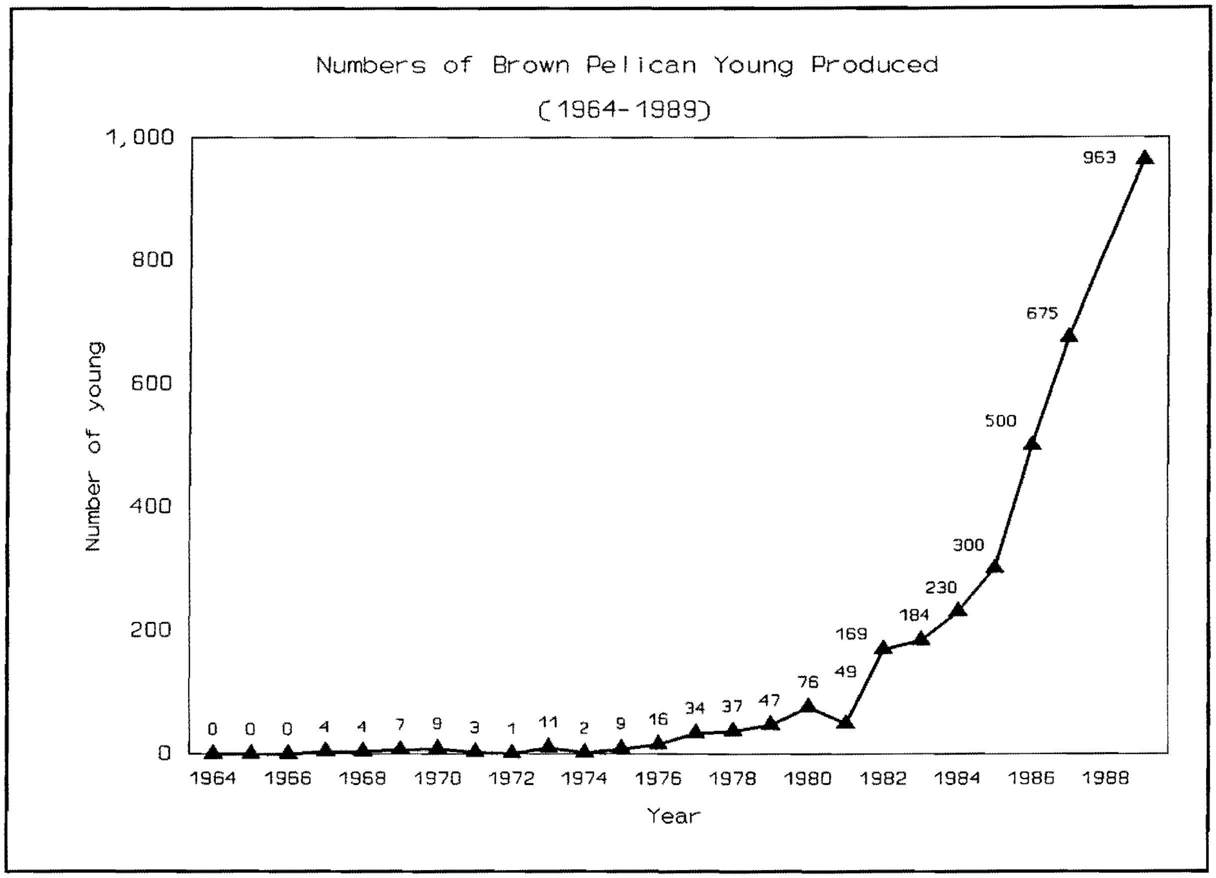

Figure 3.--Recent Historical Data for Texas Brown Pelican Wintering Population

Thus, there was an increase in the total number of B. Pelicans in spite of the severe cold weather in December 1989 when a number of pelicans died. Eighteen dead B. Pelicans were found on Dressing Point and necropsies were done on three of these by the Texas Veterinary Medical Diagnostic Laboratory. Necropsy results indicated that the pelicans had frozen to death. Another seven B. Pelican 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 lists the B. Pelican mortalities which were documented in various correspondence and in the course of this study. These deaths have occurred from September through early February. Nine pelicans were killed in the 1986-87 fall and winter season. Another five pelicans were killed during the 1987-88 winter season. Only one B.

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)
1984				
19 Sep[1]	1	Y	W	S
1986				
12 Oct	3	Y	W	S
13 Oct	2	Y	W	-
12 Nov	2	Y	W	S
25 Nov	1	Y	W	S
1987				
21 Jan[2]	1	Y	W	N
15 Dec	2	Y	D	-
1988				
5 Feb	3	Y	W	-
1989				
6 Jan[3]	1	N	D	-
18 Oct[4]	1	Y	D	
16 Nov	1	Y	D	S
29 Nov	2	S		
2 Dec	2	S		
7 Dec	2	Y	D	S

[1] Tropical Storm Edouard; 19 inches of rain on this date.
[2] Upper air disturbance in Northern Mexico.
[3] Strong winds but not from the North.
[4] An injured Brown Pelican was also recovered.

Pelican was reported killed during winter 1988-89 due to a mild winter having few fronts with strong north winds passing through the area. Eight B. Pelicans were killed in October-December 1989 and one was recovered alive from the bridge, but it had an irreparably broken wing. No B. Pelicans were reported killed on the P100 bridge after December 1989 as 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 B. Pelican deaths. Thirteen B. Pelican deaths occurred during wet fronts (seven dates) and seven deaths occurred during dry fronts (five dates). With respect to the bridge lane, all but one of the documented deaths occurred in the eastbound (south) lanes.

An examination of the Bird Rescue reports to the USFWS from 1983 to April 1988 revealed only four records of B. Pelicans hit on the causeway in 1987. There were no other references to B. Pelicans which were recovered by Bird Rescue, dead or alive, from the P100 bridge. These four records included two B. Pelicans received from the Coastal Studies Lab 2 August 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 B. 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 B. Pelican which broke its wing in a collision with the transmission line and which was later acquired by Bird Rescue from Colley's Fishing Service. This B. Pelican was sent to the Victoria Zoo, as it could not be rehabilitated to the wild. The Victoria Zoo later lost all of its B. Pelicans to disease. The injured B. Pelican recovered from the P100 bridge on 18 October 1989, initially treated by Bird Rescue, was 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 B. Pelican and a dead B. Pelican in the opposite lane, but by the time he turned around and got back to the birds, the live pelican had also been killed.

Necropsies of Brown Pelicans Killed on the P100 Bridge

Only one of the B. Pelican carcasses removed from the P100 bridge prior to the initiation of this study was recovered for necropsy. This carcass had been stored in a freezer at the Pan American University Coastal Studies Lab on South Padre Island. This bird had been killed on the P100 bridge, probably sometime during winter 1988-89, but there was no other information on this bird.

Another B. Pelican was found dead on the jetty at the Brownsville ship channel on February 6, 1989. This bird had an injured wing which 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 B. Pelicans in the area. Along with the carcass from the Pan American Lab, this carcass was sent to Dr. Nancy Thomas of the National Wildlife Health Center Resource Health Team in Wisconsin in February 1989. The results of these necropsies have not been received.

Two B. Pelicans were retrieved from the south lane at the curve in the causeway on 7 December 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 indicate that one of these was male and one was female. The birds were in good flesh, and no lesions 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 then 1 ppm.

Four other B. Pelicans which had been killed on the bridge in earlier cold fronts and which had been stored in the freezer at PAU Coastal Studies Lab 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 B. Pelican carcasses they disposed of as having a USFWS aluminum leg band. Only two B. Pelicans having leg bands were observed during this study. On 3 February 1989 there was a winter adult on the breakwater at Queen's Point with a yellow and black band on the right leg. The band consisted of a top narrow black stripe followed by a wider yellow band, another black stripe and a lower yellow band which was wider than the top yellow band.

On 7 December 1989 leg bands were observed on a winter adult B. 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 may have been one of the red bands put on B. Pelicans in Mexico, as these bands tend to fade, and could appear greenish. This bird exhibited a bright orange-red color at the base of the pouch on the neck and a reddish bill. This coloration was not observed on any of the other pelicans on the transmission lines, nor was it noted on any other B. 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 which stimulated the wind tunnel studies are:

- 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 36-39 took place 31 July 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 photos, including both prints and slides were taken. Smoke tests were conducted at 0 deg. (perpendicular to the centerline of the model) and at various angles simulating N-NE winds at angles up to 45 deg. 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 (approx. 1.5 inches), which is a continuous trace, and at the median barrier and near the upwind railing, resulting in interrupted traces. These measurements were made in both spans 36 and 38 at a free field dynamic pressure of 5.0 psf. In addition, there was 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 31 July 1989 and was concluded by approximately 2:00 p.m. on 1 August 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 deg. simulating NE winds. NW winds were not simulated, and since 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 was 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 was estimated best from the dynamic pressure measurements. On the 72:1 model, the deck height was approximately 12.25 in. from the datum (floor), and the zone of turbulence extended up to approximately 14.5 in., 15.5 in., 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 were 15.5 in., 15.75 in., 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 was concluded that the height of the turbulent zone above the deck is from 13.5 ft to 27 ft above the deck on the full-scale bridge. From the tests of the 16:1 model, a value of approximately 12 ft was obtained, with somewhat higher confidence. This latter number is more consistent with the smoke test observations. Within this region the smoke did not exhibit a static trail, but was buffetted significantly. At the level of the deck, the smoke was 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 deg angles simulating a NE wind, the smoke was blown generally parallel to the traffic flow at the deck level.

This observed zone of turbulent flow extended some considerable distance downstream of the bridge. The horizontal extent of the region of turbulence was not quantified, but it appeared to be at least one deck-width downstream of the structure, and it probably extended 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. This theory, however, 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 further theorized, based upon 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 that 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 was 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 which 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 deg, 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 indicated 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 due to 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 due to the presence of the parapet wall and railing. However, a region of turbulent flow still remained. 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. Apparently the flow is associated, to a large extent, 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 B. Pelican flying upwind, would be perceived by the bird as a wind shear; that is, the pelican would experience a suddenly encountered change in airspeed along with a suddenly decreased angle of attack. The result would be a sudden and rapid increase in the rate of descent. Field observations indicate that the birds approaching this region will approach in an orderly formation, which 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 which 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

Wildlife Authorities

A form letter describing our research on the B. 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 B. 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 other people (13) and eight of these referees responded. Subsequently, three additional persons suggested by respondents were contacted, none of whom have responded to the 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 B. Pelicans in Mobile Bay but they have not noticed any problem with bridges. However, 10% 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 B. Pelicans being killed on bridges in Georgia. They have lost some B. Pelicans to collisions with transmission lines.

Louisiana: They are not aware of any problems with B. Pelicans which are restricted to coastal barrier islands removed from transportation corridors.

Mississippi: They are not aware of any problems with B. 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 (B. 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: Three responses were received from Florida. (1) 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 B. Pelicans having been killed along with 102 Royal Terns, 24 seagulls, four anhinga, and two cormorants. B. Pelicans commonly fly under the bridge and also feed directly under the spans. (2) A response from the Florida Audubon Society indicated they were not aware of any problems with B. Pelican mortalities on bridges. (3) 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 Appalachicola. The only breeding colony of B. 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 B. Pelicans on bridges. They have initiated some traffic control measures; however, results of the traffic control measures are difficult to assess because the nesting population increased by 70% as a result of habitat manipulations. The percentage of the adult tern population killed decreased from 18% to 9% 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 B. 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 B. 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 B. 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 B. Pelican mortalities on the Bonner Bridge. It would be worthwhile to maintain contact with North Carolina to find out the results of their investigation.

Transportation Authorities

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 B. 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, B. 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 B. 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 B. Pelican traffic mortality.

Louisiana: Mr. W. L. Haymon, District Administrator in Lake Charles, and Vincent Pizzolato, 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 B. 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 B. Pelican deaths on the Herbert 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 B. 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 B. Pelicans in North Carolina is not listed as endangered. The Bonner Bridge, constructed in 1962, is 2.44 miles 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 very similar to the P100 bridge. The bridge is oriented generally north-south, while 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 B. Pelicans.

Washington: No response was received

Chronology of Brown Pelican Presence Near the P100 Bridge

There is some evidence that some B. Pelicans remain south of the bridge at night at least some of the time. During an aerial survey on 26 October 1988, Gary Waggerman of TP&WD observed 46 B. 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 minutes later there were 32 on the wires and at 7:20 there were 45 B. Pelicans on the wires. Roosting on the wires after dark and before daylight in the same 24 hour period was later confirmed by Storm Troopers, a group of volunteer B. Pelican observers organized by Waggerman. Similar observations were made 20-21 October 1989. Forty-two B. Pelicans were seen perched on the transmission lines on the south side of the west end of the old causeway after dark (7:20-7:45 p.m.), and 18 B. Pelicans were perched on the transmission lines south of the state fishing pier. Before sunrise the next morning there were still nine B. 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. B. Pelicans were not observed roosting on the wires during other trips to the study site.

B. Pelicans begin nesting in late February or March. B. Pelicans summering in the vicinity of the P100 bridge are mostly immature or young of the year. On 6 April 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 1287 individual B. Pelicans were made at the bridge. A condensed record of these observations is presented in Appendix A. 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. Visibility due to weather conditions and/or 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 summarizes the information on age class observations and the height at which the B. Pelicans flew across the bridge. Seventy-five % of adults and 67% of immature B. Pelicans (71% of all observations) crossed at or above the height of the light standards.

Table 2. Summary of Observations of Brown Pelicans Crossing Above the P100 Bridge. Height of crossing is indicated as being above or below the top of the light standards.

Age Class	Number of Observations	Number of Individuals	Height	
			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 summarizes the numbers of B. 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 Intracoastal 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 B. Pelicans crossed the bridge at the east slope

Table 3. Summary of Observations of Brown Pelican Crossings Over or Under the P100 Bridge by Location

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

(29%), the center span (29%), or the west slope (24%). All crossings made from the beginning of the west slope to the bottom of the east slope included 84% 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 B. 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%) of B. Pelicans flying under the bridge were recorded. All occurred under Sections 1, 2 or 3. Distance and visibility limited observations of B. Pelicans crossing under the other sections. An apparent reluctance to fly under the bridge was demonstrated by B. 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 B. Pelicans and cormorants flew just above the water. During southerly winds, birds flew higher under the bridge, halfway between the water and the bridge deck or higher. Sharp tilting maneuvers by B. 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.

CONCLUSIONS

The recent increase in B. Pelican mortalities on the P100 bridge correlates to a recovering B. Pelican population which has increased markedly since the first observed mortality in 1984. 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 B. Pelicans forage south of the bridge during the day and cross to the north of the bridge in the late afternoon and early evening. Strong north winds, especially when accompanied by rain or mist, often result in B. Pelicans apparently being forced down near or onto the deck where some are struck by cars. Based on observed pelican behavior and limited wind tunnel testing, turbulence and especially a strong reversed flow and downwash (wind shear) above the bridge roadway is suspected as a causal factor in the observed mortality, although the actual significance of the aerodynamics cannot be inferred without somewhat speculative observation of the flight and behavior of B. Pelicans in the vicinity of the bridge. B. Pelican mortalities are likely to occur during any strong north winds, and the passage of cold fronts accompanied by rain increases the probability that B. Pelicans will be killed on the bridge. Age, experience, and physical condition of the individuals being killed are apparently not related. Few B. 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 which deter B. Pelicans from flying under the bridge.

RECOMMENDATIONS

No evidence has been obtained indicating that B. Pelicans may be intentionally landing on the bridge to seek shelter or to roost. Consequently, contemplated measures to discourage B. Pelicans from intentionally landing on the bridge such as by flashing lights, propane cannons, or other noise makers are not likely to be effective. Nor would alternative roosting structures, such as platforms or additional railings on the bridge, be effective. Based on the information gathered in this study, the actions most likely to effectively reduce mortality involve 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 presently no evidence that the existing railings and median barrier present insurmountable obstacles to B. Pelicans, but further observation of pelican behavior after adoption of traffic control measures is recommended. If additional escape time for the grounded birds does not reduce the mortality, railing modifications for improved egress should be considered, along with further study of more radical alternatives intended to change the flight or roosting behavior of the birds. Modification of the aerodynamics of the bridge should be considered only if other measures prove unsuccessful.

Traffic Control Measures

Records of B. Pelican mortality on the Queen Isabella Causeway indicate the mortality most frequently occurs during the months of September through February, which coincides with both the peak wintering population of B. 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 B. Pelican on the roadway, but it appears that the birds which 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 weather variables which are significant 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, employing flashing lights are recommended, as is appropriate enforcement. It may not be necessary to restrict speeds except on the main spans and the adjacent sloping approaches to the main spans, since approximately 85% 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 which automatically actuate the causeway lighting should be adjusted so that the lighting is turned on 15-30 minutes earlier in the evenings. Cloudy, rainy, and foggy conditions reduce the likelihood that a motorist can see a B. 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 these 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 eyecatching. 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 B. 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 the above recommendations, consideration should be given to the installation of emergency telephones at each end of the bridge to help reduce the risk of injury to motorists who might stop on the bridge to aid downed birds. 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. Phones placed in a highly visible area could reduce the likelihood of vandalism disabling the telephones.

Should traffic control measures allow downed birds 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 also be employed. 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 B. 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 due to 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 which 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 B. Pelican strikes. Some modification of this technique, possibly using streamers, could be attempted experimentally. Another possibility is to string a lightweight but visible cable 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 B. Pelicans' behavior would be necessary to make sure the "cure" is not doing more damage than the original problem. Clearance may be required by the National Fish and Wildlife Service for any solution which may represent potential hazard to the B. Pelican. The actuation of existing causeway lighting during inclement weather, as recommended above, may give the birds a better visual reference.

Aiding Brown Pelicans in Flying Under the Bridge

Additional research would be required to determine why B. Pelicans are apparently reluctant to fly under the bridge. This research could explore the possibilities that sound, including infrasound, and/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 B. 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 B. Pelicans as well. Based on 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 B. 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/or the USFWS, as there is some interest in enhancing colonial waterbird habitat as the spoil islands degenerate.

The Texas B. Pelican population appears to be increasing at present. Should B. 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, and/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.

Traffic control measures include better warning signs, particularly decreasing the speed limit during weather conditions most likely to result in B. Pelican mortalities, and placing telephones at each end of the bridge to allow motorists to report birds or accidents on the bridge. This is the simplest and most economical approach and should result in a mitigation of B. Pelican traffic mortalities. Should these measures prove inadequate, further research will be necessary to determine whether B. Pelicans can be induced to fly higher over the bridge to avoid air turbulence close to the deck, to fly under the bridge, or to roost south of the bridge. Bird count data indicates the Texas B. Pelican population is increasing. While an increasing B. Pelican population may result in the eventual delisting of this subspecies, the hazard to motorists may increase.

Recommendations for Future Bridge Designs

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

REFERENCES

Christmas Bird Counts in American Birds (Audubon Field Notes, 1950-1969, Vols. 4-24) 1970-1989, Vols. 25-43.

Gollop, M. A., and R. A. Davis (1972) "Gas Compressor Noise Simulator Disturbance to Snow Geese, Komakuk Beach, Yukon Territory," September, 1972. C. A. G. S. L. Biol. Rep. Ser., Vol. XIV, Ch. VIII.

Gollup, M. A., J. R. Goldsberry, and R. A. Davis. (1974) "Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972." Arctic Gas Biological Report Series. Vol. Fourteen. Chapter II.

Gustafson, A.F., C. H. Guise, W. J. Haminton, Jr., and H. Rise. (1939) Conservation in the United States, Comstock Publishing Co., Ithaca, NY. 534 pp.

Henny, C. J. (1972) "An Analysis of the Population Dynamics of Selected Avian Species with Special Reference to Changes During the Modern Pesticide Era," U. S. Bur. Sport Fish. and Wild. Res. Rep. 1, 99 pp.

Oberholser, H. C. (1974) The Bird Life of Texas, Univ. of Texas Press, Austin. 1069 pp.

Mabie, David W. (1986) Final Report, Texas Federal Aid Project No. W-103-R-15, Nongame Wildlife Investigations, Job No. 41, "Brown Pelican Study," Texas Parks & Wildlife Department, Austin, TX., January 20, 1986.

Paul, R. T. (1977) "Pelican Comeback," Texas Parks and Wildlife, 35(3):12-15.

Pearson, T. G. (1920) "Exploring for New Bird Colonies," Bird Lore 23:276-277.

Thiessen, G. J., and E. A. G. Shaw (1957) "Acoustic Irritation Threshold of Ringbilled Gulls," **J. Acoust. Soc. of Am.** 29:1307-1309.

Thiessen, G. J., et al. (1957) "Acoustic Irritation Threshold of Peking Ducks and Other Domestic and Wild Fowl," **J. Acoust. Soc. of Am.** 29:1301-1306.

APPENDIX A. CONDENSED RECORD OF FIELD OBSERVATIONS

APPENDIX A. CONDENSED RECORD OF FIELD OBSERVATIONS

(BW = Queen's Point breakwater; PIC = Port Isabel Channel; I=immature; A=adult; WA=winter adult; BA=breeding adult; BSC=Brownsville Ship Channel; IBP=Isla Blanca Park, ALS=at or above the light standards; BLS=below light standards; OC=Old causeway, west end).

Date	Time	North Wind	No.	Age	Location	Behavior	Bridge Sec.	Bridge Ht.
1/12	5:45-	N	1	A	BW	Feeding	2	-
	6:00 p.m.	N	1	I	BW	Feeding	-	-
	6:15 p.m.	N	2	-	Bridge	Flying ||, South	-	-
	CF/9:00 p.m.							
2/3	CF/12:00 p.m.							
	4:30 p.m.	Y	41	-	Bridge	Flying across or in water	-	-
	(Storm Trooper Watch)							
2/4	4:30- 6:15 p.m.		None seen while driving bridge.					
2/6	5:15- 6:18 p.m.	Y	None seen while driving bridge.					
2/9	5:10 p.m.		2	I	East end			
			1	WA	PIC			
	5:21 p.m.		1	I	QP	Sitting in water off BW		
2/10	3:30-	N	2	BA	BW	Resting and preening		
	6:15 p.m.		3	WA	" (1 banded)	"		
			1	I1	"	"		
			1	I2	"	"		
			1	BA	PIC			
			1	I	PIC			
	4:30 p.m.	N	1	I	QP	Flew over, from & back to PIC		
			2	-	QP	Flew over, from & back to PIC		
			1	I2	QP	Flew onto piling		
	5:32 p.m.		1	(Of original 7 on BW)			2	-
	5:55 p.m.		1	"		Flew to PIC		
			1	"		Flew under	**under 3**	
	6:08 p.m.		1			Flew under	**under 3**	
2/12	5:00-	N	3	I1	BW	Resting and Preening	All 7 flew over bridge at 5:50 p.m.	
	6:15 p.m.		2	I2	BW	"		
			1	WA	BW(band)	"		
			1	BA	BW	Foraging off BW		
	5:45 p.m.		1	WA	QP	Foraging off BW, Flew to PIC		
	6:15 p.m.		1(same?)	WA	QP	Flew from PIC	**under 3**	
2/14	5:00-6:00 p.m.		0 (Watched bridge from lighthouse)					
10/19	5:25 p.m.	Y	15	-		North of bridge	Flying	
	5:27		1	-	P100	Flying across	2	-
			2	-	P100	" " **N->S**	-	-
	5:30		4	(3A,1I)	P100	Flew across	2	ALS
	5:38		12	-	"	" "		
	5:45		2	-	"	" "		
			2	-	"	" "	3	BLS
			9	-	"	" "	3	ALS
	5:47		2	-	"	" "	3	ALS
			1	(With previous 2; crossing not seen)				
	5:49		14	-	"	" "	3	BLS
			13	-	"	" "	3	ALS
			1	-	"	**Flew under**	3	
			3	-	"	Flew across	-	ALS
	5:50		10	-	"	" "	3	ALS
			4	-	"	" "	3	-
			1	-	"	" "	2	ALS

	5:52		1	-	"	Flew across	3	BLS
	5:55		4	-	"	" "		
	5:59		9	-	"	" "	2	-
	6:01		4	-	"	" "	-	-
			2	(Flying south of bridge; crossing not seen)				
	6:02		1	-	P100	Flew across		
	6:03		2	-	"	" " **N->S**	2	BLS
	6:07		1	(South of section 1; crossing not seen)				
	6:11		6	-	P100	Flew across	3	-
	6:11		1	-	"	" "		
			1	-	"	(In water, south)	4	-
			1	-	"	(Flying, south of)	4	-
	6:18		1	-	"	" "	2	ALS
			1	-	"	" "	-	ALS
	6:20		35	-	"	" "	4	ALS
	6:21		10	-	"	" "	3	ALS
	6:24		2	-	"	(Flying ||, north side)		
	6:37		2	-	"	" "	2	ALS
			1	(With previous 2; crossing not seen)				
	6:38		1	-	P100	Flew across	3/4	-
	6:41		3	-	P100	" "		BLS
			1	-	P100	Flew across	2	BLS
			5	-	"	" "		ALS
			6	-	"	" "	3	BLS
			3	(With previous 12; crossing not seen)				
	6:43		1	-	P100	Flew across	2	ALS
	6:49		2	-	P100	**Flew under** (just above water)	**2/3**	
	6:58		1	-	"	(Flying to bridge)	3	-
			1	-	"	(Flying ||, north)		
	7:00		11	-	P100	Flew across	3	ALS
	7:02		7	-	"	" "	2	ALS
	7:03		2	-	"	" "	-	ALS
			1	-	"	**Flew under?**		
	7:04		2	-	"	" "	2	ALS
			2	(With previous 2; crossing not seen)				
	7:05		1	-	P100	Flew across	3	-
	7:11		1	-	"	" "	1	-
			4	-	P100	" "	2	-
10/20	4:40 p.m.	N	26	_	SFP	(On transmission lines)		
	4:46		1	A	P100	Flew across	-	BLS
	4:48		1	A	P100	Flew across	-	ALS
	4:54		1	-	"	" " **N->S**	-	BLS
	4:55		1	-	"	**Flew Under**		
	5:01		1	-	"	Flew across	3	-
			2	-	"	" "	-	BLS
	5:32		1	-	QP	Flew toward bridge, Flew back		
	5:33		1	-	P100	Flew across	2	BLS
	5:34		1	-	"	" "	2	-
	5:36		4	-	"	Flying toward bridge; crossing not seen		
	5:37		1	-	"	Flew across	2	BLS
	5:45		1	-	"	Flying west, south-no crossing		-
	5:52		2	-	"	**Flew Under**	2	
	5:54		2	-	"	Flew South from pilings, no crossing		
	6:02		1	-	"	**Flew Under** just above water, **N->S**	2	-
	6:04		1	-	"	Flew across	2	BLS
	6:10		1	-	"	Flew across	2	BLS
	6:12		1	-	"	**Flew Under**	1	1
	6:13		1	-	"	Flew across	1	ALS
			1	-	"	With previous 1, turned back south		
	6:15		1	-	"	Flew across	1	ALS
	6:21		2	-	"	" "	2	ALS
	6:22		1	-	"	" "	2	ALS
	6:25		1	-	"	" "	2	-
	6:27		1	-	"	" "	3	-
	6:41		1	-	"	" "	2	ALS
			1	(With previous 1)			2	BLS
	6:43		2	-	P100	" "	1	ALS
	6:44		4	-	"	" "	2	ALS

	6:47		1	-	"	Flew ||," "	2	ALS
	6:48		1	-	"	" "	1	ALS
	6:55		6	-	"	" "	4	ALS
	7:10		1	-	"	Flying toward bridge, crossing not seen		
	7:12		45	-	OC	On transmission lines		
			3	-	OC	Flew toward bridge from transmission lines		
	7:43		3	-		Flew towards bridge		
			18	-	SFP	On transmission lines, south		
12/6	5:00-5:45	N	30-50	-	OC	(Crossing not seen)		
12/7	7:07 a.m.	N	1	WA	BW	Loafing		
	7:10		2	-	P100	Flew ||, flew across 2		ALS
	4:34 p.m.	N	2	-	P100	South--flying east		
	4:36		1	-	"	Flew across	-	BLS
			1	-	"	In water, foraging		
			1	-	"	Flying south of bridge		
			2	-	OC			
			5	-	SFP	Transmission lines		
	4:48		1	WA	P100	Sitting on channel marker		
			3	-	P100	South of section 3, foraging		
	4:51		1	-	"	Flew across	4	BLS
	4:53		4	-	SFP	Flying; foraging		
			8	-	SFP	Transmission lines		
	4:56		1	-	P100	North side on post 6		-
	4:57		2	-	P100	Flying toward; crossing not seen	5	-
	5:25	Y (Cold Front Passed Bridge)						
	5:28		1	-	"	Flew across	-	ALS
			4	-	"	Foraging south	3	
	5:29		1	-	"	Sitting in water		
			2	-	"	South; flying		
	5:30		1	-	"	Flew across	4/5	BLS
			1	-	"	North; flying crossing not seen	5	
	5:31		2	-	"	Flew across	5	BLS
			1	(With previous 2; turned back)				
	5:39		1	(Sitting in water; 3 still on trans. lines)				
	5:51		7	-	Port Isa.Flew south to north over land			
	10:30 p.m.	Y	1	WA	Carcass recovered		5	
			1	I1	" "		5	
12/8	7:00 a.m.	Y	2	-	Tried to cross; S->N;backed off 5			
			1	-	In water off north side			
			4	-	P100	Flew across; S->N	-	BLS
			1	-	"	Foraging in water--off 4		
	7:21		50	-	Laguna Madre;north;foraging			
			1	-	Soaring off north railing		5	
			1	-	Soaring off north railing		5	
			1	-	In water off section		2	
12/8	4:31		2	-	QP	On breakwater; **Flew Under**		
			1	-	QP	Foraging off BW		
(Video)	4:39		2	-	P100	Flew across	2	ALS
	5:16		1	-	(Same as 4:31?)	**Flew Under**	3	
	5:27		1	-	P100	Flew across	6	ALS
	5:40		1	-	PIC	Foraging		
	5:45		1	-	P100	Flew across	2	BLS
	5:49		1	-	PIC	Foraging(same as 5:40 bird)		
	6:10-6:31		0	-	P100	Drove Bridge		
12/9	4:58	N	1	-	P100	**Flew Under** (1/2 way above water)		
(Video)	4:59		1	-	"	Flew across	3	ALS
	5:32		2	-	"	" "	4	BLS
			1	-	"	Foraging, lost sight of		
	5:37		3	-	"	Flew across	2	-
	5:44-5:49		3	-	QP	Foraging (Crossing not seen)		
12/9	7:40-7:50		0			Drove bridge		
12/10	5:17	N	1	WA	P100	Flew across	3	ALS

(Video)	5:18		1	I1	P100	Flew across	2	-
	5:27		1	-	"	" "	5 or 6	-
	5:54		1	-	"	" "	3	ALS
12/11	4:44 p.m.	Y	3	WA	P100	In water, south	5	
			2	I	"	"		
	4:49		1	WA	BW	In water off	2	
	4:53(same as 4:44?)		5	-	P100	Flying back toward	3	
	5:01		1	-	"	Flew across	1/2	BLS
	5:07		9	-	P100	Flying toward	3	
	5:16		1	-	"	**Flew Under?**	1/2	
			5	-	"	In water, flying off	3	
	5:26		1	-	"	North side off	4	
	5:27		2	-	"	In water off	5	
	5:39		2	-	"	Flew across	1/2	ALS
			3	-	"	With previous 2 but backed off		
	5:41		4	-	"	South, flying		
	5:49		2	-	"	Flew across	5	-
			1	-	"	With previous 2, no crossing seen		
	6:01		2	-	"	Flew across	4	BLS
			3	-	"	With previous 2, no crossing seen		
	6:08		1	WA	"	Flying over north railing sec. 6 crossing not seen		
12/12	6:55 a.m.	Y	3	-		Flying low over water off	3	
	7:00		5	-		Flew across, S->N	6	ALS
			1	-		Foraging, south, off	6	
	7:01		1	-		Flew across	6	ALS
	7:14		1	-		Flying off north side of	6	
			6	-		Flying off	3	
			1	-		Flew across, N->S	3	BLS
			1	-		Flew across, N->S	2	ALS
	7:18		13	-		Flew across, N->S	1 or land	
	7:19		1	-		Flew across	2	ALS
	4:25 p.m.		1	-		**Flew under**, just above water	3	
			1	WA	BW			
	4:40		1	-	P100		4	ALS
	5:26		3	-	"	, flying toward bridge crossing not seen		
	5:35		1?	-		Headed toward	6	
	5:52		1	WA		Flying just off north rail	6	
	5:57		5	-	P100	Flew across	2	BLS
			4	-		With prev. 5, backed off		
	5:58		3	-		Flew across	3	BLS
			4	-		Backed off		
	6:05		2	-		Headed toward bridge, south		