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Decreases in the Brown Pelican Population in Southern Florida

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Abstract.—Since 1970, the population of the Brown Pelican (*Pelecanus occidentalis*) in Florida has been thought to be stable. However, one local population, in extreme southern Florida, experienced a 40% decrease from 1977 through 1981. An evaluation of the precision of the long-term statewide aerial pelican survey showed that even the complete loss of this local population would not be statistically recognizable on a statewide basis. We also found that censuses conducted in other than the month of peak nesting have a 40-60% error. We hypothesize that a decrease in food availability in Florida Bay precipitated this decrease in pelican numbers. The status of Brown Pelican populations has been evaluated on geopolitical rather than biological boundaries. The conservation of sensitive species requires consideration of local population trends, especially those that may represent special genetic stocks.

Key words: Brown Pelican, *Pelicanus occidentalis*, population, endangered species, conservation, management, Florida, census methodology.

Various population segments of the Brown Pelican (*Pelicanus occidentalis*) have undergone dramatic fluctuations in nesting numbers over the past three decades. Pelicans disappeared as nesting birds from Louisiana in the 1960's (Williams and Martin 1968). Populations also decreased in Texas (King et al. 1977a) and perhaps in South Carolina (Beckett 1966, but see Williams et al. 1980), as reproductive failures were documented in California (Schreiber & Risebrough 1972). Such decreases resulted in placement of the Brown Pelican on the Federal list of endangered species in 1969 and inspired an impressive series of studies on the status and biology of the species in various parts of North America (Blus 1970, Keith et al. 1970, Jehl 1973, Anderson et al. 1975, 1977, King et al. 1977a, Williams et al. 1980, Schreiber 1980a, Blus 1982, and Briggs et al. 1983).

In each instance organochlorine pollutants were suspected or demonstrated to have caused the decreases in population segments (Schreiber 1980a, Blus 1982); the elimination or reduction in ambient levels of the offending contaminants later resulted in natural recovery in several areas. In Louisiana recovery was accomplished by repeated restocking with Florida birds (Nesbitt et al. 1978). Expansion of various population segments encouraged re-evaluation of the Brown Pelican's status as an endangered species. Schreiber (1980a) argued for delisting in order to emphasize the positive response of some population segments to the abatement of environmental contaminants, but he also concluded that specific politically bounded population segments such as in Texas and Louisiana might remain listed as endangered. Anderson & Gress (1981) discussed the genetic importance of population segments located on the periphery of the species' range, suggesting that such birds represent specialized "genetic packages," the loss of which might prove highly detrimental to conservation of the species as a whole. Such considerations led them to advocate the administrative subdivision of the species into geographical management units.

Because of the pelican's subspecific distinctions (Wetmore 1945) and dispersion over several state and national jurisdictions, Brown Pelican conservation has historically had a regional political flavor (Schreiber & Risebrough 1972, Williams et al. 1980, Schreiber 1980a, Gress & Anderson 1983). For example, in its latest regulations, the U.S. Fish and Wildlife Service (Fed. Reg. 2/4/85) removed the pelican from endangered status in the states of Alabama, Georgia, Florida and the Carolinas while retaining it as an endangered species in Mississippi, Louisiana, Texas, California, the West Indies, and Central and South America.

The Brown Pelican population in Florida has been subjected to repeated scrutiny and is recognized for its reported stability at about 10,000 birds (Williams & Martin 1970, Nesbitt et al. 1977, Williams et al. 1980, and Schreiber 1980a). Clearly, such a regional assessment of status is necessarily artificial, demarcated as it is by state boundaries. Within Florida, population segments exist that could be biologically identified by location or breeding cycle, such as those of the Gulf coast, The Atlantic coast, Florida Bay, the lower Florida Keys, the Marquesas, and the Dry Tortugas. Where then does the logical subdivision of a species lie with respect to its conservation and what might be the importance of local population changes?

The Brown Pelican population of Florida Bay, at the southern tip of the Florida peninsula in Everglades National Park, appears distinctive from other populations because of its earlier timing of nesting (Williams & Martin 1970). It, therefore, may be a good model to assess fluctuations in a local population, the importance of such fluctuations to regional assessments of status, and the importance of managing local 'genetic packages' of endangered species. In this paper we evaluate a rapid and substantial decrease in the Brown Pelican population in Florida Bay over a five-year period, 1977-82. To do this we consider its history, colony site distribution, nesting cycle, potential limiting factors, and the efficacy of a long-term statewide survey in monitoring such a local population.

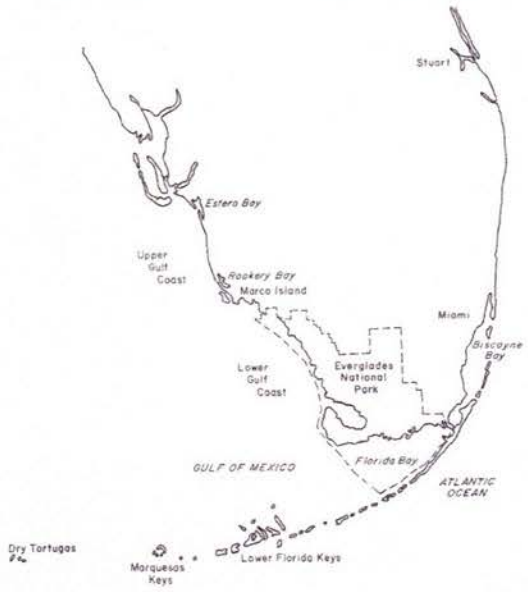

Fig. 1. Map of southern Florida.

METHODS

Once-monthly aerial censuses of all Brown Pelicans nesting in Florida Bay (Fig. 1) were conducted from December, 1976 through September, 1981. Reduced funding limited censuses to two in 1982, and no censuses specifically for pelicans were conducted after 1982. During this study we also censused all colony sites on the lower Florida Gulf Coast and in 1976 in the lower Florida Keys.

Our best estimate of the number of Brown Pelicans nesting was the maximum number of active nests counted at a colony site among all of the months we surveyed each year. We consider these carefully conducted censuses, flown specifically for pelicans, to be a valid representation of the trend in nesting numbers in the area censused. We lack information on productivity and survival desirable for an understanding of population dynamics, but no irregular fluctuations of numbers, double nesting peaks, or any indication of either substantial asynchrony within a colony site or of second nesting attempts occurred. We therefore define our population estimate in each colony to be the maximum number of pairs counted attempting to nest during each year. If indications of asynchrony or second nesting had been found or if the censuses had not been conducted specifically for pelicans, we would not suggest that such aerial census data would be valid in analyzing Brown Pelican population fluctuations.

To provide a crucial perspective on the historic and present status of pelicans in and near the study area, we assembled information from literature and all other pertinent sources. Historic and current nesting colony sites are numbered, because of variation in site names, and are given parenthetically in the text.

RESULTS

Distribution.—Brown Pelicans have nested at over 50 sites in southern Florida over the past 150 years (Fig. 1). Along the Gulf Coast, Pelicans have nested at Estero

Bay, Rookery Bay, and Marco Island, and at scattered and variable locations along the lower Gulf coast. In Biscayne Bay on the Atlantic coast, they have nested in small numbers at Bird Key for several years. There is no additional nesting along the Atlantic coast north to Stuart (Nesbitt et al. 1977). The southernmost groups of nesting Brown Pelicans are in Florida Bay and the off-shore islands of the lower Florida Keys, Marquesas, and Dry Tortugas. Information on Pelican nesting activity is spotty prior to our censuses but is of some use in tracing patterns of change.

Information on Brown Pelican distribution in the lower Florida Keys, Marquesas, and Dry Tortugas (Fig. 2) is particularly limited. The presence of pelicans on the mangroves near Torch Key and "Three Sisters Island" (a key 8 km from Key West apparently later renamed) (Pierce 1962) in 1885 is our only indication of activity, not necessarily nesting, in the southern keys in early times. Howell (1932) listed the Marquesas as being an active site in 1889. In the 1960s, 11 sites were known in the lower Florida Keys; in 1965 eight were known. These keys were observed as part of the statewide pelican surveys of the 1960's and 1970's, but other uncensused keys may also have been active. During our intensive survey in 1976 we found pelicans nesting at four sites (Appendix). A few Brown Pelicans nested on the Dry Tortugas (25) before 1860 (Bryant 1859, Holder 1874, Howell 1932), but none did so in this century until 1974 (Schreiber et al. 1975). Since then they have nested yearly (W. B. Robertson, Jr., pers. comm.).

In Florida Bay, we know of 24 sites used by Brown Pelicans (Fig. 3). The earliest record was by J. J. Audubon (Royal 1951) who found them nesting on Sandy Key (Sands Key, 1) in 1832. Pierce (1962) reported pelicans nesting at Twin Keys (2) and present at Oyster Keys (4) in 1885. The purpose of Pierce's expedition was to collect bird skins for market, an activity common at the time and profitable in that a pelican skin brought 50 cents. Pierce was disappointed not to find pelicans at Arsnicker Keys (21, 22), Sandy Key (1), and Man-of-War Key (15), where apparently he expected them. After an initial collection of pelicans nesting at Twin Keys

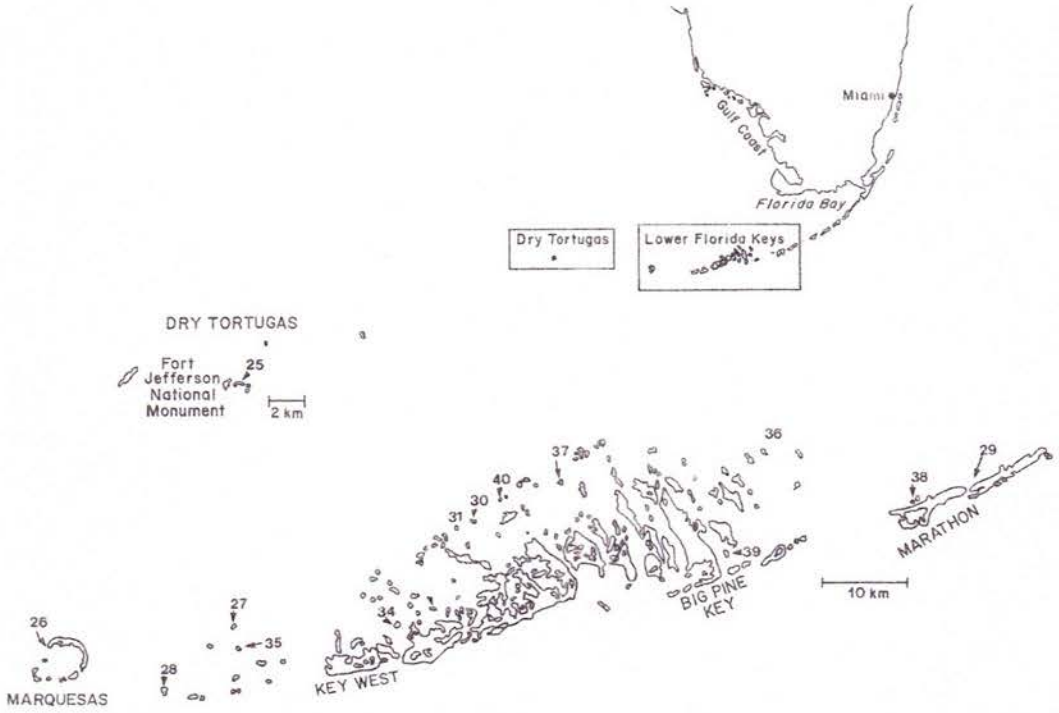

Fig. 2. Map of the lower Florida Keys, Marquesas Keys, and the Dry Tortugas. Colony site locations are shown by numbers. Colony names are listed in the Appendix.

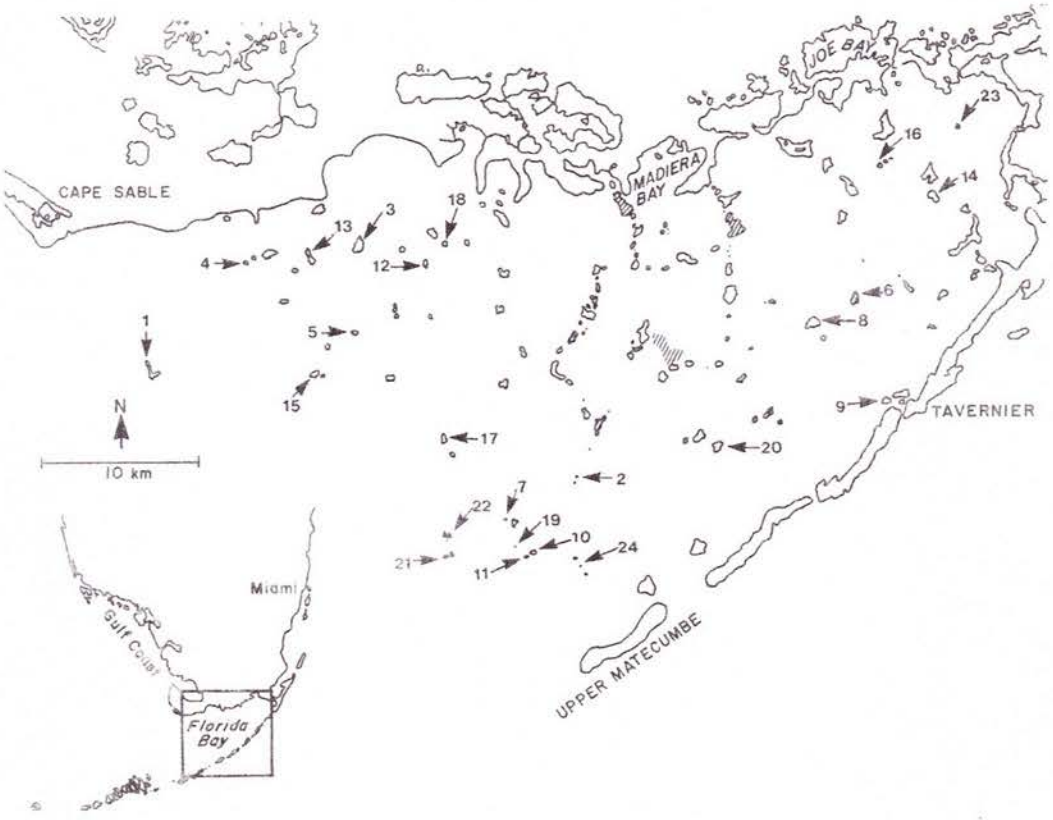

Fig. 3. Map of Florida Bay. Colony site locations are shown by numbers. Colony names are listed in the Appendix. Shaded area shows where raccoons have been observed.

(2), Pierce (1962) returned to find them gone the next evening. The following night the birds were present, but on a subsequent check of the site over a month later (June 11), all pelicans had abandoned the colony site. He frequently recorded having shot all birds possible in a colony, and this practice by other hunters may have resulted in abandonment of colony sites.

In the 1950s, we know of birds nesting at eight sites in Florida Bay primarily at Oyster Keys (4). Increased survey efforts in the 1960's resulted in the location of 17 sites. Information from the late 1960's and early 1970's in Florida Bay came from bay-wide surveys not specifically conducted for pelicans. During this period the number of colony sites used by Brown Pelicans in Florida Bay remained fairly stable at about nine sites (1969 = 9, 1970 = 10, 1971 = 8). Since that time the number of sites occupied in Florida Bay has decreased. By the time our study began in 1976 only six sites were being used. This number decreased to five in 1978, and to four in 1982. The latter figure is half the number of sites used a decade previously.

In Florida Bay, sites varied in duration of use. Some sites, such as those at Stake (8), Rabbit (17), Bottle (6), and west of Barnes (7) Keys were known to be used only once. Occupation of historically-used sites may recur after a considerable period of time. Palm Key (3), first noted active in 1926 (Howell 1932) was not reported so again until 1960, then again in 1971 and 1972. However, duration of colony occupancy can also be consistent over a much larger period of time. Oyster Keys (4) were used from the mid 1940's until 1952, and nearby Frank Key (13) has supported a pelican nesting colony since 1961.

Nesting chronology.—The nesting chronology of the Brown Pelican in Florida Bay differed from that in some other parts of Florida. Our monthly data show that nesting in Florida Bay began in De-

TABLE 1. Months when Brown Pelican nesting was first reported and months when nesting numbers peaked (in parentheses) at various colony sites in Florida Bay. For comparison, nesting chronology is also given for the lower Gulf Coast and Dry Tortugas.

Area	Colony		Year[a]				
	Number	Location	77	78	79	80	81
Florida Bay	22.	Upper Arsnicker Bay	1(2)	12(4)	1(1)	1(2)	1(2)
	10.	East Buchanan Key	12(3)	12(3)	1(3)	12(1)	12(2)
	11.	West Buchanan Key	1(1)	12(3)	1(2)	12(1)	12(1)
	13.	Frank Key	1(4)	2(4)	1(3)	1(2)	2(3)
	14.	Nest Key South	1(3)	1(3)	12(3)	12(4)	12(3)
Lower Gulf Coast		Chokoloskee	2(7)	3(6)	6(6)	5(5)[b]	
		Marco Island[b]	2(6)	3(6)	3(6)	2(6)	
		Tarpon Key[b]	2	2	2		
Dry Tortugas	25.	Bush Key[b]	3	4	4	3	3

[a]Nesting season includes December (12) of the previous calendar Year.
[b]From Below (Pers. comm.) for Marco Island, Schreiber (1980b) for Tarpon Key in Tampa Bay, and Robertson and Below (pers. comm.) for Bush Key.

cember or January and peaked variably in February, March, or April (Table 1). This timing is similar to colonies along the Atlantic coast (Kale pers. comm.) but contrasts with the lower Gulf coast, where nesting began from February to March, peaking from June to July. The chronology of these latter colonies is similar to further north along the Gulf coast such as at Marco Island and Tarpon Key near Tampa (Schreiber 1980b). It appears that pelicans on the Dry Tortugas follow the spring nesting chronology. The nesting cycle on the Marquesas and lower Florida Keys is poorly documented. In 1885 Pierce (1962) observed the same differential nesting chronology between Florida Bay and the Gulf coast; the distinction appears to be a phenomenon of long standing.

Nesting chronology was inconsistent among years. Both initiation and peak nesting varied by a month or more between successive years at a single colony site. The widest range of peak nesting was on Upper Arsnicker Key (22), varying from April 1978 to January the following year (Table 1). No relationship existed between colony size and time of nesting ($P>0.05$). Thus the colonies of a larger size did not have more constant timing of nesting.

Schreiber (1980b) suggested that annual temperature differences caused irregular nesting near Tampa. If temperature influenced nesting in Florida Bay, it did not affect all colonies in the same year, as timing often differed among colonies. Several separate or interactive external factors could modify initiation of nesting, but if so, one would anticipate that a group of local colonies would reflect parallel patterns of timing. Such synchrony was rare in Florida Bay, where colonies seemed to vary without much pattern (Table 1).

Nesting numbers.—The historical data on numbers of Brown Pelicans nesting prior to our study are infrequent and incomplete (Table 2). Despite considerable coverage by various bird wardens, rangers, and government biologists, numbers of pelicans were seldom estimated, and those given were not necessarily the peak number. Historically, Palm Key (13) with 500 nests in 1926 and 200 in 1934, and West Key (20) with 200 nests in 1970 were the largest colonies reported. On the other end of the scale, Dildo Key (5) had a single nest in 1958.

Reliable and thorough nesting censuses are as scarce for the early 1970s as in previous decades. In 1970, 861 nests were reported from Florida Bay. during censuses taken for other purposes. Also in 1970, a separate statewide census tallied 1090 nests in "Florida Bay." These, however, included an unspecified number of sites in the lower Florida Keys. The 1970 figure of 861 nests does at least provide a historic total for comparisons.

From our monthly censuses of pelican colonies from 1977 to 1981, we obtained peak numbers for each year (Table 3). In Florida Bay, our data show a steady decrease from 849 nests in 1977, to 513 in

TABLE 2. Numbers of Brown Pelicans nesting in Florida Bay 1926-1976.

Colony		Year										
Number	Location	1926	1934	1952	1958	1961	1962	1964				
3.	Palm Key	500	200									
4.	Oyster Keys			63								
5.	Dildo Key			35								
10.	East Buchanan Key				55							
12.	Curlew Key					75						
13.	Frank Key							50				
		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
16.	Tern Key	30			15							
20.	West Key		150	50	50	200	50					
13.	Frank Key		25		68	225	25			125	140	250
22.	Upper Arsnicker Key			50	48	100	25				50	20
21.	Lower Arsnicker Key			25		10	7				0	0
23.	Little Duck Key				23	75	50	100				
10.	East Buchanan Key				5	6	30				20	85
11.	West Buchanan Key				58	150	175				30	20
14.	Nes Key, south				33	50		68	20	20	50	45
18.	Southeast Buoy Key					45						
3.	Palm Key						100	60				
9.	Cowpens Key										25	30
Florida Bay Total		30	175	125	331	861	462	228	20	145	315	450

TABLE 3. Peak numbers of Brown Pelican nests in Florida Bay, 1977-1982.

Colony		Year					
Number	Location	1977	1978	1979	1980	1981	1982[a]
10.	East Buchanan Key	150	250	200	125	120	125
9.	Cowpens Key	60	0	0	0	0	0
13.	Frank Key	350	199	175	150	135	210
21.	Lower Arsnicker Key						10
22.	Upper Arsnicker Key	34	26	30	25	26	0
11.	West Buchanan Key	75	90	65	75	65	0
14.	Nest Key, South	180	150	110	125	130	102
24.	Peterson Key	0	0	0	0	37	0

[a]Late survey.

1981, and 447 in the late survey of 1982. From these data, we estimate a 40% decrease occurred in Florida Bay over our five-year study period, 1977 to 1981.

In Table 4 we summarize information on Brown Pelican populations over 12 years of the statewide survey derived from various sources. For southern Florida as a whole, the highest numbers we found during our study were in 1977. These were comparable to the highest in the available historic record, in 1970. Thus no evidence suggests that the Brown Pelican population was ever substantially higher than it was in 1977, and we calculate population trends from this date.

Wintering population.—Sightings of color-marked pelicans demonstrated that extreme southern Florida supports wintering birds from colonies as far north as South Carolina (Schreiber 1976). The winter distribution of birds from local Florida Bay colonies is unknown. But pelicans banded on the Florida east coast have been recovered as far away as the Bahama Islands, Nicaragua, and Cuba (Mason

TABLE 4. Total numbers of Brown Pelican nests reported for southern Florida, 1970-1982.

	State Total	South Florida Total		Florida Bay Total	
Year	State survey[a]	State survey[b]	This study[c]	State survey[d]	This study[e]
1970	7690	1185	1061	1090	861
1971	5923	770	462	660	462
1972	7990	585	228	485	228
1973	6010	495	20	355	NA
1974	6090	342	456	112	143
1975	5950	262	738	132	315
1976	5491	230	933	110	733
1977	6532	630	1114	530	849
1978	7780	665	940	440	715
1979	8942	570	610	540	580
1980	8095	475	500	475	500
1981	NA[f]	NA	513	NA	513
1982	NA	NA	NA	NA	447

[a]Statewide survey data from Nesbitt et al. (1981), except for 1979, which corrects a typographical error (Nesbitt, pers. comm.).
[b]South Florida portion of the statewide survey from Nesbitt (pers. comm.).
[c]1970-1976 from incomplete censuses (Tabel 2); 1977-1982 from this study.
[d]Florida Bay and Lower Florida Keys portion of statewide survey (Nesbitt, pers. comm.).
[e]1970-1976 from incomplete censuses (Table 2); 1977-1982 from this study including total coverage of Florida Bay (Table 3).
[f]NA = not available.

1945), so it is probable that southern Florida birds move further south when not nesting.

Data from the Coot Bay Christmas Count as published in Audubon Field Notes and American Birds provide information on the trend of pelicans wintering in and near Florida Bay. As indexed by either the total number of birds counted or the number of birds counted per hour of effort, the wintering pelican population appears to fluctuate (Fig. 4). Runs tests (Sokal & Rolf 1969) show that by either method of count neither a directional nor cyclical trend in numbers occurred throughout the years from 1951 to 1982 ($P > 0.05$). Schreiber & Schreiber (1973) noted that an apparent decrease of wintering pelicans in the early 1960s corresponded to coincident declines in the population on the northern Gulf Coast. Based on data up to 1972, these authors concluded that the overall wintering population in Florida has been stable since the 1950s. The Coot Bay data show a fluctuating wintering population, which has been less variable in numbers since 1967 than during 1950-1965.

Sampling errors in aerial censusing.—Our analysis of trends in the Brown Pelican nesting population is based on aerial censuses. It has become apparent that substantial errors are involved with such censuses, the importance of which depends upon the nesting cycle and the analysis to be performed.

The timing of censuses is critically important. Our five-year sample found a range of months during which the peak of nesting differed among colonies (Table 1). Thus, no single census time would have been adequate for all colonies even in as small an area as Florida Bay.

It is of value to consider in some detail the potential error that might result in

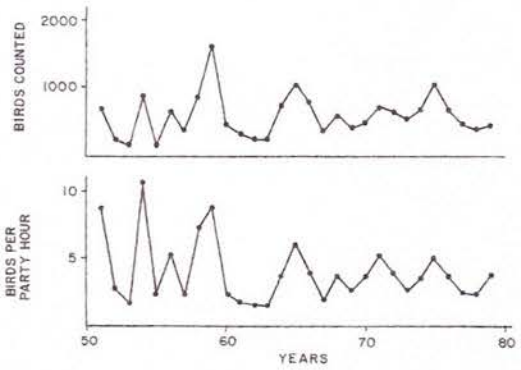

Fig. 4. Numbers of Brown Pelicans censused on the Coot Bay Christmas Count. Top graphs show fluctuations in total numbers of birds counted. Bottom graph shows fluctuations in the number of birds censused per party hour.

TABLE 5. Underestimate of peak numbers of nesting Brown Pelicans as a result of censusing in other than the peak nesting month, in five colonies, and among colonies in five years.

Colony or Year	Underestimate[a]		
	$\bar{x}$%	s.d.	n
Upper Arsnicker Key	45.6	35.28	15
East Buchanan Key	62.4	27.48	10
West Buchanan Key	58.8	35.98	10
Frank Key	58.4	24.07	12
Nest Key	56.2	20.88	6
1977	58.3	24.70	11
1978	54.8	18.54	11
1979	53.0	33.54	11
1980	61.9	40.22	10
1981	48.8	33.71	10

[a]Percentage underestimate is the percent difference between the actual peak count in a given year and colony, and any other count in the range of months in which peak nesting occurred in a colony during 1977-1981.

conducting a single census at an off-peak time. Conservatively, we attempted to determine the error at each colony, presuming that one could census each on its individual schedule. For each colony we first determined the range of months during which peak nesting had occurred. We then calculated the difference between censuses conducted during off-peak months and during the actual peak month for each year. Similarly, we examined differences over Florida Bay as a whole within each year from the peaks at each colony for that year. We found that censuses conducted off-peak, but within the period when the peak would be expected, underestimated nesting numbers by 40-65% (Table 5). A two-way analysis of variance confirmed that neither colony, nor year, nor the interaction of these two variables significantly accounted for the percentage underestimates found (colony $F=0.497$, df=4; year $F=0.234$, df=4; interaction $F=0.753$, df=16.) Thus, we cannot account for the pattern of underestimates in nonpeak months. However it is clear that censusing in off-peak months can lead to massive errors in estimating the nesting population. Only censuses conducted each month on the schedule of each colony will yield sufficiently accurate information; one-shot annual aerial censuses will not.

Potential limiting factors.—Williams et al. (1980) defined the possible limiting factors for Brown Pelican populations as pollution, human interference, low population size, and natural factors such as disease, haitat, and food.

Pelicans are known to be adversely affected by pesticide poisoning, even at sublethal levels. The severe population decreases documented in Louisiana, California, and South Carolina during the 1960s spawned several studies of the relationship between environmental pollutants and pelican population instability. DDE levels were found to be directly correlated with eggshell thinning, a phenomenon considered in part responsible for the limited reproduction and eventual population declines (Blus et al. 1974). The monitoring programs conducted periodically in the 1970s to measure and compare heavy metal and other pesticide levels of pelicans included samples from south Florida (Table 6.) In 1970, DDE residues and eggshell thickness of pelican eggs from Florida Bay were generally lower than those from other nesting colonies, and residues in adult and immature pelicans from Florida Bay were also much lower (Blus et al. 1974). Other sampling pro-

TABLE 6. Residues (geometric mean of a sample ppm) of chemical contamination in Brown Pelican eggs in south Florida.

Year	Colony	DDE	DDD	DDT	Dieldrin	PCB	Mercury	Lead	Reference
1970	Nest Key	1.06	0.16	tr[b]	tr	0.9	0.59	tr	Blus et al. 1974
1970	Buchanan Key	1.11	0.19	tr	tr	0.8	0.74	tr	Blud et al. 1974
1970	Marquesas Key	1.17	0.11	0.15	nd	0.3	0.46	tr	Blus et al. 1974
1974	Marquesas Key	0.39	nd[a]	nd	tr	0.47	nd	nd	Blus et al. 1979
1979	Marquesas Key	0.08	nd	nd	nd	tr			Mendenhall, pers. comm.
1979	Frank Key	0.14	nd	nd	nd	tr			Mendenhall, pers. comm.

[a]nd = not detected
[b]tr = trace

grams (Thompson et al. 1977, Nesbitt et al. 1981) yielded similar results. Mean levels of most contaminants analyzed have continued to decrease (V. Mendenhall pers. comm., Blus, et al. 1979) and do not appear to pose a threat to the southern Florida pelican population.

Human interference has certainly disrupted pelican colonies in the past. Historically, Brown Pelicans were shot for their skins. Pierce's (1962) 1885 account recorded 37 pelicans shot at one Gulf Coast nesting colony, 101 at another, and 28 in Florida Bay. Shooting pelicans for sport continued well beyond the skin and plume hunting days. In 1942 M. Parker reported that young pelicans had been shot in Florida Bay. Everglades National Park rangers protecting Gulf coast roosts and colonies repeatedly reported shooting in these sites through the 1960's. Apparently protection is still warranted as we know of four instances of Brown Pelicans being shot from 1976 to 1980.

Less intentional human interference also affects pelicans. Disturbance can result in incubating adult birds stepping on and breaking eggs, a problem particularly if chemical contamination is causing eggshell thinning (Schreiber and Risebrough 1972, Jehl 1973). Eggs are knocked out of the nest by quickly departing birds (pers. obs.), and unattended eggs are susceptible to predators. Although all colony sites in south Florida are in national parks, wildlife refuges, or sanctuaries, disturbance is not uncommon.

In order to determine unnatural mortality in pelican in Florida Bay, we analyzed records of Brown Pelican injuries in Everglades National Park from December 1975 to January 1981 (Table 7). In these five years, 32 deaths were officially reported. Most of these reports were from a single marina in Flamingo where pelicans have been fed at fish-cleaning tables.

Natural factors affecting pelicans may be numerous and would require detailed study to elucidate. Hurricanes and water spouts appear to have disrupted nesting sites, but many more suitable sites exist, including many that were previously used. In one area, however, suitable sites may be limiting. In Florida Bay, historical and current colonies are absent from two chains of islands in the center of the bay (Fig. 3). Raccoons (*Procyon lotor*) have been observed in this area (Fig. 3). Pelicans may avoid nesting in the area because raccoons can reach most islands via the shoals connecting them. Some other factor such as food availability may also characterize this part of Florida Bay. Many islands exist in other parts of the bay, and we believe nesting sites are not limiting to Brown Pelicans in Florida Bay.

TABLE 7. Human interference and other deaths of Brown Pelicans reported in Everglades National Park, 1975-1981.

Cause	Incidents	Deaths
Hooked	16	0
Broken wing	6	1
Shot	4	4
Ripped pouches	3	1
Injured leg	2	0
Diving into a boat	1	1
Other deaths	25	25
TOTAL	57	32

DISCUSSION

Population trend.—Brown Pelicans are known to have nested in Florida Bay for 150 years, the first report originating with John James Audubon during his stay in the area. The population decrease we found is unprecedented in recent history in south Florida. It may be that the missing birds emigrated, although we have no indication that other colony sites received these birds. The rate of decrease of 8% per year is within what might be attributed to adult mortality, accompanied by reduced recruitment of young. By whatever means the population decreased, it represents a loss to the local environment, a contradiction to the recognized stability of the Florida statewide Brown Pelican populations, and a matter of concern with respect to the conservation program for the species. It is worthwhile then to consider the 5-year population decrease from local, state, and national perspectives.

Florida Bay population.—On a local level, a decrease of this magnitude in a national park should be a matter of grave and immediate concern. This would be especially so for a species that was federally listed as endangered when the censuses were

begun and one that has previously proven to be an indicator of ecological deterioration. Lacking site-specific information on the cause of the decrease, it is necessary to review what is known about the biology of the species elsewhere in search for clues to its decrease in Florida Bay.

Decreasing population trends of the sort we found were in other places caused by pesticides. In southern Florida concentration of the contaminants were below levels known to have caused adverse effects elsewhere (Thompson et al. 1977, Blus et al. 1979, Nesbitt et al. 1981, Blus 1982). Other potential limiting factors such as colony disturbance (Schreiber & Risebrough 1972, Anderson & Keith 1980), direct harassment or killing, parasites (King et al. 1977b), oil contamination (King et al. 1979) or predation are not important problems in Florida Bay (Table 7).

One clue to factors affecting reproductive success is the variability in the nesting cycle in south Florida. Although pelicans in Florida Bay appear less variable than do pelicans in some tropical populations (Schreiber 1980b), we observed variations of up to three months in peak nesting during the five year study. Historically, nesting has occurred as early (or as late) as fall (Howell 1941). Colonies further north appear to have their phenology intrained by winter temperatures (Schreiber 1980b). However temperature is unlikely to be an overriding factor in southern Florida where colonies in a single area, such as Florida Bay, can show a three-month difference in timing in a single year. It seems unlikely that region-wide climatic factors should influence pelicans at nearby colony sites so differentially.

Food supplies are the most likely environmental control on nesting chronology, as has been demonstrated clearly for the Brown Pelican in California (Anderson et al. 1975, 1980, 1982). Schreiber (1980b) suggested that in tropical regions slight seasonal fluctuation in timing of mating may be regulated by the acquisition of adequate food reserves by individuals. Individuality would lead to a staggered and a prolonged nesting season within a colony. The strong synchronization of northern colonies by sea temperature is probably also effected through food supply (Schreiber 1980a, Briggs et al. 1981). Southern Florida Brown Pelicans appear to be in an intermediate situation in which birds within a colony are synchronized but various colonies are not. This observation suggests the effect of very localized conditions, most likely food supplies.

The major causes of nesting failure in Brown Pelicans are abandonment and juvenile starvation (Schreiber 1979), and both may be food dependent. Thus, variability in food supply results in variability of Brown Pelican reproductive performance (Anderson et al. 1982). What influences reproductive rate can also eventually influence population levels, barring recurring immigration. That Brown Pelican populations would be regulated by an extrinsic density-independent factor, such as food supply, is consistent with the pattern for most pelicaniforms (Nelson 1977). Schreiber (1980a) argued that Brown Pelicans are adapted to survive variable and unpredictable fish populations and that low productivity is of consequence to population stability only when it occurs uninterrrupted over a period of years. In Florida Bay the population decreased markedly over a period of several years. This pattern implicates reproductive failures and suggests that adverse effects of low productivity may effect local population stability in a matter of years.

Anderson & Gress (1981) showed that the Brown Pelican is a sensitive indicator of biological conditions, especially with respect to its food supplies. In California, pelican biology and food supplies are so directly interrelated that pelicans have been considered as a means of monitoring fish stocks (Anderson et al. 1980). Thus, we suggest that limited availability of food supplies has adversely affected the Florida Bay Brown Pelican population.

In that pelican food supplies are known to be regulated by hydrographic conditions (Schreiber 1980a, Anderson et al. 1982), some environmental factor must be affecting fish stocks in Florida Bay. We do not know which fish stocks are important to pelicans, although mullet (*Mugil* sp.) appear to be a dominant food item in Florida Bay (pers. obs.) as it was 50 years ago (Howell 1932). Coincident with the Brown Pelican decrease, the Osprey population (*Pandion haliaetus*) has also declined in Florida Bay probably due to food stress

during nesting (Kushlan & Bass 1983). Great White Herons (*Ardea herodias*) foraging in Florida Bay also experienced low reproduction (Powell 1983). That three fish-eating species simultaneously experienced local reproductive stresses or population decreases strongly suggests a pervasive problem with fish availability.

It is possible then that the 5-year population decrease in Florida Bay is the response of a flexible, mobile species to the operation of density-independent environmental factors. Whether the response is long-term, as it was in Louisiana and California, or short-term is not known. Irrespective, it suggests that the Florida Bay ecosystem is experiencing local ecological deterioration.

State-wide population stability.—On a statewide basis the impact of the reduction of the Brown Pelican population in Florida Bay cannot be assessed because of limits on the interpretation of the state survey data. All authors have heretofore concluded that the Florida Brown Pelican population has been stable (Nesbitt et al. 1977, Blus et al. 1979, Schreiber 1980a). If this were true, the mean number counted over the period of record would be the best estimate of the actual nesting population. From 1970 to 1980, the statewide census averaged 6954 nests (Table 4). Its 95% confidence limits are ±657 nests. Therefore, even the instantaneous deaths of birds from 447 nests in Florida Bay are not statistically detectable in statewide totals. The claim of stability despite a local loss amounting to 10% of the statewide population indicates that such a loss is not considered to be important to the whole population. On the other hand if a loss of this magnitude cannot be detected, then a statewide survey technique is not sufficiently sensitive for conservation of local populations. Our finding that an aerial census conducted one month early or late can underestimate peak nesting effort by 40 to 65% implies that single annual censuses are not suitable for long-lived species having as variable a nesting cycle as do Brown Pelicans in Florida Bay.

Furthermore, we should note, that it would not seem accurate to infer from the state survey record (Table 4) that the Florida Brown Pelican population is stable, given the high variability of the counts (s = 1111 nests). Rather the data indicate that within the resolution of the census technique there is no evidence that a statistically significant decrease has occurred state-wide over the period of record.

The Florida state censuses are aerial surveys that have been conducted once per year (1970-1984), or since 1984, once every other year (Nesbitt pers. comm.). Aerial surveys are, of course, cost-effective; but because of the high error involved, one would be able to detect only a very large loss if it should occur in the state-wide population of Brown Pelicans. Considering the large technique error and the inability to determine productivity from the air, it would seem that future census and monitoring programs should not rely on aerial censusing alone. In the present instance, because of the statistical insensitivity of state-wide census data, no judgment can be made on the wider population impact of the local decrease we found in Florida Bay. It is entirely possible that these birds shifted their nesting to elsewhere in Florida, but such movements of individual birds are undocumented.

National conservation strategy.—On a national basis, the decrease or even the elimination of Brown Pelican nesting in Florida Bay may be argued to be of no consequence. In fact, the decrease we report was pointedly minimized by the U.S. Fish and Wildlife Service in their ruling removing the Florida Brown Pelican population from the list of endangered species (Fed. Reg. 2/4/85). Biologically, the upper Gulf coast populations—still considered to be endangered—seem to be related to other Gulf coast birds in Florida. Would not this group best be managed as a unit? Similarly, the differing nesting cycle of the Florida Bay birds suggests to us that they are biologically, and perhaps genetically, more closely related to West Indian pelicans than to those occurring further north. The Florida Bay population may very well represent an important genetic package (*sensu* Anderson & Gress 1981), serving as a link between temperate and tropical adaptive zones. The preservation of such a genetic stock may be essential to the maintenance of genetic integrity of the species as a whole. That a local decrease

occurred within a national park is a matter of additional concern relative to conservation efforts for this sensitive species.

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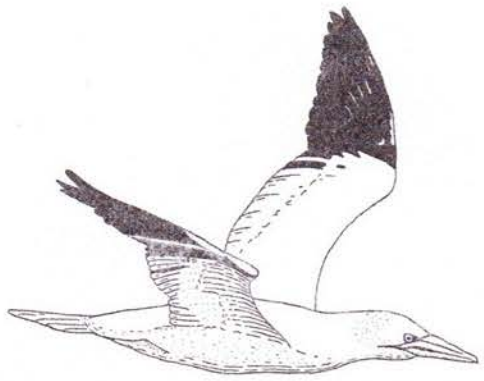
Appendix. History of Brown Pelican nesting in Florida Bay, lower Florida Bay, Marquesas, and Dry Tortugas, Florida. Colony site number, colony site name, and years of activity are given. *Florida Bay:* 1. Sandy Key: 1832. 2. Twin Keys: 1885. 3. Palm Key: 1926; 1934; 1960; 1971; 1972. 4. Oyster Keys: 1946; 1948; 1950; 1951; 1952. 5. Dildo Key: 1950-1952; 1958. 6. Bottle Key: 1950. 7. West of Barnes Key: 1952. 8. Stake Key: 1952. 9. Cowpens Key: 1955; 1972; 1975-1977. 10. East Buchanan Key: 1958; 1964; 1967; 1969-1971; 1975, 1976; 1980-1982. 11. West Buchanan Key: 1960; 1969; 1970; 1971; 1975-1979; 1980; 1981. 12. Curlew Key: 1961; 1967; 13. Frank Key: 1964; 1965; 1967; 1969-1972; 1972; 1974-1982. 14. Nest Key South: 1965; 1969; 1970; 1972- 1982. 15. Man-of-War Key: 1965; 1967. 16. Tern Key: 1966- 1970. 17. Rabbit Key: 1967. 18. Southeast Bouy Key: 1967; 1970. 19. Green Mangrove Key: 1967; 1970. 20. West Key: 1967-1971. 21. Lower Arsnicker Key: 1968-1971; 1979; 1982. 22. Upper Arsnicker Key: 1968-1971; 1975-1981. 23. Little Duck Key: 1969- 1972. 24. Peterson Key: 1981. *Dry Tortugas:* 25. Bush Key: 1859; 1860; 1974-82. *Marquesas:* 26. Marquesas 1889; 1939; 1940; 1962; 1965; 1967; 1976. *Lower Florida Keys:* 27. Cottrell Key: 1962; 1965-1967; 1976. 28. Boca Grande: 1965. 29. Near Vaca Key Cut: 1965. 30. Barracuda Key: 1965. 31. Marvin Key: 1965. 32. Happy Jack Key: 1965. 33. Bill Finds Key: 1965. 34. Channel Key: 1965. 35. Big Mullet Key: 1967; 1981. 36. West Bahia Honda Key: 1968. 37. Crane Key: 1968. 38. Fanny Key: 1976. 39. Big Mangrove Key: 1976. 40. Johnston Key Mangrove: 1976.



Northern Gannet (*Morus bassanus*) by W. E. Davis.