RECENT TRENDS IN BROWN PELICAN POPULATIONS IN TAMPA BAY

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INTRODUCTION

The Brown Pelican (Pelecanus occidentalis) is one of Florida's most popular and visible birds. Large, conspicuous and restricted to the coast where they nest in colonies, pelicans are well suited to census efforts that allow accurate monitoring of population fluctuations on a state or region-wide basis. Pelican populations therefore provide a useful index of the health of Florida's estuarine and marine environment. In 1968, the Brown Pelican was listed as Endangered by the U.S. Fish and Wildlife Service because of disastrous population declines caused by widespread use of the insecticide DDT (Williams 1976). Pelicans ingested DDT accumulated by their fish prey. DDT, and particularly its breakdown product DDE, reduced pelican reproductive success dramatically by causing adults to lay thin-shelled eggs, which broke during incubation, and also by inducing changes in breeding behavior (Anderson and Hickey 1970; Blus 1970; Blus et al. 1971, 1972; Schreiber and Risebrough 1972, Blus et al. 1974a, b). In every state where they nested except Florida, pelicans had nearly vanished by 1968. In Louisiana, the Pelican State, they disappeared completely (King et al. 1977). Florida pelicans were apparently exposed to lower levels of organochlorine and other contaminants, and eggshell thinning was less severe (Blus et al. 1970, 1977; Nesbitt et al. 1981).

After the use of DDT was banned in the United States and residues in the environment declined, pelican populations began to recover (Anderson et al. 1975, Mendenhall and Prouty 1979, Wilkinson et al. 1994). The species was removed from the
Endangered List in 1985. For the last two decades, pelican numbers in Florida have increased steadily, with more than 12,000 nesting pairs found in 1989, an all-time high (Williams and Martin 1971, Nesbitt et al. 1977, Wilkinson et al. 1994). In that year numbers at four colonies in Tampa Bay totalled 3090 pairs, also an all-time high (S. A. Nesbitt, *pers. comm.*). Between 1989 and 1992, pelican numbers decreased across the state, with the most dramatic decline in Tampa Bay where losses approached 50%. Numbers appeared to stabilize following 1992.

The cause of this recent decline is not understood. A food shortage is one possibility, but might be due to one or more of several factors including excessive commercial baitfish harvest, impacts of recent drought conditions on estuarine fish nurseries, chemical spills, and, ironically, recent improvements in bay water quality affecting ecosystem balance. Reductions in nutrient discharges to the bay, and concomitant declines in phytoplankton biomass, have been associated with improving water quality and expanding seagrass meadows. Perhaps declining phytoplankton stocks have resulted in a decrease in planktivorous baitfish. Other potential factors (e.g., predators in colonies, freeze damage to nesting habitat) would be unrelated to food supply.

The present study is an attempt to better understand recent trends in numbers of Brown Pelicans in the Tampa Bay region, and to identify factors associated with those trends.
OBJECTIVES

We had the following two objectives:

1. Describe the current status and recent trends of Brown Pelican numbers in Tampa Bay.

2. Evaluate impacts of the following factors on pelican numbers:
   a. commercial baitfish harvest;
   b. water quality improvements (i.e., reduction in nutrients and phytoplankton in Tampa Bay);
   c. sudden or short-term events including chemical spills, storms, predators, floods and freezes;
   d. chronic conditions including prolonged drought, above-normal rainfall, red tides, dredging activity, or "El Niño/Southern Oscillation" events.
METHODS AND SOURCES OF INFORMATION

We conducted no field work specifically for this study, although we continued our ongoing efforts to monitor pelican populations and nutrient loading in Tampa Bay. We consulted the following existing sources of data (see Appendix 1 for detailed discussion of the utility of these data sets) and are indebted to the named agencies for their assistance in making their information available:

1. Statewide aerial surveys of pelican nesting colonies carried out by the Florida Game & Fresh Water Fish Commission (annual since 1968, except biennial from 1983-1991). Because it was more complete than the Audubon boat surveys, we used the GFC database for our basic summaries of population trends.

2. Boat and ground counts of nesting pelicans at key Tampa Bay area colonies conducted by the National Audubon Society since 1973. Because direct counts are more accurate than aerial surveys, we used the NAS data for more focussed analyses at Alafia Bank. Audubon personnel also estimated nesting success by measuring brood size (see Appendix 2).

3. Commercial baitfish landings data compiled by the Florida Marine Research Institute. (Note: despite the existence of FMRI "fisheries-independent" surveys begun in 1988, no data on baitfish were available from this source.)

4. Water quality data compiled by the Hillsborough County Environmental Protection Commission since 1974 and the City of Tampa's Bay Study Group since 1978. Specifically, chlorophyll-a
concentrations were used as an index of phytoplankton stocks (and, by implication, nutrient loadings) in Tampa Bay.

5. Dates of freezes, chemical spills, storms and other events, and rainfall data were obtained from newspaper accounts and files maintained by National Audubon.

Pelican colonies were grouped into target populations according to logical gaps in breeding distribution. Therefore, although there are four major colonies physically inside Tampa Bay, 13 were considered to constitute the Tampa Bay population (Fig. 1; Tables 1, 2). Likewise, the Charlotte Harbor population included 10 colonies (Table 1), and the Atlantic Coast population all 16 known sites (S. A. Nesbitt, pers. comm.). Pelicans nesting in Tampa Bay have consistently comprised 25-33% of the state total, and represent the largest single "segment" of the state's population.

In this analysis we focus primarily on the period 1980-1995; data from earlier years are presented as appropriate. All pelican population data are presented and expressed as numbers of breeding pairs, not as total population estimates. Some population totals were corrected from preliminary summaries provided by the Game Commission. The Game Commission did not carry out aerial surveys in 1984, 1986, 1988 or 1990.
RESULTS

1. Pelican Population Trends: Florida and Other States

Since statewide surveys began in Florida in 1968, Brown Pelicans have increased fairly steadily from 6000-7000 pairs to over 10,000 pairs (Fig. 2). The modern high of 12,412 pairs was estimated in 1989. Between 1989 and 1993, the state population declined by about 3660 pairs (29%); since then numbers have recovered by about 1600 pairs. The most recent statewide estimate is 10,300 pairs.

No population is static. Some fluctuation should always be expected, whether the population is stable, increasing, or decreasing. Fig. 2 suggests a population dip occurring once per decade, in the early 1970s, 1980s and 1990s. It is tempting to link the dip in the 1970s to continuing effects of organochlorine contaminants, and equally tempting to attribute the 1980s dip to the strong ENSO event of 1983 (see below). However in 1983 pelicans nested several weeks later than normal at most colonies, and Game Commission surveys did not reflect peak efforts (Nesbitt, in Paul 1983). The safest conclusion to draw is that over a 25-year period, Brown Pelican numbers increased strongly, and fairly steadily, in Florida.

The story is virtually the same in all other southeastern states (Fig. 3). In the Carolinas, Louisiana (where young pelicans taken from Florida colonies were reintroduced; McNease et al. 1992) and Texas, numbers began to increase during the 1970s and accelerated during the 1980s. Pelicans now breed in every coastal state from Maryland to Texas, totalling (outside Florida) >14,100 pairs in 1989.
and >13,200 pairs in 1990 (Wilkinson et al. 1994). For the Carolinas and Louisiana, as on the Florida Gulf Coast, 1989 was a peak year although no serious decline followed (W. Golder, pers. comm.; P. Wilkinson, pers comm.). In South Carolina, recent declines were attributed to flooding and the loss of the largest colony to erosion; the birds have been accounted for in Georgia and North Carolina (P. Wilkinson, pers. comm.).

2. Pelican Population Trends: Tampa Bay

The Tampa Bay population increased from a low of about 1300 pairs in the mid-1970s to a remarkably high total of 4100 pairs in 1989 (Fig. 4, Table 2). Within the next three years numbers fell 42% to just under 2400 pairs; declines exceeded 50% at the four major colonies: Tarpon Key, Alafia Bank, Washburn Sanctuary, and Cortez Key. At the same time, some smaller colonies actually increased or were newly occupied (Dunedin Isles, Clearwater Pass, Passage Key). Pelican numbers essentially stabilized at about 2400 pairs during 1991-1993, and have since increased to about 2900 pairs. Despite the dramatic decline of 1989-1993, the pelican population in the Tampa Bay region clearly has increased over the past quarter-century. Numbers currently appear to be higher than in the years preceding 1989 (Fig. 4).

Much of the 1989-93 decline occurred at two sites, Alafia Bank and Tarpon Key. Annually among the five largest pelican colonies in Florida, these two colonies totalled over 60% of the Tampa Bay pelican population in 1989 (nearly 2600 pairs). By 1992, just 1150 pairs were found, still half of all pelicans nesting locally but just 45%
of the birds present three years before. Numbers have increased in the last two years to 1400-1500 pairs (Table 2).

Most observers are drawn to the questions raised by a sudden and precipitous decline in numbers of a species. In the case of Brown Pelicans in Tampa Bay, there is a second issue. When census data are available for a few years following the decline, as we have now been able to assemble (Table 2), the anomalous feature is not a decline but the remarkable spike in 1989. Remove that, and the population still appears to be stable or even increasing. The sudden appearance of so-many nesting birds in Tampa Bay is as much as puzzle as where they went.


In Charlotte Harbor, pelican numbers have remained generally stable or increased slightly over the period of survey (Fig. 5). As in Tampa Bay, peak breeding numbers were found in 1987 and 1989. By 1992 the population had decreased to 1500 pairs (-42%), a decline identical to that occurring Tampa Bay. In the past two years pelicans have increased to about 2000 pairs. Since 1983, the population trend is virtually identical to that observed in the Tampa Bay population (Fig. 6).

4. Pelican Population Trends: Atlantic Coast

As in Tampa Bay and Charlotte Harbor, pelican numbers on the Atlantic coast also have increased (Fig. 7). Following a low in the mid-1970s, annual estimates have consistently exceeded 2500 pairs, with the modern high of 3600 pairs recorded in 1994. A peak in
1989 was not observed, nor was a major decline between 1989 and 1993 (although 1993 and 1995 numbers were sharply below the 1994 high).

5. Summary of Trends

What have we learned? Brown Pelicans are increasing throughout the southeastern U. S. Both Tampa Bay and Charlotte Harbor birds, but not the Atlantic coast population, enjoyed a major increase in the late 1980s, and suffered a major decline after 1989, suggesting the influence of factors that are not merely local. All three Florida population segments appear to be healthy.
DISCUSSION

1. An Abbreviated Life History

A brief explanation of the life cycle and diet of Brown Pelicans is a useful prelude to discussion of potential factors in population fluctuations. The information that follows is a distillation of several sources including Schreiber (1979, 1980; Clapp et al. 1982 and references therein).

Like other coastal colonial waterbirds, pelicans nest on islands that are remote from terrestrial predators (in Florida, particularly raccoons Procyon lotor). Pair formation may occur as early as January, with the first nesting attempts initiated late that month. In much of peninsular Florida, nesting numbers increase through March and peak in late April or early May (south Florida colonies are earlier). Pelicans normally place their nests atop the mangrove canopy at heights of 2-10 meters, but occasionally nest in Brazilian peppers (Schinus terebinthifolius), low mangroves or other shrubs such as Baccharis sp., cactus (Opuntia sp.) or even directly on the ground.

Two to three eggs are laid (mean=2.6 in Florida; Schreiber 1979), two days apart. Incubation begins with the laying of the first egg, so that eggs also hatch two days apart. Incubation lasts about 32 days. Young fledge (are capable of first flight) at the age of 11 weeks, but are fed for another few weeks before they become independent. The entire cycle lasts some 4.5 months.

Nestlings compete for meals delivered by the parents. Sibling aggression is common, and the third-hatched chick, much the
smallest, rarely survives. The second chick may also fail to survive; *brood reduction* has been proposed as a means by which Brown Pelicans and some other species adjust their brood size to the available food supply (Clark and Wilson 1981).

Eggs and small young are vulnerable to predation by raccoons if they can reach the colony sites, as well as Fish Crows (*Corvus ossifragus*), Bald Eagles (*Haliaeetus leucocephalus*) and possibly gulls (*Larus* sp.). By driving adults from their nests, human intruders can expose eggs and young to the searing heat of the midday sun, causing some to die. Exposure to rains can likewise cause them to become chilled, with fatal results. Storms of several days' duration can prevent adults from foraging, and during such events some young starve. Violent storms are strong enough to destroy nests. Another significant source of mortality is entanglement in discarded monofilament fishing line; S. A. Nesbitt (*pers. comm.*) regards this as the most serious direct cause of mortality of adult pelicans.

Brown Pelicans eat fish. Menhaden are a major portion of the diet, with sardines, thread herring, anchovies, killifish, silversides, mullet, threadfin and croakers also important. Early studies in Florida, Texas and elsewhere reported that menhaden comprised >90% of the diet (Palmer 1962). The methodology of the early studies cannot now be carefully evaluated, and it appears that diet may vary somewhat among localities. Combining samples from 13 Florida localities, Fogarty et al. (1981) found nearly 50 fish species, with menhaden totalling just 21% of all individuals (Table 3a). In 28 samples totalling 74 fish collected at Alafia Bank in 1990, B. Ploeger (*unpubl. data*) found that Gulf menhaden (*Brevoortia patronus*)
constituted 47% of all fish recovered (Table 3b). Unpublished work in North Carolina in 1992-93 indicated that Atlantic menhaden (*B. tyrannus*) comprised 46% of the diet of pelicans nesting in Pamlico Sound, but 86% of the diet of birds in the Cape Fear River (W. Golder and J. Brunjes, pers. comm.). We suspect on the basis of colony location that pelicans nesting at Alafia Bank depend importantly on menhaden, while birds from colonies nearer to the Gulf of Mexico may eat more Spanish sardines (*Sardinella aurita*) and Atlantic thread herring (*Opisthonema oglinum*). We know of no studies here or elsewhere which might clarify seasonal or year-to-year variation in diet.

Because it will be important later, we must digress briefly to discuss the diet of pelicans' preferred prey. Menhaden, sardines and anchovies are largely planktivores (Lee et al. 1980). Small larval menhaden feed heavily on phytoplankton, shifting gradually to zooplankton as they grow. Following metamorphosis, juvenile menhaden become omnivorous filter-feeders, and remain so as adults (Ahrenholz 1991). Vaughan (1987) described menhaden as feeding primarily on phytoplankton.

Northern populations Brown Pelicans are migratory, moving south to winter. Northward post-breeding movements are known to occur in Texas and California, and probably also occur in the southeastern U.S. In Florida most adult pelicans are generally resident where they occur, with immatures showing stronger migratory tendencies. In studies of color-banded birds, Schreiber (1976) found a post-fledging dispersal of immatures southward from
colonies on both coasts. This movement was more pronounced in autumn as cold fronts arrived. The birds wintered in south Florida.

Pelicans are long-lived, with adults commonly surviving 15 to 20 years. Typically, birds assume their adult plumage at the age of 3 years, and breed for the first time at the same age. A few immature-plumaged birds, probably 2-year-olds, annually attempt to nest.

The reproductive rate is fairly low, with successful pelicans producing one or two young per year. Schreiber (1979) estimated that productivity of one young per pair per year is sufficient to maintain the population.

2. Identification of Possible Factors Affecting Pelican Numbers

When a population declines suddenly, one of the first questions is whether there is a food shortage. Because it may not be possible to assay the prey base directly, one often asks indirectly. With pelicans, we did just that. A food shortage might have impacts beyond a smaller nesting effort: those pairs that did attempt to nest might suffer a high rate of nesting failures, and high nestling mortality. Through the 1980s, Audubon brood count surveys indicated normal to above-normal nesting success almost every year. In 1990 and 1991, however, brood counts at Tampa Bay colonies averaged no better than 1.2, and casual observation indicated that the rate of nest failures was high. In 1992, brood counts at three Audubon Sanctuary colonies fell to 1.06, while for the region as a whole mean brood size was 1.17. Very few pairs successfully fledged young; many birds abandoned their nests during incubation. Downy young disappeared long before they were old enough to have
left the colony on their own. At the same time, GFC surveys on the Atlantic Coast estimated that broods averaged 1.4 young, well within healthy limits (Nesbitt 1992). These indications heightened our concerns that the problem was more serious on the Gulf coast, and that a food shortage might be a primary cause of the pelican decline.

Yet other factors could cause the effects observed in 1990-1992, some entirely unrelated to food supply. We assembled the following somewhat overlapping list of potential factors (see also Appendix 3):

- Prey abundance;
- Commercial overexploitation of baitfish stocks;
- Water quality changes, especially changes in nutrient loadings that might limit populations of planktivorous fish;
- Rainfall patterns
- El Niño/Southern Oscillation (ENSO) events;
- Freezes;
- Catastrophic events such as oil or other chemical spills;
- Predation or human disturbance in the colonies;
- Dredging activity;
- Red tides.

We will consider the list in reverse order.

3. Red tides

Despite frequent outbreaks in southwest Florida in the last two decades, with the most recent possibly implicated in the death of manatees (Trichechus manatus) and Double-crested Cormorants (Phalacrocorax auritus), red tides seem generally to have minor
effects on birds. To our knowlege, no pelican kills have occurred in
Florida that were attributed to a red tide. In February and March of
1974, a red tide occurred in much of the Tampa Bay system
including Boca Ciega Bay and Hillsborough Bay. A large fish kill
resulted in Boca Ciega Bay, after which non-breeding pelicans and
then breeding adults left the area. Nesting success at Tarpon Key
was 0.33 young per active pair (Schreiber 1979, Schreiber and
Schreiber 1983). No impact on pelicans nesting at Alafia Bank in
Hillsborough Bay was noted (unpublished NAS files), although a
sizeable kill of Lesser Scaup (*Aythya affinis*) occurred which
apparently could not be definitively linked to the red tide (Schreiber
et al. 1975).

4. Dredging activity
At times in the past, dredging projects have been blamed for
sediment plumes and other damage in Tampa Bay. The last large
dredging project was the Tampa Harbor Deepening Project (ca. 1977-
1984). It clearly could not have influenced pelican numbers in
1989-1993, nor could any smaller projects have affected several
colonies distributed throughout the bay system. Dredging is unlikely
to have been a factor.

5. Human disturbance

Human disturbance of bird colonies can cause significant
impacts to nesting birds, but for several reasons this factor can be
rejected as a likely factor in pelican declines. First, most people are
attracted to beaches, where gulls, terns (*Sterna* spp.), Black Skimmers
(Rhynchops niger) and American Oystercatchers (Haematopus palliatus) are most likely to be affected. Few people care to penetrate the swampy mangrove islands where most pelicans nest. Second, pelicans tolerate human activity fairly well. Only the birds close to the invader are likely to be affected, not the entire colony. Third, it is very unlikely that most of the colonies in Tampa Bay and Charlotte Harbor would be disturbed at once. Fourth, most of the colonies are already protected. The major pelican colonies are maintained as National Wildlife Refuges or Audubon Sanctuaries, and posted and patrolled. Several of the smaller sites are also posted, by local municipalities or through the assistance of volunteers.

6. Predation

Raccoons are excellent swimmers and capable of reaching any bird colony from time to time. They occur virtually annually on Alafia Bank and regularly on Terra Ceia Bird Key and Cortez Key. Audubon personnel are alert for sign of raccoons, and live-trap and remove them as quickly as possible. Other colonies do not receive the same scrutiny.

Raccoon impacts can be profound. In late 1989 two raccoons reached Terra Ceia Bird Key and reared a litter of four young. Fewer than 100 pairs of birds (including <30 pairs of pelicans) attempted to nest in 1990, and all failed by April 1. The colony, comprising 2700 pairs of 15 species including over 400 pairs of pelicans in 1989, was completely abandoned (R. T. Paul, unpubl. data). After the removal of all six raccoons, the colony recovered over a 3-year period.
By itself, predation could not have caused a 42% decline in nesting pelicans in both Tampa Bay and Charlotte Harbor. Too many colonies would be involved, over too wide an area. At most, the disappearance of 400 pairs of pelicans in Tampa Bay would correspond to a 10% decline from 1989 numbers. Further, it is likely that at least some of the birds abandoning Terra Ceia Bird Key nested at other colonies within the Tampa Bay system.

7. Oil and Chemical Spills

We identified four major spills as having potential to affect pelican populations (Appendix 3). Three of these, all at Gardinier Inc. (now Cargill Fertilizer Inc.) in 1979, 1987 and 1988, preceded the record-breaking year of 1989 and obviously played no role in the subsequent decline. Nor did they appear to cause more proximate damage: although the Game Commission surveys showed a one-year dip from 625 pairs in 1979 to 425 in 1980, numbers increased in 1988 and 1989 (Table 2).

In May 1988, a spill of 4000 tons of phosphoric acid was widely blamed for a fish kill and a variety of other wildlife impacts; in fact most claims seem to have been exaggerated and impacts were highly localized. No bird kill occurred, and a year later pelican nesting at Alafia Bank (just 1 mile away) reached a record high.

The fourth major spill occurred in August 1993. Clearly this spill could have had no impact on pelican numbers during the 1989-1993 nesting seasons, but the example illustrates the difficulty of detecting population impacts even when nesting adults and fledging young are directly injured by a chemical spill. Over 300,000 gallons
of No. 6 fuel oil were spilled near Ft. DeSoto. A fortuitous combination of wind and tide carried the oil offshore for several days. When the winds changed, oil came ashore at Johns Pass and the pelican colony suffered a direct hit. Fortunately, the spill occurred very late in the nesting season. Some 361 oiled birds were recovered including 296 pelicans, mostly from Johns Pass. Eighty-five percent of the pelicans survived and were released. Game Commission surveys did not show a decline in nesting pelicans at Johns Pass or any nearby colony in either 1994 or 1995.

8. Freezes

Severe freezes can kill mangroves, reducing the amount of available nesting habitat. Since 1980, two moderate and three exceptionally severe freezes have occurred (Appendix 3). Severe freezes in December 1983 and January 1985 did not precede population declines, while the "Christmas Freeze" of December 1989 did. Because of its inland location, close to shore near the head of the bay system, Alafia Bank always is harder hit by freezes than are other colonies in the area. But at neither Alafia Bank nor other colonies did pelican numbers decline following the 1983 freeze, which had the greatest impact on mangroves. Further, ample habitat remained at all sites despite the freezes. Elsewhere in Florida, freeze damage to mangroves has led to the breakup of colonies and redistribution of nesting birds (e.g., Port Orange, near Daytona Beach; S. A. Nesbitt, pers. comm.) but we are skeptical that freezes damage the populations themselves.
9. **Severe storms**

Severe storms can have important short-term impacts on pelican nesting numbers. On March 13, 1993, winds up to 90 mph and storm tides of 5-6 feet above normal battered the Tampa Bay area. At Alafia Bank, 60% of the 280 pelican nests then active were lost. The impact was temporary, since the birds renested. A storm in late May or early June could have more serious effects, since hundreds of young would be vulnerable and it would be too late for the birds to renest. These possibilities notwithstanding, no storms were identified that could have contributed to the 1989-1993 decline.

It should be noted that most pelican nesting is nearly over by the time the rainy season begins in mid-June. Severe thunderstorms occurring throughout the summer may represent a significant selective factor in the timing of colonial waterbird nesting.

10. **El Niño/Southern Oscillation Events**

ENSO events are known to exert profound influence over seabird nesting in the Galapagos Islands, off the coast of Peru, and in the central Pacific (Schreiber and Schreiber 1984, 1989). These interruptions of normal ocean circulation in the tropics can result in mass colony desertions affecting millions of seabirds. Occurring every three to seven years and usually lasting for 6-18 months, ENSO events also influence weather around the planet (Barber and Chavez 1983). In Florida, they typically bring increased winter or "dry season" precipitation. During 1980-1995, three ENSO events occurred. The strongest event ever studied (Schreiber and Schreiber

The influence of ENSO events on pelican nesting in Florida is not clear. One weak ENSO event (1986-87) preceded a sharp increase in pelican numbers while the other (1991-94) followed much of the 1989-1993 decline. The 1982-83 event was correlated with the dip in nesting numbers reported for all three local Florida populations (Figs. 4-7). As noted previously, however, nesting at most colonies was delayed in 1983, and the statewide survey probably underestimated true nesting numbers. Precipitation at Tampa International Airport exceeded 15.5" during February-March 1983, 9" above normal. This is when most pelicans would normally initiate nesting, and perhaps significant numbers of nesting attempts failed due to rainy conditions or were delayed. Audubon records for March 1983 indicated considerable stormy weather and specifically noted some pelican nest losses, but the NAS direct count of 677 nests on May 2 was nearly double the Game Commission's aerial estimate of 370.

A second look at events in March 1987, presumably under the influence of a weak ENSO event, also suggest nesting delay in response to heavy rains -- but not a negative impact on the entire season. Rainfall at TIA totalled 12.01", 347% of normal. Just 302 pelican nests were counted at Alafia Bank on April 1, yet the season-high aerial estimate was 1030 on May 20. This was a record high for the site at the time, and about 3 weeks later than normal. We tentatively conclude that ENSO events may delay pelican nesting or
even cause some nest failures early in the season, but have little impact on peak nesting numbers later.

11. Rainfall patterns

Rainfall patterns may impact pelican populations in two ways. We have discussed the first, outright physical impacts to eggs or young through chilling or starvation. Rainy conditions during the nesting season might be associated with a higher rate of egg and nestling mortality, while dry conditions would encourage high survival rates.

The second is through impacts on food supply. Juvenile fish typically are fairly tolerant of the variable salinities typical of estuaries, and therefore not greatly affected by short-term increases in freshwater runoff or its lack. Chronic conditions of drought or high rainfall, however, may have significant implications for juvenile fish recruitment. Long-term dry conditions would raise average salinities, and would be expected to result in reduced recruitment of juvenile fish. Long-term increases in rainfall might be expected to result in greater survival and recruitment of juvenile fish. Wet or dry, either condition might be reflected in the pelican prey base when the immature fish matured. The timing would vary with the species. In the case of menhaden, which take three to four years to mature, wetter conditions would result in larger numbers of prey in three or four years (R. McMichael, K. Peters, B. Mahmoudi, pers. comm.)

During the period of our study we identified 1983 as the single year in which rainfall was well above normal (63.8" at Tampa
International Airport, 37% above normal). Four years later pelicans nested in large numbers throughout the Tampa Bay region (Table 2). (That four-year interval is likely fortuitous; a wet 1979 was not followed by a large nesting effort in 1983, and the huge nesting of 1989 was not preceded by a particularly wet 1985: see Fig. 8.) Vaughan et al. (1986) and others have warned of the difficulties inherent in attempts to detect changes in single year classes of menhaden. In any case, 1987 marked a continuing strong increase in pelican numbers in Tampa Bay.

We also identified a single period of unusual drought: 1989 through 1993. The Southwest Florida Water Management District described the period 1989-1992 as the second driest four-year period since 1915, when recordkeeping began. For all five years combined, total rainfall was 16% below normal with a cumulative rainfall deficit of 37.2". This period coincides with the pelican population crash that occurred in Tampa Bay and Charlotte Harbor. We suggest that prolonged drought conditions may well have affected the prey base of pelicans nesting in these two systems.

12. Nutrient Loading and Chlorophyll-a Concentrations

In 1979, the City of Tampa completed conversion of its wastewater treatment plant from primary to advanced wastewater treatment. This and other actions have been credited with achieving a 45% decline in nitrogen loadings to Hillsborough Bay in 20 years (Johansson 1991). By the mid-1980s chlorophyll-a concentrations also began to fall in every segment of Tampa Bay, with maximum reductions recorded in Hillsborough Bay (Johansson

All of this is good news for the system. It is possible, however, that nutrient reductions and water quality improvements in Tampa Bay have reduced the food supply available to menhaden and other bait fish on which pelicans depend. Recall that menhaden and several other preferred prey species are planktivorous, and that menhaden in particular are filter-feeders. It is plausible, and perhaps likely, that a 45% decline in phytoplankton may have affected the local prey base.

We compared trends of Tampa Bay chlorophyll-a concentrations and numbers of nesting pelicans (Fig. 9), and saw no correlation. We felt such an effect might be most easily seen if a part of the bay could be identified where chlorophyll-a levels were high, a large pelican colony were nearby, and direct counts were available. Hillsborough Bay, with the large Alafia Bank colony right there, was the choice. We compared Hillsborough Bay chlorophyll-a trends with nesting pelican populations at Alafia Bank alone (Fig. 10). There was clearly no correlation prior to 1990, but after 1990 the trends appeared closely correlated. Because the menhaden fishery was
localized in Hillsborough and Middle Tampa Bays (and near Alafia Bank) we then examined the relationship between Tampa Bay menhaden landings and chlorophyll-\(a\) concentrations (Fig. 11). Again, the correlation seemed most encouraging in the 1990-1993 period. But a regression of menhaden landings on chlorophyll-\(a\) levels for the period 1987-1994 (Fig. 12) was not significant (Pearson \(r=0.305\), \(r^2=0.10\), n.s.). However, separate regressions of Tampa Bay mullet (striped mullet \textit{Mugil cephalus}) landings and herring landings on chlorophyll-\(a\) levels (1979-1994) both indicated significant associations (Figs. 13 and 14). Since neither of these fisheries was as highly localized as the menhaden fishery (and the herring fishery was primarily offshore), this result was unexpected. Although mullet and herring are common in pelican diets, they are much less common than menhaden and it seems less likely that reductions in phytoplankton could limit pelican numbers by affecting those two prey species.

13. Commercial bait fish harvest

Commercial fishermen have long pursued some of the same species sought by pelicans: menhaden, mullet, thread herring, and Spanish sardine (Fig. 15). During the 1980s, sharply increased landings of menhaden and Spanish sardines were followed by the collapse of both fisheries after 1987, and soon after by the sudden drop in pelicans in 1990. Most dramatic was the collapse in menhaden landings (Fig. 16). On July 1, 1993 a ban on commercial purse-seining in Tampa Bay and within three miles of the coast went into effect. Less spectacular, but declining throughout the 1980s and
early 1990s, were mullet landings (Fig. 17). Most mullet netting now has also stopped with the enactment of a constitutional amendment that took effect July 1, 1995 banning most nets. (Since small gill nets and cast nets are still legal, one likely result will be that future catches will be unreported.)

Did overfishing cause not only the collapse of the menhaden and sardine fisheries -- and perhaps mullet too -- but also the 1989-1993 pelican decline? The data are not clear. By eye, there seems to be a correlation between total pelicans nesting in Tampa Bay and total baitfish landings for 1979-1994 (Fig. 18). Though the correlation is suggestive of a trend, it is not significant (Pearson $r=0.404$, $r^2=0.16$, $p=.12$). However, the regression of Alafia Bank pelican numbers on total baitfish landings for the same period is highly significant (Fig. 19; Pearson $r=0.691$, $r^2=0.48$, $p=.003$). (Can this statistical result be biologically meaningful? Total baitfish includes sardines and thread herring presumably caught in the Gulf, where they should be out of range of Alafia-based pelicans. Can they fly farther than we thought? Were the fish closer? Or was this a spurious statistical result?)

Because most mullet are caught during the fall roe season, mullet landings may represent an index of the prey base available for the next nesting season. We adjusted the mullet (brought them forward one year), and the correlation was even higher (Fig. 20; Pearson $r=0.756$, $r^2=0.57$, $p=.001$).

Next, we compared mullet landings to Alafia Bank nesting, 1979-1994. By inspection a possible correlation from 1990 to 1993 is suggestive, but overall there is no association (Pearson $r=-0.231,$
p = .23). Why then should a one-year "adjustment" to mullet have improved a correlation (Fig. 20)?

There remains the question of whether landings data can be used to reflect fish stocks in Tampa Bay. Because purse seiners use spotter planes to locate fish schools, the fish population can decrease to virtually zero and the landings data would still indicate a large catch per unit effort. Once an overfished stock begins to decline, landings may accurately indicate standing crop. But while fishing pressure is still relatively light and the stocks relatively large, landings data reveal little about the true population of the fish.

Can these disparate date provide a unified sense of a causal link between fish harvest and pelican nesting? Despite considerable "noise" inherent in the data on both pelican numbers and fish, there appear to be too many significant correlations to ignore. The challenge is in deciding which ones are biologically meaningful. We are led to conclude that pelican numbers, particularly at Alafia Bank, were affected by overfishing of menhaden and possibly mullet. We are less confident about impacts of apparent overfishing of sardines, since a vast stock apparently remains offshore (R. Nelson, pers. comm.).

Two other points remain to be noted before we finally conclude that overfishing was the primary factor in the sudden decline of pelicans nesting in Tampa Bay. First, pelicans are capable of prey-switching: shifting from a preferred prey species to one or more others in response to varying prey abundance, whether due to human or natural influence (e.g., Anderson and Gress 1984). So the birds are capable of buffering themselves against overfishing and
even the local "commercial extinction" of a favored prey species. Second, the same 42% decline occurred in Charlotte Harbor pelicans -- where no purse seining occurred.
CONCLUSIONS AND RECOMMENDATIONS

1. Despite recent, fairly substantial, short-term declines on the Gulf Coast, Brown Pelicans numbers in the three populations defined in this study are healthy, and stable or increasing in the last few years.

2. Tampa Bay and Charlotte Harbor populations exhibited similar population curves, suggesting the influence of climatic or other regional factors.

3. Several factors including red tides, human disturbance, predation, storms, freezes, chemical spills and dredging activity, are of legitimate concern but in this study were found to have had no long-term impact on pelican breeding populations.

4. The unprecedented "spike" in pelican numbers nesting in Tampa Bay in 1989 remains unexplained. Perhaps good conditions in 1989 followed a series of productive nesting seasons, resulting in a massive nesting effort. Perhaps also, Tampa Bay cannot sustain a population of 4000 pairs of pelicans. In any case, why the population grew so large - even temporarily - is as much a puzzle as what happened to it over the next four years.

5. The population decline occurring between 1989 and 1993 was probably caused by a complex interaction of overfishing, successful efforts to reduce nutrient loading in the bay, and climatic factors, including a long-term drought. In Charlotte Harbor, the absense of commercial purse-seining and more pristine nature of the system suggest that the mix of factors worked somewhat differently.

6. Several of the logical responses to the problem have already been carried out. Pressure on prey species has been reduced. Efforts to
restore the bay to a seagrass-based system continue. Nesting colonies continue to receive protection from agencies and volunteers. What remains is to continue or even improve monitoring of pelican nesting activity. One glaring need is to learn more about what pelicans eat, and how far they fly to feed.

7. Efforts to secure remaining natural shorelines and restore altered ones should continue. Special attention needs to be directed toward tidal creeks, which are vital nursery areas.

8. Seawalls need to be seen as what they are: convenient means of protecting upland property, perhaps, but a clear and present danger to the natural functions and values of shorelines. It is time to reverse the cumulative destruction of so many miles of Tampa Bay area shoreline. New alternatives that maintain or restore shoreline functions should be found, made known to the public, and promoted by regulatory agencies. Brown Pelicans, fish and many other organisms will benefit.
LITERATURE CITED


Figure 1. Brown Pelican nesting sites in the "Tampa Bay population."
Figure 2. Breeding populations of brown pelicans in Florida, 1970-1995.
Figure 3. Breeding populations of Brown Pelicans in the Southeastern States, 1970-1994, with updates from P. Mikkelsen and M. Golden, pers. comm.
Figure 4. Breeding populations of brown pelicans in Tampa Bay, 1968-1995.
Figure 5. Breeding populations of brown pelicans in Charlotte Harbor, 1968-1995.
Figure 6. Breeding Populations of three Florida areas, compared.
Figure 7. Breeding Populations of Brown Pelicans on the Atlantic Coast of Florida, 1968-1985.
Figure 9. Brown Pelican numbers in relation to chlorophyll-a, 1974-1995, Tampa Bay.
Figure 11. Tampa Bay Menhaden Landings in Relation to Hillovernich
Figure 12. Tampa Bay Menhaden Landings in Relation to Hillsborough Bay Chlorophyll-a, 1987-1994.

\[ r = 0.305, F = 0.10, p < 0.05 \]

BAITFISH LANDINGS, pounds

MENHADEN

HB CHLOROPHYLL AND BAITFISH LANDINGS
Figure 13. Tampa Bay Mullet landings in relation to chlorophyll-a.

BAITFISH LANDINGS, pounds
(Millions)

TB CHLOROPHYLL AND BAITFISH LANDINGS

Pearson r = 0.552
p < 0.05

r² = 0.32
Figure 14. Tampa Bay Thread Herring Landings in Relation to Chlorophyll-a, 1976-1994.
Figure 15. Tampa Bay freshwater landings, 1978-1994 (menhaden, sardines, thread herring, mullet).
Figure 16. Tampa Bay Menhaden Landings, 1979-1994.
Figure 17. Tampa Bay black mullet landings, 1978-1994.
Spanish Sardines.

Figure 18. Tampa Bay pelican nesting in relation to total battfish

Spanish Sardines, 1978-1995 (menhaden, thread herring, mullet,

PAIRS - BATTISH

BATFISH LANDINGS (pounds)

YEAR

BAITFISH LANDINGS, PERIODS

TAMPA BAY BROWN FELICAN BREEDING PAIRS

0000

0000

0000

0000
Figure 19. Alafia Bank Pelican nesting in relation to Tampa Bay,

*NESTS* vs. *BAYISH*

- BAYISH LANDINGS, pounds
- ALAFIA BANK BAYISH LANDINGS AND BROWN PELICAN NESTS
1979-1994. Baltic herring stocks (with mullet at least one year - see text).

Figure 20. Alafia Bank pelican nesting in relation to Tampa Bay.

<table>
<thead>
<tr>
<th>TAMPAMAY BALTICHI HERRING (ADJM)</th>
<th>LANDINGS, POUNDS (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>18</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>22</td>
<td>140</td>
</tr>
</tbody>
</table>

Pearson r = 0.756

r^2 = 0.57

p = 0.001
Figure 21. Alaska bank pelican nesting in relation to Tampa Bay.

- NESTS
- MULLET

YEAR

MULLET LANDINGS, MILLION

BROWN PELICAN NESTS

TAMPA BAY BLACK MULLET LANDINGS

ALASKA BANK BROWN PELICAN NESTS AND
Table 1. Brown Pelican nesting colonies included in Tampa Bay and Charlotte Harbor populations, and current status.

**Tampa Bay**

<table>
<thead>
<tr>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozona</td>
<td>Active; new in 1995</td>
</tr>
<tr>
<td>Dunedin Isles (a.k.a. Sand Keys)</td>
<td>Vacant; new in 1986</td>
</tr>
<tr>
<td>Clearwater Pass (a.k.a. I-25)</td>
<td>Active; new in 1991</td>
</tr>
<tr>
<td>Indian Rocks Beach (incl. Belleair Beach)</td>
<td>Active</td>
</tr>
<tr>
<td>Johns Pass</td>
<td>Active</td>
</tr>
<tr>
<td>Tarpon Key</td>
<td>Active</td>
</tr>
<tr>
<td>Coffeepot Bayou</td>
<td>Active; new in 1994</td>
</tr>
<tr>
<td>Alafia Bank</td>
<td>Active</td>
</tr>
<tr>
<td>Terra Ceia Bird Key (a.k.a. Washburn Sanct.)</td>
<td>Active</td>
</tr>
<tr>
<td>Sneads Point (a.k.a. Washburn Jr.)</td>
<td>Vacant (1991 only)</td>
</tr>
<tr>
<td>Dot-Dash</td>
<td>Active; new in 1986</td>
</tr>
<tr>
<td>Passage Key</td>
<td>Active; new in 1986</td>
</tr>
<tr>
<td>Cortez</td>
<td>Active</td>
</tr>
</tbody>
</table>

**Charlotte Harbor**

<table>
<thead>
<tr>
<th>Location</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasparilla Pass</td>
<td>Active</td>
</tr>
<tr>
<td>Broken Islands</td>
<td>Active</td>
</tr>
<tr>
<td>Useppa Bird Key</td>
<td>Active</td>
</tr>
<tr>
<td>Hemp Key</td>
<td>Active</td>
</tr>
<tr>
<td>Matlacha Pass</td>
<td>Active</td>
</tr>
<tr>
<td>Bird Island</td>
<td>Active</td>
</tr>
<tr>
<td>Carlos Pass</td>
<td>Vacant</td>
</tr>
<tr>
<td>Caloosahatchee NWR</td>
<td>Active</td>
</tr>
<tr>
<td>McKeever Key</td>
<td>Vacant</td>
</tr>
<tr>
<td>Tarpon Bay Keys</td>
<td>Active</td>
</tr>
</tbody>
</table>


Table 2. Brown Pelican numbers in the Tampa Bay population, 1985-1995.

<table>
<thead>
<tr>
<th></th>
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</tr>
</tbody>
</table>


- Causey Key
- Passage Key
- Dool-Dash
- Washburn Jr.
- Washburn
- Alafia Bank
- College Point Bayou
- Tarpon Key
- Johns Pass
- Indian Rocks Beach
- Clearwater Pass
- Dunedin Islands
- Ozoona

First documented nesting at this site.

*2 Pelicans nested at this site in one year only.
Table 3. Diet of Brown Pelicans in Florida.

a. Regurgitated samples (n=304) from 13 colonies on both coasts, 1970-1972 (from Fogarty et al. 1981)

<table>
<thead>
<tr>
<th>Family</th>
<th>Common Names</th>
<th># Fish</th>
<th>% of Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clupeidae</td>
<td>menhaden, sardines</td>
<td>129</td>
<td>29.0</td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>trout, spot, croakers</td>
<td>95</td>
<td>21.3</td>
</tr>
<tr>
<td>Polynemidae</td>
<td>threadfins</td>
<td>57</td>
<td>12.8</td>
</tr>
<tr>
<td>Mugilidae</td>
<td>mullet</td>
<td>52</td>
<td>11.7</td>
</tr>
<tr>
<td>Sparidae</td>
<td>pinfish</td>
<td>43</td>
<td>9.7</td>
</tr>
<tr>
<td>Engraulidae</td>
<td>anchovies</td>
<td>27</td>
<td>6.1</td>
</tr>
<tr>
<td>Pomadasyidae</td>
<td>pigfish, grunts</td>
<td>9</td>
<td>2.0</td>
</tr>
<tr>
<td>Cyprinodontidae</td>
<td>killifish</td>
<td>8</td>
<td>1.8</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>25</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>445</td>
<td>100.0</td>
</tr>
</tbody>
</table>

b. Regurgitated samples (n=28) from Alafia Bank, 1990 (B. Ploger, unpbl. data)

<table>
<thead>
<tr>
<th>Family</th>
<th>Common Names</th>
<th># Fish</th>
<th>% of Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clupeidae</td>
<td>menhaden</td>
<td>35</td>
<td>47.3</td>
</tr>
<tr>
<td>Cyprinodontidae</td>
<td>killifish</td>
<td>13</td>
<td>17.6</td>
</tr>
<tr>
<td>Engraulidae</td>
<td>anchovies</td>
<td>7</td>
<td>9.5</td>
</tr>
<tr>
<td>Sparidae</td>
<td>pinfish</td>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>Sciaenidae</td>
<td>trout, drum</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>Mugilidae</td>
<td>mullet</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>Other + unknown</td>
<td></td>
<td>12</td>
<td>16.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>74</td>
<td>100.1</td>
</tr>
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### Basic Features and Advantages

<table>
<thead>
<tr>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Data were more accurate, to avoid the question of arbitrary allocation of data.</td>
<td></td>
</tr>
<tr>
<td>Coloney may not be highly synchronized (e.g., 1983).</td>
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<tr>
<td>Breeding populations (e.g., 1983).</td>
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</tr>
<tr>
<td>Misses peak nesting activity if not underestimated.</td>
<td></td>
</tr>
<tr>
<td>Surveys must be conducted in advance, if a survey.</td>
<td></td>
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<tr>
<td>Substantial, even for large birds like pelicans.</td>
<td></td>
</tr>
<tr>
<td>The amount of error inherent in aerial estimates is.</td>
<td></td>
</tr>
<tr>
<td>1. Game Commission Aerial Surveys</td>
<td></td>
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</table>

### Advantages

<p>| | |</p>
<table>
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<tr>
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</tr>
<tr>
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<tr>
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<td>Surveys must be conducted in advance, if a survey.</td>
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</tr>
<tr>
<td>The amount of error inherent in aerial estimates is.</td>
<td></td>
</tr>
<tr>
<td>1. Game Commission Aerial Surveys</td>
<td></td>
</tr>
</tbody>
</table>

### Appendix I. Evaluation of the Data Sets.

- Breeding colonies routinely performed throughout area to

- Replicate counts ensure peak nesting effort is detected.

- Some counts of smaller colonies were conducted after

- Nest counts found more efficiently than by hand.

- Most colonies not all nests visible from boat.

- In one season.

- Incomplete coverage: all colonies were rarely visited.

- Direct nest counts, not estimates, since 1973.

- National Audubon Society Surveys.

- If small colonies are missed, they are added to surveys.

- Substantial error for large birds like pelicans.

- The amount of error inherent in aerial estimates is.

<table>
<thead>
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<tbody>
<tr>
<td>2. Chlorophyll-a monitoring (Hillsborough Co. EPC and City of Tampa Bay Study Group)</td>
</tr>
<tr>
<td>3. Fl. Marine Research Institute Fish Stock Assessments (not used)</td>
</tr>
<tr>
<td>4. No data for years before major pecan decline.</td>
</tr>
</tbody>
</table>

- Lines indicate fishing effort more than fish stocks, since they use spotter
- Data for fish caught by purse seine may reflect fishing
- Accuracy depends on the fishermen who are reporting
- Most comprehensive data available on fish stocks.
- Data don't really estimate fish stocks. They indicate the size of the catch.
APPENDIX 2. ASSAYS OF NESTING PRODUCTIVITY

There are three general approaches to assessing nesting productivity in pelicans, as follows:

1. True nesting success, or number of young per active nest.

   For a number individually marked nests, nest contents are checked on a frequent basis and the number of young fledging from each nest is known. Ideally, this equates to the number of young fledged per breeding pair per year. Because some pairs fail and then renest, in practice the data reflect the number of young per nesting attempt (or per active nest). Schreiber (1979) estimated that production of one young per pair per year was enough to maintain a stable population. Schreiber also pointed out, quite correctly, that this is the most accurate, time-consuming, and potentially disruptive method of monitoring nesting success.

2. Brood counts, or number of young per successful nest.

   Single or replicate counts can be made of the number of young seen in nests. Nests of very small young are omitted, because it is difficult to see all nestlings. Large young near fledging age may not stand together, so broods of 2 young may be erroneously scored as 2 broods of 1 young. This method clearly does not reflect nesting failures, because only young are counted (Schreiber 1979), but observers can work more quickly, visit more colonies, and avoid all disturbance.
Brood count data are not directly comparable to measures of "true" productivity as outlined above. During 8 field seasons at Tarpon Key, Schreiber found the difference between the two measures to vary sharply. His comparisons were limited by small sample sizes (mean=26.7 nests, range=10-67), but when the data for all 8 years were combined he found that 1.0 young per total nest equated to about 1.5 young per successful nest (=brood size).

Since 1973, National Audubon staff have used brood counts as a convenient index of pelican nesting success at both Sanctuary colonies and others in the region. In general, normal nesting success is reflected by brood counts ranging from 1.3 to 1.7. Brood counts around 1.2-1.25 are borderline poor, and may or may not be associated with high rates of nesting failure. Brood counts below 1.2 reflect poor nesting, and below 1.1, disastrous. Throughout the 1980s, pelicans in Tampa Bay enjoyed normal to excellent nesting success.

3. Counts of adults and fledged young after nesting is completed.

Schreiber and Schreiber (1983) suggested a series of monthly counts following nesting to determine the relative proportions of adults and immatures. They found that these proportions accurately reflected nesting success but cautioned that counts over relatively large areas of coastline were needed. No nesting birds were disturbed, an advantage. We have reservations about this method because of the potential for differential seasonal movements of immatures and young to skew the results.
APPENDIX 3. MAJOR "EVENTS" THAT POTENTIALLY AFFECTED BROWN PELICAN NESTING IN TAMPA BAY, 1974-1995.

1. Severe Freezes/Warm weather


12 Jan 1982  low of 24°, browned some mangroves but no major mortality.

25-26 Dec 1983  low of 19°, below freezing for 10.5 and 18.5 hours.

21-22 Jan 1985  low of 22°, below freezing for 6.5 and 10.0 hours.

23-25 Dec 1989  lows of 28°, 24°, and 26°, below freezing for 17 and 15 hours the first two nights.

March-May 89  record-breaking warm weather.

Nov 90-Jan 91  record-breaking warm weather.

2. Storms, Floods, Rainfall, Drought

18 June 1982  "No-name storm"; winds to 60-90 mph and tides approx 5 feet above normal.

1983  Total precipitation at TIA = 63.8", 37% above normal.

24 March 1983  Strong low pressure area incl. severe thunderstorms and hail; winds to 65 mph and tides to near "No-name" storm levels.

31 Aug-2 Sept 1985  Hurricane Elena; winds to 50-60 and tides approx 5 feet above normal.

March 1987  12.01" at TIA (normal = 3.46"), at least 9" between 26th and 31st. (Gardinier recorded 14" in the same period).

September 1988  13.56" at TIA (normal = 6.23"), up to 18" elsewhere in area.

1989-1992  According to SWFWMD, this was the 2nd driest 4-year block since 1915, when recordkeeping began.

13 March 1993  "Storm of the Century"; extreme low barometric pressure; winds to 90 mph, tides to 5-6 feet above normal. Severe erosion. At Alafia Bank, 60% of 280 pelican nests were lost.
3-5 June 1995 Hurricane Allison grazes Tampa Bay area. Winds to ca. 50 mph, 3-4 foot tides.

3. Red tides

Feb-Mar 1974 Major episode; penetrated Tampa Bay more than most red tide events.

(numerous mild episodes since 1980)

4. Chemical spills

28 July 1979 Oil spill at Gardinier dock - 5000 gallons of bunker C fuel oil. Mostly contained; about a dozen oiled birds (esp. cormorants) retrieved. Fledgling pelicans at Alafia escaped impact.

28-31 March 1987 13.8 million gallons of acid water (pH=1.9) discharged into Archie Creek by Gardinier.

2-3 May 1988 4000 tons of phosphoric acid spilled into Gardinier turning basin, Alafia River. Fish kill.

10 Aug 1993 Oil spill off Ft. DeSoto; 330,000 gallons of #6 fuel oil. Slick drifted into Gulf, blown ashore at Johns Pass. 296 oiled pelicans recovered; several dozen more were not retrieved.

5. Raccoons in colonies


Washburn Tracks found 1990 and colony destroyed/abandoned; 6 animals trapped and removed and no further indication of presence noted until May 1994. One removed May 1994, 1 Mar. 1995; tracks found May 1995 but animal not captured.


Passage Key none

Tarpon Key none

(other colonies - no information)
6. Wastewater Treatment plants

Howard F. Curran Wastewater Treatment Plant (City of Tampa) comes on line January 1979 (advanced wastewater treatment, 60 mgd).

7. Dredging events

1977-1979 - Construction of Alafia Extension, Fantasy Island and 2D
1981-1983 - Construction of 3D
1977-ca. 1984 - Duration of Tampa Harbor Deepening Project

8. El Nino/Southern Oscillation Events

1982-83 Strongest one ever studied
1986-87 A weaker one
1991-94 Weak but prolonged