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Status and Trends of Colonially–Nesting Birds in Barnegat Bay

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ABSTRACT

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Population trends of several species of birds that nest colonially were examined in Barnegat Bay by either yearly census from 1976 to 1999 (common tern *Sterna hirundo*, Forster's tern *Sterna forsteri*, black skimmer *Rynchops niger* and herring gull *Larus argentatus*), or by aerial surveys in 1977, 1978, 1979, 1983, 1985, 1989 and 1995 (all other species). Yearly censuses show a significant decline in the number of colonies of common terns and black skimmers, and a significant increase in the number of herring gull colonies, although the adult numbers of herring gulls declined from 1976 to 1999. The aerial surveys indicated a significant decline in the number of adult snowy egrets (*Egretta thula*) and least terns (*Sterna antillarum*) from 1977 to 1995, as well as a significant decline in the number of colonies of least terns. There was an increase in the number of colonies and adult great black-backed gulls (*Larus marinus*), and an increase in the number of colonies of great egret (*Casmerodius albus*), black-crowned night herons (*Nycticorax nycticorax*), and glossy ibis (*Plegadis falcinellus*). The overall decline in the number of active colonies of a number of species is disturbing, and leads to consideration of management options to increase suitable nesting places. Reducing human disturbance, the deposition of dredge spoil, and vegetation removal are the most promising management techniques, along with judicious predator control (including herring and great-black backed gulls) on isolated nesting islands.

ADDITIONAL INDEX WORDS: *New Jersey, herons, egrets, ibises, terns, gulls, skimmers, population declines, predation, competition.*

INTRODUCTION

Coastal ecosystems differ from many other types of habitats in that they are the interface between continents and the open ocean. They form thin, longitudinal habitats that are influenced by tidal phenomena, the temperature moderating effects of the oceans which act as a heat sink, and oceanic storms, such as hurricanes, cyclones, and typhoons (BURGER, 1991). Within the narrow strip of estuaries and bays, there is a mosaic of habitat patches of various sizes and shapes, and landward the saline conditions change rapidly within a short distance.

Estuaries are highly productive photosynthetically (FLEMER *et al.*, 1978; HARDISKY *et al.*, 1983), as well as being nurseries for invertebrates and macrofauna such as crabs and fish (SKENKER and DEAN, 1979; ROZAS and ODUM, 1987). As the interface between the land and the sea, coastal ecosystems are particularly critical for a wide range of birds. These habitats have the advantage that birds can reach vastly different habitats by flying only a few kilometers inland or out to sea (BURGER, 1991). Some groups of species breed, forage, migrate, and overwinter in coastal environments, whereas others use them only for foraging, during migration, or during the winter.

Bays and estuaries, such as Barnegat Bay, provide birds with the necessary resources for survival, including sufficient foods for themselves and their offspring, suitable habitat for breeding or foraging, and safety from environmental hazards such as inclement weather, ground predators, contaminants, and human disturbance. Although barrier islands and estuarine islands have traditionally provided some protection from predators, with increased human use of these islands, predator risk has increased in these habitats (BURGER and GOCHFELD, 1991), as has human disturbance (BURGER *et al.*, 1995; KNIGHT and COLE, 1995; LIDDLE, 1997). The increase in the number of personal watercraft has also negatively impacted some birds, particularly common terns (BURGER, 1988, 2001).

Barnegat Bay supports some of the largest and most diverse breeding colonies of birds in New Jersey, as well as along the Atlantic coast. New Jersey is the center of the breeding population for laughing gulls (BURGER, 1996), and it contains healthy nesting populations of other gulls, terns, skimmers, herons, egrets and ibises. During the winter, a wide range of ducks and brant (*Branta bernicula*) pass through or overwinter. It is important to maintain suitable habitats for nesting, migrating, and overwintering for this diversity of birds, and to reduce conflicts with humans wherever possible, because these populations are a critical component of New Jersey's biodiversity (BURGER, 1991; JENKINS, 1997).

In this paper, we present data on population trends of birds nesting in Barnegat Bay over a 24-year period (1976–1999). We are particularly interested in population trends during the 1990s and in the number of active colony sites. We conducted our studies using two methods: ground surveys of nesting birds conducted every year for some species, and aerial surveys conducted at irregular intervals. We also suggest management strategies to preserve healthy breeding populations.

NESTING ASSEMBLAGES

Twenty species of colonial waterbirds nest in Barnegat Bay and Little Egg Harbor (Table 1). These include ten species of herons, egrets and ibises, three species of gulls, six species of terns, and the black skimmer. Three species of terns (Roseate tern, gull-billed tern, caspian tern) are sufficiently rare as breeding birds that we do not consider them here. Although green-backed herons and great blue herons are common as foraging birds in the bays, they do not normally nest in the heronries surveyed, and are not considered further. Yellow-crowned night-herons are an infrequent breeding species.

Table 1. *Colonial waterbirds of the Barnegat Bay-Little Egg Harbor Estuary.*

Gulls, Terns, and Skimmers	Long-legged Wading Birds
least tern (*Sterna antillarum*, E)	great egret (*Casmerodius albus*)
common tern (*Sterna hirundo*)	snowy egret (*Egretta thula*)
Forster's tern (*Sterna forsteri*)	cattle egret (*Bubulcus ibis*)
roseate tern (*Sterna dougalli*)	great blue heron (*Ardea herodias*, T)
Caspian tern (*Sterna caspia*)	green-backed heron (*Butorides striatus*)
gull-billed tern (*Sterna nilotica*)	little blue heron (*Egretta caerulea*, T)
laughing gull (*Larus atricilla*)	tri-colored heron (*Egetta tricolor*)
herring gull (*Larus argentus*)	black-crowned night-heron (*Nycticorax nycticorax*)
great black-backed gull (*Larus marinus*)	yellow-crowned night-heron (*Nycticorax violaceus*, T)
black skimmer (*Rhynchops niger*, E)	glossy ibis (*Plegadis falcinellus*)

(E) = State endangered. (T) = State threatened.

In general, the heronries are located on islands that are high enough to have *Iva* and *Baccharis* bushes that provide some structure for nesting. They also nest in the high places with poison ivy (*Rhus toxicodendron*) and cherry (*Prunus* spp.). In many cases, these islands also contain *Phragmites*, where the glossy ibis and black-crowned night herons sometimes nest. The birds nest in the dense vegetation where they are not usually visible from the edge of the island. The poison ivy serves as a deterrent to human disturbance.

The gulls, in contrast, usually nest on islands where they have visibility of approaching danger. They nest in habitats with *Spartina patens* and *S. alterniflora*, although they prefer to nest in the higher regions, often near *Iva* or *Baccharis* bushes. Great black-backed gulls select their nest sites the earliest in the season, and pre-empt the highest places, whereas herring gulls usually are on territory two weeks later. Laughing gulls arrive four to six weeks after the larger gulls, and are left

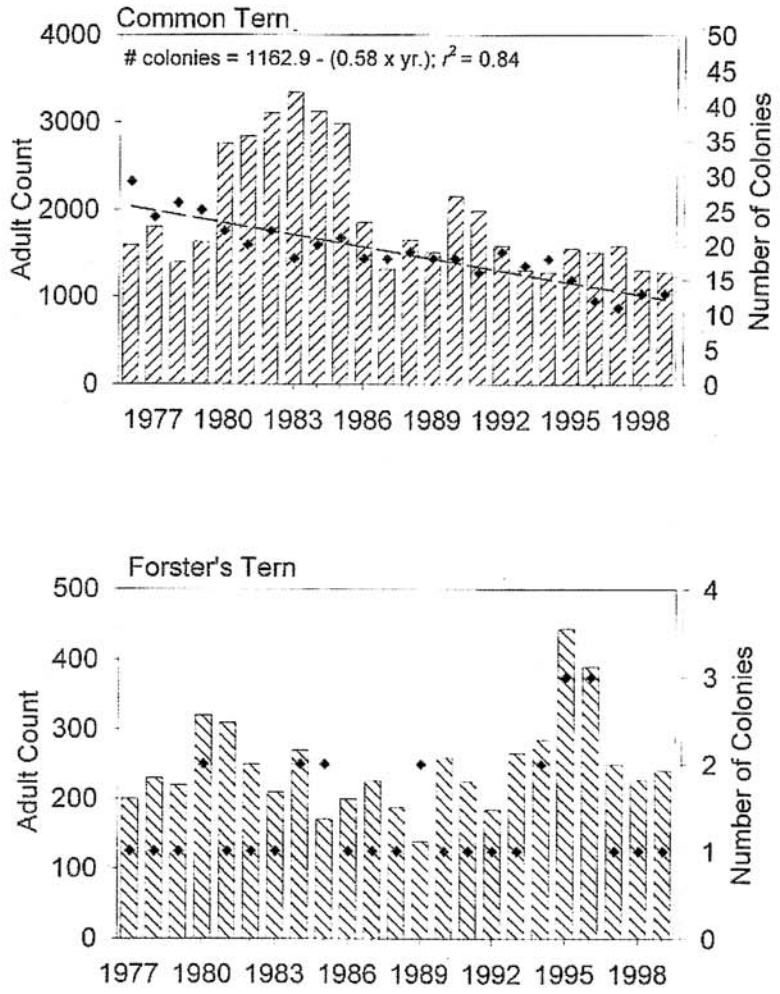


Figure 1. Adult counts and number of colonies for common and Forster's terns. Shown are adult counts (bars), number of colonies (black triangle), count versus year regression (solid line), and number of colonies versus year regression (dotted line).

with the lower *Spartina* regions of islands (BURGER, 1996).

The terns and skimmers generally nest on lower islands or at the edges of islands occupied by gulls, although success can be low because the larger gulls are predators on their eggs and chicks (BURGER and GOCHFELD, 1990a). On salt marsh islands, black skimmers always nest on small patches of sand or on eelgrass (*Zostera*) wracks, and they do not nest much farther north than Barneget Inlet. The common terns nest on wrack or on both species of *Spartina* (BURGER and GOCHFELD, 1991). Forster's terns only nest on islands near unditched marshes that have small salt marsh pools, and thus they are limited to the southern regions of Barnegat Bay. Least terns only nest on sandy areas of islands or barrier beaches (BURGER and GOCHFELD, 1990b).

Some islands (such as NW Lavalette) have a heronry on the higher ground, herring and great black-backed gulls on the *Spartina*, and common terns on the wracks on the edges of the island. This is relatively rare, however, since the larger gulls prey on the eggs and chicks of the terns.

Table 2. *Adult counts and number of colonies of colonial birds in Barnegat Bay.*

Species	Most Recent Adult Count[1]	Average Adult Count[2] (95% c.i.)	Adult Count Trend[2] Trend Direction	F	P	r^2	Most Recent No. of Colonies[1]	Average No. of Colonies[2] (95% c.i.)	No. of Colonies Trend[2] Trend Direction	F	P	r^2
Black Skimmer	440	921.8 (140.8)	ns	0.06	0.81	0.00	6	8.8 (1.1)	ns	2.49	0.13	0.10
Least Tern	0	663.9 (115.1)	↓	7.59	0.01	0.26	0	4.0 (0.83)	↓	38.52	<0.01	0.65
Common Tern	1,289	1,941.9 (288.9)	↓	5.89	0.02	0.21	13	18.8 (1.9)	↓	116.04	<0.01	0.84
Forster's Tern	241	244.5 (29.4)	ns	2.41	0.13	0.10	3	2.0 (0.3)	ns	1.49	0.24	0.06
Laughing Gull	929	6,730.7 (3,143.2)	ns	0.79	0.42	0.14	15	13.9 (5.1)	ns	1.44	0.28	0.22
Herring Gull	2,100	3,758.5 (556.1)	↓	13.07	<0.01	0.37	29	31.3 (2.6)	↑	16.18	<0.01	0.42
Great Black-backed Gull	482	161.3 (139.1)	↑	24.72	<0.01	0.83	29	17.9 (6.9)	↑	27.85	<0.01	0.85
Great Egret	139	86.4 (42.57)	ns	5.29	0.07	0.51	8	5.4 (1.68)	↑	24.22	<0.01	0.83
Snowy Egret	116	330.9 (135.1)	↓	49.76	<0.01	0.91	6	6.4 (1.30)	ns	0.59	0.48	0.11
Little Blue Heron	43	43.9 (19.59)	ns	0.43	0.54	0.08	6	4.3 (1.98)	ns	1.96	0.22	0.28
Tri-colored Heron	26	41.0 (12.84)	ns	0.32	0.60	0.06	4	3.7 (0.70)	ns	0.17	0.69	0.03
Black-crowned Night-heron	44	94.3 (62.29)	ns	3.09	0.14	0.38	10	7.3 (1.66)	↑	12.21	0.02	0.71
Yellow-crowned Night-heron	16	6.0 (8.43)	np	—	—	—	5	1.6 (1.92)	np	—	—	—
Glossy Ibis	15	142.6 (136.85)	ns	1.55	0.27	0.24	7	5.1 (1.96)	↑	8.04	0.04	0.62
All long-legged wading birds combined	442	775.4 (317.2)	↓	5.07	0.07	0.50	15	9.7	↑	41.99	<0.01	0.89

[1] For black skimmer, least tern, common tern, Forster's tern and herring gull, most recent count was 1999. For all other species, most recent count was 1995.

[2] For black skimmer, common tern, Forster's tern and herring gull: $n = 24$ (1976–1999, inclusive); least tern: $n = 23$ (1977–1999, inclusive); all other: $n = 7$, survey years = 1977, 1978, 1979, 1983, 1985, 1989 and 1995.

ns = not significant ($P > 0.10$).

np = trend analysis not performed due to infrequent occurrence in study area.

METHODS

The status of nesting colonial birds in Barnegat Bay was examined using two methods: ground censusing every year from 1976 to 1999, and aerial censusing in 1977, 1978, 1979, 1983, 1985, 1989 and 1995. Within each survey type, methodology was the same from year to year. Surveys included herons, egrets and ibises, gulls and terns, and skimmers.

Ground surveys were conducted from 1976 to 1999 for herring gulls, black skimmers, common terns, Forster's terns, and least terns, recording the number of breeding adults on each island from the north end of the bay to Tow Island in the south. Common terns (a species of special concern) and black skimmers (endangered) were examined because there are many colonies in Barnegat Bay, and they are of special conservation concern for New Jersey (BURGER and GOCHFELD, 1990a). Forster's terns were examined because they occur in only one set of islands at the southern end of the bay, and the gulls were examined because of their dynamic range expansion, and their predation and competition with the smaller species (BURGER, 1979). To understand population dynamics of these species, it is necessary to census the breeding population on each salt marsh island several times a summer. Because the censused area is 80 km long, censuses were often conducted along half

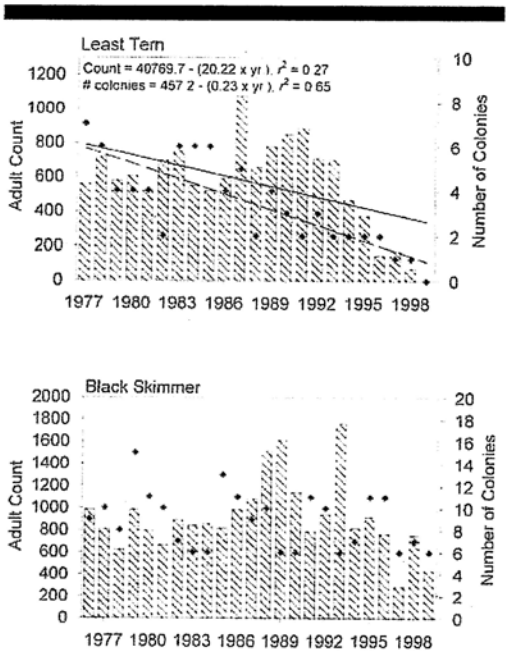


Figure 2. Adult counts and number of colonies for least tern and black skimmer. Shown are adult counts (bars), number of colonies (black triangle), count versus year regression (solid line), and number of colonies versus year regression (dotted line).

of the bay one day, and the remainder the next. Herein we present the adult counts for the census day each year that had the highest number of adults for the entire bay, not the individual colony high counts, since birds could move between colonies. We report individuals, not pairs.

Ground surveys, conducted by boat, involved checking all the salt marsh islands in Barnegat Bay, from the Lavalette Islands south to Tow Island. It usually required two days to make the entire run of the bay. An adult count was made about 10–20 m from the shore when the birds were first disturbed from the colony. The two or three people in the boat each made an independent count of the number of adults, and counts were usually within five birds of one another. We then entered the colony and counted all nests of each species. The entire bay was censused four or more times during each nesting season.

Aerial surveys, conducted from a helicopter as part of New Jersey's Endangered and Nongame Species Program, included all other species. All surveys were conducted from a Bell Jet Ranger helicopter flying at altitudes ranging from 30 to 100 m above ground level. Maps with the previous survey results were used to guide the search for nesting birds and to plot results. Each flight had three observers who directed the pilot, located colonies, counted birds, and recorded data. Birds were counted by circling slowly (or hovering) near the colony, and all adults were counted. Counts were taken in 1977, 1978, 1979, 1983, 1985, 1989, and 1995, partly as a function of the availability of funds. All species not counted annually by ground are examined with the aerial survey data.

For analysis, we applied a simple linear regression of the total adult count for each species over time. We used the F test to determine the fit of each model (ZAR, 1984). We accept a significance level of 0.10 because of the inherent population variability of colonial birds, and the severe management consequences of not recognizing a decline when one actually exists (O'CONNOR and DEWLING, 1986; BURGER *et al.*, 1994).

This paper represents a synthesis of data we have gathered over many years, and earlier accounts can be found in BURGER (1997), BURGER and GOCHFELD (1990a, 1991), and JENKINS (1997).

RESULTS

Common Terns, Forster's Terns, Black Skimmers, and Herring Gulls

Population trends of common terns, Forster's terns, least terns, black skimmers, and herring gulls were determined with annual ground surveys. The number of these species is based on adult counts and nest counts during the peak of nesting. Herring gulls and common terns are the most abundant nesting larids in Barnegat Bay, and both species nest in a large number of colonies.

The number of adult common terns breeding in Barnegat Bay fluctuated from about 1,500 to 3,000 individuals, although the number has remained at the lower end of the range for the last six years (Figure 1). The number of adults increased in 2000 and 2001 (BURGER, unpublished data). The number of adults and colonies of common terns has decreased significantly over the years (Figure 1, Table 2). The abundance of Forster's terns has remained relatively stable, with no change in the number of adults or colonies (Figure 1, Table 2). Least terns, a State endangered species, have suf-

Table 3. *Recent population trend data for colonial birds in Barnegat Bay.*

Species	"Recent"[1] Adult Count Trend				"Recent"[1] No. of Colonies Trend			
	Trend Direction	F	P	r^2	Trend Direction	F	P	r^2
Black Skimmer	↓	4.17	0.08	0.34	ns	0.44	0.53	0.05
Least Tern	↓	187.65	<0.01	0.96	↓	27.08	<0.01	0.77
Common Tern	↓	8.18	0.02	0.51	↓	14.91	0.01	0.65
Forster's Tern	ns	0.22	0.65	0.03	ns	0.19	0.68	0.02
Laughing Gull	ns	7.50	0.22	0.88	ns	0.09	0.81	0.08
Herring Gull	↓	24.04	<0.01	0.75	↓	5.90	0.04	0.42
Great Black-backed Gull	ns	16.82	0.15	0.94	ns	1.72	0.42	0.63
Great Egret	ns	1.26	0.46	0.56	ns	0.55	0.59	0.36
Snowy Egret	↓	80.08	0.07	0.99	↓	75.00	0.07	0.99
Little Blue Heron	ns	2.62	0.35	0.72	ns	0.96	0.51	0.49
Tri-colored Heron	ns	28.83	0.12	0.97	ns	0.01	0.93	0.01
Black-crowned Night-heron	ns	3.13	0.33	0.76	ns	10.08	0.19	0.91
Yellow-crowned Night-heron	np	—	—	—	np	—	—	—
Glossy Ibis	ns	1.61	0.43	0.62	ns	1.82	0.41	0.65
All long-legged wading birds combined	ns	0.73	0.55	0.42	ns	1.82	0.41	0.65

[1] For black skimmer, common tern, Forster's tern, least tern and herring gull: n = 10 years (1990–1999, inclusive) all others: n = 3 survey years: 1985, 1989 and 1995.
ns = not significant (P < 0.10).
np = trend analysis not performed due to infrequent occurrence in study area.

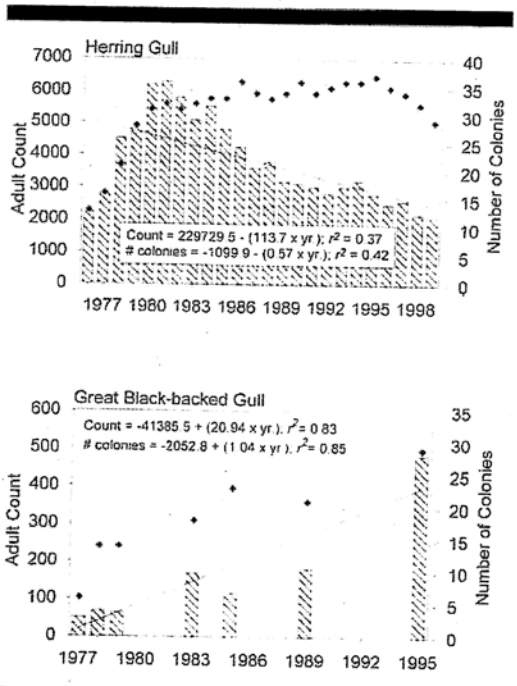


Figure 3. Adult counts and number of colonies for herring and great black-backed gull. Shown are adult counts (bars), number of colonies (black diamond), count versus year regression (solid line), and number of colonies versus year regression (dotted line).

fered a significant decline both in the number of adults and colonies (Figure 2, Table 2).

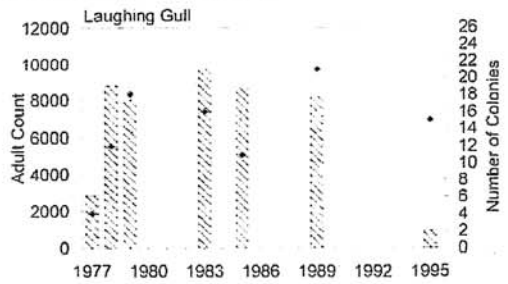
The abundance of adult black skimmers has also fluctuated, but has declined drastically since 1990 (Figure 2, Table 3). The number of colonies has also fluctuated (Figure 2), with no overall trend. The fluctuations appear cyclic, with peaks every 5–6 years.

The number of adult herring gulls has likewise fluctuated (Figure 3). The herring gulls increased markedly during the late 1970s and early 1980s, and declined significantly thereafter (Table 2). Both the number of adults and colonies showed significant declines in the last ten years (Table 3).

Other Gulls and Terns

The survey data for the other gulls and terns are presented in Table 2. We present the most recent adult counts, the average adult counts for 1977–1995, the most recent colony counts, and the average number of colonies per year.

Great black-backed gulls nested in a large number of colonies, although their abundance was relatively low. Overall, they showed a significant increase in both the number of colonies and adults during the entire period (Table 2, Figure 3). However, the increase occurred early in the period, and there was no significant trend over the last ten years (Table 3). Although laughing gulls did not



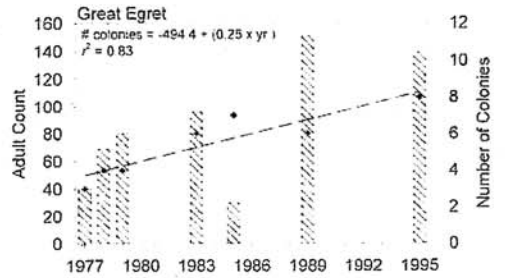
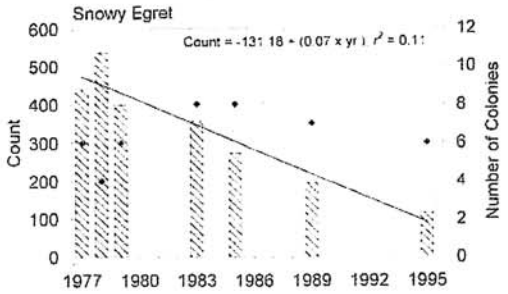


Figure 4. Adult counts and number of colonies for laughing gull and great egret. Shown are adult counts (bars), number of colonies (black diamond), and for egret count versus year regression (solid line), and number of colonies versus year regression (dotted line).



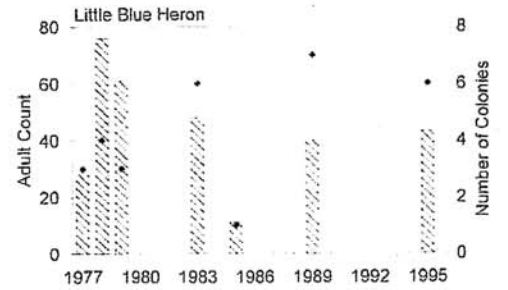


Figure 5. Adult counts and number of colonies for snowy egret and little blue heron. Shown are adult counts (bars), number of colonies (black diamond), and for snowy egret count versus year regression (solid line).

display a significant decline in either the adult or colony counts over the entire sampling period (Figure 4), the laughing gull count for 1995 was remarkable because it was seven times lower than the mean annual adult count for 1977–1995 (Table 2). Laughing gulls began to increase in 2001 (BURGER, unpublished data).

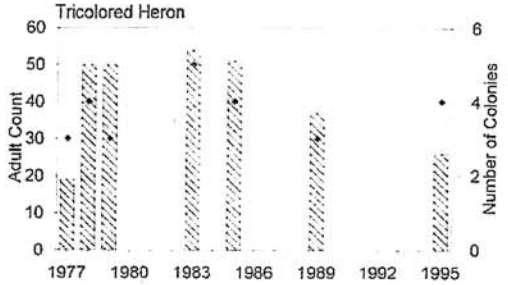
Herons, Egrets and Ibises

In 1995, the great egret was the most numerous wader, followed by the snowy egret (Table 2). However, there were many fewer adults of any species, compared to the larids. The 1995 counts for the snowy egret and black-crowned night heron, however, were less than half the mean adult counts for the 1977–1995 period (Table 2). Over the census period, there was no significant change in the number of adult great egrets, while the number of colonies increased significantly (Table 2, Figure 4). The significant increase in the number of colonies occurred during the early years, rather than the latter years (Table 3). Snowy egrets exhibited a significant decline in adult counts, whereas black-crowned night herons and glossy ibis exhibited a significant increase in the number of colonies (Table 2, Figures 5–7).

Overall, long-legged waders showed a significant decrease in the number of adults and an increase in the number of colonies (Table 2, Figure 8), suggesting that as a group they are not finding suitable colony sites, but are using many suboptimal sites which cannot support a growing population. The significant trends, however, were largely due to early differences; no significant trends were evident for the last ten years (Table 3).

Population Comparisons and Trends

Population trends can be examined by several different methods: statistical analysis of trends from 1977 to 1999 (for species with yearly counts), statistical analysis of the last ten years (for those with yearly counts), statistical analysis of the ae-



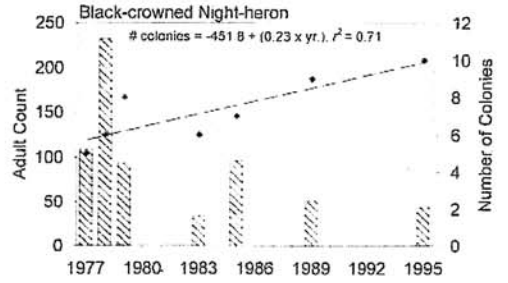
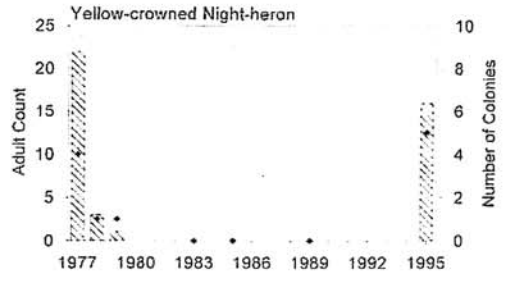


Figure 6. Adult counts and number of colonies for tri-colored heron and black-crowned night heron. Shown are adult counts (bars), number of colonies (black diamond), and for night-heron, number of colonies versus year regression (dotted line).



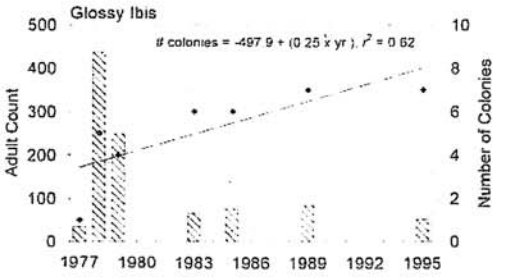


Figure 7. Adult counts and number of colonies for glossy ibis, and for yellow-crowned night heron. Shown are adult counts (bars), number of colonies (black diamond), and for ibis, number of colonies versus year regression (dotted line).

rial surveys, and finally comparison of the last year with the average adult mean count for the census periods (regardless of whether it is yearly or less frequent). The latter method is instructive, particularly if there have been recent changes in conditions, such as changes in water flow caused by the dredging of Barnegat Inlet and the reconfiguration of the south jetty. Among the larids, least tern, black skimmer, laughing gull and herring gull, the numbers of breeding adults were significantly lower (fell outside of the 95% confidence level) in 1995 (or 1999) compared to the average for the entire census period (Table 2). Forster's terns showed no significant changes either from 1977 to 1995, or from 1990 to 1999 (Tables 2 and 3).

Great black-backed gulls showed a significant increase in the number of breeding adults (and in the number of colonies) from 1977 to 1995, but not from 1989 to 1995 (Tables 2 and 3). Herring gulls displayed a significant increase in the number of colonies (but a decrease in the number of adults) from 1977 to 1995, but no change from 1989 to 1995.

The overall fewer number of long-legged waders makes it more difficult to reach significance for the trends analysis (Table 2). There were significantly

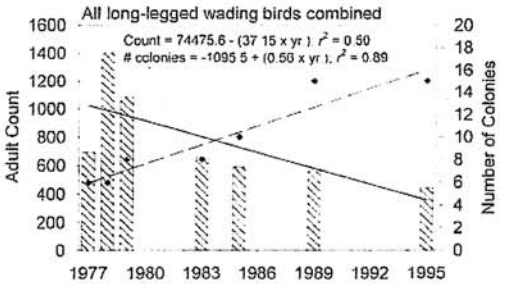


Figure 8. Adult counts and number of colonies for all wading birds combined. Shown are adult counts (bars), number of colonies (black diamond), count versus year regression (solid line), and number of colonies versus year regression (dotted line).

Table 4. *Summary of long-term and recent trends in number of adults and number of colonies of birds in Barnegat Bay.*

Species	Adult Counts			Number of Colonies		
	Long-term[1] Trend	Recent[2] Trend	Most Recent[3] Count Compared to Avg. Count	Long-term[1] Trend	Recent[2] Trend	Most Recent[3] Count Compared to Avg. Count
Black Skimmer	—	↓	↓	—	—	↓
Least Tern	↓	↓	↓	↓	↓	↓
Common Tern	↓	↓	↓	↓	↓	↓
Forster's Tern	—	—	—	—	—	↑
Laughing Gull	—	—	↓	—	—	—
Herring Gull	↓	↓	↓	↑	↓	—
Great Black-backed Gull	↑	—	↑	↑	—	↑
Great Egret	—	—	↑	↑	—	↑
Snowy Egret	↓	↓	↓	—	↓	—
Little Blue Heron	—	—	—	—	—	—
Tri-colored Heron	—	—	↓	—	—	—
Black-crowned Night-heron	—	—	—	↑	—	↑
Yellow-crowned Night-heron	np	np	↑	np	np	↑
Glossy Ibis	—	—	—	↑	—	—
All long-legged wading birds combined	↓	—	↓	↑	—	↑

[1] For black skimmer, common tern, Forster's tern and herring gull, *long-term* trend is for 1976–1999, inclusive. For least tern, *long-term* trend is for 1977–1999, inclusive. For all others, *long-term* trend is for 1977–1995.

[2] For black skimmer, common tern, Forster's tern, least tern and herring gull, *recent* trend is for 1990–1999, inclusive. For all other species *recent* trend is for 1985–1995 (3 surveys: 1985, 1989 and 1995).

[3] For black skimmer, common tern, Forster's tern, least tern and herring gull most recent count was 1999. For all other species, most recent count was 1995.

— = no significant trend.

np = trend analysis not performed due to infrequent occurrence in study area.

fewer breeding snowy egrets and tri-colored herons in 1995 compared to the average number in the period 1977 to 1995.

Taken as a group, adult counts on all heron and egret species combined showed significant declines over the period, while the number of colonies increased significantly (Figure 8). These species usually nest together.

DISCUSSION

Changes in Larid Populations

Abundance data clearly show recent declines in the number of breeding black skimmers, common terns, least terns, herring gulls, and laughing gulls with longer term declines in least and common terns and herring gulls (Table 4). Over the entire period, there were declines in the number of colonies of common and least terns, and herring gulls (Table 4). These two types of declines infer different problems. Declines in the number of individuals may represent true declines in breeding populations, whereas declines in the number of colonies may indicate a decline in the number of suitable colony sites, as well as the number of birds that inhabit them.

The yearly counts for black skimmers show a recent decline in the number of breeding adults and colonies (Figure 2). Since the ground counts involved frequent counts of both adults and nests, they reflect the number of birds breeding in those years. The continuous count data indicate that trends may be missed when the counts (of either colonies or number of birds) are fluctuating.

The two species experiencing declines in the number of colonies from 1977 to 1999 (common and least terns) may be the victims of declines in suitable habitat. Least terns only nest on sandy beaches or islands in New Jersey, and with increases in predators on barrier islands and increases in human development, they have far fewer suitable places where they can nest (ERWIN *et al.*, 1981; BURGER, 1984, 1989; KOTLIAR and BURGER, 1986; BURGER and GOCHFELD, 1990b; BURGER *et al.*, 1995). Many islands became unsuitable because of increases in the numbers of predators, primarily rats and foxes. Increases in these predatory populations also decrease the suitablity of nesting habitat.

Reductions in common tern adults appear to be consistent, although diminishing numbers of colonies were gradual over the entire sampling period (Tables 2–4). The early declines were due, in part, to direct competition with herring gulls, which forced them from their traditional nesting islands in Barnegat Bay (BURGER and GOCHFELD, 1991). More recent decreases, however, may be due to personal watercraft. There has been a large increase in personal watercraft use over the last few years, and common terns are particularly responsive to the loud, close approaches of these craft (BURGER, 1998, 2001). Competition with herring gulls, which forces the common terns to nest on lower islands subject to tidal flooding, and the harassment by personal watercraft have combined to produce several years of low tern reproduction (J. Burger, unpublished data). Moreover, harassment by both people and predators may have forced the terns to other colonies farther north or south.

Declines in the number of breeding adult laughing gulls were evident only when the most recent count was compared with the average count (Table 4). This decline may have been discovered earlier if we had yearly counts. Laughing gulls decreased partly as a result of interactions with the larger herring gulls that usurped their nesting habitat, forcing them into lower elevation islands where they were less successful (BONGIORNO, 1970; BURGER, 1979; BURGER and SHISLER, 1980; BURGER and GOCHFELD, 1985). Additionally, since 1991, an extensive control program conducted by the Animal Damage Control Program at J. F. Kennedy Airport has killed nearly 45,000 laughing gulls, many of which came from Barnegat Bay (DOLBEER *et al.*, 1994; DOLBEER and BUCKNALL, 1997). BELANT and DOLBEER (1993) estimated that this mortality represented 5–6% of the annual nesting population from Maine to Virginia. Surely such a massive control program has had an adverse effect on populations in the northeast, and it is likely that this mortality is not evenly distributed from Maine to Virginia, but falls heavily on New Jersey (BURGER, 1996). Diminishing numbers of laughing gulls in Barnegat Bay are disturbing because New Jersey remains the center of the breeding populations of this species, and has historically had the largest breeding population of any state or region (BURGER, 1996). This is a cause for concern, although large colonies of laughing gulls still persist in Atlantic and Cape May counties to the south. The number of breeding laughing gulls increased in 2001, which coincided with a lack of depredations at Kennedy Airport.

Increases in the populations and number of colonies of great black-backed gulls were very clear from this analysis (Table 4). This represents a range increase, since the first black-backed gulls nested in New Jersey in the 1950s, and they have been increasing ever since. In the early 1970s, any given island had only one nesting pair, but by the early 1980s, the number of pairs on any given island had already started to increase markedly (BURGER, 1978). At first the black-backs were merely using the herring gull colonies as places to nest, but more recently they have started to force herring gulls from some of the smaller islands, the same islands where herring gulls forced laughing gulls to leave in the 1980s (BURGER, 1979, 1996).

Regional Population Status and Trends of Larids

One of the thorny issues in understanding the population dynamics of colonial birds is the appropriate region for analysis. While metapopulation analysis is straightforward for species such as Roseate terns that nest in only a few colonies in the northeast (SPENDELOW *et al.*, 1995), it is more difficult for common species that have a nearly continuous distribution along coasts. Many of the colonial species that nest in Barnegat Bay and Great Bay also nest southward along the coast of New Jersey, although most do not nest in northern New Jersey. Exceptions include a few small colonies, and least terns which sometimes nest in large colonies north of Barnegat Bay. The closest northern populations of most species are on Long Island.

One possible explanation for the decline in least terns, common terns, and black skimmers is that these nesting populations shifted southward in New Jersey. However, the aerial surveys reported in this study were conducted along the entire New Jersey coast from Cape May to Manasquan. The decreasing numbers noted for Barnegat Bay were also observed in other regions of the State (Jenkins, unpublished data), although the reductions in Barnegat Bay were the largest. These declines suggest that regional factors may account for the overall statewide decline.

Surveys conducted in New York (MESKILL and SOMMERS, 1995) and Maryland (BRINKER *et al.*, 1996) did not indicate any significant trends for skimmers or least terns in 1985 and 1994 or 1995, respectively, although the declines may have occurred before 1985. In the early 1980s, common

terns were increasing in the northeast (BUCKLEY and BUCKLEY, 1984), but from 1985 onward they declined in Maryland (BRINKER *et al.*, 1996) and showed no trend in New York (MESKILL and SOMMERS, 1995). This suggests that common terns may be generally declining in the Maryland to New York region. Status and trends of Forster's terns are less clear regionally, largely because there are few colonies in most mid-Atlantic states.

Laughing gulls, which declined in Barnegat Bay only recently, have also declined in Maryland (from 2000 nesting birds in 1977 to four pairs in 1995) (BRINKER *et al.*, 1996). Recently laughing gulls have also decreased in New York (MESKILL, personal commications, 1996), suggesting a regional drop. While laughing gull populations were doing well in the 1970s and 1980s (BELANT and DOLBEER, 1993), they have apparently undergone a recent regional reduction, which may be partly due to the harassment and control campaign at Kennedy International Airport (BURGER, 1996).

The number of breeding herring gulls has declined in New Jersey, partly due to the closing of garbage dumps, which decreases survival of the young-of-the-year (BURGER and GOCHFELD, 1981). Great black-backed gulls have increased both in New Jersey and throughout the region (ERWIN, 1995), although they may have stabilized in some states (Maryland, BRINKER *et al.*, 1996). Their expansion has mirrored that of herring gulls a few decades earlier.

Changes in Long-legged Wader Populations

While analysis of population levels of long-legged waders is generally complicated by the relatively low population sizes, combining all long-legged waders that nest in Barnegat Bay and Little Egg Harbor clearly reveals that overall numbers of adults have declined, whereas the number of colonies has increased. We suggest that this partly relates to changes in habitat suitability within the system from 1976 to 1995. During this period, herring and great black-backed gulls increased significantly (BURGER, 1977, 1978), rendering many colony sites unsuitable for other species. Even though the two groups generally use different habitats (gulls nest on the ground in the marsh grasses, and waders nest in low bushes), herring gulls prey on the eggs and young chicks of waders. The habitat problems are borne out by the observation that they have moved from suitable habitat with some bushes to less suitable habitat with *Phragmites* or *Iva*, largely because their traditional colony sites were taken over by herring and great black-backed gulls. There are, however, few salt marsh islands in the bay that are high enough to support a heronry, without being so high that predators can remain throughout the year. Normally, high winter tides wash over the salt marsh islands, removing any predators that have arrived there (BURGER, 1979).

Regional Population Status and Trends of Long-legged Waders

The analysis for this group was less clear, partly because species abundances are relatively low in Barnegat Bay. There are two key aspects to these data: (1) comparisons with statewide and region-wide trends; and (2) the relationship between overall declines in the number of individuals of this group with increases in the number of heronries (see Figure 8).

Our surveys for Barnegat Bay and Little Egg Harbor show that these birds comprise between 4% (glossy ibis) and 30% (great egret) of the New Jersey Atlantic coast populations for individual long-legged waders. These data indicate that the maintenance of healthy populations of these species in this region is important for the total State populations.

A review of the literature reveals that snowy egrets and black-crowned night herons may be declining throughout the eastern U.S. PARSONS' (1996) review of these two species from Delaware to Maine suggests a declining trend for both species, and BRINKER *et al.* (1996) reported a decline in Maryland. ERWIN (1995) reported a similar reduction in Virginia and Florida. Data from Maryland (BRINKER *et al.*, 1996) and the general region (PARSONS, 1996) suggest that decreases in these species have been accompanied by increases in great egrets, but this trend is not apparent in Barnegat Bay.

We did not find a significant decline in tri-colored herons from 1976 to 1995, although a decline has been reported for this species in Maryland (BRINKER *et al.*, 1996). Population trends in glossy ibis are difficult to interpret, partly because this species appears to change colony sites more often than other long-legged waders (ERWIN, 1995). In addition, glossy ibis often nest on the ground, and are dark-colored, making them more difficult to census from the air unless all birds are flushed from colonies. Glossy ibis usually flushed during

the aerial surveys (R. Kane, personal communication). However, they normally nest with the white-colored egrets, which are easy to see from the air. When ibis nest in monospecific colonies, glossy ibis are difficult to find because they may not be visible from the air. Black-crowned night herons are perhaps the most difficult to count for some of the same reasons. Since both ibis and night herons often nest on the ground, the seasonal distribution of rain pools caused by heavy rains may affect their distribution.

The decline in the numbers of breeding herons, egrets, and ibises in the face of increases in the number of colonies is interesting. We believe it represents two phenomena: (1) an increase in the number of predators on their nesting islands; and (2) a decrease in suitable habitat. Over the period of the aerial surveys (1977 to 1995), there was an increase in a number of predators on these islands—notably herring gulls and great black-backed gulls—that prey on the eggs and very young chicks of the waders (BURGER, 1977, 1978). There has also been an increase in rats on some islands. With an increase in the number of gulls, traditional colony sites are less suitable, forcing the birds into less optimal habitats (thus reducing the number of birds in each colony).

We suggest that the number of suitable colonies has not only declined because of increases in predators, but because of changes in the tidal regime. In 1989 and 1990, Barnegat Inlet was dredged, and there were changes in the configuration of the south jetty, with an associated change in the tidal flow into the bay (BURGER, 1997). Some of the islands that were sufficiently high, with *Iva* and *Baccharis* bushes along with dense stands of *Phragmites*, have suffered either the complete loss of these habitats or a substantial decrease in size, particularly in the islands near the inlet. The colony of snowy and great egrets on Clam Island disappeared shortly after these changes. This has resulted in fewer available habitats in the region, but the effect is much less in other parts of the bay. To some extent, the herons and egrets have responded by moving onto other islands that were not used in the early years. Some of these islands were newly created by the addition of dredge spoil (such as the islands just inside Barnegat Inlet), but some were simply not used in the early 1970s because there was little suitable habitat. There are even some black-crowned night heron colonies in small patches of *Iva* that now are regularly flooded and have herring gulls nesting under the bushes. Some of these colonies once had snowy egrets, but they have moved out as the gulls have moved in.

These negative factors are somewhat ameliorated by succession on dredge spoil islands. With time, small shrubs and bushes begin to grow on open sandy islands, providing nesting habitat for the herons and egrets.

Management Implications

The populations of colonially breeding birds that reside in Barnegat Bay are a function of a number of factors: available habitat, reproductive success over many years, foraging success, and other coastal factors that occur over the wider geographical region, as well as sea level rise and possible changes in availability of forage fish because of global or regional changes in ocean temperatures. Only some of these factors are amenable to management.

Habitat suitability is partially a function of the physical habitat (flood-free islands or barrier beaches, and suitable vegetation). Sea level rise renders low-lying salt marsh islands unsuitable for nesting because of the potential for flooding. All of the colonial species require nesting space that is high enough to avoid flood tides during the nesting season. The herons, egrets, and ibises partly avoid flood tides by building their nests in small shrubs or *Phragmites*, but usually there is insufficient habitat and many individuals still nest on the ground. Terns and skimmers avoid flooding by nesting on the wrack that is high on the marshes, although this habitat may also be limited. For many species, most terns and all the gulls, the only available habitat is salt marsh, and they attempt to nest on the highest places.

The potential for the creation, modification, and maintenance of suitable nesting habitat for colonially nesting birds is critical. For example, skimmers will only nest on open sand or on wracks on salt marsh islands. Both can be maintained and created (BURGER and GOCHFELD, 1990a), thus increasing reproductive success. For many years in the 1980s when there were few winter storm tides to deposit wrack high on the marsh, we built artificial wrack on several islands in Barnegat Bay, and the only skimmers that were fledged in the bay nested on these artificial wracks (BURGER and GOCHFELD, 1990a).

Most species will use suitable habitat when it becomes available without further management. However, least terns have been attracted success-

fully to newly created or predator-free habitats by the use of decoys and play-back of vocalizations (KOTLIAR and BURGER, 1984; THOMPSON *et al.*, 1997). Although least terns do not nest on rooftops in New Jersey, this habitat elsewhere provides opportunities for management and protection (FISK, 1975). Because least tern numbers have decreased in many places, their populations are managed more frequently than other species (see BRITTON, 1982; CARRIKER, 1985).

Skimmers and least terns normally nest on open sand with sparse vegetation, which can be created either by removal of vegetation or by deposition of fresh dredge spoils. Spoil islands are suitable for common terns and skimmers immediately after spoil disposition, and will remain suitable if vegetation is kept off the islands (BURGER and GOCHFELD, 1990b). Deposition of fresh soil has the added advantage that it does not contain a seed bank, and it takes a number of years before vegetation becomes established. Such deposition can also discourage herring gulls that prefer nesting in vegetation.

However, habitat suitability also involves the absence of predators, competitors, and human disturbance (BURGER, 1979; BURGER *et al.*, 1995). Habitat suitability differs on islands compared to the barrier beaches because of the increased potential for regular intrusion by humans and predators. This aspect can be partially mitigated on barrier islands by erecting fences or by posting wardens for particularly sensitive species such as least terns (MINSKY, 1980; BURGER, 1989).

Some of the species (*e.g.* laughing gulls and common terns) have suffered because of increases in herring gulls, which are both competitors and predators. In addition, since herring gulls arrive several months earlier than both laughing gulls and terns, they occupy the highest nesting sites when the smaller species arrive. Managing this aspect requires extensive control of herring gull numbers, or at least, removing them from islands used by the smaller species.

The problem of competition between herring gulls and smaller species of gulls and terns may be decreasing in Barnegat Bay as the populations of herring gulls decline. However, even small colonies of herring gulls are a deterrent for the smaller species, and if habitat is available on these islands for the terns and skimmers, they will avoid them because of the presence of the gulls.

Although red foxes (*Vulpes vulpes*) sometimes control the gulls, this is uncommon because these predators seldom reach the nesting island colonies. Direct control of herring gulls is problematic, both because they are hard to control and because of adverse public reaction to such control measures. Control of other predators, such as the raccoon (*Procyon lotor*), may be necessary on nearshore islands and barrier beaches to ensure tern and skimmer nesting success. However, it will be difficult. Where terns and skimmers nest on small islands, it is possible to control predators, but on barrier beaches it is much more difficult because of the continual immigration of predators from elsewhere (BURGER and GOCHFELD, 1990a). Even on small salt marsh islands, the appearance of a fox or raccoon can have devastating effects, and in only one year the successful heronry on Lavalette Island was deserted because of the presence of a fox early in the reproductive cycle. This had been one of the most successful heronries in Barnegat Bay for nearly 20 years, and in only one year it disappeared. In our experience, the abandonment of every heronry in Barnegat Bay was caused by the presence of a predator on the island at the time of colony-initiation.

A wide range of predators affect reproductive success of colonially-nesting species in Barnegat Bay, as well as elsewhere in the world (BURGER and GOCHFELD, 1994), and birds mainly cope with predators by selecting islands that are free from predators. Management, however, can involve direct predator control by removal or killing, or by such techniques as aversive conditioning (AVERY *et al.*, 1995) or establishing nesting shelters (SPENDELOW, 1982).

The potential for predators reaching nesting islands increases the importance of suitable habitat on other islands. Without such suitable habitats, colonies of birds have no place to move when their traditional colony site is no longer available, or is invaded by a predator or humans. This argues for continued protection of abandoned colony sites as a buffer for future movement among sites.

Human disturbance on the nesting islands themselves can be controlled, but it takes management personnel and constant vigilance. Different species do not respond the same way to human disturbance (BURGER and GOCHFELD, 1988); hence, they require different degrees of protection. Recently, the increase in the number of personal watercraft (PWCs) has created a new kind of disturbance, because these craft maneuver in very shallow water, bringing them near foraging herons, egrets, and ibises, as well as nesting colonies

of terns and skimmers. BURGER (1998) showed that common terns are disturbed by PWCs, and increases in such disturbances may account for recent declines in reproductive success. While the terns can partially habituate, they still avoid the parts of the island that are closest to the PWCs, which limits the number of suitable nesting sites (BURGER, 2001). Continued management is required to allow PWCs and nesting birds to coexist (BURGER, 2001).

Human disturbance can be partially controlled by establishing a buffer of at least 100 m around nesting colonies, but this requires signage and regular enforcement. This is a minimum, and some sensitive species will require much more intense efforts (see ERWIN, 1989; CARNEY and SYDEMAN, 1999). There are a few exceptions where the buffer can be smaller, but they are usually impacted by boats, cars, and people walking by colonies that are fenced. The 100-m buffer zone will be easier to maintain on barrier beaches, where wardens or monitors can patrol the colony, but it will be more difficult to maintain the buffer in the bay itself, where there are no wardens and where there are few enforcement officers. While existing laws protecting endangered, threatened, and other nongame species prohibit harassment of birds, enforcement is difficult in practice because intent to harass must be demonstrated, and this is a difficult task to prove. Regulations to prevent access to nesting and foraging areas can be developed under existing statutes.

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