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ABSTRACT / During the 1980s, the exponential growth of laughing gull (*Larus atricilla*) colonies, from 15 to about 7600 nests in 1990, in the Jamaica Bay Wildlife Refuge and a correlated increase in the bird-strike rate at nearby John F. Kennedy International Airport (New York City) led to a controversy between wildlife and airport managers over the elimination of the colonies. In this paper, we review data to evaluate if: (1) the colonies have increased the level of risk to the flying public; (2) on-colony population control would reduce the presence of gulls, and subsequently bird strikes, at the airport; and (3) all on-airport management alternatives have been adequately implemented. Since 1979, most (2987, 87%) of the 3444 bird strikes (number of aircraft struck) were actually bird carcasses found near runways (cause of death unknown but assumed to be bird strikes by definition). Of the 457 pilot-reported strikes (mean = 23 ± 6 aircraft/yr, N = 20 years), 78 (17%) involved laughing gulls. Since a gull-shooting program was initiated on airport property in 1991, over 50,000 adult laughing gulls have been killed and the number of reported bird strikes involving laughing gulls has declined from 6.9 ± 2.9 (1983–1990) to 2.6 ± 1.3 (1991–1998) aircraft/yr; nongull reported bird strikes, however, have more than doubled (6.4 ± 2.6, 1983–1990; 14.9 ± 5.1, 1991–1998). We found no evidence to indicate that on-colony management would yield a reduction of bird strikes at Kennedy Airport. Dietary and mark–recapture studies suggest that 60%–90% of the laughing gulls collected on-airport were either failed breeders and/or nonbreeding birds. We argue that the Jamaica Bay laughing gull colonies, the only ones in New York State, should not be managed at least until all on-airport management alternatives have been properly implemented and demonstrated to be ineffective at reducing bird strikes, including habitat alterations and increasing the capability of the bird control unit to eliminate bird flocks on-airport using nonlethal bird dispersal techniques. Because the gull-shooting program may be resulting in a nonsustainable regional population of laughing gulls (>30% decline), we also recommend that attempts be made to initiate an experimental colony elsewhere on Long Island to determine if colony relocation is a feasible management option.

KEY WORDS: Aircraft; Bird strike; Gull; Management; John F. Kennedy International Airport; Jamaica Bay Wildlife Refuge; New York City

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Airports are attractive to birds because they are generally flat, open, and provide sources of food and fresh water. Meanwhile, bird activity on airports can create hazardous operating conditions for aircraft. Bird-strike reports, filed with the Federal Aviation Administration, indicate that 22,320 civilian aircraft were struck by birds at airports in the United States between 1990 and 1998. During that nine-year period, the civil aviation industry reported monetary losses totaling $67.6 million (Cleary and others 1999). Three approaches used in an effort to control birds and reduce bird strikes at airports include culling local gull populations, eliminating on-airport attractants (standing water, refuse), and dispersing birds using pyrotechnics and distress calls (Burger 1983a–c).

During the 1980s, the exponential growth of laughing gull (*Larus atricilla*) colonies in the Jamaica Bay Wildlife Refuge and a correlated increase in the bird-strike rate at nearby John F. Kennedy International Airport, New York City, led to a controversy between wildlife and airport managers over the elimination of the colonies. In this paper, we review information and data collected from the literature and during our field studies to evaluate if; (1) the colonies have increased the level of risk to the flying public; (2) on-colony population control would reduce the presence of gulls, and subsequently bird-strikes, at the airport; and (3) all on-airport management alternatives have been adequately implemented and demonstrated to be ineffective at reducing bird strikes. We begin by outlining the history of the laughing gull controversy.

History

The Jamaica Bay Wildlife Refuge (JBWR, about 3600 ha), located at the southwestern end of Long Island, is of major wildlife importance to the New York metropolitan area because it provides excellent nesting, migrating, and wintering habitats for over 300 species of shore-, land-, and waterbirds and is one of the few relatively unmodified greenscapes remaining in an otherwise highly urbanized area. Jamaica Bay is a shallow (<3 m at low tide except for dredged channels) tidal lagoon with one inlet. Major habitat types include numerous saltmarsh (characterized by *Spartina* grasses) and upland islands, several manmade fresh- and brackish water ponds, and expanses of tidal mudflats and waterways (Burger 1983a). The refuge, a unit of the Gateway National Recreation Area managed by the US National Park Service (NPS), supports one of the largest heronries (about 800 pairs in 1997) on Long Island, and the only laughing gull and Forster's tern (*Sterna forsteri*) nesting colonies in New York State (see Sommers and others 1996, Brown and others 2001).

John F. Kennedy International Airport (JFKIA), one of the three major airports that service the New York metropolitan region, is located immediately adjacent to the northeastern boundary of Jamaica Bay (Figure 1.); the airport is operated by the Port Authority of New York and New Jersey (PANYNJ). This location creates a situation where bird activities in and near Jamaica Bay can be potentially hazardous to aircraft operations at JFKIA. In fact, a major runway [4L-22R (built on fill)] extends into Jo Co Marsh, which contains the largest colony of laughing gulls in the bay. As a measure of the potential hazard that birds pose to aircraft, PANYNJ records all bird strikes by aircraft each year (or bird-strike rate). Bird-strike data include those bird–plane collisions reported by pilots and ground crews, as well as all dead birds (*assumed* to be nonreported bird strikes) found within 200 feet of the center line of a runway (Dolbeer and others 1989, US Department of Agriculture 1994; also see below, Definition of a Bird Strike).

Since it was built in the late 1940s, JFKIA (formerly Idlewild International Airport) has had problems with waterbirds attracted to its flat, freshwater-collecting areas. In 1975, a DC-10 aborted takeoff, following collision with 'sea gulls,' resulted in the destruction of the aircraft and the evacuation of all 139 people on board (National Transportation Safety Board 1976). After that incident, PANYNJ established a bird-control unit to disperse birds from runways and collect bird carcasses found on the airport (bird strikes by definition). The first dead laughing gull was found in the 1970s, two in 1979, and by 1984 had reached 60 (Buckley and McCarthy 1994). PANYNJ assumed that the newly established laughing gull colony in the refuge was the source of these birds.

Between 1984 and 1986, following extended discussions with NPS to remove the colony, PANYNJ contracted for a study (block-design) to determine what could be done to make the airport unattractive to the gulls (Buckley and Gurien 1986, Buckley and McCarthy 1994). The authors concluded that Oriental beetles (*Anomala orientalis*) were the major food of gulls foraging at the airport; short grass, favored by airport maintenance, made it easy for gulls to land and consume beetles, while longer grass deterred most gulls from foraging; and standing water areas were attractive to birds and should be removed. Another study between 1990 and 1992, which involved tracking color-dyed birds in the vicinity of the airport,

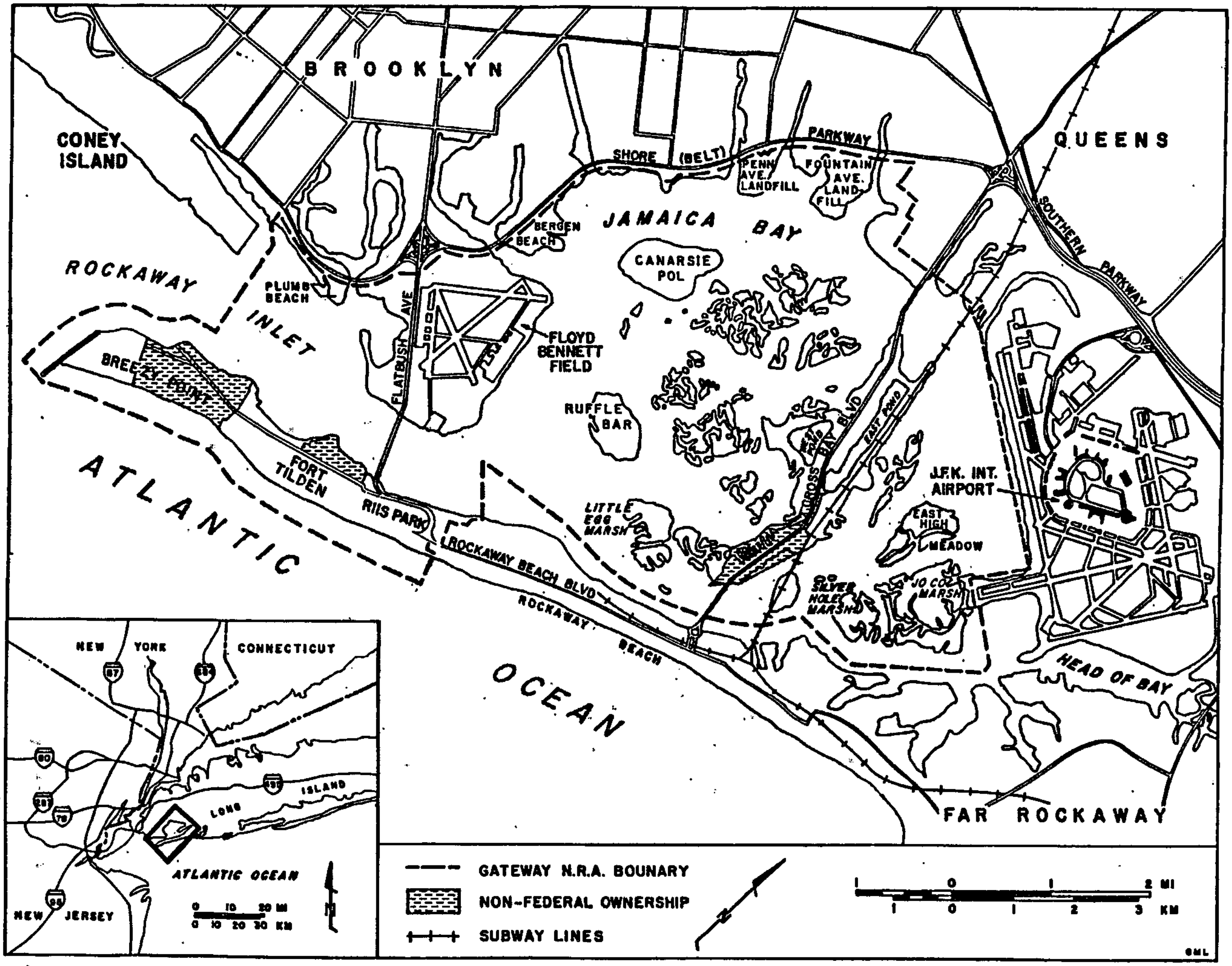

Figure 1. Locator map of Gateway National Recreation Area, Jamaica Bay Wildlife Refuge, and John F. Kennedy International Airport, in the Boroughs of Brooklyn and Queens, New York City.

reached similar conclusions and recommendations (Griffin and Hoopes 1992).

Airport authorities only partially implemented those recommendations and bird strikes continued to increase as the gull colonies grew (Figure 2). From 1987 through 1990, the laughing gull accounted for 48%–54% of all bird strikes at JFKIA. PANYNJ attributed the high incidence of laughing gull strikes, particularly during the months of June and July, to the movement of breeding adults from the colonies to foraging sites within the urban areas surrounding the airport. They insist that the colonies represent an unacceptable risk to the safety of the flying public and argue that reducing and/or eliminating them would decrease the frequency of flyovers, and ultimately reduce the bird-strike rate at the airport (Dolbeer and others 1989, USDA 1994, Dolbeer and Bucknall 1997).

Although concerned about human safety, the NPS maintained that the frequency of bird strikes could be minimized at JFKIA by full implementation of an airport-wide integrated wildlife management program that was designed to eliminate all on-airport and off-airport attractants to birds and included an adequately staffed bird control unit, trained and equipped to disperse all birds that entered the airport (Buckley and Gurien 1986, Buckley and McCarthy 1994). In this case, NPS also maintained that the more conservative stance (nonpark management) was desirable given that the JBWR laughing gull colonies were the only ones in New York State.

In 1991, in the midst of the laughing gull controversy, a gull-shooting program was initiated at JFKIA by the US Department of Agriculture's Wildlife Services Division (USDA, formerly known as its Animal Damage

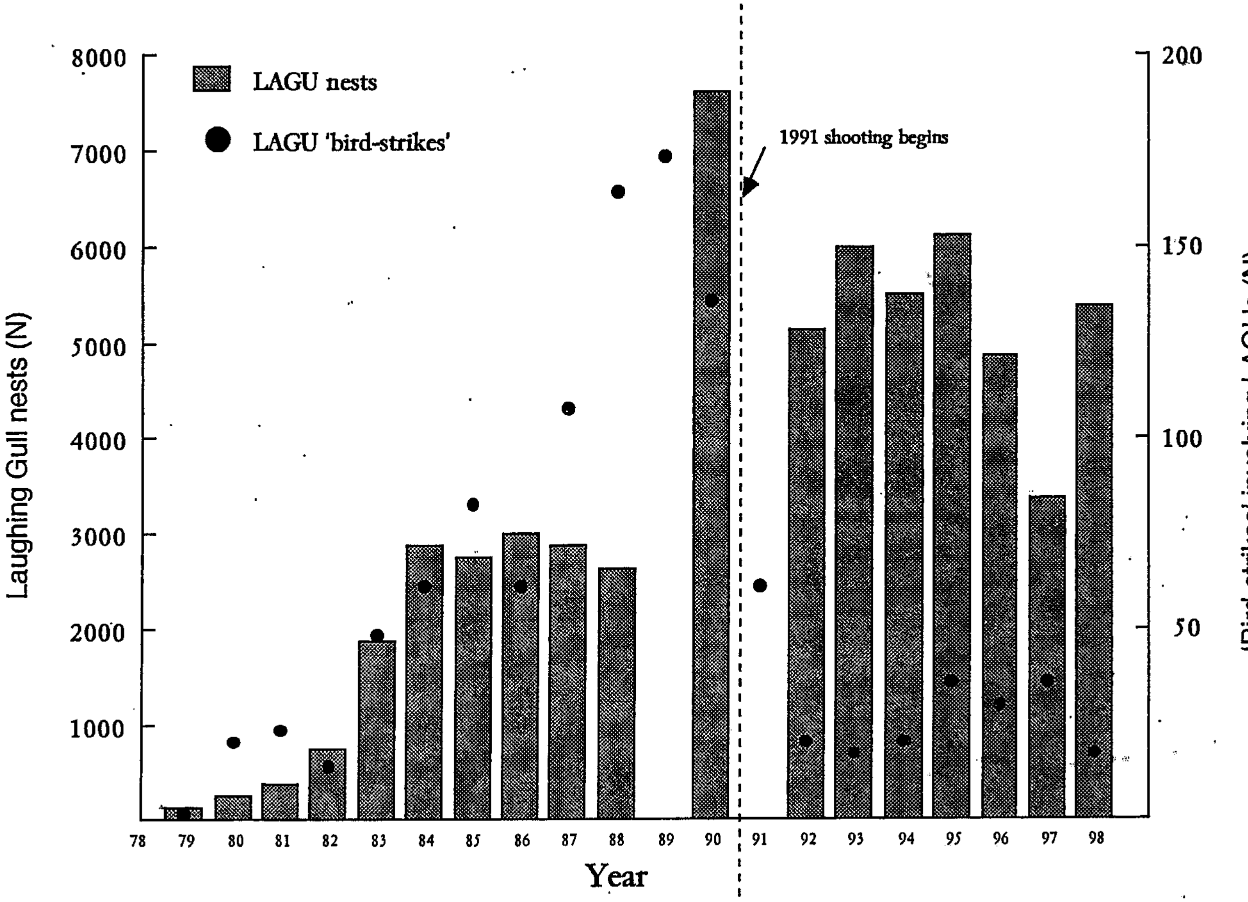

Figure 2. Numbers of laughing gull (LAGU) nests in Jamaica Bay and numbers of bird strikes, involving Laughing Gulls only, at John F. Kennedy International Airport between 1979 and 1998. 'N' is the total number of aircraft struck. Since 1991, a gull-shooting program has been conducted by USDA biologists at Kennedy airport and three nearby landfill sites were closed in 1985 and 1993. Nest count data were taken from: 1978–1984, Buckley and Buckley (1984); 1985–1988, Sommers and others (1994); 1990, Griffin and Hoopes (1992); 1992–1995, Dolbeer and others (1997); 1996–1997, Dolbeer and Bucknall (1997); 1998, Dolbeer and Chipman (1998). Bird-strike data were taken from Dolbeer and Chipman (1998) and include both reported strikes and nonreported strikes; all dead birds found within 200 feet of the center line of a runway are *assumed* to be nonreported bird-strikes (Dolbeer and others 1989, US Department of Agriculture 1994; also see text).

Control Unit) (Dolbeer and others 1993). During the first two years of the program, a reported 26,038 laughing gulls were shot as they attempted to overfly or pass the airport. During the same period, the number of bird strikes involving laughing gulls was reduced from 135 in 1990 to 60 and 22 aircraft struck in 1991 and 1992, respectively (Figure 2). However, because USDA did not prepare an environmental impact assessment prior to the shooting program, conservation groups (The Fund for Animals Inc.) and private citizens filed a lawsuit against them and other government agencies (Fish and Wildlife Service, Department of Transportation, Department of Interior). The lawsuit resulted in completion of a final environmental impact statement (EIS) regarding bird hazards at JFKIA and a review of management alternatives at the airport and in Jamaica Bay Wildlife Refuge (USDA 1994).

In the Final (EIS), each management alternative was evaluated for feasibility, effectiveness at reducing bird strikes, and environmental impacts. The preferred alternative was an integrated management program that included six management actions divided between the two agencies (USDA 1994, Lambertson 1994, 1996). Management actions to be conducted by PANYNJ outside of NPS property included; (1) the continued development of on-airport management programs (habitat alterations; enhanced capability of the bird control unit); (2) reduction of off-airport attractants of birds;

Table 1. Integrated management program (preferred alternative) as reviewed in final environmental impact statement (USDA 1994) and Department of the Interior's record of decision (Lambertson 1994, 1996)[a]

Category 1

1. The continued development of "on-airport" management programs including:
   (a) habitat alterations on airport property (e.g., vegetation management, improved drainage of standing water, improved sanitation, and insect control);
   (b) enhancing the professional capability of the bird control unit at Kennedy airport (e.g., increased staffing, training and equipment);
   (c) establish the capability to assess and monitor the effectiveness of on-airport control programs on target species;
   (d) prepare a written wildlife management plan for on-airport control programs;
   (e) organize the Bird Hazard Task Force[b] to assist as an independent review body.
2. Reduction of off-airport attractants of birds.
3. On-airport shooting of gulls.

Category 2

4. Laughing gull nest and egg destruction in Jamaica Bay Wildlife Refuge.
5. On-colony shooting of adult laughing gulls.
6. Display of gull models to harass gulls.

[a]Category 1 management actions were to be implemented by the Port Authority outside of National Park Service (NPS) property while category 2 management actions were to be implemented (if deemed necessary) by NPS in Jamaica Bay Wildlife Refuge.

[b]The Bird Hazard Task Force, a nonregulating group, is comprised of representatives from the administrating and regulating agencies involved in the laughing gull management issue including: Port Authority of New York and New Jersey, US National Park Service, US Fish and Wildlife Service, US Department of Agriculture, New York State Department of Enviromental Conservation, New York City Department of Enviromental Protection; and the Federal Aviation Administration.

and (3) on-airport shooting of gulls (also see Table 1). Management actions on NPS property included: (4) destruction of laughing gull nests and eggs in the refuge; (5) on-colony shooting of adult laughing gulls; and (6) display of gull models to harass gulls. While airport authority actions were to begin immediately, NPS would not be required to initiate steps towards implementing on-colony actions until it was demonstrated that the off-colony components were ineffective at reducing bird strikes (Lambertson 1994, 1996).

In this paper, we review information collected from the literature and during our field research activities in Jamaica Bay pertaining to the question: Does NPS now need to attempt management of the laughing gull colonies in JBWR and, if so, how? We accept that some form of management of the laughing gull colonies might be justified if either: (1) the presence of the colonies has increased the level of risk to the flying public and all alternative on-airport management options (elimination of attractants to gulls) had been adequately/correctly implemented and shown to be ineffective; or (2) on-airport management practices (the gull shooting program) have been effective but are detrimental to the sustainability of the local and regional laughing gull populations; that is, management might be necessary for the sake of the viability of the wildlife population. In the sections that follow, we present data in the context of these two criteria and conclude by discussing the feasibility of establishing a new laughing gull colony on Long Island.

Gull Populations in Jamaica Bay

Three species of *Larus* gulls nest in JBWR. The laughing gull is a summer resident (April–November) and nests on three saltmarsh islands (about 400 total acres): Jo Co Marsh, Silver Hole Marsh, and East High Meadow (hereafter, the colony). Herring and great black-backed gulls (*L. argentatus* and *L. marinus*) are year-round residents and nest sympatrically on the four largest upland islands in the bay. The ring-billed gull (*L. delawarensis*) is present year-round but does not yet nest on Long Island.

Although common along the Atlantic coast during the nineteenth century, the laughing gull was extirpated from Long Island before 1890 by egg collectors and feather hunters (Bent 1921). It did not return to Long Island as a breeding bird until 1978 when one nest was found on the Line Island complex in Great South Bay, near Jones Beach (Buckley and others 1978).

In 1979, 15 pairs of laughing gulls colonized Jo Co Marsh in JBWR (Post and Riepe 1980). During the 1980s, the number of nests in the colony increased exponentially to about 7600 nests in 1990 (Buckley and Buckley 1984, Griffin and Hoopes 1992) (Figure 1). In 1991, the gull-shooting program began at JFKIA. Since then, a total of 50,521 laughing gulls have been shot at the airport and the number of nests in the colony has declined about 30% to 5200 ± 850 nests/year ($N = 7$ years, 1991–1998; data taken from Dolbeer and others 1997, Dolbeer and Chipman 1998).

During the past 25 years, the number of herring gull pairs nesting in JBWR has decreased linearly from about 3300 pairs in 1974–1978 to 2350 pairs in 1998 ($r = 0.6$, $P = 0.0232$) while nesting great black-backed gulls have increased in the same period from about 50 to 400 pairs in 1998 (linear relationship, $r = 0.8$, $P =$

0.0001) (Buckley and Buckley 1980, Brown and others 2001).

Has the Laughing Gull Colony Increased the Level of Risk to the Flying Public?

Next, we review information pertaining to five factors that will help to determine if the laughing gull colony in JBWR has indeed increased the level of risk to the flying public at JFKIA including: (1) the definition of a bird strike; (2) the frequency of bird strikes; (3) intraspecific risk; (4) sources and status of gulls reported as bird strikes; and (5) aircraft wake turbulence as a source of bird mortality. In order to determine whether or not the laughing gull colony has increased the relative risk to aircraft and passengers, we need a baseline level for comparison. Here, we use the frequency of bird strikes as an indirect measure of risk (also see Intraspecific Risk below). Ideally, it would be best to compare risk imposed by laughing gulls and other birds between the 20-year period since laughing gulls began nesting in JBWR (i.e., 1979–1998) to a similar period prior to colonization. However, Bird-strike data are not available prior to 1979, and so, as a baseline for comparison, we use bird-strike data collected during the four-year period between 1979 and 1982 when the colony was relatively small (≤715 nesting pairs).

Definition of "Bird Strike" and Implications for Kennedy Airport

The international standard definition of a bird strike, developed by Bird Strike Committee Canada and endorsed by the United Nations' International Civil Aviation Organization (USDA 1994), is as follows: a bird strike is considered to have occurred when either (1) a pilot reports a bird strike, (2) aircraft maintenance personnel identify damage to an aircraft as having been caused by a bird(s), (3) personnel on the ground report seeing an aircraft strike a bird(s), or (4) a bird carcass, or parts thereof, is found on an active runway, or within 200 feet of a runway, unless another cause of death is identified. This standard definition is used to collect bird-strike data at JFKIA and most other airports in the United States, Canada, and Europe (USDA 1994).

Thus, bird-strike data at JFKIA come from two different sources: (1) all reported bird strikes (includes 1–3, above) were investigated by searching the designated runway and the adjacent areas for dead birds and, when possible, inspecting the aircraft for bird remains; and (2) bird control unit personnel at the airport continually search runways and adjacent areas on their patrols and collect all dead birds, which are *all assumed* (our emphasis) to be unreported bird strikes (4, above) (Burger 1985, Dolbeer and others 1989, also see Linnell and others 1999). Thus, any dead birds that were found within 200 feet of a runway were considered bird strikes by definition unless another cause of death was identified. At JFKIA, reported strikes accounted for 8%–22% of all bird strikes each year (Dolbeer and Chipman 1998). At Lihue Airport, Hawaii, pilot-reported strikes accounted for 25% of all recorded bird strikes from 1990 to 1994 (Linnell and others 1999). The assumption that bird carcasses represent unreported bird strikes dramatically inflates the magnitude of the bird-strike problem. If indeed one assumes that 80% of all bird strikes in the United States go unnoticed or unreported, then estimates of monetary losses to the civil aviation industry increase, on average, from a reported $7.5 million/yr to about 350 million/yr (see Cleary and others 1999).

While it may be correct to assume that all reported strikes are indeed bird–plane collisions, especially if they are confirmed by inspection of the plane, it is unlikely that all bird carcasses collected near runways (unreported bird strikes) are the result of actual collisions with aircraft. Given the large breeding population of gulls adjacent to the airport, it is probable that some birds die near runways from natural (avian botulism, poor body condition, high mortality of newly fledged young, predation) and other causes (wake turbulence, see below). This rationale is supported by the fact that while laughing gulls accounted for 51.8% (± 2.4; range = 48%–54%) of all bird strikes from 1987 through 1990, it accounted for notably fewer (32.6 ± 11.0%, range = 19%–45%) of the reported strikes (Dolbeer and others 1989, Dolbeer and Bucknall 1997) (Appendix 1).

Based upon the differences regarding the known information between reported and unreported bird strikes, we believe that the number of reported strikes is a somewhat better measure of actual risk to the flying public. It seems logical that if a bird actually collides with a plane, then some evidence (freeze-dried tissue; similar to when an insect strikes the windshield of a car) should be found during regular inspections and maintenance by ground crews; tissue would most likely be found on the nose/cockpit area or in an engine, and occasionally on the leading edge of a wing. While the number of reported strikes might represent a minimum estimate of the actual number of bird–aircraft collisions (Burger 1985), because air-carriers may be reluctant to report bird strikes, the most serious cases

Table 2. Mean (±1 SD) number of bird strikes and reported strikes at Kennedy airport from 1979 to 1998[a]

Category/period[b]	Aircraft striking birds at Kennedy airport (mean ± SD)			
	Laughing gull	Other gulls**	Other birds	All birds
All Bird strikes				
1979–1982	13.8 ± 8.3abd	74.0 ± 23.5d	33.0 ± 4.7fg	120.8 ± 19.0h
1983–1990	104.4 ± 49.3ac	96.0 ± 29.7e	51.4 ± 18.0f	251.8 ± 61.7hi
1991–1998	30.0 ± 14.4bc	32.9 ± 10.7de	55.5 ± 24.7g	118.4 ± 34.8i
Kruskal-Wallis	H = 13.9	H = 13.4	H = 6.3	H = 11.5
ANOVA (df = 2)	P = 0.001	P = 0.0012	P = 0.0423	P = 0.0031
Reported bird strikes only				
1979–1982	0.5 ± 1.0jk	9.5 ± 4.9m	8.0 ± 1.8o	18.0 ± 3.2q
1983–1990	6.9 ± 2.9jl	13.1 ± 6.1n	6.4 ± 2.6p	26.4 ± 6.9q
1991–1998	2.6 ± 1.3kl	4.2 ± 3.2mn	14.9 ± 5.1op	21.8 ± 5.8
Kruskal-Wallis	H = 15.2	H = 9.0	H = 14.4	H = 5.7
ANOVA (df = 2)	P = 0.0005	P = 0.011	P = 0.0008	P = 0.0587

[a]Bird strike data include both reported and unreported (i.e., bird carcasses found near runways) strikes.

[b]Laughing gull colonized (15 pairs) Jamaica Bay in 1979. The gull-shooting program was implemented at Kennedy airport in 1991 and has continued each year since then.

[c]Other gull species included great black-backed gull, herring gull, and ring-billed gull.

[d]Same letter denotes significant differences between two time periods (Mann-Whitney U tests): a, U = 32, P = 0.007; b, U = 28, P = 0.042; c, U = 61, P = 0.002; d, U = 31, P = 0.011; e, U = 63, P = 0.001; f, U = 26, P = 0.087; g, U = 31, P = 0.011; h, U = 31, P = 0.011; i, U = 61, P = 0.002; j, U = 32, P = 0.006, k, U = 28.5, P = 0.028; l, U = 63, P = 0.001; m, U = 26.5, P = 0.072; n, U = 59, P = 0.004; o, U = 32, P = 0.006; p, U = 64, P = 0.001; q, U = 28.5, P = 0.033.

(i.e., collisions that cause aircraft damage and delays) are likely reported and investigated.

In the sections that follow, we use the term bird strike to refer collectively to unreported and reported strikes (data taken from Dolbeer and others 1989, Dolbeer and Chipman 1998); we also discuss reported strikes separately (unpublished data from R. Dolbeer, personal communication; see Appendix 1).

Frequency of Bird Strikes at Kennedy Airport

Since 1979, there have been a total of 3444 bird strikes at JFKIA (N = 20 years; Appendix 1). Most (1052, 93%) of the 1130 bird strikes involving laughing gulls were unreported strikes or carcasses found near runways. From 1979 through 1990, the numbers of laughing gull bird strikes at JFKIA were correlated with the numbers of laughing gull nests in the JBWR colony (Spearman rank correlation: r = 0.8, Z = 2.5, P = 0.0124; Figure 2). Since the gull-shooting program began at JFKIA in 1991, the mean (± 1 SD) number of laughing gull bird strikes has dropped from 104 ± 49 (1983–1990, 8 years) to 30 ± 14/yr (1991–1998, = 8 years; Table 2).

Of the 457 reported bird strikes since 1979, 78 (17%) involved laughing gulls. From 1979 to 1990, there was also a significant correlation between the number of reported laughing gull strikes and the size of the colony (Spearman rank correlation: = 11 years, r = 0.9, P = 0.0045). Reported strikes increased from 0.5 ± 1.0 to 6.9 ± 2.9 aircraft per year between 1979–1982 and 1983–1990, respectively (Mann-Whitney U test: U = 32, P = 0.006; Table 2). During the eight years since the shooting program began in 1991, the number of reported strikes involving laughing gulls (21 reports, three aircraft were damaged or delayed) has declined to 2.6 ± 1.3 aircraft per year but still remains higher than between 1979 to 1982 when the colony was small (U = 63, P = 0.001; U = 28.5, P = 0.028; respectively).

The laughing gull is one of over 50 species recorded in bird strikes at JFKIA (USDA 1994). For all species taken together, the number of reported bird strikes has ranged from 14 to 37 aircraft per year since 1979 (mean = 23 ± 6 aircraft/year, = 20 years) (Dolbeer and Chipman 1998) (see Appendix 1). From 1979 to 1990, the total number of reported bird strikes was not correlated with the number of laughing gull nests in JBWR (Spearman rank correlation: 1979–1990, 11 years, r = 0.4, P = 0.1937; Figure 3).

Correctly identifying the species involved in reported strikes requires analyses of tissues collected from the aircraft because bird carcasses found near runways are often gulls. During the late 1980s, about half the bird carcasses found near runways at JFKIA were laughing gulls, raising the possibility that some reported strikes may have been incorrectly attributed to it; that is, when PANYNJ personnel searched runways for dead birds after a reported strike, they were most likely to find a laughing gull carcass, especially prior to the onset of shooting program in 1991. It is interesting to

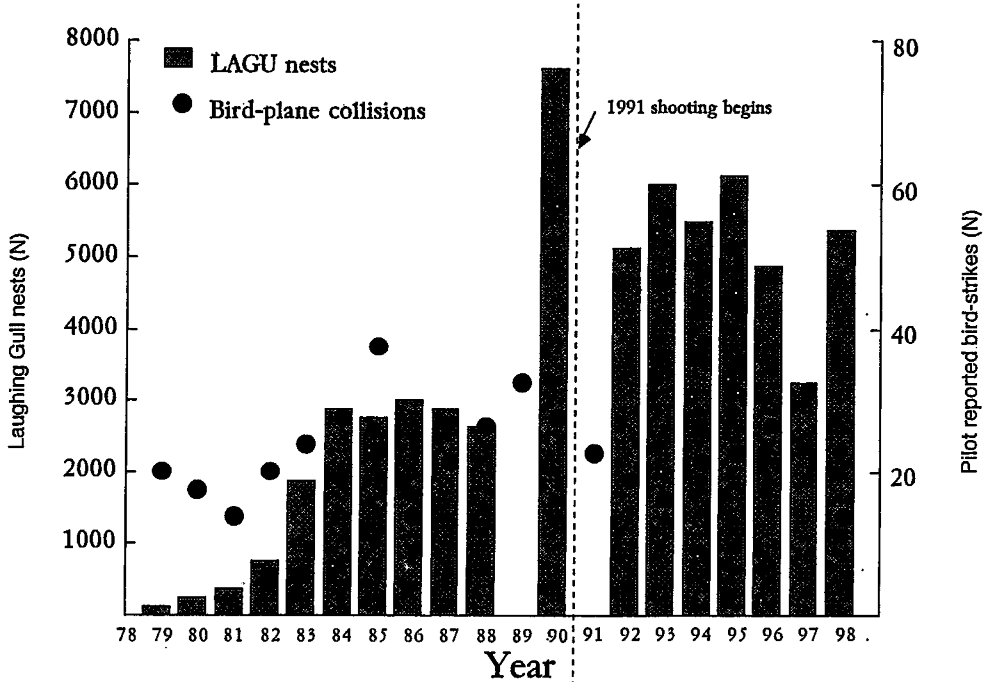

Figure 3. Numbers of laughing gull (LAGU) nests in Jamaica Bay and the numbers of reported bird-strikes, involving all species, at John F. Kennedy International Airport between 1979 and 1998, reported strike data were taken from Dolbeer and Chipman (1998); 'N' is the number of aircraft struck.

note that while the frequencies of bird strikes involving other birds (nongull carcasses found near runways) are similar between 1983–1990 and 1991–1998, the number of nongull reported strikes has more than doubled since 1991 (6.4 ± 2.6 to 14.9 ± 5.1, respectively; $U = 64$, $P = 0.001$; Table 2).

While the association between the size of the laughing gull colony and the frequency of bird strikes and reported strikes with aircraft at JFKIA is strong (the laughing gull colony appears to have increased the level of risk to the flying public), it is important to point out that simply finding a correlation (an association) between two variables does not determine causality; variable A may cause variable B or, equally likely, B may cause A (Zar 1996). Obviously we do not believe that the rise in the bird strike rate at JFKIA caused the growth of the laughing gull colony in JBWR, but more importantly, both variables could be correlated to a third factor that was either not quantified or controlled for in the analysis. For example, both the growth of the laughing gull colony and the increase in bird strikes could be related to the dramatic increase in the total North American population of laughing gulls between 1966 and 1994 and the eventual expansion of their breeding range to Long Island (reviewed by Burger 1996), coupled with increases in on-airport attractants to gulls at JFKIA (food, standing water) (see Buckley and Gurien 1986, Griffin and Hoopes 1992, Buckley and McCarthy 1994). Other confounding variables include: (1) increasing numbers of aircraft operations at JFKIA (over 3% each year between 1986 and 1992) (USDA 1994); (2) increasing use of wide-bodied aircraft (Boeing 747, L1011, DC-10), equipped with larger and quieter engines, that were involved in disproportionately more bird strikes than the old-type, narrow-bodied aircraft (Boeing 707, 727) (Burger 1983b); and (3) inadequacies in the definition of a bird strike.

Intraspecific Risk

Primarily because of size differences, not all bird species are equally hazardous to aircraft. Intraspecific risk can have important implications to wildlife managers at airports because actions to reduce one species may increase the abundance of another species (Burger 1983c, Dolbeer and others 2000). For example, at JFKIA, maintaining grass height above 14 in has apparently reduced the numbers of laughing gulls feeding on scarabaeid beetles but increased the abundance of small mammals, in turn attracting more raptors (L. Ryder, PANYNJ personal communication).

Several authors have suggested that gulls pose the greatest avian threat to aircraft (Burger 1983c, 1985, Dolbeer and others 1989, Seubert 1990). In addition to the sheer number of individuals, numerous other factors also contribute to the inherent risk of different bird species to aircraft collisions, including their ecology and behavior, body mass and density, wing-loading (body mass per wing area, g/cm^2), and aerial agility. For example, birds such as swallows and starlings that form large flocks can be particularly hazardous to aircraft because engine failures are more likely to occur when multiple birds are ingested (USDTFAA 1992). Birds like laughing gulls with low wing-loading are typically maneuverable and agile flyers and so are better able to avoid aircraft than those with relatively higher wing-loading, such as Canadian (*Branta canadensis*) and snow geese (*Chen caerulescens*) and mute swans (*Cygnus olor*).

The probability of engine damage increases with the mass of the ingested bird. In a wind tunnel experiment with Boeing 737 engines, birds heavier than 0.5 kg were more likely to cause engine damage than lighter ones (USDTFAA 1992). From the Federal Aviation Administration's Wildlife Strike Database, Dolbeer and others (2000) estimated the relative hazard scores for 19 species groups of birds that had been involved in 17 or more bird strikes since 1991. Based upon the extent of damage to aircraft and the effect on flight, they found that relative hazard scores were significantly and positively correlated with body mass; vultures and geese ranked the most hazardous among the 19 groups of birds. Among four species of gulls, ranked ninth as a group, the larger-bodied great black-backed and herring gulls were more likely to cause damage or affect flight than relatively smaller-bodied ring-billed and laughing gulls (Dolbeer and others 2000). These four species of gulls had intraspecific body masses of respectively, 1.20–2.10 kg (Good 1998), 0.72–1.38 (Pierotti and Good 1994), 0.38–0.65 (Ryder 1993), and 0.20–0.37 (Burger 1996). For example, from 1979 to 1998, herring gulls have caused more damaged and delayed aircraft at JFKIA than laughing gulls (15 vs 11 cases, respectively) (Dolbeer and Chipman 1998); it was not stated how many aircraft were damaged versus delayed.

Sources and Breeding Status of Laughing Gulls at JFKIA.

Based upon observations of color-marked gulls, the JBWR colony is known to be a periodic and seasonal (April–August) source of gulls at JFKIA (Griffin and Hoopes 1992). What is not clear, however, is the actual proportion that are breeders from the JBWR colony among all gulls present at the airport any one time. Based upon differences between nesting diet (predominantly marine origin), and that of adults collected at the airport (mostly insects), Buckley and Gurien (1986) and Buckley and McCarthy (1994) concluded that most (90%) of the laughing gulls foraging on JFKIA property were not current breeders; this estimate would include nonbreeders as well as those breeders that failed during the incubation stage or had come in from elsewhere. Of the laughing gulls shot at JFKIA each year, about 9% are second-year birds and young-of-the-year fledglings (Dolbeer and Bucknall 1997).

In 1996–1998, as part of a related study in JBWR (Brown and others 1999), we color-marked one or more laughing gull chicks on their heads with rhodamine B (pink) dye from 79, 247, and 179 nests, respectively. Chicks were marked at hatching and dye was subsequently transferred to the breast and side feathers of their brooding parents. Assuming that one parent was marked per chick dyed (maximum two parents per nest), we estimate that about 91, 433, and 312 adult gulls were marked with dye in 1996, 1997, and 1998, respectively; of those color-marked, 5, 24, and 31 (5.5, 5.5, and 9.9%) were subsequently shot at JFKIA in the three years (Table 3).

In 1996, 1997, and 1998, totals of 1970, 3242, and 2920 laughing gulls were shot at JFKIA. Assuming that our sample of color-marked gulls was representative of the breeding population, then about 5%–10% of the breeding population was shot at the airport each year; equivalent to 471, 372, and 1079 breeding gulls, in the three years, respectively (Table 3). Accordingly, we estimate that 11%–37% of those shot were parental gulls with chicks; the remaining 63%–89% were either failed breeders or nonbreeding birds.

The sources and breeding status of gulls (those with young versus failed breeders and nonbreeders) that contribute most to the bird-strike rate at JFKIA have critical management implications concerning the laughing gull colony in JBWR. If indeed most of the laughing gulls that frequent JFKIA airspace are failed breeders and nonbreeders, then nonlethal control techniques (in-colony nest destruction and egg-oiling, and falconry) would increase the population of nonbreeders in the JBWR/JFKIA complex and so possibly increase the frequency of bird strikes and the numbers of gulls shot at the airport. During an egg-oiling experiment at the colony in 1990, Griffin and Hoopes (1992) observed disproportionately more red-dyed adults (marked at oil-treated nests) on airport property than green-dyed adults (marked at untreated nests), suggesting that recently failed breeders were more likely to visit JFKIA than those tending eggs and chicks.

Wake Turbulence as a Source of Bird Mortality

If not collisions with aircraft, what accounts for the other 80%–90% of the birds found dead near runways?

Table 3. Laughing gulls at Jamaica Bay Wildlife Refuge and Kennedy airport

Year	Breeding adults (N)[a]	Dyed adults (N)[b]	Dyed adults shot[c]		Total adults shot (N)[d]	Estimated proportion of adults shot that were breeders	
			N	%		N[e]	%[f]
1996	9,652	91	5	5.5	1970	471	24
1997	6,762	433	24	5.5	3242	372	11
1998	10,896	312	31	9.9	2920	1079	37
Pooled	27,310	836	60	7.2	8132	1966	24

[a]The number of breeding adults in Jamaica Bay Wildlife Refuge was estimated by doubling the number of nests counted.

[b]Adults were dyed with rhodamine B that was transferred from a chick(s) to its brooding parent.

[c]Data pertaining to the number of color-dyed adults shot at Kennedy were obtained from R. Dolbeer (personal communication).

[d]The total number of laughing gulls that were shot at Kennedy (data taken from Dolbeer and Chipman 1998).

[e]We estimated the number of breeders shot at Kennedy by multiplying the percentage of dyed-adults shot by the total number of breeding adults.

[f]The percentage of shot breeders was estimated from the proportion of shot adults that were breeders (i.e., the remainder were probably nonbreeders). For example, in 1996, we estimate that about 24% (471/1,970) of the laughing gulls shot at Kennedy airport were breeders from the Jamaica Bay Wildlife Refuge colonies.

We suggest, as did Buckley and Gurien (1986), that many of the dead birds found near runways at JFKIA are being killed by the wake turbulence (i.e., wing-tip vortex) produced by large commercial aircraft. As an airfoil passes through the air, the air rolls up and back about each wing tip producing two distinct counter-rotating vortices, one trailing each wing-tip. The intensity of the turbulence within these vortices is directly proportional to the weight and inversely proportional to the wing span and the speed of the airplane; that is, the heavier and slower the airplane, the greater is the intensity of the air circulation in the vortex cores. Therefore, the most violent vortices are generated during take-off and landing, and near maximum gross weights. The vertical gusts encountered when crossing laterally through the vortex can impose structural loads as high as 10 Gs and can cause the structural failure of small light aircraft such as the Cessna 152/172 and Piper Cherokee. The combined effect of an up-gust followed immediately by a down-gust has been estimated to be as high as 80 feet per second; most small planes are designed to withstand vertical gusts of only 30 feet per second (MacDonald 1963).

Wing-tip vortices are generated at the point of lift-off and end when the aircraft touches down (i.e., they occur only between take-off and landing). The vortices settle below and behind the aircraft and may trail the aircraft by 10 miles; in still air, they decay slowly and may be encountered as long as 5 min after the passage of the airplane. When vortices sink to the ground, they tend to move laterally outward over the ground at a speed of about 5 knots and so may position themselves parallel to the designated, or a parallel, runway (MacDonald 1963). Given the potential hazard that wake turbulence poses to the structural integrity of light aircraft, it is not surprising that many bird carcasses are found near runways at JFKIA and other large airports. Their role in the causes of bird deaths on airports remains unstudied.

Management Options to Reduce Presence of Birds at Kennedy Airport

Three approaches have been used in an effort to reduce the abundance of gulls and other birds at airports: (1) the reduction of gull populations on or near the airport; (2) habitat manipulations to reduce and eliminate on-airport and off-airport attractants to birds; and (3) dispersing and removing birds from the airport. In this paper, we do not attempt to review all of the various techniques employed to control bird populations, or their effectiveness at doing so (see reviews by Burger 1983c, Seubert 1990, USDA 1994). Instead, we focus our discussion on those category 1 and 2 management options (after USDA 1994) that are applicable to the laughing gull controversy in the JBWR/JFKIA complex (also see Table 1).

Category 1: Integrated Wildlife Management Program at Kennedy Airport

Airports are attractive to birds because they are generally flat and open, and they provide roosting and loafing areas that have good visibility of predators (e.g., runways, light stands), sources of fresh water for drinking and bathing, and a variety of food resources, including seeds, insects, small mammals and human refuse (Burger 1983c). Presumably then, bird–plane interactions could be minimized by making the airport and its vicinity unattractive to birds. Indeed, several authors stress that habitat modification is the best long-term solution to bird control at airports and that management must extend beyond the airport to reduce the numbers of birds that come to the vicinity of the airport (e.g., Burger 1983c, and references in Seubert 1990, Buckley and McCarthy 1994). Thus, a good wildlife management program would include eliminating both on-airport and off-airport attractants to birds, and a bird control unit sufficiently staffed, trained, and equipped to disperse all birds that enter the airport at any time of the day or night, 365 days per year.

Habitat alterations at Kennedy Airport. The development of the Bird Hazard Reduction Program at JFKIA has been an on-going process since the 1960s when PANYNJ began removing water and vegetation that were attractive to birds and harassing birds with carbide cannons and pyrotechnics (USDA 1994). Since then, several studies have been conducted at the airport to evaluate the bird-strike problem and to identify on-airport attractants to birds (Buckley and Gurien 1986, Buurma and others 1989, Griffin and Hoopes 1992, Buckley and McCarthy 1994). For example, in 1965, J. Bull (American Museum of Natural History, cited in USDA 1994) submitted several recommendations to PANYNJ including: (1) the elimination of water on the airport; (2) modification of the airport's shoreline with Jamaica Bay; (3) the employment of a shotgun patrol to harass birds; and (4) the elimination of nearby landfill sites.

Based upon these and other recommendations, the PANYNJ has implemented a variety of management programs at JFKIA in an effort to make the habitat less attractive to birds. For example, in 1985 and 1986, Buckley and Gurien (1986) and Buckley and McCarthy (1994) identified ten areas on runways where gulls were attracted to pools of standing water. Similarly, from June to August 1990, Griffin and Hoopes found that gulls spent the majority (60%–100%) of their time on JFKIA engaged in maintenance behaviors (resting, preening), usually in a large area (50 × 20 m) of standing water between two taxiways. Accordingly, between 1991 and 1994, PANYNJ has filled or repaved many of these wet areas and installed styrofoam wicks to improve drainage near most runways and taxiways (USDA 1994).

Buckley and Gurien (1986) and Buckley and McCarthy (1994) also found that areas with short grassy near runways were attractive to laughing gulls foraging for Oriental beetles, their dominant on-airport food, and recommended that these areas be eliminated by reducing the frequency of mowing and maintaining grass height above 45 cm. Since 1987, PANYNJ has attempted to maintain tall-grass conditions near runways during the summer, regularly applies pesticides (at two-week intervals) to control insect populations (USDA 1994) and, in 1998, began to remove shrubs, brush, and other cover attractive to birds and rodents (Dolbeer and others 1999). PANYNJ has also improved sanitation at the airport by replacing open trash containers with closed trash compactors and prohibiting taxi drivers from feeding birds (USDA 1994). Despite all of these initiatives, however, insects and human refuse have consistently been the most frequent food types found in the stomachs of adult laughing gulls collected on JFKIA (Griffin and Hoopes 1992, Brown and others 1999).

PANYNJ has committed less effort to eliminating off-airport attractants located nearby (<5 km) although several have been identified, including three landfills located adjacent to Jamaica Bay (Burger 1983a), the Jamaica Sewage Treatment Plant, and Aqueduct Race Track (Griffin and Hoopes 1992). The Pennsylvania and Fountain Avenue landfills were closed in 1985 and Edgemere in 1991 (Figure 1).

Removal and dispersal of birds from Kennedy Airport. One of the earliest bird control recommendations to PANYNJ was the employment of a shotgun patrol to harass and disperse birds from the airport. After the 1975 DC-10 aborted take-off, PANYNJ employed a bird control unit to keep runways clear of birds and stationed one full-time person in the FAA control tower to monitor bird activity and potential hazards. During each of two consecutive 8-hour shifts every day, unit staff (one supervisor and one agent per shift) conduct roving patrols and runway sweeps to disperse birds from the vicinity of runways, collect dead birds, and keep records of all bird strikes (USDA 1994). During the 1980s, however, several independent evaluations included recommendations directed at enhancing and modernizing the capability of the bird control unit to disperse birds, including higher levels of staffing (i.e., >2 patrols); better training of staff to detect, identify, and disperse birds; and the availability of state-of-the-art bird dispersal equipment (Buckley and Gurien 1986, Buurma and others 1989, Griffin and Hoopes 1992, Buckley and McCarthy 1994). These recommendations have not been fully implemented (USDA 1994, Lambertson 1994, 1996).

Given the location and the size of JFKIA (about 4930 acres), are two bird control personnel/patrols per shift sufficient to protect the airport? The increasing numbers of bird strikes (an indirect measure of bird activity on the airport) during the 1980s indicates that the bird control unit was not effective at detecting and dispersing birds. For example, in August 1990, Griffin and Hoopes (1992) observed three feeding flocks each of about 2000 gulls (95% laughing gulls) hawking insects over three separate areas of the airport. In one case, a flock persisted within the vicinity of two active runways for at least 75 min. During this time, there were three reported bird strikes involving six laughing gulls, one immature herring gull, and one adult great black-backed gull.

In response to the increasing numbers of gull strikes, PANYNJ contracted with the USDA's Wildlife Services Division to conduct a gull-shooting program at JFKIA since 1991, usually for about 10 weeks during the gull nesting season (mid-May to early August) (see Dolbeer and others 1993). Each morning, five biologists, armed with shotguns and live ammunition, were stationed along the airport perimeter adjacent to the bay to shoot all gulls that flew within the immediate vicinity (30–40 m) of the airport. In 1996, an experimental falconry program was also added to aid bird dispersal efforts at the airport.

While the shooting program has reduced the number of bird strikes involving gulls, the reduction also may have been due to the overall increase in human effort to control birds before they enter the airport. It cannot be ruled out that an equal effort by bird-control personnel (seven persons per unit per shift) using nonlethal bird dispersal techniques (distress calls, pyrotechnics) would also have reduced bird strikes at the airport during the 1980s and 1990s. This hypothesis could be tested by manipulating the number of personnel using nonlethal techniques to disperse birds and recording the numbers of bird strikes. Such a study could be conducted at JFKIA by encouraging USDA shooters to use nonlethal techniques to disperse gulls (and also other birds) prior to lethal control. Reductions in the numbers of reported bird strikes, bird carcasses near runways, and gulls shot at JFKIA would support the hypothesis.

Currently, it is not possible to determine whether or not the on-airport wildlife management programs have already reduced, or eventually will reduce, bird hazards to aircraft because: (1) PANYNJ has yet to produce a written Wildlife Management Plan that is in compliance with the final EIS (USDA 1994), and (2) on-airport management programs often fail to include the appropriate control groups and sampling protocols that are necessary for rigorous scientific evaluation (e.g., falconry, nonlethal bird dispersal) (also see Burger 1983c).

Category 2: On-Colony Population Management

In the final EIS (USDA 1994), and in the USDA's and USFWS's records of decision, the preferred on-colony management option (category 2) was the relocation of the laughing gull colony from Jamaica Bay to another suitable location more remote from the airport. Implicit in this option is the establishment of a new colony on Long Island and the simultaneous elimination of the existing one in JBWR. Is colony relocation a feasible management option (i.e., practical to implement and effective at long-term reduction of bird strikes)?

Eliminating the laughing gull colony. USDA (1994) biologists reviewed numerous lethal (e.g., poisoning and shooting adults, destruction of nests and eggs) and nonlethal (e.g., habitat modifications, harassment, exclosures) management techniques aimed at reducing and/or eliminating the laughing gull colony in JBWR. The colony (about 5450 nests in 1998) spreads over three adjacent marshes (about 400 total acres). Based upon their literature review and interviews with knowledgeable professionals, the USDA evaluated each method for technical feasibility (practical to implement), effectiveness at reducing the colony, and environmental impacts. They concluded that a combination of colony-wide nest and egg destruction every two weeks, on-colony shooting of adults from blinds, and continuous harassment with models of dead gulls would be the best approach to reduce and eliminate the colony (USDA 1994).

While it is probable that nest destruction and gull harassment would reduce the nesting population, at least during the implementation period, the elimination of the colony will likely require long-term management (>5 years, possibly indefinitely) (see Olijnyk and Brown 1999) and might ultimately depend upon the availability of alternative nesting sites (Burger 1983c, USDA 1994). In this case, it is also important to point out that frequent and prolonged human intrusion into the colony would result in structural damage to the marsh habitat (trampling of grasses) and also have detrimental effects (nest and egg loss) on other non-target, marsh-nesting species including common (*S. hirundo*) and Forster's terns, clapper rails (*Rallus longirostris*), and black ducks (*Anas rubripes*).

Given the potentially adverse consequences associated with nest destruction activities, it is important to evaluate a priori whether or not population reduction would indeed reduce gull hazards to aircraft at JFKIA. While the USDA (1994) described the various management protocols in detail and reviewed the literature regarding the effectiveness of each technique to reduce populations, they were unable to cite a single case study that shows that on-colony reduction of a gull population did indeed reduce bird strikes. In her review of bird control techniques at airports, Burger (1983b) points out that such information is sparse and often available only in non-peer-reviewed reports from bird control meetings.

Does population reduction actually reduce gull hazards at airports? Seubert (1990) reviewed eight cases where gull populations were reduced or eliminated from colony sites near airports (1–40 km). Of these eight case studies, herring gull strikes were apparently reduced at two airports. Although Seubert provided details pertaining to control method, numbers of gulls killed, and/or the extent of the population reduction, he did not provide any data pertaining to the degree of gull hazard reduction. Upon reviewing data from five other bird control programs, Burger (1983b) found that killing large numbers of birds achieved only a temporary population reduction. She concluded that: (1) attempts to maintain bird populations below the carrying capacity of the environment have generally been expensive and unsuccessful; and (2) killing gulls at airports has also failed to reduce populations because other gulls move in from elsewhere to fill vacant niches. Burger (1983b) asserts that permanent reductions of birds can be achieved only by lowering the carrying capacity of the environment by direct manipulation of habitat.

Burger's conclusions remain particularly relevant to the Laughing Gull situation at JFKIA. First, despite the shooting of over 50,000 laughing gulls at the airport, the colony in JBWR remains at about 5200 ± 850 pairs (1992–1998; a 30% reduction since 1990) because of immigration from New Jersey and elsewhere (Dolbeer and Chipman 1998). Second, numbers of reported nongull strikes have more than doubled since the gull-shooting program was initiated in 1991 (Table 2). Third, numbers of reported strikes involving all birds has remained relatively constant since 1979 (14–37 aircraft struck/yr; mean 23 ± 6 aircraft/year, 20 years). Taken together, these facts suggest that, during the 1980s laughing gulls may have displaced other birds from foraging and loafing habitats on and near JFKIA.

While intuitively it seems logical that reducing bird populations near an airport would decrease bird hazards to aircraft, there is no evidence to indicate that a reduction of the JBWR laughing gull colony would yield any reduction in bird strikes at JFKIA. Conversely, nest destruction and harassment activities at a gull colony located adjacent to an airport could create additional hazards to aircraft because harassed birds would tower above the colony site and/or failed breeders would disperse to loafing areas on or near the airport (Seubert 1990, Griffin and Hoopes 1992, USDA 1994).

Table 4. Colony sites in New Jersey where laughing gulls nested with other tern and gull species

Indicator species	Colonies in 1989 (N)	Colonies with laughing gulls present N	%
Forster's tern	32	27	84
Common tern	80	50	62
Black skimmer	9	4	44
Herring gull	93	53	57
Great black-backed gull	51	30	59

Data from Jenkins and others (1990).

Establishing a new colony, Relocating the JBWR laughing gull colony to another location on Long Island requires identifying suitable nesting habitat that is in close proximity to abundant natural food resources and attracting prospecting birds to the desired colony site. Currently, it is not known if another suitable nesting site exists on Long Island.

During the past 20 years, laughing gulls have made few attempts to nest elsewhere on Long Island. In 1978, one nest was found on the Line Island complex in Great South Bay, near Jones Beach (Buckle and others 1978). In 1990 and 1991, up to four pairs nested on North Cinder Island (the Cinder Island Group, Town of Hempstead; Sommers and others 1994), and two pairs nested on Young's Island, Smithtown, in 1995 (Sommers and others 1996); these sites were abandoned after one or two years of nesting attempts. Historically, laughing gulls nested in South Oyster Bay up to 1884, at Amityville until 1887, and on Cedar Island as late as 1888 (W. Dutcher in A. C. Bent 1921).

In New York and New Jersey, laughing gulls typically nest on nonbarrier saltmarsh islands, characterized by *Spartina* grasses; tidal flooding is often the major cause of nest loss (Bongiorno 1970, Montevecchi 1978, Burger and Shisler 1980). It may be possible to use marsh-nesting Forster's and common terns to identify those marsh habitats suitable (low wave action and tidal flooding) for nesting by laughing gulls. For example, in New Jersey during 1989, laughing gulls nested with Forster's and common terns at 27 (84%) and 50 (62%) colony sites (Jenkins and others 1990) (Table 4). Although the bulk of breeding Forster's terns on Long Island are in JBWR colonies, they are slowly expanding into saltmarshes north of Long Beach and Jones Beach where common terns have long had a large presence. Breeding common terns are widely distributed on Long Island, and in the period 1974–1983 alone, colonies were found at 115 different sites, with as many as 50 marsh colonies in a given year (Buckley and Buckley 1980, 2000).

In addition to identifying suitable nesting and foraging habitats, several extrinsic factors must be considered when choosing a location to establish a gull colony, including land ownership, human disturbance, potential conflicts with human interests (marinas, vineyards) and resident species, and the distance from the site to JFKIA and other airports. At a colony on Egg Island, New Jersey, radio-tagged laughing gulls were located up to 40 km from the colony foraging at airports, agricultural fields, and other sites (Dosch 1996, 1997).

If a suitable location is found for a new colony, prospecting gulls could be attracted to the site using physical (wrack) and social stimuli (decoys of courting laughing gulls, vocalizations broadcast through speakers). Kress (1983) used tern decoys and nonaggressive vocalizations to encourage the settlement and nesting of arctic terns (*S. paradisaea*) on Eastern Egg Rock, Maine. Similarly, Blokpoel and others (1997) used decoys and gull harassment techniques to restore a common tern colony on Ice Island in the St. Lawrence River.

Animal Welfare Considerations

It may be desirable to relocate the colony for ethical reasons and necessary to sustain the natural population in New York. Since the gull-shooting program began in 1991, a total of 50,521 laughing gulls have been shot at JFKIA. After one year of shooting, the number of nests in the JBWR colony declined about 30% from 7600 nests in 1990 to 5100 in 1992. Since 1992, the colony has remained relatively stable at 5200 ± 850 nests/year [7 years, 1992–1998; data taken from Dolbeer and others (1997) and Dolbeer and Chipman 1998)].

The shooting program could also be having adverse effects on regional populations of laughing gulls. The recent stability of the JBWR colony, despite the loss of thousands of adults each year, suggests that the Jamaica Bay population may be acting as a sink. That is, prospecting gulls immigrate to JBWR and are subsequently shot at JFKIA. Of the banded laughing gulls shot at JFKIA, most (97%) were banded as chicks at colony sites in New Jersey (Dolbeer and Bucknall 1997). During the 1980s, the New Jersey population increased from 30,700 adults in 1977 to 58,722 adults in 1989, but has subsequently declined to 39,085 adults in 1995 (Jenkins and others 1990, D. Jenkins personal communication). It is not clear to what extent this apparent decline (about 34%) is the direct result of the shooting program at JFKIA.

Given that JBWR represents the only laughing gull nesting area in New York State, we recommend that attempts be made to initiate an experimental colony elsewhere on Long Island to determine if colony relocation is a feasible management option. By providing an alternative breeding site for young and prospecting birds, a second colony also may attract some laughing gulls from JBWR and reduce the level of recruitment into this population. Furthermore, it is more important to determine if a second colony would reduce gull abundance at JFKIA. While it is possible that an alternative breeding site would attract young and prospecting gulls away from the JBWR/JFKIA complex, a second colony could also result in more laughing gulls at local airports.

Conclusions and Recommendations

In this paper, we have attempted to objectively review information pertaining to the effect that the JBWR laughing gull colony has had on bird stikes at JFKIA. Has the colony increased the level of risk to the flying public? Below, we list our conclusions:

1. The laughing gull is one of more than 50 species of birds that have been struck by planes at JFKIA. Given the relatively low mass of laughing gulls (about 0.3 kg), they are less likely to cause engine damage to aircraft than larger, heavier (>0.5 kg), less agile birds like herring and great black-backed gulls or geese.

2. The definition of a bird strike at JFKIA requires redefinition. Bird strike data come from two very different sources including (1) reported strikes and (2) all bird carcasses found near runways that are *assumed* to be unreported bird strikes (see above, and Dolbeer and others 1989). Most (80%–90%/yr) bird strikes at JFKIA are actually dead birds found near runways and the actual causes of mortality are unknown (collision with an aircraft versus wake turbulence and natural causes).

Based on differences between reported and unreported bird strikes, we strongly urge that these two data sets always be presented separately. In addition, the misleading term bird strike should be changed to 'carcasses' since the latter term more accurately reflects the *known* information pertaining to unreported bird strikes. Similarly, confirmed reported strikes could be referred to as 'bird–plane collisions.' We believe that the number of reported strikes (known collisions) each year is a better measure of risk to planes and passengers; all airlines should be encouraged to report such strikes.

3. Data pertaining to whether or not the laughing gull colony has increased the level of risk to aircraft at

JFKIA are the subject of dispute. From 1979 to 1990, the number of laughing gulls involved in reported strikes increased with year and with the number of pairs nesting in the refuge. Including all bird species, however, the numbers of aircraft actually struck by birds were not correlated with either the size of the laughing gull colony or year.

Including all bird species, numbers of reported strikes have fluctuated between 14 and 37 aircraft each year (mean = 23 ± 6 aircraft/year, 20 years). While reported strikes were highest from 1983 to 1990, only about 25% involved laughing gulls, while 50% involved other gulls. Since the shooting program began at JFKIA in 1991, numbers of aircraft struck (reported strikes) by laughing gulls have been reduced to a levels similar to that recorded between 1979 and 1982 when the colony was small (Dolbeer and Chipman 1998). Reported strikes involving non-gull species, however, have more than doubled since 1991. Taken together, these data suggest that the level of risk to planes and passengers at JFKIA has remained constant during the past 20 years, irrespective of the size of the laughing gull colony.

4. Based upon three years of mark and recapture data (1996–1998), we estimated that 11, 24, and 37% (average of 24%) of laughing gulls shot at JFKIA were breeding adults from JBWR; the remaining 60%–90% were either failed and/or nonbreeding birds. If most of the laughing gulls frequenting JFKIA airspace are failed breeders and nonbreeders, then nonlethal control techniques (on-colony nest destruction, egg-oiling, and falconry) to manage the colony would actually increase the population of nonbreeders in the JBWR/JFKIA complex, in turn possibly increasing the frequency of bird strikes and numbers of gulls shot at the airport.

5. While PANYNJ has moved towards implementing several on-airport management programs, they have often done so only recently (long-grass management since 1987; improved drainage installed 1991–1994) or partially (removal of vegetation 1998–1999); recall that some recommendations were formally submitted to them as early as 1965. Thus, it is likely that the rise in the bird-strike rate during 1980s could have been avoided, or at least lessened, by timely and appropriate implementation of wildlife management practices at JFKIA including habitat alterations (eliminating sources of food and water) and increasing the capability of the bird control unit until it had successfully eliminated bird flocks on-airport.

6. Since the gull-shooting program began at JFKIA in 1991, the number of laughing gull nests in JBWR has declined about 30% to 5200 ± 850 nests (over seven years). While the Jamaica Bay population has remained relatively stable for seven years, despite the loss of 50,521 adults, the laughing gull population in New Jersey has declined from 58,722 in 1989 to 39,085 adults in 1995. This 34% reduction may be conservative because investigators counted adult gulls on nesting areas from helicopters and usually technique-dependent conversion factors equate one adult on the ground to one nest/pair (Erwin 1979). Thus, it is possible that as many as 38,000 adults are missing from New Jersey colonies.

7. At this time, we argue there is no scientifically supportable evidence that the laughing gull colony in JBWR needs to be managed (reduced or eliminated) and that, in any event, this should not be considered until all on-airport management options have been implemented and proven ineffective. Some form of management, however, may be warranted to preserve the local laughing gull populations. It is possible that the shooting program at JFKIA is resulting in a nonsustainable regional population. Given that a large number of bird strikes involve nonbreeding birds and that a large number of gulls are shot each year at the airport, we do recommend that attempts be made to establish a new laughing gull colony elsewhere on Long Island in order to determine if: (1) colony relocation is a feasible management option; (2) it would lure breeding and nonbreeding gulls away from the JBWR/JFKIA complex; and (3) whether said birds would nonetheless also wind up at the airport.

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Appendix 1. Laughing gull (*Larus atricilla*) nests in Jamaica Bay, numbers of aircraft involved in bird-strikes, and pilot-reported strikes with respect to type of bird at John F. Kennedy International Airport, 1979–1998

Year	Laughing gull nests (*N*)[b]	Number of aircraft involved in bird-strikes (type of bird struck)[c]				Number of aircraft involved in pilot-reported strikes (type of bird)[d]			
		Laughing gull	Other gull[e]	Other bird	All birds	Laughing Gull	Other gulls[e]	Other birds	All birds
1979	15	2	86	29	117	0	15	6	21
1980	235	19	98	29	146	0	10	7	17
1981	325	20	44	36	100	2	3	9	14
1982	715	14	68	38	120	0	10	10	20
1983	1805	48	89	62	199	5	11	9	25
1984	2802	58	114	79	251	5	17	5	27
1985	2741	82	139	72	293	4	24	9	37
1986	3000	59	42	37	138	6	5	3	14
1987	2875	118	73	35	226	10	8	4	22
1988	2665	164	114	36	314	5	16	5	26
1989	—	171	108	36	315	12	15	6	33
1990	7629	135	89	54	278	8	9	10	27
1991	—	60	54	42	156	2	10	11	23
1992	5117	22	37	42	101	0	6	12	18
1993	6032	18	25	37	80	3	2	11	16
1994	5554	21	37	45	103	3	1	18	22
1995	6065	36	32	49	117	4	7	12	23
1996	4826	29	33	83	145	3	3	20	26
1997	3381	37	27	105	169	4	4	24	32
1998	5448	17	18	41	76	2	1	11	14
Total		1130	1327	987	3444	78	177	202	457

[a]Bird-strike data were taken from Dolbeer and Chipman (1998) and R. Dolbeer (unpublished data).

[b]Laughing gull data of: 1978–1984 from (Buckley and Buckley (1984); 1985–1988 from (Sommers and others (1994); 1990 from (Griffin and Hoopes (1992); 1992–1995 from (Dolbeer and others (1997); 1996–1997 from (Dolbeer and Bucknall (1997); 1998 from Dolbeer and Chipman (1998).

[c]Bird strikes include (1) pilot-reported strikes and (2) all dead birds (cause of death unknown) found within 250 feet of a runway; all assumed to have been struck by planes.

[d]Only those bird strikes that were reported by pilots and air-carriers.

[e]Other gull species include great black-backed gull (*L. marinus*), herring gull (*L. argentatus*), and ring-billed gull (*L. Delawarensis*).

thors and should not be interpreted as representing the opinions or policies of the US Government. Mention of trade names or commercial products does not constitute their endorsement by the authors or the US Government.

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