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A review of the hazards and mitigation for airstrikes from Canada geese in the Anchorage, Alaska bowl

Darryl L. York[1,*], Richard M. Engeman[1], John L. Cummings[1], Corey L. Rossi[2] & David R. Sinnett[2]
[1]*National Wildlife Research Center, 4101 LaPorte Avenue, Ft. Collins, CO 80521, USA*
[2]*USDA/APHIS/WS, 1800 Glenn Hwy, Suite 12, Palmer, AK 99645, USA*
[*]*Author for correspondence: U.S. Fish and Wildlife Service, 4000 Airport Parkway, Cheyenne, WY 82001, USA (Tel.: +1 307 772 2374; Fax: +1 307 772 2358; E-mail: Darryl_York@fws.gov)*

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Abstract

Bird strikes to aircraft are a globally pervasive safety and economic concern. In particular, the Anchorage, Alaska area holds substantial risk for destructive collisions between birds and aircraft. An international airport, a municipal airport, a seaplane base, and a U.S. Air Force base are situated throughout the area. Anchorage also has a burgeoning population of Canada geese (*Branta canadensis parvipes*), one of the species identified as posing the greatest airstrike hazards. A variety of methods are applied and a variety of research has been conducted to reduce the potential for airstrikes with geese around Anchorage. We review the nature of the problem, as well as the research and mitigation procedures applied to address the problem.

Introduction

Bird strikes to aircraft are a serious safety and economic problem in the U.S., annually causing millions of dollars in damage to civilian and military aircraft and occasionally loss of human life (Cleary *et al.* 1998). From 1990 to 1999, wildlife strikes cost the U.S. civil aviation industry over $380 million/year, and approximately 5000 bird strikes were reported for U.S. civil aircraft in 1999 (Dolbeer 2000). Military aircraft are especially susceptible to bird strikes because many exercises involve high speeds at low altitudes, where birds are commonly present. Losses of military aircraft have been numerous and costly (Blokpoel 1976). The U.S. Air Force reported 13,427 bird/wildlife strikes to aircraft worldwide from 1989 to 1993 (Arrington 1994), and recorded over 3500 bird strikes just in 1998 (Dolbeer 2000).

On 22 September 1995 at Elmendorf Air Force Base (EAFB) in Anchorage, Alaska an E-3 Sentry Airborne Warning and Control System (AWACS) aircraft was taking off when several Canada geese (*Branta canadensis parvipes*) flew in front of the aircraft and were ingested into the two left engines, destroying one and causing the other to lose power. The crew was unable to maintain control of the disabled aircraft and crashed less than a mile from the runway killing all 24 people aboard (Bird 1996).

Canada geese may soon become the most common bird species involved in aircraft bird strikes as a result of population increase and propensity to become permanent residents in urban environments (Forbes 1996; Cleary *et al.* 1997). Geese rank high in the U.S. for every descriptive criteria for wildlife airstrike hazard including number of strikes, percentage of strikes resulting in aircraft damage, percentage of strikes effecting the flight of aircraft, and the cost/strike (Dolbeer *et al.* 2000). Geese were exceeded only by deer and vultures in a composite ranking of their airstrike hazard (Dolbeer *et al.* 2000).

Lesser Canada geese nest in Cook Inlet and throughout river drainages from western and interior Alaska to the Yukon Territory, and migrate along the Gulf of Alaska coast south, or up the Tanana River through British Columbia to their wintering grounds in western Oregon (Rothe 1994). During the spring and fall migrations, urban geese attract geese migrating to and from breeding grounds elsewhere in Cook Inlet and western Alaska, and during the last half of September and early October, tens of thousands of Canada geese pass through Anchorage, stopping briefly to feed when they see other geese already there (U.S. Fish and Wildlife Service 1998). However, since geese nest in the location where they learned to fly, these migrants do not remain in Anchorage to nest, and are a concern to aircraft only during migration (U.S. Fish and Wildlife Service 1998).

In Anchorage, Alaska numbers of lesser Canada geese nesting and residing over summer have increased more than 10-fold during the past two decades (U.S. Fish and Wildlife Service 1998), increasing rapidly in the 1980s and through the early 1990s (12–15% annually), but since slowing to an annual increase of approximately 6%. An estimated 4650 geese returned to Anchorage in spring 1998 (Crowley 1998). The primary reasons for the increase in this urban goose population are the habitat and food conditions and low rates of harvest and natural mortality (U.S. Fish and Wildlife Service 1998).

Anchorage, Alaska occupies a triangular area projecting into the Pacific Ocean with Cook Inlet's Knik Arm to the north and Turnagain Arm to the south, and the Chugach Mountain range to the Northeast (Miller & Dobrovolny 1959). Since the establishment of Anchorage in the early part of the twentieth century, local vegetation has been highly modified, including the conversion of forested and bog habitats into residential and commercial developments (U.S. Fish and Wildlife Service 1998). Local terrain and hydrology have created a variety of freshwater wetlands and brackish pools and marshes on coastal tidelands. Anchorage's deepwater wetlands include approximately 20 glacial kettle lakes and another 11 artificial lakes (U.S. Fish and Wildlife Service 1993). From 1950 to 1990, new impoundments increased surface water area from 125 to 268 ha, and lawn/grassy areas doubled as a result of new housing development (U.S. Fish and Wildlife Service 1993). Consequently, excellent nesting and brood-rearing goose habitat has been created by urbanization in Anchorage with the juxtaposition of mowed lawns, ballfields and numerous lakes (U.S. Fish and Wildlife Service 1998) (Figure 1). Situated throughout Anchorage are the three main airports including Ted Stevens Anchorage International Airport (AIA)/Lake Hood Seaplane Base the municipal airport at Merrill Field (MFA), and EAFB.

In 1996, a coalition of local government agencies, airports, and State and Federal natural resource agencies, including the U.S. Fish and Wildlife Service, formed the Anchorage Waterfowl Working Group (AWWG), which is developing a multi-agency Canada goose management plan. The U.S. Fish and Wildlife Service and the AWWG recognize that the primary responsibilities for implementing solutions to the problems related to the increase in the Canada goose population rest with the Municipality of Anchorage (MOA) and military and civilian airport authorities (U.S. Fish and Wildlife Service 1998).

This paper reviews issues and research associated with the urban goose population and the high volume of air travel in the Anchorage area, as well as potential management options for alleviating bird/aircraft strike hazards in the area.

General hazard mitigation methods

Urban goose/federal policy

The U.S. Fish and Wildlife Service has had a policy on urban geese since 1982 which established guidelines for management of urban Canada geese (U.S. Fish and Wildlife Service 1982). However, problems encountered due to urban geese, particularly year-round residents, became so widespread the U.S. Fish and Wildlife Service in 1996 issued an environmental assessment of proposed changes to regulations governing control of resident Canada geese (U.S. Fish and Wildlife Service 1998). These changes did not specifically affect Anchorage, since these geese are migratory and not year-round residents, but they are discussed here to indicate the widespread nature of the problem. The proposed changes would allow states and the U.S. Department of Agriculture's Wildlife Services (WS) program to take geese and/or eggs. The purpose of the change was to provide a quicker response to alleviate human health and safety concerns, allow for greater local oversight in control actions, and reduce government administrative costs and overhead related to issuance of these permits (U.S. Fish and Wildlife Service 1998).

Translocation of geese

Translocation efforts in the Metropolitan Twin Cities Area suggested translocation can be beneficial in reducing goose numbers by 50% over a period of five

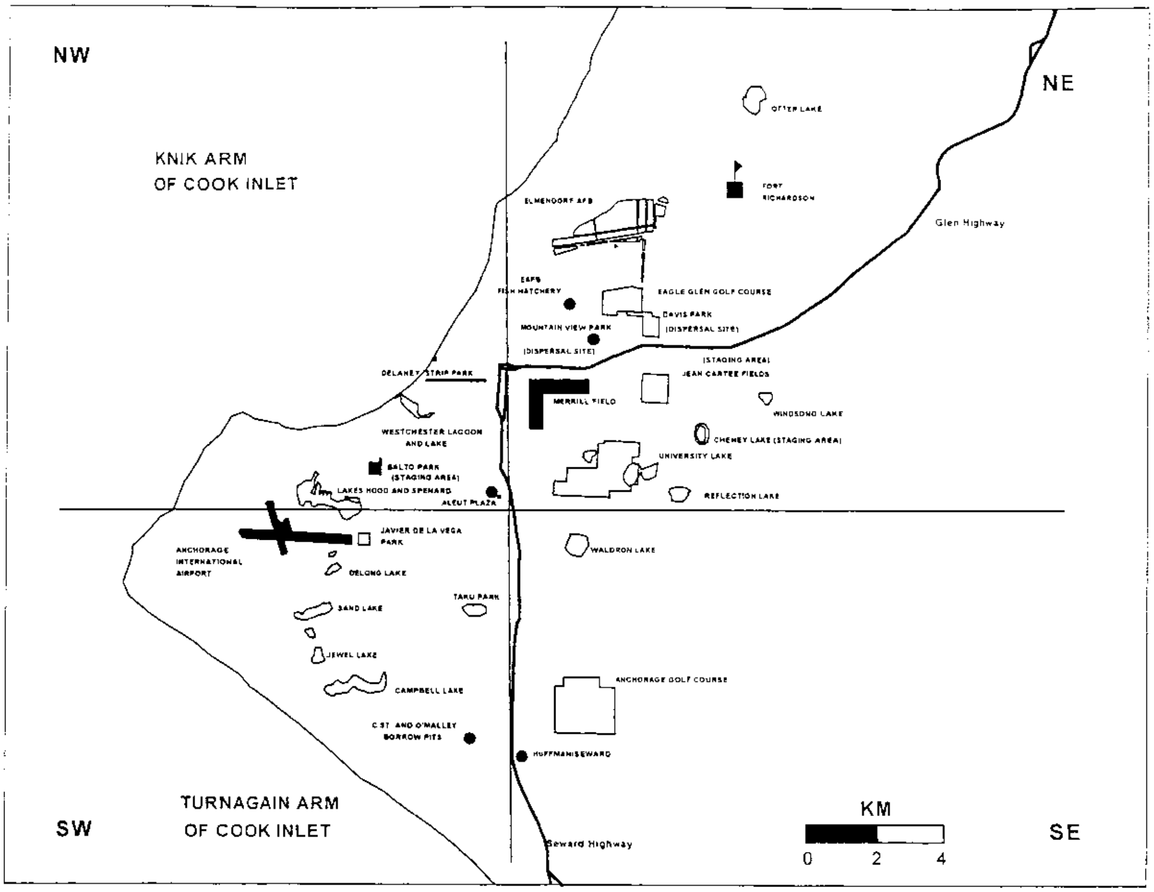

Figure 1. Location of Anchorage airports in relation to the numerous lakes and parks which serve as Canada goose nesting, molting and feeding areas.

or more years (Cooper & Keefe 1997). However, in Anchorage translocating adult geese 36 km from EAFB provided a certain degree of relief in reducing risks to aircraft safety. Twenty-six percent of neckbanded geese observed on EAFB had been previously translocated (York *et al.* 2000). Translocating geese north placed EAFB between them and Anchorage molting and breeding sites, perhaps explaining the large numbers of translocated geese observed on EAFB when they regained flight. However, any management action that might encourage goose flight paths over an airport must be avoided to lessen the possibility of geese entering active airspace as they attempt to return to original capture locations (York *et al.* 2000). Moving geese at least 800 km and preferably to the south of capture locations where they will be subjected to hunting pressure is ideal for preventing returns (Dolbeer *et al.* 1996). In addition, translocation of juvenile geese separate from adults has been found to be effective in preventing large numbers of returns when moved at least 32 km from the capture site (Cooper 1987).

Habitat alteration

Vegetation management may offer a long-term solution and decreased costs compared to other bird management techniques (Pochop *et al.* 1999). This technique can be effectively used to redistribute geese away from areas where they are causing problems, and could possibly affect population levels in the long term if practiced on a large scale (U.S. Fish and Wildlife Service 1998). Where possible lawn grass (mostly Kentucky blue grass in Anchorage) should be replaced with other less palatable ground covers such as beach wildrye, bluejoint reedgrass, and lupine (Pochop *et al.* 1999). Also, grass should be mowed and fertilized as little as possible. Airports commonly allow grass to grow 10 in in height. Open lawn spaces planted with trees and shrubs discourage goose use by minimizing visual escape routes for geese. Constructing small fences on lake edges and/or planting edges with tall grasses, sedges, or shrubs can also discourage goose use (Conover & Kania 1991; Gosser *et al.* 1997).

Egg oiling and collections

An advantage of oiling over other techniques is that the incubating birds continue to incubate eggs well past the normal hatching time, which precludes renesting (Christens & Blokpoel 1991). In the Seattle area, treatment of goose eggs with a single application of white mineral oil proved effective, inexpensive, environmentally and socially acceptable as a management tool for preventing local population increases when nests were clustered (Cummings *et al.* 1991). Geese continued to incubate eggs up to 30 days beyond the estimated hatch date, in most cases preventing renesting and eliminate recruitment into the population. Oetting (1987) believed this method was better for controlling very localized populations and not as effective for large-scale population reduction, because nests scattered over a wide area are difficult to locate.

Egg collections can be used as an added technique to lower population levels, but is labor intensive. When implemented in the Anchorage area collectors would usually leave one egg in the nest so that the female continues incubating without renesting. It is estimated five eggs must be removed to effectively stop one adult from joining the breeding population (U.S. Fish and Wildlife Service 1998). A goose lays many eggs but usually only a few offspring reach adulthood. Thus, it is difficult to lower a population simply by taking eggs. Half the eggs in Anchorage goose population would have to be taken to maintain the population at the 1997 level of approximately 4300 geese; taking 80% of all eggs might lower the population 2000 in ten years (U.S. Fish and Wildlife Service 1998).

Chemical repellents

The chemical repellent, ReJeX-iT™ AG-36 (active ingredient: 14.5% methyl anthranilate (MA)), if applied in combination with a diverse management plan, can deter geese foraging on treated sites near airport runways. However, the need for repeated applications and the associated costs restrict the feasibility of this method for large-scale control (Conover 1985; Cummings *et al.* 1991). MA is an artificial grape flavoring commonly used in foods and beverages. MA acts as an irritant to birds, and the chemical irritancy is modulated via the trigeminal nerve (Clark 1997). Thus, birds have an aversion to MA, apparently reacting in much the same way that mammals react to concentrated ammonia (Cleary & Dolbeer 1999).

Dolbeer *et al.* (1998) concluded that Flight Control™ (active ingredient: 50% anthraquinone (AQ)), registered with the U.S. Environmental Protection Agency (Reg. No. 69969-1) as a general use turf treatment against geese, was effective as a grazing repellent for Canada geese in pen experiments. Birds that ingest food treated with AQ become slightly ill and develop a post-ingestion aversion to the food (Cleary & Dolbeer 1999).

MA and AQ commercial products are liquid formulations that must be applied by sprayer to the vegetation. In addition, both chemicals are feeding deterrents. If geese are on site for other reasons the chemicals will have no effect. Effectiveness of both repellants is highly variable, depending on growing condition, rainfall, mowing, availability of alternate feeding areas, and hunger of geese. Gordon & Lyman (2000) conducted a study at the Portland International Airport and found AQ to be an effective temporary goose deterrent for specific areas. In general, effectiveness is least, perhaps lasting only a few days, when grass is growing rapidly (Cleary & Dolbeer 1999). The Municipality of Anchorage spent $6000 in 1997 to apply MA on turf at selected parks and ball fields, although a quantitative evaluation of this effort was not conducted to determine efficacy (York *et al.* 1997).

Hunting

Hunter harvest is effective for localized control, but not for range-wide population reduction in urban areas. In most cases, hunting at one site merely shift the geese to other sites. Minnesota set special early and late hunting seasons in 1987 to control resident goose populations in urban areas. While moderately successful, this hunt did not control population problems there. The method is most effective if orchestrated at many problem areas simultaneously (Oetting 1987). Cooper & Keefe (1997) concluded that hunting was the least costly goose population management technique, was effective in reducing goose density in hunted areas, and was especially effective when combined with removals (e.g. trapping and processing, and translocation) in reducing overall numbers in the Twin Cities area.

Hunting in acceptable areas in and around Anchorage, would reduce overall goose numbers and consequently help reduce the incidence of geese moving onto Anchorage airports. Liberalized harvest regimes in areas where winter populations can be identified can help control nuisance flocks (Conover & Chasko 1985). However, dusky Canada geese *(B. c. occidentalis)* and lesser Canada geese from Anchorage winter in the same areas of western Oregon and southwestern Washington. As such, concerns over the declining dusky population and difficulty in distinguishing these from other subspecies of Canada geese limit harvest opportunities for lessers on their winter range in Oregon and Washington (Hills & Naughton 1991).

Hazing

Hazing, or harassment, redistributes geese at airports but is unlikely to affect population levels. At airports, safety personnel frequently move noisemakers, flagging, and animal effigies to various locations to disperse geese. Anchorage airports are experimenting with trained falcons to move geese away from airfields (U.S. Fish and Wildlife Service 1998). Dogs, particularly border collies, will haze geese away from limited areas, and are most effective when used in spring, before geese are flightless, or in the fall, after they regain flight ability (U.S. Fish and Wildlife Service 1998). Additional hazing methods include pyrotechnics such as pistol-launched rocket and whistle bombs, cracker shells fired from 12-gauge shotguns, and propane cannons. Other possibilities include bioacoustic methods where recordings of irritating sounds or bird distress calls are played loudly. Aguilera *et al.* (1991) compared the effects on geese of loud noises and tapes of geese distress calls, and found noisemakers to be most effective if used intensively and unpredictably. Marsh *et al.* (1992) reported that scarecrows and predator models repel geese if used with loud, startling noises, but that habituation to both scarecrows and noisemakers occurs over time. Visual frightening devices such as falcon silhouettes could be used in conjunction with the audio methods. Some testing would probably be required to determine the optimal applications and combinations of methods to achieve the greatest efficacy. York *et al.* (1997) documented 20% of the neckbanded geese on EAFB returned multiple times to the exclusion zone, despite hazing. In addition, 23% at AIA, and 38% at Merrill Field also returned multiple times following hazing by dispersal personnel. These geese presented a special hazard to aircraft safety in the Anchorage bowl because they appear to have become habituated to non-lethal scare tactics. A single pair of geese originally marked at a nearby city park was hazed from EAFB on 11 separate occasions (York *et al.* 1997).

Direct removal

Direct removal of nuisance goose populations by euthanasia is perhaps the least socially acceptable control technique, but when used in combination with some of the previously mentioned techniques, can provide population reduction and long-term, cost-effective control. Adult geese found at sites other than airports can be rounded-up during July, when Anchorage geese are molting and cannot fly. Round-ups can be conducted by Alaska Department of Fish and Game (ADF&G), U.S. Fish and Wildlife Service, and WS personnel under State and Federal permits issued to the MOA (U.S. Fish and Wildlife Service 1998). Rounding up geese is not difficult, expensive or particularly stressful to geese when conducted correctly. In July 1997, agencies rounded-up, banded and released more than 3000 geese in Anchorage Parks (York *et al.* 1997; U.S. Fish and Wildlife Service 1998). Removal of excess populations can be made more acceptable to the public by turning the geese over to qualifying institutions and welfare agencies for distribution to the elderly and poor (AWWG 1997).

As suggested by Cooper (1991), bird–aircraft strike hazards can be dramatically reduced by identifying and removing the local origins of breeding geese using an airport. York *et al.* (2000) recommended a substantial reduction in goose numbers at molting sites within a 9 km radius of EAFB to improve aircraft safety. Identified staging and dispersal refuge sites also provide opportunities to control geese that have repeatedly entered airports and been hazed by non-lethal methods. However, selecting certain sites for control efforts, and ignoring the substantial growth in the bowl-wide population, would provide only temporary relief and no guarantee of increased aircraft safety (York *et al.* 1997).

Current operational control practiced at Anchorage airports

Anchorage International Airport

AIA, like many other Alaskan airports, has large areas of short grass, ditches, bogs, woodlands, lakes, ponds, and snow dumps which form ponds when the snow melts. In the spring, large numbers of geese and ducks stop at AIA and attempt to nest.

In 1996, at the request of AIA, WS began operational management of the wildlife hazards under a cooperative service agreement. Two personnel (in separate vehicles) patrol the AIA airfield environment 24 h per day, seven days per week. After spring migration, only one person per shift patrols the airport. Deterrent efforts are carefully coordinated on a moment-by-moment basis with the AIA control tower and airport operations personnel. A special database is used to keep records of control activities; wildlife presence, behavior and movements; date; time-of-day; weather; and other factors that influence wildlife behavior. During the course of one filed season, WS often deters in excess of 50 different wildlife species at AIA.

A variety of techniques are used to deter wildlife from areas where they pose a strike hazard to aircraft, preferably in the following sequence:

1. Make recommendations to airport management for removing or altering wildlife attractants, including habitats.
2. Whenever possible use fencing or barriers to exclude wildlife from critical areas.
3. Deploy static deterrent devices such as propane cannons, coyote effigies, and mylar flash-tape. Propane cannons and coyote effigies are placed in areas where geese were frequently observed.
4. Haze wildlife with pyrotechnics, vehicle harassment, or other scare devices to disperse wildlife that pose a potential hazard to aircraft. Pyrotechnics used are 15 mm bangers, 15 mm screamers, and 12 gauge cracker shells.
5. When applicable, capture and translocate potentially hazardous wildlife away from the airport.
6. Use lethal techniques to remove wildlife that are unresponsive to the previously mentioned methods and/or that pose an imminent threat to aircraft safety. Lethal methods include shooting and egg removal. The lethal removal of urban geese at Anchorage airports is consistent with the goals and procedures of the Anchorage Goose Management Plan.

Steps 1–3 of this sequence are ongoing procedures to diminish the attractiveness of the airport to wildlife. Steps 4–6 are taken in response to wildlife hazards that develop despite other efforts. All edible carcasses, including eggs, that are collected during wildlife deterrent operations at the airport are salvaged and distributed to charity as per agreement with U.S. Fish and Wildlife Service and ADF&G.

Lake Hood Seaplane Base

Waterfowl build nests around Lake Hood and connecting Lake Spenard, as well as a few other smaller ponds, ditches, and bogs. If left alone, most nests on this busy float plane lake would successfully produce hundreds of ducklings and goslings. During the breeding season, nest searches are conducted near all wetlands on a weekly basis. When a nest is found, the female is shot with a 12 gauge shotgun or 0.20 caliber air rifle, and the nest is destroyed. Eggs are collected and donated to local charities. If the female cannot be taken, then eggs are added.

It is inevitable that some nests will be overlooked and produce young. Traps are placed around Lake Hood and Lake Spenard to capture waterfowl, which are subsequently translocated at least 81 km from the Anchorage area. Canada geese are captured when adult geese are molting and goslings are old enough to survive on their own. All juvenile geese are fitted with leg bands and neck collars for easy identification. In years past, adult and juvenile geese were translocated to separate locations by float plane, 64 km from Anchorage. In 2000, all adult geese captured on the airport ($n = 24$) were destroyed and given to a local charity.

From 1993 to 1997, pigs were used on Gull Island at Lake Hood Seaplane Base to control nesting of Canada goose, ducks and gulls. Gull Island is located between the taxiway and the E/W water lane. Each spring, three pigs were leased from a local farmer, placed on the island, and trained with electric shock-collars to keep them from swimming away from the island. This successful operation became a routine bird hazard management measure for five years. By 1997, bird nesting on Gull Island was sufficiently reduced that pigs were no longer needed.

Merrill Field

Operations extended from late July to late October each year since 1996. One WS Specialist patrols the airfield from approximately 05:00 a.m. to 22:00 p.m. on weekdays and 12 h day on weekends. The balance of the day is covered by Merrill Field airport personnel with a WS Specialist on call during the winter months. The same wildlife hazard management strategy and records are applied as at AIA.

Elmendorf Air Force Base

Control activities at EAFB were initiated in April 2000 and extended through October when most birds migrated from the area. Similar techniques and procedures utilized at AIA were also used at EAFB. EAFB encompasses less terrain than AIA and has fewer ditches, ponds, and marshland. In addition, Canada geese were captured at EAFB during the summer molt. Juveniles were banded, collared, and translocated with the geese captured at AIA. Adult Canada geese captured at EAFB ($n = 37$) were euthanized and given to a local charity.

Other efforts

During the last three years, a joint effort among three agencies captured Canada geese at several locations around Anchorage. All captured juveniles were marked with leg bands and neck collars (if the juvenile was large enough). They were subsequently translocated via float plane to Susitna Flats State Game Refuge. Two hundred and eighty-seven goslings, including 47 captured at AIA and six captured at EAFB, were marked and translocated in 2000 compared to 145 in 1998, and 184 in 1999.

Specific research

Canada goose distribution and movements around Anchorage

York *et al.* (2000) monitored the movements of 1236 neckbanded lesser Canada geese throughout the Anchorage bowl and concluded that the number of geese on EAFB and other Anchorage airports are a threat to aircraft safety. The majority of neckbanded geese observed at EAFB originated from molting sites within an approximate radius of 9 km, suggesting geese molting closer to the airfield were more likely to move into operational airspace (Figure 1). Furthermore, it was noted that all of the larger lakes in Anchorage served as molting sites, and most parks as feeding and loafing sites (York *et al.* 2000). As Figure 1 graphically demonstrates every airport in the Anchorage bowl has several adjacent parks and/or lakes. This situation creates constant movement of geese through operational airspace as they move from site to site seeking forage, loafing, or roosting locations.

Of special concern to aircraft safety were geese that returned to airports multiple times following hazing (approximately 20% of visiting geese). These geese were of particular concern because they had probably become habituated to non-lethal scare tactics. Schultz *et al.* (1988) found that some geese returned to feeding locations even after they were hunted, either as a result of habitual site use or habituation to scare tactics. Either way, returning geese presented a significant threat to aircraft safety and required the increased use of lethal control on recognized individual geese at Anchorage airports.

Cooper (1991) found at the Minneapolis-St. Paul International Airport that certain goose groups from the surrounding area consistently moved onto the airport more than others, and removing these geese reduced the bird/aircraft strike hazard. Numerous geese moved onto EAFB late in September and early October along with an increased utilization of feeding sites during autumn. Similarly, 40% of wildlife strikes to civil aircraft in the U.S. occurred from August to October for the 7 year period between 1991 and 1997 (Cleary *et al.* 1998). The U.S. Air Force also found peak number of strikes occurring in the spring and fall from 1988 to 1997 (Tedrow *et al.* 2000). This dictates a need for increased surveillance and control efforts at airports during this season of premigratory staging when geese are especially active and abundant in Anchorage.

Flightline vegetation for Anchorage airports

Preferences of captive, wild-caught, lesser Canada geese were determined for alternative vegetation types that could be used to reduce goose visitation at airports (Pochop *et al.* 1999). Goose preferences Kentucky bluegrass (*Poa pratensis*), bluejoint reedgrass (*Calamagrostis canadensis*), beach wildrye (*Elymus mollis*), Bering hairgrass (*Deschampsia beringensis*), lupine (*Lupinus nootkatensis*), and flightline turf (a mix of smooth brome [*Bromus* sp.], dock [*Rumex acerosella*], and red fescue [*Festuca rubra*]) were compared. Geese preferred flightline turf over Kentucky bluegrass. Bering hairgrass was marginally less preferred than Kentucky bluegrass. Kentucky bluegrass was preferred over lupine, bluejoint reedgrass, and beach wildrye (Pochop *et al.* 1999).

Beach wildrye has tough, heavily cutinized leaves and stems, which protect it from the abrasive effects of blowing sand (Klebesadel 1985) and give it a greater tensile strength over plants that are less heavily cutinized. Some studies have indicated that tensile strength may be a proximate cue that geese use to select or avoid forage (Owen *et al.* 1977; Conover 1991). However, Buchsbaum & Valiela (1987) found that phenolic compounds had a greater role than fiber in deterring feeding on unpalatable plants by Canada geese. High-fiber (and therefore presumably less digestible) grasses were generally favored over the low-fiber succulent forbs, because the succulents (such as marsh-rosemary [*Limonium carolinianum*] and goldenrod [*Solidago sempervirens*]) were protected by secondary metabolites (Buchsbaum *et al.* 1984).

An interesting and discomforting result was that flightline turf was preferred over Kentucky bluegrass (Pochop *et al.* 1999). Conover (1991) found that tall fescue (*Festuca arundinaceae*) was significantly disliked by Canada geese compared to red fescue, colonial bentgrass (*Agrostis tenuis*), and perennial ryegrass (*Lolium perenne*). The flightline turf contained red fescue, and geese may have selected for this component, but research is available concerning palatability of smooth brome or dock to Canada geese, and therefore they cannot be ruled out as a preferred food source (Pochop *et al.* 1999). The flightline turf was fertilized in the spring, which contributed to its attractiveness to geese (Owen 1975).

Other non-grass forage may deter airfield use by geese. For example, Conover (1991) found that even hungry Canada geese refused to eat common periwinkle (*Vinca minor*), Japanese pachysandra (*Pachysandra terminalis*), and English ivy (*Hedera helix*). Smith (1976) found that mouse-eared hawkweed (*Hieracium pilosella*) reduced invertebrate and bird (primarily herring gulls [*Larus argentatus*]) activity over a mixed-species cover primarily consisting of (wild carrot [*Daucus carota*], daisy [*Chrysanthemum* sp.], and dandelion [*Taraxicum* sp.]. Buchsbaum and Valiela (1987) found that geese avoided forbs during all seasons. Non-grass species (i.e., forbs that contain phenolic compounds) that are native to Alaska, such as sweet holygrass (*Hierochloe odorata*) which contains coumarin, should be tested as alternative vegetative covers in Anchorage (Pochop *et al.* 1999).

Habitat management might be an effective method to deter Canada goose use of Anchorage area airports. The three vegetation types (beach wildrye, bluejoint reedgrass, and lupine) that were found to be the most effective required different planting schemes and maintenance (Pochop *et al.* 1999). Beach wildrye seed was not available commercially, but a local source of supply in the Anchorage area was under development. Advantages of beach wildrye included reproduction through rhizomes, good ground stabilization attributes, resistance to chemical deicers used on aircraft, resistance to lodging by wind and rain, and ability to out-compete other plants. One disadvantage of beach wildrye is its sensitivity to compaction by airport vehicles (Pochop *et al.* 1999).

In 1996, bluejoint reedgrass was commercially available on a limited basis in Anchorage and seeding cost approximately \$104 ha^{-1}. Wild bluejoint grass is native to Alaska and grows most commonly in meadows and wet areas. However, bluejoint reedgrass has a very small seed, which is difficult to cultivate. Because bluejoint reedgrass already grows in stands at Anchorage airfields, another option might be to transplant it to areas adjacent to airport runways.

Lupine is the most difficult of the three plant species to maintain. Seeds would need to be gathered from wild stands. If problems arise in cultivating the seeds, transplanting entire plants may be difficult because of the extensive taproot. However, lupine is resistant to lodging, and, though susceptible to mowing, usually grows to about 30–60 cm high.

Rehydration of Klatt Bog near AIA

To comply with Federal Clean Water Act regulations that require the mitigation of wetlands lost to airport development, federal resource agencies in Anchorage have proposed a wetland mitigation project in Klatt Bog, located 5.6 km southeast of Runway 6L and 4 miles southeast of Runway 6R/24L at AIA (Figure 2). In its present state, Klatt Bog is presumed not to have contributed to aircraft safety hazards at AIA. However, the proposed rehydration of Klatt Bog could potentially increase its attractiveness to birds, which could in turn increase hazards to incoming and departing aircraft at AIA. If this were to occur, the rehydration of Klatt Bog would be in direct conflict with Federal Aviation Administration (FAA) Advisory Circular Parts 139/150, which stipulate FAA's position on potential bird habitat within 8.0 km of an airport. These guidelines recommend against establishing and/or modifying habitat that could create an attractant to wildlife species that pose a threat or hazard to aircraft safety. An airport that is certified under Part 139 of the Federal Aviation Regulations, or that received federal funds from the FAA is required to comply with these guidelines (Clark *et al.* 2000).

It is unknown how the rehydration of Klatt Bog will evolve, and to what extent, if any, the rehydration will

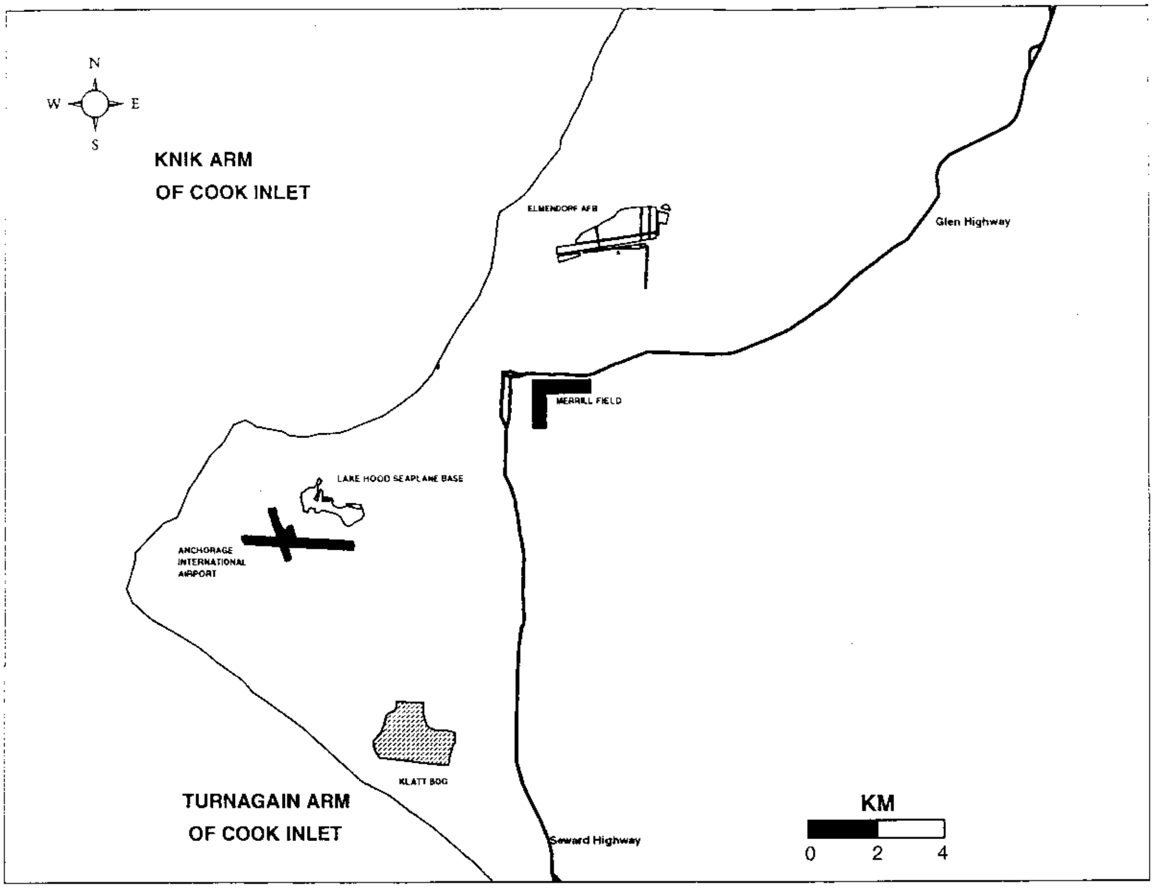

Figure 2. Location of airports and Klatt Bog in Anchorage, Alaska.

increase the potential for aircraft hazards attributable to birds. Therefore, the likely scenarios of aircraft use at AIA, and waterfowl use of wetland and lake habitats surrounding AIA were modeled to investigate whether Klatt Bog would contribute to an increase in the potential for birds and aircraft to simultaneously occupy the same airspace, and to estimate the magnitude for the potential conflict (Clark *et al.* 2000). The model was constructed based on general spatial and temporal properties of aircraft and waterfowl flight characteristics. These data were combined into a Geographical Information Systems (GIS) format to construct a model of the most likely conflicted airspace assuming the presence and absence of Klatt Bog as suitable wetland habitat for waterfowl. Risk implies a probability of an event occurring. The model generated did not generate such a value, but rather estimated relative changes in the volume of airspace where such airstrikes might occur should a rehydrated Klatt Bog be used by birds as a suitable habitat. The utility of this spatial GIS model lies in its ability to direct the focus of where such biological data (e.g., flight activity, direction, and altitude for a variety of species of birds taken by ground observers over the course of a breeding–migration cycle under a variety of weather conditions) need to be collected (Clark *et al.* 2000).

Birds in migration, flying at high altitudes at undefined points of origin, could descend directly onto to Klatt Bog and might encounter aircraft at 305–701 m in elevation (i.e., the modeled altitude of commercial aircraft directly over Klatt Bog). However, national incidence of such encounters within this latitude range accounts for only 7.4% of all reported bird–aircraft collisions (Clark *et al.* 2000).

This report concluded the rehydration of Klatt Bog and its use as a bird habitat could contribute to conflicted airspace within the southeastern areas outside AIA at aircraft altitudes of 152–942 m (Clark *et al.* 2000). How this conflicted airspace contributes to increasing the risk of bird–aircraft collisions will depend on obtaining detailed biological habitat use patterns of birds as a function of time of day, time of year, local movement patterns of birds between habitat types, and weather, as detailed information on aircraft activity patterns for use of runways 06R/06L. If these ground surveys were conducted and indicated a high level of bird use the model would indicate a 12% increase in conflicted volume of air space over Klatt Bog (Clark *et al.* 2000).

Conclusions

Success at reducing airstrike hazards at Anchorage airports requires an integrated management approach that utilizes various control techniques and direct manipulation of habitat. Cooperation and coordination are required among a variety of federal, state, and municipal agencies. The proposed action (Alternative C) in the Environmental Assessment (U.S. Fish and Wildlife Service 1998) to control the Anchorage Canada goose population provides for a population of 2000 geese, approximately half the current goose population. This alternative calls for the direct removal of approximately 730 adult geese and reducing production of juveniles by 290 through egg collection and translocation of juveniles from 1998 to 2001. To maintain this target level of 2000 geese, approximately 150 adults would need to be removed annually, along with the annual removal of approximately 100 juveniles achieved through egg collections and juvenile translocations (U.S. Fish and Wildlife Service 1998). Local airport managers believe safety hazard to aircraft will still be significant with 2000 geese in Anchorage, since potential strike hazards would be reduced by only half of the 1996 level (U.S. Fish and Wildlife Service 1998). However, this population was found to be the most acceptable to Anchorage residents. With a lower population level of geese in the Anchorage bowl costs of dispersing geese would decrease over time, as well as noise complaints from adjacent home owners resulting from hazing programs. However, it should be stated that this population level is not a solution for the continental U.S. The recent exponential increase in the overall goose population is a serious and ongoing threat to other North American airports. These airports cannot rely solely upon regional population control to alleviate bird strike risks at airports. Population control is a hazard reduction technique that cannot be used everywhere. Other airports need other risk based reduction techniques (e.g., active hazing programs, habitat modification, policies discouraging the feeding of geese, etc.).

Burger (1983) suggested that no one technique is 100% effective in reducing birds' use of airports, so it is essential that many techniques be considered and utilized. Although various sites were identified from which geese originated prior to movement onto area airports, selecting certain sites for control efforts and ignoring the substantial growth in the city-wide population provides only temporary relief and no guarantee of increased aircraft safety. As long as the Anchorage goose population is allowed to increase, large numbers of geese will arrive from other areas of Anchorage and enter area airports and constitute a serious risk to aircraft safety.

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