Title

Quantifying Risk Associated with Potential Bird-Aircraft Collisions

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Abstract: Bird-aircraft collisions (hereafter, bird strikes) pose substantial hazards to aviation safety. The most common method employed to objectively quantify bird hazards on airport property is a point-count survey. However, we questioned the adequacy of point counts in prioritizing bird-strike hazards. Our objectives were to 1) quantify relative risk associated with potential bird strikes at Seattle-Tacoma International Airport (SEA) based on data from point counts and a supplemental survey of species time spent within runway protection zones (RPZs) for active runways; and 2) contrast risk based on each survey method against airport-specific bird-strike statistics obtained from the U.S. Federal Aviation Administration (FAA). We defined risk as the product of an index of frequency of use and a damage metric associated with a bird strike. We referenced observational data collected by USDA Wildlife Services biologists (over 50 weeks between 10 June 2003 and 11 June 2004) and assigned 51 species observations to 14 groups based on American Ornithologist's Union classification and bird-strike data obtained from the FAA. Ranks for risk within survey method were similar between surveys for 9 of 14 groups. Waterfowl (excluding Canada geese, *Branta canadensis*, but including double-crested cormorants, *Phalacrocorax auritus*), Corvidae, gulls (Laridae), and Canada geese ranked among the top 5 groups for risk in both surveys. Notably, raptors ranked 4th in risk based on the RPZ survey, but 9th based on point-count survey. Strike statistics for SEA indicate that gulls and some passerine species tied for the most strikes/year (1990-2005), followed by ties among raptors, shorebirds (Laridae), and swallows/swifts (Hirundinidae/Apodidae). Data from the RPZ survey indicate that raptors posed a greater bird-strike risk at SEA than indicated by point-count data. This risk associated with a potential raptor strike was corroborated by strike statistics at SEA.

Introduction

Wildlife, particularly birds, poses substantial hazards to aviation. From 1990 through 2005, 66,392 wildlife collisions with aircraft were reported to the U.S. Federal Aviation Administration (FAA); 97.5 percent of these incidents involved birds. The approximate cost to the civil aviation industry in the USA due to collisions between aircraft and birds (hereafter, bird strikes) exceeded $600 million annually in direct monetary losses and associated costs (Cleary et al. 2006). Recent work by Dolbeer (2006) shows that for bird strikes ≤152.4 m above ground level (AGL), passerines, gulls/terns (Laridae), doves/pigeons (Columbidae), and raptors (excluding owls) were the species groups most frequently struck. For strikes >152.4 m AGL, waterfowl (Anatidae), gulls/terns, passerines, and vultures were the species groups most frequently struck. Blackwell and Wright (2006) found that 82 percent of strikes involving red-tailed hawks (*Buteo jamaicensis*) occurred at or below 30.5 m AGL and nearly 63 percent occurred while the aircraft was operating on the ground. Approximately 29 percent of strikes involving vultures occurred at or below 30.5 m AGL and 17 percent occurred while the aircraft was operating on the ground (Blackwell and Wright 2006). Relative to strikes resulting in substantial damage to the aircraft (see Dolbeer et al. 2000, Clearly et al. 2006), 67 percent occurred at ≤152.4 m AGL (Dolbeer 2006). These data indicate that most bird strikes occur on or in immediate proximity to the airport (i.e., air operations area, AOA), and they highlight the need for further development of wildlife-management methods to reduce strikes that are applicable to the AOA.

The AOA comprises areas designated for takeoff, landing, and surface maneuvers of aircraft (see 14 CFR Part 139, Subpart D) and falls within FAA siting criteria for certificated airports (i.e., within 1.5 km of a runway for airports servicing piston-powered aircraft only and within 3.0 km of a runway for airports servicing turbine-powered aircraft; FAA 2004). Management programs to reduce wildlife strikes have traditionally concentrated on species-specific hazards (Dolbeer et al. 2000; Cleary and Dolbeer 2005). Hazardous wildlife species are those species causing strikes with aircraft that result in structural damage to the aircraft and, potentially, result in damage to airport facilities and the environment (Dolbeer et al. 2000, Cleary and Dolbeer 2005). Damage resulting from a bird strike, for example, is related to body mass and velocity at impact; damage data are readily available through the U.S. Federal Aviation Administration (FAA) National Wildlife Strike Database for U.S. civil airports (Cleary et al. 2006).

Effective prioritization of species management on airports entails an assessment of the realistic potential for damage associated with those hazards (i.e., risk, the product of an index of frequency and a damage metric). However, airport habitats vary and, subsequently, affect how, when, and which avian species use these habitats. In turn, how the biologist perceives bird use of airport habitats will affect the prioritization of species management.

A common method for quantifying relative use of airport environments by avian species (i.e., a component of an airport wildlife hazard assessment) is a 3-minute point-count survey (Cleary and Dolbeer 2005) based on the field methods of the North American Breeding Bird Survey (Robbins et al. 1986). The survey also allows airport biologists to identify areas used by non-avian wildlife species, and thereby direct management at a variety of actual and potential hazards posed to aviation safety. However, airport managers and wildlife managers frequently inquire as to the risk of bird strikes associated with birds observed near, while not actually recorded as crossing a runway. In addition, to point count surveys, USDA Wildlife Services (WS) at Seattle-Tacoma International Airport (SEA) supplement point-count surveys with surveys within the runway protection zone (RPZ). The RPZ, encompassing airspace used on approach or departure, is a trapezoidal area centered on the runway centerline and beginning approximately 61 m beyond the end of the area usable for takeoff or landing (fig. 1). Airport owners are required to protect RPZs from incompatible land uses and obstructions, including avian hazards to aviation safety (FAA 1989). The RPZ survey was designed specifically to quantify species time within the airspace used for takeoffs (near the point of rotation by the aircraft) and landings (i.e., to identify species posing an immediate hazards to aviation safety). Importantly, the RPZ survey does not link an avian species or group to a particular airport resource, in contrast to point-count surveys.

Our purpose was to determine whether point-count surveys at SEA adequately identify species posing the greatest risk of bird strike. Our objectives were to 1) quantify risk associated with potential bird strikes at SEA based on data collected during point-count and RPZ surveys, respectively; and 2) contrast risk based on each survey method against airport-specific, bird-strike frequencies obtained from the FAA.

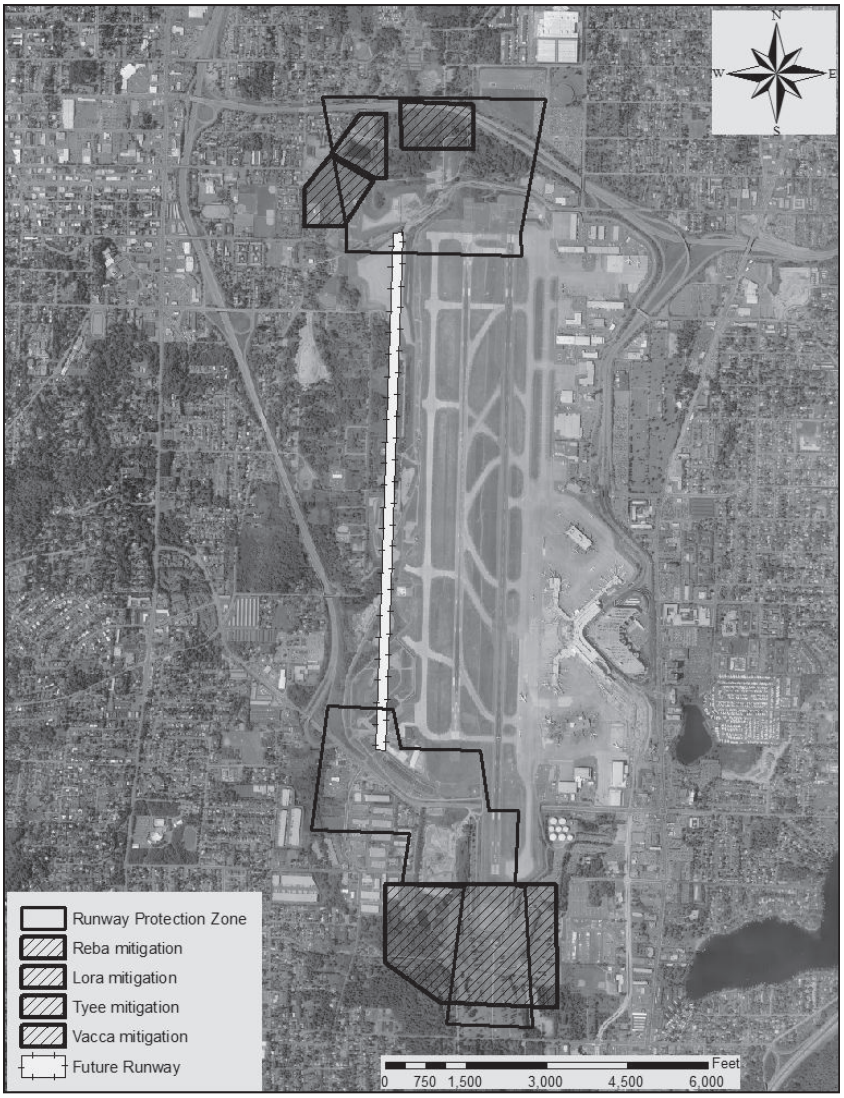

Figure 1. Seattle-Tacoma International Airport maintains two parallel runways approximately 2873 m and 3627 m in length, respectively, and 174 m apart. We conducted point-count and runway-protection zone surveys from four wetland mitigation areas (Lora, Reba, Vacca and Tyree) proximate to the runways.

Study Area

Located in the southwest portion of King County, WA (47°26'29" North, 122°17'35" West), SEA is the 16th busiest passenger airport in the USA. The airport annually serves close to 29 million passengers, receives 359,000 flights, and moves 346000 metric tons of air cargo. Further, SEA covers approximately 853 ha and includes, in addition to structures, 339 ha of impervious surface, 205 ha of short vegetation (grasses), 15 ha of shrub/woodlots, 215 ha of water bodies, and 11 464 m of stream habitat. Also, SEA maintains two parallel runways, 2873 m and 3627 m in length, respectively, and 174 m apart (fig. 1). A third runway is under construction (Port of Seattle 2004: http://www.Portseattle.org/seatac/).

Methods

Seattle-Tacoma International Airport has implemented an integrated wildlife management plan (e.g., see Cleary and Dolbeer 2005) to reduce the likelihood of wildlife-aircraft collisions (Port of Seattle 2000). Thus, we assumed that all birds observed during surveys conducted at SEA were, at some point, subject to the effects of the wildlife hazard-management methods (e.g., dispersal; see Port of Seattle 2000).

We referenced observational data collected by WS biologists at SEA. These observational data reflect point-count and RPZ surveys conducted from 4 wetland-mitigation areas proximate to SEA runways (fig. 1). The wetlands, though 3 sites were essentially adjacent (fig. 1), are each the subject of mitigation between the Port of Seattle and the state (Port of Seattle, unpublished data. The RPZ comprises approximately 32 ha and is 305 m wide proximate to the runway, 762 m long and extends beyond the runway terminus, 533 m wide at the end of the zone, and of unlimited altitude above ground level (fig. 1). Because of the proximity of each of the 2 active runways and a future third runway, the RPZs were merged into one zone. Also, due to concerns over potential wildlife hazards within the RPZs, officials with SEA included the 4 wetland-mitigation areas in the standard wildlife point-count survey conducted at the airport (see Port of Seattle 2000).

Point Counts

Wildlife Services biologists at SEA conducted weekly surveys (across 50 weeks between 10 June 2003 and 11 June 2004) at the wetland sites noted above. Day, timing of the survey, and the sequence in site visits were not selected at random, but were functions of day-to-day work assignments for the airport biologists. Surveys by airport biologists are intended to identify wildlife hazards and attractants to wildlife, with subsequent mitigation the objective (see Cleary and Dolbeer 2005). The point-count survey differs from a standard scientific sampling protocol in which indices of species diversity, richness, or density might be objectives (e.g., Buckland et al. 1993). However, the biologists varied the times of day that each site was visited, and all sites were visited on the same day. All surveys were conducted during daylight hours and, when possible, 2 surveys were conducted per week. Three WS biologists conducted the surveys, but only 1 observer was present on any day.

Each observation at a site included a 3-min count of all avian species physically on the wetland or hunting over the wetland, as well as birds observed moving from cover or arriving during a 3-min period. No attempt was made to flush birds from cover, therefore, the data referenced are not reflective of more secretive avian wetland species (e.g., Gibbs and Melvin 1993). Further, because 3 of the wetlands were essentially adjacent, and the fourth was approximately 3700 m to the south (Fig. 1), birds counted at 1 site likely used the other sites as well. Thus, we did not consider the 4 wetlands as independent sites (see Analyses below).

RPZ Surveys

Concurrent with the 3-min point count at each site and over an additional 17 min (i.e., a total of 20 min), the biologist recorded all species and flock sizes for birds entering the RPZ proximate to the wetland (fig. 1). In addition, the observer estimated the altitude (via comparison to an object of known height) of each species individual or flock within 4 elevation intervals (below runway grade [fig. 2]; 0–15.2 m; 15.3–30.5 m; and >30.5 m) and depicted the flight path of the individual or flock on an aerial photo of the site. For purposes of depicting the flight path, the flock was the focus of observation, not individuals within the flock.

Figure 2. Runways at Seattle-Tacoma International Airport, King County, Washington, are raised above surrounding grade.

Analyses

We first assigned species observations (within survey and by day, time, and site) to groups that reflected American Ornithologist's Union classification or, in some cases, species of interest because of documented hazards to aircraft (Cleary et al. 2006; table 1). We summarized the point-count data relative to the maximum count per group by site and week.

For RPZ data, we used a geographic information system (ArcMAP, ESRI) to digitize the recorded flight paths and convert them to distance (m) traveled while in the RPZ. We included individuals or flocks in our analysis only if they were not flushed into the RPZ by the observer (noted by the biologist during each RPZ survey). In addition, because of the raised grade of the runways (fig. 2), we included only those individuals or flocks that were at grade or above (i.e., some birds entered the RPZ, but were flying below grade and therefore posed no immediate hazard to aircraft).

To estimate time (sec) in the RPZ, we divided the distance an individual or flock traveled in the RPZ by the average flight speeds (see Wege and Raveling 1984, Pennycuick 1997, Bird 2004) for those species composing our groups (table 1). We next converted each time estimate to flock seconds in the RPZ by multiplying the time estimate by flock size for each observation. Similar to the point-count data, we summarized the RPZ data relative to the maximum time in the RPZ, respectively, per group by site and week.

Table 1: Avian group classification and associated species observed between two bird surveysa made at four locations on the Seattle-Tacoma International Airport, Washington, USA: 3-min point counts and concurrent 20-min observations of birds flying through runway protection zones (RPZs). Flight speeds for each group are noted. Both surveys were conducted over 50 weeks from 11 June 2003 through 10 June 2004.

	Counts	Surveys	Speed (m/sec)[b]
Wading birds:			
American bittern (*Botaurus lentiginosus*)	*		
Great blue heron (*Ardea herodias*)	*	*	9.4
Shorebirds:			
Common snipe (*Gallinago gallinago*)	*		
Greater yellowlegs (*Tringa melanoleuca*)	*	*	13.0
Killdeer (*Charadrius vociferous*)	*	*	13.0
Shorebirds:			
Least sandpiper (*Calidris minutilla*)	*		
Spotted sandpiper (*Actitis macularia*)	*		
Geese:			
Canada goose (*Branta canadensis*)	*	*	18.0
Other Waterfowl:			
American Green-winged teal (*Anas crecca*)	*		
American coot (*Falica americana*)	*		
American widgeon (*Anas americana*)	*	*	18.0
Barrow's goldeneye (*Bucephala islandica*)	*		
Bufflehead (*Bucephala albeola*)	*	*	18.0
Blue-winged teal (*Anas discors*)	*		
Canvasback (*Aythya valisineria*)	*		
Common merganser (*Mergus merganser*)	*		
Double-crested cormorant (*Phalacrocorax auritus*)	*	*	13.2
Gadwall (*Anas strepera*)	*	*	18.0
Greater scaup (*Aythya marila*)	*		
Hooded merganser (*Lophodytes cucullatus*)	*		
Mallard (*Anas platyrhynchos*)	*	*	18.0
Northern shoveler (*Anas clypeata*)	*	*	18.0
Pied-billed grebe (*Podilymbus podiceps*)	*		
Ring-necked duck (*Aythya collaris*)	*		
Wood duck (*Aix sponsa*)	*		
Belted kingfisher (*Ceryle alcyon*)	*	*	10.0[c]
Northern flicker (*Colaptes auratus*)	*	*	10.0[c]
Swallows/swifts:			
Barn swallow (*Hirundo rustica*)	*	*	10.0
Tree swallow (*Tachycineta bicolor*)	*	*	10.0
Vaux's swift (*Chaetura vauxi*)	*	*	10.3

[a]Point counts entailed an instantaneous count of all avian species physically on the wetland or hunting over the wetland, as well as birds observed moving from cover or arriving during the initial 3 min. During the initial three min and the subsequent 17 min, the observer monitored avian use of the RPZ and recorded, by species, flock size,

Calculation of Risk

We considered risk as the potential for damage to the aircraft that each group posed if struck. We defined risk as the product of the relative frequency of each group in total counts or total group time in the RPZ over the period of the study (i.e., the sum of the weekly maximum group counts and times, respectively) and the proportion of bird strikes involving the group that have resulted in damage to aircraft (across U.S. civil airports and civil aircraft). Importantly, risk does not equate to the probability of a future bird strike at SEA, but simply the relative potential for negative effects (i.e., damage to the aircraft) that might be incurred by bird strikes involving species at SAE. We used bird-strike related damage statistics from the FAA National Wildlife Strike Database for U.S. civil and joint-use airports (Cleary et al. 2006; http://wildlife-mitigation.tc.faa.gov/public_html/). In addition, we report the proportion of total risk within survey type associated with a bird strike involving a particular group, and the corresponding rank of the proportionate risk. Also, because the RPZ survey is considered supplemental to point counts, we refer only to the group rank within survey type and include no statistical comparison of proportionate risk between surveys.

Strike Frequency

We ranked groups relative to strike frequency at SEA through the period in which the survey data were collected (2003-2004) and over the period represented by the FAA National Wildlife Strike Database (1990-2005; see Cleary et al. 2006). Strike data collected by the FAA are provided in voluntary reports by pilots and ground crews via standard form (5200–7) for wildlife strikes to civil aircraft in the USA.; strike reports are also made directly to the FAA National Wildlife Strike Database via the web address cited above. We note that a strike report might involve more than 1 bird, only about 20 percent of wildlife strikes are reported, not all bird strikes are identified to species, and bird-strike damage and down-time costs are underreported (Linnell et al. 1999, Cleary et al. 2006). Thus, species-specific losses and the associated costs to aviation due to those bird strikes are highly underrepresented by strike data within the FAA National Wildlife Strike Database. In addition, we emphasize that strike statistics represent past occurrences and do not necessarily reflect future hazards to aviation safety.

Results

Wildlife Services biologists at SEA observed 51 avian species during point counts, 30 of which were also seen within the RPZ; we classified these species into 14 groups. Each group was represented in the RPZ survey as well as point-count data (table 1). Species categorized as other waterfowl, European starlings, swallows/swifts, corvids, and gulls were among the top 5 groups most frequently observed during point counts, composing 88.7 percent of observations (table 2). With the addition of raptors, the same groups represented 89.5 percent of the time recorded for species observed in the RPZ per week (table 2).

Table 2: Relationship between two bird surveys made at 4 locations on the Seattle-Tacoma International Airport, Washington, USA: 3-min point counts and concurrent 20-min observations of birds flying through runway protection zones (RPZs). Both surveys were conducted over 50 weeks from 11 June 2003 through 10 June 2004.

Bird Group	Mean maximum birds/wk (SD)	Mean maximum sec in RPZ/wk (SD)
Blackbird	0.29 (1.06)	0.09 (1.24)
European starling	2.62 (12.16)	22.0 (108.94)
Other passerines	0.87 (4.46)	12.98 (76.78)
Corvids	1.35 (7.48)	54.10 (222.07)
Doves/pigeons	0.07 (0.42)	0.92 (6.80)
Raptors	0.12 (0.32)	21.11 (107.41)
Gulls	0.82 (6.46)	28.94 (131.39)
Shorebirds	0.02 (0.22)	0.26 (2.66)
Wading birds	0.18 (0.40)	1.30 (7.98)
Geese	0.16 (0.94)	3.71 (37.28)
Other waterfowl, including Double-crested cormorant	7.73 (7.98)	14.39 (57.14)
Belted kingfisher	0.06 (0.27)	0.10 (1.38)
Northern flicker	0.04 (0.23)	0.22 (3.12)
Swallows & swifts	1.71 (8.08)	39.51 (363.35)

Between surveys, we found divergent proportionate risk values (i.e., the proportion of total risk within survey represented by a group) by factors ranging from 5.9 to >32 for 5 of the 14 groups (corvids, raptors, gulls, and other waterfowl; table 3). Overall, ranks for proportionate risk were similar between surveys for 9 of 14 avian groups. However, in both surveys, other waterfowl, corvids, gulls, and Canada geese were included in the top 5 groups for proportionate risk. Further, other waterfowl represented >85 percent of the proportionate risk based on proportionate risk in each survey (table 3). Notably, raptors ranked among the top 4 groups in proportionate risk (>16.0 percent of proportionate risk) based on the RPZ survey, but represented <1.0 percent of the proportionate risk based on point-count data. In contrast, European starlings represented similar proportionate risk between surveys, but ranked among the top 4 groups based on point-count data, versus the top 6 for the RPZ survey.

Actual strike statistics for SEA indicate that gulls, raptors, and European starlings were the groups most frequently struck (2003-2004). Gulls and other passerines tied for most frequent strikes/year (1990-2005), and were followed by ties among raptors, shorebirds, and swallows/swifts (table 4). Waterfowl (not including Canada geese) ranked 13 in groups most frequently struck (2003-2004) and 6 in strikes/yr (1990-2005).

Discussion

We used risk analysis to contrast bird-strike hazards to aviation safety at SEA based on data collected during point-count surveys within habitats bordering active runways and concurrent surveys within the RPZ. For this study, risk comprised both a frequency component (based on the 2 surveys) and a damage metric, with damage associated with body mass and velocity at impact (Dolbeer et al. 2000; Cleary et al. 2006). Across 50 weeks of observations (between 10 June 2003 and 11 June 2004) biologists at SEA observed 51 species of birds, composing 14 groups in our analyses. Six of these groups appear in the FAA National Wildlife Strike Database and are associated with frequent (≥6 percent of reported bird strikes) and damaging strikes (see table 3; Cleary et al. 2006), and range ecologically from habitat specialists (e.g., shorebirds) to opportunistic generalists (e.g., European starlings).

Table 3: Relationship between risk[a] based on two bird surveys[b] made at four locations on the Seattle-Tacoma International Airport, Washington, USA (3-min point counts and concurrent 20-min observations of birds flying through runway protection zones [RPZs]) and bird-strike data from the U.S. Federal Aviation Administration FAA National Wildlife Strike Database for U.S. civil and joint-use airports (Cleary et al. 2006; http://wildlife-mitigation.tc.faa.gov/public_ html/). Both surveys were conducted over 50 weeks from 11 June 2003 through 10 June 2004.

Bird Group	Proportionate risk based on point counts (rank)[c]	Proportionate risk based on RPZ surveys (rank)[c]
Blackbirds[d]	0.004 (7)	0.000 (12)
European starling[d]	0.030 (3.5)	0.043 (6)
Corvids	0.034 (2)	0.232 (2)
Other passerines	0.006 (8)	0.014 (8)
Doves/pigeons[d]	0.001 (12.5)	0.003 (12)
Raptors[d]	0.005 (9)	0.160 (4)
Gulls[d]	0.033 (3.5)	0.196 (3)
Shorebirds	0.000 (12.5)	0.000 (12)
Wading Birds	0.006 (6)	0.008 (9)
Canada goose[d]	0.021 (5)	0.079 (5)
Other waterfowl, including double-crested cormorant[d]	0.853 (1)	0.247 (1)
Belted kingfisher	0.000 (12.5)	0.000 (12)
Northern flicker	0.001 (12.5)	0.001 (12)
Swallows & swifts	0.006 (9)	0.016 (7)
Sum of proportionate risk	1.000	1.000

[a]Risk is defined as the product of the relative frequency of each avian group in counts or group time in the RPZ over the period of the study and the proportion of bird strikes involving the group that have resulted in damage to aircraft. We used bird-strike data from the U.S. Federal Aviation Administration National Wildlife Strike Database for U. S. civil and joint-use airports (Cleary et al. 2005; http://wildlife-mitigation.tc.faa.gov/public_ html/).
[b]See footnote in Table 1.
[c]Rank of proportionate risk value = 1 > 2 > 3, etc.
[d]Group associated with frequent (?6percent of total reported strikes) bird strikes and strikes that result in damage to the aircraft (see Cleary et al. 2006).

We found that ranks for proportionate risk were similar between surveys for only 9 of 14 avian groups. However, other waterfowl (not including Canada geese, but including double-crested cormorants), corvids, gulls, and Canada geese were included in the top 5 groups in proportionate risk in both surveys. Most notable was that the rank based on proportionate risk for raptors differed by a factor >2 between surveys. Whereas raptors represented on average only 0.7 percent of observations during point counts, they composed 11.3 percent of total time recorded across groups during the RPZ survey. Clearly, the numbers of individuals observed during point counts diminished the risk value for raptors. In contrast, European starlings represented a similar proportionate risk between survey methods, yet overall rank within survey differed. Specifically, European starlings ranked 6 in proportionate risk for the RPZ survey, but fell among the top 4 for the point-count survey. The lower ranking of European starlings for the RPZ survey reflects the effect of the relative frequency of raptor sightings in the RPZ, which elevated the risk associated with raptors.

Table 4: Avian species group most frequently involved in bird strikes at the Seattle-Tacoma International Airport, Washington, USA. Bird-strike data were obtained from the U.S. Federal Aviation Administration FAA National Wildlife Strike Database for U.S. civil and joint-use airports (Cleary et al. 2006; http://wildlife-mitigation.tc.faa.gov/public_html/).

Bird Group	Bird strikes/yr (1990–2005)	Total Bird Strikes (2003–2004)
Blackbirds	0.5	2
European starling	1.8	5
Corvids	0.2	0
Other passerines	1.2	10
Doves/pigeons	0.6	0
Raptors	2.0	7
Gulls	2.2	10
Shorebirds	1.2	7
Wading Birds	0.1	0
Rallids	0.1	2
Canada goose[d]	0.2	0
Other waterfowl, including double-crested cormorant	1.1	0
Swallows/swifts	0.9	7

The FAA strike statistics for SEA, though not representing strike probability or effects of current management, underscore the risk assigned to European starlings, gulls, and, particularly, raptors based on the supplemental RPZ survey. For example, over 18 percent strikes involving raptors result in damage to the aircraft. Further, given that 10 percent of reported bird strikes involve waterfowl and 45 percent of those strikes result in damage to the aircraft, the level of risk associated with other waterfowl based on both survey methods is also warranted. However, the frequency of strikes (1990-2005) involving other passerines, shorebirds, and swallow/swifts versus the respective ranks in both surveys (ranging 7-12.5) is indicative that strike frequency alone does not necessarily connote a high level of hazard (i.e., damage to the aircraft, as per Dolbeer et al. 2000) or risk.

Management Implications

Priorities given to management of wildlife hazards at airports stem not only from data collected during surveys across all airport habitats, but also airport-specific bird-strike records, and species representation in the FAA National Wildlife Strike Database. We suggest, however, that airport biologists evaluate the RPZ survey as a supplement to point counts. The addition of the RPZ survey at SEA revealed raptor use of the airspace over active runways (i.e., raptors posed a greater bird-strike risk), whereas raptors were rarely observed during point counts.

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Biographical Sketches: Laurence M. Schafer began his career with USDA Wildlife Services after earning his BS in Wildlife Biology from the University of Montana in 1997. His first position was as a wildlife biology specialist at Atlantic City International Airport. In 1999, he became the Project Leader for the Wildlife Program at O'Hare International Airport, where he conducted his master's research on the efficacy of raptor translocation as a management tool. Though devastated to leave the soothing climate of Chicago, Laurence accepted a position as the Airport Coordinator/Staff Wildlife Biologist for USDA Wildlife Services in Washington and Alaska in 2002. While there, Laurence has assisted with the development of numerous Wildlife Hazard Assessments and Management Plans for WA and AK airports. His secondary interests are collaborating with the USDA Wildlife Services National Wildlife Research Center to develop additional operational management tools and Wildlife Hazard Assessment techniques.

Brad Blackwell received a B.S. in Animal Science and an M.S. in Zoology from North Carolina State University. He received a Ph.D. in Wildlife Ecology from the University of Maine and was selected as a National Oceanic and Atmospheric Administration, Cooperative Marine Education and Research Fellow through the Department of Forestry and Wildlife Management at the University of Massachusetts. Over the last 10 years, Brad has worked as a Research Wildlife Biologist with the USDA Wildlife Services, National Wildlife Research Center. His research has focused on the application of demographic models to wildlife management plans that include population reduction as a component, and avian behavioral ecology as related to response to visual, physical, and chemical repellents. Currently, Brad is involved in studies to quantify avian and mammalian avoidance response to a combination of vehicle approach and specific vehicle-mounted lighting treatments, as well developing design recommendations for airport stormwater-management facilities to reduce use by wildlife.

Mike Linnell is the Utah State Director for USDA Wildlife Services and has extensive experience conducting airport wildlife hazard assessments and developing wildlife hazard management plans.

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