Avian cholera mortality in lesser snow geese nesting on Banks Island, Northwest Territories

Michael D. Samuel, John Y. Takekawa, Gustaf Samelius, and Diana R. Goldberg

Abstract Avian cholera is one of the most important diseases affecting waterfowl in North America, but little is known about its ecology and its impact on waterfowl populations. We documented avian cholera mortality in breeding lesser snow geese (*Chen c. caerulescens*) at the Egg River colony on Banks Island, Northwest Territories, Canada, in 1995 and 1996. Area of the breeding colony, core nesting area, and number of nesting geese were greater in 1996 (colony=7,537 ha, core area=1,581 ha, 401,000 nesting geese) than in 1995 (colony=6,637 ha, core area=996 ha, 318,000 nesting geese). Density of nesting geese also was greater in the core area during 1995 (120 geese/ha) than in 1996 (90 geese/ha). *Pasteurella multocida* (serotype 1) was cultured from the leg bones of adult snow goose carcasses collected after outbreaks. Mortality from avian cholera began during nesting and continued until birds dispersed at hatch. Mortality appeared to be in foci scattered throughout the nesting colony, but generally was greater where there were greater densities of nesting geese. We estimated that 30,000 and 20,000 geese died in 1995 and 1996, respectively, about 5–9% of the nesting colony. Between 1991 and 1997, at least 4 avian cholera outbreaks occurred at Banks Island. It appears that avian cholera has become endemic in this population of snow geese, and these birds have the potential to transmit the disease to other waterfowl, especially on wintering areas where waterfowl are very concentrated.

Key words avian cholera, Banks Island, *Chen caerulescens*, lesser snow geese, mortality, *Pasteurella multocida*

Avian cholera, an infectious disease caused by the bacterium *Pasteurella multocida*, is among the most common diseases affecting wild waterfowl in North America. This disease naturally infects over 100 species of wild birds and kills thousands of waterfowl annually in North American wetlands (Botzler 1991). Since the first reported outbreaks during 1943–44 in Texas (Quortrup et al. 1946) and northern California (Rosen and Bischoff 1949), avian cholera mortality has been reported throughout most of North America (Friend 1987). Despite the apparent need to manage this extremely virulent disease (Bolen et al. 1989) and the level of waterfowl mortality it causes, little is known about the reservoir for this disease or how it is transmitted (Botzler 1991). Some authors have speculated

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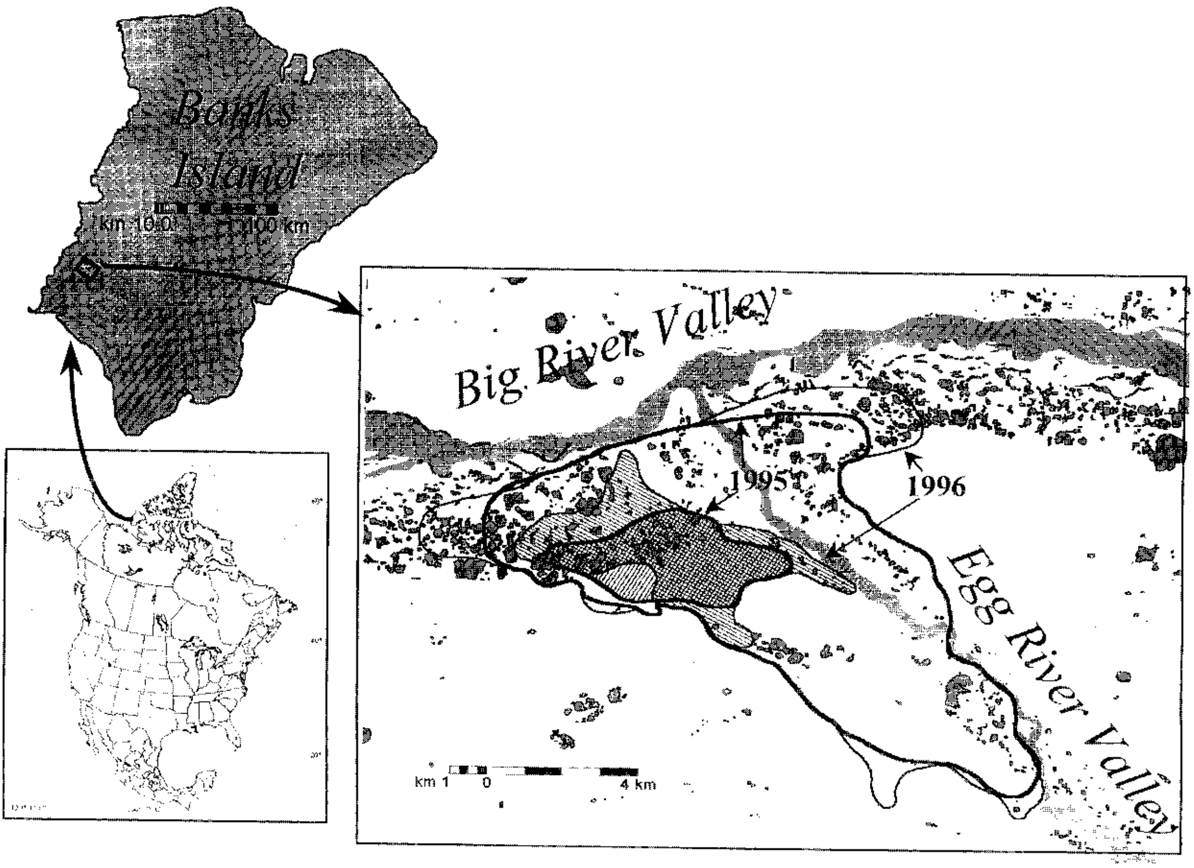

Figure 1. Egg River colony of lesser snow geese nesting on Banks Island, Northwest Territories, Canada during 1995 and 1996. The entire nesting colony (open polygons) and core nesting areas (shaded polygons) was smaller in 1995 (bold polygon boundary) than in 1996 (light polygon boundary).

that waterfowl carry the bacteria north to the breeding grounds, birds sustain mortality there (Rosen 1972), and the disease is thus maintained through carrier birds (Botzler 1991, Wobeser 1992). Lesser snow geese (*Chen c. caerulescens*) and Ross' geese (*C. rossii*) have been suspected as important sources of avian cholera because outbreaks follow snow and Ross' goose migration movements (Wobeser et al. 1979, Brand 1984, Wobeser 1992), outbreaks commonly occur in these species, and these white geese comprise a large portion of the mortality during many outbreaks (National Wildlife Health Center [NWHC], unpublished data).

Published reports of outbreaks for arctic nesting geese are sketchy, despite the potential significance of these birds in maintaining the avian cholera disease cycle. Arctic outbreaks in lesser snow or Ross' geese have been reported from the Queen Maud Gulf area of north-central Canada (Wobeser et al. 1983; R. H. Kerbes, Canadian Wildlife Service, personal communication), from Hudson Bay (Brand 1984), and from Banks Island (Nieman and Trost, unpublished report); however, the frequency and magnitude of these outbreaks has not been well documented. For most outbreaks occurring in the arctic, reported mortality has been small (several hundred birds), perhaps due to remoteness of the breeding areas and the difficulty of conducting extensive field investigations. However, an estimated 5,000 lesser snow geese carcasses were observed (R. E. Trost, United States Fish and Wildlife Service, personal communication) during a June 1991 aerial survey of Banks Island. Our study reports on our investigation of avian cholera mortality in lesser snow geese nesting at Banks Island during 1995 and 1996.

Study area

Banks Island (Figure 1) is one of the primary breeding areas for lesser snow geese of the Pacific Flyway. Most of the population winters in the Central Valley of California, where birds are exposed annually to avian cholera epizootics.

Table 1. Number of snow goose carcasses observed, transect length, and carcasses/m along 11 transects in the core lesser snow goose nesting colony on Banks Island, Northwest Territories, 20 July 1995 and 16–17 July 1996. Transects 1–5 were replicated in both years, whereas transects 6–11 were conducted in different locations in 1996. Nest density classes were based on random productivity plots conducted each year.

	1995					1996				
Transect	Nest density class (nests/ha)	Carcasses observed	Transect length	Carcasses/m	Density carcasses/ha	Nest density class (nests/ha)	Carcasses observed	Transect length	Carcasses/m	Density carcasses/ha
1[a]	<25	5	489	0.010	3.1	25–50	4	489	0.008	2.5
2[a]	<25	15	987	0.015	4.5	25–50	7	987	0.007	1.2
3	>100	15	528	0.028	7.4	25–50	6	528	0.011	2.0
4	>100	20	468	0.043	10.4	25–50	20	468	0.043	8.8
5	>100	11	652	0.002	3.3	25–50	5	652	0.008	2.2
6[b]	>100	24	466	0.052	16.8	25–50	34	371	0.092	30.5
7[b]	>100	34	328	0.104	26.0	25–50	16	649	0.025	9.7
8[b]	>100	24	573	0.042	15.2	25–50	24	582	0.041	13.9
9[b]	>100	58	333	0.174	55.1	25–50	15	582	0.026	8.2
10[b]	>100	89	163	0.546	237.1	25–50	37	656[c]	0.056	21.5
11[b]	50–100	84	209	0.402	177.0	25–50	39	596	0.065	22.1
Summary		379	5,196	0.073	27.9[a]		207	6,560	0.032	10.2

[a] Transects 1 and 2 were not included in overall density estimates in 1995 because they were subsequently found to be outside the core nesting area in 1995.

[b] Transects 6–11 were conducted in different locations in 1995 and 1996.

[c] Transect 10 endpoints determined by GPS were recorded incorrectly, transect length was estimated as the mean transect length of the other 9 transects.

Another portion of the population winters in New Mexico, Texas, and Mexico, where birds also are exposed to avian cholera epizootics but outbreaks have occurred less frequently than in California (NWHC, unpublished data). The Egg River colony on Banks Island comprises more than 90% of the snow geese breeding in the western Canadian arctic (Kerbes et al. 1999). Like snow goose populations in the eastern and central Canadian arctic, the Egg River colony has grown rapidly during the last decade. During the 1970s and 1980s, the population remained relatively stable between 165,000 and 197,000 geese, but has increased to >400,000 birds since 1987 (R. H. Kerbes, Canadian Wildlife Service, unpublished report).

The overall colony area and core nesting area for snow geese at Egg River was slightly smaller in 1995 than in 1996 (Figure 1). A late spring occurred in 1995, and bird nesting was concentrated in a core area where snow melted early. In contrast, most of the snow had melted when geese arrived for nesting in 1996, which allowed for a more even distribution of nests throughout the colony. High-density (core) and low-density nesting areas within the colony were defined based on a density of 25 nests/ha, and these areas were determined following the guidelines in Kerbes (1986). Area of the total colony was estimated as 6,637 ha in 1995 and 7,537 ha in 1996. The core nesting area was estimated as 996 ha in 1995 and 1,581 ha in 1996. Number of nesting geese was estimated at 318,000 (95% CI=224,000 - 412,000) and 401,000 (95% CI=336,000 - 466,000) in 1995 and 1996, with 121,000 (95% CI=78,000 - 164,000) and 144,000 (95% CI=121,000 - 167,000) in the core area, respectively (G. Samelius, University of Saskatchewan, and R. Alisauskas, Canadian Wildlife Service, unpublished report).

Methods

We used nest density to stratify the Egg River breeding colony into core (>25 nests/ha) and low-density (<25 nests/ha) areas (Figure 1). We determined avian cholera mortality in the core nesting area by conducting line transect surveys on 20 July 1995 and 16–17 July 1996 to estimate density of carcasses (carcasses/ha). In 1995, we initiated transects at the intersections of 1-km grids within the core nesting area and surveyed in a random com-

Female lesser snow goose that died during avian cholera outbreak (1995).

pass direction. In 1996, we resurveyed transects in the same areas as in 1995. Two observers recorded carcasses on opposite sides of each transect and visually estimated the perpendicular distance from each carcass to the transect line. Observers walked at a slow but continuous pace, and a geographical positioning system (GPS) unit with an estimated accuracy of 100 m was used to record the coordinate endpoints of the transect line. Our field experience indicates that GPS error was usually consistent while conducting individual transects and thus unlikely to substantially affect estimated transect length. We surveyed 5.2 km of transects in 1995 ($\bar{x}$=470 m/transect) and 6.6 km in 1996 ($\bar{x}$=590 m/transect). We subsequently found that two transects (1 and 2) were outside the core nesting area during 1995, and these were deleted from the 1995 analysis. We used the program DISTANCE (Laake et al. 1991, Buckland et al. 1993) to estimate density of carcasses in the core area. We reduced the effect of short, high-density transects in our analyses by calculating density estimates weighted by transect length.

Mortality in the core and low-density portions of the colony also was estimated at plots of either 25-m radius (n=53, 1995) or 30-m radius (n=86, 1996), established at 1-km intervals during the nesting season to determine colony nest success. We visited plots either regularly (every 3–5 days) or once during nesting and once after hatch. Number of nests and number of carcasses observed were recorded for each of these productivity plots. Density of carcasses was estimated as the mean density of carcasses on productivity plots in each year.

We diagnosed avian cholera by isolating *P. multocida* from bone marrow of carcasses (Rhoades and Rhimler 1991). Leg bones were removed from a sample of carcasses found during transect surveys, stored in plastic bags at ambient temperatures (4–20° C), and transported to NWHC for bacterial isolation. We collected leg bones because carcasses were badly scavenged and *P. multocida* may persist for several weeks or months in bone marrow (Friend 1987). Leg bones were opened using sterile procedures, and the marrow was tested for presence of *P. multocida* bacteria. If the marrow cavity contained only dry marrow or was empty, the cavity was swabbed with a sterile cotton swab (moistened with brain heart infusion broth) to test for *P. multocida.* Samples were cultured and identified to *P. multocida* serotype following the procedures in Samuel et al. (1997).

Results

Chronology of mortality

During 1995 and 1996, snow geese initiated incubation in early June, with peak initiation about 7 June 1995 and 6 June 1996. Dead birds were observed throughout the colony and mortality was observed until hatching (peak hatch 30 June 1995 and 29 June 1996), when birds dispersed to brood-rearing areas and could no longer be observed. In both years, dead birds were found early in the nesting period and throughout incubation; however, mortality occurred primarily during the latter half of incubation in 1995 and the first half of incubation in 1996.

Avian cholera diagnosis

We confirmed *Pasteurella multocida* serotype 1 from 12 of the 38 goose carcasses collected in 1995 and 19 of 40 carcasses collected in 1996. Previous studies (see Awad et al. 1976, Rhoades and Rimler 1991) indicated that survival of *P. multocida* may be reduced under the types of conditions (dry, cold, 24 hr of daylight) found on Banks Island. We believe the frequency of carcasses with *P. multocida* was underestimated because many of the carcasses had been scavenged and were desiccated after long periods (30–60 days) on the tundra.

Nest and dead male lesser snow goose (Banks Island 1995).

Egg River colony of lesser snow geese at Banks Island (1997).

We found 2 carcasses at 207 nests monitored on 40 productivity plots from the low-density portion of the colony during 1995 (0.5% mortality=2 dead/414 nesting birds). Mean density was 0.26 carcasses/ha (95% CI=0 - 0.60). In 1996, we found 10 carcasses on 67 productivity plots containing 415 nests (1.2% mortality=10 dead/830 nesting birds). Mean density was 0.53 carcasses/ha (95% CI=0 - 1.19). Because nesting birds were not uniquely marked, accurate association of mortality with nests was not always possible and birds from monitored nests also may have died outside the productivity plots or vice versa. Based on the carcass density on productivity plots and the area of low-density nesting at the colony, we estimated that 1,467 snow geese (0.26 carcasses/ha × 5,641 ha) died in 1995 and 3,157 geese (0.53 carcasses/ha × 5,956 ha) died in 1996 during the incubation and nesting period. We calculated an alternative estimate of mortality using the percentage of nesting birds that died on productivity plots (0.5% in 1995 and 1.2% in 1996) and the estimated number of nesting geese in the low-density breeding area (197,000 in 1995 and 257,000 in 1996). These estimates of 952 in 1995 and 3,096 in 1996 closely corresponded with estimates using carcass density.

Total mortality

We counted 379 carcasses on 11 transects in 1995 (Table 1). Although transect lines were longer in 1996, we observed fewer total carcasses (207) that year. Carcasses were detected at distances of 0 to 230 m from transect lines, but we excluded carcasses >140 m to delete outliers and facilitate modeling of the detection function (Buckland et al. 1993:107). We grouped the remaining carcass data into 7 20-m intervals from the transect line and analyzed the grouped data to determine the best probability detection function and estimate carcass density using the program DISTANCE (Burnham et al. 1980, Buckland et al. 1993).

Overall, the half-normal model with 5 parameters provided the best visual fit to the data, and AIC values for that model (1995 AIC=1,715; 1996 AIC=886) were considerably lower than values obtained for the hazard or the uniform models (AIC=3,063 - 7,446). In 1995, estimated carcass density for transects in the core nesting area ranged from 3.3 to 237.1 carcasses/ha (Table 1). Mean density for transects was 27.9 carcasses/ha (log-based 95% CI=9.2 - 84.2). In 1996, carcass density among transects in the core breeding area varied from 1.2 to 30.5 carcasses/ha with mean density substantially lower at 10.2 carcasses/ha (log-based 95% CI=8.9 - 11.7) than in 1995 (Z=1.772, P=0.076). The number of carcasses inside the core breeding area was estimated as 27,788 (27.9 carcasses/ha × 996 ha) in 1995 and 16,126 (10.2 carcasses/ha × 1,581 ha) in 1996.

Discussion

We found that avian cholera mortality at the Egg River colony began during nesting and continued through the incubation period. However, we are not certain whether mortality occurred prior to nesting or continued after hatch, when birds were more widely distributed on brood-rearing areas. Transmission of avian cholera through a susceptible population of wild birds may occur by ingestion, by inhalation of water aerosols when birds take flight (Botzler 1991), or from bird-to-bird contact (Wobeser 1992). While the route of transmission for snow geese nesting on Banks Island is unknown, we believe that inhalation of contaminated water aerosols (Rosen and Morse 1959) is unlikely, due to the generally sedentary behavior of geese during incubation and the absence of wetland roosting areas where birds are concentrated. Instead, transmission by ingestion of bacteria from the contaminated environment or from bird-to-bird contact seems more plausible. Direct contact may be facilitated by dense concentrations of nesting geese and frequent interaction among them. Ingestion of bacteria also may occur when birds move from their nest to feed or drink at nearby wet areas that have become contaminated.

We estimated that approximately 30,000 and 20,000 nesting snow geese (9% and 5% of the nesting population) at the Egg River colony died from avian cholera in 1995 and 1996, respectively; however, for several reasons, we believe that actual mortality was higher. First, during our transect counts, all the carcasses we examined were extremely scavenged, and we suspect that at least some of the carcasses were removed by arctic fox (*Alopex lagopus*) during the month preceding our surveys. Secondly, transect methods typically underestimate actual density by 10–12% (Anderson and Southwell 1995). Finally, we found that mortality estimates from productivity plots in the core nesting area were less than estimates we obtained from line transects, suggesting that mortality in the low density area also was underestimated. We suspect the small size of the productivity plots (25- to 30-m radius) made this method inefficient to estimate mortality.

Mortality of geese from avian cholera was not uniformly distributed throughout the breeding colony. Within the core breeding area, we observed considerable patchiness in the distribution of carcasses among transects (Table 1 and personal observations). In particular, we observed more carcasses along some of the waterways in the core area of the colony, and we observed a higher concentration of carcasses in some unsampled areas than in areas with transects. We also found that densities of carcasses were greatest in the core breeding area of the colony, which also had the highest density of nesting birds. Estimated mortality of 27,788 in the core area during 1995 exceeded 20% of the estimated 121,000 snow geese nesting in the core area, where average density approximated 120 nesting geese/ha. In 1996, estimated mortality of 16,126 exceeded 10% of the 144,000 snow geese nesting in the core area, with average density of 90 nesting geese/ha. Estimated mortality rates were even lower in the low-density portion of the colony in both 1995 (<1% mortality with 35 nesting geese/ha) and 1996 (<2% mortality with 45 nesting geese/ha). Although we found a general trend in mortality rate with nesting density, we caution that mortality in the low-density portion of the colony was likely underestimated by using productivity plots.

In addition to the direct mortality on nesting adults, we suspect a substantial indirect effect on productivity when avian cholera outbreaks occur at arctic breeding areas. At least one member in 15,000 breeding pairs in 1995 and 10,000 pairs in 1996 died before hatch was completed. Nesting failure occurs following mortality of the incubating female goose, and mortality of the male may reduce brood survival (Martin et al. 1985, Schneider and Lamprecht 1990, Paine 1992). Because carcasses were scavenged when we conducted line transect surveys, we were unable to determine gender of birds that died or whether avian cholera mortality was equal between males and females. However, previous studies on wintering areas have reported that males had higher mortality from avian cholera than females for Ross' and lesser snow geese (McLandress 1983) and in Canada geese (*Branta canadensis*, Windingstad et al. 1998).

Management implications

Rosen (1972) hypothesized that infected waterfowl carry the *Pasteurella multocida* bacterium from the wintering grounds to the breeding areas, where mortality recurs and the avian cholera disease is maintained. In particular, snow geese have been suspected of playing an important role in distributing avian cholera because mortality patterns have coincided with snow goose migration in the Central and Mississippi flyways (Brand 1984) and with the arrival of snow geese in California (J. G. Mensik, United States Fish and Wildlife Service, personal communication). In addition, regular mortality has been observed in northward migrating lesser snow and Ross' geese in Saskatchewan (Wobeser et al. 1979, 1983) and snow geese have frequently been involved in larger avian cholera outbreaks (NWHC, unpublished data). Our studies at Banks Island provide further support for these hypotheses. Three major outbreaks of avian cholera occurred at Banks Island between 1991 and 1996. Additional avian cholera mortality also was observed at the Egg River colony during the 1997 nesting season (G. Samelius, unpublished data), but the magnitude of mortality was not determined. During related research studies, we found that approximately 50% of the adult snow geese infected with *P. multocida* during the outbreaks in 1995 and 1996 survived infection, and thus a portion of these birds may be carriers of the bacteria (M. D. Samuel, unpublished report). We believe these consistent outbreaks, survival of potential carrier birds following outbreaks, and isolation of *P. multocida* from a healthy lesser snow goose nesting on Banks Island in 1994 (Samuel et al. 1997) provide evidence that avian cholera has become endemic in Banks Island snow geese, and this population may play an important role in transmitting this disease to other waterbirds, especially to wintering areas where many species are concentrated.

Lesser snow geese, especially in the mid-continent population, have increased dramatically in North America during the past 30 years and have affected arctic habitats (Ankney 1996, Abraham and Jefferies 1997, Batt 1997). Some observers have speculated that these expanding snow goose populations may eventually decline due to disease or starvation (Ankney 1996). At present, avian cholera is the most significant cause of disease mortality in lesser snow goose populations, and many of these outbreaks occur in late winter or during the breeding season when mortality is likely to have the most significant affect on population demographics. While avian cholera has the potential to kill tens of thousands of lesser snow geese during a single outbreak, it does not appear likely that avian cholera alone will limit growth of snow goose populations (Samuel et al. 1999). However, the prospects of winter avian cholera outbreaks of sufficient magnitude to substantially reduce overabundant snow goose populations could have devastating effects on other waterfowl, such as northern pintail (*Anas acuta*), mallard (*Anas platyrhynchos*), and white-fronted geese (*Anser albifrons*), species that are particularly susceptible to this disease.

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