AVIAN CHOLERA MORTALITY IN MISSISSIPPI FLYWAY CANADA GEESE

RONALD M. WINDINGSTAD, U.S. Geological Survey, National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711

MICHAEL D. SAMUEL, U.S. Geological Survey, National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711 (Corresponding author)

DENNIS D. THORNBURG, Illinois Department of Conservation, Union County Refuge, R.R. 2, Jonesboro, IL 62952

LINDA C. GLASER, U.S. Geological Survey, National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711

Abstract: Avian cholera has caused mortality of Canada geese (*Branta canadensis*) on wintering and fall migration areas in the Mississippi Flyway. Losses of Canada geese from avian cholera in Wisconsin, Minnesota, and Missouri have been sporadic. Avian cholera outbreaks have occurred in southern Illinois and Kentucky every year from 1986 to 1990, and this disease should be considered enzootic in these areas. Snow cover, cold temperatures, and increases in the number of geese in an area were not related to the initiation of these avian cholera die-offs, but cold weather seemed to be correlated with mortality rate once a die-off began. Immature geese had higher mortality rates during avian cholera outbreaks than adults, and adult male geese had higher mortality rates than adult females. Additional research is need to understand the role of susceptibility, immunity, and carriers in the epizootiology of avian cholera in Mississippi Flyway Canada geese.

Key words: avian cholera, *Branta canadensis*, Canada geese, Mississippi Flyway, mortality, neck band, *Pasteurella multocida*.

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Avian cholera, a disease caused by the bacterium *Pasteurella multocida*, first was reported in wild North American waterfowl in the Texas Panhandle (Quortrup et al. 1946) and the San Francisco Bay area (Rosen and Bischoff 1949) during 1944. Since avian cholera was first reported, the severity of losses among waterfowl populations has varied annually wherever this disease has become enzootic. Rosen (1971) estimated that 2% fewer ducks and 6% fewer swans migrated north each spring as a result of mortality from avian cholera, primarily in California. Petrides and Bryant (1951) were the first to report Canada geese dying from avian cholera during 1949-50 in the Texas Panhandle. Rosen (1969) reviewed species mortality from avian cholera in California during 1961-69 and reported 102 cackling Canada geese (*B. c. minima*) among 6,266 waterfowl that had been found dead from avian cholera. Using a relative mortality index, Rosen (1969) estimated that cackling Canada geese often suffered disproportionately high mortality during avian cholera outbreaks (Botzler 1991).

Avian cholera occurs in all major flyways of North America (Friend 1987), but was not documented in the Mississippi Flyway until 1964 at Squaw Creek National Wildlife Refuge (NWR), Missouri. Waterfowl losses recorded during that die-off included over 1,000 snow geese (*Chen caerulescens*) and 66 small Canada geese (*B. c. hutchinsii*), but none of the 7,000 large Canada geese (*B. c. interior* and *B. c. maxima*) in the area were affected (Vaught et al. 1967). The first recognized avian cholera losses in large Canada geese occurred in southern Illinois during the winter of 1978-79, when about 850 birds died (Windingstad et al. 1983).

Increased density of waterfowl on wetlands has been suggested as one factor that predisposes birds to avian cholera or expedites transmission of *P. multocida* between birds (Petrides and Bryant 1951). Botzler (1991) suggested that waterfowl density may influence the mortality from avian cholera by either increasing the risk of an outbreak starting or increasing the mortality rate during an outbreak. However, the effect of bird density appears to vary considerably among populations and years (Nat. Wildl. Health Res. Cent. [NWHRC], unpubl. data). Similarly, precipitation and temperature have been suggested as factors in inducing and/or prolonging avian cholera mortality (Windingstad et al. 1988, Botzler 1991).

The influence of age and sex of waterfowl also has been considered as a possible predisposing factor to avian cholera, but findings have been inconsistent (Botzler 1991). Korschgen et al. (1978) found that a large portion of the avian cholera mortality among common eiders (*Somateria mollissima*) in Maine occurred in females. McLandress (1983) compared the age and sex composition of Ross' (*Chen rossii*) and lesser snow geese (*C. c. caerulescens*) that died during avian cholera outbreaks in California with those of trapped or shot geese. He found a larger proportion of adult male Ross' geese died from avian cholera than were trapped or shot. In addition, immature geese of both species died at a higher rate than adults during the period of highest mortality. McLandress (1983) found that adult female geese were less susceptible than geese of other age or sex categories. Mensik and Botzler (1989) investigated the age and sex susceptibility of coots (*Fulica americana*) during an avian cholera epizootic in northern California. They concluded that age and sex composition of birds that died from cholera did not differ from hunter-killed birds; however, only 135 coots were examined in their study.

This paper documents losses of Canada geese from avian cholera in the Mississippi Flyway and presents a review of the geographic and annual variations in mortality. Age- and sex-specific mortality, effects of weather, and effects of the number of geese in an area on avian cholera outbreaks also are discussed.

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METHODS

We summarized losses of Canada geese from avian cholera in the Mississippi Flyway from published accounts, from reports to NWHRC, and from field and laboratory investigations conducted by NWHRC personnel.

Carcasses of Canada geese found during field investigations were chilled or frozen and shipped to the NWHRC for necropsy. Necropsies were conducted using techniques similar to that described by Wobeser (1981). A provisional diagnosis of avian cholera was made if lesions indicative of avian cholera were observed (i.e., focal liver necrosis or petechial or ecchymotic hemorrhages of the coronary band or epicardium). When avian cholera was suspected, tissues were cultured with standard bacterial methods and characterized biochemically to identify *Pasteurella multocida*. Serotyping of *P. multocida* isolates was conducted according to Heddleston et al. (1972).

We used the estimated number of Canada geese from aerial surveys conducted by state game agencies to evaluate the relationship between avian cholera die-offs and numbers of geese present. We also examined the relationship between inclement weather and outbreaks of avian cholera using climatological records of minimum and maximum temperature, precipitation, and snow cover for the 3 days preceding initiation of each avian cholera die-off. A period of 3 days was used because exact date of the onset of mortality could not always be determined. A heating-degree index was calculated by subtracting the mean daily temperature from 18 C, thus, colder temperatures (e.g., <0 C) produce larger heating-degree values. We used correlation analysis to evaluate the relationships among goose population size, mortality rates, and weather data (temperature and precipitation).

We evaluated age and sex mortality of Canada geese during avian cholera die-offs at Union County and Horseshoe Lake, Illinois, in 1979 and at Lac qui Parle, Minnesota, in 1989. The age and sex composition of geese that died from avian cholera at Union County and Horseshoe Lake (Windingstad et al. 1983) were compared to the composition of birds captured during banding operations immediately prior to the die-off. Age and sex distributions of dead or moribund neck-banded geese collected during the avian cholera die-off (22 Oct to 14 Nov 1989) at Lac qui Parle were compared to age and sex distributions of neck-banded geese observed during the die-off. The relative risk of cholera mortality was calculated by dividing the proportion of males (or immatures) that died by the proportion of males (or immatures) at risk in the population (Kahn 1983:46). Chi-square tests comparing sex or age composition of geese trapped or observed to the composition of dead geese were used to determine if these relative risks for males (immatures) were >1.0. Fisher's exact test was used to adjust for bias in the chi-square test when ≥ 1 cell in the contingency table had expected counts <5. The significance of the relative risk of mortality by age and sex over all die-offs was determined with the Mantel-Haenszel test. The Mantel-Haenszel procedure is the uniformly most powerful test for combining the results of age and sex differences from these independent die-offs, and is advantageous for combining results from small samples (Freeman 1987:282-283).

RESULTS

Avian Cholera Die-offs

Avian cholera die-offs of Canada geese in the Mississippi Flyway were reported in Minnesota, Missouri, Illinois, Wisconsin, and Kentucky between 1978-79 and 1989-90 (Table 1). Die-offs occurred at waterfowl refuges (Fig. 1) used primarily by the Mississippi Valley Population (MVP) Canada geese or the Eastern Prairie Population (EPP) Canada geese (Samuel et al. 1991: Fig. 1). The first documented losses at MVP wintering areas were reported in southern Illinois during winter 1978-79 (Table 1). Mortality from avian cholera in EPP Canada geese first was reported during the winter of 1979-80 at Swan Lake NWR (Brand 1984) and at one of its minor satellite areas (NWHRC, unpubl. data). Avian cholera losses occurred frequently (8 of 12 years) in MVP wintering areas and less often (3 of 12 years) in EPP wintering areas.

Avian cholera occurred in geese once on the MVP and once on the EPP fall staging areas. Avian cholera occurred in MVP geese during the fall

Table 1. Avian cholera mortality, Canada goose population estimates, and weather data for the Mississippi Valley (MVP) and Eastern Prairie Populations (EPP) of Canada geese in the U.S. from winter 1978-79 through 1989-90. NWHR data unless otherwise indicated.

Location	Dates	Estimated mortality	Population		Weather[a]	
			Week prior to onset	At onset	Mean heating-degree index	Snow cover (cm)
MVP						
Union County CA[b], Ill.[c]	01/16/79-02/09/79	850	60,000	30,000	23.8	7.6
Horseshoe Lake CA, Ill.[c]	02/09/79-02/15/79	133	29,000	30,000	22.6	3.4
Eastcentral, Wis.[d]	10/25/79-02/06/80	850	72,500	65,565	9.8	0
Union County CA, Ill.[e]	01/19/81-02/12/81	71	65,000	50,000	19.6	0
Ballard County WMA[f], Ky.[e]	01/23/81-02/10/81	25	55,000	65,000	14.6	0
Union County CA, Ill.[e]	01/29/86-02/06/86	450	30,000	39,000	23.4	Trace
Union County CA, Ill.[e]	01/13/87-02/20/87	1,500	63,000	46,000	16.5	Trace
Horseshoe Lake CA, Ill.[e]	02/15/87-02/20/87	300	55,000	45,000	9.3	0
Ballard County WMA, Ky.[e]	01/21/88-02/01/88	358	54,000	59,000	11.6	0
Union County CA, Ill.[e]	01/09/89-03/09/89	452	135,000	120,000	7.3	0
Horseshoe Lake CA, Ill.[e]	01/11/89-02/08/89	1,200	260,000	300,000	15.6	0
Union County CA, Ill.[e]	12/25/89-01/15/90	6,000	160,000	190,000	35.6	Trace
Ballard County WMA, Ky.[e]	12/31/89-01/04/90	400	55,000	170,000	16.4	0
Horseshoe Lake CA, Ill.[e]	01/01/90-02/02/90	1,000	350,000	360,000	12.8	0
Rend Lake CA, Ill.[e]	01/18/90-02/01/90	500	90,000	170,000	6.8	0
EPP						
Brookfield, Mo.[g]	12/20/79-01/03/80	155	8,900	Unknown	20.1	0
Swan Lake NWR, Mo.[g]	01/03/80-01/09/80	700	61,850	13,300	16.1	0
Swan Lake NWR, Mo.[g]	11/15/80-12/15/80	50	Unknown	Unknown	8.2	0
Lac qui Parle WMA, Minn.[e]	10/19/89-12/31/89	7,000	112,000	120,000	15.3	0
Swan Lake NWR, Mo.[e]	11/20/89-01/02/90	< 100	56,000	54,900	19.9	0
Brookfield, Mo.[e]	12/08/89-01/02/90	< 100	4,500	450	14.0	0
Slater, Mo.[e]	12/26/89-01/02/90	< 100	800	13,000	35.2	4.2
Montrose WMA, Mo.[e]	12/28/89-01/04/90	19	10,175	14,600	22.7	2.5

[a] Average of the 3 days prior to the reported onset of avian cholera.
[b] CA = Conservation Area.
[c] Windingstad et al. (1983).
[d] Brand (1984).
[e] NWHRC Unpublished data.
[f] WMA = Wildlife Management Area.
[g] Humburg and Babcock (1982).

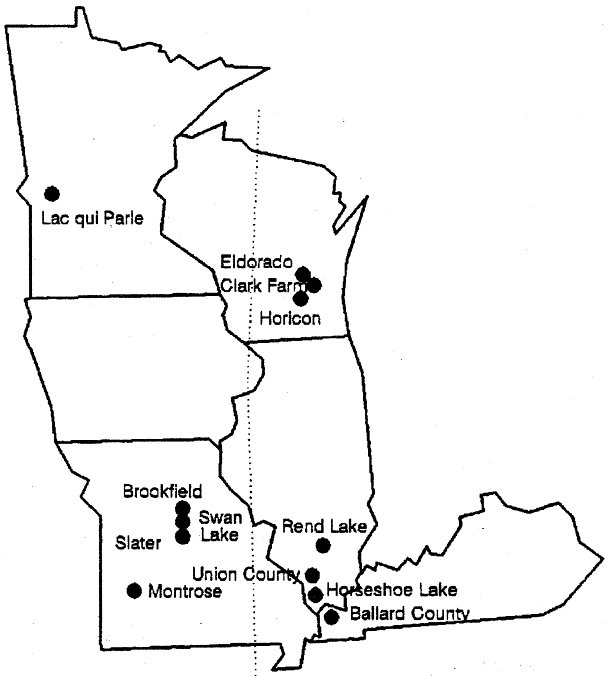

Figure 1. Locations of reported avian cholera mortality for Canada geese in the Mississippi Flyway 1978-79 to 1989-90. Line indicates approximate boundary between MVP and EPP wintering areas (Samuel et al. 1991).

migration (late October) 1979 in eastcentral Wisconsin. By mid-February 1980, an estimated 850 Canada geese in this area had died from avian cholera (Brand 1984). Canada geese in eastcentral Wisconsin are usually affiliated with the MVP (Samuel et al. 1991). However, observations of neck-banded geese in the Mississippi Flyway during the fall and winter of 1979-80 indicated a possible shift in the distribution of EPP and MVP geese throughout the flyway (Samuel et al. 1991). Whether this apparent shift in distribution is related to the outbreak in Wisconsin is unknown. Avian cholera was reported in EPP Canada geese on their migration area for the first time in October 1989 in western Minnesota at Lac qui Parle Wildlife Management Area, Big Stone NWR, and 3 other lakes in the vicinity (NWHRC, unpubl. data).

Serotype

All of the *P. multocida* isolates (>100) serotyped from Canada geese that died in the Mississippi Flyway were serotype 1 (Brogden and Rhoades 1983). This is the most common serotype found in waterfowl throughout the United States (Hirsh et al. 1990).

Weather Factors

The mean heating-degree index for the 3 days preceding initiation of an avian cholera outbreak was 17.3 (range 6.8 at Rend Lake, Ill. to 35.6 at Union County, Ill.). Initiation of avian cholera die-offs occurred in mild weather as frequently as in cold weather (Table 1). No significant correlations were found between the average heating-degree index and either the number of Canada geese that died during an outbreak ($r = 0.25$, $n = 23$, $P = 0.24$) or the mortality rate (mortality/population at disease onset) ($r = -0.003$, $n = 21$, $P = 0.99$). However, the mortality rate based on the population 1 week prior to the cholera outbreak and the average heating-degree index were positively correlated ($r = 0.52$, $n = 22$, $P = 0.01$).

Thirteen of the 23 locations where weather data were collected received a trace or more of precipitation during the 48 h preceding a die-off; on 5 of these occasions the precipitation was snow. Three of the snowfalls were reported as trace amounts, 1 was 0.25 cm, and the fifth was a 5.3 cm snowfall at Horseshoe Lake just prior to the die-off in 1979. Only 4 of the 23 sites had more than a trace of snow on the ground during the 3 days preceding a die-off (Table 1). Snowfall did not appear to affect the initiation of avian cholera mortality in either EPP or MVP populations of Canada geese.

Mortality by Age and Sex

Of 1,266 neck-banded Canada geese observed at Lac qui Parle during the 1989 avian cholera outbreak, only 1 was immature. This high proportion of adults primarily reflects previous banding efforts, high annual survival of adult geese, and the low number of immature geese banded in 1989 prior to October. Adults also comprised the largest proportion (97.5%) of neck-banded geese that died during the outbreak. The low number of neck-banded immature geese precluded an analysis of differential mortality based on age.

A higher proportion ($\chi^2 = 32.7$, 1 df, $P < 0.001$) of immature geese at Horseshoe Lake died from avian cholera than were trapped 1 week prior to the die-off (Table 2). The relative risk of cholera mortality was 3.89 times higher for immatures than for adults. However, mortality rates did not differ ($\chi^2 = 0.25$, 1 df, $P = 0.62$) by age (relative risk for immature geese = 1.08) during the die-off at Union County. The combined test for mortality indicated a higher proportion ($\chi^2 = 10.65$, 1 df, $P < 0.001$) of immature geese died (average relative risk = 2.49) from avian cholera than adults.

The relative risk of cholera mortality at Lac qui Parle was 1.44 times higher for adult males than adult females; however, this difference was not significant ($\chi^2 = 1.63$, 1 df, $P = 0.20$). At Horseshoe Lake the mortality rate for males was not different ($\chi^2 = 0.0$, 1 df, $P = 0.998$) from females (relative risk = 1.00). However, the proportion of male geese that died during the Union County outbreak was higher (χ^2 = 15.3, 1 df, $P < 0.001$) than the proportion of males trapped during the outbreak (Table 2). The relative risk of mortality of male geese at Union County was 1.73 times higher than females. The combined test for mortality indicated that males were more likely (χ^2 = 13.0, 1 df, $P < 0.001$) to die (average relative risk = 1.39) from avian cholera than females.

We conducted additional comparisons by testing for overall trends in age and sex susceptibility using the Mantel-Haenszel statistic. Adult males (average relative risk = 1.40) had a higher mortality rate (χ^2 = 10.0, 1 df, $P = 0.002$) than adult females. Immature males (average relative risk = 1.32) also had a higher mortality rate than immature females; this difference was marginally significant (χ^2 = 2.85, 1 df, $P = 0.092$). There was significantly (χ^2 = 4.16, 1 df, $P = 0.041$) higher mortality in immature males (relative risk = 1.66) during the Union County die-off, but not at Horseshoe Lake (relative risk = 0.98, χ^2 = 0.002, 1 df, $P = 0.968$).

DISCUSSION

Avian cholera has occurred with relative frequency in MVP Canada geese and continues to periodically cause mortality in EPP geese. In the Mississippi Flyway, the disease has been reported primarily during fall and winter. This is in contrast to the Rainwater Basin in Nebraska, where avian cholera has caused mortality in Canada geese and other waterfowl during the late winter to early spring (Windingstad et al. 1984). Major losses (>1,500) in the Mississippi Flyway occurred during the fall and winter of 1979-80, 1986-87, 1988-89, and 1989-90. These losses were generally concurrent in both MVP and EPP geese. Our data show that the total annual mortality and frequency of avian cholera outbreaks has increased since 1979-80.

Our reports of avian cholera in new areas, such as western Minnesota, indicate that avian cholera may be expanding geographically within the Mississippi Flyway. The mechanism for the spread of avian cholera to new areas is unknown. Brand (1984) discussed several reasons for the initiation of avian cholera in wild waterfowl, including latent carriers. Stress may cause carrier birds to shed *P. multocida* organisms and trigger a die-off. Stressors such as crowding, adverse weather conditions, and movement were present in some of the cases described in this paper; however, in other die-offs, no easily discernible stress was present. Another possibility is that *P. multocida* persists in either mammalian or avian reservoir species (Brand 1984) or the bacterium persists in the environment for long periods of time. Either could account for the die-offs in southern Illinois where avian cholera continues to occur. However, further studies are needed to understand the

Table 2. Age and sex of Canada geese trapped at Horseshoe Lake and Union County, Ill., or observed at Lac qui Parle, Minn., and of geese that died during avian cholera epizootics.

	Trapped/observed		Dead	
Age/sex	***n***	**%**	***n***	**%**
Horseshoe Lake[a] (1979)				
Immature males	36	(11.2)	26	(27.1)
Immature females	30	(9.3)	22	(22.9)
Adult males	139	(43.0)	26	(27.1)
Adult females	118	(36.5)	22	(22.9)
All geese	323	(100.0)	96	(100.0)
Union County (1979)				
Immature male	102	(14.5)	58	(19.2)
Immature female	111	(15.7)	38	(12.6)
Adult male	235	(33.3)	127	(42.0)
Adult female	257	(36.5)	79	(26.2)
All geese	705	(100.0)	302	(100.0)
Lac qui Parle (1989)				
Immature male	0	(0.0)	1	(2.5)
Immature female	1	(0.1)	0	(0.0)
Adult male	567	(44.8)	21	(52.5)
Adult female	698	(55.1)	18	(45.0)
All geese	1266	(100.0)	40	(100.0)

[a] From Windingstad et al. 1983.

factors that initiate avian cholera epizootics and that determine the magnitude of mortality among areas and years in the same area.

We suggest that southern Illinois, especially Union County, has become an enzootic area for avian cholera in Canada geese. Avian cholera caused die-offs of wintering Canada geese in Illinois during 4 of the last 5 years of this study and in 6 of 12 years at Union County. In addition, portions of southwestern Iowa (Riverton and nearby wetlands) have become enzootic for avian cholera in snow geese and mallards (*Anas platyrhynchos*). Although avian cholera die-offs in these areas principally have involved other species, Canada geese may also be exposed to *P. multocida.*

Serotype 1 was the only serologic type of *P. multocida* recovered from Canada geese that died during avian cholera epizootics reported here. *Pasteurella multocida* isolates from waterfowl dying from avian cholera in the Pacific Flyway and the Central Flyway, where avian cholera has been common, were predominately serotype 1 (Brogden and Rhoades 1983; NWHRC, unpubl. data). In contrast, isolates from the Atlantic Flyway, where avian cholera has been less common, were predominately serotype 3 or serotype 4 (Brogden and Rhoades 1983). NWHRC records, as well as those of Brogden and Rhoades (1983) show that serotype 1 has been the only serotype isolated from Canada geese.

We did not find cold weather associated with initiation of avian cholera outbreaks. Windingstad et al. (1988) suggested that cold weather may have exacerbated the mortality of mallards during an avian cholera die-off in western Nebraska and eastern Wyoming. Our data on Canada goose mortality likewise suggested that cold weather may exacerbate mortality when an avian cholera outbreak is in progress, although our estimated mortality rates were crude. Additional investigation of the effect of cold weather on avian cholera die-offs is warranted.

Our analysis of age- and sex-susceptibility of Canada geese to avian cholera in the Mississippi Flyway indicated that overall mortality rates were higher in immature Canada geese than in adult geese. We also found evidence that avian cholera can affect adult males more than adult females. At least 2 plausible reasons have been offered to explain these differences. First, physiological stress has been mentioned in discussions of susceptibility to avian cholera (Petrides and Bryant 1951, Vaught et al. 1967, Rosen 1971, Korschgen et al. 1978). Immature geese may be more vulnerable to stress-related diseases because they usually have lower body weight and body reserves than adults. However, McLandress (1983) found that Ross' and lesser snow geese that died from avian cholera had the same body weight (by age and sex) as geese killed by hunters. Korschgen et al. (1978) attributed female eider mortality to physiological stress on breeding hens; however, male eiders were widely dispersed when avian cholera occurred on the nesting grounds and may not have been exposed to the avian cholera bacterium. Because acute infections of avian cholera are common and can result in death 6-12 hours after exposure (Friend 1987), physiological stress likely promotes shedding of bacteria by birds carrying the organism, rather than increasing the susceptibility to infection.

Secondly, differential susceptibility by age may depend on immunity acquired by adult birds previously exposed to avian cholera. Immunity could lower the overall risk of cholera mortality more in adults than in immature birds. Price (1985) reported that Canada geese vaccinated with *P. multocida* antigen survived experimental exposure to avian cholera bacterium $\geq$12 months after immunization. Whether geese acquiring immunity to avian cholera become carriers of the bacteria is unknown. McLandress (1983) also found that adult female Ross' geese were less susceptible to avian cholera than other conspecifics. However, no reasons have been proposed to explain the differences in susceptibility between males and females. Further research is needed to understand the role of susceptibility, natural immunity, and carriers in the epizootiology of avian cholera.

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