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Characterization of an Avian Cholera Epizootic in Wild Birds in Western Nebraska

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SUMMARY. Avian cholera killed an estimated 2500 birds in western Nebraska and eastern Wyoming from 28 November 1985 to late January 1986. Wild mallards (*Anas platyrhynchos*) suffered the most losses. Other wild waterfowl, wild turkeys (*Meleagris gallopavo*), a few domestic fowl, and a bald eagle (*Haliaeetus leucocephalus*) also died. *Pasteurella multocida* serotype 1 was the predominant isolate from these carcasses. Cold, wet weather persisted throughout the outbreak, but daily losses in the flock of 50,000 mallards using the area were low. *Pasteurella multocida* was isolated from nasal swabs of 35 of 37 cattle from a feedlot in which many of these mallards were feeding. Eighty percent of the cattle isolates had antigenic characteristics of serotype 3 or serotype 3 with cross-reactivity. Isolates from wild mallards, wild turkeys, and the bald eagle were virulent to game-farm mallards when inoculated subcutaneously, but *P. multocida* isolates from cattle were not.

RESUMEN. Caracterización de una epizootia de cólera aviar en los aves silvestres en el oeste del estado de Nebraska, E.U.A.

Se estimó que 2500 aves perecieron por cólera aviar en el oeste del estado de Nebraska y el este del estado de Wyoming entre noviembre 28 de 1985 y finales de enero de 1986. Las pérdidas más altas las sufrieron los patos silvestres (*Anas platyrhynchos*). Otras aves silvestres acuáticas, pavos salvajes (*Meleagridis gallopavo*), algunas aves domésticas y un águila calva (*Haliaeetus leucocephalus*) también perecieron. El serotipo 1 de *Pasteurella multocida* aislado de cadáveres fue el más predominante. Durante el brote persistió un clima frío y húmedo, sin embargo, la mortalidad diaria en una bandada de 50.000 patos salvajes localizados en esa área fue baja. Se aisló *Pasteurella multocida* en 35 de los 37 hisopos nasales tomados de vacunos que se encontraban en la misma área. Ochenta por ciento de las cepas aisladas de los vacunos tuvieron características de serotipo 3 o de serotipo 3 con reactividad cruzada. Las cepas aisladas de los patos salvajes, pavos silvestres y del águila fueron muy virulentas cuando se inocularon subcutáneamente en patos salvajes. Las cepas aisladas de los vacunos no fueron virulentas.

Avian cholera (fowl cholera), a bacterial disease caused by *Pasteurella multocida,* has been recognized as an important disease in domestic poultry for over 200 years (16), but it was not reported in wild waterfowl until an outbreak occurred in Kenya in 1940 (9). In North America, avian cholera in wild waterfowl was first reported in 1944 in the Texas Panhandle (15) and in the San Francisco Bay area (17). Since then, avian cholera has become an increasingly serious problem in migratory birds as prevalence and geographic distribution of the disease have increased (2).

In the Rainwater Basin of south-central Nebraska, mortality from avian cholera in migratory birds has occurred annually since 1975 (23), with losses of as many as 72,000 birds in the spring of 1980 (2). Recent studies in the Rainwater Basin have determined differences in certain water quality variables related to areas of high and low avian cholera mortality (23). Laboratory studies at the National Wildlife Health Research Center (NWHRC) have suggested that these differences may be related to survivability of *Pasteurella multocida* in water (J. Price, unpubl. data).

During the winter of 1985–86, an outbreak of avian cholera occurred in wild waterfowl, wild turkeys, domestic ducks, geese, and chickens in western Nebraska and eastern Wyoming. This die-off was characterized by a relatively long-term, constant daily loss of small numbers of birds throughout the winter; this is in contrast to explosive losses common to many other out-

breaks of avian cholera, such as those in the Rainwater Basin approximately 350 km east of the die-off area. As part of field investigations of this outbreak, water quality variables were measured and compared with those of the Rainwater Basin compiled during previous outbreaks (23). We characterized the outbreak in terms of climatological events; potential relationships between *P. multocida* isolates from wild waterfowl and those from cattle, domestic fowl, and wild turkeys; and the apparent geographic spread of this outbreak over time. We report herein results of these investigations.

MATERIALS AND METHODS

Die-off area. The avian cholera die-off occurred near Scottsbluff, Nebraska, and spread into eastern Wyoming (Fig. 1). Major mortality of wild waterfowl was first noted on two warm-water (13 C) spring-fed ponds (approximately 1 ha each) adjacent to a farmyard (Farm A). Free-ranging domestic fowl were present at this site. Additional mortality occurred later downstream from these ponds on Spring Creek and 2 km away on Summerville Creek. Summerville Creek flows through Farm B, site of a cattle feedlot. Waterfowl at a nearby construction-firm pond did not suffer losses except for one goose. An antibiotic (tetracycline) was being administered in the feed provided to waterfowl at the construction-firm pond, because avian cholera had occurred there the previous spring in two wild geese. Mortality occurred in Lingle, Wyoming, west of Scottsbluff in early January when waterfowl moved to that area, affecting birds along the North Platte River.

Carcass examination. Field personnel from the Nebraska Game and Parks Commission and the U.S. Fish and Wildlife Service searched the ponds and creeks for sick and dead birds on foot or in all-terrain vehicles 20 times during the 8-week die-off. Domestic fowl that died on the adjacent farmyard (Farm A) were picked up by the owner and submitted to field personnel for necropsy. Species involved in the die-off were identified, and representative carcasses of each species involved were necropsied. A provisional diagnosis of avian cholera was made if lesions indicative of avian cholera were observed, namely petechial and/or ecchymotic hemorrhages of the coronary band or epicardium, or focal liver necrosis. *Pasteurella multocida* was isolated from livers according to methods described by Weaver *et al.* (21) to confirm the diagnosis. All carcasses were incinerated.

Swabs. Cloacal and pharyngeal swabs were taken for bacterial culture from 20 apparently healthy domestic ducks and geese at Farm A 5 weeks after avian cholera mortality was detected in wild waterfowl. Swabs were placed in Amies transport medium with charcoal (Difco Laboratories, Detroit, Michigan) and frozen for transport to the NWHRC for processing. Swabs were thawed and streaked onto 5% sheep blood agar plates (BAP) and eosin methylene blue (EMB) plates for attempts at *P. multocida* isolation (21).

Nasal swabs were taken from 37 apparently healthy cattle from the feedlot along Summerville Creek (Farm B) after they were shipped from the farm to the slaughterhouse. Swabs were placed in Amies medium and stored frozen until they were streaked onto BAP and EMB and also onto a selective plating medium for *P. multocida* isolation (11). The presence of *P. multocida* was confirmed using the API 20E® enteric bacterial identification kit (Analytab Products, Inc., New York, N.Y.). Isolates were serotyped by the gel diffusion precipitin test (7). Antisera for types 1 through 16 were obtained from the National Veterinary Services Laboratory, Ames, Iowa.

Isolate pathogenicity. Five *P. multocida* isolates from birds dying of avian cholera were inoculated subcutaneously into four groups of three and one group of two healthy game-farm-reared mallards, and seven isolates from cattle nares were inoculated into seven groups of three mallards to determine the pathogenicity for ducks. The isolates from BAP were grown in brain heart infusion broth for 18 hours at 37 C. Approximately 10^6 organisms (0.1 ml of culture) were inoculated into each mallard. Colony-forming units per 0.1 ml were determined by plate count on dextrose starch agar. Mallards surviving the challenge were observed for 21 days postinoculation. All birds were necropsied following death or at termination of study.

Water sampling. Water samples were collected on 5 January 1986, at the Spring Creek ponds for water chemistry analysis. One-liter polyethylene containers were submerged 5–10 cm below the surface for water collection. Sample bottles were kept chilled during transport to the Nebraska Department of Environmental Control Laboratory for analysis. Analysis for chloride, sulfate, sodium, magnesium, and calcium as described by the U.S. Environmental Protection Agency (20) began within 24 hours of collection.

Climatological data. Monthly summaries of local climatological data for Scottsbluff, Nebraska, for November and December 1985 and January 1986 were used to obtain minimum and maximum temperatures, precipitation, and snow depth on the ground (National Climatic Data Center, Asheville, North Carolina).

RESULTS

Avian mortality. Mortality was first noted in wild mallards at Spring Creek ponds adjacent to Farm A on 28 November 1985 (Fig. 1). An estimated 50,000 wild waterfowl, mainly mallards, had been using the ponds when 15 fresh carcasses were found. These were necropsied, and cause of death was provisionally diagnosed as avian

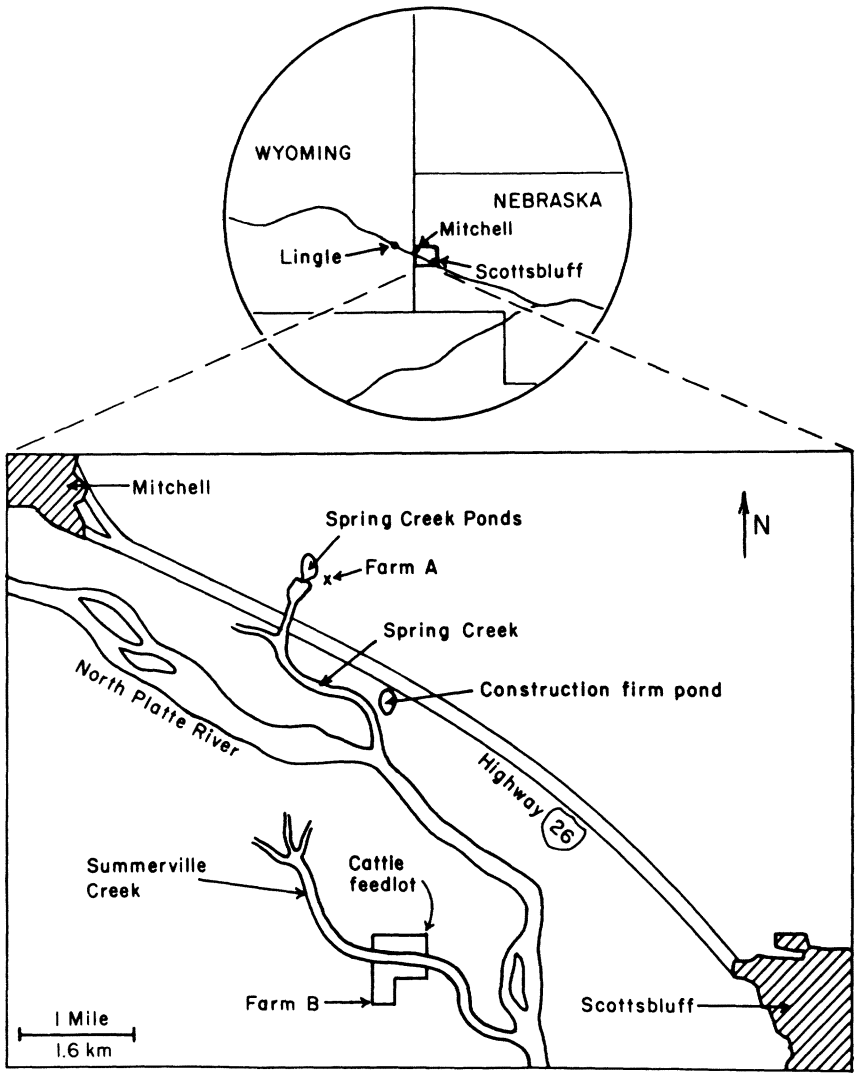

Fig. 1. Site of an avian cholera die-off affecting wild waterfowl, domestic fowl, and wild turkeys. Also shown is an area used heavily by wild waterfowl for feeding (cattle feedlot).

cholera. Three days later, 45 additional carcasses were recovered; bird use of the area remained the same. Mortality spread to Spring Creek, and in mid-December dead mallards were found on Summerville Creek adjacent to and on a cattle feedlot. Decomposition of the carcasses indicated that mortality had been occurring on Summerville Creek for some undetermined period of time. During the 2 months of the die-off, over 1200 wild mallard carcasses from the Scottsbluff area were incinerated; 820 of these were found at the Spring Creek ponds (Fig. 1). A total of 93 were necropsied and 17 of 18 livers cultured were positive for *Pasteurella multocida*; the one negative for *P. multocida* was a gunshot victim.

Other wild birds in the area that died from avian cholera were present in lower numbers; these included northern pintail (*Anas acuta*), American wigeon (*A. americana*), and a black-billed magpie (*Pica pica*). Species died in similar proportions relative to numbers present. An immature bald eagle (*Haliaeetus leucocephalus*) was found moribund, exhibiting signs of respiratory distress, and was taken into captivity, where it was treated with gentamicin but died 2 days later from avian cholera. This was one of 19 bald

eagles observed in the vicinity of the die-off. A single Canada goose (*Branta canadensis*) was found dead from avian cholera on the nearby construction-firm pond on 27 January.

The first reported avian cholera victim in the flock of 45 domestic fowl on Farm A was a domestic goose found dead on 6 December. A second goose succumbed on 28 January. On 7 February, 2 weeks after the last wild mallards died on Spring Creek ponds, three domestic ducks, another goose, and three domestic chickens were found dead on the farm. Avian cholera was confirmed in all these domestic fowl.

By the first week in January, the total number of mallards using the Scottsbluff area had declined to less than 10,000. During this same period, Wyoming Game and Fish Department personnel noted a dramatic increase in the mallard population on the North Platte River near Lingle, Wyoming (Fig. 1). On 7 January, investigations by Wyoming Game and Fish Department personnel revealed 25 dead mallards on the river, and 48 wild turkeys (*Meleagris gallopavo*) were found dead from avian cholera on an island on the river. A total of 168 turkeys were present in this flock before mortality began. Avian cholera was noted in mallards, Canada geese, and a gyrfalcon (*Falco rusticolus*) on a Wyoming Game and Fish management area 15 km from Lingle (22).

Total mortality for both areas from 28 November 1985 to 14 January 1986 is estimated at 2500 wild birds. Wild mallards comprised the majority of these losses.

Necropsy results. We necropsied 93 mallards from the Scottsbluff area and 4 from Lingle, Wyoming. Gross lesions most frequently observed were petechial and ecchymotic epicardial hemorrhages, serosal hemorrhage along the small intestine, and swollen and friable livers with multifocal necrosis. Lesions in two pintails were similar to those observed in the mallards. Domestic fowl had lesions typical of avian cholera, petechial and ecchymotic hemorrhages on the epicardium but few or no necrotic foci in the liver.

Avian cholera was identified as the cause of death for wild turkeys submitted to Wyoming's Veterinary Diagnostic Laboratory (22). Similarly, 14 turkeys we examined were also diagnosed as dying from avian cholera; lesions included petechial epicardial hemorrhages on the coronary band, multifocal liver necrosis, distended small intestines containing thick mucoid material, and occasional petechial hemorrhages in the subcutaneous fat.

Swabs. No *P. multocida* isolates were recovered from cloacal or pharyngeal swabs taken from 20 of the 45 domestic ducks and geese on Farm A on 4 January. However, one or more serotypes of *P. multocida* were isolated from nasal swabs of 35 of 37 apparently healthy cattle after the cattle had been shipped from the feedlot on Summerville Creek to slaughter.

Bacteriology. Serotype 1 was the most common serotype (56% of isolates) recovered from tissues of wild mallards that died from avian cholera. In several isolates, serotype 1 was cross-reactive with other serotypes: it was cross-reactive with serotype 15 in 33% of isolates, serotypes 13 and 15 in 5.5% of isolates, and serotypes 15 and 16 in 5.5% of isolates. Serotype 1 was isolated from a domestic duck, a chicken, and the bald eagle. Isolates from livers of six wild turkeys were serotype 1 (33%), serotype 1 cross-reactive with serotype 15 (33%), and serotype 1 cross-reactive with serotypes 13 and 15 (33%).

Pasteurella multocida isolates (n = 113) from 37 cattle were predominantly serotype 3 (30.1%) or serotype 3 with cross-reactivity to serotypes 4, 7, 12, 13, 15, and 16 (50.4%). Serotype 13 and serotype 13 with cross-reactivity were found in 7.1% and 9.7%, respectively. A weak serotype 1 cross-reactive with serotypes 3 and 13 was found in one sample, as were two isolates of serotype 15 cross-reactive with serotype 16.

Colonies of *P. multocida* from wild mallard and turkey tissues grown on BAP were medium gray, smooth, glistening, and butyrous. A greenish discoloration of the blood agar was produced. Isolates from the bovine nasal swabs tended to be more watery and mucoid, giving the appearance of spilled milk. Colony size varied from small, round, gray entire colonies to large, milky, cream-colored colonies. None of the isolates grew on EMB. All isolates had an odor characteristic of *P. multocida.*

Mallard inoculations. The 14 game-farm mallards inoculated with *P. multocida* from tissues of wild birds died within 48 hours (Table 1). Birds were checked for the first time at 19 hours postinoculation. The *P. multocida* serotype 1 cross-reactive with 13 and 15 from a turkey took the longest (41 hours) to cause death in inoculated mallards. Necropsy revealed petechial and ecchymotic hemorrhages on the epicardium of

Table 1. Mortality of mallards inoculated subcutaneously with 10^6 *Pasteurella multocida* isolated from birds that died of avian cholera and from cattle at site of avian mortality.

Isolate origin	Heddleston serotype	Number of mallards inoculated	Average time to death[A] (hours)	Range of time to death (hours)
Wild mallard	1 × 13 × 15	3	21	19–26
Wild mallard	1 × 15 × 16	3	24	19–26
Wild turkey	1 × 13 × 15	3	34	19–41
Wild turkey	1 × 15	2	19	19
Bald eagle	1	3	19	19
Domestic steer	13	3	No mortality	
Domestic steer	13	3	No mortality	
Domestic steer	3 × 13	3	No mortality	
Domestic steer	3 × 13	3	No mortality	
Domestic steer	3 × 13 × 15	3	No mortality	
Domestic steer	1 × 13	3	No mortality	
Domestic steer	13 × 15	3	No mortality	

[A]Checked for first time at 19 hours postinoculation.

all birds. Hemorrhages were also noted on the syrinx of five birds, pleura of eight, peritoneum of eleven, and abdominal organs of five. The spleen was mottled or congested in 11 birds. Six of the 14 birds had multifocal liver necrosis.

No mortality occurred in the 21 mallards inoculated with *P. multocida* isolates from cattle nares. No lesions were observed on necropsy following euthanasia of these mallards at 21 days postinoculation; *P. multocida* was not isolated from the livers.

Water analysis. Results of analysis of two water samples taken on Spring Creek ponds are given in Table 2. Also shown for comparison are water-chemistry data for 1983 of two wetlands in the Rainwater Basin of Nebraska—one where explosive avian cholera die-offs have occurred in wild waterfowl, and a second where little avian cholera mortality occurs (23).

Climatological data. Fig. 2 shows daily minimum temperatures and snow cover on the ground from 6 November 1985 to 30 January 1986. Temperatures for November were the coldest on record, with averages 10.2 C below normal. Relationships between mortality and weather are unclear, but it appears that there were two "major" peaks in mortality in early and mid-December that followed several days of extreme cold temperatures (below −23 C).

DISCUSSION

The source of *P. multocida* that initiated this avian cholera outbreak is unknown. Possible sources include carrier birds, either wild or do-

Table 2. Comparison of water analysis of Spring Creek ponds with avian cholera mortality and 1983 data for two wetlands in the Rainwater Basin area of Nebraska.[A]

Site	Calcium (mg/liter)	Magnesium (mg/liter)	Chloride (mg/liter)	Sulfate (mg/liter)	Sodium (mg/liter)
Spring Creek					
Sample 1	95.8	26.9	11.4	155.8	61.2
Sample 2	100.6	28.3	12.4	205.4	59.7
Rainwater Basin[B]	424.2	87.7	56.0	437.0	107.5
Rainwater Basin[C]	47.3	38.6	17.0	25.0	9.6

[A]From Windingstad *et al.* (23).

[B]This wetland near Funk, Nebraska, has been considered one of the "Hot Spots" for avian cholera outbreaks in wild waterfowl since 1975. Values given are mean values found during Spring 1983.

[C]In this wetland near Clay Center, Nebraska, there is little to no mortality of waterfowl from avian cholera. Values given are mean values found during Spring 1983.

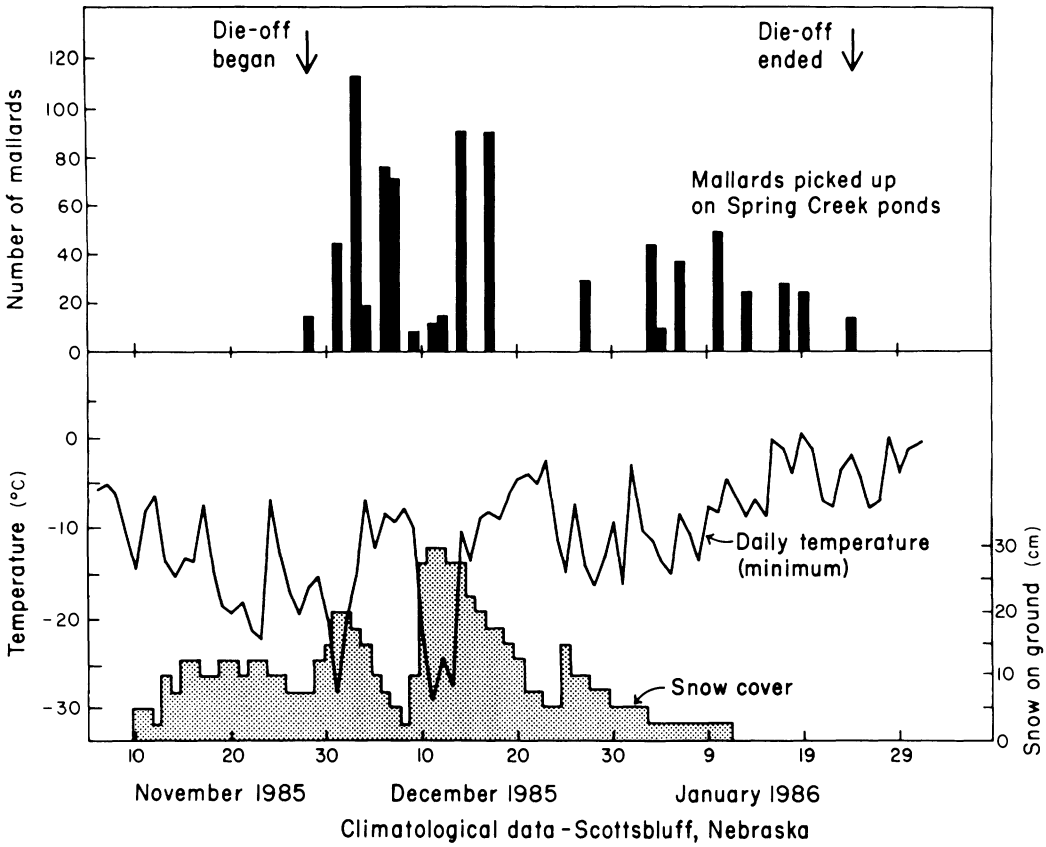

Fig. 2. Climatological data and mallard mortality from avian cholera at Spring Creek ponds near Scottsbluff, Nebraska, during winter 1985–86.

mestic, or mammalian reservoirs (3,14). In November, wild mallards used a construction-firm pond in which two geese died of avian cholera the previous May. The resident birds had been fed grain mixed with antibiotics and may have been carriers of the organisms but were not clinically ill. Mallards had also been feeding heavily on cracked corn in cattle feces at the feedlot. Although *P. multocida* isolated from cattle and artificially inoculated into waterfowl has not been virulent for avian species, mammals could act as reservoirs of the bacterium from a previous avian cholera outbreak. Heddleston and Watko (6) showed that *P. multocida* from avian cholera victims could survive at least 34 days in cattle nasal passages and when removed still be virulent for fowl.

Little is known regarding *in vivo* changes in virulence of *P. multocida* that might occur when the organism is transmitted naturally between hosts, or between the environment and susceptible hosts. Such changes might result from extrachromosomal DNA or plasmid transfer or transduction in the bacteria. The means by which plasmids determine pathogenic characteristics of host bacteria have stirred much interest in recent years (1,4,5,12,13,18,19), especially with respect to gram-negative bacteria. Hirsh *et al.* (8) showed that conjugal transfer of R-plasmids in *P. multocida* does occur. Perhaps conjugal transfer may result in changes in virulence of *P. multocida* for different hosts.

We believe that once avian cholera began, it was perpetuated by wild mallards. This population then carried the disease westward into Wyoming. Daily losses to avian cholera during this outbreak were low compared with explosive mortality observed in many other outbreaks. We believe that low concentrations of calcium and magnesium in water and rapid circulation and flow of water contributed to this low rate of mortality. *P. multocida* shed into the water by af-

fected birds or carcasses probably did not survive long owing to dilution below lethal infection levels or to the low concentrations of calcium and magnesium, ions which have been shown to enhance survival of *P. multocida* (J. Price, unpubl. data).

Mallards have adapted well to changes in modern agricultural practices, thereby allowing many to winter farther north than traditional wintering areas (10). Feeding on corn stubble that has been grazed by cattle and in feedlots, especially during periods of heavy snow cover, allows these birds to meet their energy requirements (10). However, this adaptation can lead to crowding and can confine mallards to restricted sites.

Our data suggest that periods of cold weather may have exacerbated mortality, so if birds winter farther north owing to changes in agricultural practices, diseases such as avian cholera may occur with increasing frequency. This may be a function of additional stress induced by cold, increased transmission due to crowding, or changes in feeding patterns related to snow cover. Further research into understanding the organism and relationships between avian cholera and agriculture, water quality, and bird density are needed.

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