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Wetland Characteristics of Avian Cholera Outbreaks and Surface Water Transfer in the Nebraska Rainwater Basin Area

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WETLAND CHARACTERISTICS OF AVIAN CHOLERA OUTBREAKS AND SURFACE WATER TRANSFER IN THE NEBRASKA RAINWATER BASIN AREA

BY

BRIAN J. SMITH

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

BRIAN J. SMITH

Avian cholera (Pasteurella multocida) has infected and killed thousands of migrating waterfowl each year since 1975 in Nebraska's rainwater basin area. Disease outbreaks in migrating waterfowl populations just prior to the nesting season are of concern to biologists. Feedlots and inter-wetland basin surface water transfer mechanisms of the avian cholera causative agent, P. multocida, were investigated using remote sensing techniques. Wetland basin characteristics (classification type, adjacent landuse, basin landuse, and basin densities) were also investigated for relationships to 1981 avian cholera outbreaks. No surface drainage relationships were found that would permit the transfer of P. multocida from one wetland basin to another. Feedlots were not found to be associated with avian cholera outbreaks. My findings suggest that wetland basin density, basin landuse, water regimes, and adjacent landuse are related to and may have an influence on avian cholera outbreaks in the Nebraska rainwater basin area. Management recommendations include evaluation of hazing techniques, managing wetlands for open areas of surface water, and the development of a plan for wetlands restoration to increase basin density.

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INTRODUCTION

The rainwater basin area in south-central Nebraska has served historically as a spring staging area for waterfowl. Annually, an estimated 5 to 9 million ducks and several hundred thousand geese use these wetlands on their way north to breeding grounds (Windingstad et al. 1984). In 1975, an estimated 25,000 waterfowl and 3,000 crows (Corvus brachyrynchos) were infected with acute avian cholera in the rainwater basin area (Zinkl et al. 1977). Each spring since 1975, avian cholera has infected and killed varying numbers of ducks and geese that migrate through the area. The largest outbreak, an estimated die-off of between 72,000 and 80,000 ducks and geese, was in 1980. Although such large cholera-related losses of waterfowl do not occur every year, any disease outbreaks that do occur are particularly important because of the related stress to large segments of these populations just prior to the nesting season. The avian cholera causative agent, Pasteurella multocida, also poses a potential hazard to federally-listed threatened and endangered species such as piping plover (Charadrius melodus) and whooping crane (Grus americana), which also use the rainwater basin wetlands and surrounding areas (Windingstad et al. 1984).

Although numerous biological studies pertaining to avian cholera have been published, most represent accounts of the disease, possible causative factors, and suggested methods for controlling the disease; few relate to the effects of the environment to disease outbreaks. However, Friend (1981) has suggested that the micro-environment of the wetland basin may be one of the critical factors involved in the retention of the disease. The rainwater basin area wetlands offer a unique opportunity to geographically study the environmental and bacterial factors that may be associated with avian cholera outbreaks and mortality.

Little or no geographic research has been conducted in the rainwater basin area on the potential source or transfer of bacteria among wetland basins via surface water travel ways. Brown et al. (1983) and Windingstad et al. (1984) mention feedlots as possible sources of P. multocida. In playa wetlands in Texas, Eric Bolen of the Dept. of Range and Wildlife Managment at Texas Tech. Univ. suspected that organic matter accumulates in water near feedlots causing the water to stay warmer than usual. When wetlands in the surrounding area "freeze up" these wetlands near feedlots often remain free of ice. Waterfowl often concentrate on these few open areas. If one bird contracts the bacteria, due to a large number of concentrated birds in a relatively small area, all of the birds will be exposed (pers. comm.). Vaught et al. (1967) found that healthy waterfowl may act as carriers and spread the disease. They also suspected that the bacterium passed from wetland to wetland via artificial pumps. Backstrand and Botzler (1986) stated that while water may be capable medium of transmitting the bacterium between susceptible wildfowl, there is little evidence that soil or water act as year round reservoirs of P. multocida.

Brown et al. (1983) evaluated remote sensing tools as an efficient method to evaluate environmental conditions favorable to the survival of the avian cholera bacterium, P. multocida. Based on a sample of only two wetland basins, they also suggested that vegetation in wetlands with histories of avian cholera were of single species dominance and low species diversity. They also reported a possible "grass edge" width relationship to some wetland basins without a history of avian cholera suggesting that the grass edge might provide a buffer effect to either the transfer of the contaminants or the bacterium among wetland basins via surface drainages. Landuse of the wetlands may play an important role in the presence of P. multocida (Brown et al. 1983). Pastured or idle wetlands may provide a grass edge whereas cropped wetlands may not. Wetland basin landuse information (e.g.; cropped, hayed, pastured, idled) as well as adjacent landuse of the wetland has not been investigated in other studies concerning avian cholera.

Questions researched in this biogeographic study include:

1) Is there a difference in wetland types concerning avian cholera outbreaks?
2) Is there a relationship between feedlots and avian cholera outbreaks?
3) Is there an outbreak relationship among wetland basins with connecting surface drainage systems?
4) Is there a relationship between adjacent landuse of wetland basins and avian cholera outbreaks?

5) Is there a relationship between landuse of wetland basins and avian cholera outbreaks?

6) Is there a difference in spatial wetland density in the areas of high incidence of avian cholera outbreaks vs. areas of low incidence of avian cholera outbreaks?

STUDY AREA

The rainwater basin area is located in south-central Nebraska (Figure 1). The basic parent material typifying the area is loess plains deposited during the Wisconsin stage of the Pleistocene (Evans and Wolfe 1967). The basic formations characteristic of the area are thought to have been caused by irregular loess deposits, as controlled by topography and modified wind (Evans and Wolfe 1967; Starks 1984). The most common soil type associated with the wetland basins is Scott silt loam, a soil type composed of a high percentage of clay and thus poorly permeable by water. This type of soil in combination with wetland basins with closed drainages results in accumulations of surface water, usually of temporary nature (Evans and Wolfe 1967).

At the turn of the century, approximately 4,000 wetland basins existed and occupied over 38,000 ha of the rainwater basin area (Farrar 1982). Currently, less than 10 percent of the original wetlands remain. The decrease in wetland basins is due primarily to agricultural practices (Farrar 1982). Agricultural drainage has accounted for 70 percent of this loss (Nebraska Game and Parks Comm. 1972). The rainwater basin area occupies approximately 10,878 square km of land area. In 1962, the U.S. Fish and Wildlife Service (USFWS) began purchasing Waterfowl Production Areas (WPA's) in the area to help conserve the wetland and waterfowl resource. To date, about 6,275 ha of uplands and wetlands have been purchased by USFWS

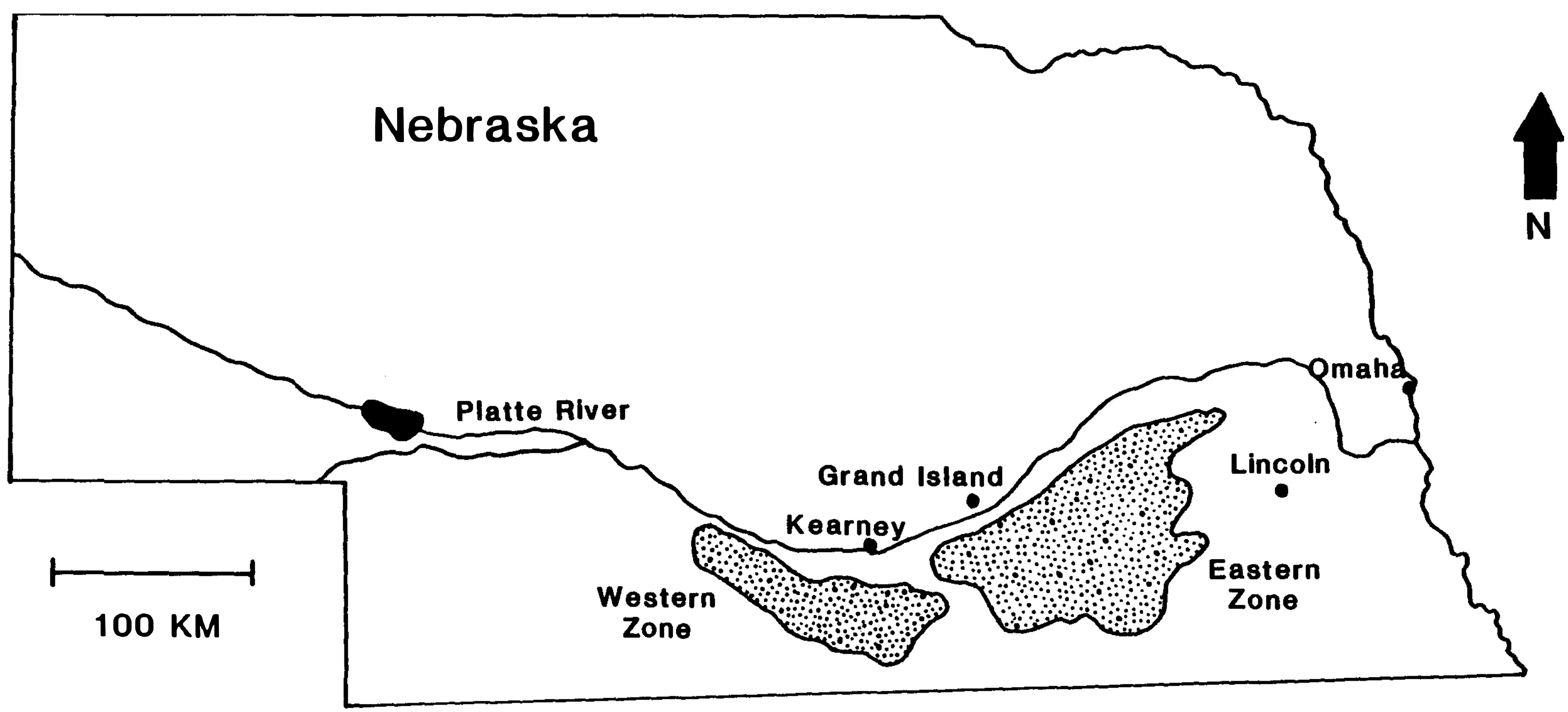

Figure 1. Location of the Nebraska Rainwater Basin Area

and about 809 ha by the state of Nebraska. In drier years water in most of the WPA wetlands is supplemented by pumping directly from the Ogallala aquifer.

The uplands surrounding most wetland basins experience intensive agricultural practices and deep well irrigation. Spring water levels of the basins depend largely on direct precipitation and runoff from snowmelt. Annual precipitation ranges from 75 cm in Fillmore County in the east to 62 cm in Phelps County in the west. Irrigation runoff from row crops, primarily corn, contribute appreciably to some basins. Water loss is due primarily to evaporation and transpiration and averages more than 125 cm annually. Most wetland basins were dry during the growing season of the severe drought years of 1963, 1965, and 1967. In wetter years, annual and perennial smartweeds (Polygonum spp.) grow profusely in many of the basins (Nebraska Game and Parks Comm., 1972).

Although the wetland basins occur as a continuum, the rainwater basins area is administratively divided into an eastern and a western region. According to Alan Trout, USFWS Wetlands Management District Manager, Kearney, NE, the main differences between eastern and western basin areas are: 1) the topography is more rolling in the east than in the west resulting in deeper wetland basins, 2) rainfall is greater in the east allowing for more permanent wetlands due to more runoff, and 3) gross visual observations of water clarity indicate that the eastern basins are less turbid (pers. comm.). The most severe outbreaks of avian cholera have been reported in the western region (Windingstad et al. 1984).

METHODS

Two-hundred and thirty-eight wetland basins were selected for study using remote sensing techniques. Existing high altitude color-infrared aerial photography at a scale of 1:58,000 was supplied by the USFWS. The photography was taken between 24 May 1981 through 27 September 1981. These photos were used in conjunction with National Wetland Inventory (NWI) maps (which include elevations and contours) and with ground truth visitations in March 1988 to confirm data accuracy. Three wetlands were excluded from the sample: 1) the Platte river was not included in the sample because it is a flowing system, 2) the Harlan County Reservoir was not included in the sample because of its tremendous size (5,913.5 ha) and also it is discussed seperately from the basin wetlands in the Wildlife Disease and Mortality Report (Nebr. Game and Parks Comm., 1984), and 3) a Seward county wetland was not included because of the lack of available aerial photography for that area.

Dead bird pickup data for 1981 (to correspond with the date of aerial photographs) was supplied by the USFWS Wetlands Management District office in Kearney, NE. These data included numbers of dead birds picked up, dates and location of the pickups, and estimated number of dead birds for that particular wetland. According to Dr. Ronald Windingstad, Wildlife Disease Specialist for the National Wildlife Health Research Center, Madison, Wisconsin, 1981 was a dry year for the western region of rainwater basin area and received less bird use than the eastern region (pers. comm.). Because of this, bird die-offs were probably higher in the east.

The dates of the pickup operation were used as an index of when an outbreak occurred relative to other outbreaks of avian cholera. A wetland basin was considered to have had a severe outbreak if more than 100 dead birds were recorded per season and a mild outbreak if there was less than 100 birds.

Classification (Cowardin et al. 1979) of the 238 wetlands were ascertained from NWI maps and categorized by water regime. Wetlands classified as having a permanent water regime are defined to contain water at all times. Wetlands classified as having a semipermanent water regime are defined to contain water throughout the growing season during most years. Wetlands classified as having a seasonal water regime are defined to contain water through the middle of the growing season but are usually dry by the end of summer. Wetlands classified as having a temporary water regime are defined to contain water only at the start of the growing season. Wetlands of semipermanent and permanent classification were compared to seasonal wetlands for the occurrence of avian cholera outbreaks. This was done with 1980 (year of most severe recorded outbreak) die-off data and with 1981 (year wetlands were classified) die-off data. An applied categorical data analysis procedure (CDA) as described by Freeman (1987) and SAS Institute Inc. (1985), at the $P \leq 0.05$ level of significance, was used on the hypothesis that there was no difference in water regime of wetland basins experiencing avian cholera outbreaks.

Aerial photos were examined to identify the number of feedlots located within 1,610 meters of all 238 wetlands. The distance between feedlot(s) and wetland basin boundary was measured to the nearest meter (m) and direct surface drainage between a feedlot and a wetland basin was determined to the best of my ability. CDA procedures at the $P \leq 0.05$ level were used to test the hypothesis that no difference in avian cholera outbreaks occured in wetlands less than 100 m from feedlots and wetlands more than 100 m from feedlots whether or not a visible surface drainage into a wetland was present. Feedlots within one-hundred meters was considered to be close enough to a wetland to possibly contaminate the water by means other than surface drainage. This was done for all wetlands regardless of water regime and then again for wetlands of semipermanent water regime or of greater permanence as described by Cowardin et al. (1979).

Aerial photography (described above) was used in conjunction with NWI maps in order to identify a means of transfer of P. multocida via surface drainageways among wetlands. Wetlands experiencing avian cholera outbreaks were identified on the maps. An effort was made to identify whether a surface drainage, gully or depression led from wetland basins with outbreaks into other non-outbreak wetland basins.

Using aerial photography, adjacent landuse of 238 wetland basins was classified as being cropped, pastured, hayed, or idled.

Landuse around each wetland basin was categorized to a type of landuse if 70% or more of the land adjacent to the basin perimeter was in that landuse. Statistical comparisons of adjacent landuse effects was determined by CDA procedures at both the $P \leq 0.05$ and $P \leq 0.01$ level, on the hypothesis that no difference in avian cholera outbreaks exist in wetland basins adjacent to fields that are cropped, pastured, hayed, or idled.

Landuse of the wetland basin proper for 238 wetlands was also ascertained from aerial photography. Landuse of each wetland basin was classified as being cropped, pastured, hayed, or idled. Wetland basins were categorized to a certain landuse if 70% or more of the basin was in that type of landuse. CDA procedures at the $P \leq 0.05$ level were used to test the hypothesis that no difference in avian cholera outbreaks exist in wetlands that are cropped, pastured, hayed, or idled.

Wetland basin densities were calculated around 15 semipermanent wetland basins that have commonly experienced avian cholera outbreaks. These were compared to 20 semipermanent wetland basins that have not commonly had outbreaks of avian cholera by using a CDM procedure at the $P \leq 0.05$ level. Wetland basin densities were calculated by counting the number of semipermanent wetland basins within 3.22 km of the perimeter of each comparison wetland basin.

RESULTS AND DISCUSSION

In 1981, between 5,845 and 10,000 waterfowl died as a result of avian cholera in the Nebraska rainwater basin area(Nebraska Game and Parks Comm., 1985). Avian cholera outbreaks were recorded at 12 different Nebraska wetlands in 1981 (Table 1). Three wetlands were not selected for reasons stated in the Methods section of this paper.

Water Regime

According to the NWI maps, all nine (100%) of the wetland basins experiencing recorded avian cholera outbreaks in 1981 were of semipermanent or permanent water regime as described by Cowardin et al. (1979). Only eighty (35%) of the 229 wetland basins without recorded outbreaks in 1981 were of semipermanent and permanent regimes (Table 2). However, this difference was not significant ($P = 0.26$).

In 1980, the year with the worst mortality ever recorded in the rainwater basin area, only 10 (22.2%) of 45 wetland basins with recorded outbreaks were of seasonal nature. The remaining (77.8%) basins were semipermanent or permanent (Table 2). The difference in the number of outbreaks in seasonal and semipermanent wetland basins in 1980 is significant ($P < 0.01$).

A high percentage (64%) of the existing 12,454 ha of wetlands in the rainwater basin are of seasonal or temporary nature

Table 1. Summary of 1981 avian cholera mortality on sampled wetland basins.

Wetland Name	Water Regime	Recorded Pickup	Estimated Mortality
Kennesaw	Semipermanent	92	115
Elwood Reservoir	Permanent	10	100
Sac-Wilcox	Semipermanent	2	2
Harvard	Semipermanent	1312	2625
McMurtrey	Semipermanent	132	264
Smith	Semipermanent	32	100
Massie	Semipermanent	178	258
Mallard Haven	Semipermanent	2	2
Eckhardt	Semipermanent	1	1

Table 2. Breakdown of the water regimes of basins with and without avian cholera outbreaks.

Year	Semipermanent or permanent with outbreak	Semipermanent or permanent without outbreak	Seasonal with outbreak	Seasonal without outbreak
1981	9	80	0	149
1980	35	54	10	139

(Nebraska Game and Parks Comm., 1972). These are of lesser water permanence and greater vegetative species diversity than are wetlands of higher water regimes. This is consistant with Brown et al. (1983) although they did not discuss water regime.

Waterfowl will congregate on seasonal wetlands during migration if surface water is present. However, dense residual vegetation may impede extensive use by waterfowl even though water is present. Apparently, surface water must be available and visible from the air if birds are to use wetlands to any extent. During dry years water may only be present in the semipermanent or permanent wetlands.

Feedlot Associations

No associations were found to exist between feedlot runoff and avian cholera outbreaks. The first outbreak recorded in 1981 occurred on 22 February at Harvard Marsh, followed by Smith and Massie (Table 3). No feedlots were found to be associated with Harvard Marsh, Massie, or Kennesaw basin. Elwood reservoir has three feedlot associations, the closest being 59 m distant, and it appears to have runoff flow into the wetland. Eckhardt and Smith have feedlot associations but no visible direct drainage flow is evident into these wetland basins. Eckhardt had only one mortality, while Smith had a relatively mild loss of 32 birds in 1981.

Three wetlands in my sample, Harvard, McMurtrey, and Massie, had severe waterfowl die-offs (>100 dead birds). Two of these

Table 3. Summary of avian cholera outbreaks on nine Nebraska rainwater basin area wetlands.

Wetland Name	1st Date of Pickup	Order of Outbreak	# of Feedlots	Direct Drainage Visible	> 100 Birds in Pickup
Kennesaw	na	na	0	-	
Elwood Reservoir	na	na	3	yes	
Sac-Wilcox	na	na	1	no	
Harvard	2/22	1	0	-	yes
McMurtrey	3/6	4	1	yes	yes
Smith	2/23	2	1	no	
Mallard Haven	3/10	5	6	yes	
Eckhardt	3/13	6	1	no	
Massie	2/26	3	0	-	yes

wetlands, Harvard and Massie, have no feedlot associations but were ranked 1st and 3rd respectively in the temporal order of dead bird pickup in 1981. McMurtrey has one feedlot directly adjacent and uphill, however this wetland basin is ranked 4th from the first date of dead bird pickup. Also, in a memorandum dated 6 May 1981 from A. Trout USFWS, Kearney, NE, the die-offs on McMurtrey accelerated from 1 bird/day to 22 birds/day within 48 hours after the waterfowl were dispersed off of Harvard (approx. 3.5 km distant). This suggests that the disease, at least in this case, may have been transmitted by the birds themselves and not via a surface drainage system. In addition, two wetland basins, Theeson and Kissinger, are adjacent to two different and very large feedlots. Yet avian cholera has never been recorded on either of these basins. On the basis of these data and observations, I submit that no relationship exists between surface drainage from feedlots to wetland basins experiencing avian cholera outbreaks.

Three (33.33%) of nine wetland basins experiencing avian cholera die-offs in 1981 had no feedlots within 1,610 m of their borders (Table 4). One basin had a feedlot directly adjacent and another basin had a feedlot within 100 m of its border. For the 229 wetland basins with no recorded avian cholera outbreak in 1981, 12 basins had feedlots directly adjacent and 13 more basins had feedlots within 100 m of their borders. Sixty-five wetland basins (28.4%) had no feedlots within 1610 m of their borders. There were no significant differences ($P = 0.28$) in avian cholera outbreaks in wetland basins with feedlots closer than 100 m and further than 100 m. The prevelence of avian cholera does not seem to be a function of feedlot distance from wetlands.

Of the 238 sample wetland basins, 89 were of at least of the semipermanent or permanent water regime (Table 4). Twenty-seven of these had no feedlot associations within 1,610 m, two with recorded avian cholera outbreaks were less than 100 m from feedlots, and ten of the wetland basins without recorded outbreaks were less than 100 m from feedlots. There was no significant difference ($P = 0.39$) between semipermanent or permanent wetland basins with feedlot associations of less than 100 m and more than 100 m.

Wetland to Wetland Surface Drainage

No suface drainages were visible on the aerial photography or the NWI maps between wetland basins experiencing avian cholera outbreaks and wetland basins not experiencing outbreaks in 1981. There does not seem to be a surface drainage transfer mechanism for P. multocida in the Nebraska rainwater basin area. Some western basins, particularly Johnson Marsh and Funk Lagoon, are influenced by the Tri-County Canal which affects water quality due to seepage and infiltration (Spalding 1981). However, these two wetlands were not sampled for surface drainage relationships as they were not reported to have outbreaks in 1981.

Backstrand and Botzler (1986) reported a poor survival rate of P. multocida and that concentrations of it decline rapidly in

Table 4. Feedlot associations for 238 rainwater basin wetlands.

	No Feedlots	Adjacent (0m)	<100m	<1610m
Basins with no recorded outbreak in 1981	65 28.4%	12 5.2%	13 5.7%	139 60.7%
Basins with recorded outbreaks in 1981	3 33.3%	1 11.1%	1 11.1%	4 44.4%
- - - - - - - - - -				
Semipermanent basins with no recorded outbreaks in 1981	24 27.0%	5 5.6%	5 5.6%	46 51.7%
Semipermanent basins with recorded outbreaks in 1981	3 3.4%	1 1.1%	1 1.1%	4 4.5%

soil and water. Even if there were a mode of transfer via surface waterways among wetlands, the water movement may be too slow to allow the survival of *P. multocida*.

Adjacent Landuse

Adjacent landuse of nine sample wetland basins experiencing avian cholera outbreaks was compared to the adjacent landuse of 229 wetland basins not experiencing outbreaks of avian cholera (Table 5). Of the nine wetland basins experiencing outbreaks, two (22.2%) had cropped fields adjacent, three (33.3%) had pastures adjacent, and 4 (44.4%) had idle ground adjacent. None of the wetlands were bordered by hay fields. Of the 229 wetland basins not experiencing an outbreak, 110 (48.0%) had cropped fields adjacent, 52 (22.7%) had pastures adjacent, 6 (2.6%) had hay fields adjacent, and 12 (5.2%) had idle ground adjacent.

There were no significant differences in adjacent landuse of wetland basins with and without avian cholera outbreaks in idle or hayed situations. Uplands adjacent to wetland basins without avian cholera outbreaks were cropped at a significantly higher rate than basins with outbreaks ($P < 0.01$). Also, uplands adjacent to wetland basins without avian cholera outbreaks were pastured at a significantly lower rate than were basins with outbreaks ($P < 0.01$). This is inconsistent with what Brown et al. (1983) reported; however, they were apparently considering seasonally flooded zones around the open water portion of the wetland basin. In addition, on

Table 5. Adjacent landuse to 238 wetland basins in 1981.

	Cropped	Pastured	Hayed	Idle
Basins without outbreak	110 48.0%	52 22.7%	6 2.6%	12 5.2%
Basins with outbreaks	2 22.2%	3 33.3%	0 0%	4 44.4%

many WPA's and state-owned lands, adjacent uplands are planted to grasses to provide nesting cover for waterfowl and upland birds. Because the adjacent uplands are cropped more often on basins without outbreaks, these grassy areas do not seem to provide a buffer to stop P. multocida from being transferred over the land surface.

Landuse of Wetland Basins

Basin landuse for 8 of 9 (88.9%) sampled wetlands with avian cholera outbreaks in 1981 was idle (Table 6). The 9th wetland basin was mostly idle (58.0% of the basin area) but did not fit the defined criteria of 70% being in a certain type of landuse. These eight basins were compared (Table 6) to 88 (38.4%) wetland basins which were idle and did not have recorded outbreaks of avian cholera. The comparison of basin landuse could not be tested statistically because none of the wetland basins with avian cholera outbreaks were cropped, pastured, or hayed.

The eight basins experiencing avian cholera outbreaks were left idle because of the presence of surface water. Apparently, this is directly related to the water regime of the wetland basins.

Wetland Basin Densities

Densities of semipermanent wetland basins around 15 individual semipermanent wetland basins which commonly experience avian cholera were compared to 20 individual semipermanent wetland

Table 6. Landuse of wetland basins in 1981.

	Cropped	Pastured	Hayed	Idle
Without recorded outbreaks in 1981	33 14.4%	46 20.1%	5 2.2%	88 38.4%
With recorded outbreak in 1981	0 0%	0 0%	0 0%	8 88.8%

basins with no recorded histories of avian cholera outbreaks (Table 7). Each wetland basin experiencing an outbreak was found to have fewer semipermanent wetlands (1.93) within a 3.2 km radius than did semipermanent wetland basins not experiencing outbreaks of avian cholera (3.45). This difference is significant ($P < 0.01$). Apparently the waterfowl in areas of high wetland densities tend to disperse over the greater number of wetland basins resulting in a lower numerical concentration of birds per wetland. If a large number of birds are using a particular area, and only one wetland is present in that area to use, then the waterfowl will become very concentrated on that particular wetland. As Friend (1981) suggested, this may result in more stress, poorer water quality, and higher disease susceptibility.

Table 7. Comparison of 15 semipermanent wetland basins with a high incidence of avian cholera outbreaks versus 20 semipermanent wetland basins with zero or low incidence of avian cholera outbreaks.

Wetland Name	Number of semipermanent wetlands within a 3.2 km radius	Wetland Number	Number of semipermanent wetlands within a 3.2 km radius
McMurtrey	1	01050	0
Harvard	1	50007	1
Smith	4	37019	3
Eckhardt	6	50006	1
Massie	5	18109	4
Mallard Haven	4	30018	8
Sac-Wilcox	0	65003	1
Kennesaw	0	18023	0
Seward - 57	1	18011	5
Pintail	1	30024	2
Prairie Dog	1	30005	11
Funk (3 basins)	0	18212	1
Cottonwood	0	18097	4
Hansen	5	18074	3
Gleason	0	18048	8
		37020	3
		65002	2
		37018	4
		18138	5
		30111	3
Total	29 Mean 1.93		69 Mean 3.45

CONCLUSIONS AND RECOMMENDATIONS

Feedlots were not found to be associated with avian cholera outbreaks in the rainwater basin area of Nebraska. No surface drainage relationship was found to exist between wetland basins and feedlots. No surface drainage relationship was found to exist for transfer of P. multocida from one wetland basin to another. These findings corroborate those of Vaught et al. (1967) and the bird dispersal information contained in the memorandum dated 6 May 1981 by A. Trout, USFWS, Kearney NE. These combined findings suggest that the birds themselves may be the primary mechanism of transfer of P. multocida.

It is possible that adjacent landuse of wetland basins influences the susceptibility of that wetland to avian cholera outbreaks. Fields around wetland basins with zero or low avian cholera incidences were cropped at a higher rate and, in turn, wetlands of less water permanence are cropped easier. When cultivating, farmers may be inhibited by the presence of water in and around semipermanent wetland basins, and therefore are unable to plow up to the wetland border. This conclusion does not correspond with Brown et al. (1983), however, their wetland sample was much smaller.

My data suggest that wetland basin density, basin landuse, and water regime have a greater influence on avian cholera outbreaks than do either feedlots or adjacent landuse. Idled wetland basins had a higher rate of avian cholera outbreaks than basins in other landuses. All nine basins sampled were at least 58% idle, probably due to the presence of surface water. This diffence (perhaps) can be related directly to water regime.

Densities of semipermanent wetland basins within a 3.2 km radius of non-outbreak semipermanent wetland basins were significantly higher than densities of semipermanent wetland basins with outbreaks. The waterfowl may be using the only available wetland basins in outbreak situations, thereby causing relativley high concentrations of birds on fewer available wetlands.

Recommendations as a result of this study are:

1) Evidence suggests that fewer outbreaks occur in areas of high wetland basin density. A plan for wetlands restoration or creation to provide a higher density of wetlands would facilitate the dispersal migrating waterfowl.

2) Manage wetlands for open areas of surface water. Haying, grazing, mowing, or herbicide use on seasonally-flooded wetland basins would provide more surface water free of residual vegetation and help disperse birds.

3) Evaluate the hazing methods used to move waterfowl off wetlands during severe avian cholera outbreaks. Moving birds from a basin with a rate of on-site mortality may actually facilitate the transmission of the disease, as is noted in the memorandum dated 6 May 1981 by A. Trout, USFWS, Kearney, NE.

4) Initiate a study to investigate the migration of waterfowl from the Texas playa wetlands. It is still possible that P. multocida is being transmitted from those wetlands by healthy ducks and geese to the rainwater basin area in Nebraska. However, avian cholera outbreaks in more northerly latitudes confound this issue. According to Dr. Gary Wobeser, Western School of Veterinary Medicine, Saskatoon, Saskatchewan, there was a severe outbreak of avian cholera on Lake Manito, Saskatchewan, Canada in July and August 1988. Approximately 4,900 carcasses, 75% of which were redhead (Athya americana) ducks were collected on this molting area (pers. comm.).

LITERATURE CITED

Backstrand, J. M., and R. G. Botzler. 1986. Survival of Pasteurella multocida in soil and water in area where avian cholera is enzootic. J. Wildl. Dis. 22:257-259.

Brown, P. C., J. P. Sherz, and R. M. Windingstad. 1983. Remote sensing and avian cholera in Nebraska wetlands. Tech. Papers Am. Congress on Surveying and Mapping-Am. Society of Photogrammetry. Pages 483-492.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U. S. Dept. of the Interior, Fish and Wildlife Service. FWS/OBS-79/31. Washington D.C. 131pp.

Evans, R. D., and C. W. Wolfe, Jr. 1967. Waterfowl production in the rainwater basin area of Nebraska. J. Wildl. Manage. 31:788-794.

Farrar, J. 1982. The rainwater basin, Nebraska's vanishing wetlands. Nebraska Game and Parks Commision, Lincoln, Nebraska. 14pp.

Freeman, D. H. 1987. Applied categorical data analysis. Dekkar Press, New York, N.Y. 318pp.

Friend, M. 1981. Waterfowl management and waterfowl disease: independent or cause and effect relationships? Trans. N. Am. Wildl. Conf. 46:94-103.

Nebraska Game and Parks Commission. 1972. Survey of habitat. Work Plan K-71. P-R Project W-15-R-28. 78pp.

Nebraska Game and Parks Commission. 1984. Wildlife diseases and mortality summary (1950-1983). Work Plan S-83. P-R Project W-15-R-40. 77pp.

Nebraska Game and Parks Commission. 1985. Wildlife disease and mortality summary. Work Plan S-85. P-R Project W-15-R-42. 9pp.

SAS Institute, Inc. 1982. SAS user's guide: statistics. Cary, N.C. 584pp.

Spalding, M. E. 1981. Areal groundwater quality in the Tri-Basin

Natural Resources District, 1978-1980. Conservation and Survey Division, Institute of Agriculture and Natural Resources, Univ. Nebraska, Lincoln. 104pp.

Starks, P. J. 1984. Analysis of the rainbasin depressions of Clay County, Nebraska. M.S. Thesis. Department of Geography/Geology, Univ. Nebraska-Omaha. 91pp.

Windingstad, R. M., J. J. Hurt, A. K. Trout, and J. Cary. 1984. Avian cholera in Nebraska's rainwater basin. Trans. N. Am. Wildl. Conf. 49:576-583.

Vaught, R. W., H. C. McDougal, and H. H. Burgess. 1967. Fowl cholera in waterfowl at Squaw Creek National Wildlife Refuge, Missouri. J. Wildl. Manage. 3:248-253.

Zinkl, J. G., N. Dey, J. M. Hyland, J. J. Hurt, and K. L. Heddleston. 1977. An epornitic of avian cholera in waterfowl and common crows in Phelps County, Nebraska, in the spring, 1975. J. Wildl. Dis. 13:194-198.