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Spatiotemporal Distribution of Waterfowl Disease Outbreaks in Kansas, USA

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ABSTRACT Causes and impacts of disease outbreaks in wild bird populations are rarely studied beyond documentation of large epizootic events. In Kansas, USA, a central disease surveillance and reporting protocol currently does not exist within the Kansas Department of Wildlife, Parks and Tourism, which has led to a lack of available knowledge of disease occurrences that could be used to predict and manage future outbreaks. We compiled historic records of documented waterbird disease outbreaks in Kansas from 1967–2014 and related the frequency of outbreaks with light geese (Ross's goose [*Anser rossii*]; Snow goose [*A. caerulescens*]) populations from 1970–2014. We found 32 reports across 16 counties that documented various outbreaks of avian cholera, avian botulism, aspergillosis, renal coccidiosis, West Nile, aflatoxicosis, and mycotoxicosis across multiple waterbird taxa. Avian cholera and avian botulism represented nearly 70% of documented disease outbreaks. Frequency of disease outbreaks increased across the time period with a positive relationship between annual Midwinter Waterfowl Survey counts of light geese and number of reported of avian cholera outbreaks in Kansas. Changes in the continental abundance and distribution of light geese has resulted in increasing residence times in Kansas during winter, potentially increasing risk and severity of avian cholera outbreaks. Disease mitigation efforts by the Kansas Department of Wildlife, Parks and Tourism (KDWPT) should strategically plan for future avian disease outbreaks.

KEY WORDS *Anser caerulescens*, *Anser rossii*, avian disease, botulism, Central Flyway, cholera, Kansas, Ross's goose, snow goose, wetlands.

An array of diseases potentially affect migratory bird populations including avian cholera, avian botulism, duck plague, aspergillosis, West Nile, Newcastle disease, and avian influenza (Arnall and Keymer 1975, Wobeser 1997, Friend et al. 2001). Some diseases can significantly affect localized waterfowl populations and, in some instances, cause die-offs equating to tens of thousands of individuals (Wobeser 2012).

Avian cholera and avian botulism are diseases that frequently affect migratory waterbirds and have the potential for large outbreaks (Blanchong et al. 2006*a*, Samuel et al. 2007, Wobeser 2012). Avian cholera is an acute bacterial disease caused by *Pasteurella multocida* that can cause mortality in <48 hrs (Samuel et al. 2007, Wobeser 2012). Waterfowl most frequently affected by avian cholera are snow goose (*Anser caerulescens*) and northern pintail (*Anas acuta*; Blanchong et al. 2006*a*, Samuel et al. 2007). In the Central Flyway, avian cholera outbreaks have typically occurred in the Rainwater Basin of Nebraska, USA and in Texas, USA (Smith and Higgins 1990, Blanchong et al. 2006*a*, Samuel et al. 2007). Avian botulism is a paralytic disease caused by ingestion of food (usually invertebrates) containing either Type C or Type E biotoxins of the seven distinct biotoxins (Types A–G) produced by the anaerobic bacterium *Clostridium botulinum* (Locke and Friend 1989, Friend and Franson 1999, Wobeser 2012). Disease outbreaks from exposure to Type C toxin is most common in wetlands where dabbling ducks are most at risk; whereas Type E toxin causes mortality events for fish-eating birds in the Great Lakes region. Exposure to botulism is often fatal for many species of waterfowl (Friend and Franson 1999). Type C botulism can persist in a population for several months and is commonly associated with warm seasonal temperatures and fluctuating water levels (Soos and Wobeser 2006, Wobeser 2012).

A wide variety of waterfowl species have been affected by diseases within wetland and wildlife management areas in Kansas, USA, where disease outbreaks frequently occur, often resulting in the mortality of hundreds to thousands of birds. For example, approximately 15,000 birds died as a result of an unidentified disease in 1967 at Cheyenne Bottoms Wildlife Refuge, Barton County (Cheyenne Bottoms Wildlife Refuge, unpublished report). Outbreaks such as this are usually overshadowed by other mortality events of larger size and annual frequency occurring elsewhere within the Central Flyway (e.g., Nebraska, Texas; Smith and Higgins 1990, Smith et al. 1990, Blanchong et al. 2006*a*, Samuel et al. 2007). Kansas' infrequent reporting of disease history and outbreak severity has resulted in a lack of information for wildlife managers to effectively manage avian disease outbreaks in the region.

Located in the Central Flyway, Kansas is a vital stopover for migratory waterfowl and more recently a possible wintering area for some species (e.g., snow goose, Ross's goose [*Anser rossii*]) due to climate and landscape changes (Robertson and Slack 1995, Kruse 2015). With increasing concerns for threatened and endangered migratory species (e.g., whooping crane [*Grus americana*]), the health of wetland ecosystems, and threats to livestock and human health, surveillance and monitoring for diseases are typically at the forefront of discussion of wildlife managers (Friend 2002, Boadella et al. 2011). Standardized waterfowl disease surveillance and monitoring schemes should be established to determine factors that result in disease outbreaks. Our objectives were to 1) compile all known records of naturally occurring waterfowl disease outbreaks (i.e., not related to chemical toxicosis) for Kansas; 2) assess frequency of disease occurrence, species affected by diseases, and temporal trends of disease reports; and 3) assess relationship between annual frequency of occurrences of waterfowl disease in Kansas and the Midwinter Waterfowl Survey light geese counts.

STUDY AREA

Kansas is situated within the Central Flyway and encompasses roughly 213,100 km^2 in the central United States. The state includes many state and federal parks, reservoirs, wildlife areas, and fishing lakes primarily developed for recreational activities, many of which support migratory and wintering waterfowl. Although there is potential for disease outbreaks anywhere waterfowl congregate, outbreaks are principally reported at state and federal wetland and wildlife management areas. The primary contiguous wetland system in Kansas is the Cheyenne Bottoms Wildlife Area, a 16,591-ha land sink located in Barton County, Kansas. As the largest inland freshwater marsh in the United States, it was designated as a wetland of international importance in 1988 under the Ramsar Convention on Wetlands of International Importance (Aber et al. 2006). Located approximately 29 km from Cheyenne Bottoms is Quivira National Wildlife Refuge; this unique salt marsh and sand prairie encompasses 8,958 ha. The majority of available data on waterfowl disease outbreaks were retrieved from these areas; however, a complete search for avian disease records was conducted throughout Kansas.

METHODS

Narrative reports from Kansas Department of Wildlife, Parks, and Tourism's (KDWPT) individual wildlife area offices, KDWPT's wetland management offices, and U.S. Geological Survey's National Wildlife Health Center (NWHC) database were the primary sources utilized for this retrospective survey. We supplemented these records with a search of records in published literature and other government agency reports. We created a spreadsheet that included names, phone numbers, and email addresses of sources, including area wildlife managers and biologists from KDWPT, Kansas area U.S. Fish and Wildlife Service (USFWS) stations, and NWHC. We used the spreadsheet to systematically contact and note results of findings per conversations with wildlife personnel. Eighty-five wildlife personnel were contacted by a general email requesting any information on avian disease outbreaks in Kansas. Throughout summer 2014, direct contact was made with 44 of these individuals concerning availability of records for avian disease outbreaks in their respective areas. The most effective method of data retrieval was phone calls, as this allowed explanation of research being conducted and questions to be answered.

Information and data on reported waterfowl disease outbreaks in Kansas were obtained by accessing electronic records, retrieval of paper copies of completed data forms, or mailed photocopies of field notes and other data on waterfowl disease outbreaks. Disease information collected by the USFWS field stations in Kansas was kept and maintained by the NWHC in Madison, Wisconsin, USA. An extensive search on disease events in Kansas was made with the assistance of the NWHC. We conducted a literature review to find available data on avian disease events in Kansas. Additionally, we searched Google Scholar, Web of Science core collection, Web of Science, and other databases provided by Kansas State University Libraries to obtain records of disease outbreaks. Records were noted and compared to findings from the statewide search.

We obtained average daily high and low temperatures during months associated with botulism (August and September) and cholera (December, January, and February) disease outbreaks from the Kansas State University Weather Data Library from weather stations located nearest the disease outbreak. We obtained population counts for the mid-continent population of light geese (snow goose and Ross's goose) in Kansas from the annual (January) Midwinter Waterfowl Survey counts (Kruse 2015). We analyzed data as an index of abundance of light geese from 1970 to 2014 to be consistent among the recovered records of disease events in Kansas. We used separate linear regressions to evaluate relationships between 1) average monthly high (botulism) and number of disease events per year, 2) average monthly low temperature (cholera) and number of disease events per year, and 3) Midwinter Waterfowl Survey counts of light geese in Kansas and annual number of disease outbreaks. Midwinter Waterfowl Survey counts of light geese were logarithmic transformed prior to analysis to normalize their distribution. All analyses were performed in SAS v.9.3 (PROC GLM; SAS Institute, Cary, North Carolina, USA) and Program R (R Core Team 2016) using $\alpha = 0.05$.

RESULTS

During the fall of 1968, approximately 12,000 waterfowl died at Cheyenne Bottoms Waterfowl Management area (Great Bend, Kansas) from exposure to avian botulism, with approximately 63,000 waterfowl at risk (Supplement 1). This event was preceded in 1967 by a disease outbreak without a confirmed diagnosis (later believed to be caused by avian cholera, although more likely avian botulism) where 10,000 to 15,000 ducks and numerous shorebirds were reported dead. Specimens from the 1967 outbreak were submitted to the Denver Wildlife Research Center (which tested for pesticides) and Kansas State University College of Veterinary Medicine whose findings were inconclusive. An outbreak of avian botulism was confirmed the following year by Kansas State University Veterinary Diagnostic Laboratory. These were Kansas' first attempts to record the loss of thousands of waterfowl and shorebirds due to a specific disease.

1967–2014

All reported waterbird disease events from 1967 through 2014 (n = 30) were documented (Supplement 1, Fig. 1). Records of 7 unique diseases were reported in 17 locations throughout Kansas (Fig. 2). Of these events, 37.5% were a result of avian cholera (n = 12), 31.3% were caused by avian botulism (n = 10), and the remaining 31.3% (n = 10) were a mix of 5 identified diseases and one unknown diagnosis (Fig. 3). Disease outbreaks most frequently occurred during March, September, and December (Fig. 3).

Species distribution of waterbird mortality events identified as avian cholera were 81% snow goose (n = 7,310), 5% greater white-fronted goose (n = 445, *Anser albifrons*), 7% mallard (n = 628, *Anas platyrhynchos*), and the remaining 7% was comprised of 17 other species. The majority of species involved in events caused identified as avian botulism were dabbling ducks with 21% green-winged teal (n = 4,678, *A. crecca*), 14% blue-winged teal (n = 3,027, *Spatula discors*), 14% northern pintail (n = 3,013), 10% American wigeon (n = 2,290, *Mareca americana*), and the remaining 41% were comprised of 42 different additional species including unidentified shorebirds and waterfowl.

There were 10 reported events for avian botulism occurring from June to October with greatest frequency in September. The minimum average monthly high for a botulism recorded event was 23.8º C and maximum of 36.2º C with a mean of 31.0º C. There was no statistical relationship between the reported botulism events per year and mean high temperature during months most susceptible to disease outbreaks ($F_{1, 45}$ = 1.02, P = 0.32).

There were 10 reported events associated with avian cholera ranging from November to March with December being the mode, and one event in May. The relationship

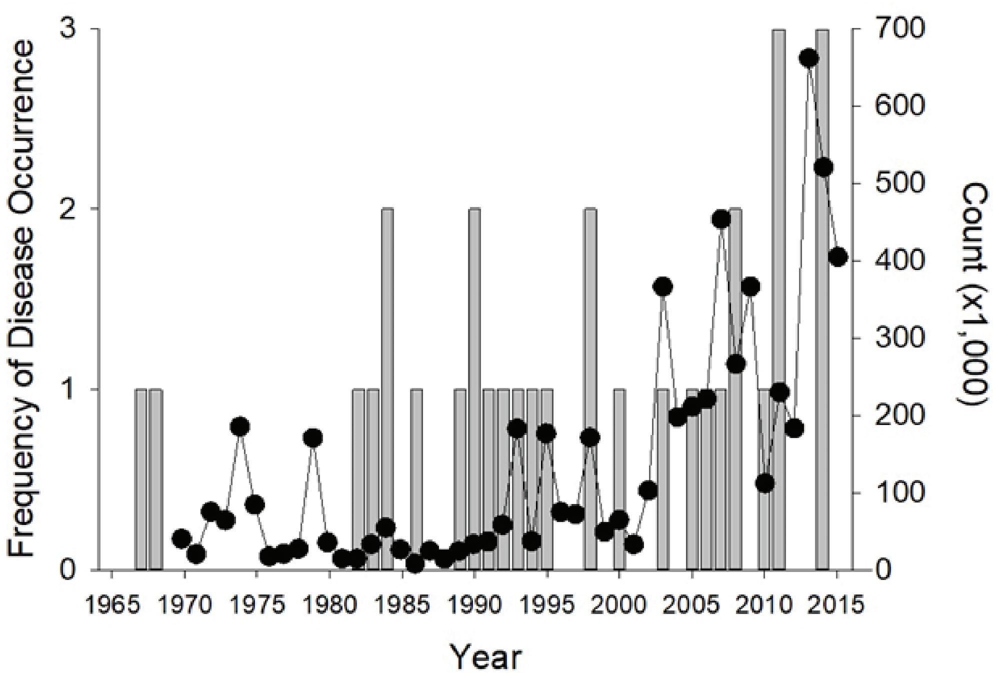

Figure 1. Temporal distribution of reported waterbird natural disease outbreaks (vertical bars) and counts of light geese from the Midwinter Waterfowl Survey (connected dots) in Kansas, USA, (n = 30) during 1967–2014.

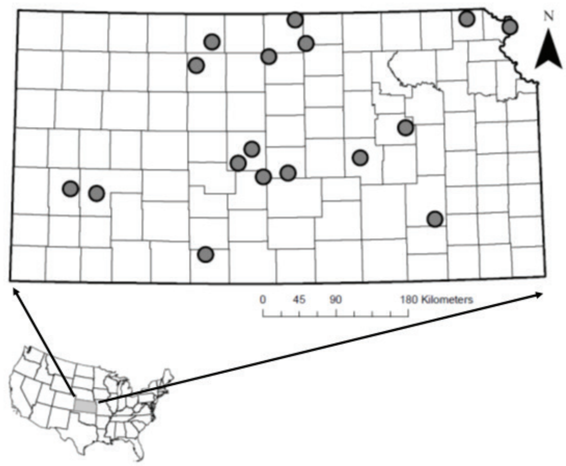

Figure 2. Spatial distribution of reported waterbird natural disease outbreaks in Kansas, USA, during 1967–2014. Circles represent approximate location of disease occurrence.

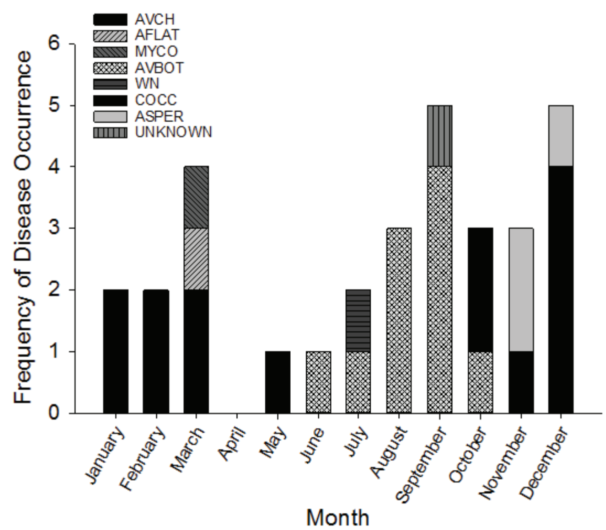

Figure 3. Monthly frequency of reported wild avian disease outbreaks in Kansas, USA (n = 30) during 1967–2014. AVCH = Avian cholera; AFLAT = Aflatoxicosis; MYCO = Mycotoxicosis; AVBOT = Avian botulism; WN = West Nile; COCC = Coccidiosis; ASPER = Aspergillosis; UNKNOWN = Unknown disease.

between avian cholera events and average monthly low temperatures (minimum = –10.4° C, maximum = 6.29° C, mean = -3.5° C) in Kansas was not significant ($F_{1, 46}$ = 0.04, P = 0.84).

Light goose counts

The Midwinter Waterfowl Survey of light goose counts in Kansas provided a range of 8,111 (1986) to 661,928 (2013) with a mean of 129,916 (1970–2014; Fig. 1). Ten disease events were reported to involve light goose populations in Kansas during this time frame. Of these events, 8 (80%) occurred after 1998, corresponding to increased populations of light geese. The mortality counts for these 8 events ranged from 6 to 4,039. All but 2 of these events were the result of avian cholera; the remaining 2 were due to outbreaks of aspergillosis. There was a marginal positive, albeit not statistically significant, relationship between the annual Midwinter Waterfowl Survey count of light geese and annual frequency of disease outbreaks ($F_{1, 43}$ = 3.86, P = 0.06). In many of these years, there were no reported disease events, however, there was an increasing frequency of disease occurrence during the past decade (Fig. 1).

DISCUSSION

Our study revealed that efforts to record natural disease events affecting waterbirds was not a consistent priority for wildlife personnel in Kansas. This may be due to the increased effort and challenging logistics required to survey a disease outbreak (e.g., extra personnel, hours, available equipment and a delay of other daily duties [Friend and Franson 1999, Soos and Wobeser 2006]). In a few cases, retrospective recording of disease outbreaks resulted in approximations in observed mortality of avian species; however, there were cases of disease outbreak reports that were well documented, with extensive records kept on the wildlife area. These well-documented cases will be helpful in developing future collaborative disease management plans for Kansas Department of Wildlife, Parks, and Tourism. Future development of disease reporting at the state level requires a greater emphasis on disease surveillance and documentation.

Future surveillance efforts would benefit from a better spatial and temporal understanding of disease outbreaks (Chan et al. 2010). The data we recovered spanned greater than decades with few gaps in time of no reported occurrence. Friend and Franson (1999) suggested that the lack of disease reports may not be due to the lack of events, but rather the lack of reporting. Given that the underlying cause of many cholera outbreaks is presence of concentrations of light geese, it is unlikely that cholera outbreaks were not recorded during the 1970s when no disease outbreaks were reported. However, it is likely that other disease outbreaks (e.g., botulism) likely occurred during this period in Kansas but were not recorded or reported.

Recorded avian cholera outbreaks in Kansas show seasonality ranging from November to March, with December being the mode. This pattern coincides well with periods of outbreaks in other regions (Wobeser 1997, Friend and Franson 1999, Samuel et al 2007). Avian cholera does not persist among years in a wetland system; rather it persists within populations of a few primary species (e.g., northern pintail and snow goose; [Blanchong et al. 2006*b*, Samuel et al. 2007]). The majority of recovered carcasses from cholera die-offs were snow geese (estimated recovered 7,310), which are believed to be the primary carriers of *P. multocida* (Friend and Franson 1999, Blanchong et al. 2006*a*, Samuel et al. 2007). The risk of disease outbreaks is believed to be associated with species abundance at epizootic locations, but past findings were inconclusive (Blanchong et al. 2006*a*). Our results indicate, although not statistically significant based on extant data, that there is a trend for increasing frequency of reported avian cholera events associated with increasing light geese counts in Kansas during the Midwinter Waterfowl Survey.

We anticipate a continued increase in the probability of avian cholera outbreaks in Kansas because of increasing residence times by snow geese and other waterfowl during winter (Kruse 2015). The Midwinter Waterfowl Survey data indicates a 213% increase in wintering light geese in Kansas during the past 20 years (when comparing the five-year averages of 1995–2000 and 2010–2014; Kruse 2015). Concurrent with these population increases are increases in reported disease outbreaks within the last 15 years. This observation suggests that as light goose population densities increase, the probability of a disease outbreak (primarily avian cholera) increases as well (Smith et al. 1990; Blanchong et al. 2006*a, b*). This trend may be due to physiological stressors (e.g., extreme temperature change, weather conditions, decreased resource availability) experienced by increasing densities of light geese during winter (Smith and Higgins 1990, Smith et al. 1990, Arzel et al. 2006). These stressors may lead to more immunosuppressed individuals where disease risk is increased (Wobeser 1997, Arzel et al. 2006). These data are limited and thorough reporting of disease outbreaks is essential for the future of disease forecasting and testing hypothetical relationships with environmental conditions and bird densities.

For avian botulism, there are many complex ecological relationships believed to occur prior to an epizootic event. Botulism bacterial growth is likely the result of certain environmental conditions that causes deterioration in water quality in wetlands. Factors that contribute to botulism outbreaks in wetlands include water drawdown, pH, salinity, seasonal temperatures ranging from 25º C to 40º C, and other environmental conditions (Wobeser 1997, Friend and Franson 1999, Rocke and Samuel 1999, Soos and Wobeser 2006). Warmer temperatures during June through October may relate to increased frequencies of annual botulism outbreak events. Although higher temperatures are not the mechanistic cause of botulism outbreaks, this is an easily measured index for other factors that are known to affect disease outbreaks (Rocke and Samuel 1999, Soos and Wobeser 2006). Rocke and Samuel (1999) found that water temperatures influenced *C. botulinum* growth by increasing pH of the water, which in turn increased risk and suitability of conditions for botulism. Water temperature also influences the availability of invertebrate as a potential food source containing biotoxins (e.g., maggots; Rocke and Samuel 1999, Soos and Wobeser 2006). It is likely with the shifting global climate, Kansas' risk of avian botulism outbreaks will increase as seasonal temperatures continue to rise, and drought and precipitation events become more severe (Easterling et al. 2000, Patz et al. 2008, Dai 2013).

The narratives of botulism events from Cheyenne Bottoms indicate there were drawdowns of water in the pools affected by disease or precipitation totals ≥15 cm within the month previous to outbreaks. Those few instances where rain events were ≥15 cm occurred during the month or month prior to an outbreak at Cheyenne Bottoms in 1993, 1998, and 2000. Future research should attempt to relate water fluctuations, water and ambient air temperature, and other possible characteristics such as decaying organic material that create anaerobic conditions that promote *C. botulinum* growth in wetland ecosystems in Kansas.

Due to the nature of botulism and environmental conditions favoring rapid decay, it was difficult to obtain species-specific identification during botulism outbreaks. Furthermore, it may not have been possible to detect all carcasses due to decay and submersion during cholera outbreaks. Therefore, our collected reports likely underestimate the extent and frequency of mortality associated with botulism and cholera outbreaks in Kansas. The weak relationship between Midwinter Waterfowl Survey light goose data and outbreak events was likely an artifact of incomplete reporting. Detectability of carcasses during any disease event may have been an issue when estimating mortality (Soos and Wobeser 2006). There are a number of biases to overcome when estimating mortality due to disease loss; such as carcass loss to scavengers, imperfect detection by searchers, variable ecological site characteristics (e.g., vegetation height, type, and density; water depth and clarity), species characteristics (e.g., size and colorization), non-standardized searches and/or data recording, weather conditions, timing of search (immediate vs. week later), mortality occurring outside primary search area, and time (Homan et al. 2001, Soos and Wobeser 2006, Huso 2011). These biases, in addition to carcass decomposition, may cause inconsistencies in estimating true losses and not adequately reflect the impact of disease on the affected population(s).

MANAGEMENT IMPLICATIONS

Development of station and state disease management plans could be an initial step to better document and understand avian disease dynamics occurring in Kansas wetlands. These disease management plans would benefit from a standardized state-wide monitoring and surveillance scheme for a more holistic approach to disease investigations. Through the development of a plan, such actions would be emplace to track and monitor disease events, as well as continue database maintenance, assess management practices, and assist investigators in future efforts to predict disease outbreaks.

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Supplement 1. Natural disease events for waterbirds in Kansas, USA, reported by the Kansas Department of Wildlife, Parks and Tourism and available in the data base of disease outbreaks available through the National Wildlife Health Center during 1967–2014.

Approximate start date (mm/yyyy)	Location	Disease	Species	Estimated number affected
Sep 1967	Cheyenne Bottoms Wildlife Area, Barton County	Unknown	Unknown	15,000
Sep 1968	Cheyenne Bottoms Wildlife Area Pool 2, Barton County	Avian Botulism	American Wigeon (*Mareca americana*) Blue-winged Teal (*Spatula discors*) Green-winged Teal (*Anas crecca*) Northern Pintail (*Anas acuta*) Gadwall (*Mareca strepera*) Shorebird	12,000
Sep 1982	Glen Elder Reservoir, Mitchell County	Avian Botulism	American White Pelican *(Pelecanus erythrorhynchos*)	65
May 1983	Webster Reservoir, Rooks County	Avian Cholera	American Coot (*Fulica americana*)	1
Oct 1984	Council Grove Reservoir. Morris County	Renal Coccidiosis	Double-crested Cormorant (*Phalacrocorax auritus*)	100
Dec 1984	Brown County	Avian Cholera	Snow Goose (*Anser caerulescens*)	165
Dec 1986	Marion Reservoir, Marion County	Renal Coccidiosis	Double-crested Cormorant	40
Oct 1989	Kirwin National Wildlife Refuge, Phillips County	Renal Coccidiosis	Double-crested Cormorant	200
Feb 1990	Fall River Wildlife Management Area, Greenwood County	Avian Cholera	Canada Goose (*Branta canadensis*)	10
Oct 1990	Cheyenne Bottoms Wildlife Area Pool 2, Barton County	Avian Botulism	Green-winged Teal Northern Pintail Northern Shoveler (*Spatula clypeata*) Blue-winged Teal American Wigeon Mallard (*Anas platyrhynchos*) Gadwall Ruddy Duck (*Oxyura jamaicensis*) Redhead (*Aythya americana*) Lesser Scaup (*Aythya affinis*) Canvasback (*Aythya valisineria*) Ring-necked Duck (*Aythya collaris*) Cinnamon Teal (*Spatula cyanoptera*) Coot (*Fulica americana*) American White Pelican Double-crested Cormorant Sandhill Crane (*Antigone canadensis*) Snowy Egret (*Egretta thula*)	4,237
Mar 1992	Quivira National Wildlife Refuge, Stafford County	Aflatoxicosis	Mallard	5
Aug 1993	Cheyenne Bottoms Wildlife Area, Barton County	Avian Botulism	Green-winged Teal Mallard Blue-winged Teal Northern Shoveler Northern Pintail Ruddy Duck Redhead Wood Duck	2,035

			Gadwall	
			American Wigeon	
			Coot	
			Grebe	
			Rail	
			Heron	
			Gull	
			Shorebird	
			Egret	
			Unidentified	
Sep 1994	Cheyenne Bottoms Wildlife Area Pool 1A, Barton County	Avian Botulism	Green-winged Teal	604
			Blue-winged Teal	
			Northern Shoveler	
			Mallard	
			Ruddy Duck	
			Northern Pintail	
			Gadwall	
			American Wigeon	
			Cinnamon Teal	
			American White Pelican	
			Yellowlegs (*Tringa melanoleuca*)	
			White-faced Ibis (*Plegadis chihi*)	
			Pectoral Sandpiper (*Calidris melanotos*)	
			Avocet (*Recurvirostra americana*)	
			Least Sandpiper (*Calidris minutilla*)	
			Common Snipe (*Gallinago delicate*)	
			Black-necked Stilt (*Himantopus mexicanus*)	
			Coot	
			Egret	
			Gull	
			Grebe	
			Unidentified	
Aug 1995	Cheyenne Bottoms Wildlife Area Pool 1A, Barton County	Avian Botulism	Mallard	259
			Redhead	
			Northern	
			Blue-winged Teal	
			Wood Duck (*Aix sponsa*)	
			Ruddy Duck	
			Gadwall	
			Green-winged Teal	
			Mottled Duck (*Anas fulvigula*)	
			Coot	
			Egret	
			Heron	
			Rail	
			Shorebird	
			Unidentified	
Mar 1998	Lovewell Reservoir, Jamestown Wildlife Area, Jewell County	Avian Cholera	Mallard	4,906
			Northern Pintail	
			Blue-winged Teal	
			Green-winged Teal	
			American Wigeon	
			Northern Shoveler	
			Gadwall	
			Redhead	
			Canvasback	
			Lesser Scaup	
			Ruddy Duck	
			Bufflehead (*Bucephala albeola*)	
			Ring-necked Duck (*Aythya collaris*)	
			Goldeneye (*Bucephala clangula*)	
			Canada Goose	
			White-fronted Goose (*Anser albifrons*)	

			Snow Goose Ross's Goose (*Anser rossii*) Coot Unidentified	
Jul 1998	Cheyenne Bottoms Wildlife Area, Barton County	Avian Botulism	Blue-winged Teal Green-winged Teal Cinnamon Teal Mallard Northern Pintail Northern Shoveler Gadwall American Wigeon Wood Duck Redhead Ruddy Duck Lesser Scaup Ring-necked Duck Black Duck (*Anas rubripes*) Canada Goose American White Pelican Double-crested Cormorant Killdeer (*Charadrius vociferus*) Coot Green Heron (*Butorides virescens*) Black Tern (*Chlidonias niger*) Avocet (*Recurvirostra americana*) Teal Egret Gull Heron Ibis Stilt Rail Grebe Unidentified	2,304
Aug 2000	Cheyenne Bottoms Wildlife Area Pool 4B, Barton County	Avian Botulism	Mallard Blue-winged Teal Redhead Northern Pintail Wood Duck Green-winged Teal American Wigeon Northern Shoveler Gadwall Ruddy Duck Scaup Coot American White Pelican Grackle (*Quiscalus quiscula*) Grebe Shorebird Gull Heron Egret Unidentified	432
Jul 2003	Quivira National Wildlife Refuge, Stafford County	West Nile	American White Pelican	36
Jun 2005	Lee Richardson Zoo, Barton County	Avian Botulism	Mallard	75
Mar 2006	Quivira National Wildlife Refuge, Stafford County	Mycotoxicosis	Sandhill Crane	200

Sep 2007	Cheyenne Bottoms Wildlife Area, Barton County	Avian Botulism	Northern Pintail Green-winged Teal	6
Mar 2008	McKinney Lake, Kearny County	Avian Cholera	Snow Goose	550
Dec 2008	Dundee, Barton County	Avian Cholera	White-fronted Goose	243
Nov 2010	Quivira National Wildlife Refuge, Stafford County	Avian Cholera	Snow Goose	6
Nov 2011	Cheyenne Bottoms Wildlife Area, Barton County	Aspergillosis	Ross's Goose	1
Dec 2011	Cheyenne Bottoms Wildlife Area Pool 1A, Barton County	Avian Cholera	Ross's Goose Snow Goose Greater White-fronted Goose	150
Dec 2011	Cheyenne Bottoms Wildlife Area, Barton County	Aspergillosis	Ross's Goose	50
Jan 2014	Coldwater City Lake, Comanche County	Avian Cholera	Mallard Snow Goose	Unknown
Feb 2014	Lovewell Reservoir, Jewell County	Avian Cholera	Mallard Snow Goose	3,000