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Differentiation of Naturally Occurring From Non-Naturally Occurring Epizootics of Anthrax in Livestock Populations

Contributor

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Summary

Anthrax is an acute, febrile disease of warm-blooded animals, including humans. Anthrax is caused by *Bacillus anthracis*, a gram-positive, non-motile, spore-forming bacterium, and it occurs most commonly as a rapidly fatal septicemia in animals. Naturally occurring anthrax outbreaks in animals in nearly 200 countries are recorded by The World Anthrax Data Site, a World Health Organization Collaborating Center for Remote Sensing and Geographic Information Systems for Public Health.

Anthrax is a globally distributed disease, having been reported by all continents. Anthrax infection in livestock is enzootic in some geographical regions in the U.S. Anthrax epizootics appropriately were considered to be naturally occurring infections prior to the events surrounding September 11, 2001. After September 11, concerns were heightened greatly that anthrax may be used deliberately to harm livestock populations due to the upsurge in terrorism, specifically agroterrorism. Consequently, anthrax is among the list of pathogens that could be used as a bioweapon not only in humans, but also in animals.

A simple methodology that can be used to differentiate naturally occurring epizootics of anthrax from non-naturally occuring epizootics could be of benefit to determine subsequent response and control strategies. This paper describes briefly several US incidents of anthrax in livestock and discusses the criteria that potentially can be used to differentiate naturally occurring from non-naturally occurring epizootics of anthrax. A template was developed that is intended to be used by the early-responders to an anthrax incident (e.g., private veterinary practitioners). The template utilizes approximately 20 ecological and epizootiological criteria to differentiate one type of epizootic from the other type, the latter of which may require intervention by law enforcement officials.

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Introduction

Anthrax infection in livestock is enzootic in some geographical regions in the U.S. Until recently, anthrax epizootics appropriately were considered to be naturally occurring infections. However, there are heightened concerns now that anthrax may be used deliberately to harm livestock populations due to the upsurge in terrorism, specifically agroterrorism. A methodology that can be used to differentiate naturally occurring epizootics of anthrax from non-naturally occuring epizootics could be of benefit to determine subsequent response and control strategies. This paper describes briefly some recent US incidents of anthrax in livestock and discusses the criteria that potentially can be used to differentiate naturally occurring from non-naturally occurring epizootics of anthrax.

Objectives

1. To describe the incidence and geographical distribution of anthrax in livestock in the U.S. during the years 1996 to 2001.

2. To establish a list of criteria that can be used as a tool to differentiate naturally occurring epizootics from non-naturally occuring epizootics of anthrax in livestock populations.

Methods

Incidence and Geographical Distribution:

The data for the incidence and geographical distribution of anthrax in the US were obtained from three different sources: **(a)** information was requested via electronic mail and teleconference from the Area Offices of USDA:APHIS Veterinary Services, **(b)** data published by the International Society for Infectious Diseases (ProMed-mail at http://www.promedmail.org), and **(c)** data published by an internationally renowned anthrax expert at Louisiana State University *(http://www.vetmed.lsu.edu/whocc/outbrks.htm).*

Differentiation Criteria:

The data for the differentiation criteria were obtained by establishing observed values for 19 different epizootiological and ecological attributes reported during the five naturally occurring epizootics of anthrax in livestock. The expected values for a non-naturally occurring epizootic of anthrax were established using two methods:

Method 1. For the discrete attributes (e.g., the seasonal distribution of the epizootic), the expected values for a non-naturally occurring epizootic of anthrax would be the opposite of the observed values for a naturally occurring epizootic of anthrax. For example, if the observed value for the seasonal distribution of a naturally occurring epizootic of anthrax equals “summer”, then the expected value for the seasonal distribution of a non-naturally occurring epizootic of anthrax would be “winter”.

Method 2. For the continuous attributes (e.g., mean number of livestock deaths per premises), the observed values were determined by simply computing the mean, the median, and/or the interval for the values of various attributes reported for the naturally occurring epizootics of anthrax. The expected values for a non-naturally occurring epizootic of anthrax then, would be determined by selecting values outside of the range of values defined for a naturally occurring epizootic of anthrax. For example, if the observed value for the median number of deaths per premises for a naturally occurring outbreak of anthrax equals 10, then the expected value for the median number of deaths per premises for a non-naturally occurring outbreak of anthrax could be less than 3 or greater than 20.

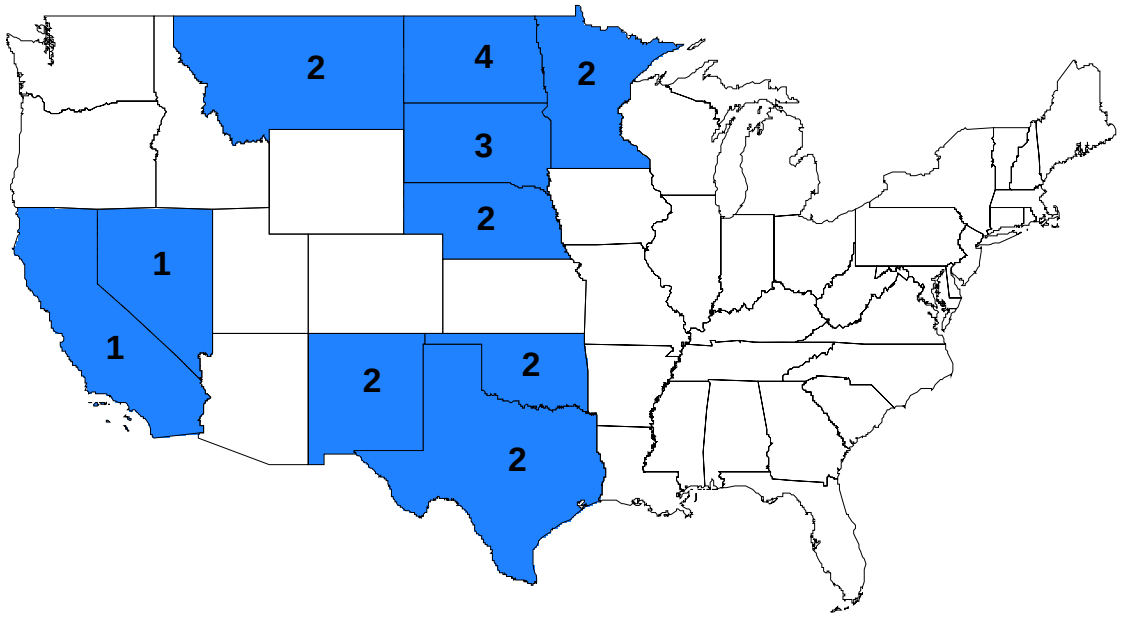
Results and Discussion

Incidence and Geographical Distribution of Anthrax in the U.S.

There was no comprehensive data source for all occurrences of anthrax in domestic animals in the United States during the period of this study. The following information therefore, was derived from various scientific studies, State records, and other data sources that had been published on the Internet.

There were ten States with at least one documented epizootic of anthrax from January 1996 through October 2001 **(Figure 01)**. Most States with epizootics were located west of the Mississippi River, specifically in the Midwest, the Southwest, and the Western United States. Historically, these States have been referred to as the Plains States. Some States experienced epizootics during consecutive years, whereas other States reported a time span between epizootics of decades. Reports of epizootics may not have been complete, because sporadic cases of anthrax may have gone undiagnosed, or were diagnosed but were not reported. Also, livestock producers in enzootic areas may recognize the signs of anthrax and respond by vaccinating their animals, without reporting the disease to the appropriate authorities. During January to October 2001, six States reported anthrax epizootics. During years 2000, 1999, 1998, 1997, and 1996 there were four, two, three, three, and two State(s) that reported epizootics, respectively **(Table 01)**.

Figure 01. States reporting at least one animal anthrax outbreak, January 1996 toOctober 2001



Numbers = Number of outbreaks, January 1996 to October 2001

Summary of Recent U.S. Epizootics

Data about the most recent epizootic of anthrax that occurred in each State are provided in **Table 01**. The species most commonly affected was cattle. Most epizootics involved a small number of premises (i.e., one to three). However, the epizootics that occurred in Minnesota and Texas during year 2001 were relatively large; the Minnesota epizootic involved 23 premises, and the Texas epizootic involved 63 to 71 premises. The epizootics occurred as early in the year as January and as late as December, but they were more common during the summer months.

Differentiation Criteria For Anthrax Epizootics

Approximately 19 criteria were identified that potentially could be used to differentiate naturally occurring from non-naturally occurring epizootics of anthrax **(Table 02)**. These criteria can be assigned to two broad categories, either ecological criteria or epizootiological criteria.

One example of an ecological criterion is “the seasonal distribution of the epizootic.” Although the seasonal distribution of naturally occurring epizootics of anthrax in livestock may vary with the earth’s latitude, these epizootics are restricted generally to the summer season, specifically June, July, and August. Thus, an epizootic of anthrax that would occur during the winter months would not be consistent with the pattern of a naturally occurring epizootic.

An example of an epizootiological criterion is “the mean number of livestock deaths per premises”. The published investigations of epizootics of anthrax have shown that the mean number of livestock deaths per premises was approximately five. One explanation for such a value is that, after the index cases on affected premises have been identified, and certainly after additional cases have been identified for any given premises, some form of intervention will be sought by many livestock producers. Potentially beneficial interventions for anthrax could include translocation of animals to an uncontaminated environment on the premises, chemotherapeutic intervention such as antimicrobial therapy, and prophylactic intervention in the form of vaccination against anthrax. Either one of these interventions, or combinations thereof, may reduce significantly the number of deaths due to anthrax. The mean number of livestock deaths per premises during a non-naturally occurring epizootic

could be expected to be higher for various reasons, one reason being the deliberate exposure of the animals to an infective dose that would far exceed an infective dose that would have been acquired naturally.

Table 01. States reporting at least one epizootic of anthrax, January 1996 to October 2001.

State	Most Recent Epizootic	Species / Deaths (#)	Premises Affected (#)	Month	County	Year of Previous Epizootic
California	2001	Cattle/21	2	October	Santa Clara	NR
Minnesota	2001	Cattle/100 Horses/2 Deer/2	23	June to October	Roseau, Kittson, Polk, Marshall	2000
Montana	1999	Cattle/8	1	May	Yellowstone	NR
Nebraska	2001	Cattle/1	1	January	Boyd	1999
Nevada	2000	Cattle/79	3	August	Washoe	NR
New Mexico	1998	Cattle/7	1	August, December	Mora	1997
North Dakota	2001	Cattle/11	1	Summer	Cavalier	1996, 1998, 2000
Oklahoma	1998	Cattle/1	1	March	Payne	1996
South Dakota	2001	Buffalo/11 Donkey/1 Cattle/2	2	August	Jerault	1997, 2000
Texas	2001	Farmed and wild deer, cattle, elk, horses, bison, goats also affected / 1,637	63 to 71	June to September	Val Verde, Uvalde, Bandera, Edwards, Kinney, Real	1997

NR = not reported. *Sources:* USDA APHIS Veterinary Services Area Offices, Promed, Louisiana State University anthrax website *(http://www.vetmed.lsu.edu/whocc/outbrks.htm)*

The criteria in **Table 02** are not intended to be fully conclusive when differentiating natural epizootics from non-natural epizootics. However, it is anticipated that the criteria may be beneficial as an initial reference when determining the potential origin of an epizootic, and therefore the subsequent control measures. The differentiating criteria are based on thorough investigation of several anthrax epizootics (Conger et al., 2001; Fox et al., 1973; Fox et al., 1977; Johnson, 2006; Turner et al., 1999). As new epizootics of anthrax occur, it will be important to collect similar data, enabling these criteria to be refined further.

Epizootic Classification Template

A template was created to serve as a tool to assist early responders (e.g., private veterinary practitioners) in classifying an epizootic-in-question as a natural occurrence or non-natural occurrence **(Appendix Table 01)**. The epizootic-in-question should be evaluated with respect to each of the criteria listed, and each individual criterion should be designated as being consistent with one type of epizootic or the other, i.e. natural or non-natural. If a high percentage of the criteria are consistent with a naturally occurring epizootic, the epizootic-in-question should be investigated using the traditional epidemiological approach. Likewise, if a high percentage of the criteria are consistent with a non-natural occurring epizootic, the epizootic-in-question should be investigated using measures which probably should include appropriate forms of law enforcement.

To demonstrate use of the template, **Appendix Table 02** provides an example, using all information about an anthrax epizootic that was available. This epizootic occurred on a beef cattle ranch in Sheridan county Nebraska, and the first cases were identified during the month of June. The most recent, laboratory-confirmed epizootic of anthrax had taken place 15 years prior to this epizootic. Relocation of cattle in affected pastures was associated with a decrease in the number of incident cases. Six of the 20 criteria for a naturally occurring epizootic were met, but none of the criteria for a non-naturally occurring epizootic were met. Thus,

this 1994 epizootic was classified as a naturally occurring epizootic.

Table 02. Criteria used to differentiate naturally occurring epizootics from non-naturally occurring epizootics of anthrax (*Bacillus anthracis*) in livestock populations.

	Reporting State or Country					Classification of the Epizootic	
Criterion to be Evaluated	**LA**	**TX**	**AU**	**ND**	**TX**	**Natural Occurrence**	**Non-natural Occurrence**
Epidemiologic classification of the geographic region in which the epizootic occurred	Enzootic	Enzootic	Sporadic	Enzootic	Enzootic	Enzootic; sporadic	Not recorded previously
Affected premises located at origin of, or along an historic livestock movement route	Yes	Yes	Yes	Yes	Yes	Yes	No
General location of epizootic in US	Central	West	-------	West	West	West	East
Seasonal distribution of the epizootic	Summer	Summer	Summer	Summer	Late spring, summer	Late spring, summer, early fall	Late fall, winter, early spring
Volume of rainfall for several consecutive weeks immediately preceding the outbreak	Drought	Drought	Drought	Drought	Drought, then rain	Drought	Extended rain
Ambient temperature for several consecutive weeks immediately preceding the outbreak	Normal	Normal to above normal	Above normal	NR	Normal to above normal	Above normal	Normal, below normal
Soil pH in the epizootic region	Neutral to alkaline	Mildly acidic to alkaline	NR	Alkaline	NR	Inconclusive	Inconclusive
Excavation of earth on the affected premises, or on neighboring premises	NR	NR	Yes	Yes	NR	Yes	No
B. anthracis recovered from grasses and/or soils on affected premises	Yes	NR	No	No	NR	Yes	Inconclusive
Affected animals on premises were exposed (e.g., via grazing) to an environment potentially contaminated with *B. anthracis*	Yes	NR	Yes	Yes	Yes	Yes	Feedlot, other confinement
Predominant livestock species affected during epizootic	Cattle	Cattle	Cattle	Cattle	Cattle	Cattle	Swine, horses, sheep, etc.
Week during which the maximum number of newly-affected premises was identified	3rd to 4th	5th	3rd	3rd	NR	3rd to 5th	1st to 2nd; 8th or more
Week during which the maximum number of newly-affected animals were identified	2nd to 3rd	5th	3rd	3rd	NR	3rd to 4th	1st to 2nd; 6th or more
Duration (weeks) of the period in which newly-affected premises were identified	3	7	5	9	9	9 or less	1 to 2; 12 or longer

Table 02. Criteria used to differentiate naturally occurring epizootics from non-naturally occurring epizootics of anthrax (*Bacillus anthracis*) in livestock populations.

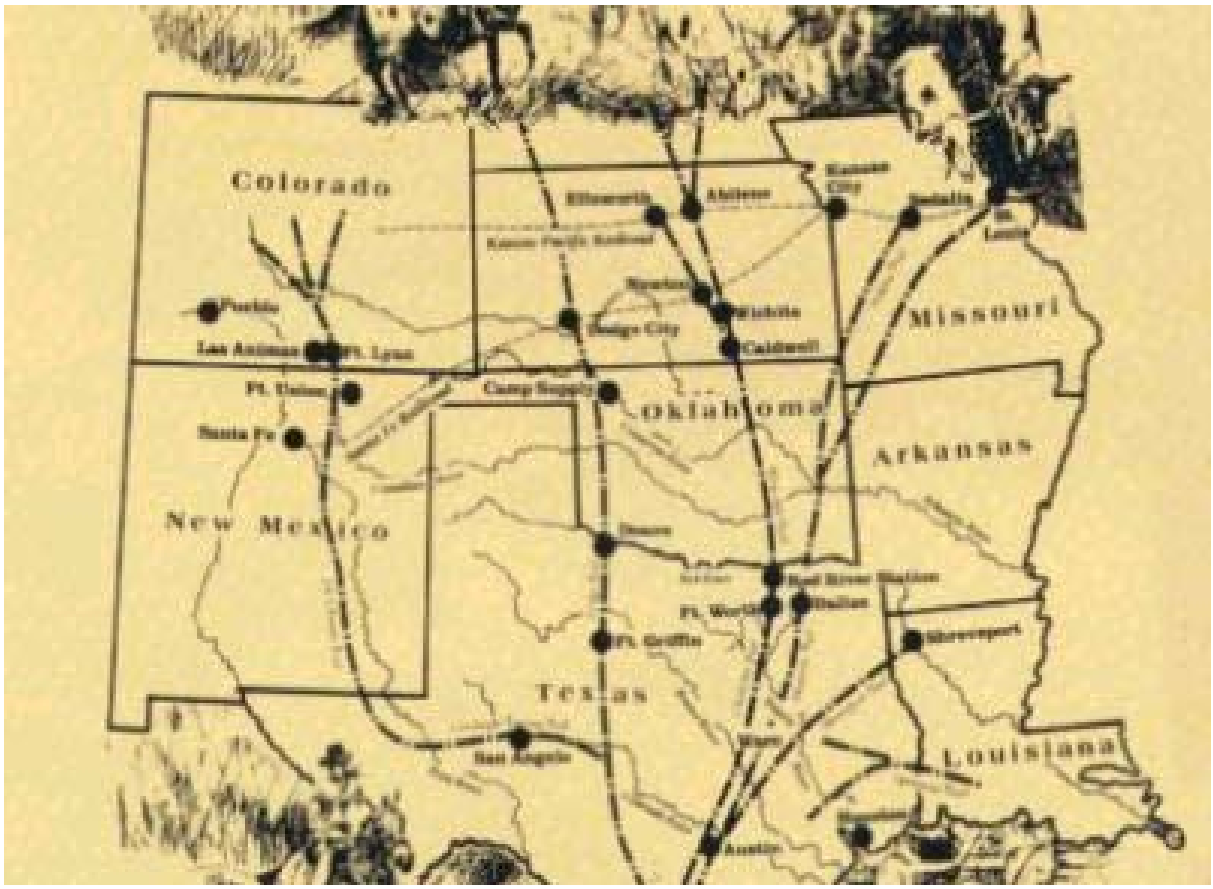
	Reporting State or Country					Classification of the Epizootic	
Criterion to be Evaluated	**LA**	**TX**	**AU**	**ND**	**TX**	**Natural Occurrence**	**Non-natural Occurrence**
Duration (weeks) of the period in which newly-affected animals were identified	11	7	8	9	9	9	6 or less; 14 or longer
Mean number or median number of livestock deaths per premises	9.3	4.9	2.5	4.7	2	5	14 or higher
Percent-mortality in cattle on the affected premises	9.1	5.3	NR	6	2.7	6%	12% or greater
Percent-mortality in horses on the affected premises	22.5	18	NR	12	14.1	17%	25% or greater
Percent-mortality 14 days after vaccination compared to percent-mortality prior to vaccination	NR	Lower	Lower	NA	NR	Lower	Higher

AU=Victoria, Australia. NR=not reported at time of completion of this paper.

Role of U.S. Cattle Trails in Anthrax Epizootics

There has been speculation in the literature that current epizootics of anthrax in the U.S. are related to anthrax infections that occurred during the historical movement of large numbers of cattle during cattle drives and the migration of pioneers and their livestock westward. A map of the cattle trails originating in Texas has been included for purposes of geographical comparison **(Figure 02)**. Although the map is not a comprehensive map of all important western cattle trails, it has been estimated that more than one million cattle were herded along these trails during the years 1866 to 1890.

Figure 02. Map of the locations of various trails for cattle drives in the United States, circa 1800s. (From Texas Longhorn Showcase, http://www.longhornshowcase.com, 2000).



Molecular Epidemiological Criteria

Laboratory diagnostic tools based on the molecular diversity of *Baccilus anthracis* can be a beneficial complement to the traditional methods of investigating epizootics of anthrax. Epizootics that emanate from a single source will result in molecularly identical or very similar *Baccilus anthracis* isolates. On the other hand, epizootics in which the sources are uniquely different may yield very different isolates, and the differences among these isolates would suggest a more distant evolutionary commonality among the sources. Molecular typing of *Baccilus anthracis* during epizootics is relatively new. This technology was used to type isolates from the epizootic of anthrax in Santa Clara County, California during October 2001. Unfortunately, there was only one isolate from previous epizootics of anthrax in California in the laboratory's collection; none the less, the Santa Clara County isolate did not match that specific isolate. It was concluded by the laboratory that the Santa Clara epizootic " . . . looks like a natural outbreak and is not tied to the anthrax letters." (Dr. Paul Keim, personal communication, November 2001). It is likely that molecular typing as an investigative tool will be used with increasing frequency during future epizootics of anthrax.

Conclusion

The recent series of international agro-terrorism conferences are clear evidence of the level of global concerns about the potential impact of agroterrorism on animal health, and thus public health. The Centers for Disease Control and Prevention (CDC) has compiled a list of "Bioterrorism Agents/Disease" to

assist in addressing these global concerns. In addition to anthrax, there are no less than 18 pathogens and 23 diseases on the CDC's list of bioterrorism agents and diseases (Centers for Disease Control and Prevention, 2007). While anthrax may be one of the most notable diseases due to its recent involvement in terrorism, animals in general, and livestock specifically, are equally susceptible to many of the remaining diseases and pathogens on the list (e.g. brucellosis, Q fever, viral encephalitides). Thus, just as an attempt has been made here to develop a simple differentiation tool for anthrax, similar attempts to develop tools for other disease may be beneficial. One limiting factor will be the frequency and extent to which thorough epizootiological investigation of these naturally occurring diseases is undertaken.

Appendix

Appendix Table 01. A template to determine if an epizootic of anthrax in a livestock population is more likely to be a naturally occurring or non-naturally occurring epizootic.

Criterion to be Evaluated	Natural Occurrence	Epizootic In Question	Non-natural Occurrence	Epizootic In Question
Epidemiologic classification of the geographic region in which the epizootic occurred	Enzootic; sporadic		Not recorded previously	
Affected premises located at origin of, or along an historic livestock movement route	Yes		No	
General location of epizootic in US	West		East	
Seasonal distribution of the epizootic	Late spring, summer, early fall		Late fall, winter, early spring	
Volume of rainfall for several consecutive weeks immediately preceding the outbreak	Drought		Extended rain	
Ambient temperature for several consecutive weeks immediately preceding the outbreak	Above normal		Normal, below normal	
Soil pH in the epizootic region	Inconclusive		Inconclusive	
Excavation of earth on the affected premises, or on neighboring premises	Yes		No	
B. anthracis recovered from grasses and/or soils on affected premises	Yes		Inconclusive	
Affected animals on premises were exposed (e.g., via grazing) to an environment potentially contaminated with *B. anthracis*	Yes		Feedlot, other confinement	
Predominant livestock species affected during epizootic	Cattle		Swine, horses, sheep, etc.	
Week during which the maximum number of newly-affected premises was identified	3rd to 5th		1st to 2nd; 8th or more	
Week during which the maximum number of newly-affected animals were identified	3rd to 4th		1st to 2nd; 6th or more	
Duration (weeks) of the period in which newly-affected premises were identified	9 or less		1 to 2; 12 or longer	
Duration (weeks) of the period in which newly-affected animals were identified	9		6 or less; 14 or longer	
Mean number or median number of livestock deaths per premises	5		14 or higher	
Percent-mortality in cattle on the affected premises	6%		12% or greater	
Percent-mortality in horses on the affected premises	17%		25% or greater	
Percent-mortality 14 days after vaccination compared to percent-mortality prior to vaccination	Lower		Higher	
Molecular typing of *B. anthracis* isolate from affected animals	Isolated previously		Not isolated previously	

Appendix Table 02. An example of using a template to determine if an epizootic of anthrax in a livestock population is more likely to be a naturally occurring or non-naturally occurring epizootic.

Criterion to be Evaluated	Natural Occurrence	Epizootic In Question	Non-natural Occurrence	Epizootic In Question
Epidemiologic classification of the geographic region in which the epizootic occurred	Enzootic; sporadic	+	Not recorded previously	
Affected premises located at origin of, or along an historic livestock movement route	Yes		No	
General location of epizootic in US	West	+	East	
Seasonal distribution of the epizootic	Late spring, summer, early fall		Late fall, winter, early spring	
Volume of rainfall for several consecutive weeks immediately preceding the outbreak	Drought		Extended rain	
Ambient temperature for several consecutive weeks immediately preceding the outbreak	Above normal		Normal, below normal	
Soil pH in the epizootic region	Inconclusive		Inconclusive	
Excavation of earth on the affected premises, or on neighboring premises	Yes		No	
B. anthracis recovered from grasses and/or soils on affected premises	Yes		Inconclusive	
Affected animals on premises were exposed (e.g., via grazing) to an environment potentially contaminated with *B. anthracis*	Yes		Feedlot, other confinement	
Predominant livestock species affected during epizootic	Cattle	+	Swine, horses, sheep, etc.	
Week during which the maximum number of newly-affected premises was identified	3rd to 5th	+	1st to 2nd; 8th or more	
Week during which the maximum number of newly-affected animals were identified	3rd to 4th		1st to 2nd; 6th or more	
Duration (weeks) of the period in which newly-affected premises were identified	9 or less	+	1 to 2; 12 or longer	
Duration (weeks) of the period in which newly-affected animals were identified	9	+	6 or less; 14 or longer	
Mean number or median number of livestock deaths per premises	5		14 or higher	
Percent-mortality in cattle on the affected premises	6%		12% or greater	
Percent-mortality in horses on the affected premises	17%		25% or greater	
Percent-mortality 14 days after vaccination compared to percent-mortality prior to vaccination	Lower		Higher	
Molecular typing of *B. anthracis* isolate from affected animals	Isolated previously		Not isolated previously	

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