Surveillance for Hemorrhagic Disease in White-tailed Deer and Other Wild Ruminants, 1980–1989[1]

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Abstract: The orbiviruses, epizootic hemorrhagic disease (EHD) virus or bluetongue (BT) virus, cause a disease syndrome termed hemorrhagic disease (HD) in white-tailed deer (*Odocoileus virginianus*) and several other wild ruminants. An annual mail survey of state wildlife agencies was conducted from 1980–1989 to estimate the occurrence of HD in the continental United States. Thirty-one states reported confirmed or suspected HD activity, and 1,608 occurrences were reported in 880 counties or parishes. Cases of HD were reported throughout most of the Southeast and much of the Midwest and northern Great Plains. Reports also were received from the Pacific Coast states. Death losses of deer accounted for 33.8% of the reports, whereas chronic, post-infection lesions alone were seen in 55.0%. Virus isolations were reported in 57 counties in 21 states; EHD virus was identified twice as often as BT virus. Recurrences of HD were noted during the 10-year period at both the state and county level. There was a strong geographic difference in the frequency of occurrence and clinical type of HD; the disease syndrome was milder but more frequent in the southernmost states of the southeastern United States.

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The term hemorrhagic disease (HD) describes infection of white-tailed deer with epizootic hemorrhagic disease (EHD) virus or bluetongue (BT) virus (Prestwood et al. 1974, Couvillion et al. 1981, Thomas 1981). Both EHD and BT can cause high death losses in wild deer populations, and the clinical manifestations of infection with either virus are indistinguishable. Because many incidents occur where virus isolations are not achieved from deer with typical lesions, the term HD often is used for unconfirmed cases. Both EHD and BT viruses are transmitted by biting midges of the genus *Culicoides* which are widespread in the United States.

The relative numbers of animals received for diagnostic studies indicates the importance of HD as a deer mortality factor. This disease ranked second only to trauma as a diagnostic finding in deer submitted to the Southeastern Cooperative Wildlife Disease Study (Couvillion et al. 1981). At present, preventive or therapeutic measures are not available, and wildlife managers can react to deer die-offs only by attempting to confirm the cause and by estimating mortality. In 1967, Shope stated that EHD "constitutes one of the major unresolved problems in management of the white-tailed deer population on this continent." To learn more about the epizootiology of HD in wild deer, which might lead to disease control or prevention mechanisms, a broad overview of HD activity was obtained by disease surveillance questionnaires from 1980–1989. The authors are greatly indebted to the many wildlife biologists throughout the nation for their diligence in responding to the questionnaires.

Methods

Questionnaires, similar to that used by Couvillion et al. (1981), were mailed each fall to the wildlife administrator and selected biologists of the state fish and wildlife agencies at addresses obtained from the Conservation Directory published by the National Wildlife Federation, Washington, D.C., for the appropriate year. The inquiry was posed as follows:

Any of the following criteria should be reason to suspect HD in a deer population:

Criterion 1. Sudden, unexplained high deer mortality during the later summer and early fall of 19___.

Criterion 2. Necropsy diagnosis of hemorrhagic disease as rendered by a trained wildlife biologist, a diagnostician at a State Diagnostic Laboratory or Veterinary College, or by SCWDS personnel.

Criterion 3. Isolation of Epizootic Hemorrhagic Disease Virus or Bluetongue Virus from a white-tailed deer. Please do not include results for blood serum antibodies.

Criterion 4. Observation of hunter-killed deer that show sloughing hooves (2 or more feet), ulcers in the mouth, or scars on the rumen lining.

Please list the counties in your state where hemorrhagic disease was suspected or confirmed based on any of the aforementioned criteria. If possible, place the criteria number(s) that were used for each county.

Rationale for criterion 1 was based on observations that deer mortality due to HD is highly seasonal. Criterion 4 was used because chronic lesions of HD are manifested by hoof, mouth, or rumen lesions (Couvillion et al. 1981, Thomas 1981).

For 1980 and 1981, only the 16 southeastern states were polled; all states except Hawaii were included from 1982–1989. Respondents were asked to provide their name and telephone number so that unclear answers could be further evaluated. Each winter, an interim report was prepared from the questionnaires, and this report was sent to the states for review and corrections. Telephone contact was made with state agencies that failed to respond to the survey in order to receive a reply from every state. A final report was submitted to all state fish and wildlife agencies on an annual basis to help maintain interest in the study. In addition to state fish and wildlife agency personnel, biologists with the U.S. Fish and Wildlife Service and veterinary diagnosticians referred to the authors by state agencies were included in the annual mailing.

Tests for independence were performed using the G-statistic with the Yate's correction for continuity (Sokal and Rohlf 1981).

Results

During the 10-year period, 31 states reported confirmed or suspected HD activity in deer based on the questionnaire criteria (Fig. 1). One thousand six hundred eight instances were recorded in 880 counties. Nearly contiguous instances of HD were reported throughout the Southeast and in a transverse band in the general direction of the Missouri River northwestward through the Great Plains. Another nearly contiguous band of observations was in coastal and northern California extending into central Oregon and western Washington. Isolated reports came from Texas, Utah, and Wisconsin.

Reports were received that included either a single criterion or multiple criteria covering all possible combinations of criteria 1 through 4. Sudden, unexplained high deer mortality during late summer/early fall (criterion 1) was reported from 568 counties, and necropsy diagnosis (criterion 2) of HD was reported in 233 counties.

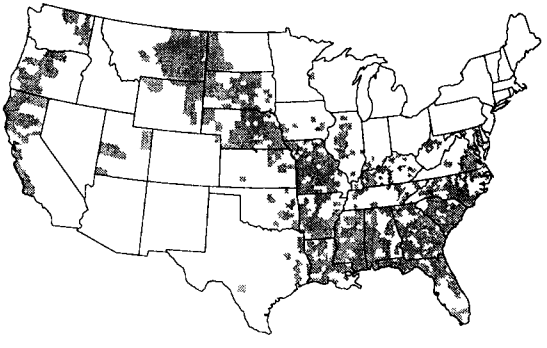

Figure 1. Reports of hemorrhagic disease in wild ruminants from 1980–1989 in the United States.

Virus isolations (criterion 3) were reported in 57 counties in 21 states. EHD virus was reported in 18 states (Alabama, Arkansas, California, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Missouri, North Carolina, North Dakota, Nebraska, South Dakota, Virginia, Washington, West Virginia), and BT virus was isolated in 8 (California, Georgia, Illinois, Nebraska, Oklahoma, South Carolina, South Dakota, Wyoming). EHD virus was given as the virus isolated in 36 (63%) of the instances reported. BT virus isolation was indicated in 17 instances (30%), and 4 (7%) accounts did not give specific information. Nineteen instances of virus isolations were given without a necropsy diagnosis. When these were added to the 233 accounts of necropsy diagnosis, the data indicated that HD was confirmed by virus isolation in only 22.6% (57/252) of the cases where necropsies were performed. Unfortunately, the number of virus isolation attempts could not be determined.

All states with HD activity except Colorado, Washington, and Wisconsin provided observations of HD for more than 1 year during the survey. In fact, 18 of 31 states had evidence of HD during 5 or more years (Table 1). For contrast, data from 7 states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina) were compared against the remaining states to show geographic differences. The aforementioned strongly "endemic" states were chosen because they each had evidence of HD for $\geq$8 years during the study and $\geq$60.0% of their county reports were limited to chronic lesions (criterion 4). Nationwide, 57.1% of the 880 counties with confirmed or suspected HD were reported for only 1 year, and multiple years of reporting were given for the remaining 42.9% of the counties. Repeat reports for 6 to 9 years were received for counties in the strongly "endemic" southern states (Fig. 2).

Overall, the report of chronic lesions of HD, as indicated by a response only to criterion 4 of the questionnaire, i.e., sloughing hooves, ulcers in the mouth, and scars on the rumen, was the most frequent observation returned (884 reports; 55.0%). Deer mortality indicated by reports in criteria 1, 2, or 3, i.e., unexplained death losses, necropsy diagnoses, or virus isolations, were reported less frequently (544 reports; 33.8%). Combination of acute and chronic forms, termed a mixed

Table 1. Number of years that hemorrhagic disease (HD) was suspected or confirmed in various states as reported by surveillance questionnaire (1980–1989).

N years reported	States reporting HD
10	Alabama, California, Florida, Georgia, Mississippi, South Carolina
9	Arkansas, Kentucky
8	Louisiana, Oklahoma, Tennessee
7	Nebraska
6	Montana, Virginia
5	North Carolina, Oregon, South Dakota, Texas
4	Iowa, Maryland, Missouri
3	Illinois, Kansas, North Dakota, Utah, Wyoming
2	Indiana, West Virginia
1	Colorado, Washington, Wisconsin

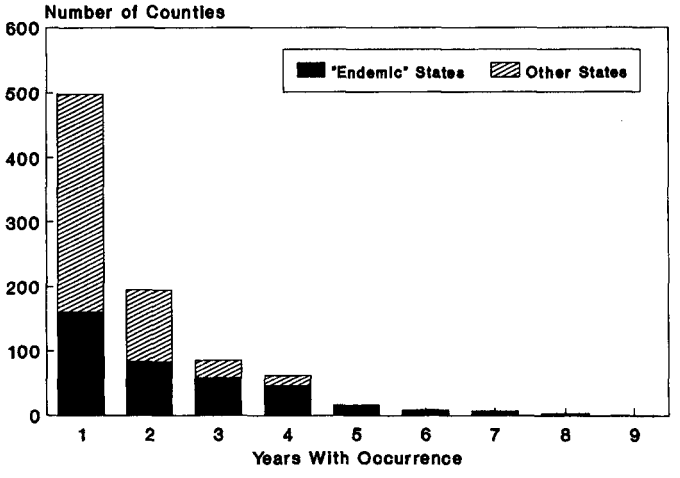

Figure 2. Number of years that hemorrhagic disease was observed per county, 1980–1989.

type, were reported least (180 reports; 11.2%). The clinical type of HD (acute, mixed, or chronic) reported was dependent upon geographic area ($P < .0001$). Death losses predominated outside the Southeast, whereas chronic lesions were most evident in the endemic area (Table 2).

When HD was reported in a certain county, review of the nationwide data set revealed that an adjacent county had reported the disease during the prior year 39.2% of the time. Furthermore, HD had been seen in the same county the year before in 19.2% of all instances reported. One or more counties adjacent to the affected county had concurrent HD activity in 82.9% of the reports.

In 273 instances, HD was reported from the same county on consecutive years (Table 3). When this data set was subdivided geographically, strong trends were revealed for the chronic lesions to repeat in the South. Annual repetition of acute infections in the same county was far more likely to occur in states outside the endemic zone.

Table 2. Instances of hemorrhagic disease (HD) reported by county during surveillance questionnaire, 1980–1989. Death losses correspond to responses for Criteria 1, 2, or 3; chronic lesions correspond to response for Criterion 4. Mixed type corresponds to observations of a combination of acute and chronic forms.

Geographic area	Deer mortality	Mixed type	Chronic lesions
Endemic states[a]			
N = 887	88 (16%)	101 (56%)	698 (79%)
Other states			
N = 721	456 (63%)	79 (44%)	186 (21%)
All States			
N = 1,608	544	180	884

[a]Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina.

Table 3. Change in clinical type of hemorrhagic disease (HD) observed over consecutive years in 273 counties, as reported in surveillance questionnaire, 1980–1989.

Change in HD type	Nationwide	Endemic states[a]	Other states
Acute to acute	14.3%	1.0%	45.7%
Acute to mixed	1.8%	0.0%	6.2%
Acute to chronic	4.0%	4.2%	3.7%
Mixed to mixed	2.6%	2.1%	3.7%
Mixed to chronic	4.0%	5.7%	0.0%
Mixed to acute	1.8%	1.0%	3.7%
Chronic to chronic	64.8%	80.2%	28.4%
Chronic to mixed	1.1%	0.5%	2.5%
Chronic to acute	5.5%	5.2%	6.2%

[a] Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina.

The year of peak HD activity was not synchronous, even for adjacent states. The peak number of counties reported per state for the 10-year period are as follows:

1980—Oklahoma ($N = 2$), South Carolina ($N = 34$);
1981—Arkansas ($N = 34$), Oklahoma ($N = 2$);
1982—Florida ($N = 19$);
1984—Colorado ($N = 2$);
1985—Alabama ($N = 22$), Mississippi ($N = 50$), Texas ($N = 5$), Wisconsin ($N = 1$);
1986—California ($N = 11$), Virginia ($N = 20$);
1987—Indiana ($N = 3$), Iowa ($N = 3$), Montana ($N = 20$), North Dakota ($N = 12$), Washington ($N = 5$);
1988—Georgia ($N = 60$), Illinois ($N = 16$), Iowa ($N = 3$), Kansas ($N = 9$), Kentucky ($N = 18$), Maryland ($N = 8$), Missouri ($N = 71$), North Carolina ($N = 38$), Nebraska ($N = 36$), Tennessee ($N = 12$), Utah ($N = 2$), West Virginia ($N = 6$), Wyoming ($N = 3$);
1989—Iowa ($N = 3$), Louisiana ($N = 22$), Oregon ($N = 7$), South Dakota ($N = 22$).

The survey data did not clearly demonstrate a cyclic pattern for HD activity; however, the incidence rates of reporting from affected counties for the entire 10-year surveillance period differed when "endemic" states were compared with the others. As a whole, numbers of counties affected were low immediately before and after the peak year reported for a given state.

Discussion

During the 10-year course of this surveillance effort, we had many opportunities to discuss HD with participating biologists. Through these contacts, we recognized that there was a large variation in observer skill and effort among our survey participants. Both under- and over-reporting probably occurred. For exam-

ple, we doubt that all episodes of unexplained deer mortality reported were due to HD, and it is likely that there was wide variation in what was observed to be "sloughing hooves," the predominant chronic lesion observed. Nevertheless, we are confident that these data do provide a sound overview of HD distribution in deer. The contiguous geographic pattern (Fig. 1) derived through independent observations reported to us by over 385 wildlife biologists is evidence that the questionnaire was delivering good information.

Geographic differences in frequency and clinical manifestations of HD observed in this survey might be due to differences in the seasonality, abundance, or competence of *Culicoides* vectors. Bluetongue virus surveillance in Central America, the Caribbean, and Florida has shown that viruses are commonplace but that clinical disease is nonexistent (Gibbs et al. 1983, Gibbs and Greiner 1983, Gumm et al. 1984). Companion surveys for *Culicoides* in the Caribbean and Florida revealed that midges were present nearly all year (Greiner et al. 1984, Kramer et al. 1985). Under these hyperendemic conditions, young animals might be receiving "vaccinating" doses of EHD and BT viruses early in life while maternal antibodies provide protection from severe disease. In contrast, *Culicoides* populations in more temperate states may be distinctly seasonal, and sudden "blooms" of midges may result in delivery of higher virus dosages to immunologically naive animals.

Confounding the possible effects of seasonality and abundance of *Culicoides* is the likelihood that genetic variants exist among *Culicoides* populations that possess dramatically different virus vector capabilities. Selective breeding of laboratory-reared *Culicoides variipennis* resulted in flies that ranged from 2% to 92% for susceptibility to oral BT virus infection (Jones and Foster 1974). Further studies have shown that field populations of *C. variipennis* differ widely in their susceptibility to BT virus serotypes (Jones and Foster 1978). Other unstudied species of *Culicoides* also may have similar variation in regard to their vector capabilities.

When the geographic distribution of HD reports in wildlife is compared to recent serologic surveys for BT and/or EHD in deer or livestock, there is strong agreement on the lack of virus activity in the northeastern United States (Metcalf et al. 1981, Osburn and Miller 1989). In contrast, the absence of HD reports in deer and other wild ruminants in the Southwest and Rocky Mountain Regions is notable, particularly since serologic studies have revealed high prevalence rates for BT antibodies in cattle (Metcalf et al. 1981), white-tailed deer (Trainer and Jochim 1969, Hampy et al. 1979), bighorn sheep (Trainer and Jochim 1969), Barbary sheep (Trainer and Jochim 1969, Hampy et al. 1979), elk and pronghorn antelope (Trainer and Jochim 1969) in these areas. Antibodies for EHD virus have not been surveyed extensively in these areas even though EHD virus is known to occur in Colorado (Foster et al. 1980, Thompson et al. 1988). Although EHD virus and BT virus were incriminated as causes of deer deaths in the current survey, EHD was more prevalent. Given that the known distribution of EHD viruses corresponds better geographically with the clinical observations in this survey than does the distribution of BT viruses, there is a possibility that EHD virus is more significant than BT virus to deer populations.

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