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BRUCELLOSIS IN THE WIND CAVE BISON HERD

James E. Cole, Biologist
Region Two Office
National Park Service

August 5, 1949

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TRANSMISSION OF BRUCELLOSIS BETWEEN BISON AND CATTLE

Management of the Wind Cave bison herd for control of brucellosis apparently has been considered necessary partly because of the possibility that the disease may be transmissible from infected park animals to domestic cattle on adjacent ranges. The several aspects of this problem will be discussed in the following order:

1. Significant Pathological Factors.
2. Drainage as a Factor in Transmission of Brucellosis.
3. Carriage of Infective Material by Scavengers.
4. Transmission of Brucellosis by Other Animals.
5. Disease Status of Animals in Land Adjacent to Wind Cave National Park.

Significant Pathological Factors

The following summary of important factors concerning brucellosis in cattle should be kept in mind in considering the transmission of brucellosis from bison to cattle and vice versa:

- (a) Brucellosis is a disease of the genital organs of both sexes (Lash and O'Rear, 1942).
- (b) The disease is not normally fatal to young or adult animals.
- (c) The male is a relatively unimportant factor in transmitting the disease (Lash and O'Rear, 1942).
- (d) Proof that bulls transmit the disease through the act of service is lacking (ibid.).
- (e) Infection occurs mainly through the digestive tract (Richhorn and Crawford, 1941).
- (f) The disease has a tendency to become chronic (Evans, 1947).
- (g) Cows that may have aborted once may abort a second time, but abortion in the same cow more than twice is an unusual occurrence (Mohler and Traum, 1911).

- (h) Following abortion some cows may recover from infection and thereafter remain immune or greatly resistant to reinfection (Eichhorn and Crawford, 1941).
- (i) Freedom from abortion does not necessarily indicate immunity, for only one-third to one-half of infected cows ever fully recover (Evans, 1947).
- (j) The infection generally leaves the uterus in three or four weeks; it rarely lasts longer; but may persist in the udder and associated lymph nodes for a longer period--in some cases for year (Traum, 1930).
- (k) A good proportion of infected cattle never show the virus in the udder, and soon rid themselves of the infection in this organ (Traum, 1930).
- (l) Most of the animals that contract the disease will become chronically infected in the udder. The udder infection may persist for several years and sometimes for the life of the animal (Eichhorn and Crawford, 1941).
- (m) The disease may be transferred to the uterus from the udder on succeeding pregnancies even though normal parturition occurs (Eichhorn and Crawford, 1941).
- (n) Experiments have indicated that cows which have ceased to eliminate germs from their udders possess a marked degree of resistance to infection (Buck, 1933).
- (o) It is unusual for the udder to become infected unless there is or has been infection in the uterus (Eichhorn and Crawford, 1941).
- (p) In pregnant cattle the Brucella organisms reach the cotyledons (connecting tissues between placenta and fetus) and eventually cause necrosis of the cells resulting in premature expulsion of the fetus (Eichhorn and Crawford, 1941).
- (q) The period of incubation is usually about 3 months but under unusual conditions may vary from 6 weeks to 6 months (Eichhorn and Crawford, 1941).
- (r) Abortion may occur any time after the second month of pregnancy depending upon the susceptibility of the animal and the period during pregnancy when exposure occurs. When exposure occurs from late in the seventh month to early in the ninth month, a living but weak calf may be expelled. By far the greatest number of abortions occur during the fifth to the seventh month (Eichhorn and Crawford, 1941).

- (s) Nonpregnant females eliminate Brucella organisms after ingesting or otherwise being exposed to them (Eichhorn and Crawford, 1941). Heifers from aborting cows may be less susceptible than those born to noninfected cows (Mohler and Traum, 1911).
- (t) Calves show a marked resistance to the disease (Buck, 1933). The germs are not known to localize in the bodies of young calves. When calves harbor the infection in their bodies at birth, it is usually overcome in a reasonably brief period (Buck, 1933).
- (u) In some herds that have been freed from the disease by test-and-slaughter methods, it has been impossible to keep them clean and reinfection has been more disastrous than the initial infection (Hendricks, 1939).
- (v) The most common manner in which brucellosis is transmitted to a clean herd is through the introduction of infected animals (Eichhorn and Crawford, 1941).
- (w) In chronic infection in a herd, abortions are most often confined to additions to the herd and to heifers during their first pregnancy after exposure (Eichhorn and Crawford, 1941).
- (x) There is no drug, chemical, or medical compound that has been proved to be effective in the prevention or cure of Bang's disease (Eichhorn and Crawford, 1941).
- (y) The agglutination test has its limitations and is not 100 percent authentic (Eichhorn and Crawford, 1941; Corn, 1942).
- (z) Calfhood vaccination in calves of domestic cattle provides considerable protection for the first gestation period after exposure, but the immunity is challenged in the third and fourth gestation periods (Beach, et al., 1947).

Whereas a considerable amount of factual knowledge exists concerning pathology of brucellosis in cattle, the known data for bison are quite meager. For purposes of management, it has to be assumed, until demonstrated otherwise, that the above factors are the normal reactions of the disease in bison. There is some evidence, however, which indicates there are differences between the processes and effects of the disease in bison and cattle.

Undoubtedly, Dr. Coburn will indicate these differences in his forthcoming report on brucellosis in the Wind Cave and Yellowstone buffaloes.

The following items constitute the pertinent information regarding brucellosis in bison:

(1) There is no possibility of determining whether brucellosis was a disease of the American bison before introduction of domestic cattle into the buffalo country (Turnicliiff and Marsh, 1935).

(2) Evidently brucellosis does not produce abortion in the buffalo herd or at least in so small a proportion that it becomes insignificant (Turnicliiff and Marsh, 1935).

(3) There is considerable evidence that buffaloes are quite resistant to the strains of Brucella infection with which they are known to be infected. All strains of Brucella isolated from buffaloes have been found to be of the abortus species. There is no reason to believe that they are different from the strains which infect domestic cattle (Coburn, 1945, August 20).

(4) Adult male bison appear to be more susceptible to brucellosis infection than are the males of domestic cattle (Turnicliiff and Marsh, 1935).

(5) Infectivity of the bison strain of brucellosis to cattle remains undetermined (Quortrup, 1945, May 9).

(6) There was a marked decline in the percentages of reacting bison cows in Yellowstone from three to six years of age (Turnicliiff and Marsh, 1935).

(7) Post mortem examinations did not show any difference between breeding condition of bison cows and their reactions to the agglutination tests (Turnicliiff and Marsh, 1935).

(8) The responses shown as a result of calfhood vaccination is considered very satisfactory. The degree of reaction produced in 28 of 42 head is considered good evidence of immunity production in yearling bison vaccinated as calves (Coburn, 1947, February 27).

Drainage as a Factor in Transmission of Brucellosis

In earlier discussions of the transmission of brucellosis, (Buck (1933) considered it probable that the disease could be "introduced through

a pasture that receives drainage from a farm where the malady is present." Lash and O'Rear (1942) advise the diversion of drainage from infected premises. Eichhorn and Crawford (1941) considered the possibility of transmission by drainage, although remote, should be recognized. These authors in discussing flies as a possible factor in transmitting the disease stated, however, that groups of infected and healthy cattle have been maintained for years on the same premises, but in separate fields at the Bureau of Animal Industries Animal Disease Station, Beltsville, Maryland, without the spread of the infection from diseased to normal cattle.

The results of an experiment related by Quortrup (1944) in which a clean herd of cattle was fenced in on a slope below an infected herd--the two herds being separated by a fence only--yet the clean herd did not become infected--led him to conclude, "This would indicate that possible brucellosis dissemination to the outside of the park Yellowstone through water drainage would be remote."

On the basis of laboratory determinations made by the Chief of Laboratory Service, Bushnell General Hospital, Brigham, Utah, of buffalo feces collected in Yellowstone, Quortrup (1945, May 9) advised Dr. Coburn, "The data on hand would indicate that the bodily discharges studied do not constitute a serious hazard with regard to dissemination of brucellosis in Yellowstone Park to the surrounding areas."

While Brucella organisms will remain alive in water for periods of several days and can be transported by running water (see section on "Maintenance of a Disease-Free Herd"), the intermittent character of the Wind Cave streams flowing from park lands to adjacent range land would seem to constitute reasonable cause to question the danger of transmitting the disease by drainage.

In the semi-arid climatic zone in which Wind Cave is located, the dry season is April through September. The streams draining from the park are not flowing in these months except following occasional thunder storms. According to Eichhorn and Crawford (1941) "... the larger the stream and the faster it flows the less danger there is ..." of infection being carried by streams.

Until it has been demonstrated that brucellosis is transmissible by drainage under conditions prevailing at Wind Cave (aridity and free-roaming animals on large ranges), it is believed that the available evidence is sufficient to question seriously the need of controlling brucellosis in the Wind Cave bison to prevent possible transmission of the disease to areas outside the park.

Carriage of Infected Material by Scavengers

This subject is discussed at some length by Quortrup (1944) and contains the views of Mr. Olaus Murie. Quortrup concludes by stating, "It does not appear from Mr. Murie's comments that scavengers would play any appreciable role in the brucellosis picture [at Yellowstone] as mechanical carriers."

Transmission of Brucellosis by Other Animals

The possibility exists of extensive spreading of the disease by coyotes which may be actively infected with brucellosis. "The canine species are known to be susceptible to Br. abortus and Br. suis" (Coburn, 1945, February 6), and a few cases of brucellosis infection in dogs have been reported in this country (Evans, 1947).

Other animals susceptible to brucellosis infection are horses, and rodents (Evans, 1947), moose (ibid.), deer (McKean, 1948), pigeons, turkey, duck, pheasant, goose, and rat (Katz, 1941).

With regard to transmission of brucellosis, the important factor is whether the disease can be passed from these animals to cattle. Not many references in the literature have been found regarding this phase. Several investigators (Fitch and Dodge, 1939; Stone, 1943, and others) believe the disease is transmissible from horses to cattle. Eichhorn and Crawford (1941) after relating an experiment in which two horses, afflicted with fistulous withers from which Brucella abortus was recovered, were placed with six normal pregnant cattle and the disease was not spread from horses to cattle, concluded: "It appears, therefore, that equines play only a minor part in the spread of this infection to cattle." On the other hand, the 1947 Executive Officers report to the Montana Livestock Sanitary Board states: "... that a number of what were thought to be obscure outbreaks [of brucellosis] were traced definitely to the introduction of diseased horses."

Katz (1941) states that there is no evidence the birds listed above pass Brucella organisms along to cattle. With respect to the wild rat, he also states it can pass viable organisms in the feces and urine but there is no proof that infected rats can pass the organism back to cattle.

The above discussion indicates that while it is known that many animals besides cattle and bison are susceptible to Brucella organisms, not too much is known concerning its transmission back to cattle. Certainly there is insufficient data upon which to predicate control of any Wind Cave wildlife based upon the possibility that cattle on adjacent ranges might be infected by these other animals.

The carrying and transmission of brucellosis by elk involves many factors. It is known that the infection exists in the Wind Cave elk, and it is suspected to exist in elk in Custer State Park. Moreover, there are good reasons for believing that the game fences around these parks do not prevent intermingling of the Black Hills elk herds. Consequently, the disease may be widespread provided elk are as susceptible to the infection as are cattle and bison.

There are entirely too many unknowns about brucellosis in elk to permit any safe conclusions. Although "The elk is proven an animal susceptible to Br. abortus infection, as demonstrated by the presence of specific serum agglutinins" (Katz, 1941), Coburn (1945, February 6) states, in discussing the work of Hadley Marsh reported in the June 1935 issue of Journal of the American Veterinary Medical Association, "It is possible that a certain number of reactions observed in these animals were the result of contact sensitization rather than specific infection. However, it is not the commonly accepted practice to so interpret such reactions nor to minimize their importance in evaluating a disease condition." In addition, Katz (1941) points out, "Laboratory tests with elk serum evidenced great irregularity between rapid plate and tube tests. This occurred in spite of the use of three antigens which gave constant reasonable agreement of cattle serum tests. Those who may consider use of the agglutination test for elk should remember these irregularities. Why they occur has not been answered."

Regardless of the fact that agglutination tests show evidence of brucellosis infection in these elk, Albert M. Day (1944) wrote, "There has been no evidence of immature births or abortions among the northern Yellowstone elk that were traceable to brucellosis." In Jackson Hole, Olaus Murie (1934) records, "By a study of blood serum we have demonstrated the presence of contagious abortion amongst these elk. Many cow elk fail to produce a calf in the spring and many abortions have been observed." However, there is no evidence presented to demonstrate brucellosis was the causative agent. Malnutrition or other facts could have produced the abortions.

"The finding of reactor animals in the elk herd substantiates the fears of cross-infection between the bison and elk. The problem of contact with domestic cattle through the medium of the elk migration is also confirmed. No solution for the problem under present conditions is apparent." (Coburn, 1948)

Considerably more investigations will have to be made before facts will be available to prove or disprove the assumptions that elk are capable of transmitting brucellosis to bison, or cattle, or to other elk. While

available information indicates elk produce agglutinins, there apparently have been no post mortem examinations made to demonstrate that Brucella organisms produce necrosis of the elk cotyledons as occurs in cattle.

Since elk and bison will use the same watering places at Wind Cave, there will always be a good possibility of transmitting the disease if elk eliminate viable organisms in body discharges or in aborted fetuses or uterine discharges.

Disease Status of Animals on Lands Adjacent to Wind Cave

The only information at hand on this phase is quoted below from Mr. Liek's memorandum to the Regional Director dated September 13, 1948:

"Until such time as the State and Federal laws require the testing and vaccination of all livestock including removal of all positive reactors and Custer State Park launches a comprehensive disease survey and control program, there appears little value in our program. Custer State Park has not been accused of harboring a brucellosis reservoir or requested to control such. Neither has there been any great activity among the ranchers. The Sanson Brothers, and the 7-11 Ranch, both adjoining the park, vaccinate the calves, but no tests are run on the range stock. The Streeter Brothers run no foundation stock, but buy light steers, heifers, cows, and run them through the grass-fattened stage, or until the market is right, and then sell. They carry out no brucellosis control work, nor is the stock they purchase certified free from brucellosis. The three described operators occupy land along one-quarter of the park boundary and are somewhat typical of the other adjacent operators ... According to the County Agent very few ranchers practice any type of brucellosis control, except for testing dairy cattle. There has been no active campaign to eradicate brucellosis, and the State laws do not make brucellosis control in range animals mandatory."

It would thus appear that the National Park Service is the only owner of grazing animals in the immediate vicinity of Wind Cave National Park that has tried to control brucellosis in range animals. If the disease is transmissible by any of the means discussed above, it would appear that the disease cannot be eradicated and kept out of one herd unless all owners instigate and successfully eradicate the disease from their herds. Any such program, however, would be jeopardized by operators such as the Streeter Brothers who import untested cattle including heifers and cows.

In this connection the fact should be kept in mind that there is a difference in the management of herds of cattle between operators of dairy

and blooded breeding herds and range herds. The first operators are required to maintain clean herds and eradication of brucellosis is possible because the herds are confined. While some brucellosis control is frequently exercised by owners of range stock, testing and vaccination are not required nor universally practiced. Management of bison for disease control is more closely analogous to methods used by operators of range cattle than dairy cattle.

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Marsh and Welch (1940) pointed out by stating, "It seems evident that the methods which have been evolved for the control of Bang's disease in dairy and purebred cattle should be modified to make them applicable to the range and semi-range conditions under which beef cattle of the West are handled."

Dr. Coburn in a November 26, 1948, memorandum considered that the "spread of infection at Wind Cave from the buffalo herds to domestic cattle is highly probable," but in Mr. Drury's memorandum, dated January 10, 1949, which Dr. Coburn had read and in which he concurred, in connection with the possibility of reinfection of a disease-free bison herd, this statement occurs: "Domestic cattle and bison are so definitely antagonistic, and stock is so well excluded from the park range, that they cannot be considered an actual hazard." The interpretation given this statement is that diseased domestic cattle on adjacent ranges would not be an actual hazard in disseminating brucellosis to the Wind Cave bison.

It is difficult to reconcile these two statements. It is not evident in view of the above discussions on transmission of brucellosis why transmission of the disease from bison to cattle is highly probable, but transmission from cattle to bison is not an actual hazard.

The entire question, however, is quite academic since the National Park Service is the only owner of grazing animals in the vicinity of Wind Cave that has seriously attempted to control the disease. If brucellosis exists in adjacent range stock and as it undoubtedly does in the Custer State bison herd, transmission of the disease from one herd to another will always be a possibility until all owners instigate control programs. It does not appear probable that a valid criticism can be directed against the National Park Service by any individual directly involved until he has cleaned up his herd.

Until there is a State-wide program in South Dakota to eradicate brucellosis in range cattle and State laws prevent introduction of diseased animals, the eradication of brucellosis from the Wind Cave bison herd would play an insignificant role in preventing spreading of the disease in the area around the park.

EFFECTS OF BRUCELLOSIS ON BUFFALO REPRODUCTION

The first policy in the section on wildlife states, "Every species in the areas of the National Park System shall be left to carry on its struggle for existence unaided as being to its greatest ultimate good, unless there is real cause to believe it will perish if unassisted." (above and following underlining supplied)

In view of this policy statement, management of Wind Cave buffaloes for control of disease would appear appropriate if no other factors were involved, only if the disease endangered the existence of the herd.

As a disease in cattle and, so far as is known in bison, brucellosis is not fatal to adult animals and with the exception of a small proportion of "weak calves," is not normally fatal to the young. It is a disease primarily of pregnant females which frequently produces abortions in cattle in the first and second pregnancies and less frequently in bison.

Brucellosis as a limiting factor in the survival of a herd of buffaloes is a disease which would be important only if the reproductive success of the herd was endangered. While brucellosis in confined herds of domestic cattle may drastically lower the reproduction rate of the herd when the disease is first contracted, there is no evidence or even suggestion that the same thing occurs in herds of free-roaming buffaloes which have had the disease for many years.

On the contrary, all the evidence at hand indicates brucellosis in bison herds does not significantly reduce the herd productivity. Tunnicliff and Marsh (1935) in reporting on brucellosis studies made of Yellowstone and National Bison Range buffaloes states, "The number of calves has been greater [in 1931 and 1932] than would ordinarily be expected among range cattle with such a high percentage of [brucellosis] reacting cows." These veterinarians believed that the ratio of buffalo calves to cows on the Bison Range in 1932 was slightly less than 74 percent and concluded, "Evidently there has been very little ill effect upon the reproductive organs of these cows up to the present time, since a 70 percent calf crop from range cattle free from Bang's disease would be very close to an average for Montana."

In a Special Report on Yellowstone National Park Bison prepared by Assistant Chief Ranger Curtis K. Skinner (1944), the following comments of two veterinarians are quoted:

Dr. E. R. Quortrup: "Evidently brucellosis does not produce abortion in the buffalo herd or at least in so small a proportion that it becomes insignificant."

Dr. F. D. McKenney: "Although there seems to be little noticeable effect of this disease on buffalo, it does constitute a focus of infection for possible spread to domestic livestock."

Tunnicliff and Marsh, in the above-mentioned study summarize their findings regarding this phase as follows: "The only conclusion which can be drawn is that, while the infection is evidently active in the Yellowstone herd, any reproductive inefficiency which may exist is not entirely due to Brucella infection in the cows."

Dr. E. R. Quortrup (1944) in considering the pathology of brucellosis in bison stated, "Abortions have been known to occur on the Yellowstone range as well as in the corrals at the Buffalo Ranch, but never to the extent that the situation might be considered serious in regard to the natural perpetuation of the herd. If control methods are to be instituted, this should be done to avoid public criticism and to facilitate future live shipments rather than to safeguard the herd itself."

So far as known no pathological examinations have ever been made of aborting buffalo and their fetuses to ascertain whether brucellosis was the causative agent. Dr. Coburn has found that some bison cows, at time of testing, showed evidence of recent abortions and in every instance such cows were positive reactors. Considering the rough handling bison receive when being corralled, sorted, and tested, in addition to the punishment bulls inflict on cows when confined in small pens, these abortions could easily be due to factors other than brucellosis, even though the aborting cows were positive reactors.

It is a recognized fact that diseased bison abort much less frequently than domestic cows, and in this regard the observation of Traum (1930) is significant: "Abortion in cattle, however, does not invariably follow infection. Cattle may even give birth to normal full-time calves in a normal manner and still have infection in placenta and discharges, and in the udder and the super-mammary lymph nodes."

Dr. Don R. Coburn (1945, August 20) records, "There is considerable evidence that buffaloes are quite resistant to the strains of brucella infection with which they are known to be infected." In a recent private communication he stated, "On various occasions I have agreed that the economy of the bison herd, from a reproductive standpoint, does not appear to be affected by B. abortus infection. Many herds of dairy cattle and beef cattle showing lower incidences of infection than has been demonstrated in the bison at Yellowstone and Wind Cave, have had to be abandoned."

Bison censuses in Wind Cave generally have not included sufficient data so that herd productivity can be evaluated. In February 1941, the female portion of this bison herd was reported by Park Ranger Suter (1941) to consist of 36 mature cows, 10 two-to-three-year-old heifers, and 8 heifer calves. The calf crop in the summer of 1941 numbered 37. While it is not possible to determine accurately the ratio of calves to cows from these figures because of the inclusion of two- and three-year-old heifers in the same group, since some three-year-old heifers produce calves and because some females were live-shipped, it is evident the calf-cow ratio that year was in excess of 80 percent.

The amount of infection present in the herd in 1941 is not known, but it was probably high because part of the Wind Cave bison originally came from Yellowstone where brucellosis has been known to exist since 1917. In 1945 when the Wind Cave herd was first tested, the evidence of infection of tested females was 88 percent.

Until positive evidence to the contrary is available, it is logical to assume, in view of the above, that brucellosis in bison does not jeopardize the existence of the Wind Cave buffalo herd and that there is no real cause to believe the herd will perish unless intensive management measures designed to reduce the incidence of the disease are continued. Since there is no cause for believing brucellosis endangers the existence of the herd and Service policy prescribes that "every species in the areas of the National Park System shall be left to carry on its struggle for existence unaided" there appears to be no reason to make an exception to this policy in the case of the Wind Cave bison.

VALUE OF A BRUCELLOSIS-FREE BISON HERD

The disease-control program in the Wind Cave bison, in addition to the desire to produce a disease-free herd and thereby eliminate criticism of the Service for maintaining reservoirs of the disease, has been designed to produce a brucellosis-free herd because the experiment would "prove of unusual interest to scientists and wildlife managers" (Tolson's memo October 23, 1944), and because it would result in "an outstanding natural exhibit." (Drury's memo of January 10, 1948)

The value of a brucellosis-free herd to scientists and wildlife managers is not disputed, but there would appear to be some question of experimenting with park wildlife to produce a disease-free status when it is not definitely known that the existence of brucellosis in bison is unnatural.

While there is no proof that brucellosis is an indigenous disease in bison, neither is there any proof that it is an exotic infection. The views of various informed persons on this phase are as follows:

"There is no possibility of determining whether this was a disease of the American bison before introduction of domestic cattle into the buffalo country." (Tunnickliff and Marsh, 1935) In the case of Yellowstone, there is a known possible source of infection from domestic cattle as a few were maintained on a part of the buffalo ranch until about 1919 (Rush, 1932). Prior to this time, however, the bison comprising the "tame herd" could have become infected from contact with domestic cattle on either the Howard Eaton, Charles Allard, or Charles Goodnight ranches from which some of the bison originally came. (Garretson, 1938)

Katz (1941) in explaining the high incidence of infection in bison males considers that it may be due to the fact that the infection is recent for the more susceptible host. Tunnickliff and Marsh (1935) in discussing this condition suggested that it indicated "buffalo may be more susceptible to Bang's disease than are domesticated cattle."

Quortrup (1944) stated, "It is probable that brucellosis has existed in the Yellowstone buffalo herd for a long time and that a natural immunity has been acquired through years of exposure. This is indicated by the relatively few abortions observed and rarity of gross lesions observed on post mortem examinations." Just what Quortrup means by a long time is not known, but ordinarily immunity to a disease is not naturally acquired by animal species in a few decades.

Quortrup sums up this phase by stating, " * * * it will never be known whether the disease existed originally in the Yellowstone bison

herd or whether it was introduced by cattle." He quotes Homes (1940) as stating that it is quite possible that brucellosis has existed for 4,000 years. "It is possible that brucellosis (Bang's disease) was present in the American bison before the introduction of domestic stock to this continent, but it is impossible now to prove or disprove the supposition" (Tolson's memo of February 29, 1944, to Mr. Marshal McLean).

Obviously the available information on this phase is not based upon any factual data. Since there is a possibility that brucellosis in bison is a natural condition and that the elimination of the disease in bison would produce an unnatural condition, it would appear, from the standpoint of Park Service wildlife policies, that the Park Service is not in a firm position in attempting to produce a disease-free herd because such a status would be of unusual interest.

With regard to the statement that a brucellosis-free herd would result in "an outstanding natural exhibit," it is not evident why the presence or absence of brucellosis would make any difference.

"The symptoms of brucellosis in cattle are rather inconsistent and indefinite. Abortion is probably the most widely known and readily observed symptom in cattle, but it may be easily misinterpreted since not all cows that abort are affected with the disease." (Lash and O'Rear, 1942) "Cattle may show no indication of the disease which, as a rule is not attended by any great inconvenience to the cow." (Traum, 1930)

Presumably, since infected bison abort less frequently than cattle, the symptoms of the disease and its effect on buffalo would be less than with cattle.

In discussing the artificial handling of Yellowstone buffalo, Mr. Cahalane in a memorandum for Mr. Drury dated December 27, 1943, wrote: "The aim of the Park Service is to maintain a natural spectacle. Animals should pursue their normal routine in normal numbers in an environment where they can find adequate food. This is the only presentation that can stand on its own feet over a long period of time." While this statement deals primarily with overstocking, the reference to a "natural spectacle" and pursuit of their normal routine would appear applicable to Wind Cave bison.

It would seem more consistent with Park Service policies not to practice control measures which are more artificial than winter feeding and which in themselves have more unfortunate consequences than artificial feeding.

BRUCELLOSIS CONTROL AND LIVE-SHIPMENT OF BISON

Another reason given for brucellosis control is the desire to produce brucellosis-free buffaloes so they can be live-shipped outside the park. This phase involves many factors including the assumption that brucellosis can be eliminated from bison herds as has been done with herds of domestic cattle, that vaccination always produces persistent immunity in calves, that the agglutination test always indicates whether a buffalo is infected with brucellosis, and that a "disease-free herd" of bison at Wind Cave will remain clean.

Eradication of Brucellosis from a Bison Herd

The question is not raised here whether brucellosis can be eliminated from a free-roaming bison herd by a combination of vaccination and removal of reactors and suspects as has been proved possible with herds of cattle. However, it should be noted, this is as yet a hypothesis and not a demonstrated fact. The question is raised, however, whether the Wind Cave bison herd can be managed in accordance with practices found necessary for eradicating brucellosis in herds of dairy and breeder cattle. Hendricks (1939) held, "It is not possible under range conditions to test the range and semi-range cattle frequently enough to produce clean herds."

One of the problems involved in this phase is the feasibility of rounding up all the bison on the range so the calves can be vaccinated and the adults tested and slaughtered if infected. Since the calves cannot be segregated from the herd on the open range, the entire herd, with the exception of a few solitary, old bulls must be corralled if all the calves are to be vaccinated. Dr. Coburn (1947, January 15) has held that only twice vaccinated and twice tested calves should be used for the nucleus of the "disease-free herd" and it is the general consensus that only vaccinated calves should be live-shipped.

According to Coburn (1944, February 14), reports of the Bureau of Animal Industry indicate vaccinations between the ages of 4 and 8 months, with the preference between 6 and 8 months, are most successful. Records of calf vaccinations under 4 months indicate that little protection is afforded. Animals of 18 months or older are often vaccinated but pregnant animals should never be vaccinated.

According to reports submitted by Park Ranger Suter from 1937 to 1944, bison calves are born in Wind Cave principally in April, May, and June the percentages being 29, 58, 13, respectively, for these three months. A few calves were born each year in the period between July and December.

The average over the 8 years covered by Suter's reports was 2 plus each year. During this period the average bison population was around 180 head. As the herd increases, calves born in the off-season will probably increase proportionally.

With regard to control for production of disease-free animals, it would appear that the calves should be vaccinated about the middle of November in order to produce the best results. All vaccination of Wind Cave buffalo calves has been made in late January and early February. This period is about 2½ months late if the most successful calfhood vaccinations are made between the sixth to eighth month. In 1947 two "large calves" were vaccinated. These calves may have been considerably older than optimum age when vaccinated. Each year, although there is no record made in the reports, a few quite young calves are vaccinated. These are late calves and some undoubtedly were less than 4 months old. Little protection was afforded these buffaloes by being vaccinated at this early age provided vaccination reacts with bison as it does with cattle.

It is possible that both the young and old calves can be identified by ear-tag numbers so they could be segregated from the buffaloes which received the more successful calfhood vaccinations. Such buffaloes should not, it is believed, be used for live-shipping or stocking the new area if a disease-free herd is to be established.

The principal problem in managing the Wind Cave bison for disease-control purposes involves corralling the animals. It appears from reports, with the exception of one year, that all of the bison have never been rounded up for testing and vaccination at Wind Cave. The bison apparently resent the confinement and intensive handling required for a successful test-and-slaughter and vaccination program. Each year they have become more wary and difficult to trap. This situation is covered in memoranda and reports from Wind Cave. In a memorandum of December 16, 1944, Acting Superintendent Watson wrote, "However, it is very unlikely that we will be able to corral all of the cows and calves every year, and in 1944 it was not possible to corral over half of the herd. We have used both the baiting and round-up methods to corral herds. Baiting is the most satisfactory method, but its full usefulness is dependent upon snowfall. Round-up is less satisfactory, more dangerous, and probably causes a greater calf loss due to "slumping" induced by excessive running than can be attributed to brucellosis. Therefore, it appears that the program will have to be based upon the fact that it will not always, or even usually, be possible to corral and vaccinate all eligible calves." Watson (1948) pointed out it required 17 days to trap the buffaloes and stated, "We are having a little more trouble each year as the herd has been through the same routine for the past four years. They will probably be a little harder next year as they were held in the holding pastures so long, and run through the squeeze-chute twice this year." The 1948 roundup was

not complete as a number of solitary bulls could not be baited or driven and one band of cows and calves led by two wise cows simply could not be approached, let alone be baited or driven. It was necessary to shoot all of these buffaloes resulting in the loss of a herd of truly wild buffaloes and some of the solitary, old bulls which undoubtedly were the finest specimens in the entire world.

Unquestionably, a number of cows and calves can be corralled each year. Sufficient calves could thus be made available for live-shipment, but it is doubtful if the entire herd can ever be corralled when the new area is added and the separating fences removed. Certainly a complete bison roundup cannot be made in November after the buffaloes are released in the new area where they will have nearly twice as much range as is now available, unless new capturing techniques are tried and found successful.

There is some question as to whether the test-and-slaughter program of the Wind Cave bison is done at the proper time. In handling range cattle, Marsh and Welch (1940) recommended the testing and removal of infected cows within three or four months after calving is completed. The recommendation of these veterinarians, who specialize in managing range cattle, is based upon the assumption, which is also held by many other investigators, that brucellosis is spread only at time of parturition or abortion and for a period not to exceed 30 days thereafter, and that nonpregnant cows are only slightly susceptible to infection.

Removal of positive reactors from the herd before abortion and early in pregnancy would give additional protection to the remaining susceptible animals. At Wind Cave this would require corraling in September or October. Since roundup methods are not feasible or desirable, and baiting would be completely unsuccessful during this time of the year, it is evident that bison cannot be managed in accordance with recommendations of Marsh and Welch. Removal of an infected bison cow after it has aborted will eliminate a potential source of reinfection during succeeding pregnancy periods, provided the animal aborts again. Since cattle rarely abort more than two times and bison abort less frequently than cattle, there is a good probability the slaughtered bison cow normally would not have aborted again. Slaughtering infected cows in January or February instead of September or October may not accomplish the expected results.

In addition to not preventing the spread of the disease, the disease-control program at Wind Cave may indirectly facilitate its spreading. Experience with diseases in wildlife has indicated the best way to spread

an infection is to confine the animals. Not only are bison closely confined for a period of several weeks during the operations, at a time of year when the pregnant females are highly susceptible to infection, but the treatment they receive, both from being handled and from other animals, is sufficient to cause abortions whether the disease is present or not. A diseased cow which has been hazed by a car, butted by numerous other buffaloes, driven through ice-covered corrals upon which she may have slipped, slid, and piled up against a fence with several other animals on top of her, jammed in gates by operators or bison, half-starved for a week or more, and finally squeezed twice in the testing chute certainly is a good way to produce abortions. Atkinson, et al. (1923) in discussing the causes of non-contagious abortions lists several of the above as contributory to premature births in domestic cattle. Induced abortions of diseased cows occurring in holding pastures would provide much more chance of contact of infected material than abortions on the range. Under these conditions, it is probable that the benefits derived from elimination of reactors are more than offset by the spread of disease due to confinement and rough handling. While some of the above mentioned practices could be eliminated most of them are inherent either with the character of the bison or with the management program.

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From the standpoint/calves for live-shipments, it should always be possible to corral a few cows and calves. The calves could be vaccinated and shipped. But if all the bison on Wind Cave have to be corralled every year for vaccinations, tests, and slaughter, it is believed the program cannot be successful without the expenditure of a considerable amount of funds for new physical improvements, additional equipment, and more personnel.

Immunity Provided by Vaccination

The practice of the Park Service is to live-ship only vaccinated calves and bison that react negatively to the agglutination test. The benefits from vaccination are not being questioned here. However, it should be pointed out that not all veterinarians, as indicated below, are in agreement that vaccinations of cattle calves always produce immunity.

"There is evidence to indicate that vaccine prepared from B. abortus strains of low virulence, when administered to unbred sexually mature cattle or during calthood, generally reduces the danger of establishing the infection in them and at the same time affords a serviceable degree of resistance against the disease." (Buck, 1933) However, the immunity that may be imparted has not given evidence of always being sufficient to afford complete protection against the disease (ibid.).

"It is true that the vaccine which has been developed for immunizing cattle against brucellosis has proven to be reasonably satisfactory for

cattle. Because of the fact that buffaloes are so closely related to cattle that they will interbreed justifies the belief that the vaccine would act similarly in buffaloes." (Shillinger, 1941) However, Beard (1941) stated that McKenney pressed doubt that there is sufficient evidence to conclude that buffalo react the same as cattle.

"Opinions differ with respect to calfhood vaccination program. Experimental work so far is promising. Some herds have been brought to an approximate disease-free status by a program of calfhood vaccination in combination with a test and slaughter method. Calves vaccinated between 4 and 8 months of age seem to develop a great deal of immunity. Those that react after a period of 18 months following vaccination are removed from the herd. Those that remain negative are added to the mature breeding herds. The mature animals that remain in the herd are tested annually, and where practical, semi-annually, and the reactors removed." (Hendricks, 1939)

"Vaccination is sometimes practical but it does not eradicate the disease and should only be done under expert advice." (Thompson, 1935) "We believe thoroughly and absolutely in the value of vaccination but no disease has ever been, or probably will ever be completely eradicated by vaccination alone." (1947 Executive Officers Report to the Montana Livestock Sanitary Board) "The aim in the use of vaccine in a brucellosis infected herd should be directed toward the eradication of the disease ... The eradication of the disease is possible only through the removal of the animals that continue to show an agglutination reaction on repeated tests." (Lash and O'Hear, 1942)

"It has been well established that considerable protection against bovine brucellosis is engendered in cattle for the first gestation period following their vaccination as calves with strain 19 of Brucella abortus. All reports of the results of tests of this acquired immunity, whether dealing with animals under controlled conditions or in the field, are in general agreement that vaccination with strain 19 definitely enhances the resistance of the animals. However, what proportion of the vaccinated animals is protected against a virulent strain of Br. abortus by calfhood vaccination with strain 19 is a question which has been answered somewhat differently by workers in different laboratories." (Beach, et al., 1947)

"Assuming, as had indeed been found to be true, that the majority of the animals vaccinated as calves will be protected from the causative agent of brucellosis in their first gestation period, one obvious question is that of the duration of this resistance ... The immunity of 23 animals vaccinated as calves, and of six vaccinated as young adults, with strain 19 of Br. abortus was challenged in the third gestation period of the first group

and in either the third or fourth of the second group. Each of the 10 controls aborted following exposure [to virulent strain No. 2308]. Among those vaccinated as calves, there were 12 cows [52%] which aborted, 2 [9%] with living, weak calves, and 9 [39%] with calves born alive at full term. Among those vaccinated as young adults, there were 2 [33%] animals with living but weak calves, 3 [50%] with normal calves, and 1 [17%] which aborted. These results indicate that there was a smaller number of resistant animals than would have been expected had the immunity been challenged in the first gestation period." (Beach, et al., 1947)

In another experiment reported by Richhorn and Crawford (1941) in which 70 animals vaccinated during calfhood and exposed artificially to Brucella abortus during pregnancy, the immunity was challenged in from 10 to 17%, depending upon interpretation of the experiment.

In a summary of the results of a study on field tests of effectiveness of vaccination of 260 herds in 24 states involving vaccination of 8,182 cattle calves, the figures presented by Lash and O'Rear (1942) show that 20 percent of the cows vaccinated as calves either aborted or had positive or suspicious reactions after calving. Since some of the aborting cows had negative reactions and the abortions were not considered due to brucellosis infection, the number of cows, vaccinated as calves, in which the immunity was challenged was at least 18 percent and could have been more because it is now believed agglutination tests do not invariably indicate the presence of the disease in pregnant cattle.

The findings of these investigators, while not in agreement, in connection with the qualifying statements of other quoted veterinarians, indicate quite strongly that calfhood vaccination does not immunize all the calves and that such immunization may be challenged in the third and fourth pregnancies of cattle which were resistant to the disease in their earlier pregnancies.

Thus live-shipment of vaccinated calves from infected herds is not complete protection against possible transmission of the disease. Also, these experiments and observations of veterinarians throw considerable doubt upon the success of the proposal to establish a disease-free herd by using vaccinated calves.

Reliability of Agglutination Tests

Live-shipment for restocking purposes of bison which have a negative response to the agglutination test has been considered a safe practice. Conflicting opinions as to the reliability of this test are held by investigators of brucellosis control in domestic cattle.

"While the test for Bang's disease is not 100 percent authentic, it does give a fairly accurate check on the amount of infection present in the herd. It is known that occasionally an infected animal will not react to a single blood test, and sometimes it will require several blood tests before a reaction is secured." (Conn, 1942)

Cotton (1939), however, stated that there was no "... indication that the state of pregnancy had any influence on the accuracy of the agglutination test. Moreover, experience in the field in connection with the Federal-State Bang's disease program seems to support these observations."

"The agglutination test, like most other biological tests for the detection of disease has its limitations. Its use is sometimes criticized because: (1) a single test does not allow a differentiation to be made between the different stages of infection of an animal; (2) on very rare occasions an animal may abort before a positive reaction to the test is obtained; and (3) low-titer reactions may sometimes result from causes other than Bang's disease.

"To one skilled in its interpretation, however, the agglutination test offers a very valuable and dependable means of diagnosing this disease and the degree of error in its practicable application is very slight. The fact that thousands of herds have been freed from infection through its use is evidence of the dependability of this test." (Eichhorn and Crawford, 1941)

"The period of incubation of the disease, which is the time elapsing between exposure and the first indication of infection (abortion or the development of a titer in the blood to the agglutination test) is variable. This period is usually about 3 months, but under unusual conditions may vary from 6 weeks to 6 months. A few instances have been reported in which pregnant cows did not react to the agglutination test until a short time after they calved. It is obvious, therefore, that a bovine animal although negative to the agglutination test, when purchased, should not be placed with a negative herd until further tests over a period of several months, and in the case of a pregnant cow until she has calved, continue to show the animal to be negative." (Eichhorn and Crawford, 1941)

"Because experiments have shown that Brucella abortus reactions are slow in developing and require as much as 3 or 4 months before demonstrable by agglutination tests, a single test cannot always be expected to give the owner of exposed animals definite assurance that they are not in the early stage of the disease." (Buck, 1933)

"It should be observed also that many young animals will react to the abortion tests even though they are not carrying an actual infection

in their systems. This is due to agglutinins resulting from ingesting milk from an infected cow or agglutinins in the blood stream developed as a result of the organisms passing through their systems as contaminated feed without becoming established as a disease in these young nonpregnant animals." (Shillinger, 1941)

These opinions cast a reasonable doubt upon the practice of live-shipping adult bison which have been tested once only. Moreover, they apply to domestic cattle in which brucellosis has been investigated for many years. Whether any or all of these conditions would hold for bison is not known.

In order to be absolutely safe and above criticism of transmitting brucellosis, the Park Service should only release bison from either Wind Cave or Yellowstone National Parks upon the understanding that the recipient will isolate the animals and have them retested. It should be the responsibility of the new owner to see that the bison are not run with domestic cattle until after a veterinarian has certified they are not infected. This should apply to vaccinated calves as well as adult animals. In the case of a pregnant heifer or cow the isolation and tests should be continued for at least 30 days after parturition.

Maintenance of a Disease-Free Herd

There is no assurance that a herd of bison freed of this disease will naturally remain clean. With reference to cattle, experience has shown that in some herds which have been freed of the disease by a test-and-slaughter program, it has been impossible to keep them clean, and reinfection has been more disastrous than the initial infection (Hendricks, 1939). The history of brucellosis of cattle in this country and the efforts to control the disease point to the conclusion that Brucella organisms are readily transmissible.

In this respect the Wind Cave bison herd is very vulnerable. With known infection in another bison herd which will be separated only by a single fence, and brucellosis demonstrated in the Wind Cave elk whose movements from infected to noninfected areas are not prevented by the fences, the probability certainly exists that a disease such as brucellosis eventually will become established again if there are susceptible animals in the herd. It should be pointed out here that it is more than just probably that there will be local concentrations of bison on both sides of the fence separating the Custer State Park and Wind Cave National Park bison herds. It can be assured that this will occur in the dry portions of the year because the best supply of permanent water occurs on both sides of the boundary fence. It originates from springs about a half a mile north of the boundary and flows across the boundary for a few hundred yards. Fine hay producing meadows will exist on both sides of the boundary fence and even without water these meadows would be natural concentration points.

Brucellosis organisms live in various media for varying periods of time. Experiments conducted by Quorstrup (1945, January 30) demonstrated that two strains of buffalo brucellosis organisms survived in Madison River water for 3 days and a third strain survived for 5 days. Coburn (1944, November 22) remarking on viability of brucellosis organisms pointed out that, "According to Bosworth Br. abortus will remain alive in an infected bovine fetus for 182 days. Bang noted that Br abortus was alive in infected exudate from the bovine uterus seven months after being stored in an ice chest. Cameron states that, "The organisms were found to live for four and one-half hours when exposed to direct sunlight ... four days in normal bovine urine at room temperature, ... for one hundred days in bovine feces which were kept in an unheated cellar and did not dry."

"The malady appears to be commonly acquired by the mouth in feed and drink contaminated with the germs, or by licking infected animals, contaminated mangers, or other objects to which the germs may adhere." (Lash and O'Rear, 1942).

"The danger of infection through streams is proportional indirectly to the size of the stream and its rate of flow, that is, the larger the stream and the faster it flows the less danger there is." (Richhorn and Crawford, 1941) Highland Creek flowing into Wind Cave is a small meandering stream.

In addition, since this watering place will undoubtedly draw and hold bison as do the present watering places in the park, it will be a good place for park visitors to observe buffaloes. Lash and O'Rear (1942) advised stockmen to be careful when visiting farms where brucellosis exists as the germs may be brought home on shoes and clothing. Richhorn and Crawford (1941) believed that carrying infection in this manner, although remote, should be recognized. This veterinarian, in discussing control, however, went on to advise the thorough washing of hands with soap and scrubbing--not dipping--of shoes in a disinfecting solution when leaving a maternity barn contaminated with Brucella organisms.

A third factor developed this year in connection with the winter storms. The blizzards drifted snow across the cattle guards permitting Custer State Park bison to enter Wind Cave National Park. If, as appears likely, a road will connect the two parks in the vicinity of Highland Creek, there is a possibility that Custer Park bison may mix with the Wind Cave herd or vice versa.

In any event, it would certainly appear probable that brucellosis will be carried across the boundary fence by at least one of the several possible agencies. While annual vaccination of the calves would immunize a large percentage of them, provided they respond to vaccine as do calves of domestic cattle, there would be a few unprotected which could become infected. Also, if immunization of bison as in cattle is challenged in the third or fourth pregnancy, many cows, even though vaccinated as calves, may become infected if exposed to quantities of Brucella organisms.

"Probably in no other infectious disease of cattle does the affected animal eliminate so excessive a quantity of infected material during a brief period as does the aborting cow." (Buck, 1933). The readiness with which susceptible, pregnant cows and pregnant heifers may be infected through the digestive tract by feeding them discharges from cows which have recently aborted has strongly indicated that the malady is commonly acquired by way of mouth ... Not only has it been possible to infect cows readily in this manner, but it has been accomplished when the quantities of material fed, containing the germs, have been surprisingly small." (ibid.)

While it is true that practically all of the above information refers to brucellosis of cattle, and may or may not directly affect bison in the same manner, it throws considerable doubt upon the feasibility of ever maintaining a clean herd in the new section of Wind Cave National Park without continuous control measures including yearly roundups, test-and-slaughter programs and calfhood vaccinations. As pointed out elsewhere, it is not believed that such programs are possible for all of the herd.

It must be admitted, however, that a solution can be found for practically any problem provided sufficient funds are available. With regard to the plan to create a disease-free herd so that Wind Cave bison could be live-shipped, the cost would be excessive. In combination with such other factors as brought out above and the domestication which would accompany intensive management, the efforts necessary to maintain a disease-free herd, in view of the uncertainties involved, would appear undesirable, unwarranted, and not in accordance with Park Service policy.

CONCLUSIONS

The data presented above are believed to constitute sufficient evidence to justify the following conclusions:

1. Transmission of brucellosis from bison to cattle on adjacent ranges by drainage, although always a possibility, is not probable under conditions which prevail at Wind Cave National Park.
2. Carriage of infected material by scavengers would not appear to play any appreciable role in spreading the disease.
3. Too little is known about the spreading of brucellosis by elk and other animals which are susceptible to the infection to permit any conclusions or to require any control of them.
4. Brucellosis is believed to exist in Custer State Park bison and suspected in cattle on ranges adjacent to Wind Cave.
5. Control of brucellosis in Wind Cave cannot be considered mandatory until concerted efforts by all owners of grazing animals in the vicinity of the park are made to eradicate the disease and laws exist to prevent its reintroduction.
6. Brucellosis in the Wind Cave bison does not jeopardize the existence of this herd. There appears to be no reason to make exceptions to the wildlife policy that every species shall be left to carry on its struggle for existence unaided as being to its greatest ultimate good.
7. Since it is not known whether brucellosis is an indigenous or exotic disease in bison, intensive management measures to eradicate the disease are not warranted on the basis that elimination of the disease would prove of unusual interest to scientists and wildlife managers.
8. The presence or absence of brucellosis in bison would be of no significance as an outstanding natural exhibit to Wind Cave visitors.
9. Wind Cave buffaloes cannot be corralled often enough with existing facilities and at the proper time of the year for effective control by test-and-slaughter methods.
10. Vaccination does not always give immunity to vaccinated cattle calves and the immunity imparted may be challenged in later pregnancies.

11. The agglutination test for brucellosis is not always 100 percent authentic in pregnant, diseased domestic cows. If similar conditions exist in buffaloes, the live-shipment of mature animals with only one negative test is not a thoroughly safe practice.

12. To be above criticism of transmitting brucellosis, the Park Service should release bison, either vaccinated immature or negative mature ones, on the understanding that it is the responsibility of the recipients not to run them with cattle until after a veterinarian has certified the bison are not infected with brucellosis.

13. The feasibility of maintaining a brucellosis-free herd on the new addition to Wind Cave is questioned under existent conditions unless continuous disease-control measures are carried on.

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