During the 1994 Desert Bighorn Council meeting, a panel discussion was conducted on livestock/bighorn sheep disease transmission. The discussion was recorded. Speakers had the opportunity to edit their comments that are presented in this volume.

LIVESTOCK/BIGHORN SHEEP DISEASE TRANSMISSION

Moderator: **Mike Miller,** Colorado Division of Wildlife, Ft. Collins, CO

Panel: **Walter Boyce,** University of California, Davis, CA
Marie Bulgin, University of Idaho, Caldwell, ID
Bill Foreyt, Washington State University, Pullman, WA
David Hunter, Idaho Department of Fish and Game, Caldwell, ID
Terry Spraker, Colorado State University, Ft. Collins, CO

Mike Miller - We want to spend some time this afternoon talking about disease interactions that involve bighorn sheep and livestock, particularly with reference to policies on sheep relocations and grazing policies on public lands where bighorn and livestock may commingle. We've been very fortunate to assemble such a distinguished panel who've spent a great deal of time over the last several years, if not decades for some, working with bighorn sheep disease problems. Everyone should benefit from the expertise they have to offer.

Mike stated that he would introduce each of the panel members as the panel proceeded and that everyone should try to keep their comments fairly brief as there would be an opportunity at the conclusion for open discussion among both panel members and the audience. He said he wanted to start by briefly trying to frame up the problem.

You're going to hear a lot about pasteurellosis this afternoon, I have no doubt, and you'll probably hear a lot about, hopefully, a number of other significant respiratory diseases, but one of the bigger problems we're going to be talking about and probably one of the root causes of a lot of the problems with respiratory disease in bighorn sheep, be they desert sheep or Rocky Mountain bighorns in North America, is attributable to pasteurellosis. Disease, as all of you know, plays a significant role in bighorn sheep population dynamics. Specifically, there are really two ways this occurs. Obviously this isn't the desert sheep except maybe anywhere but in Colorado. But, we see these tremendous, explosive die-offs of bighorn sheep that can create significant harm to populations. These die-offs have been reported since the last century, for over the last 100 years. Probably some of these pneumonia outbreaks have been occurring with fairly regular "irregularity," but they can be absolutely devastating. Certainly, one of the sequels to these outbreaks that's maybe a little less well understood, but in my opinion is as devastating to overall population performance of bighorn sheep is the lamb mortality that follows the outbreaks. We get to work with captive sheep and we've seen a lot of examples in Rocky Mountain sheep in Colorado, and I know that it's been seen in desert sheep, in Rocky Mountain sheep in other places, where in the follow-up, in the aftermath of one of these explosive pneumonia outbreaks, lamb survival can be abysmal for a number of years. We have one herd in Colorado and it's been 13 years now since it went through a significant pneumonia outbreak and we still see pneumonia every summer in lambs in that population and lamb survival is particularly poor. That population has taken over 10 years to double in size since that pneumonia outbreak occurred. So these things can really drag down populations in the long haul.

The results of these kinds of processes are very erratic — unstable populations that certainly don't recover very well in the face of these pneumonia outbreaks, and may in fact go extinct because of not only continuing problems with disease but also problems with predation, weather, and other kinds of things that can easily waylay small populations after they get driven down to a very low point.

The process appears, basically, to have two components. There certainly is opportunity and measurement opportunity historically in some cases for novel pathogens to be introduced into bighorn populations. We don't see these same kinds of patterns in more northern sheep species, in the Dall sheep and the stone sheep, which might suggest that some of these things are relatively new in an evolutionary sense. Certainly, in some of these, novel introductions do go on today. Once they occur, there seems to also be epizootic or

endemic processes that go on. Again, with pasteurellosis, in many cases there are other bacteria and other agents that can be involved but the pasteurellosis seems most often to be the most common cause of problems. Certainly stress, viruses, chlamydia, and bloodworms can, from time to time, contribute to these problems. Once these epizootic cycles begin they seem to be very, very difficult to break.

What the panel is going to mainly talk about this afternoon is the introduction of novel pathogens. In particular, as I've said before, you'll be hearing a lot about *Pasteurella.* I hope you'll hear about some other pathogens as well and their relative importance in contributing to these cyclic pneumonia problems that seem to plaque our bighorn herds throughout North America. What we hope to do is to try to get a feel for the relative importance of these novel pathogen introductions from the epizootic cycles that are maybe sequela to those kinds of things. Certainly, some of these are going to be much more preventable than others. I think that you should get a fair bit of good information from our panel members and hopefully this will lead to some stimulating discussion as we proceed this afternoon.

I'd like to introduce our first speaker at this point, Dr. Bill Foreyt. Bill received both his masters and Ph.D. in veterinary sciences from the University of Wisconsin and is currently a professor in the veterinary microbiology and pathology department at Washington State University at Pullman. Most of you familiar with the literature on bighorn sheep and domestic sheep diseases, with respect to pasteurellosis, I am sure will be familiar with Bill's name and so I'll turn this over to Bill.

Bill Foreyt - Thank you Mike. Thank you everybody for corning. I got involved in the domestic livestockhighorn sheep interaction in 1979 purely by accident. So we're involved in this area of interest, not intentionally, but because it proved so interesting we pursued this area of research. In 1979, we had a herd of 14 bighorn sheep and into that herd we put some domestic sheep to try to produce a hybrid, primarily to do some additional disease studies, and 13 of 14 of those bighorn sheep dropped dead. This was purely circumstantial, but because we thought there might have been a cause/effect relationship we published the paper in the *Journal of Wildlife Disease* in 1982. Then, in 1988, the Lostine Mountain outbreak occurred in Oregon where two-thirds of those bighorn sheep died after contact with domestic sheep. At that time we had some domestic sheep in captivity at Washington State University and we decided to become actively involved, to look at this domestic livestockhighorn sheep interaction. We began by trying to duplicate what we saw from that initial situation that I described. We put 6 domestic sheep in with 6 bighorn sheep that had been in captivity for 1 year and within less than 2 months all of the bighorn sheep died from pneumonia. *Pasteurella haemolytica* was the agent that was isolated from all the dead bighorn sheep. Previous to the experiment, using only nasal swabs, we could not demonstrate *P. haemolytica.* So we published this paper which I thought was one of the best pieces of work that I have ever done and it probably resulted in the most controversy of any paper. It became a very interesting story to look at. We repeated that experiment on about three more occasions where we would put bighorn sheep and domestic sheep together and in every instance the mortality rate in the bighorn sheep was close to 100 percent. Mortality rate in the domestic sheep was zero. So it looked like there was an adverse association between bighorn sheep and domestic sheep. The question then came up, what about other adverse interactions? What about elk, deer, and the other animals that often associate with bighorn sheep in the wild? So we replicated those experiments. We put elk into our pens with captive bighorn sheep at Washington State University (WSU). The standard protocol is to keep the animals in a 1-acre pasture for 60 days, evaluate the *Pasteurella* that are there before you put the animals together, evaluate the *Pasteurella* that are there at the end of 60 days, and also from any animals that died. Well, elk seemed to be compatible because none of the bighorn sheep died in our replicated trials. We used white-tail deer on one trial, mule deer on one trial, and nothing happened there. We did one experiment with domestic goats and nothing happened. With llamas, we were not even able to isolate I? *haemolytica* from the llamas in the experiment or any of the llamas that came through WSU during this period. Llamas seemed to be compatible with bighorn sheep. We just completed a 60-day trial with mountain goats. Nothing happened with the mountain goats or the bighorn sheep. We also just completed a trial with cattle, using three cattle and four bighorn sheep in a very confined pen, and nothing happened in the bighorn sheep. Again, we always have to question these results because I? *haemolytica* is such a diverse organism. There are probably a hundred different kinds of I? *haemolytica* and when we select three cattle randomly, we don't get very many types of *P. haemolytica* in a specific kind of animal. So some of these experiments will have to be repeated using the type of I? *haemolytica* we think is more serious in bighorn sheep that is usually carried by the domestic livestock in a nonpathogenic way. The other study

we did this winter was with mouflon sheep. We put five mouflon sheep into a herd of five bighorn sheep and all the bighorn sheep died from pneumonia.

The conclusion to these interaction studies were that bighorn sheep are incompatible with domestic sheep and mouflon sheep. In other words, when they have close contact, the probability of bighorn sheep dying from pneumonia is very high. We went a little further to be sure that it was the *Pasteurella* that was killing the bighorns and not stress or viruses or airplanes flying over or other stress-type factors. What we did was to take *P. haemolytica* from a normal, healthy, domestic sheep. It's a very common type of strain we call biotype A, serotype 2. A majority of domestic sheep carry it. We took it from the healthy, domestic sheep and grew it in culture, and we inoculated it into bighorn sheep and into domestic sheep. The bighorn sheep that were inoculated died from pneumonia within 24 hours and the domestic sheep never sneezed. We replicated that trial three times using different levels of *P. haemolytica* and in each trial all of the bighorn sheep except one died. So the result from that experiment is that bighorn sheep are very sensitive to some strains of *P. haemolytica* that are carried by domestic sheep and that those strains don't affect the domestic sheep.

We then began looking at the mechanism behind the pneumonia in bighorn sheep. Was there a way we could prevent it? Was there a way we could minimize the effects? That's where my colleague, Dr. Ron Silflow, has done almost all the work. His role was to look at the function of the lung and the function of these bacteria in terms of producing toxins in the lung and adversely affecting the bighorn sheep. He takes various strains of bacteria and grows them in culture. He isolates the toxin from the different strains and then evaluates that toxin against neutrophils from different kinds of animals. If the toxin kills the neutrophils, we then speculate that the bacteria will kill the kind of animals those neutrophils came from. If the *Pasteurella* toxin kills more than 50 percent of the bighorn neutrophils, we classify that *Pasteurella* strain as a pathogenic strain for bighorn sheep that is likely to cause pneumonia.

We have also tested host-resistance or host-sensitivity based on their neutrophils. What we've found is that in every healthy wild herd of bighorn sheep that we tested, none of those sheep had ever yielded a toxic-type P. haemolytica even though every bighorn sheep carries *P. haemolytica.* When we sampled domestic sheep, about 60 percent of the isolates that we tested were toxic. How do we know they're toxic? Because, if we took that same organism and inoculated it into a bighorn sheep and a domestic sheep, in every instance the bighorn sheep died. There's one exception to that and that's one toxic isolate that we found in an Oregon bighorn sheep that was found dead of pneumonia. It was a toxic isolate in our test. We inoculated it into two bighorn sheep and the bighorn sheep never got sick. We repeated it and again the bighorn sheep didn't get sick. We're hoping that this could be a vaccine strain. It's toxic enough in our test, but yet it won't kill bighorn sheep. Next week we'll challenge those same bighorn sheep with a domestic sheep isolate of our toxic strain to see what happens. If those sheep live, we may have an eventual solution to this problem.

The conclusions from these studies, then, are based on the neutrophil toxicity test. Bighorn sheep are very, very sensitive to pneumonia. They die very easily and I guess all of you know that already, but now we have the data. We've worked with Dall sheep this summer. Dall sheep are even more sensitive to pneumonia based on this test than are bighorn sheep. Domestic sheep are also relatively sensitive but five times less so than bighorn sheep. Deer, elk, and some of the other ruminants we've tested are essentially resistant to these kinds of bacteria. So, in terms of management guidelines, which you people are looking for, my suggestions are if you want to keep healthy bighorn sheep in the environment, you must avoid contact with domestic sheep and mouflon sheep or the probability of those sheep dying from pneumonia is very high. The other conclusion is that bighorn sheep are very sensitive to pneumonia, and that if they contact any of these toxic strains through nose-to-nose transmissions, they are likely to die.

Mike Miller - Our next speaker will be Dr. Marie Bulgin. Marie received her veterinary training at the University of California-Davis. She is a board-certified microbiologist and is very actively involved in the small ruminant health program at the Caine Veterinary Teaching Center in Caldwell, Idaho. Marie's going to be presenting some of the information that she brought with her and also providing some information that her colleague, Dr. Al Ward, would have presented.

Marie Bulgin - Thank you, Mike. I guess we can start out with the first overhead. I'd like to start by saying that there's actually been a lot of people involved in the research I'm going to talk to you about today. And, as you can see, I've really had very little to do with it, but I would like to comment that Dr. Ward, who isn't here, probably did the majority of it. Dr. Hunter will talk about some of the work that he's been involved in, and these other folks are really the

ones that did all the culturing, did all the tough stuff, so this certainly wasn't a one-person effort by any means.

The perception of the problem of bighorn and domestic sheep has led to many groups being at dagger-point as you all know. But, in the state of Idaho, it has brought together some very diverse groups. The Idaho Wool Growers, the Department of Fish and Game, the University of Idaho, and the State Department of Agriculture have all banded together in an effort to search for knowledge, to help provide reasonable answers about how to manage our bighorns and our domestic sheep, and I think it's to their credit that this has taken place. It's my intent to try to summarize the research that's come out of that effort.

Pneumonia, specifically that caused by *Pasteurella hemolyticum,* has been one of the most recent diseases, certainly one of the most controversial ones of recent years to be looked at. As a result of several die-offs in the state, specifically two in Hell's Canyon and one in the Salmon River area, we decided to look at the *Pasteurella* that are carried by bighorn sheep. So with the cooperation of Fish and Game, the State Department of Agriculture, and the Caine Veterinary Center, we have sampled and surveyed most all of the herds in Idaho as well as samples from Arizona, California, Nevada, Montana, Wyoming, Colorado, and North Dakota. So we've looked at quite a few bighorn sheep—probably somewhere in the vicinity of 450 animals.

Let's go to the next overhead. When we began, we discovered several things. We discovered that the nasal swab is not a very good way to find *Pasteurella* in bighorn sheep. As a result, our first isolations are probably fairly low. We have here a slide that was made some time ago and we found that our isolations from both bighorn sheep and domestic sheep were about 60 to 70 percent. Since that time, since going to both the nasal and tonsilar swab, plus getting samples from the field to the laboratory faster, plus using transport media, we've improved those isolations to almost 90 percent both in bighorn and domestics. So, we did discover that bighorns do carry quite a large population of *Pasteurellas.*

I guess I ought to say a little bit about identification of these *Pasteurellas.* Next slide please. This is the part that confuses me and I'm sure it's going to confuse you too. I'll do my best here. Of course *Pasteurella* is the genus, *hemolyticum,* the species, then we go to biotyping. We have three biotypes: A, T, and 3. I've always wondered why they threw this 3 into the alphabet, but that's the way they do it. We talk about serotyping. This is where they take serum from animals that have been inoculated with various types of *Pasteurella* and then use that for identification. We have many, many serotypes. In addition to the serotyping that we don't even have on this slide, they're now doing biogrouping. The biogrouping includes quite a number of groups as well. And then, of course, you've heard about fingerprinting. That's what Dr. Ward has done a lot of work with and this breaks it down even further. So, you'll hear me talk about serotype and biogroup and biotype and if you get as lost as I do, I'm going to have you totally confused. Next slide please. This is just an example. Biotype A, as you can see, has a number of serotypes. You'll hear me talk about biotype A, serotype 1, or serotype 2. You'll hear me talk about biotype T. Serotype is not used as much or we haven't looked at it as much as we have biotype. You'll hear me talk about biogroup 2 which is not a serotype 2. And on biotype 3, although we had none identified at the time this slide was made, we now have a serotype 11, biogroup 11, that's important as you'll see in a few minutes.

The incidence of isolation of *Pasteurella* of bighorn sheep seems to run about the same as it does in domestics. About 90 percent of them will yield *Pasteurella* and that's about what we've gotten out of the bighorn sheep. Interestingly enough, one animal can carry many different serotypes. We find that in the bighorn sheep, the greatest majority of them carry T. As you can see, we do find some As. We find some that carry both As and Ts, some that carry some 3s, some that carry As and 3s, but the majority, about 60 percent of the bighorns will yield just Ts. There may be several different serotypes and several different biotypes. The domestics, on the other hand, are reversed. The majority of organisms that they carry usually biotype A, but some may have Ts, some 3s, and some combinations, but the majorities are As.

Before I go on, I should mention hemolysis. In the literature, you'll find that a lot of people relate hemolysis to pathogenicity. In other words, if they see a hemolytic organism on a blood agar plate, they assume that it is more pathogenic than one that shows no hemolysis. We feel that that's probably true. However, whether you see hemolysis or not on a blood agar plate in the laboratory has to do with a lot of factors, one being where you got the blood. In other words, if you got the blood from a sheep, and we do use sheep blood for these tests, and that sheep happens to have antibodies to the hemolysin you're testing for, you're not going to see hemolysis on the blood agar. Presently we're looking into a more reliable test for hemolysis.

One of the interesting things that we have been able to do is look at bighorn herds that have actually come into contact with domestics. Probably the most interesting work, in this regard, has come out of Nevada. I think Dr. Hunter's going to cover that so I

won't go into any great detail except to tell you that we have some information that shows that we do have domestics and bighorns carrying not only the same strain and the same biogroup, but the same fingerprint, indicating that there was some transmission from somebody to somebody, but not knowing which way it went. In that particular herd, there hasn't been a die-off and it could be because the organism isn't very pathogenic. It was the biotype 3, biogroup 11, and it could be that it's just not a very pathogenic strain.

In the last 3 years, we've only had the opportunity to look at sick bighorns about 18 times. Unfortunately, it is seldom that bighorns have been found soon after death and that the finder is able to get samples to us. This is one of the weaknesses of our research. In the 18 that we've looked at, only 5 of these have been field isolates—sick bighorns out in the wild. The others have all been captive bighorns that we've had good accessibility to. The interesting thing about this is that the organism that's been isolated in five of six necropsies has been type T, the same type from 10 of 12 sick animals where we merely got a nasal or tonsilar swab. This has been type T, biogroup 2. It appears as if that particular strain, which is also carried by the majority of bighorns, can be pathogenic. For example, of 297 *Pasteurella* species that we've gotten out of healthy bighorns, approximately 42 percent of them were the same strain and the same biogroup as this organism that we've gotten out of the sick bighorns, type T, biogroup 2. It's also interesting that of the wild elk, deer, antelope, moose, mountain goats, and bison that we have cultured looking for *Pasteurella*, the elk, deer, goats, and moose all carry the same strain of *P. haemolytica*, T biogroup 2.

Marie stated that no fingerprinting had been done to determine if they are identical, but that they are the same in terms of type and biogroup. As stated by Dr. Foreyt, there has been enough research indicating that the commingling of bighorns and domestics is detrimental to the bighorn's health. Mane stated that Dr. Foreyt is not the only one who has had this experience. There have been other researchers in other states who have had this problem and in Idaho's case, it happened recently. She stated that they had nine domestics that were all positive for ovine progressive pneumonia and they were interested in observing whether or not this was a disease that could be transmitted to bighorns as well.

The domestics were placed in a pen and several days later four, 1- to 2-year-old bighorn males were placed next to them. Within 48 hours of placing the bighorns, a domestic sheep died. Interestingly, when the bighorns were placed with the domestics, we noticed that they were very curious about each other and that they all ran up to the fence on both sides and licked and sniffed noses. It was actually observed that one of the bighorns was licking the nose of one of the less healthy domestics. That was the domestic that died within 48 hours, and the bighorn died the next day. The day after the first bighorn died, the second bighorn died. The day after that, the second domestic died. By this time, we wised up, took the temperatures of the remaining bighorns, and when we found that they were exceeding 104°, we put the bighorns on antibiotics. They survived.

The organism isolated from that small die-off was *P. haemolytica* biotype A, biogroup 1. The organism had identical fingerprints in the four sheep (bighorn and domestic) that had died and the two living, remaining bighorns, as well as in two of the remaining seven domestics. This organism is of relative interest because biotype A, serotype 1, biogroup 2 is an organism that is carried by cattle, not sheep. We do not know where it came from. However, in the two domestics carrying it, it died-out after a month or so, never to be seen again in that group. The two remaining bighorns that survived, however, continued to carry the organism.

It was decided to see what would happen if all the sheep were blitz-treated with tetracycline in the feed. This was an effort to see if *Pasteurella* could be cleared from the domestic sheep in case we wanted to commingle the sheep again. Before the sheep were commingled initially, 27 different groups of *Pasteurella* were identified among all the domestic sheep mostly in biotype A. The bighorns only started out with a biotype A, biogroup 1, which they were now getting along with quite well, as well as a biotype A, biogroup 7X. After the blitz treatment with tetracycline, we wiped out a number of the groups, but there were still plenty left. However, we did wipe out that group A, serotype 1, in the two remaining bighorns, that had killed off the bighorns and the two domestics. It was eliminated after the bighorns had carried it for several months. It was thought that all the groups weren't eliminated because some were resistant to tetracycline. However, only two biogroups were found to be resistant to tetracycline. The others were residing in the sheep in spite of being sensitive to it. It was further thought that perhaps not all the animals were eating the feed with the tetracycline in it, so it was decided to inject the sheep with an antibiotic. The sheep were injected with ampicillin for 5 days, which we had determined that all the biotypes were sensitive to. In spite of ampicillin treatment, we were unable to affect the number of *Pasteurellas* we were able to isolate. One thing accomplished, although it was hard to quantitate, was we did knock

numbers down. When we put swabs on plates and looked at them, there were many, many, many fewer colonies. However, the *Pasteurella* was still present. It seems safe to say that nose-to-nose contact is a good way of transmitting *Pasteurella* from one species to another in spite of prior treatment with antibiotics.

Our next consideration was to determine if *Pasteurella* could be transmitted through water or forage. We looked at water from water troughs the sheep were drinking out of, sampling the water for 14 days running. We never did isolate a *Pasteurella* out of the water. There was about a 2-gallon capacity in the trough. Next, it was decided to add *Pasteurella* to the water to see what would happen. Initially, we placed log 4 number of *Pasteurellas* per ml. in filtered sheep trough water. We just dipped it out of the water trough, filtered it, and then started culturing for *Pasteurella* one, two, four, six, and so forth hours afterwards. We discovered at 2°C or almost freezing (refrigerator temperature), that the organism was completely gone by the end of 48 hours. At higher temperatures, for example 27°C which is room temperature, we found that *Pasteurella* lasted for a full 2 hours. However, at incubator temperatures or body temperature, we couldn't isolate it after the first 20 minutes. Obviously, *Pasteurella* doesn't survive very well in filtered sheep trough water.

The next slide shows what happens in distilled water. In this experiment, we started with a larger number of *Pasteurellas.* We felt it was subjective how many *Pasteurellas* an infected sheep will put into a water trough and because we had no idea we started out by thinking a good practical number would be 104. Then, after we kicked it around for awhile, we decided to go with a worse case scenario and upped our numbers. Consequently, we discovered that the more *Pasteurellas* we put in the water, the longer they lasted. Even if you get a 90 percent die-off in the first day, the remaining 10 percent of $\overline{10^7}$ lasts quite a bit longer than 10 percent of 1,000 (100). When we threw in $\overline{10^7}$ organisms, they lasted a lot longer. At $\overline{4°C}$ and it was more like 5 days that we could recover *Pasteurella* out of such a sample. Unfortunately, we have not inoculated $\overline{10^7}$ organisms into sheep trough water, but we have inoculated 104 organisms into distilled water and we find that *Pasteurellas* last longer in distilled water than they do in sheep trough water. We're conjecturing that there may be some toxic elements in the sheep trough water, perhaps from the algae or other bacteria that fall in. This is something that we need to follow up on.

Finally, we looked at forage. Although we need to do a lot more work with it, we find that alfalfa plants are fairly toxic to *Pasteurella.* At least at the 8 a.m. temperature during August, *Pasteurella* will not last longer than 1 hour on an alfalfa plant in the sunshine.

In summary, from our research, we can say that 90 percent of the bighorns do carry *Pasteurella* species. Of those that are positive, most of them come from the tonsils. This says something about the method of spreading the disease. If it isn't found in the nasal cavity, then the sheep probably aren't shedding a lot.

Of those that are positive for the *Pasteurella* species, only about 30 percent carry either the biotype A or 3. We have found that, geographically, biotypes tend to vary and that it's possible to determine the geographic area where the animal is from by the . Animals within an area tend to share the species. Elk, deer, antelope, and other wild ruminants also carry *Pasteurella* species.

We can say the most common isolated species in 18 dead sheep has been type T, biogroup 2, which seems to also be the main organism bighorns tend to carry.

Pasteurella species do not survive in the environment very well and are probably not transmitted via the environment. They probably require nose-to-nose contact to spread.

Mike Miller *- Mike stated that just from the first two talks he hopes everyone can appreciate how complicated a problem all of this is, especially as we are only talking about one species of bacteria even though there's a whole milieu of strains that appear to be out there and operating. Mike introduced the next speaker, Dr. Terry Spraker. Mike stated that Terry received both his DVM and Ph.D. from Colorado State University. Mike observed that Terry had been working on bighorn sheep respiratory problems for a number of years, at least 15 and probably closer to 20 years. Mike said that Terry is currently a pathologist with CSU's diagnostic lab and that Terry would be talking about pasteurellas as well as some of the other health problems that can arise from bighorn sheep and livestock interactions.*

Terry Spraker *- Terry gave a quick history of his background: he grew up in Wyoming and worked on sheep ranches during the summers when he attended high school. Because of this, he does have a basic understanding of sheep ranching and some of the associated issues. He stated that since veterinary school his work has involved investigating diseases in free-ranging animals, both terrestrial and marine mammals, and birds. Terry stated that he has had a particular interest in bighorn sheep and*

has invstigated diseases of bighorn sheep for the last 20 years.

Because of long-time isolation of bighorn sheep, they seem to be more susceptible to many of the common diseases that otherfree-ranging ruminants are more resistant to. When you consider the past interactions of bighorn sheep with man, there have been numerous problems including market hunting, loss of range because of use by man and his domestic animals, and diseases. When one looks at the diseases, especially in the older literature, several diseases are mentioned, including scabies, anthrax, and pasteurellosis. Anthrax may have been misdiagnosed in these earlier days and, clinically, anthrax could look similar to acute pasteurellosisin bighorn sheep. Over the years many diseases have been diagnosed in bighorn sheep. Some of the diseases that are important in bighorn sheep that could possibly come from domestic animals include blue tongue, contagious ecthyma, and in some areas, an upper respiratory viral disease called bovine respiratory syncytial virus. Parainfluenza type 3 and chlamydia are other organisms that can be transmittedfrom domestic animals to bighorn sheep. There are other potential viral diseases that may affect bighorn sheep that can be carried by domestic sheep; however, these viral diseases have not been diagnosed in bighorn sheep to date. One of these viral diseases is bovine virus diarrhea. Scrapie is another important chronic neurological disease of domestic sheep and whether this disease can be transmitted to bighorn sheep at the present time is not known. No evidence so far has incriminated domestic sheep as being able to transmit scrapie to bighorn sheep. Ovine progressive pneumonia, which is a slow progressive viral pneumonia that occurs in range sheep is another disease of concern. Howevel; to date, at least in Colorado, this disease has not been found in bighorn sheep. Other bacterial diseases to be aware of, besides Pasteurella is Johne's disease. The etiological agent is an acid-fast organism that causes a chronic wasting and diarrhea in bighorn sheep. There are several herds in Colorado with this disease. This disease is a devastating disease to these free-ranging bighorn sheep. Recently we have found a mycoplasma in wild bighorn sheep populations with pneumonia. The significance of this organism is not known at the present time; howevel; we found this organism in the 1970s in association with a lamb mortality. Howevel; usually when mycoplasma is found, bighom sheep also have pasteurella, lungworm, and in some instances, a respiratory syncytial virus. There are also various parasites that can be transmitted from domestic sheep to bighorn sheep. One of these parasites is Oestrus ovis. This parasite manifests itself as a chronic sinusitis, especially in desert bighorn sheep. Occasionally we also see a tapeworm cyst in the abdominal cavity in bighorn sheep that are from areas in which there is an abundance of sheep, sheepdogs, and coyotes. This tapewomz is usually not pathogenic to the bighorns, but in cases of extremely high infestation could cause death to young animals.

In conclusion, we have been trying to study diseases offree-ranging animals because we think that many of the diseases of domestic animals can spill over into the free-ranging populations and can be a population-limiting factor. Any time bighorn sheep intermix with domestic animals, whether naturally or artificially, usually the bighorn sheep suffer in various ways. The problem with domestic sheep and bighorn sheep is nzore extensive than just disease transmission. There is a problem with interbreeding and probably with loss of range due to the domestic animals occupying the normal bighorn sheep habitat. Howevel; there does seem to be more of a problem with domestic sheep than other domestic animals, probably because the bighorn sheep and domestic sheep are so closely related genetically, and especially since they can interbreed. The domestic sheep appear to have an increased immunity to many of the diseases as compared to that of the bighorn sheep. Therefore, the bighorn sheep appear to be more susceptible to some of these domestic sheep diseases. It appears at the present time that we are enjoying fairly good success with bighorn sheep management for several reasons. One of the reasons is that there is a fairly extensive transplanting program in the westem United States. In these instances, people are trying to transplant animals into clean habitats and they are also trying to transplant healthy bighorn sheep. Howevel; the habitat is still slowly decreasing, so even though intensive management including transplantation is showing promise at the present time, this is probably only a "temporary fix" for bighorn sheep management.

***Mike Miller** - Mike stated that he would like to underscore Terry's message that this isn't a simple problem with respect just to pasteurellas. He said that's what we hear a lot about, and certainly that's a very common organism, but there are many other agents that we haven't spent the time and energy studying as we have the pasteurellas over the last 5 to 10 years. Mike said he's afraid that the more we look, the worse the news is going to be.*

Mike, in introducing Dr. Walter Boyce, stated that Walter received his veterinarian training at Auburn, has a masters degree from the University of Florida, and a Ph.D. from Purdue. He's an associate profes-

sor of parasitology at the University of California-Davis in the veterinary school. Mike said Walter had his own news as well as information from Dr. Dave Jessup, who wasn't able to attend, about disease problems as they relate to interactions with cattle.

Walter Boyce - Walter stated that rather than talk about data, he wanted to discuss conclusions. He said in his mind it's been brought home very clearly that domestic sheep and bighorn sheep don't mix. However; it's much less clear with domestic sheep and bighorn sheep. He said that to the best of his knowledge there is no sound data that suggests that domestic cattle and bighorn sheep share diseases that are of importance to bighorn sheep. Walter said he needed to talk about sharing diseases versus detecting diseases. Oftentimes, the way to determine whether or not an animal has been exposed to a disease is to go out and collect a blood sample. Sera is submitted to a laboratory and examined for antibodies to these infectious disease agents. The presence of antibodies does not mean that the animal ever had clinical disease or will ever have clinical disease. The fact that bighorn sheep and domestic sheep or bighorn sheep and cattle have antibodies to the same infectious disease agents does not mean that those animals have been infected with the same infectious disease agent or that clinical disease occurred in either or both of those species. Walter said it's a fairly complex situation and that one can't generalize. However; he said he was going to generalize: Put domestic sheep and bighorn sheep together and there are problems. The problems clearly occur due to pasteurella pneunzonias. With domestic cattle and bighorn sheep, these problems haven't been evident. He said that in California for tlze past 4 years, they have been looking at one bighorn sheep/cattle interaction in particular and that his focus has been scabies as the primary infectious disease agent although they have also been looking at other viruses and bacteria. What they found is that bighonz sheep that have scabie mites in their ears (and about 50 percent of the sheep do), that year after year, cattle in that area have never shown signs of having mites, they've never isolated mites from the cattle, and have never found antibodies to the mites in the cattle. Deer also occur in this area as well and they have never shown signs of infection. If one takes sera from these three different species, one can find tlzat they have antibodies to several dzfferent viruses and bacteria, but at this point it doesn't look like clinical disease results from any of those infections. Walter said in this one particular situation, it's possible to say that there are infectious disease agents that these animals have been exposed to that may or may not have been the same ones, but clinical disease has not been a problem. Even then it's not that simple because tlze cattle in this particular drainage are what's called a closed herd. No new animals are introduced from the outside on a year-to-year basis, and as discussed, the introduction of novel pathogens is very important. After awhile, if the group in this room all lived in close harmony, some would survive and some wouldn't because of exposure to all the dzfferent infectious disease agents in tlze room. When one introduces new cattle into this bighorn sheep herd that's closed because it's not being augmented, then there's a possibility that they can bring in new pathogens and the situation that's been seen during the past 4 years could change radically. Walter said he didn't want to say that just because we haven't seen disease interactions occurring between these animals that is always going to be the case. Most cattle operations (grazing on public lands in particular) are not closed operations and disease interactions are still an open question. But, at this point, when asked if he knows of any evidence tlzat indicates that cattle and bighorn sheep interactions are important from a disease point of view, he says no. He doesn't think the evidence is out there, but possibly someone here on the panel has evidence to the contrary and he would like to hear it.

Walter next brought up the issue of vaccination and treatment options. Walter said this gets a little bit into the philosophical realm but let's say, for example, in the case of pasteurella that we're able to clearly identify a potential vaccine. The use of a vaccine in free-ranging animals is a decision that has to be very carefully thought through. There are several considerations to think about. Is it going to have to be used year after year? Is this a management strategy we can commit to over tlze long-term? Is this the best option we want to pursue? Walter said Amy Fisher talked earlier today about the fact that we used ivermectin in the San Andres this year to try to treat scabies mites. She said it was used primarily for humane reasons because those animals had been suffering from an infestation for a prolonged period of time. It's extremely doubtful that the administration of ivermectin at this particular point in time, however; would have any effect on the population as a whole. Walter said his personal feeling was, that in terms of managing the diseases that need to be managed so that we're actually having effects on populations, probably the single best thing that has happened in recent years regarding diseases shared between bighorn sheep and domestic sheep was the recommendation that we keep those animals separate. He would much prefer to see that management strategy employed than for us to rely on a vaccine and then

feel we can mix the animals as long as we go in and intervene on a year-to-year basis and vaccinate. That's a personal decision on his part, but he thinks there are some valid reasons for doing this in that over the long-term is the commitment really going to be there to deliver vaccines year after year? Is the funding going to be there to do that? Walter said he'd like to hear opinions from the audience, many of whom are land managers and are the people that would actually be faced with implementing those sorts of decisions.

Mike Miller - Thank you Walter. I think we'll go ahead and proceed to Dr. Dave Hunter who will wrap things up. Dave received his veterinary training from Washington State. Dave worked with the California Game and Fish Department for a number of years, 5 years I believe, and then most recently has had a joint appointment in Idaho. He's veterinarian for the Idaho Department of Fish and Game and also for the Idaho Department of Agriculture, serving two masters with sometimes slightly different perspectives and agendas. I think Dave's going to try to bring some of this into a personal perspective and also from an agency/management context.

Dave Hunter - Well, first of all you heard that my job as wildlife veterinarian for the state of Idaho is a doubly-funded position to work on wildlife. My job is wildlife, my funding is from two agencies. The reason for that is my job was legislated as a double-funded position. My job was basically created because of the bighorn sheep/domestic sheep interaction. Again, it kind of threw me in a new spotlight. Along with Dave Jessup in California, there were two of us wildlife veterinarians for the state at that time, so you always kind of have someone covering your backside. Well, it's like the difference between bacon and eggs at breakfast. You guys know that difference. You know the hen was involved in that breakfast, but the pig was committed to the breakfast. Well, my pork was now really on the line because I had two masters telling me there was no pressure on me, but go forth and prosper. Well, it was actually a little hard and you've heard about some of the research that's been done in regard to *Pasteurella.* Again, this is the organism that appears to be the final nail in the coffin. I think after 5 years in Idaho, we can reach a consensus. Walter mentioned it and Bill mentioned it, that what we can't do is put the two species together. You put bighorn and domestic together, in nose-to-nose contact, and there's a good possibility that you're going to end up with the demise of the bighorn sheep. After 10 years I'm a little smarter than that. We knew going in, at least I did, that what we had to do was to look at all those factors that were involved. So we came in and we said, well, we're looking at this literature here that was done under confinement and does this really happen in the wild.

There was an episode that came up about 3 years ago in Nevada. I got a call from Greg Tanner, who said all of a sudden they found domestic sheep in with their bighorn sheep populations and these were not in areas that had any kind of allotments, either a trailing allotment or a general allotment. So, they called and asked if I would be interested in looking at these animals and I said yes. Our whole objective was to see what happened in a range situation. This was like a controlled experiment and, no, I didn't do it, and I don't know who did. We went down there and were able to capture the domestic sheep out of three areas: the east range, the Desatoyas, and the Granites. Then we went into the bighorn population, net gunned those animals, and took samples. We've been able to get samples for 3 years from those populations.

First of all, we were wondering if there'd be a die-off and if we could substantiate the die-off, what caused it to occur, and was it the domestic sheep put in there or not. We brought the domestic sheep back alive and keep them alive and serially sampled them for 6 months. Again, it sounds like we really knew what we were doing when we were talking about *Pasteurella,* but when you streak out a tonsilar swab you may have a hundred different colonies that may look like four to five different types. We picked the predominant colonies. We did not get all the *Pasteurella* out of every throat swab that we tell you we do. So, we serially followed these domestic sheep and went in and followed the bighorn sheep. What we found surprised me in many ways. We didn't find a lot of similarities in organisms. In the east range we found there was a big die-off of bighorn sheep and until we saw five animals—that's what's in the east range now, anyway, three rams and two ewes. From 87 animals from the first year we went in there, we now have five left. So, basically, as far as I'm concerned, that's almost an extirpated population. And did we find that domestic sheep were the cause? Boy, it'd sure be nice if I could say we did, but we didn't. We did find a lot of *Pasteurella* haemolytica which is a different species of *Pasteurella* in those animals and we know it's a factor. We know it's in domestic sheep and we know it's in bighorn sheep and it seems to be the one that was probably instrumental in that die-off. So, we lost our east range contingent. We move onto the Desatoyas. In that population, we talked a little bit before about looking at the organisms according to the species they're

normally found in and in the Desatoya Range, we found an A2. Now remember, we had domestic sheep in there, now we find an A2. An **A2** is the one we use as our standard for virulence on bighorn sheep. What we found was that was only (we did four animals that year) in one animal I believe at that time. There's two strata to the Desatoya Range—an upper and a lower. We found it down in the lower. I expected that the next year we'd go in and find a horrendous die-off. Well it didn't occur at that point in time. Again, it sure would have been nice if we could have documented that this organism, I mean if we were looking for incriminating evidence you're really pushing pretty hard, so we did look very hard at those animals. But what I think is the third major piece to the puzzle was in the Granite Range. There was a trespass animal from a good operation that had broken free and gotten in with the bighorn sheep. We went in and net-gunned the trespass animal, brought it out, took it back to Caine, and eventually I think it was sold at a BLM auction. Then we went into the bighorn population and sampled the bighorn. For the first time ever, and this may not sound like much to you, we found an organism that fingerprinted identically from the domestic to the bighorn. The kicker was that it was type 3, biogroup 11, probably not a pathogenic organism but I don't think that matters. We know that domestic sheep carry very virulent organisms, deadly organisms to bighorn sheep; now we know at least for whatever method of spread, we had fingerprinted an organism in both species after an interaction. On management decisions, I think we have to look at this as saying that domestic sheep have organisms that are potentially virulent.

Do all interactions between domestic and bighorns cause the demise of the bighorn? No. We have areas in Idaho where they're together every year. But, in a lot of cases and even in our experimental work, when we put the two together, within 96 hours all four of our bighorn were dead or dying. So, we now have that major piece. We've got to keep them apart. Also, can it spread in a wild situation? I don't care which way that organism went, I say that we got something to say, that organisms can pass between sheep species. To me, that's a big piece of the puzzle because we did some work with the water, you saw the water work and the temperature and all that, because we wondered if you could contaminate a water source and spread *Pasteurella* that way. That apparently isn't the way it happens. We tried it on alfalfa, to see if on the species they're browsing on if they could lick the twigs, stems, rocks, whatever bighorn sheep are eating at that time of year, could domestic sheep spread it to bighorn that way? Apparently, that's even more toxic to *Pasteurella* than water. So what you need to complete this scenario is what Bill Foreyt has said for many years: Keep them from going nose-to-nose. Does it take 20 miles to keep them from going nose-to-nose or 6 inches or 3 inches? I think the problem arises in that what we have to look at is not letting them get nose-to-nose under range conditions or under research conditions. So, we've got some pieces to the puzzle that now allow us to manage the two species.

To throw another kicker in, I think Walter who's been looking at cattle and their interaction with bighorn sheep, well you know the one that killed our sheep, the one Marie told you about, basically that's an organism normally found in cattle, but here it was in the domestic sheep before they were put in with the bighorn sheep and it did kill some domestics, but it would have killed all the bighorn. So, I think cattle could potentially carry *Pasteurella* organisms that are deadly to bighorn sheep, but why haven't we found it? Well, if you look on the hillside, I think you'll find that bighorn sheep and domestic sheep will get together. You know they're kind of curious; they do go nose to nose. But, I don't think bighorn like cows. Those of you who work on these allotments will see that bighorn sheep and cattle rarely, if ever, have been seen nose to nose. The potential is there although they do not get together. So, I think we've got another piece of the puzzle. I don't think these other species on the range are less lethal, I just don't think the opportunity is there to pass organisms.

We've done deer, elk, and pronghorn down in Nevada, and we wondered if the pronghorn might not be a carrier between domestic sheep to the pronghorn; the pronghorn don't die but carry it to the bighorn sheep. No, in our experiments we've had deer, elk, pronghorn, just about everything in and next to our bighorn sheep without any problems. So, I don't think those species on their own are of much concern to bighorn sheep. We've got to watch what we do on our management areas and realize that we've been putting a lot of time and effort into *Pasteurella* and domestic sheep and this isn't a panacea for our bighorn sheep problems on the mountainside. In Idaho, we've got wilderness areas where we don't have domestic sheep or many domestic animals at all and we have horrendous die-offs. In researching these die-offs, I was involved in the Warner Mountains when we extirpated our population out of the Warner Mountains after a potential interaction with domestic sheep. I know it happened in the Lostines, it happened in the Lava Beds in California before I got there, and apparently it happened down in the east range here. One recommendation I think you guys are going to talk about tomorrow is when to do our transplants. It seems like most of these transplants where we have

extirpation of populations, I mean total die-offs because of apneumonia outbreak whether it's questioned to be livestock-induced or whether it's one of these epizootics that come through, but I think what were doing is that all of these started out with transplants of 20 to 25 animals. In the east range, it was up to 80 to 87 animals. The domestic sheep went in there and we've just about lost them all. I think when we do transplants, we have to look at transplanting bigger numbers of animals. I think we need to be looking at a little bit more genetic diversity...

(Tape problem)

...we ought to be starting out with maybe 70 to 75 animals and where we have done that, in our Wybie Canyon Range, what happens (in fact if anyone needs California bighorns, please give us a call) is that we're taking a lot of animals from our desert out there. (Taking animals is not a problem there, that's the area where the Air Force is putting in a bombing range.) There's a lot of problems out there for bighorn sheep and *Pasteurella,* in a lot of cases, is the final nail in the coffin. It might be that we can work on our management practices and if we can't put a greater number of animals in each time, augment as heavily as we can for the first **3** or 4 years so that when that population starts it's upward growth, there will be a lot of diversity in there. In the east range, of the three, four, or five animals that make it out of that die-off, it appears that the *Pasteurella* that they carry is the same one that we found that potentially killed off the rest of the animals. So maybe they have something in their own immune system that allows them to carry on. We did also get the last animal out of the Tolkein Range that is about an 11-13 year old ram. It is the last animal out of the Tolkein Range that is carrying an isolate—a cattle isolate—and this ram is not dead. We put him in with our Rocky Mountain bighorn and he's doing fine. There's a lot of questions yet to be answered; *Pasteurella* isn't the only problem out there. It may seem like the biggest one right now, but again, we have a lot of areas in Idaho where we have populations die-off, and the summer lamb mortality carrying on for 4 to 5 years, and then they come back up to a level of 80 to 100 animals. But, they don't crash to zero.

Everyone on the panel has put a lot of time and effort into these studies and we've learned a lot of interesting and boring things, but in my estimation we need to start spreading out from *Pasteurella* and looking at some of these other factors. I personally think that the livestock industry in general, in Idaho anyway, we're working together to say we're not trying to put the wool growers under. We're trying to keep sheep on the mountain and trying to remain viable as an industry. Let's look at these areas where there's a potential problem and handle them each individually by spreading it out or whatever. Also in Idaho, the evidence is strong enough that if we have bighorn sheep coming down into a domestic sheep flock, which happens quite regularly, our orders are now either to dart them and get them out of there or to kill them. If we have feral or trespass animals in with bighorn populations, instead of notifying the BLM or Forest Service and waiting 48 hours for them to pull them out, those animals are shot and sent to me. We do think that potential problems are there. I think you ought to look at that—to sacrifice two rams that come down into a domestic flock in order to save the population on the hillside. I think the evidence is there to support that.

Mike Miller - Thank you, Dave. Part of the reason I wanted Dave to finish up is because I knew he'd raise more questions than he'd answer. I want to reemphasize some things he mentioned, especially the idea of no contact between bighorn and domestic sheep. We've certainly had a couple of cases I know of in Colorado where bighorn that have spent time with domestic sheep have been captured and returned to the nearest herd of bighorn sheep. In one case at least, the animal died fairly soon after it was moved; in the other case, we don't know what happened. But, it's a very dangerous practice and I don't know of any place, at least in our state, where we have that desperate a need for single rams that we can afford to run that risk. If we really believe that this has high potential for transmission and for loss of a population, I just don't think it's a risk we can afford. But it does go both ways. We can't expect livestock to stay off of bighorn ranges, but to cut a lot of slack for bighorn sheep that tend to wander off and go places where they shouldn't isn't acceptable either. Tom Porter and I, several years ago, wrote a letter that ended up in the American Association of Wildlife Veterinarians newsletter. One of the things that we recommended was essentially having no-sheep zones in some of these places where, no matter which species it is, if they show up in these areas where there's potential for them to go back and intermix with a wild, free-ranging herd, that those animals not be allowed to survive.

Another thing I want to mention and I'm sure it's going to be covered in more detail tomorrow is the idea of translocations. What Marie mentioned earlier in terms of the tremendous variety of diseases and strains of *Pasteurella* among wild sheep herds in Idaho, we've also been seeing in Colorado. In

contrast to some of Bill's work, we have isolates that appear to be pathogenic, at least according to the neutrophil toxicity assays we've been running. In healthy bighorn sheep and also in dead bighorn sheep, one of the things I've grown real concerned about in looking at trapping and transplanting is the way we've been behaving with some of that over the last 20 years or so. How many of these problems have we actually brought on ourselves by moving bighorn sheep and intermixing bighorns in areas where we may be the ones bringing novel pathogens in by moving bighorn sheep from one place to another. Again, it cuts both ways and we need to be as careful as the other entities we're asking to be responsible in terms of preventing disease introductions. Thanks largely to Kerry Swagert's efforts, we have a great wealth of information on health and exposure to a variety of pathogens for most of the bighorn herds in Colorado that we use as donor herds. Unfortunately, we haven't always paid a lot of attention to where we move those sheep, but I think as we start talking about metapopulation management, genetic supplementation, and some of these kinds of things, the potential impacts of novel disease introduction are things that really need to be weighed in there in a cost-benefit-typeapproach. With that, I'd like to go ahead and open this up to questions. They want to get the questions and answers on tape, so holler your questions really loud. I'll repeat the question, then I'll hand the microphone to someone on the panel to answer. If you want a general answer that's fine. If you have a specific individual you're targeting with your question, that's fine too.

QUESTION AND COMMENT PERIOD

(Comment/question from audience)

Mike Miller - I'm going to summarize and paraphrase what was just said. Basically, the comment was that there are places in the southeastern comer of Utah where cattle and sheep, over a number of decades, probably developed sympatric uses of range where they actually separate themselves in space. Yet just across the border in Colorado, with a recent transplant, there's a situation where some transplanted desert sheep are actually interacting in an area with cattle. It sounds like it's partly due to operating with other, supplemental feed. I guess another point to make would be that traditional movement patterns and range uses of established sheep herds are going to be very, very different from transplant herds. Another reason we see so many more problems in our transplant herds could be because some of the patterns that may allow for this separation may just go completely out the door when you start moving animals into novel environments and into places where they don't know where they should and should not go. Places where they haven't been selected for going or not going.

(Comment/question from audience)

Mike Miller - The comment was that in California's experience with desert sheep transplants there are a variety of mortality factors including predation, accidents, etc., that can lead to the demise of the transplant herd, and that simply talking about genetic diversity with respect to disease resistance may be something to think a little bit longer and harder about. I guess I would tend to agree. Small populations are likely to become extinct. There's just not anything good to say about tiny populations over long periods of time and it doesn't really matter what kills them I guess. They just don't do well. It seems like, from my perspective anyway, if we're going to spend the time and energy moving sheep or any other species for the purpose of starting new populations, we certainly owe it to them to try and give them a population size that will ultimately be viable. I don't know if I completely agree with the magic number being 50 or 100 or whatever, but the point is well taken that there are a lot of things that can contribute to bighorn demise. I think the metapopulation approach with respect to mixing sub-populations of animals that may be exposed to different groups of pathogens does have some potential for leading to problems with disease.

Walter Boyce - I'd like everyone to save all their interesting questions about transplants until after tomorrow's panel, otherwise we're not going to have much to talk about then.

(Comment/question from audience)

David Hunter - Dick Weaver's question to me was concerning the areas in Idaho where we had bighorn sheep come into contact with domestic sheep populations. This occurs very frequently, at least once a year in our Salmon-Challis area. These are normally young rams that come down into a band of ewes and they seem to do it every summer with regularity and it's not always the same sheep. I questioned what happened there too. We've gone over and taken a lot of samples from that area, and we do indeed have samples that do not show any compatibility. We have no A types. We have none other than what we consider the normal flora in our bighorn sheep there. Again, we believe strongly enough now, that that's such a potential problem that we do indeed take those

animals when they're seen with domestic sheep. So, I'm not saying that it's not a problem but that we've just not found a problem associated with it. Realistically, in these ram bands, some of these *Pasteurella* may be so hot that the rams won't make it back by breeding season alive to the ewes that need to be bred. Again, that's speculation.

Terry Spraker - Let me interject a statement here because there seems to be confusion in regard to goats and llamas. How many of you have experienced an increase in utilization of goats or llamas being used as pack animals? This is becoming an increasingly frequent request. We have primarily talked about *Pasteurella,* however there are numerous other pathogens that eventually may turn out to be important. I would like to hear what the other panelists would say specifically in regard to pack animals.

The answer to your question, Amy (New Mexico Game and Fish), is Johne's disease. Johne's disease has been found in llamas by several veterinarians at Colorado State University. However, goats with Johne's disease may be more of a problem. Goats may or may not show diarrhea. Goats can easily be shedders of the organism for extremely long periods of time without showing any clinical signs, so they could easily spread the disease. We do not have very much information about caprine arthritis/encephalitis of goats as far as its transmissibility to bighorn sheep. At the present time, we have no evidence that this disease of goats has been transmitted to bighorn sheep.

Marie Bulgin - I would wonder too about the contact. I think a domestic goat and a wild sheep might very well come into contact, because we do know that they breed with domestic sheep. So I think there might be the same contact you'd have between domestic sheep and wild sheep.

(Comment/question from audience)

Mike Miller - The question basically was that most of the discussion has focused on pasteurellosis which is a disease that we all agree requires fairly intensive, direct contact between domestic animals and whatever species of bighorn sheep. We're being asked to address some of the other arthropods and possible airborne pathogens that could also be equally important in terms of disease problems in bighorn herds.

Terry Spraker - The disease in question is blue tongue. The actual distance that the blue tongue virus can be spread is not known. The distance would be dependent on the distance that the *Culicoides* species of gnat could fly, since they are the primary vectors for transmission of this disease. If they are caught in the right types of winds, these organisms probably could be spread for miles. We have seen one instance where we had bighorn sheep in captivity near Fort Collins. There were domestic sheep about 3 or 4 miles away from this bighorn sheep enclosure. Two of the animals died during one summer due to blue tongue. There was a suggestion that the blue tongue may have been transmitted from these domestic sheep. To date, we have not seen blue tongue in the free-ranging bighorn sheep. However, blue tongue has been diagnosed and is considered to be an extremely important disease of desert bighorn sheep. The other part of the question, in regard to Johne's disease, is that this organism is deposited on the ground and can remain on the ground from up to 6 months to 1 year depending on the alkalinity and type of soil. Contagious ecthyma is another viral disease of domestic sheep that can be transmitted to bighorn sheep. This organism can remain on the ground in specific circumstances for up to 20 years without losing virulence.

Bill Foreyt - The one arthropod-transmitted disease that we worked with was anaplasma. We found that anaplasma can kill bighorn sheep fairly easily. So ticks from cattle or possibly from sheep, after they fall off that animal, can transmit it to bighorn sheep.

Walter Boyce - Let me follow up on the anaplasma situation in our sheep in California. In the desert regions, bighorns commonly had antibodies to anaplasma. This is true in areas where there are cattle-grazed allotments; it's also true in areas where there are no cattle-grazed allotments. When you move into some of the higher elevations, where the tick species that occur on sheep change, we don't see anaplasmosis in bighorn sheep or cattle even if they occur together. So, you have to look at it on a case-by-case basis.

Another arthropod, just to bring it up, is the scabies mite. Once again, in the situation in the San Andres, was that mite there prior to the late 1970s or was it introduced and has it now become established in the environment, perhaps on deer? Essentially it's there now and for forever. The sheep that are there are going to have to deal with it. That's an issue we would really like to resolve. Another way to think about this, and it goes back to something I said we shouldn't talk about until tomorrow, is transplants.

That is that you may only have the opportunity to make certain mistakes one time. If you introduce an infectious disease that becomes established in the environment, regardless of whether or not the sheep that were there survive initially, you may never be able to put sheep there again. With something like *Pasteurella,* if you get rid of domestic sheep and bighorn sheep, it seems like okay, we can kind of start over, we have a clean playing board. But, that's not necessarily the case when we're talking about some of these arthropods, bug-borne viruses, and other infectious disease agents that can persist out in the environment. So if we're going to err, we should err on the side of caution, because often times you introduce things you'll have problems you can't deal with down the road.

(Comment/question from audience)

Mike Miller - Two-part question. I'll try to remember both parts. The first part was relative to the applicability of the experimental work that has shown that these *Pasteurella* isolates don't survive for very long in filtered water and in distilled water, when in fact in most of the situations where domestic sheep and bighorn sheep share a water source, the water source is somewhat less pure than might otherwise be related in these experiments. The idea is that perhaps these organisms can survive in soil or in situations with high sediment content, in bottom sediment layers, or in situations where there may be high organic matter content in water, if in fact that would aid *Pasteurellas* in surviving. We'll let Marie answer that one. The second part of the question was regarding horses and burros and the fact that nobody's really mentioned any potential pathogens of horses or burros that could be problematic to bighorn sheep.

Mane Bulgin -Yes, you're right, they generally don't drink filtered water or distilled water. That was to get rid of some of the organisms that would make it difficult to find *Pasteurella* such as proteus that spreads across plates. I think *Pasteurella* is a very poor competitor in the environment and my guess would be, although I can't back it up with the data, that in the water, without being filtered, *Pasteurella* would live even less long. As far as living in sediment, it's an aerobe which means it needs oxygen. I don't think it would compete very long in depth of sediment; however, we are going to look at mud, thinking possibly that in muddy, shallow, cool areas it might survive for a longer period of time. I can't comment on whether it might or might not. I really don't know.

As far as burros and horses go, actually they don't, unless one of you can think of some organisms that they share. Generally, they don't share too many organisms. The ruminants and the monogastrics seem to have their own set.

Bill Foreyt - The horse is next on our list of animals and I think it's the last one we're going to be checking. So hopefully next month, we'll have horses in with our bighorn sheep. They do have *Pasteurella haemolytica.*

Mike Miller - *I* guess I would just add a note of agreement with what Marie has said. Based on some of our experimental work with *Pasteurella* isolates under different laboratory conditions, one of the things we had to do to improve our ability to recover *Pasteurella* from bighorn sheep was to cut down the competition with other bacteria. They seem not to do particularly well, in at least media-type situations, where there's any opportunity for other bacteria to overgrow them. Colder temperatures may somewhat offset that, certainly, but they don't tend to be particularly good competitors outside the host. Even inside the host, in some cases, they don't compete very well. So, they're a relatively fragile organism compared to some of the other things we've talked about.

(Comment/question from audience)

Mike Miller - ...conjunctivitis in mule deer. I believe it is mule deer in Zion National Park that actually get two agents of bacteria, moraxella and also chlamydia that are involved. To date it is not spread into the desert sheep as I understand it, but the question is, first of all, how long is that likely to persist and in terms of maybe bringing other sheep in or using these sheep as a source of animals for other places, what kind of period of watching and waiting is necessary? I know that there have been a couple of fairly recent cases where moraxella has been isolated in pneumonia outbreaks. Probably the most significant one is the Whiskey Mountain die-off several years ago in Wyoming where they lost several hundred sheep and moraxella was the primary bacteria that was isolated from the dead animals. There have been some outbreaks of chlarnydiosis in bighorn sheep. I know that Terry's had some experience with some in Colorado and there was a pinkeye outbreak in Yellowstone in Rocky Mountain bighorns about 10 years ago.

David Hunter - In Idaho, of the first 93 animals that came out of one of our hunting units, 91 had lesions that were pinkeye-type lesions. We did culture out bronomello, which used to be moraxella, but taxonomists like to break things apart. Well, again, this one hit that population very hard. We went back in the spring and sampled some animals and we did hunter surveys coming out the next year and it was cleared up. The reason we believe it was in there that year was because we had an Indian summer type condition where we had a large gnat and fly bloom right around hunting season. What happened was that some of the animals weren't taken off the grazing allotment, and it was during a drought year, so they were all concentrated in one area. We have not found it since. We have not found any wildlife reservoir for those organisms at least in the eyes of the animals that have come out in the 3 years preceding that. But, it was up in the 95 percent range that the animals had severe lesions, corneal apastacices, and the whole bit from the organism. It seems like we lost the necessary conditions. The winter came on and we took away the carrier animals. We don't believe it was in that deer population.

Terry Spraker - In regard to the question dealing with chlamydia and bighorn sheep—Yes, we have seen a variety of conditions with this organism. We have seen a mild, upper-respiratory problem in captive sheep that clinically looked like a mild bacterial or viral pneumonia, and in this instance, the animal spontaneously recovered. In this instance, chlamydia was isolated; however, viral and bacterial organisms were not isolated in this particular incidence. We have seen herds of free-ranging bighorn sheep with antibodies to chlamydia and in these herds occasionally you would see animals with ocular lesions. These animals had a form of keratoconjunctivitis. We have also seen a type of keratoconjunctivitis in deer; however, chlamydia could be part of this syndrome in deer, but we have also isolated a bacteria called *Moraxella* species. Therefore, I think that both wild and domestic animals can be carriers of chlamydia. Therefore, the importance of chlamydia in free-ranging bighorn sheep populations is not known at the present time; however, I think in some situations it can be pathogenic, whereas in other situations, it carries a relatively low pathogenicity. I think there has only been one isolated instance where chlamydia was isolated from an aborted bighorn sheep fetus. This was done, I think, in the mid-sixties by Jim England.

Mike Miller - I don't think we've really answered your question, so maybe I'll stick my neck out and take a stab at it. Since you haven't seen problems in—and I got a little bit lost on which way you were talking about moving animals, whether you were talking about bringing sheep in to supplement this population or the other way around—the fact that the disease has been present for 2 years in deer and hasn't been seen yet in your bighorn sheep may just be luck or it may be a function of what we've been talking about in terms of direct contact.

Frank, are those sheep some of the sheep that have been sampled as part of the Park Service survey work and have we seen any evidence of conjunctivitis in any of the sheep that have been sampled there? I know we've see titers to chlamydia. As Walter said, titers don't really prove much of anything except that the animal may have been exposed to something at some point along the line. But I know that we've seen titers in just about all of the herds that we've sampled for chlamydia. We have not been looking specifically for moraxella or moraxella titers. I think there is some likelihood, as we mentioned earlier, with translocated animals. We're going to hear more about this tomorrow—that as they spread and wander and go places that you may not expect them to, that they could certainly come into contact with them. It really depends on how badly you want more sheep in there and what you're willing to risk I guess. If it were me calling the shots and these were bighorn sheep from a surplus area and all other things were equal, this was the only thing you were worried about, the potential for them getting chlamydia or moraxella from these deer, I guess I wouldn't worry a whole lot about it with respect to some of the other potential problems you might run into.

If you had the luxury of waiting, you could wait until you stop seeing the large scale problems in mule deer. That would probably be the most prudent thing to do. Maybe also give it another year or two and see if it's ever going to get into your bighorn sheep if you have that kind of time to wait. I agree with Terry, there are places in Colorado where we see these kinds of things on pretty much a yearly basis if enough people are looking. It seems to be in deer and we don't really see it in much of anything else. The extent to which some of these things may be more host-specific then we might realize, we just haven't looked at all the things that are out there. It's great job security for the people who are doing disease work because there's many more things to look at than anyone has the time to do right now. So if you have the time to wait, you might watch existing herds and see what happens. I guess that's because there's some likelihood, from my perspective, that the transplanted

herd, for several reasons, might end up being more susceptible to becoming infected with this problem. If that happens, going from one group of bighorn sheep to another group of bighorn sheep is probably much more likely than going from a group of deer to a group of bighorn sheep.

(Comment/question from audience)

Mike Miller - I guess the only comment I would add is if that is a private land situation, it would probably be more incumbent on the responsible agencies to keep their bighorn sheep off that private land by whatever means necessary. I think that's a situation where you really get into some difficult issues with respect to private land use and civil rights. That's a case where, yes, there'd certainly be some potential for concern, but it's going to be much more the responsibility of the agency to try to keep those things from happening.

If those are all the questions, I want to thank all our panel members, some of whom have traveled quite a long way to get here. And, I want to thank all of you for some good questions.