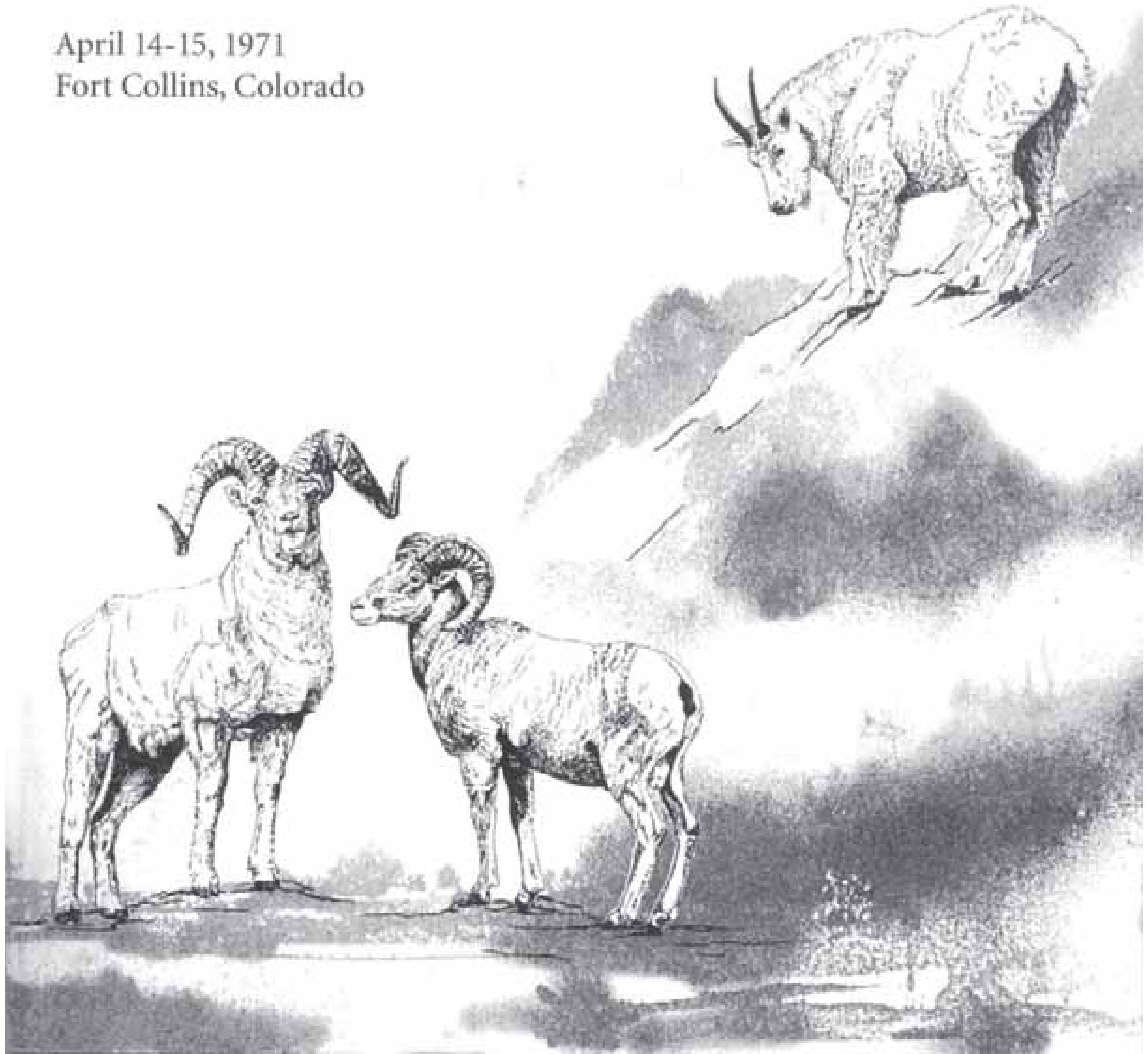
North American Wild Sheep Conference

1st Transactions

April 14-15, 1971
Fort Collins, Colorado



Transactions of the
First North American Wild Sheep Conference

Colorado State University

April 14-15, 1971

Edited by Eugene Decker

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CONTENTS

SECTION I

MANAGEMENT AND CURRENT STATUS

THE DALL SHEEP AND ITS MANAGEMENT IN ALASKA

by

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Before discussing factors of sheep management in Alaska, it might be desirable to give a brief summary of the known life history of the Dall sheep (*Ovis dalli*) for those unfamiliar with it. This species inhabits the alpine zones of Alaska's mountains south through the Kenai and Alaska Ranges to approximately the 60th parallel. They range north through the Brooks Range to the Sadlerochit and Shublik Mountains at about 69°30' north latitude, and west to approximately 165° of longitude in the Delong Mountains north of Kotzebue. Their range includes the following mountain ranges in Alaska: the Kenai Mountains, the Chugach Range, the Talkeetna Mountains, the Wrangell Mountains, the Tanana Hills and White Mountains north and east of Fairbanks and the Brooks Range.

They breed from mid-November through mid-December with local variations. Winter conditions are well established in their mountain habitat by this time. Sheep usually winter in alpine zones although in some local areas they may descend into the brush zone or even into timbered areas. In general, these animals are dependent upon and become restricted to the high, windblown ridges where vegetation is available.

With the spring thaw, sheep move down to the lower slopes, alpine valleys and, in some places, even into the timber to feed on the early green vegetation. They follow the melting snowline upward as summer progresses and generally spread over their entire range in late summer and early fall. In at least one area, migration from winter to summer range takes place, but in general the movement appears to be one of spreading over their range in summer and retreating to the smaller, snowfree areas in winter.

Lambing commences in mid-May and continues until mid-June, again with local time variations as yet unexplained. A single lamb is the rule, with twins being very rare. Murie considered an average good lambing rate to be about 50 lambs per 100 ewes (Murie 1944). Rates we have observed during aerial surveys vary greatly indicating wide differences between herds and years.

As with other sheep species, rams segregate themselves into "bachelor" groups during the spring and summer, joining the ewe bands for the rut and remaining with them through the winter probably because of the restricted available range.

Although Dall sheep utilize natural mineral licks extensively during the summer, the importance of these licks to sheep and to their distribution is not yet understood but is currently under study.

Predation by wolves has been cited as a major mortality factor (Murie 1944). It appears, however, that predators normally have little effect on sheep populations unless the animals are already jeopardized by such things as overcrowding or severe winters. Accidental deaths caused by falling from icy cliffs or snowslides in winter take a limited toll and provide scavengers with easy meals. Such "kills" are often blamed on wolves which may have fed upon them.

Disease and parasitism have not yet been demonstrated to cause important losses in Dall sheep populations, although "lumpy-jaw" (probably necrotic stomatitis) may do so locally and needs more investigation.

The major cause of sheep population declines in Alaska appears to be inclement winter weather. This species has adapted physiologically and behaviorly to the cold, dry snow and frequent high winds of Alaska's interior mountains. As long as snow remains cold and dry, the wind blows it off exposed ridges, piling it deep on lee slopes and in valleys. Sheep are dependent upon these exposed ridges for their winter feed. Deep, wet snows which do not blow away and thawing and refreezing conditions which sheathe the alpine vegetation in ice or an impenetrable snow crust severely restrict the food supply and/or mobility of the sheep. Documented herd declines appear to have been directly caused by severe winters. The severity of winter-initiated die-offs is related to herd size and range condition.

The last recorded large-scale population decline in Alaska occurred in the early 1930's (Murie 1944) and apparently was statewide in scope. Sheep numbers remained low for a time, then began to increase. Comparable aerial counts reflect population rises during the past two decades in a number of representative areas, and it is assumed that statewide populations have followed this trend. Several examples of this trend are listed below:

AREA	YEAR	ESTIMATED HERD SIZE
Kenai Peninsula	1949	350
	1968	2,220
Boulder Creek, Talkeetna Mountains	1949	45
	1968	460
Peters Creek area, Chugach Mountains	1949	54
	1969	403
McKinley Park	1949	795
	1968	3,500

The best understood sheep herds in the state are several on the Kenai Peninsula where repetitive counts have been made over a number of years. These show steady rises in numbers until the present time. It is possible that some of these relatively isolated herds are approaching the maximum carrying capacity of their range, and at least one (that on Surprise Mountain) suffered a limited die-off during the winter of 1969-70, probably caused by severe snow conditions.

Fortunately, competition with man for habitat has been slight so far in Alaska. Because sheep spend most of their lives in the rugged alpine regions, which are little suited to man's development, serious competition is not likely to occur in the foreseeable future. Consequently, Alaska's wild sheep are free of some of the major problems faced by their southern cousins.

Hunting regulations in Alaska have allowed only the taking of Dall sheep rams with horns of three-quarter-curl or larger. The hunting season traditionally runs from August 1 to September 20 in the Arctic, and from August 10 to September 20 throughout the remainder of the state. Resident sheep hunters are not required to have tags or guides in order to hunt, but nonresidents (with certain exceptions) must obtain a $50 sheep tag and the services of a licensed guide before they can pursue a Dall ram. The guide requirement has variously been imposed then waived over the years, but is presently in effect. There is some question as to its constitutionality, but this has not been tested in court yet. The only other statewide restriction on sheep hunting is that hunters who fly in may not hunt on the same day that they are airborne.

All sheep hunters are required to obtain, fill out and turn in to the Department a free hunter report card showing, among other items, whether or not they killed a ram and where it was taken. Return of hunter report cards has run about 90 percent of those issued since 1963, when these cards first came into widespread use. The annual sheep harvest has, therefore, been assessed with a reasonable degree of accuracy during recent years, and has remained fairly constant between about 900 and 1200 rams reported taken each year.

Because only adult rams may be taken, hunting has had little recognizable effect on populations. Several herds on the Kenai Peninsula are near highways and are therefore easily accessible to hunters. Almost every legal ram is taken from these herds each year, yet upward population trends in these hunted areas closely resemble that of a nearby herd which has been completely protected from hunting. Although no harmful effects have yet been demonstrated, it is possible that such extensive removal of adult rams may have some long-term effect on reproduction. This situation is currently under study. Throughout most of the state, hunting pressure is considerably lighter than on these Kenai herds and has had little noticeable biological effect upon the sheep populations.

To date, there has been little public interest in hunting ewe sheep. In fact, public opinion presently appears to be fairly strong against any general either-sex hunting for sheep. A very limited experimental ewe hunt conducted during 1970, the first of its kind to be undertaken in Alaska, stirred up considerable public criticism. A research program in association with that hunt is designed to determine the effects of either-sex hunting on a sheep herd. Until it can be ascertained that either-sex hunting is either beneficial or harmless to the herds, there seems little reason to alter the present ram-only regulations in the face of public opposition.

Because of Alaska's great size and the remoteness of most of our sheep hunting country, light planes are the only practical means by which hunters can reach game country in much of the state. Aircraft are as essential to the Alaskan hunter as are the pack horse in the Rockies, the canoe in the Northwoods lake country or the jeep in Hawaii.

Use of aircraft, as with any equipment, is occasionally abused. Infrequently reports are received of planes herding sheep past waiting shooters (I won't use the term "hunters"). This practice is illegal, of course, but such violations are very difficult to halt.

A common misuse of the plane is searching for large rams prior to hunting. Sheep are unnecessarily harassed in this manner, and sometimes they are actually, intentionally or unintentionally, frightened at the very time they are being stalked by foot hunters. Some people undoubtedly locate rams from the air, land nearby (in the few places where this is possible) and commence hunting immediately despite the regulation prohibiting hunting on the same day as being airborne.

Unfortunately, no game regulations are 100 percent effective in any state, and violations do occur. When such violations are witnessed and the word gets out (not usually with any identifying names or numbers) the public is led to believe such abuses are common practice and angrily condemns the use of airplanes.

The so-called "aircraft hunting" of sheep in Alaska has been receiving increased attention by the public both within and outside the state. There is actually no such thing as "aircraft hunting" of sheep. Shooting from an airplane is definitely a violation of the law and has been reported only rarely.

The most common problem with the airplane is congestion rather than violation. The many fly-in hunters are limited to relatively few suitable bush airstrips or lakes. This leads to considerable hunter concentration, especially in popular areas. The backpack or horse-pack hunter gets particularly discouraged and angry wnen, after a long pack into a lonely, remote sheep range, he suddenly finds one or more planes swooping in to nearby gravel bars after a short flight. This regularly spoils the hunt for the "traditional" hunter who got into sheep country the hard way.

To help alleviate congestion and reduce mechanical competition for the foot hunter, a large area near Anchorage has been closed to transportation involving hunting by any motor-powered vehicle during the sheep season. A few people hunt this area by pack horse, but it is primarily utilized by backpackers. The idea was received favorably by the public and now two similar areas are proposed for the Fairbanks vicinity. These will differ slightly in that they will be closed to all but foot hunting during the early part of the season, then opened to all legal forms of transportation for the remainder of sheep and other big game seasons to allow harvest of other species.

Obviously, restricting an area to use by the foot hunter alone is practical only where it is readily accessible to the foot hunter. It would help nobody to close remote hunting grounds to aircraft access since the foot hunter could not reach them. As human populations and hunting pressure increase, such zoning of accessible hunting areas in time and space for restricted access or hunting method will probably increase in scope.

Several areas in Alaska are entirely closed to the taking of sheep. Mt. McKinley National Park is one such area that provides the nonhunting public an opportunity to observe a large herd of sheep under relatively natural, unhunted conditions. This herd is also available for limited scientific study subject to the rules of the U. S. National Park Service. The Sheep Mountain Closed Area, on a small mountain adjacent to the Glenn Highway northeast of Anchorage, is also closed to the taking of sheep and provides an excellent opportunity to view them from the main highway. A third, the Cooper Landing Closed Area on the Kenai Peninsula, contains a herd of some 300 sheep, many of which are easily visible from a main highway at all seasons. The latter two sanctuaries are under control of the Alaska Department of Fish and Game. They not only provide the opportunity to readily view and photograph sheep, but also give the game manager and scientist unhunted "control" herds for study purposes.

Comparatively little research has been conducted on the life history, ecology and management of the Dall sheep and it is not as well understood as many other species. The Department of Fish and Game now has several dynamic and imaginative studies underway which should add greatly to our knowledge of this species. One such study being conducted in the Alaska Range south of Fairbanks entails trapping and marking sheep at a large natural mineral lick, then monitoring their movements to determine the area served by the lick as well as the movement pattern of the sheep. Use of this lick is also being studied in an attempt to determine its importance to sheep.

Another ongoing study consists of measuring a large number of horns taken by hunters to determine whether real size and growth differences exist between major habitats and if so to try to learn what factors affect horn growth.

A third study, recently initiated on the Kenai Peninsula, is designed to provide information on the basic life history of Dall sheep, on the effects of intensive ram harvest and, especially, on the effects of either-sex harvest. It involves comparing three isolated but nearby herds, all of which have had similar recent growth rates and all of which may be approaching the point of overpopulation. One herd is being reduced by one-third using a public either-sex hunt and a winter collecting program. The 60 specimens taken periodically throughout the winter should reveal much about reproductive physiology, food habits, physical condition and diseases and parasites. This herd will be maintained for five years at about 60 percent of its pre-experiment level by controlled annual either-sex hunts.

A second herd is in the Cooper Landing Closed Area, mentioned before as being closed to sheep hunting. This herd will provide an unhunted "control" for comparison with the other two. The third herd is intensively hunted and each year nearly every ram of three-quarter-curl or greater is removed by hunters.

Population trends, productivity and survival of these three herds are being compared in conjunction with the range condition and climate on the three areas.

These studies should provide considerable information of direct value to the future management of this species in Alaska. Other sheep programs conducted by the State include the previously mentioned harvest monitoring program and routine inventory surveys which reveal trends in distribution and abundance of sheep throughout the state.

In summation, I believe that Alaska's Dall sheep populations are presently in good condition and are generally on the increase. Man-made problems of biological significance are relatively minor in importance. Weather-related natural crashes have occurred in the past and could occur again but we do not have the knowledge or means to prevent them yet. The State has an active sheep research/management program which hopefully will give us the knowledge by which we can understand and possibly dampen such natural population fluctuations, and which will enable us to adequately handle man-made problems as they occur.

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DISCUSSION

Question by Dale Jones, USFS, New Mexico

QUESTION: Did you find any difference in the plant composition between the areas which were windswept and subject to sheep use and those which are snow-covered?

ANSWER: We don't know yet, but we are trying to get into a long term range study this year. Incidentally, I am trying to find a range ecologist to come help me set it up. This would be on a contract basis.

REPLY BY JONES: Concerning the closure of the areas for backpacking, was this closure a state regulation?

REPLY BY NICHOLS: Yes. It was done through our Board of Commissions which closed it through our regulations.

QUESTION BY GUS SWANSON, CSU: Could you explain the objective of the experiment where you are trying to reduce the population from 300 to 200 animals?

REPLY BY NICHOLS: The major objective is to determine the effect of either-sex hunting which has never been done up there. The public is more or less against it, but as it stands with the ram only, we are not managing sheep. Nature is managing the sheep and we are only harvesting the rams. Perhaps in some accessible areas, we can produce more rams by either-sex hunting if it works the same as in deer and other species. So, we are trying to reduce this herd quite drastically by the collection program as well as the hunting program to determine whether or not there will be any effect on reproduction, survival and range trends.

QUESTION BY DWIGHT SMITH, CSU: We recently had a study in Colorado of hunted and unhunted herds. It was found that perhaps one of the adverse effects of hunting is related to the disturbance of the animals resulting in their changing some of their essential ranges. In the herd you mentioned, where they are taking all the 3/4-curl rams, have you detected any change in the ranges?

ANSWER BY NICHOLS: In this case there is no way they can change their range. They are not completely typical because they are on isolated mountains and not in a continuous range. Therefore they are held to their present range. Maybe in other areas of heavy hunting they have moved somewhat but right outside Anchorage, where hunting has been heavy, they seem to occupy almost the entire traditional range.

THE DESERT BIGHORN OF ARIZONA

by

John P. Russo, Chief of Game Management
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Bighorn sightings were seldom mentioned by early travelers, explorers or settlers of Arizona. The first mention of bighorn in Arizona, and in the United States, is found in writings of Pedro de Castaneda, a soldier in Coronado's army (Hammond 1940). Castaneda, in the army following Coronado in 1540, searching for the cities of Cibola, mentioned sighting bighorns at the confluence of the Gila River and San Francisco River, near what is now Clifton in the southeastern part of Arizona. Bighorn sheep are no longer found in this area.

In 1567, a Spanish captain, Juan Mateo Mange, while escorting Padre Eusibio Francisco Kino, recorded that they had arrived at Tusonimon, a town so named for a great heap of horns from the wild sheep. Juan Mateo Mange indicates that from the numbers of horns it appeared that the wild sheep made up an important food item. (Russell and Swantson 1929).

More than two centuries lapse before there is another reference to bighorn in Arizona. Pattie (1905), in his personal narrative of Early Western Travels, relates that he and his companions saw bighorn sheep in the canyon of the San Francisco River in January 1825 at or near the New Mexico line. This may have been the same locale where sheep were first seen 285 years earlier. In 1826, Pattie also recorded bighorns along the lower Colorado River somewhere between the mouth of the Gila and Bill Williams Rivers.

The next record of bighorns in Arizona was made by the Emory expedition which found a large number of mountain sheep near the Gila River at the northern end of the Mohawk Mountains on November 19, 1846 (Emory 1848). From this herd a ewe was shot by none other than Kit Carson, then a lieutenant in the United States Army.

In 1858, the Ives expedition made the first steamboat trip up the Colorado River. During the voyage bighorn sheep were recorded at Lighthouse Rock in the upper part of what is now the Imperial National Wildlife Refuge (Ives 1861). In his report, Lt. Ives said that on January 17, 1858, a dozen desert bighorn sheep were seen scampering over a gravel hill near Lighthouse Rock.

From then until the 1930s, there is little mention of bighorns in Arizona literature. Merriam (1890), then with the U. S. Biological Survey, reported seeing bighorns on the San Francisco Mountains in August 1889, and a small herd at the Grand Canyon the following month. Cahalene (1939) quotes a lifetime resident of the Chiricahua Mountains as saying that bighorns were fairly numerous in all the lava hills of the vicinity, including the Chiricahuas. The bighorn were gradually shot and the few remaining were thought to have succumbed during the drought of 1903-1905. Sheep no longer inhabit the San Francisco or Chiricahua Mountains.

Major E. A. Mearns (1970) of the United States Army provided a comprehensive report on the known status of desert bighorns in Arizona at the turn of the century, a result of his work for the International Boundary Commission from 1892 to 1894. Mearns found bighorns in almost every mountain range along the border, from the Pajaritos Mountains west to northern Baja, California. He either saw bighorns or found reliable evidence of their presence on San Francisco Mountain; along the Grand Canyon, especially Cataract Creek; on the Papago Indian Reservation; in the Quitobaquito vicinity; and in the Tule, Granite and Tinajas Altas Mountains. He also found evidence of their presence in the 1880s, in the general region of Camp Verde on Bill Williams Mountain, and in the Santa Rita and Santa Catalina Mountains. Sheep are now found in all these localities, except the Santa Ritas, Camp Verde, San Francisco Mountain and Bill Williams Mountain.

Information was compiled on the distribution of bighorn in Arizona by A. A. Nichol, for the National Association of Audubon Societies and the University of Arizona (Nichol 1937 & 1940). Nichol reported sheep in most mountain ranges of the southern, southwestern and western desert areas.

Arizona began a serious and intensive desert bighorn sheep management and research program in 1950 (Russo 1956). This was the first concentrated effort to investigate desert bighorn and learn something about numbers, distribution and the habitat requirements of this animal. An important phase of this study was the information to support hunt recommendations.

Bighorn hunting was in a true sense a calculated plan with a complete understanding of what we wanted to learn in research and apply to the management of the species, and what we looked for to guide us in this management. The early hunts were "experimental" only in the thought of game commission approval, sportsman acceptance, hunter participation and success. Bighorn hunting was not an experiment on the animal.

Understandably, our first hunt was viewed critically, mostly by our own administration and the Arizona Game and Fish Commission. Not too much was known about the animal, its distribution, habits and habitat. It was difficult to reconcile the sportsmen of the state, much less the commission and the department, that a hunt could be held on desert sheep. No sheep hunting had been allowed for over 50 years, even before Arizona became a state.

Our first hunt, which took place in January 1953, allowed 20 hunters to take to the field for a ten-day season. In that memorable first season ten rams were taken. The largest ram measured 102 1/8 inches, while the average measurement was 82 1/2 inches. For our own use, measurements are found by adding the length of right and left horn and the basal circumferences.

What started out as a conservative hunt, a part of a research project study, has blossomed into an important feature of our annual hunts. Nineteen seasons later, in 1970, a total of 79 hunters took to the field for a 16-day hunt. In this season, 39 rams were taken. The largest ram measured 104 6/8 inches, and the average ram in 1970 measured 89 5/8 inches. Using the Boone and Crockett standards, at least ten of the 39 rams will measure better than the minimum 155 point score.

This may be regarded as the end product of a succession of events that has made bighorn sheep hunting what it is today. However, in order that we may appraise the hunting in Arizona, it may be well to look back to that time when hunting was first considered. It was thought that the estimated total number of sheep would not warrant a season, but it was also reasoned that the ram population could be hunted without harming the herd. To this end, the primary objectives of the bighorn sheep hunt were:

(1) To examine the animals for disease and parasites.
It was hoped that the examination of the animals would reveal reasons for the low lamb survival. Although many desert sheep were examined for disease and parasites, not much could be learned to add to what had already been found in earlier studies. Examinations of lungs and the thoracic cavity continued to reveal adhesions, abcesses and scars. This is a subject of considerable importance, and we hope to someday interest researchers in this program. We have learned that desert sheep are subject to many "abnormal" disorders ranging from separation of the parietal suture to fractured carpal joints, and from missing teeth to broken tails. We have seen these things so often that we have come to accept them as "normal."

(2) To spread the ram:ewe ratio and evaluate the reproduction trend if any was evident.
It was thought that, since the ram:ewe ratio approached a one to one basis, the yearly removal of a small number of rams over an extended period of time could be accomplished without damage to the sheep herds until an ideal ratio was determined. There was no reason to believe the sheep population would not continue to increase in the meantime.

Our attempt to spread the ram:ewe ratio was not a success. The original area open to hunting has been hunted for 19 seasons. We have been unable to detect any spread in the ram:ewe ratio. Are we now taking any smaller rams from the area than we did 19 hunts ago? Let us look at a few figures of average measurements taken on the first three hunts and compare them with those of the last hunt. On the first hunt, the average head measured 82.5, on the second, 87.9 and on the third, 84.3. In 1970, the average head from that area measured 93 5/8. We might conclude that it is impossible to take enough rams from this area to spread the ram:ewe ratio unless we take sub-trophy and younger rams.

(3) To give sportsmen an opportunity to remove a number of old trophy animals, thereby generating public interest in the animal.

In this attempt we have been highly successful. It is felt that when a game animal is protected for an indefinite period with no foreseeable opportunity for hunting, the sportsman loses interest in the species. Prior to the time of the first hunt, very few people were aware of our bighorn sheep herds. Even sportsmen were ignorant of their existence, whereabouts or potential. Until recently, no value could be placed on the animal, dead or alive. The courts, in some instances, found no criteria for placing a value on this animal.

Violations dealing with illegal take or possession of bighorns were treated with token fines or dismissed. Such is not true today. People are not only aware of the bighorn sheep, but sportsmen are avid defenders of the animal and its habitat.

To go along with the original objectives, recommendations were made to hunt additional areas to determine if similar physiological conditions exist in the bighorn in other parts of the state. In 1958, additional areas were opened and 20 more permits were added. Until this time, there were no restrictions on nonresident hunters, and resident and nonresident had equal opportunities to draw a permit. Even with the increased number of permits in 1958, only four nonresidents drew permits. In 1959, permits were again increased to 65. Twenty-one nonresident applicants drew. The Commission quickly took measures to limit the number of nonresident applicants to 10 percent. The following year in 1960, permits were again increased, to 80, and the number of applicants increased to 266.

Arizona's bighorn hunting has produced some surprises and some disappointments. Most of the results and findings have been gratifying in many respects. However, each year we are disappointed with one or two hunters who take rams with insufficient horn growth, which cannot be classed as trophy animals. Probably the greatest disappointment facing Arizona sportsmen today is the loss of lands that will exclude game management of any type. This is especially true in our sheep areas where ranges are limited. The loss of land is a constant threat.

Each year an increased number of applications is received, and a growing interest for desert sheep hunting continues. Last year, 1,540 applications were received for 79 permits. This is a far cry from the 26 applications received for 20 permits on the first hunt.

Undoubtedly, one of the factors that helped increase the number of applications was the reduction of permit fees from $50.00 to $25.00 in 1959. The nonresident permit was also reduced from $150.00 to $125.00. However, much of the interest generated by nonresident hunters came about through solicitation by state guides.

Today, we are permitting approximately four times more sheep hunters in the field than we did 19 years ago. Yet, our hunts are considered to be conservative in every respect. We are hunting about

12 additional areas of which three are located on U. S. Fish and Wildlife Service lands, the Kofa and Cabeza Prieta Game Ranges and Imperial Wildlife Refuge. Some of our bighorn ranges are in part of the National Park Recreation Area. Certainly, bighorn sheep hunting is a form of recreation, and these lands are providing recreation as they were meant to do.

We are not only taking more rams each year, but we are taking larger trophy animals. Last year the average bighorn sheep trophy measured 89 5/8 inches. Some of this has come about through hunter cooperation, a better understanding of sheep hunting and a greater knowledge of the hunt in general. Possibly this was helped by an education program started several years ago by an organization made up of dedicated sheep hunters.

I think I can speak for the sportsmen of the state when I say they have confidence in our sheep management abilities and in the way our sheep program, management and hunts are being conducted. True, you will always find some discord or dissent, but in general, we have been able to work things out.

What have we learned from 19 bighorn sheep seasons? Most important, we have learned that we can successfully hunt desert bighorn on a permit basis when the hunt is controlled. Results of the hunts have given us valuable information relative to the distribution of bighorn in its habitat and considerable information contributing to life history studies. Sportsmen are spontaneous contributors of personal experiences, and with the aid of a questionnaire, or even personal contact and notes, much information is obtained.

Each year we put about 150 hours of helicopter time in desert bighorn survey work. In addition to this, wildlife personnel make counts during the summer months when the sheep are concentrated around water holes.

Arizona maintains a fenced area where sheep have been held as part of a transplanting program. The exclosure is located in historic range. Just recently three young ewes were added to the group. These animals not only represent an addition to our exclosure, but an important development to our capture technique. The three ewes were tranquilized with a drug combination and shot from a helicopter, using a capture gun and darts.

Our management objectives have changed over the past 20 years. We were once deeply involved in managing the wildlife and habitat to provide game for recreation and the future. Today, we face the task of trying to keep what we have, and in trying to save a little of the desert bighorn sheep habitat from human encroachment.

ARIZONA DESERT BIGHORN HUNT INFORMATION

Year	Number Permits	Number Hunters	Accum. Total Hunters	Largest Head	Smallest Head	Average Head	Total Harvest	Accum. Total Harvest	Percent Success
1953*	20	20	20	102 1/8	56 3/8	82 4/8	10	10	50.0
1953	20	17	37	100 2/8	72 3/8	87 7/8	10	20	58.8
1954	20	19	56	99	65 3/8	84 2/8	12	32	63.2
1955	20	20	76	93 6/8	85	87 5/8	5	37	25.0
1956	20	19	95	93 4/8	65 2/8	79 7/8	6	43	31.6
1957	20	20	115	90 6/8	60 6/8	76 4/8	6	49	30.0
1958	40	37	152	102 6/8	74	86 6/8	18	67	48.6
1959	65	62	214	100 2/8	73	87 1/8	19	86	30.6
1960	80	80	294	100 2/8	68 2/8	87 1/8	24	110	30.0
1961	85	84	378	110 5/8	63 2/8	84	26	136	31.0
1962	90	89	467	101 2/8	63 6/8	82 7/8	27	163	30.3
1963	81	79	546	105 4/8	56 4/8	82 4/8	31	194	39.2
1964	78	76	622	102 2/8	72 4/8	88 3/8	25	219	32.9
1965	90	83	705	113 1/8	71 4/8	88 6/8	42	261	50.6
1966	84	84	789	108 6/8	74	91 2/8	35	296	41.7
1967	84	83	872	102 3/8	76 2/8	91 2/8	31	327	37.3
1968	81	77	949	103 5/8	70 6/8	89 4/8	47	374	61.0
1969	86	84	1033	106 2/8	71	89 2/8	42	416	50.0
1970	79	76	1109	104 6/8	76 2/8	89 5/8	39	455	51.3

A total of 1143 permits was issued since hunting started.
A total of 1109 hunters participated to take 455 rams for an average 41.0 percent success.

* First hunt in January 1953.

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BIGHORN SHEEP MANAGEMENT IN NEW MEXICO

by

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INTRODUCTION

Two subspecies of wild mountain sheep occur in New Mexico: the Rocky Mountain Bighorn (*Ovis canadensis canadensis*), and the Mexican Bighorn (*O. c. mexicana*). We have five distinct herds of Rocky Mountain sheep, and the total statewide population would lie within the limits of 300-425. Our two separate herds of desert bighorn would total between 200 and 275 animals.

The northern bighorn was exterminated from New Mexico around the turn of the century, and the present herds have developed from trapping and transplanting efforts which began over 30 years ago. The desert sheep, perhaps not as vulnerable due to a habitat less hospitable to man, survived the exploitation period until the two remnant herds came under the protection of State and Federal game refuge systems. Both concepts of game management, reintroduction and refuges, have proved successful to the extent that all herds except the newest transplant of three years ago have furnished hunting for trophy-size rams. Last year, twenty-three permits were issued on five of the herds, the greatest diversity of hunting opportunity since 1866 when the Territorial Legislature first enacted laws to protect bighorn.

These encouraging aspects are not, unfortunately, the whole story. All is not peaches and cream! We have two instances where populations appear static, at levels well below the suspected optimum carrying capacity of the habitat. We have had some poaching problems and erratic wanderings of transplanted animals. Also there are several instances of increasing human encroachment and "development" in prime bighorn areas. Thus, I suspect we share many of the successes and potential problems of the other states represented here.

HISTORICAL

New Mexico is fortunate in that several early day travelers have left written accounts of bighorn occurrence and distribution. Indeed, the first known record is provided by Coronado in 1540. In a report describing Hawikuh, the westernmost Zuni pueblo, he wrote: "There are many animals here... and some sheep as big as horses, with very large horns and little tails. I have seen some of their horns, the size of which was something amazing. There are wild goats (ewes?), whose heads I have also seen." Whether he actually saw bighorn in the western Zuni Mountains, or was referring to trophies brought into the pueblos from the lava flows fifty miles to the east, is a matter of speculation.

Somewhat later, in 1825, James Ohio Pattie passing through the San Francisco River canyon, a tributary of the Gila, wrote in his journal: "multitudes of mountain sheep. One of them that we killed had the largest horns that I ever saw on any animal." Following these early explorers we have a more scientific fund of literature contributed by such naturalists as: E. A. Mearns 1892, W. T. Hornaday 1901, Ned Hollister 1905, E. A. Goldman 1908, J. S. Ligon 1927, and Vernon Bailey 1931. A combination of these and other accounts graphically depict the decimation of the Rocky Mountain bighorn which probably will be complete by 1903. Similarly, the loss of a population of desert bighorn in the Guadalupe Mountains, then classified as *O. c texianus*, can be traced through the writings of Ligon and Bailey. The obituary of this herd is found in Department of Game and Fish records dating as late as 1946. This abundance of early narratives has provided more than interesting reading. It has given us encouragement to revitalize some of these herds through a vigorous program of reintroduction.

MOUNTAIN SHEEP MANAGEMENT

The initial attempt to reestablish Rocky Mountain bighorn in New Mexico was made in 1932. Six sheep obtained from Banff National Park, Alberta, Canada were released in the Pecos area of the Sangre de Cristo Mountains northeast of Santa Fe. This attempt to bring back the mountain sheep did not succeed. The Canadians did not give up on us however and, during the period 1940-42, three more rams and six ewes were made available to us. These were released in the Sandia Mountains, a north-south oriented fault block range with an extremely rugged western escarpment, lying just east of Albuquerque. By 1958, ground surveys indicated a minimum population of 104 animals, with 36 rams. The first hunt was held in 1959, with 20 licenses being available. Only two rams were killed, largely due to severe weather complications. This herd was also hunted in 1960, 1961, 1965, and 1970. Sixty-eight permits have been issued on these five hunts, with twenty-one rams being taken for an average hunter success rate of thirty-one percent.

By 1961, in addition to hunting value, the Game & Fish Department began to view the Sandia herd as a source of animals for transplanting purposes. Three potential release areas were evaluated, with the lower Gila River canyons receiving the highest priority. A large rope-net corral trap was built around a well used artificial salt station. No bighorn were trapped during the fall of 1961, and it was not until September 1964 that three rams and thirteen ewes were captured and transplanted along Sheridan Ridge adjacent to the Gila Wilderness Area. Six months earlier ten additional bighorn from Banff, Alberta (two rams and eight ewes) were released at Turkey Creek. At the time, it was believed these two bands would merge into a single herd. By 1967, however, it was clear that most or all of the Sheridan Ridge band had moved westward into the breaks of the San Francisco River. It is perhaps more than coincidental that these sheep had selected for their home range the same general area where Pattie had reported their predecessors almost 150 years before.

The next in our series of transplants in 1965 also began with bighorn from Banff, Alberta. These fifteen animals were lifted in individual crates by helicopter to an alpine tundra ridge near Pecos Baldy Peak in the Sangre de Cristos east of Santa Fe. This placement of sheep on the alpine winter range has proved highly successful. Because of heavy snow cover in the lower timbered areas, the animals do not scatter, and have a chance to become accustomed to the selected range.

In August 1966 we were again successful in trapping bighorn from the Sandia herd, and nine more animals were scheduled for release in the Pecos. An administrative change-of-heart on the part of the Forest Service regarding Wilderness Area sanctity and helicopter use led to the development of a new technique in transporting bighorn. Crates with wheels were to be pulled the twelve miles into the Pecos Wilderness to the release site by packstock. To keep accidents to a minimum, 3 men per cart were required. Thus the Department of Game and Fish hesitates to recommend this technique for further application. This rough handling did not result in any injury to the sheep so at least another indication of the hardiness of the Rocky Mountain sheep in captivity was obtained. Unfortunately, the same physical stamina or determination to live is seemingly not shared by the desert races of sheep. These two transplants in the Pecos, slightly over five years ago, have developed into a herd of between 73 and 100 animals, a rate of increase which must be close to the maximum.

Our newest bighorn herd began in 1968 with the movement of ten animals from Banff National Park to the Wheeler Peak area north of Taos. This was a winter operation with the crates being lifted by helicopter to the alpine tundra zone as in the first Pecos transplant. The first summer the sheep remained in the selected range, but by the second year some erratic wandering had taken place into lower and less desirable areas. We hypothesize that this movement might have been influenced by summer grazing of domestic sheep on some of the prime alpine habitat. Bighorn again became available for transplant, this time from the Wyoming Game and Fish Commission, during January 1970. These 19 animals were ferried by the helicopter to the same release site north of Wheeler Peak. By late spring, many of these sheep were known to have moved, and a search showed them to be approximately 15 miles to the southeast. They had crossed the Moreno Valley and selected a new home range which fortunately is on a tract of some 50,000 acres owned by the Game Department. It is interesting to speculate whether these Wyoming bighorn knew that the Cimarron Canyon they migrated to is an anglicized name from the original Borrego Cimarron, or literally, wild sheep canyon.

These accounts of our reintroduction efforts fairly well summarize one management approach to the Rocky Mountain bighorn. That is, we actively solicit animals from other areas, and we will continue to attempt to trap the surplus from the Sandia Mountains until transplants have been made in all suitable habitats. Some of our other present herds which are increasing at a rapid rate may also furnish transplant stock if a workable capture technique other than a large, fixed and baited trap can be developed.

A second aspect of our mountain sheep management program is our willingness to issue hunting licenses for old, trophy-sized rams even though herd size and the number of known legal rams are small. We have recently had a hunt where only three permits were issued for a particular mountain range. We also have hunted relatively new herds where large mature rams are considered a biological surplus. Last fall, fifteen permits were issued on three areas where the transplanted herds had been in existence for approximately six years. With intensive utilization such as this, we census very closely and only issue licenses for the number of rams known to be unquestionably legal. We use the three-quarter-curl minimum, but add an alternative restriction of 144 points using a modification of the Boone and Crockett scoring system. We carefully instruct each hunter, classify and measure mounted heads, show photographs or movies and verbally discourage shooting of "borderline" rams. We have experienced very little trouble with hunters taking the small "sickle-horn" rams, or with illegal kills or crippling loss.

We have not had a full-time biologist conducting research on bighorn for several years, so our Area Game Managers conduct the population surveys and habitat evaluations. The New Mexico Game and Fish Department has its own super-charged helicopter; thus we have done quite a bit of aerial survey work the last few years. We recognize the need for detailed investigations into several facets of bighorn population dynamics, but financial and manpower limitations relative to other big game management priorities have kept us from getting into this more intensive phase of Rocky Mountain bighorn management.

The success of our Sandia, Gila, and San Francisco River herds, in habitat types somewhat atypical from those normally associated with Rocky Mountain sheep, gives rise to some interesting speculation concerning the sub-specific requisites of *O. c. mexicana and canadensis*. The Sandias have fringes of vegetation common to the Canadian and Hudsonian Life Zones, but they are predominately a Transition Zone mountain range. Much of the lower escarpments and foothills are Upper Sonoran, and the sheep utilize this type too, especially as winter range. The Gila and San Francisco areas are lower in altitude and more xeric. The vegetative associations vary from transition down to Lower Sonoran, and the bighorn, emanating from Banff, Alberta, seem to be doing quite well. Certainly, a much longer period of evaluation must pass before this rather amazing example of bighorn adaptability can be substantiated. It is possible, however, that such an intergrade area could furnish suitable habitat for either *O. c. mexicana* or *canadensis*.

DESERT SHEEP MANAGEMENT

Management of desert bighorn in New Mexico has followed a different pattern. The Guadalupe Mountain herd perished probably due to the combined hazards of illegal hunting and intensive husbandry of domestic sheep and goats. Similar conditions in the San Andres Mountains undoubtedly reduced this desert sheep population to a very low level. The San Andres National Wildlife Refuge, an area of 57,215 acres, was established in 1941. From an initial level of approximately 40 animals, this herd has increased to approximately 200. Unfortunately, our surveys have not shown any significant populations of desert bighorn in the vast expanses of suitable habitat adjacent to the Refuge. During the last few years inter-Agency cooperation between the Fish and Wildlife Service and the New Mexico Department of Game and Fish has increased considerably, and three hunts have been held on the San Andres Refuge. Five permits have been allowed per year, and the fifteen hunters have killed thirteen rams. Only one "borderline" ram has been killed, with all the others being trophy size. The southern end of the Refuge in the favored bighorn areas has received almost all the hunting, with obviously a high degree of success. As some of the rougher, more remote portions of the San Andres are hunted, some Boone and Crockett record-size rams will probably be taken.

The desert sheep of the Big Hatchet Mountains were also undoubtedly reduced to a very low level by 1926 when the 105,000-acre State Game Refuge was established. This herd increased to approximately 125 animals by 1953 when surveys indicated a high proportion of mature rams. Hunts were held during 1954 and 1955 and 26 hunters took 17 rams for a 65% success rate. During this extended period of refuge protection the desert mule deer population also built up to a very high level, and extreme competition between sheep and deer existed. Grazing by domestic livestock was also heavy. Several limited deer die-offs had occurred, but the population remained higher than the range carrying capacity. The period 1953-1957 was one of extreme drought, in fact dendrochronological evidence suggests that this was the most severe drought in 700 years. On some slopes, over 50% of the most desirable browse died. The deer herd crashed from a minimum population of 1000 to a level where sightings were very rare by 1959. The bighorn herd also declined to less than 25 animals between 1956 and 1959, when a full-time biological investigation of the desert bighorn was resumed. These studies continued until 1962, but little conclusive information on factors limiting the Hatcher bighorn could be obtained. Some reproduction was noted, also some mortality, and incomplete surveys and incidental sightings up to the present time suggest that this population is just holding its own.

Plans during the 1930's by J. S. Ligon called for capture of bighorn in the Hatchets, with young to be raised on "Spanish Goats" as foster mothers. A trap with pole and wire wings was built, and some bighorn reportedly entered it on occasion, but none were ever successfully trapped. During the last few years, our Game Department again attempted to trap desert bighorn, this time on the San Andres National Wildlife Refuge. This project was also a failure. The objective was to raise these bighorn in captivity at our Red Rock Game Farm. A ram was obtained from Nevada for breeding purposes in anticipation of the ewes to be trapped. This ram later died from accidental causes, thus our desert bighorn nursery is still in the theoretical stages. If this project can be carried out successfully, reintroduction into the Guadalupes would probably receive highest priority.

These efforts at trapping and creation of a captive herd, together with development of artificial water sources and predator control in the Big Hatchet Mountains, limited aerial survey work, and cooperative administration of annual hunting season on the San Andres, summarize our Department's management program for desert bighorn during recent years. If we don't know the factors limiting bighorn, we do know those limiting our department's ability to perform more detailed management investigations: money and manpower restrictions. We suspect that other states are faced with the same uncomforting restraints.

THE BIGHORN SHEEP IN COLORADO

by

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The Rocky Mountain bighorn sheep is of both historic and current interest in Colorado. Indian petroglyphs depicting the bighorn attest to early day attention. More recently, on May 1, 1961, the General Assembly enacted legislation establishing this species as the state animal of Colorado; and on July 7 of that year the then Game and Fish Commission officially adopted the bighorn as the Department (now Division) insignia. As a result, the bighorn symbol was placed on Division uniforms, vehicle seals, badges of Wildlife Conservation Officers and other law enforcement personnel, and on appropriate materials used by the Division organization.

Interest in the status and welfare of the Rocky Mountain bighorn remains intense, not only on the part of those responsible for its management, or who pursue it as a trophy big game animal, but also by Colorado citizens as well as visitors to the state. This paper summarizes a part of the past and the present Colorado bighorn sheep management program, and briefly describes plans designed to enhance the future welfare of the species.

DISEASE AND THE INITIAL HUNT

Although the bighorn is a magnificent and symbolically sturdy animal, it is not immune to disease and other factors which control animal populations. According to Moser (1962), the bighorn sheep in the Tarryall Mountains of Colorado comprised probably the largest and best known sheep herd in the United States until the winter of 1952-53 when a die-off caused by lungworm disease severely decimated the herd. Prior to this event, the Tarryall herd was twice depleted in numbers: in 1885, supposedly from losses caused by the psoroptic mite; and in 1923-24, from losses attributed to hemorrhagic septicemia (Spencer 1943).

A report by George W. Jones (in Moser and Pillmore 1954) provides insight into the severity of the bighorn sheep die-off in the Tarryall and Kenosha ranges during 1953: "The sheep started dying in the Tarryall from lungworms (pneumonia) starting January 26, 1953. It hit each individual herd working seventeen miles northwest along Tarryall Creek taking 37 days to reach the last herd on the west end of the sheep range.

"To date, we have found 157 rams (including 21 yearlings), 126 ewes and 62 yearling ewes, making a total of 345 animals. The death included all age classes from yearlings to those 14 years of age.

"The first death noticed on the Kenosha Mountains was on July 23. This included 32 ewes, 16 rams and 18 lambs making a total of 66 sheep found dead in this area."

A summary of statistics on dead bighorn sheep found in three areas during the winter of 1952-53 (Moser and Pillmore 1954) is shown in Table No. 1.

Table 1 - Statistics on dead bighorn sheep found during the winter of 1952-53, prior to the initial 1953 hunting season

	Number of Dead Sheep				
Area	Rams	Ewes	Yearlings	Lambs	Total
Pikes Peak	24	24	9	0	57
Tarryall-Kenosha	173	158	93	18	442
All areas	197	182	102	18	499

The bighorn epizootic received considerable attention by biologists and management staff of the then Colorado Game and Fish Department. State Game Manager, Gilbert N. Hunter, and others firmly believed that the loss could be reduced or eliminated by preventing over-concentration of animals, using hunting seasons as a management manipulation. A proposal was made for an 11-day hunting season on rams with one-half or greater curl during September 3-13, 1953.

The contention that hunting was a necessary management tool to "break up" bighorn sheep concentrations and thus help the animals was not universally accepted. Considerable opposition against the season on the part of newspapers, officials, and other interests resulted. However, the need for a hunt was "sold" and the season was established through Commission action. This was the first of 18 consecutive hunting seasons in Colorado that have followed (1953-1970).

Through this 18-year period the advisability of selective bighorn harvest has become accepted. At the same time hundreds of hunters have been able to obtain a trophy ram while enjoying thousands of hours of exhilarating outdoor recreation and returns of the hunts.

REGULATION AND LEGISLATIVE HISTORY HIGHLIGHTS

Several significant dates and features relative to bighorn sheep have been reflected in Commission regulations and Legislative action, a portion of which are recorded in Table No. 2.

Details of regulations for sheep hunting, Table 3, show a trend toward restrictions as seasons have progressed, 1953 to 1970. The horn-size restriction remained at 1/2-curl for legal rams during all years, 1953-1965, except in 1958 and 1959. From 1965 through 1969, 3/4-curl or greater has been required for legal bighorns in most areas. In 1970 the full-curl requirement was imposed in all except three open areas.

Either-sex hunting of bighorn sheep was permitted in one area during 1954, 1957 and 1958, but has not been permitted since, and has never been permitted in any other area.

HARVEST

A total of 3,439 bighorn sheep hunting licenses were issued during the 18-year period, 1953-1970, resulting in the harvest of 817 animals (Table 4). As shown, high and increasing interest in bighorn sheep hunting is indicated. Hunter success has averaged 23.8 percent, the highest, 34.9 percent, in 1954, the second open season; and the lowest (15.3) was in 1970 when only 98 licenses were allowed and full-curl restrictions were imposed in all except three areas.

BIGHORN SHEEP POPULATIONS

Estimates of the bighorn sheep population in Colorado before the lambing period in 1971 ranged from 1,500 to 1,800. These figures are based on estimates from Division personnel, combined with information from the U. S. Forest Service, hunters, and other sources.

Efforts to obtain population estimates have perhaps been more intensive in recent years than for a period immediately preceding this time. It is impossible for this reason to determine trends in bighorn sheep numbers with full accuracy as of this writing.

Moser (1962) stated that there are at least 52 known major sheep herds in Colorado. In 1949, on the basis of trend counts, it was estimated that 70 percent of the sheep were on the eastern slope (east of the Continental Divide). Here, in 1949, the trend count was 1,694 animals whereas, after the die-off in the Pikes Peak, Tarryall and Kenosha herds, the count was 1,283 in 1954.

There is some belief, speculation and evidence that bighorn sheep are declining in Colorado for various reasons, although sizable and healthy herds are still present. It is estimated that the two largest and healthiest herds (Pikes Peak and Saguache) alone account for nearly a third of the total number of bighorns in Colorado. That statewide

Table 2 — Regulation and legislation history highlights

Year	Highlights
1953	First season, September 3-13 (11 days), 18 areas, 1/2 curl, 169 licenses sold.
1958	First year 3/4-curl regulation, 21 areas, rams only, 1 area either sex. Last year either-sex harvest permitted. First year post-season (Nov.) in Poudre, South Platte, Georgetown-Empire, Empire-James Peak Areas. 212 licenses sold. Last year post-season (Nov.) Georgetown-Empire and Empire-James Peak Areas.
1961	Rocky Mountain bighorn sheep designated as State animal, State of Colorado, May 1.
1963	First year successful applicant was restricted to every other year in drawing.
1965	Last year 1/2-curl in all areas but Sheep Creek-Trickle Mountain, Glenwood Canyon, Sheep Mountain, Cimarron Peak, Cow Creek, San Luis Peak, Battlement Mesa, Vallecito Creek, Blanco River.
1969	Last year 1/2-curl allowed.
1970	First year, full-curl regulation in 13 of 16 areas open. 3/4-curl other three areas; 98 licenses, fewest on record.

Table 3 — Summary of bighorn sheep regulations in Colorado, 1953-70

Year	Days in Regular Season	No. of Areas: Curl 1/2	Curl 3/4	Curl Full	Sex: Rams	Sex: E.S.	No. of Areas: Regular Season	Post-Season
1953	11	18	0	0	18	0	18	0
1954	9	21	0	0	21	1	22	0
1955	9	20	0	0	20	0	20	0
1956	9	19	0	0	19	0	19	0
1957	16	17	0	0	17	1	18	0
1958	16	0	20	0	20	1	17	4
1959	16	0	18	0	18	0	16	2
1960	16	21	0	0	21	0	19	2
1961	16	24	0	0	24	0	22	2
1962	17	23	0	0	23	0	23	0
1963	16	23	0	0	23	0	23	0
1964	37	22	0	0	22	0	20	2
1965	23	20	1	0	21	0	19	2
1966	22	1	21	0	22	0	20	2
1967	18	0	18	0	18	0	17	1
1968	23	9	10	0	19	0	18	1
1969	23	1	21	0	22	0	21	1
1970	24	0	3	13	16		16	0

Table 4 — Bighorn sheep hunting applications, licenses and harvest in Colorado, 1953-1970

Year	No. of Applications	Licenses Issued (No. Hunters)	Animals Harvested	Percent Success
1953	Unknown	169	58	34.3
1954	Unknown	226	79	34.9
1955	Unknown	179	45	25.1
1956	Unknown	175	34	19.4
1957	Unknown	218	60	27.5
1958	Unknown	209	51	24.4
1959	234	144	25	17.4
1960	297	177	40	22.6
1961	361	210	46	21.9
1962	485	229	61	26.6
1963	529	226	66	29.2
1964	501	208	59	28.4
1965	596	205	40	19.5
1966	748	285	33	11.6
1967	579	205	36	17.6
1968	462	131	32	24.4
1969	552	145	37	25.5
1970	526	98	15	15.3
Total		3,439	817	23.8

numbers continue to hold at 1,500 plus must be attributed largely to the excellent status of these two herds, with strong evidence suggesting that most other herds are either static or declining. New and concerted efforts are underway to improve census and population trend data permitting the current and changing status of herds to be more accurately determined.

The approximate distribution of bighorn sheep in 1971 is shown in Figure 1. As indicated, 16 areas were hunted in 1970; 15 additional areas have been hunted in the past, and six areas have never been hunted. Areas never hunted include those primarily in National Parks and Monuments, as well as those containing low sheep numbers.

RESTORATION

In September of 1944, a project was established under the Federal Aid in Wildlife Restoration Act in Colorado to initiate trapping and transplanting of bighorn sheep. Cooperation was given by the U. S. Forest Service (Moser 1962). Through the entire Federal Aid trapping and transplanting program, projects W-32-D and W-41-R, 202 sheep were captured and moved into 12 new areas (Table 5). Data do not include animals trapped and moved because of nuisance damage or other reasons. George W. Jones, Clifford A. Moser and Claude E. White played a major part in restoration efforts throughout the trapping and transplanting operations.

PROPOSED MASTER PLAN FOR BIGHORN SHEEP MANAGEMENT

The preceding sections in this paper provide a summary of hunting, population status and restoration efforts undertaken to date in behalf of bighorn sheep in Colorado. It is indicated that much additional effort is needed.

Upon recommendation by the Division, the Legislature earmarked $50,000 during the 1970-71 session for an accelerated study of the bighorn. These and additional monies will be used to implement certain phases of a Master Plan designed to improve the status and management of the species. Basic provisions in the Master Plan are:

1. Identify occupied range and determine the status of each herd.
2. Identify areas where additional sheep are needed.
3. Trap and transplant sheep to all suitable areas.
4. Identify unproductive areas, determine limiting factors, and improve herd status.
5. Obtain data for these objectives through research and field investigations.
6. Utilize the resource through appropriate hunting regulations.

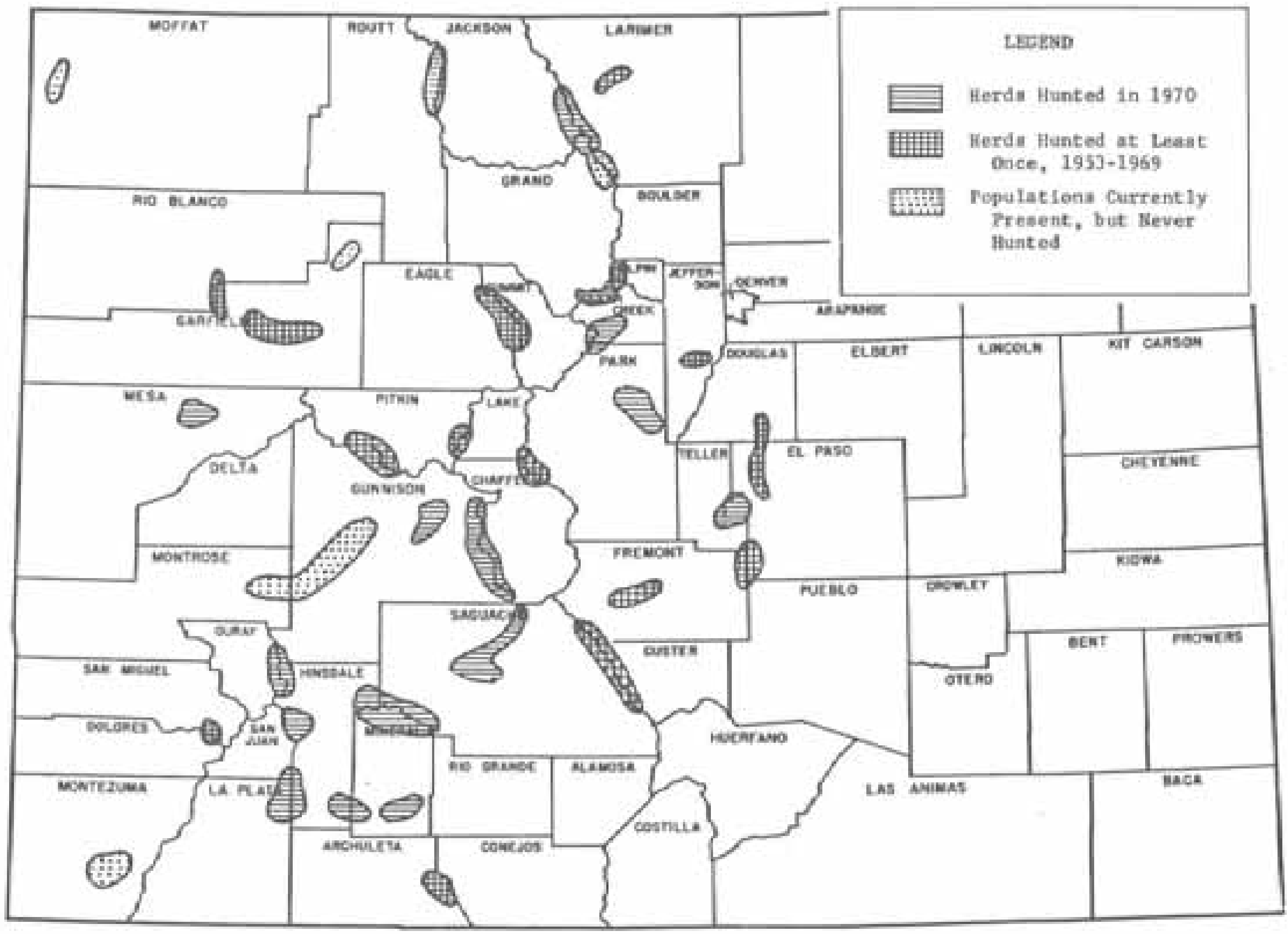

Figure 1-- Approximate Distribution of Bighorn Sheep in Colorado, 1971.

Table 5 -- Bighorn sheep trapping and transplanting in Colorado, 1944-1952

Year	Transplanted to	Number Released				
		Rams	Ewes	Lambs	Yearlings	Total
1944-46	Geneva Creek	3	3	5	0	11
	Sangre de Cristo Range	1	7	6	0	14
	Mesa Verde N.P.	3	7	4	0	14
1946-47	Georgetown	3	20	7	3	33
	Cache la Poudre	3	6	4	3	16
	Rampart Range	3	11	2	0	16
1947-48	Geneva Creek	0	5	0	0	5
	Glenwood Canyon	4	9	4	0	17
	Gore Range	1	6	0	0	7
	Rifle Hogback	4	8	5	0	17
1948-49	Georgetown	2	8	2	2	14
1949-50	Brush Creek	2	3	3	0	8
1950-51	Saguache Creek	3	8	4	0	15
1951-52	Ladore Canyon	3	12	0	0	15
1952-53	Tarryall die-off -- end of trapping and transplanting					
Totals		35	113	46	8	202

FUTURE CONSIDERATIONS

The Master Plan for bighorn sheep indicates the general procedures or approaches considered necessary in effecting improved management. Specific consideration in this plan and in on-going management activities relate to two basis purposes, production and utilization. Subsequent to research and field investigations, the Division hopes to improve sheep production through: (1) trapping and transplanting, (2) disease control or abatement, and (3) perhaps most importantly, range improvement.

For the utilization phase of management it is anticipated that: (1) harvest will be selective by area based on improved population information; (2) evaluation of the biological reasons for trophy ram harvest, curl limitation, and the potential need for bighorn harvest will be made; (3) studies on time of year for hunting and length of season will be conducted; (4) the bighorn sheep is a "privilege" species from the hunting standpoint and that the existing regulation limiting harvest to an animal in a lifetime is consistent with this philosophy; and (5) clearer identification of the role the bighorn plays in providing consumptive and non-consumptive recreational enjoyment is both necessary and desirable.

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THE BIGHORN SHEEP IN UTAH -- PAST AND PRESENT[1]

by

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and

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ABSTRACT

There is archeological and historical evidence that bighorn sheep once were prevalent throughout most of what is now Utah. Skeletal remains of bighorns have been found in many parts of the state. Some of these date back to a late Pleistocene period, early to middle Wisconsin; however, most are more recent and are associated with caves inhabited by prehistoric man. This association and the petroglyphs and pictographs of bighorns, common in many parts of the state, indicate the bighorn must have been a very important source of food and clothing for prehistoric man.

The first white man to record bighorn sheep in Utah was Father Escalante. He stated that in 1776 bighorns were abundant along the Colorado River and the frequency of their tracks was comparable to large flocks of domestic sheep. Many trappers, explorers, and early pioneers in the state also reported the abundance of bighorns. However, with the advance of Western civilization, a steady decline in bighorn sheep numbers resulted. By the late 1800's, bighorns were sparse throughout most of the state, and by the mid-1920's bighorns had disappeared from most ranges in northern Utah.

Two subspecies of bighorn sheep, the Rocky Mountain bighorn (*Ovis canadensis canadensis*) and the desert bighorn (*Ovis canadensis nelsoni*), are found in Utah today. The presence of the former is primarily a result of re-introductions into Dinosaur National Monument and along the Wasatch Range near Brigham City. Utah's largest bighorn population consists of desert bighorns. This population inhabits the Colorado drainage from Dead Horse Point to the confluence of the Colorado and Green Rivers, through Cataract Canyon down to Red Canyon on the eastern side of the northern end of Lake Powell. As a result of studies conducted by the Utah Cooperative Wildlife Research Unit and the Utah

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[1]Contribution from the Utah Cooperative Wildlife Research Unit, Utah State University, U. S. Bureau of Sport Fisheries and Wildlife, The Wildlife Management Institute, and the Utah Division of Fish and Game cooperating.

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Division of Fish and Game, limited bighorn trophy hunts have been held in the Red and White Canyon areas of southeastern Utah each year since 1967.

Although bighorn populations in Utah presently are not large, they attract considerable attention. Interest by Federal and State agencies in bighorns has grown steadily through the 1960's. Also, many of the mountains and deserts of Utah provide suitable bighorn habitat. With continued interest, foresight and effective management, the bighorn may again become plentiful in many parts of the state.

INTRODUCTION

Bighorn sheep are one of North America's most highly prized trophy animals. From the aesthetic point of view, they are one of the most challenging and exciting animals to find and to observe in its natural habitat.

A Eurasian bighorn (*Ovis ophion*) is considered to represent the ancestral stock of all bighorn sheep (Stokes and Condie 1961). Although authorities agree that the bighorn migrated across the Bering Land Bridge to North America from Eurasia (Cowan 1940, Clark 1967, and Hopkins 1967), there are a number of different opinions concerning the ancestry of the two species of North American bighorns--the Alaskan bighorn (*O. dalli*) and the Canadian bighorn (*O. canadensis*).

PREHISTORIC EVIDENCE OF BIGHORNS IN UTAH

Bighorn sheep were prevalent before the appearance of the white man throughout what is now Utah. Two subspecies of bighorn sheep, the desert bighorn (*O. c. nelsoni*) and the Rocky Mountain bighorn (*O. c. canadensis*), are found in Utah today (Wilson 1968).

Skeletal remains of bighorns have been found in many parts of the state (Figure 1). Some bighorn remains consisting of the posterior cranial elements with horn cores have been found at the Hardman gravel pit near Salt Lake City. According to Stock and Stokes (1969), these date back to a late Pleistocene period, early to middle Wisconsin in age. They considered these Pleistocene bighorns to be an evolutionary population which eventually developed into *O. canadensis*.

Bighorn dung, which archeologists reported to be about 11,000 years old, and sheep remains showing use by prehistoric man have been found in various layers during the excavation of Danger Cave near Wendover, Utah (Dibble et al. 1959). Dibble also postulated that bighorns could have existed in this area before then, but there is no evidence of this because the cave previously was filled with the waters of Lake Bonneville.

The bighorn must have been important to prehistoric men who inhabited what is now Utah, because bighorn remains often are found in caves which were inhabited by them (Jennings 1970). Hansen and Stokes

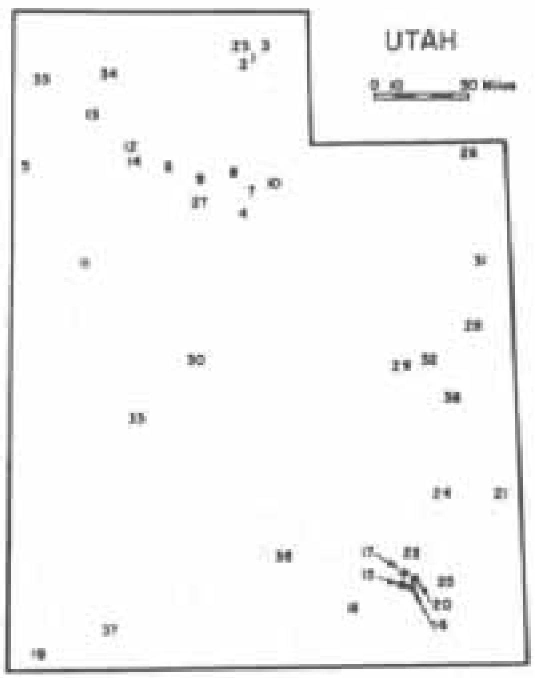

Figure 1. Locations of bighorn skeletal remains found in Utah (see Appendix for key to locations).

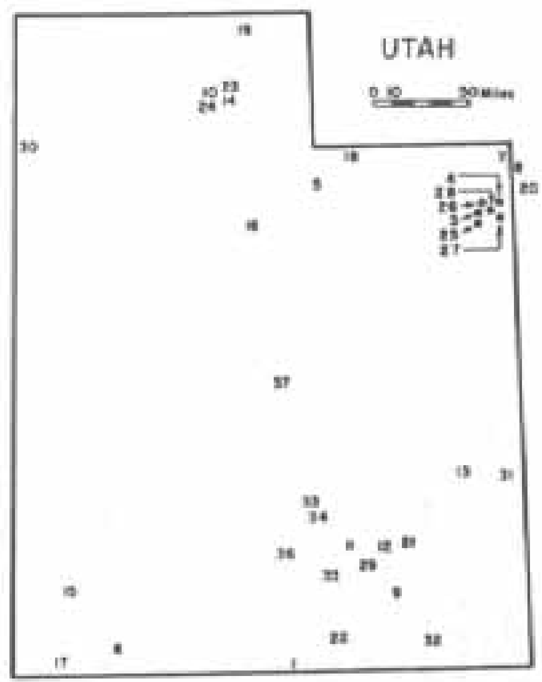

Figure 2. Locations of recorded bighorn sightings in Utah between 1776 and 1950 (see Appendix for key to locations).

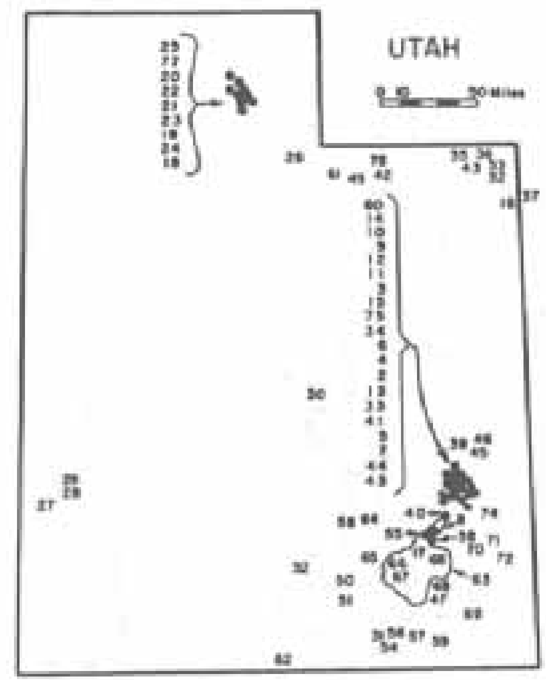

Figure 3. Locations of recorded bighorn sightings in Utah since 1950 (see Appendix for key to locations). Area 63, outlined by a heavy dark line, encompasses the study areas of Wilson (1968) and Irvine (1969).

See Appendix at end of article for key to locations.

(1941) found skulls and other bighorn skeletal bones in a cave inhabited by prehistoric man in American Fork Canyon. Stokes (1970) stated that this cave was important in illustrating the fact that prehistoric men heavily utilized the bighorn. The number of bighorn hides and bone awls found there is convincing evidence that these people used the bighorn as a source of both food and clothing. Stokes (1970) also has postulated that the bighorn was the most important source of protein to Indians in Utah before the white man's civilization caused a decrease in bighorn populations.

HISTORICAL REPORTS OF BIGHORNS IN UTAH

The earliest records of bighorns in Utah are the petroglyphs and pictographs left behind by early man. These early records have been found in many parts of the state (Hague 1970). Father Escalante was the first white man to record bighorn sheep in Utah. He stated that bighorns were very abundant along the Colorado River in 1776, and the frequency of their tracks was comparable to large flocks of domestic sheep (Wilson 1968). Most trappers and explorers who entered Utah also recorded something about bighorns in their journals. Locations of recorded bighorn sheep sightings in Utah between 1776 and 1950 are presented in Figure 2.

Osborne Russell, an early western trapper, visited Utah in late 1841 and 1842. While camped near the present town of Willard in December of 1841, he hiked into the rugged cliffs nearby to hunt for camp meat. When daylight came, Russell shot a number of bighorns in this area. He again returned to these mountains in February of 1842 and again was successful in killing bighorns (Haines 1955).

Bighorns were easy to kill when trappers were the only white men in the Rocky Mountains. Dodge, a western trapper, stated that if a hunter could approach a band of sheep, he could easily kill five or six. He claimed that with the first shot a band of sheep would bunch up to watch the smoke from the gun. Then four or five could easily be killed before they became frightened (Dodge 1959).

The flesh of bighorns was considered to be delicious, and Indians and trappers alike pursued the bighorn for its meat. The Indians considered it more sweet and delicate than any other kind of wild meat (Irving 1898). Western trappers also admired the bighorn for its beauty. Trappers occasionally wrote in their journals that the bighorn could elude predators and man by diving over the edge of a high precipice. It was their belief that the animal could survive the fall by landing on its enormous horns (Dodge 1959, and Hafen 1956).

Captain Fremont (1945) reported bighorns in the uinta area during June of 1844. His party killed several bighorns at Browns Park, along the Green River. Browns Park, known to the trapper as Browns Hole, was a favorite wintering place for trappers. There was an abundance of game, including bighorn sheep, in the surrounding mountains. He also reported bighorns in the rocks along the river bottom in the area where Vermillion Creek enters the Green River.

Dellenbaugh (1908 and 1962), a member of the Powell expedition, was amazed at the abundance of deer, bear, and mountain sheep which he observed between Browns Park and Split Mountain in 1871.

Powell (1869) reported seeing mountain sheep around a small park at the confluence of the Yampa and Green Rivers. He explained that the Indians often used a steep trail to gain access into this park to kill bighorns. During July of 1875, Powell's party killed two bighorns in Cataract Canyon along the Colorado River.

George Hobbs, a Mormon pioneer in the late 1800's, was led to the bottom of some seemingly impassable slick rocks while following a bighorn sheep down to the edge of the Colorado River at a place now called Hole-in-the Rock. Hobbs reported bighorns to be curious, and told how one came within 15 feet of his campfire (Jones et al. 1957).

LAWS FOR PROTECTING BIGHORNS IN UTAH

Prior to 1876, the territory of Utah had no regulations regarding the taking of bighorn sheep. However, a season from July through December was set in 1876 for all big game animals. There were very liberal game laws between 1876 and 1899, but when Utah became a state in 1899 the state legislature passed a law prohibiting the hunting of bighorn sheep. This law remained in effect until 1967 when a limited number of permittees were allowed to hunt the desert bighorn (John 1968). However, there are not enough Rocky Mountain bighorns in Utah to provide a harvestable surplus, and both John (1970) and Huff (1970) agree that it will be far into the future before the Rocky Mountain bighorn will be hunted as a game animal in Utah.

DECLINE IN BIGHORN POPULATIONS

Bighorns inhabited almost every mountain range in Utah before the coming of the white man. The advance of Western civilization, however, caused a steady decline in bighorn sheep numbers. This decline was noted as early as 1870 (Buechner 1960). Civilization brought domestic animals and centers from which our natural resources could be exploited. This meant disaster for bighorns, as they are unable to tolerate the activities of mining and cattle and sheep raising (Irvine 1969).

Irvine (1969) found that the diet of the desert bighorn consisted of climax plants. Climax plants become less available to bighorns when overgrazing occurs, and, because of improper nutrition, they then are unable to combat parasites. Domestic livestock also exposed the bighorn to both scabies and lungworm and, due to poor range conditions caused by overgrazing, the bighorn has been reduced in numbers and forced to inhabit less desirable areas (Wilson 1968).

BIGHORN POPULATIONS IN UTAH

The advent of the white man in Utah resulted in the demise of bighorn sheep populations. Remnant populations persist, however, in various parts of the state, and the list of valid bighorn sightings since 1950 continues to grow (Figure 3). Information concerning bighorn populations within geographical areas of Utah will be discussed briefly.

NORTH CENTRAL UTAH

Rocky Mountain bighorns were known to exist on Mt. Nebo in the 1800's and still were found along the Wasatch Mountains between 1890 and 1927 (John 1970). A bighorn was killed in 1905 near Tony Grove in Logan Canyon (Barnes 1927). In 1917, Rulon White of Ogden saw 23 head of bighorn sheep behind Willard Peak. He also reported seeing about 15 animals in the same area in 1923. This was the last time native Rocky Mountain bighorns were reported in the Willard Peak area (Huff 1970).

Bighorns were reported on Mt. Timpanogos during 1926 and 1927 (Barnes, 1927). These were probably the last of the native bighorns reported on the Wasatch Mountains. Although these few reported sightings of Rocky Mountain bighorn sheep were along the Wasatch Front, there is evidence that bighorn sheep once inhabited the entire range. Skeletal remains have been found at various points throughout the Wasatch Mountains. Several skulls with horn cores have been found in the mountains east of Logan, and also along the Wasatch Front east of Salt Lake City.

NORTHWESTERN UTAH

Increasing evidence indicates that bighorn populations once inhabited the mountain ranges bordering the Great Salt Lake, as well as various ranges in the Great Salt Lake Desert. Skeletal remains have been found on many of these northwestern mountains and, in a few cases, there have been actual sightings of bighorns. Skulls with horn cores and an occasional horn have been found on Stansbury Island, Granite Mountain, and on the Oquirrh, Newfoundland, and Lakeside Mountains (see Figure 1). Bighorn sightings were reported for Granite Mountain in the early 1900's (Barnes 1927), and in 1910 a bighorn was killed 25 miles north of Wendover (Buechner 1960). One of the former ranges being considered for re-introduction of bighorns is the Newfoundland Mountains (Drobnick 1970).

NORTHEASTERN UTAH

There have been sporadic reports of sightings of Rocky Mountain bighorns in the Uinta Mountains and the Uinta Basin area in northeastern Utah since white men first entered the area. Bighorns were reported in the Red Canyon area, which is now part of Flaming Gorge Dam, as early as 1849 (Barmore 1962). Trappers and explorers persistently remarked about the abundance of bighorns along the Green River near Browns Park and Split Mountain Canyon, which is now part of Dinosaur National Monument on the Utah-Colorado border.

An estimated 150 bighorns inhabited Split Mountain Canyon around 1910, and at that time bands of 25 to 50 bighorns occasionally were seen. National Park Service employees verified the presence of bighorns on Split Mountain in 1943, but the last sighting of the herd was near the mouth of Split Mountain Canyon in 1944 (Barmore 1962).

The Colorado Fish and Game re-introduced Rocky Mountain bighorns into the Monument in 1952. Since then, bighorns have been seen occasionally along the rivers that flow through the Dinosaur National Monument (Barmore 1962). As recently as 1970 bighorns were seen at Jones Hole (Hannah 1970).

In addition to Dinosaur National Monument and the surrounding canyons and mountains, the high peaks of the Uinta Mountains and the canyons at Flaming Gorge also serve as Rocky Mountain bighorn range (Drobnick 1970). Outside of occasional sightings by people working in or visiting the Uinta Mountains, little is known about the remnant population in this area (see Figures 2 and 3).

A Rocky Mountain ram wandered into the Coalville area and bred a domestic ewe belonging to Herman Edgel during the fall of 1959. A hybrid ewe was born the following spring, and she has since given birth to a lamb (Dearden 1967).

A bighorn skull was found near Fruitland during the 1950's. It was wedged (about 6.5 feet off the ground) in a large Juniper tree. This section of the tree containing the bighorn skull can be seen at the Current Creek Cafe on Utah Highway 40 between Strawberry Reservoir and Fruitland (Chatwin 1970).

In 1964, two sightings of bighorns were made by Forest Service employees in Summit County (Dearden 1967). Bighorns were observed on the Uinta Mountains at Henry's Fork and also in the Dead Horse area. The two latest recorded sightings for the high Uintas were made in 1965 and 1970. Ralph Noble, a Utah Fish and Game employee, sighted a mature ram north of the Weber River in 1965 at Lofty Lake (Drobnick 1970). In 1970, Reddin (1971), a sheepman for G. R. Broadbent, photographed two bighorn rams near the confluence of the East Fork of Black Fork and the Little East Fork.

Rocky Mountain bighorns were reported several times by construction workers during construction of Flaming Gorge Dam (Barmore 1962). A mature ram was reported in 1966 near the Cart Creek bridge on Utah Highway 44. Since then tourists also have reported bighorns in this area (Drobnick 1970).

WEST-CENTRAL UTAH

West-central Utah, which consists of Juab, Millard, San Pete, and Sevier counties, apparently has no bighorn populations. Barnes (1927) however reported that horns from a bighorn sheep were found near Salina. Drobnick (1970) also found a bighorn skull in the Canyon Mountains east of Oak City. Bighorns also are known to inhabit both the Needles and Wah Wah Mountain ranges, which extend from Beaver County into Millard County, but the only sightings on record for these two mountain ranges have been in Beaver County.

This section of Utah probably never will have significant numbers of bighorns.

EAST-CENTRAL UTAH

East-Central Utah, which consists of Carbon, Emery, Grand, and the lower one-third of Uinta County, supports populations of both Rocky Mountain and desert bighorns. A small bighorn population is believed to inhabit the San Rafael Swell. There have been occasional sightings in this area, but the only confirmed sighting was a young ram observed by a Fish and Game employee near the Feron City garbage dump in 1964 (Drobnick 1970). However, archeological records indicate that bighorns existed just north of Thompson (Wormington 1955).

Bighorns occasionally were sighted in Arches National Monument during the 1950's. Two sightings were made as late as 1958: one bighorn was seen watering in the Upper Courthouse area, and the other was seen in the Lower Fiery Furnace area (Follows 1969).

SOUTHWESTERN UTAH

Evidence indicates that bighorns were plentiful in southwestern Utah in the late 1800's and early 1900's, although few bighorn apparently exist there today. Barnes (1927) reported that the bighorn was once very numerous in the mountains north and west of Panguitch. He also mentioned bighorn sightings on the Frisco Mountains in Beaver County, and on the Pink Ledge of Little Zion in Washington County. Desert bighorns were reported on Little Pinto as early as 1899, and a bighorn was found floating in the Virgin River in 1919 (Barnes 1927).

Bighorns have been known to exist in the mountains west of St. George. Around 1958 a skull was removed from a dead bighorn on the Beaverdam Mountains about 15 miles west of St. George. The skull presently is in the University of Utah's Museum of Zoology in Salt Lake City.

References have been made to desert bighorns in the Wah Wah Mountains since the early 1900's. A bighorn ram bred domestic ewes in these mountains in 1966, and a bighorn ram and six ewes were seen in the Wah Wahs in 1968 (John 1970). Also, the Utah Division of Fish and Game range crew spotted bighorns on two different occasions in the Needles Mountain Range in 1968 (Drobnick 1970).

In the 1800's bighorns were common in the vicinity of what is now Zion National Park (Metherell 1970). In 1939 a band of 25 bighorns was observed at the junction of the North Fork and the Virgin River (Cowan 1940). Many authorities were convinced that bighorns at Zion were increasing in numbers during the 1930's and 1940's (Buechner 1960). However, bighorn numbers dwindled in the Park, and in 1953 the last reported bighorn (a ewe) was observed on a promontory called the Watchman (Metherell 1970).

SOUTHEASTERN UTAH

The largest present day bighorn population in Utah is in the southeastern part of the state (see Figure 3). According to Drobnick (1970), the range of the desert bighorn in Utah

> . . . is from Dead Horse Point along the Colorado River to the confluence of the Colorado and Green Rivers, through Cataract Canyon down to Red Canyon. The area from the confluence up to Dead Horse Point in Canyonlands is a non-huntable population, but the area in Cataract Canyon south of Gypsum Canyon to include lower Dark Canyon, Woodenshoe Canyon, White Canyon, and Red Canyon drainages is a relic hunting population.

Based on sightings gathered, it appears two distinct populations of desert bighorns exist within the boundaries of Canyonlands National Park. Frequent sightings come from the area around Junction Butte; and Follows (1969) stated that the major bighorn population in Canyonlands is in the "triangular shaped area north of the confluence."

A population of bighorns once existed just east of Canyonlands in Lockhart Basin, but it has vanished during the past few years. Drobnick (1970) postulated that these bighorns may have been exterminated by miners. Occasional bighorn sightings have been made from the visitors' center at Dead Horse State Park north of Canyonlands (John 1970).

Two Master of Science theses have been done on the desert bighorn populations in the White and Red Canyon areas. The first study of Utah's desert bighorns was initiated by Wilson in 1965, and the second was undertaken by Irvine in 1967. Both were associated with the Utah Cooperative Wildlife Research Unit at Utah State University, and supported by the Utah Division of Fish and Game. As a result of Wilson's study, limited hunting of trophy bighorn rams in this area was initiated in 1967. Hunts have been held each year since.

Sightings within the White and Red Canyon areas have been numerous, and their numbers continue to grow. Interest in Utah's desert bighorns began during the late 1940's and early 1950's when uranium was discovered in southeastern Utah. Much of this part of the state was virtually unexplored, but the discovery of uranium drew great numbers of people into the area. Miners and prospectors soon saturated the area and reports of desert bighorns began to increase. Miners living in the desert often utilized the bighorn for both sport and food. Although illegal to do so, they often hunted the bighorn; and, in a few cases, the bighorn apparently was a primary source of meat (Wilson 1968).

Navajo Indians also hunted desert bighorns. In 1942, residents in White Canyon reported seeing Indians leaving the canyon with 60 or 70 bighorn hides loaded on three pack horses (Wilson 1968).

A decrease in mining activities, the initiation of more conservative grazing programs, and increased interest by both State and Federal agencies in the welfare of desert bighorns have helped and will continue to help these sheep. Both Irvine's (1969) and Wilson's (1968) studies indicated increasing bighorn populations in the Red Canyon area.

In addition to Canyonlands and the Red Canyon area, desert bighorn populations also exist in other parts of southeastern Utah. Road crews have reported bighorns in the Henry Mountains (John 1970). A population of bighorns also is known to exist on the Little Rockies, at the southern end of the Henry Mountains (Follows 1970). Warburton (1970) similarly reported bighorn sightings at two locations in the Henry Mountains during 1969: on Mt. Hillers and east of Mt. Ellen at the north end of the range.

Charles Hunt reported seeing bighorns near the top of Mt. Peale in the La Sal Mountains in 1949 (Buechner 1960), and the skull of a ram which was illegally killed 1.5 miles north of La Sal in 1954 presently resides in the Museum of Zoology at the University of Utah.

Bighorns occasionally have been reported from areas south of Moab. Mel Stewart, a rancher, reported in 1923 that he often observed bighorns along the Colorado River bottoms about 20 miles below Moab (Barnes 1927). Another stockman, Lloyd Somerville, reported that in 1951 bighorns of both sexes had mixed with his domestic sheep on their winter range 15 miles south of Moab (Buechner 1960).

Warburton (1970) reported recent bighorn sightings in areas south of Moab. In 1968 he observed bighorns at the confluence of Indian Creek and the Colorado River, and near Hatch Point in the Needles overlook area.

Follows (1970) stated that a group of bighorns was observed on Iron Top Mesa at the southern end of the Waterpocket Fold. Fifteen bighorns were observed on Deer Point Mesa in 1968, which is also near the southern end of the Fold (Drobnick 1970). Bighorns historically inhabited the full length of the Fold. They existed in Capital Reef National Monument until 1948, when the last one apparently was shot by a sheepherder (Follows 1970).

Bighorns occasionally are sighted along the San Juan drainage. Five bighorns were observed at the mouth of John's Canyon in 1956, and 14 bighorns were reported along the San Juan River at the upper end of Lake Powell in 1967. Bighorns were observed in Mike's Canyon during 1968, and during a helicopter survey conducted by the Utah Division of Fish and Game in 1969, a ram was seen along the San Juan River near the mouth of Castle Creek (Drobnick 1970).

RE-INTRODUCTION OF BIGHORNS INTO UTAH

THE WASATCH MOUNTAINS

In 1960, the Utah Division of Fish and Game became interested in re-establishing the bighorn on its former ranges in Utah. Between 1961 and late 1965, the Division began looking for a parent stock of bighorn sheep, and made the necessary preparations to receive them. An 80-acre paddock was built to hold bighorns on Brigham Mountain near Brigham City, Utah. By April of 1966, 34 bighorns from Wyoming and Canada had been shipped to Utah. However, the 80-acre paddock was capable of supporting only about 20 animals. Therefore, an additional 1200-acre adjoining paddock was built.

A few bighorns have escaped from the paddocks each winter because of snow and wind damaging sections of the fence. As a result of these escapes, there have been occasional bighorn sightings in the Willard Peak area and along the Wellsville Mountain Range (Huff 1970) and Chronological Diary of Bighorn Project, 1966 to 1970). It appears these animals will result eventually in the establishment of a herd of Rocky Mountain bighorns on the Wasatch Range. The bighorns remaining in the paddocks will be held as parent stock from which releases will be made when suitable areas have been determined (Huff 1970).

Many problems are involved in the re-introduction of bighorns. A major problem is that the sheep must be handled frequently: during capture, transportation, veterinarian checks, and unloading. Bighorns are easily injured and readily contact pneumonia. Dr. Smart of the Veterinary Science Department at Utah State University has developed a cultured vaccine, which appears to be effective in combating pneumonia in bighorns (Huff 1970).

THE BOOK CLIFFS

A few skeletal remains have been found in the Book Cliffs, and the Hill Creek Indians have re-introduced Rocky Mountain bighorns into the Book Cliffs at Florence Creek Canyon. They received 10 bighorns (nine ewes and only one immature ram) from Wyoming in 1969. These animals were released, but nothing concerning them has been reported since their release. The Indian Tribe hopes to receive more bighorns from Wyoming during the winter of 1970-71 (Curry 1970).

ZION NATIONAL PARK

A program to re-introduce desert bighorn sheep into Zion National Park was initiated in 1967. An 80-acre holding paddock for parent stock was completed in January 1970. This paddock which includes year-round bighorn habitat is strategically located for ease of surveillance and care of the parent stock. It also is secluded from the view of tourists to minimize disturbances. Bighorns have not yet been located for this project, but when they are, a detailed study will be made regarding the basic conditions under which desert bighorns may be restored into other areas (Metherell 1970).

FUTURE OF UTAH'S BIGHORN SHEEP

The future for the bighorn in Utah appears to be bright. Existing stocks are being protected and conservationists are working towards the re-introduction of Rocky Mountain and desert bighorns into suitable areas.

The Bureau of Land Management has made a special request to the mining industry to reduce explorations during the bighorn's lambing period (Call and Mahon 1970). Cooperation from such industries will greatly enhance the chances of lamb survival. John (1968) claimed lamb mortality is very high during the first year, but if a lamb survives its first year, it can be expected to live at least 10 years.

Water seems to be a limiting factor for desert bighorn populations. Twelve seeps or springs in southeastern Utah were developed or improved during 1968 and 1969 by the cooperative efforts of the Bureau of Land Management and the Utah Division of Fish and Game so that bighorns could use them all year (Call and Mahon 1970).

The Utah Division of Fish and Game, the Bureau of Land Management, and the Intermountain Forest and Range Experiment Station have initiated a cooperative study in 1966 to investigate possibilities of improving the forage on desert bighorn ranges. As a result, it was found that mesa tops could be improved as desert bighorn habitat (John 1969).

SUMMARY

Although Rocky Mountain and desert bighorn populations in Utah are not large, the bighorn is an important animal in the State. The bighorn already provides limited recreation. With time and effective management, the bighorn undoubtedly will provide many more hours of enjoyment, as well as economic benefits,to the state.

Interest in bighorns by both Federal and State agencies has grown steadily through the 1960's. However, governmental interest alone is not enough to guarantee the survival and restoration of bighorn populations. Public interest and conservation action must be stimulated.

Many of the mountains and deserts of Utah have suitable bighorn habitat. Re-establishment of the bighorn should be given priority in some of these areas to ensure that it will again become plentiful in Utah.

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DISCUSSION

QUESTION BY JOHN RUSSO, ARIZONA G & F: Did they ever decide what species or subspecies you have?

REPLY BY DALTON: Dr. Durant, the mammalogist at the University of Utah, doesn't commit himself.

QUESTION BY NORMAN SIMMONS, CANADIAN WILDLIFE SERVICE: In the northern sheep, which are in the scabies area, is there any evidence that sheep have been dying from this and also is this domestic sheep range?

REPLY BY DALTON: There are no domestic sheep there now but there is a history of grazing on the range. We don't know about die-offs but all the rams taken, which is a limited number, have had scabies.

KEY TO FIGURE 1 - SKELETAL REMAINS OF BIGHORNS FOUND IN UTAH

	YEAR	LOCATION OF SHEEP SKELETONS	OBSERVER AND/OR SOURCE
1.	1968	Skull found in Providence rock quarry (Figure 5).	(Anderson 1970).
2.	1968	Skull found in Providence rock quarry (Figure 5).	(Campbell 1970).
3.	1967	Skull found in Right Hand Fork of Logan Canyon (Figure 6).	(Holden 1970).
4.	1941	Skeletal remains of bighorns were found in a cave in American Fork Canyon about 3 miles above the Timpanogos Cave offices.	(Hansen and Stokes 1941).
5.		Danger Cave, near Wendover Utah. Skeletal remains and droppings were found here.	(Dibble et al. 1959).
6.	1970	Skull found on Stansbury Island.	(Wilson 1970).
7.	1907	Skull found at the head of Hughes Canyon near the twin peaks in Salt Lake City.	(Barnes 1927).
8.	1900's	Several bighorn skulls collected at the Hardman gravel pits northeast of Salt Lake City are in the Geology Department at the University of Utah.	(Stokes and Condie 1961).
9.	1968	Skull found in Black Rock Canyon in the Oquirrah Mountains by highway construction crews.	(Madsen 1970).
10.	1967	Skull found at Silver Creek by highway construction crews.	(Madsen 1970).
11.	1969	Skull found in Tooele County at the west base of Granite Mountain.	(University of Utah, Museum of Zoology).
12.	1958	Skull found in Tooele County on the west side of Lakeside Mountain.	(University of Utah, Museum of Zoology).
13.	1967	Skull found in Box Elder County on the northeast side of the Newfoundland Mountains.	(University of Utah, Museum of Zoology).
14.	1958	Skull and a single horn found in Tooele County on the west side of Lakeside Mountain.	(University of Utah, Museum of Zoology).
15.	1965	Skull found two miles west of Soldier Crossing and Utah Highway 95 on Piute Mesa.	Ruby Drobnick (University of Utah, Museum of Zoology).
16.	1965	Skull found in Slope Hollow on the southeast ridge of Fry Point Mesa, San Juan County.	Rodney John (University of Utah, Museum of Zoology).
17.	1950's	Skull from Jacob's Chair, White Canyon. Poached by uranium miners.	(University of Utah, Museum of Zoology).
18.	1954	Skull from bighorn killed at the junction of Hall's Crossing and the Colorado River. Donated by June King.	(University of Utah, Museum of Zoology).
19.	1958	Skull from bighorn found on Beaverdam Mountain, 15 miles west of St. George.	Arthur Bruhn (University of Utah, Museum of Zoology).
20.	1963	Skull found at Horse Flat, White Canyon, San Juan County.	Rodney John (University of Utah, Museum of Zoology).
21.	1954	Skull from the La Sal Mountains. Confiscated by Utah Fish & Game 1.5 miles north of La Sal.	(University of Utah, Museum of Zoology).
22.	1966	Ram skeleton found near Dark Canyon along the east side of the Colorado River Terrace.	(Follows 1969).
23.	1970	Ram's skull found in a draw northwest of Zanavoo Lodge in Logan Canyon. (Figure 6).	(Abee 1970).
24.	1957-1960	Two skulls found by Col. Mikesell in a cave on the south end of Squaw Flat in Canyon lands. Now at Pat Creek Ranch near Moab.	(Drobnick 1970).

KEY TO FIGURE 1 - (CONT.)

	YEAR	LOCATION OF SHEEP SKELETONS	OBSERVER AND/OR SOURCE
25.	1950	Skull from an illegally killed bighorn confiscated by Fish and Game at the Bears Ears.	(Drobnick 1970).
26.	1960	Skull found on east side of Hide Out Flat Ridge at Flaming Gorge by clearing crew foreman.	(Drobnick 1970).
27.	1953	Skull found on Coons Peak, in the Oquirrah Mountains.	Eldon Jenkins (Drobnick 1970).
28.	1970	Two ram skulls found in the Book Cliffs west of P.R. Springs in the Main Canyon drainage.	(Drobnick 1970).
29.	1969	Skull found along Range Creek in Desolation Canyon, now at the Highway Junk House in Wellington.	(Drobnick 1970).
30.	1957	Skull uncovered by storms in a 9-foot deep wash at forest boundary and Oak Creek Canyon in the Canyon Mountains east of Oak City.	(Drobnick 1970).
31.	1933	Skull found 20 miles east of Ouray.	J.K. Doutt (Drobnick 1970).
32.	1936	Skull found at Florence Creek in Desolation Canyon.	J.K. Doutt (Drobnick 1970).
33.	1970	Skull found in cave along Utah Highway 30 at southern end of Grouse Creek Mountains.	(Wagner 1970).
34.		Bighorn remains found in Hogup Cave.	(Jennings 1970).
35.	1955	Skull found ca. 8 miles east of Desert Range Experiment Station on the mountain slope.	(Butcher 1971).
36.	1955	Bighorn remains in the Turner Ranch site representing the Fremont Culture just north of Thompson.	(Wormington 1955).
37.	1955	Bighorn or deer bones identified in the archaeological investigations of Zion National Park.	(Schroeder 1955).
38.	1959-1961	Bighorn bone fragments of prevalent archaeological investigations of the Coobs Site at Boulder.	(Lister 1959, 1960, and 1961).

KEY TO FIGURE 2 - RECORDED BIGHORN SIGHTINGS IN UTAH BEFORE 1950

	YEAR	LOCATION OF SHEEP SIGHTINGS	OBSERVER AND/OR SOURCE
1.	1776	Colorado River "Crossing of the Fathers."	Escalante (Wilson 1968).
2.	1776	Breaks of the Colorado River.	Escalante (John 1968).
3.	1871	Green River through Split Mountain.	(Dellenbaugh 1962).
4.	1871	Green River in Whirlpool Canyon.	(Dellenbaugh 1962).
5.	1939	Mt. Baldy in the Uinta Mountains.	N. B. Cook (Cowan 1940).
6.	1939	Junction of the Virgin River and the North Fork of the Virgin River in Zion National Park.	Cliff Presnall (Cowan 1940).
7.	1844	Green River and Browns Hole.	(Fremont 1845).
8.	1844	Junction of Green River and Vermillion Creek, inside Colorado.	(Fremont 1945).
9.	1942	White Canyon, San Juan County. Residents saw Indians remove 3 pack horses loaded with bighorn hides.	(Wilson 1968).
10.	1841	Wasatch Mountains near Willard. Russell killed mountain sheep here on two different days.	Osborne Russell (Haines 1955).
11.	1947	Henry Mountains.	(Durrant 1952).
12.	1946	Junction of Colorado River.	(Durrant 1952).

KEY TO FIGURE 2 - (CONT.)

	YEAR	LOCATION OF SHEEP SIGHTINGS	OBSERVER AND/OR SOURCE
13.	1923	Twenty miles below Moab on Colorado River bottoms. Rancher reported seeing bighorns every time he visited his cattle.	Mel Stewart (Barnes 1927).
14.	1896	Band of bighorns reported on Willard Peak.	(Barnes 1927).
15.	1899	Bighorns were known on Little Pinto in southwestern Utah.	(Barnes 1927).
16.	1926	Bighorns reported on Mt. Timpanogos.	(Barnes 1927).
17.	1919	Bighorn found floating dead in the Virgin River.	(Barnes 1927).
18.	1910	Bighorns reported around the mouth of Black's Fork on the north slope of the Uinta Mountains.	(Barnes 1927).
19.	1905-1914	Bighorn killed in Logan Canyon near Tony Grove. Many bighorns also seen in Cottam Canyon.	Ted Seeholzer (Durrant 1952).
20.	1875	Junction of Yampa and Green Rivers.	(Powell 1869).
21.	1875	Cataract Canyon on the Colorado River.	(Powell 1869).
22.	1897	Hole in the Rock, along the Colorado river. Bighorn led a Mormon pioneer to the bottom of a seemingly impassable slick rock.	George Hobbs (Jones 1957).
23.	1917	Bighorns seen on Willard Peak.	Rulon White (Huff 1970).
24.	1923	Bighorns seen on Willard Peak. These were the last native Rocky Mountain bighorns reportedly seen in the Willard Peak area.	Rulon White (Huff 1970).
25.	1938	Ram observed near Dinosaur Quarry.	(Barmore 1962).
26.	1943	National Park Service verified the presence of bighorns on Split Mountain.	(Barmore 1962).
27.	1921	Robert C. Thorne believed bighorns to exist on Blue Mountain. Last animal shot there in 1921.	(Barmore 1962).
28.	1944	Last bighorns from original Dinosaur Nat'l Monument herd seen by Robert C. Thorne near the mouth of Split Mountain Canyon.	(Barmore 1962).
29.	1938	Golden Durfey estimated 100 to 300 bighorns in the Little Rockies.	Golden Durfey (Follows 1969).
30.	1910	Bighorn killed 25 miles north of Wendover.	(Buechner 1960).
31.	1949	Several bighorns reported near the top of Mt. Peale, San Juan River.	Charles Hunt (Buechner 1960).
32.	1878	Bighorns sighted at the goosenecks of the San Juan River.	Chris Christiansen (Buechner 1960).
33.	1933	Sheepherder shot a ewe at Capitol Wash in Capitol Reef Nat'l Monument.	Golden Durfey (Follows 1969).
34.	1948	Last bighorn in Capitol Reef Nat'l Monument killed.	Charles Kelley (Follows 1969).
35.	1920's	Hunter killed a ram on Deer Point in Capitol Reef Nat'l Monument.	Charles Chestnut (Follows 1969).
36.	1938	Bighorn observed in fields below Boulder, Utah. Last reported bighorn in that area.	(Davis 1970).
37.	1940	Mature ram observed in Joe's Valley during the winter of 1940. The ram was curious and followed Edmonds' horses	(Edmonds 1970).

KEY TO FIGURE 3 - RECORDED SIGHTINGS OF BIGHORN IN UTAH SINCE 1950

	YEAR	LOCATION OF SHEEP SIGHTINGS	OBSERVER AND/OR SOURCE
1.	1953	Ram seen on Watchman promontory in Zion National Park.	(Metherell 1970).
2.	1969	Ram seen on top of Lathrop Trail in Canyonlands National Park.	(Budge 1970).
3.	1969	One ram, two ewes, and one lamb seen on White Rim, one mile inside of Canyonlands National Park.	(Budge 1970).
4.	1969	One ram, three ewes, and two lambs seen in White Rim area in Canyonlands National Park.	(Budge 1970).
5.	1969	Ram seen at the southern base of Junction Butte in Canyonlands National Park.	(Budge 1970).
6.	1969	Bighorn seen 3 miles north of Monument Basin.	(Budge 1970).
7.	1969	Two bighorns seen at airstrip on the White Rim road.	(Budge 1970).
8.	1969	Sixteen bighorns seen 5 miles above Gypsum Canyon.	(Budge 1970).
9.	1969	Two rams, two ewes, and one lamb seen at Musselman Arch.	(Budge 1970).
10.	1969	One bighorn seen at the gate below Dead Horse Point.	(Budge 1970).
11.	1969	Four ewes seen on White Rim road below Sharps Trail.	(Budge 1970).
12.	1969	Four ewes and two lambs seen near the ranger trap on White Rim.	(Budge 1970).
13.	1969	One ram, three ewes, and two lambs seen at Murphay Range.	(Budge 1970).
14.	1969	One ram and one ewe seen below Dead Horse Point.	(Budge 1970).
15.	1969	Four ewes and four lambs seen at the Loop of the Colorado River.	(Budge 1970).
16.	1970	Bighorns observed in 1969 and 1970 at Jones Hole in Dinosaur National Monument.	(Hannah 1970).
17.	1967	Fresh bighorn tracks seen across the Colorado River from the mouth of Dark Canyon.	(Follows 1970).
18.	1967	One ram, one ewe, and one lamb seen on Francis Peak.	Fish and Game files, Ogden, Utah.
19.	1968	Five sheep seen on Ben Lomond Peak in the Wasatch Mountains.	Lynn Mikkelson (Fish and Game files, Ogden, Utah).
20.	1968	Six bighorns seen above canal at Willard.	Fish and Game files, Ogden, Utah.
21.	1967	Six bighorns seen 0.5 miles north of Rulon White's residence in Ogden, Utah.	Seth Thorpe (Fish and Game files, Ogden, Utah).
22.	1967	Nine bighorns seen on Willard Peak by Fish and Game personnel.	Fish and Game files, Ogden, Utah.
23.	1967	Bighorn shot during deer season near Willard picnic area.	Fish and Game files, Ogden, Utah.
24.	1968	Seven bighorns seen at a salt lick on Willard Peak by Fish and Game personnel.	Fish and Game files, Ogden, Utah.
25.	1968	Ram seen along Highway 91 near Mantua.	Fish and Game files, Ogden, Utah.
26.	1959	Bighorn ram bred a domestic sheep in Coalville. Hybrid offspring still living.	Herman Edgel (Fish and Game files, Ogden, Utah).

KEY TO FIGURE 3 - (CONT.)

	YEAR	LOCATION OF SHEEP SIGHTINGS	OBSERVER AND/OR SOURCE
27.	1968	Four bighorns seen in the Needle Range by Utah Division of Fish and Game range survey team.	(John 1970).
28.	1966	Bighorn ram bred domestic sheep in the Wah Wah Mountains.	(John 1970).
29.	1968	One ram and six ewes reported in the Wah Wah Mountains.	(John 1970).
30.	1964	Ram observed at the Feron dump by a Fish and Game employee.	(John 1970).
31.	1969	Bighorns reported along the San Juan River at Nakai Dome.	(John 1970).
32.		Bighorns reported at Deer Point along the Breaks of the Escalante River.	(John 1970).
33.	1969	Bighorn seen at the southeast end of the neck inside Canyonlands National Park.	(Budge 1970).
34.	1966	Five bighorns, two ewes, two yearling rams and one lamb seen two miles south of the White Rim Slot.	(Budge 1970).
35.	1958	Four bighorns seen along the Green River in Red Canyon, upstream from Green Lakes.	Bruce Lean (Barmore 1962).
36.	1969	Three bighorns seen near Flaming Gorge dam site.	(Barmore 1962).
37.	1959	Two ewes reported at the mouth of Whirlpool Canyon.	(Barmore 1962).
38.	1966	Nine bighorns seen at the mouth of Gypsum Canyon during June.	(Follows 1969).
39.	1958	Ram seen watering in the Upper Courthouse at Arches National Monument.	Dan Winburn (Follows 1969).
40.	1954	48 bighorns seen above the Confluence in Canyonlands National Park. The sheep appeared sick and had sores on their ears.	(Follows 1969).
41.	1969	13 bighorns seen southwest of Junction Butte in the Sals Hole area.	Carl Wadsworth (Follows 1969).
42.	1954	Five sheep seen on east side of Red Castle Peak in the Uinta Mountains.	Robert F. Hoag, Jr. (Buechner 1960).
43.	1955	Two rams, four ewes, and two lambs seen in Commissary Park, Ashley Nat'l Forest.	(Buechner 1960).
44.	1954	Old ram often seen on Deadman Point and around Spring Canyon in Canyonlands Nat'l Park.	LaVern Young (Follows 1969).
45.	1950's	Two bighorns seen along the west boundary of Arches Nat'l Monument near Suicide Curve.	Bates E. Wilson (Follows 1969).
46.	1958	Ram seen in the lower Fiery Furnace area of Arches Nat'l Monument.	Bates E. Wilson (Follows 1969).
47.	1958	34 ewes and lambs seen just off the Moss Backs in White Canyon in Natural Bridges Nat'l Monument.	Chap Blake (Follows 1969).
48.	1968	Two ewes and a lamb seen going off the Moss Backs into White Canyon.	Carl Mahon (Follows 1969).
49.	1960	Mature ram observed in Uinta Mountains by Fish and Game pilot.	Ralph Noble (Drobnick 1970).
50.	1968	15 bighorns seen on Deer Point Mesa at the southern end of the Waterpocket Fold.	Keith McFall (Drobnick 1970).
51.	1970	Several bighorns observed by construction crews at Clay Hill Pass on the Halls Crossing road.	(Drobnick 1970).
52.	1956	Ram killed by a sheepherder in lower Crouse Canyon in the Uinta Mountains. This ram previously observed alive and photographed by Fish and Game personnel.	Steve Radosevich (Drobnick 1970).

KEY TO FIGURE 3 - (CONT.)

	YEAR	LOCATION OF SHEEP SIGHTINGS	OBSERVER AND/OR SOURCE
53.	1963	Mature ewe seen with a band of domestic sheep in Crouse Canyon in the Uinta Mountains by Fish and Game personnel.	John Fannery (Drobnick 1970).
54.	1969	Ram seen by Fish and Game helicopter survey near mouth of Castle Creek on the north side of the San Juan River.	Rodney John (Drobnick 1970).
55.	1969	One ram and nine ewes seen by Fish and Game helicopter survey at the mouth of the first small canyon north of Gypsum Canyon on the east side of the Colorado River.	Rodney John (Drobnick 1970).
56.	1965	Tracks of six ewes and one ram found by Carl Mahon and Rudy Drobnick at Nakai Dome.	(Drobnick 1970).
57.	1968	Seven bighorns reported in Mikes Canyon along the San Juan River.	(Drobnick 1970).
58.	1967	24 bighorns seen above timberline on the north side of Mt. Ellen in the Henry Mountains.	(Drobnick 1970).
59.	1956	One ram and four unclassified bighorns seen by river floaters at the mouth of John's Canyon along the San Juan River.	Norm Nevilles and Frank Wright (Drobnick 1970).
60.	1959	13 bighorns seen by Fish and Game personnel at Dead Horse Point.	Lee Robertson (Drobnick 1970).
61.	1965	Mature ram seen in Uinta Mountains at Lefty Lake north of the head of Weber River.	Ralph Noble (Drobnick 1970).
62.	1968	One ram and two ewes spotted on Nipple Bench between Warm and Wah Weap Creeks, Kane County.	Ralph Noble (Drobnick 1970).
63.	1950 to present	Sightings in this area are very numerous (see Wilson, 1968, and Irvine, 1969). This area probably contains Utah's major desert bighorn population.	(Drobnick 1970).
64.	1969	Bighorns observed in the Poison Spring Canyon drainage.	(Warburton 1970).
65.	1969	Bighorns observed on Mt. Hillers.	(Warburton 1970).
66.	1966	Bighorns observed at Hites Crossing on the west side of the Colorado River.	(Warburton 1970).
67.	1968	Bighorns observed in White Canyon near the Colorado River.	(Warburton 1970).
68.	1968	Bighorns observed along Dark Canyon.	(Warburton 1970).
69.	1966	Bighorns observed along Fish Creek on Comb Ridge.	(Warburton 1970).
70.	1968	Bighorns observed along Cottonwood Creek.	(Warburton 1970).
71.	1966	Bighorns observed in Harts Draw upstream from Indian Creek.	(Warburton 1970).
72.	1966	Bighorns observed west of Monticello City limits.	(Warburton 1970).
73.	1969	Bighorns observed at the Mouth of Indian Creek.	(Warburton 1970).
74.	1968	Bighorns observed in Harts Draw near the Manti-La Sal Nat'l Forest boundary.	(Warburton 1970).
75.	1969	Bighorns observed in Lockhart Basin.	(Warburton 1970).
76.	1970	Two bighorn rams observed and photographed during July in the area near the confluence of the East Fork of Blacks Fork and the Little East Fork.	(Reddin 1971).
77.	1970	A mature ram and a ewe observed about 3 miles east of Brigham City on Highway 91 in early October.	(Mathews 1970).

Dr. Tom Thorne , left, Research Veterinarian of the Wyoming Game and Fish Commission, received the Jonas Bighorn Trophy for the outstanding paper presented at the conference. Jack H. Jonas of Denver Jonas Brothers presented the trophy for Dr. Thorne's paper "A Die-off Due to Pneumonia in a Semi-captive Herd of Bighorn Sheep."

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SECTION II

PHYSIOLOGY AND PATHOLOGY

DEVELOPMENT OF A PROTECTIVE BACTERIN AGAINST PASTEURELLOSIS IN BIGHORN SHEEP

by

Peter Nash, Graduate Student
Colorado State University

ABSTRACT

The development of a protective bacterin for Rocky Mountain Bighorn Sheep was studied. A total of forty-five (45) *Pasteurella*-like organisms was isolated from nasal swabs and tissues of bighorn sheep from Wyoming, Colorado and Pennsylvania. Each isolate was examined for its cultural, morphological, staining and biochemical characteristics and compared to standard *Pasteurella multocida* and *Pasteurella hemolytica* cultures from domestic sheep. Two isolates showing characteristics most similar to *Pasteurella* sp. were chosen from each of the geographic locations: one from nasal swabs and the other from tissue isolates. These six isolates were tested both individually and combined in mice and combined in rabbits and domestic sheep for their virulence capacities. A living whole cell suspension was tested in domestic sheep using a two dose series given seven days apart. Hemagglutination titers were determined on blood samples from the sheep at given intervals to determine the ability of the suspension to be immunogenic as well as the numbers of organisms needed to yield highest antibody titer. Formalinized bacterins of individual organisms were tested in rabbits for antibody titers and in mice using both active and passive immunity studies. Formalinized whole cells and fractionated mixed bacterins were studied in rabbits and domestic sheep. These bacterins were tested for their ability to produce hemagglutination titers in the blood serum of the animals and the protective ability of the antibody against *Pasteurella* challenge.

The bighorn sheep population in the Rocky Mountain area has declined since the beginning of this century. One cause of these losses has been attributed at least in part to various species of *Pasteurella* bacteria when associated with a pneumonia-septicemia. The disease condition many times developes when the animals are under some specific stress factor. March (1927) reported losses of bighorn sheep on the Sun River Game Preserve, Montana. Necropsy reports showed typical pasteurellosis with lungs congested. Potts (1937) observed hemorrhagic septicemia among bighorns in Rocky Mountain National Park, Colorado in 1935 and 1936. *Pasteurella oviseptica*, along with *Corynebacterium pyogenes*, was isolated at necropsy. Packard (1946) reported additional losses at Rocky Mountain National Park due to *P. oviseptica*.

Post (1958) observed losses among bighorns which were held in captivity and attributed it to pasteurellosis. Even though commercial bacterins were used on the animals, death still occurred due to *Pasteurella* infections. A heat-killed bacterin was prepared from cultures of *Pasteurella* isolated from dead bighorns. Sheep losses were prevented when this was administered.

Post (1962) improved upon the bacterin and its protective ability by using formalinized cells in a septivalent bacterin. Rufi (1961) was able to show that this type of bacterin could give protection to bighorns and that low titers can give immunity to captive bighorns.

The purpose of the present study has been to isolate various *Pasteurella*-like bacteria from bighorn sheep and develop a protective bacterin against pasteurellosis in bighorn sheep so they may be held in captivity for further research. Since commercial bacterins do not seem to protect these animals, a bacterin using *Pasteurella* isolates with specific immunogenic properties from bighorns must be tested.

MATERIALS AND METHODS

Bacterial cultures were collected from nasal swabs from apparently healthy bighorn sheep and from tissue cultures of dead bighorns from Sybille Experimental Unit, Wyoming, Rachelwood Wildlife Research Preserve, Pennsylvania, Rocky Mountain National Park and Glenwood Park, Colorado. Isolated bacterial colonies grown on Brain-Heart-Infusion Agar (BHI) plates were picked, smeared and stained using gram stain. All gram negative rods or coccal bacillus were subcultured and subjected to differential examination. They were compared to results from ATCC *P. oviseptica* 9657 and *P. hemolytica* 9-2183 from domestic sheep. Those cultures yielding characteristics similar or identical to these *Pasteurella* sp. were held for further testing.

Six cultures were chosen to be most similar to the standard *Pasteurella* sp. and were tested both individually and in combination for toxicity in mice. Viable cultures were diluted in a peptone-saline buffer and injected into groups of mice in serial concentrations as well as used for challenges in rabbits and domestic sheep.

Immune sera for each of the individual six isolates and the ATCC 9657 culture were produced by injecting groups of rabbits intravenously with formalinized cells. The doses ranged from 1 mg to 11 mg of dry weight bacteria over a 21-day period. The rabbits were bled by heart puncture four weeks after the last dose, and the serum collected. Hemagglutination antibody titers were determined using polysaccharides from the individual bacteria coated to sheep red blood cells and the microtiter technique.

Passive immunity was determined in mice using either 0.3 ml, 0.2 ml, or 0.1 ml of immune sera from rabbits and sheep injected intraperitoneally. This was followed twenty-four hours later by a challenge dose of either individual bacteria or a combination of the isolates. The number of mice which survive challenge was compared to the number of uninoculated control mice to determine any immunity protection.

A living bacterin composed of a combination of the six chosen isolates was inoculated into a group of 5 domestic sheep in various doses. The doses were given as follows one week apart:

Sheep No.	1st Dose	2nd Dose
5	5×10^9 organisms	1.7×10^9 organisms
4	5×10^8 organisms	1.7×10^8 organisms
3	5×10^7 organisms	1.7×10^7 organisms
2	5×10^6 organisms	1.7×10^6 organisms
1	5×10^5 organisms	8.5×10^4 organisms

The doses were injected intrathoracically. Sheep sera were collected four weeks after the last dose for hemagglutination titer tests.

A combined formalinized cell bacterin was developed using equal amounts of formalinized cells of the six isolates. The dry weight of the bacterin was determined and diluted in normal saline to make a stock suspension containing 1 mg per ml. Various groups of laboratory animals were inoculated with different amounts of the material at one week intervals. The number of animals, kind and amounts received are as follows:

Mice - 0.33 mg dry weight bacteria per dose given I. P.

Group A - 3 doses - 20 mice
Group B - 2 doses - 20 mice
Group C - 1 dose - 20 mice
Group D - no doses - 20 mice controls

Rabbits - 3 mg dry weight bacteria per dose given S. Q.

Group A - 3 doses - 2 rabbits
Group B - 2 doses - 2 rabbits
Group C - 1 dose - 2 rabbits
Group D - no doses - 2 rabbits controls

Sheep - 5 mg dry weight bacteria per dose given S. Q.

Group A - 3 doses - 2 sheep
Group B - 2 doses - 2 sheep
Group C - 1 dose - 2 sheep
Group D - no doses - 2 sheep

The mice were challenged I. P. two weeks after the last doses with 5×10^9 organisms. The survivors were observed for 7 days after challenge.

H. A. titers were determined on the rabbits and sheep. The rabbits were challenged with 1.7×10^9 organisms five weeks after the last dose and the sheep were challenged with 8×10^{10} organisms. The body temperatures of the sheep were recorded before and after challenge for at least 72 hours.

A fractionated bacterin was developed using the six *Pasteurella* isolates grown on BHI agar. The cells were washed off the agar and heated in distilled water at 56°C for 1 hour to detach the capsular material. Equal amounts of the individual cells were added to a suspension and fractionated under 20,000 psi pressure. The capsular material was twice precipitated out of the supernatant using 3 volumes of 95% alcohol and added back to the fractionated cell suspension. The dry weight was determined per ml and diluted in normal saline to a concentration of 1 mg per ml. Groups of rabbits and sheep were inoculated according to the same procedure as the formalinized bacterin. The sera was collected for antibody production testing and the animals were challenged. Body temperatures of the sheep were taken at given intervals after challenge.

RESULTS

A total of forty-five (45) *Pasteurella*-like organisms were isolated from cultures obtained from Wyoming, Colorado and Pennsylvania. They were all gram negative, small oval rods, bipolar stained and produced only acid in sugars if at all. From these isolates, six cultures were chosen with one from a nasal swab and one from tissues of dead bighorns from each area. Sources of each of the six organisms are given in Table 1. The bio-chemical differential of these isolates compared favorably to the standard cultures. Table 2 gives those specific biochemical activities which were used to estimate organism specificity. Table 3 shows the results obtained on individual virulence tests of the organisms as well as in combined suspensions in mice. Also, it shows protection given by serums from rabbits and sheep in passive immunity testing and the formalinized bacterin protective ability against challenge. These organisms as shown in Table 3 have a relatively low virulence in mice.

Table 4 shows that using serial concentrations of individual organisms in rabbits produces a variety of antigenic responses. It also shows the hemagglutination titers obtained in rabbits when inoculated with various doses of the two bacterins. All experimental control rabbit sera had negative titers. No rabbits died from the challenge.

Table 4 also contains the results of antibody titers from domestic sheep which received the various doses of the three bacterins. The living bacterin seemed to have low immunogenic response even when given in two doses. The sheep all had negative titers to these seven antigens before inoculations were begun. All experimental control sheep were negative for titers to these organisms before challenge.

Figure 1 shows the average body temperatures of sheep recorded after challenge at 0, 8, 24, 48, and 72 hours. Two pairs of experimental control animals were challenged and recorded as one group. All groups seem to have increased body temperature within 8 hours of challenge (Figure 1). Observations showed this was accompanied by increased respiration rate and coughing. Within 48 hours all animals except those receiving the fractionated bacterin (Group C) showed normal body temperature. Two sheep in Group C died within 60 hours after challenge. Necropsy showed heavy pneumonic lungs with *Pasteurella* sp. isolated from liver, lung, kidney, spleen and heart blood.

Table 1 - Original sources of the *Pasteurella* isolates

RM - 1	From tissue cultures of a dead bighorn ram in Rocky Mountain National Park. It is a gram negative, bipolar, encapsulated rod.
399-L	From nasal swabs taken from a young lamb ram at Glenwood Park Colorado. It is a gram negative, bipolar, encapsulated rod.
WYO-2	From tissue cultures of dead bighorns at Sybille Experimental Unit, Wyoming. It is a gram negative, bipolar, encapsulated small rod.
WYO-1	From nasal swabs taken from young bighorns at Sybille Experimental Unit, Wyoming. It is a gram negative, encapsulated rod.
70-326	From tissue cultures from a dead bighorn at Rachelwood Wildlife Research Preserve, Pennsylvania. It is a gram negative, bipolar, encapsulated, small rod.
2-29R	From nasal swabs of bighorn sheep at Rachelwood Wildlife Research Preserve, Pennsylvania. It is a gram negative, bipolar, encapsulated, small rod.

Table 2 - Comparison of specific biochemical tests of bighorn sheep isolates to standard cultures

	MEDIA			
ORGANISM	NITRITE	INDOLE	HEMOLYSIS	MAC CONKEY'S
RM-1	+	+	-	-
399-L	-	+	-	+
WYO-2	+	+	?	+
WYO-1	-	+	-	-
70-326	-	-	?	+
2-29R	+	+	?	-
9657	+	+	-	-
9-2183	+	-	+	+

Table 3 - Percent of survivors in active and passive immunity studies.

Challenge Organism	LD50	Active Immunity A	Active Immunity C**	Form. rabbit	Bact. sheep	Fract. rabbit	Bact. sheep	Control Normal Sera	Exp. C**
Combined	1 x 10^8	75%*	0%	78%	72%	69%	56%	33%	25%

Challenge Organism	LD50	Passive Immunity A	Passive Immunity C
RM-1	5.4 x 10^6	86%	80%
399-L	5 x 10^9	86%	80%
WYO-2	1 x 10^6	53%	0%
WYO-1	1 x 10^9	N. D.	
70-326	7 x 10^7	46%	60%
2-29R	1 x 10^8	100%	80%
9657	5 x 10^9	N. D.	
9-2183	5 x 10^9	--	--

* This is the average for group A receiving 3 doses of formalinized bacterin.
** C is the averages for the experimental controls receiving only the challenge dose.
***N. D. means not done.
A is the average of all groups receiving serial doses of the specific immune sera.

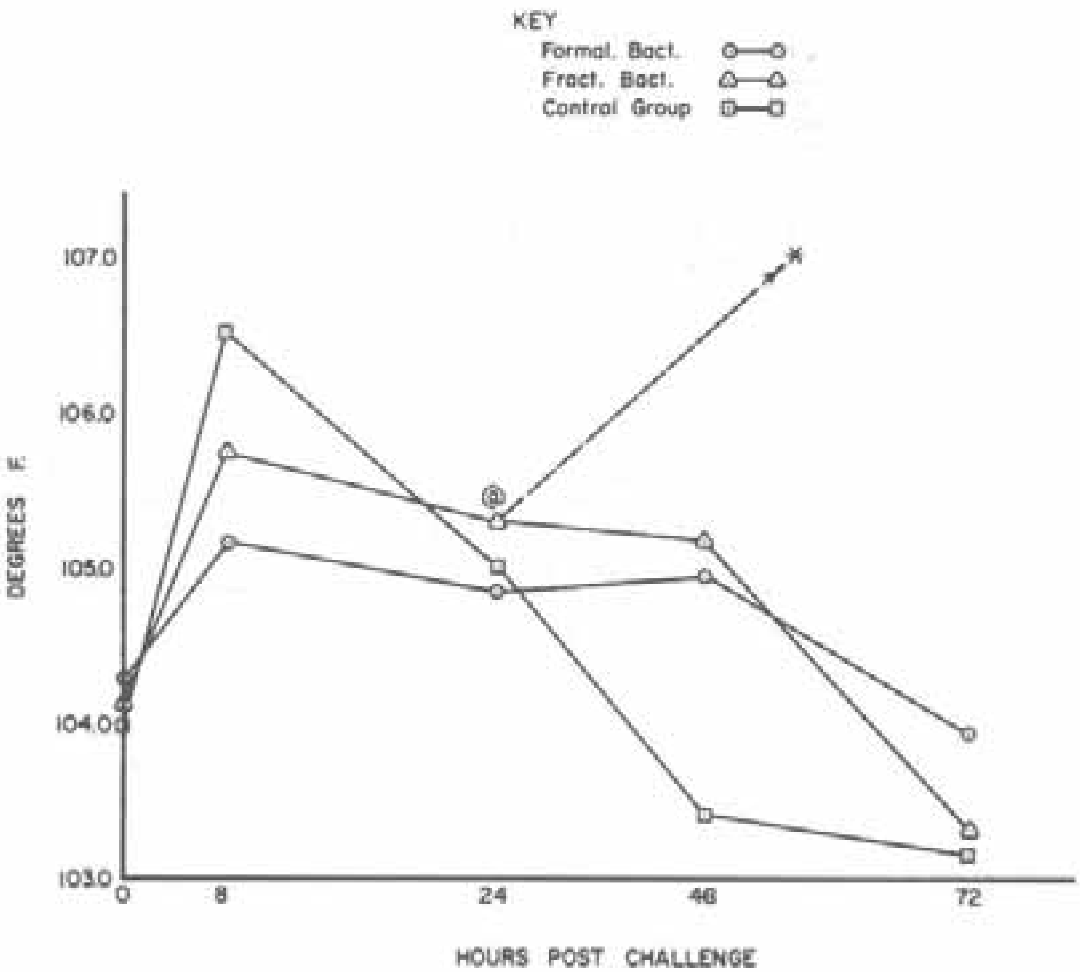
Table 4 - Average hemagglutination antibody titers from rabbit and sheep sera versus Polysaccharide *Pasteurella* antigens.

ANTIGEN	Individual Series RABBITS	Living Bacterin SHEEP	Formalinized Bacterin RABBIT	Formalinized Bacterin SHEEP	Fractionated Bacterin RABBIT	Fractionated Bacterin SHEEP
9657	1:8*	1:8	1:8	1:64	1:64	1:64
WYO-2	1:64	1:16	1:8	1:128	1:64	1:128
WYO-2	1:32	1:32	1:32	1:128	1:64	1:128
RM-1	1:256	1:32	1:8	1:128	1:128	1:128
399-L	1:256	1:16	1:32	1:128	1:128	1:128
70-326	1:64	1:8	1:32	1:128	1:128	1:128
2-29R	1:128	1:16	1:32	1:138	1:128	1:128
Controls						

*Average of all the animals in all groups given the specific bacterin and rounded off to the nearest dilution well. This is the highest dilution with a +2 reading in the microtiter well.

FIGURE I

BODY TEMPERATURE AVERAGES FOR DOMESTIC SHEEP AT GIVEN TIME INTERVALS AFTER I.V. CHALLENGE



1. Ⓢ Time when first animal of I dose Fract. bact. died so temperature not included.

2. ✱ Time when second animal died.

DISCUSSION

Any one working with *Pasteurella* organisms soon finds that they are a difficult group of bacteria to understand. These organisms may be isolated from both living and dead bighorns, as seen by the number of isolates made in this study. The *Pasteurella* sp. from bighorns are difficult to differentiate.

These organisms seem to be virulent to mice both individually and in combination but in high doses. The organisms isolated from dead bighorns appeared to be more virulent that those from nasal swabs. The antigenic response tests show that they vary in immunogenic response to rabbits which may indicate different antigens or that some organisms may have a larger quantity of one antigen than another. This factor seems to be further substantiated in the amount of capsular material that was observed around each specific culture of organisms.

The problem of experimental pasteurellosis becomes greater when attempts are made to reproduce the disease in larger laboratory animals. A variety of factors must be combined to produce the disease in rabbits and domestic sheep. An example of this is the Wyo-2 organism which was isolated from a number of dead bighorns and seemed to kill the animals quite rapidly. It killed mice at a low dose, yet would not cause death in inoculated rabbits or experimental control sheep. It did produce the disease and death in Group C of the fractionated bacterin group. This lack of reproductability of the disease makes for difficulty in estimating the protective ability of a given bacterin against active challenge. The results do indicate that a variety of organisms should be used in a bacterin to get a heterogeneous antigenic make-up even if all of the organisms do not stimulate high titers. Both the inoculations in rabbits and mice seemed to indicate that this variation was needed due to the variability in immune response in the various animals.

The formalinized bacterin showed good protection (75%) for those mice receiving 3 doses of the bacterin. All the rabbits showed low titers (Table 4) when immunized with this bacterin yet were protected against challenge. The formalinized bacterin showed about equal ability in protecting sheep whether given in one, two, or three doses. These results seem to indicate that the amount or number of doses needed depends upon the animal used.

The fractionated bacterin seemed to give high titers in both rabbits and sheep and was best among all animals as far as total antibody production was determined. This was especially true for those animals receiving three doses. The results seem to indicate a need for multiple inoculations of this bacterin as indicated by the results of Group C deaths.

Both bacterins appeared to have good points and should be tested further. As mentioned above, one problem with the one dose of fractionated bacterin could mean enhanced infection with only one dose of this bacterin. This may also indicate that titers of antibody may not mean that the animals are protected from disease since the animals had relatively high H.A. titers. The passive immunity tests in mice (Table 3) seemed to support the idea. All immune serums, no matter what titer, were protective to the mice passively to some degree.

Possibly both bacterins can be used effectively, as Rufi (1961) pointed out, the protective ability of a bacterin may not be in how high the titers are, but in the ability of it to protect the animal from disease.

Further studies must be done on bighorn sheep. New parameters may be introduced which may help choose the best bacterin for protective ability to bighorn sheep.

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DISCUSSION

QUESTION BY MILT FRAN, FISH AND WILDLIFE SERVICE: I'd be curious to know if the isolates you made from living animals were characterized as opposed to the ones from the dead animals in terms of the form of bacteria. Were they rough or smooth colonies?

REPLY BY NASH: They were characterized. The bacteria from the living animals were the rough form and the bacteria from the dead animals were the smooth form.

REPLY BY FRAN: Would you care to comment on the possibility of stress? You have two populations of bacteria in the sheep, the rough form and the smooth form, and stress making environmental conditions in the host more preferable for multiplication of the smooth or more virulent form to cause the outbreak of disease. Did you have any comment or ideas on this?

REPLY BY NASH: I have not done work in this, but the literature indicates that with *Pasteurella pestis* that this is the case. You have an avirulent form going to a virulent form when psychological, biological and chemical changes occur in the body of various laboratory animals. I can grow this organism on a defined media and get a capsule material greater than when I isolated the organism. All this is tested from the capsule material, not from the cell wall.

THE CLINICAL AND PATHOLOGICAL EFFECT OF *PROTOSTRONGYLUS STILESI* ON BIGHORN X MOUFLON HYBRID SHEEP[1]

by

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Colorado State University

ABSTRACT

Blood parameters were measured in an attempt to find a clinical method of assessing lung damage and to correlate the level of *Protostrongylus stilesi* infection with clinical changes and lung damage. These parameters were: the complete blood count, blood pH, sedimentation rate, color index, mean corpuscular hemoglobin concentration, serum electrolytes, serum proteins, albumin/globulin ratio and the pattern of lactate dehydrogenase isoenzymes. A method to quantify physical lung damage was devised. The *P. stilesi* infection caused nodular formation in lung tissue, an indication of a slight increase in the proportion of eosinophils in peripheral blood and a slight increase in the serum bicarbonate concentration. No other alteration was noted. The conclusion was made that the level of *P. stilesi* parasitism achieved was not great enough to be detrimental to the experimental animals.

INTRODUCTION

Protostrongylus stilesi is a widespread parasite of bighorn sheep (*Ovis canadensis*). There is no reliable method to determine the extent of an infection of *P. stilesi* without sacrificing the animal. The method most widely used to estimate the intensity of a lungworm infection is that of Baermannizing weighed fecal samples and calculating the number of first stage larvae per gram of feces. Forrester and Senger (1964) found this method unacceptable because of extreme variation between fecal samples and even between individual fecal pellets from the same defecation.

The present study was undertaken to find a clinical method to indicate the extent of lung damage caused by lungworms (*P. stilesi*) in wild sheep. Blood parameters were selected, since blood is a relatively easily obtained substance and the quantity needed for the tests would not harm the animal.

[1]Project financed by Rachelwood Wildlife Research Preserve, New Florence, Pennsylvania and administered through the Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins.

Protostrongylus-free bighorn sheep were not available. Therefore, *Protostrongylus*-free bighorn X mouflon hybrid sheep were used for this study. The assumption was made that the hybrids would become infected under the test conditions since both bighorn and mouflon sheep are susceptible to *P. stilesi* (Dikmans 1931, Howe 1965).

Blood was drawn from experimental animals before and during infection experiments. The following blood categories were examined: red blood cells, white blood cells, serum electrolytes, serum proteins and serum LDH isoenzymes. Estimation of physical damage to the lungs by the lungworms and possible histopathological effects to other body organs were also considered.

MATERIALS AND METHODS

The animals used for this study were Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) x mouflon sheep (*Ovis musimon*) hybrids. These animals were selected because of the difficulty in obtaining lungworm-free bighorns. A total of four sheep were studied. Sheep #1 was a 1/4 bighorn x 3/4 mouflon two-year-old ram. Sheep #2 was a 1/4 bighorn x 3/4 mouflon three year old ram. Sheep #3 was a second generation 1/2 bighorn and 1/2 mouflon one-year-old ewe. Sheep #4 was a second generation 1/2 bighorn x 1/2 mouflon two-year-old ram. Sheep #1 and #2 and sheep #3 and #4 were studied together.

The experimental animals were maintained in an isolation shed at Rachelwood Wildlife Research Preserve at New Florence, Pennsylvania. The windows of the shed were covered with double screening and the base of the building was circled by a Creosol-filled trough to protect the animals.

The infective stage larvae were administered to the sheep by feeding infected snails in gelatin capsules. Sheep #1 and #2 were each fed 345 infective stage larvae in 14 doses during the prepatent period. Sheep #3 was fed 203 infective stage larvae (11 doses) during the prepatent period and 173 infective stage larvae (7 doses) during the patent period. Sheep #4 was fed 162 infective stage larvae (9 doses) during the prepatent period and 210 infective stage larvae (9 doses) during the patent period. Fecal samples were collected at regular intervals in an attempt to monitor the infection intensity. Lungworm infections were established in three of four sheep (Monson 1971).

Three blood sampling periods were decided upon. The preinfection period constituted those blood samples drawn before infection was attempted. The prepatent period was initiated when infective stage *P. stilesi* larvae were being fed to the sheep. This lasted until the start of the patent period or that period when first stage larvae were being eliminated from the animals in the feces.

Blood was drawn from the jugular vein of the experimental animals with a California bleeding needle. The animals were caught by hand and held for bleeding. Approximately 25 ml of blood was taken each time. Two tubes of blood were taken for blood serum requirements. One tube of blood was treated with Sequester Sol for blood tests requiring anticoagulated blood. Another tube of blood was heparinized and kept in an ice bath for pH determination. The tests requiring the use of whole anticoagulated blood were completed at the Rachelwood Wildlife Research Preserve directly after bleeding. Serum was prepared by allowing the blood to clot at room temperature, ringing the clot and centrifuging for 10 minutes. In some cases, the clot was removed prior to centrifuging. The serum was drawn off with a Pasteur pipette. The serum was then frozen and transported to Fort Collins, Colorado where the remainder of the tests were completed.

WHOLE BLOOD PARAMETERS

The packed cell volume (PCV) was determined by the micro hematocrit method. The red (RBC) and white (WBC) blood cell counts were determined microscopically. Hemoglobin (Hb) was determined by the cyanmethemoglobin method. The color index (CI) was calculated as follows:

$$CI = \frac{Hb(g/100ml)}{RBC \text{ in millions} \times 3}$$

The mean corpuscular hemoglobin concentration was calculated as follows:

$$MCHC = \frac{Hb\ (g/100ml) \times 100}{PCV}$$

The Wintrobe-Landsberg method was used to determine the erythrocyte sedimentation rate (ESR) except the time period examined was extended to 24 hours instead of the customary one hour. The differential leucocyte count was done on blood smears on standard microscope slides stained with Wright's stain. Blood pH was determined by means of an electronic pH meter.

SERUM BLOOD PARAMETERS

Serum bicarbonate was determined by the titration method. Sodium and potassium were determined by flame photometry. Total serum protein was determined by the biuret technique. Protein fractionization and lactate dehydrogenase (LDH) isoenzyme determination were done by electrophoresis of serum on cellulose acetate. The strips were scanned with a densitometer. Albumin, alpha globulin, beta globulin and gamma globulin percentages and the five LDH isoenzyme percentages were calculated from data determined by automatic integration.

DETERMINATION OF LUNG INVOLVEMENT

Linear slices were cut from anterior to posterior of the central part of the diaphragmatic lobes of the lungs of sheep #3 and #4. Histological sections of these lung slices were cut from parafin and stained with hematoxylin and eosin. First stage larvae were counted microscopically throughout the linear slices of lung tissue. Areas of nodular and non-nodular involvement in the linear slices were calculated.

Lungworm nodules outside of the linear slices were removed from the lungs, counted and weighed. Adult worms were teased from the nodular tissue, counted, and identified (Monson 1971).

The remaining lung tissue was minced and Baermannized. The number of first stage larvae from the Baermannized lung and the larvae teased from the nodules were calculated to produce a total larval count exclusive of the tissue sectioned.

Histological sections of liver, spleen, kidney, myocardium, adrenal glands and spinal cord from sheep #3 and #4 were cut from parafin and stained with hematoxylin and eosin. These sections were examined for possible effects of lungworm involvement.

RESULTS

There were no significant differences in results obtained at the achieved level of parasitism for PCV, Hb, RBC, CI, MCHC, ESR, WBC, blood pH, serum sodium and potassium, total protein, protein fractions, the albumin:globulin ratio and lactate dehydrogenase isoenzymes. There was an indication of an increase in the serum bicarbonate and in the number of eosinophils. The other leucocytes remained proportionately normal. The hematological values possibly affected by *P. stilesi* are given in Table 1.

The relationship of the infection of *P. stilesi* to the damage found in the lung tissue is given in Table 2. Histopathologic results which were found in tissue sections cut from slices of lung tissue from sheep #3 and #4 revealed nodular areas. These areas contained adult lungworms, first stage larvae and eggs. The nodular area was small in comparison to the entire lung. They showed the usual symptoms of verminous pneumonia with lymphocytic infiltration, scarring and an occasional giant cell. Alveoli in these areas were non-functional. The lung tissue of both animals immediately outside the nodule and throughout the organ was normal for sedentary animals.

Wandering *P. stilesi* first stage larvae were extremely rare in the non-nodular lung tissue. Those that were present were found adjacent to the parasitic caused nodules.

The histology of the liver, kidney, spleen, adrenal gland, myocardium and lumbar spinal cord was considered to be normal in sheep #3 and sheep #4.

DISCUSSION

The bighorn sheep x mouflon sheep hybrids used for this study were very satisfactory. Trauma experienced during bleeding and other handling was minimal due to the animals being partially tame.

Table 1 - Hematological values possibly affected by *Protostrongylus stilesi*

	Bicarbonate Mean	Range	meq/l SS	Eosinophils Mean	Range	% SS
SHEEP #1						
Preinfection	23.0	21.3-24.7	2	1.3	1-1.7	2
Prepatent	21.8	17.1-28.5	9	4.7	1-10.5	10
Patent	22.7	16.5-30.7	4	6.0	4-8	4
SHEEP #2						
Preinfection	25.2	22.5-27.9	2	4.0	2-6	2
Prepatent	21.7	14.7-26.8	12	8.3	2-15	14
SHEEP #3						
Preinfection	17.3	11.5-25.1	6	1.2	0-3	6
Prepatent	19.7	13.3-24.8	10	5.8	2-12	10
Patent	22.1	17.6-29.4	8	4.0	1-9	8
SHEEP #4						
Preinfection	18.7	16.4-21.1	5	2.8	1-6	6
Prepatent	20.0	17.6-24.8	8	4.3	1-6	5
Patent	22.3	17.5-28.8	11	2.3	0-6	11

SS = sample size

Table 2 - Lung involvement with *P. stilesi* infection

	Sheep #3	Sheep #4
Infectious stage larvae fed	376	372
Number of nodules in lung tissue*	18	4
Adult worms recovered in lung tissue**	2	14
First stage larvae recovered from lung tissue	6,910	23,100
Area of lung slices scanned histologically (mm^2)	1,037	2,214
Area of lung tissue slices disrupted by lungworms (mm^2)	43	18
Percent of lung tissue slices disrupted	4.2	0.8
Weight of lung tissue (g)	224	381
Weight of nodular tissue (g)	6.0	3.6
Percent of nodular tissue	2.7	0.9
First stage larvae in lung tissue/g of lung tissue	31	60
Adult worms in histological slides of lung slices	4	3
First stage larvae in histological slides of lung slices found outside of formed nodules	5	4

Sheep #1 was fed 345 infective stage larvae. There were five nodules with six adults.

Sheep #2 was fed 345 infective stage larvae. No nodules were seen. No worms were recovered.

* Lung tissue refers to the tissue of the lung minus the slices removed for histological sections

**The number of adult worms are those with identifiable male and female parts. Other portions of worms were disregarded.

Three of the four sheep accepted the *P. stilesi* infection. This success was probably achieved because both bighorn sheep and mouflon sheep are susceptible to *P. stilesi* (Dikmans 1931, Howe 1965).

Effects of *P. stilesi* on the animals would be expected to be an immunological response by the animal and/or decreased lung function. The decreased lung function would occur only after the infective stage larvae reached the lung. Lung function would be most disrupted when the presence of the mature worms had resulted in nodular information and the production and movement of first stage larvae through the lung tissue.

Some of the blood parameters used in the present study would be more sensitive to the presence of the parasite rather than any disruption the parasite might cause. This would be expected with tests which would monitor immune reactions such as a change in the gamma globulin fraction.

The hematology of sheep #1 and sheep #2 was not tested consistently as the possibility of transmission of an infection of *P. stilesi* was not certain. Once a method of infection and procedures for testing blood parameters had been established, blood samples were drawn with more regularity from sheep #3 and sheep #4.

Sheep #2 did not become infected with *P. stilesi*. A prepatent method was established nonetheless. The animal was challenged by infective stage *P. stilesi* larvae and a reaction by the animal to this challenge was expected.

Sheep #3 became pregnant and aborted a half resorbed fetus 89 days into the parasitic patent period. This was accompanied by excessive vaginal exudate and inflamation and must be considered one of the factors causing changes in the hematological values for this animal.

The WBC differential in peripheral blood is the enumeration of the relative proportions (percentages) of the various types of WBC as seen in stained films (Lynch et al 1969). Leucocytosis is usually due to an increase of only one type of cell and is given the name of the increased cell type (Bauer et al 1968). Therefore, eosinophilia would be expected in increased parasitism based on past research.

No appreciable change in the leucocyte count was noted in the present study. All four sheep indicated a slight eosinophilia from the preinfection to the prepatent period. Sheep #1 continued the increase of eosinophils into the patent period. The percent of eosinophils decreased during the patent period for sheep #3 and #4 (Table 1). The rise for sheep #2 may have been part of a successful attempt to resist infection. The eosinophilic response in the experimental animals was similar to results reported by Poynter and Selway (1966), Weber (1957), and Wintrobe (1967). Trends in the change of neutrophils, lymphocytes and monocytes were inconclusive. The basophils during the patent period of sheep #3 may have been due to the abortion. Djafar et al (1960) found no alterations in the percentage of basophils or monocytes by increased parasitism.

Decreased pulmonary function results in an increase of H^+ in the blood. Changes in the concentration of H^+ in the extracellular fluid are accompanied by passage of a K^+ in the opposite direction. Serum K concentration is increased in acidosis purely as a result of changes in pH (Cantarow and Trumper 1962).

Sodium concentration of the blood serum is expected to remain normal with decreased pulmonary function. Serum bicarbonate is expected to increase as a result of renal compensation for acidosis. This would result in bringing the blood pH back to normal if a decrease occurred. Therefore pulmonary parasitism of a magnitude which would cause physiological or biochemical effects would decrease blood pH, increase serum bicarbonate, increase serum K and maintain a stable serum Na.

The blood pH did not decrease in any of the four experimental animals. Serum bicarbonate showed a slight progressive increase in sheep #3 and #4. There was no change in the bicarbonate of sheep #1. No rise was expected nor achieved from sheep #2 as there was no lung involvement. Serum K showed a decrease instead of the expected increase. Serum Na remained normal.

An explanation of these findings is that the destruction of pulmonary function was too insignificant or that tissue damage was gradual and the renal H^+ excretory and HCO_3- generative processes kept pace showing no marked increase in H^+. This is in agreement with Refsum (1966). There was no rise in K since the H^+ concentration did not increase. The K decreased as would be expected with a rise in pH. The rise in pH was explained by Refsum (1966) as a pathologic condition tending to cause metabolic alkalosis which sometimes leads to reduced H^+ concentration.

Many alveoli in the lungs of the experimental animals were not being utilized. The confinement of the sheep would greatly reduce their ability to exercise. This would be expected to cause a decrease in lung function.

The animals' defense mechanisms seem to have efficiently walled off the lungworm infection from the remainder of the lung tissue. This resulted in the formation of nodular elements and scar tissue. Also, there were few larvae outside the nodular area, and the larvae that were outside had not wandered far from the nodule. Lymphocytes and giant cells had invaded the area. The method used for estimation of lung damage in these animals could be used as an index for hunter-killed bighorn sheep as well as for collected specimens.

CONCLUSION

The level of lung involvement in the *P. stilesi* infection caused localized nodular verminous pneumonia, an indication of a possible increase in the proportion of eosinophils and a possible increase in the bicarbonate concentration. There were no other alterations in blood chemistry or hematology beyond the usual fluctuations. The conclusion was made that the level of *P. stilesi* parasitism achieved was not great enough to be detrimental to any of the experimental animals.

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DISCUSSION

QUESTION BY CHARLES HIBLER, CSU: Sara, these sheep had three lungworms, right? Three species?

REPLY BY MCGLINCHY: They had one at necropsy.

REPLY BY HIBLER: You didn't find any *Muellerius* or *Pneumostrongylus*?

REPLY BY MCGLINCHY: No, we did not.

REPLY BY HIBLER: Did you find *Ostertagia* or *Trichuris*?

REPLY BY MCGLINCHY: There were a few adult *Ostertagia* recovered.

REPLY BY HIBLER: What is one of the cardinal signs of parasitism?

REPLY BY MCGLINCHY: Eosinophilia.

REPLY BY HIBLER: Anyway, I understood from Ruth's thesis that you did not clean all the lungworms from these sheep, that *Muellerius* and *Pneumostrongylus* were present.

REPLY BY MCGLINCHY: They were not found at necropsy.

REPLY BY HIBLER: Did you find first stage larvae?

REPLY BY RUTH MONSON: Prior to necropsy, there were some first stage larvae of *Pneumostrongylus*. The *Muellerius* were removed by the Tramisol.

REPLY BY HIBLER: Is it possible that the presence of *Pneumostrongylus*, which were not removed, and the presence of *Ostertagia* and *Trichuris* could have interfered with your physiological values?

REPLY BY MCGLINCHY: I think that in the case of eosinophilia, yes. I think in the case of bicarbonate, no. As I said, I consider these only trends and to be looked into more closely.

QUESTION BY GEORGE POST, CSU: The number of *Ostertagia* present, I think, was 4 *Ostertagia* on sheep #3; sheep No. 4 had 1. On number 3 we found no adult *Trichuris*, just occasional eggs on flotation. Somehow or another we couldn't find that worm. It wasn't a heavy parasitism at all here with *Ostertagia* and *Trichuris*. The *Pneumostrongylus* must have been in there in such low numbers we couldn't find them either. Concerning *Muellerius*, these sheep were put into isolation on April 10. They were kept in isolation until the 12th of March of the next year. Shortly after isolation they were given Tramisol. No *Muellerius* larvae were seen from mid-April until March of the next year and we couldn't find *Muellerius* on necropsy. So we're pretty sure Tramisol did an excellent job on *Muellerius capillaris*.

REPLY BY HIBLER: What species of *Pneumostrongylus* is common back there?

REPLY BY AL WOOLF, RACHELWOOD, PENNSYLVANIA: It's the one in white-tailed deer, *P. tenuis*.

REPLY BY HIBLER: I didn't know that *Pneumostrongylus tenuis* was normally found in domestic sheep. Therefore, I would wonder if the mouflon or the bighorn would be susceptible to it.

REPLY BY GEORGE POST: It's the one that's in white-tailed deer back there. Since they are raised in the same general vicinity with the white-tailed deer, they have this *Pneumostrongylus*. We never saw an adult, that's why I cannot say what species we are dealing with here. All we ever saw was a first stage larvae of *Pneumostrongylus* in the mouflon x bighorn cross. We assume that its source was the white-tailed deer.

REPLY BY WOOLF: We frequently find the adults in our deer, but we never have seen them in any of our sheep upon necropsy.

REPLY BY HIBLER: Where did you find the adults?

REPLY BY WOOLF: In the cranial wall.

REPLY BY POST: On our necropsies we have gone through the brain, the cranial case, as much of the spinal cord as we could get. We cut sections of spinal cord, but we saw no scarring on these animals, even though we knew they had *Pneumostrongylus*.

REPLY BY HIBLER: The point I am driving at here -- Sara's pretreatment evaluation found such and such a physiological value when these parasites were present and then upon treatment found a certain value. Then upon post-treatment with *Protostrongylus* found a value. Maybe I misunderstood, but a lungworm is a lungworm and I would expect in the case of *Pneumostrongylus* or *Protostrongylus*, since they are very closely related species, a very similar physiologic response on the part of the animal.

REPLY BY POST: This could be, except that you get very little lung damage from *Pneumostrongylus* and very low levels of first stage larvae.

REPLY BY HIBLER: Okay, then I might ask, "on an H and E section, how do you separate *Protostrongylus* and *Pneumostrongylus* larvae?" but I won't. What I'm driving at is, I would hate to try to evaluate a physiologic condition in an animal when lungworm is present and has been removed and then re-introduced. I'd hate to try to evaluate these levels.

REPLY BY POST: You mean you would hate to do this over a year's time?

REPLY BY HIBLER: Let's take this up after the meeting.

THE LIFE CYCLE OF PROTOSRONGYLUS STILESI IN BIGHORN SHEEP[1]

by

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ABSTRACT

The objective of this research was to complete the life cycle of the lungworm, *Protostrongylus stilesi*, in bighorn sheep through the experimental transmission of infection. First stage larvae of the lungworm were obtained from naturally infected animals in Rocky Mountain National Park, Colorado. Land snails of the species *Vallonia pulchella* were exposed to these larvae in the laboratory. The larvae were allowed to develop to the infective stage. The snails were then fed to bighorn x mouflon sheep which were lungworm-free. The animals were in isolation. Daily fecal samples were collected and analyzed to monitor the progress of the infection attempts. Three of four hybrid sheep have shown *Protostrongylus* larvae in their droppings after as little as a 60 day prepatent period. Adult *Protostrongylus stilesi* have been recovered and identified upon necropsy.

Lungworms are thought by some to be the reason for the decline in present populations of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). (Pillmore and Moser 1954, Moser 1962). Bighorn sheep losses have been described by a number of people (Rush 1928, Marsh 1938, Potts 1938, Packard 1939, Pillmore and Moser 1954). Some believe that lungworms such as *Protostrongylus stilesi* (Dikmans 1931) predispose animals to bacterial lung disorders, though the primary cause of the fatalities may be traced to malnutrition and insufficient winter range (Honess 1955, Buechner 1960). Parasitism is the natural condition in wild ungulates (Cowan 1951), and the *P. stilesi* - *O. canadensis* relationship is one of long standing (Pillmore 1958).

The life cycle of *Protostrongylus stilesi* in bighorn sheep (*Ovis canadensis*) has not been completely known. The adult nematode lives in the lung parenchyma of the definitive host. The eggs are laid in the lung, hatch into first stage larvae and eventually make their way into the intestinal tract, leaving the body of the host with the feces. The first stage larva must leave the sheep feces and enter an intermediate host where it develops to the infective stage. This stage must then enter the definitive host. This part of the cycle has been the subject of intensive experimentation (Pillmore 1955-1961, Post 1958).

[1]This project was financed by Rachelwood Wildlife Research Preserve, New Florence, Pennsylvania and administered through the Department of Fishery & Wildlife Biology, Colorado State University, Fort Collins.

The life cycles of some members of the genus are known. All species of *Protostrongylus* with known life cycles require terrestrial molluscs as intermediate hosts. Therefore studies on the life cycle have been primarily focused on finding the correct terrestrial mollusc which would transfer the infection back to the definitive host.

Past research has shown several species of terrestrial molluscs which will accept first stage larvae of *P. stilesi*. Metamorphosis from first stage to third (probably the infective stage) has been observed on several occasions (Honess 1955, Pillmore 1955-1961, Post and Winter 1957, Post 1958). Attempts to complete the life cycle of the worm have met with inconclusive results or failure because lungworm-free bighorn sheep have not been available for experimentation. Therefore, genetic crosses of bighorn with domestic sheep or mouflon sheep (*Ovis musimon*) have been used as possible experimental definitive hosts of *P. stilesi*.

The purpose of the present research was to complete the life cycle of *P. stilesi* by transmission of the infective larvae from the intermediate host to the definitive host. *Vallonia pulchella* was used as the experimental intermediate host. Definitive hosts were mouflon-bighorn sheep hybrids.

MATERIALS AND METHODS

First stage larvae of *P. stilesi* (and possibly *P. rushi*) were obtained from the feces of wild-ranging bighorn sheep in Rocky Mountain National Park, Colorado. Fecal droppings were collected in bighorn sheep bedding areas on the crater rim of Specimen Mountain. These fecal droppings were air dried for maximum preservation of larvae. A Baermann apparatus (Baermann 1917) was used to separate first stage lungworm larvae from fecal samples.

Land snails of the species *Vallonia pulchella* were obtained from Laramie, Wyoming. Other snails (*Gastrocopta pellucida hordeacella*, *Pupilla muscorum* and *Zonitoides arboreus*) were collected from Pikes Peak and Larimer County, Colorado and from Rachelwood Wildlife Research Preserve, New Florence, Pennsylvania. Dr. H. Van der Schalie, Curator of Molluscs at the University of Michigan Museum of Zoology, identified all snails for this study.

Hybrid sheep from a cross of bighorn and mouflon were provided by Rachelwood Wildlife Research Preserve. These animals harbored infections of *Muellerius* sp. and *Pneumostrongylus* sp. The sheep were treated with Tramisol for removal of these infections.

Snail cultures were maintained in two different ways. Cultures were started in fingerbowls on autoclaved soil. These snails were fed finely ground oatmeal and calcium oxide. Temperature of the cultures was kept at 29-32 C, at all times and the soil was kept moistened. However, cultures were found to thrive better in clay pots of mulch, moss, leaf debris and wood fragments. These snails were kept moist at all times. The clay pots were kept in an incubator at 25C.

Infection of snails with the first stage larvae of *Protostrongylus* was accomplished in several ways. Some snails were placed on moistened, infected bighorn sheep fecal pellets. Any movement of the snail then necessitated contact with the infected surface of the pellet. Baermannized fluid was used for infection of other snails. A drop of liquid containing a concentration of first stage larvae was placed on autoclaved soil in a fingerbowl and the snails placed directly on the moistened spot. This method produced higher levels of infection in individual snails.

Infections in the snails were detected and followed by use of a dissecting microscope at 15X and 25X magnification. Details of larval development were observed with a compound microscope at 40X and 100X.

Two experimental sheep were used at a time. These animals were kept in a 12' x 12' isolation shed set on a two-inch concrete pad. The concrete pad was surrounded by a cresol-filled trough. The trough was set in under the walls of the shed and extended six inches outside the walls. Snails and crawling insects were thus kept out of the isolation shed. Windows were designed to be insect-proof while providing ventilation for the animals.

Some fecal samples from experimental sheep were collected from the floor of the isolation shed. An isolation crate was used when 24 hour fecal samples were needed. This crate accommodated a single animal at a time and was used inside the isolation shed. The entire unit was set on cement blocks and a collecting screen was placed underneath. Fecal matter passed through the wire floor of the crate and onto the lower screen. Urine passed through both screens. Total fecal material was removed from the lower screen at 24 hour intervals. Three consecutive 24 hour collections were taken from each animal at regular intervals in order to evaluate production of larvae by the sheep during attempts at infection.

Infections in experimental sheep were induced by the oral administration of snails containing larvae which had been in the heavily chitinized, third stage for at least two weeks. Two weeks were allowed for further development in the snail in the event the third stage needed to mature somewhat before becoming infective. The snails were examined microscopically to determine number of larvae present. Snails were then put into gelatin capsules and fed to the sheep with a balling gun. Sheep #1 and sheep #2 each received 345 infective larvae in 14 doses. Sheep #3 and sheep #4 received 376 and 372 larvae respectively in 18 doses.

Fecal samples from experimental sheep were monitored daily after infective larvae had been administered to determine infection. Three aliquots of the 24 hour fecal collections were Baermannized to estimate the numbers of first stage larvae present. The entire collection was weighed. The number of larvae were counted in four gram aliquots and daily production of larvae and larvae per gram of feces were calculated.

Fecal samples of hybrid sheep not in isolation were irregularly examined. This was done as an experimental control measure. These hybrid sheep had the same natural lungworm infections as did the sheep in isolation.

Proof of infection was obtained at necropsy. Lungs were minutely dissected with the aid of a dissecting microscope and all adult worms, larvae and nodules were carefully preserved. Adult nematodes were then measured and identified.

RESULTS

Three of four transmission attempts with hybrid sheep from bighorn x mouflon crosses were successful. The three successful attempts gave prepatent periods varying from 63 to 122 days (Table 1).

Table 1 - Results of transmission experiments with *P. stilesi* to hybrid sheep.

Animal number	No. larvae given (Oral administration)	Number of doses	Transmission	Days from first dose to first stage larvae production
1	345	14	+	119*
2	345	14	-	
3	376	18	+	122
4	372	18	+	63

*Time not reliable. See discussion p. 11.

Adult *Protostrongylus* recovered at necropsy from experimentally infected sheep are described in Table 2. The measurements given for these sepcimens are compared with measurements given by Dikmans (1931) for *P. stilesi*. The specimens from the present study were identified as *P. stilesi* by comparison of measurements.

Numbers of adult *P. stilesi* recovered upon necropsy were compared to first stage larval production of the infected animal (Table 3).

DISCUSSION

The experimental sheep used in this study were hardier and more easily handled than bighorn sheep. Rocky Mountain bighorn sheep are known to be a susceptible definitive host of *P. stilesi*. Mouflon sheep have also been found to harbor natural infections of the same parasite (Howe 1965). Therefore the hybrid sheep were expected to be suitable definitive hosts. Successful transmission of infections to the hybrid sheep proved that they were susceptible.

Precautions were taken to prevent accidental infections of any kind from becoming established in the experimental sheep. The cresol-filled trough and double screened windows were the major means of

Table 2 - Measurements of *P. stilesi* recovered from experimental sheep compared to Dikmans (1931).

	Present study Average (Range)	Dikmans (1931)
Males		
number recovered*	16 (1 complete)	none complete
body length	19.8 mm	8 mm
body width in front of bursa	85.6μ (72.6-103.5)	150-160μ
esophagus	212μ (172.5-239.2) x 38.8μ (29.9-53)	235-270 x 50μ
spicules	332.2μ (290-368)	300-340μ
accessory pieces		
proximal	54.8μ (41.4-63)	58μ
distal	85.7μ (71.3-98.9)	96μ
bursa	short	short
gubernaculum	present	present
Females		
number recovered*	6 (none complete)	none complete
body length	uncertain	uncertain
body width	77.3μ at vulva (64.6-92.4)	100μ at vagina
anus to tip of tail	64.1μ (46.0-83.7)	67-75μ
anus to vulva	124.5μ (103.5-165)	190-200μ
provagina	prominent	prominent
vagina	340μ (290-390)	475μ
eggs in vagina	76.0μ (59.8-85) x 34.8μ (27.6-50)	85-90μ x 30-38.5μ
Eggs		
number measured	100	
length	90.7μ (60-110)	
width	48.8μ (35-65)	
Larvae (first stage)		
Number measured	50	
length	251.1μ (197.8-368.0)	
width	15.7μ (9.8-24.6)	
tail	23.6μ (18.4-32.2)	

*Only ♂ and ♀ parts were counted.

Table 3 - Relationship of first stage larvae in feces to numbers of adult *P. stilesi* in the definitive host.

	Sheep #1	Sheep #3	Sheep #4
Fecal samples	1-10 larvae/ gram		
Average of samples		0.4 larvae/ gram	9.4 larvae/ gram
sample No. 1*		0.25 larvae/ gram	5.3 larvae/ gram
sample No. 2		2.75 larvae/ gram	0.9 larvae/ gram
sample No. 3		0.75 larvae/ gram	0.33 larvae/ gram
sample No. 4		0.25 larvae/ gram	0.5 larvae/ gram
sample No. 5		0.37 larvae/ gram	0.0
Necropsy Results			
Fecal	few	------------	2.75 larvae/ gram
Larvae in lungs	---	6,910 larvae	23,100 larvae
Adults recovered (only ♂ and ♀ parts were counted)			
Male	5	2	9
Female	1	0	5
Seen in Histological sections of lungs		3	3
Total	6	5	17

*Samples 1 through 5 were 24 hour collections taken the 5 days prior to necropsy of the sheep.

keeping out possible parasitic vectors. Despite these precautions, insects on occasion got into the isolation shed. Nevertheless, isolation was felt to be sufficient to have prevented infections from sources other than those intended with this study.

Maintenance of snail cultures required constant attention to moisture and to temperature conditions. Incubation at 25 C was the most successful temperature used for snail production.

V. pulchella was a suitable intermediate host for *P. stilesi*. *Pupilla muscorum* may also be a suitable host since a single experimental infection was obtained. Infection in *P. muscorum* was difficult to detect due to conformation and thickness of the shell. *V. pulchella* was used for all infection attempts since it proved to be better suited to microscopic examination and laboratory propagation.

The present study yielded infected snails as early as three days after exposure to *P. stilesi* larvae. Second stage larvae were seen in as little as six days following exposure. Third stage larvae were observed at 14 days post-exposure. Pillmore (1955-1961) found that rate of development of *P. stilesi* in snails of species of *Pupilla*, *Vallonia* and *Vertigo* was quite variable. Larvae were first noted in the foot of the snail in 4 to 10 days after exposure. The second stage was reached in 8 to 30 days. The second molt occurred in 11 to 60 days after exposure. These times agree closely with those given above for the present study.

The 119 day prepatent period (days from first feeding of infective larvae to first stage larval production) given for sheep #1 (Table 1) may have been considerably shorter because larvae of *Protostrongylus* may have been present in the feces before they were noted. Fecal samples were collected in Pennsylvania and mailed to Colorado where they were found to be negative, yet similar fecal samples were later found to be positive when examined in Pennsylvania. The disappearance of the larvae in transported fecal samples is unexplained.

Prepatent periods for sheep #3 and #4 were 63 and 122 days respectively. This is considerably longer than those given by Pillmore (1959) for species in rabbits and mule deer. The general prepatent period was given as 25-60 days. The longer periods observed in this study may reflect specific differences in the parasites or the hosts. The fact that the definitive hosts were hybrid animals may have had an effect on the length of time necessary for the development of the infective larvae to the sexually mature adults.

Adult *Protostrongylus* recovered from sheep #1, #3 and #4 were identified as *P. stilesi*. These experimental specimens compared favorably with measurements of specimens given by Dikmans (1931) and Honess (1942). Body widths were somewhat less in the present study but variation was great in the earlier descriptions and the discrepancy in widths was not thought to be significant.

Hybrid sheep in pens adjoining the isolation shed were used as experimental control animals. The experimental sheep had been taken from this group. Examinations of fecal pellets from this group were conducted during the transmission experiments. All examinations of the non-isolated hybrid sheep revealed infections of *Muellerius* and *Pneumostrongylus*. *Protostrongylus* larvae were not found in any samples.

The results of the present study prove that the life cycle of *P. stilesi* does indeed involve a mollusc as an intermediate host. *V. pulchella* has been shown to be a suitable intermediate host for the development of the parasite to the infective stage. Transmission from this intermediate host to the Rocky Mountain bighorn sheep, the definitive host, is now considered to be possible. The activity of infective stage *P. stilesi* in bighorn x mouflon hybrids is strongly indicative that similar results do occur in bighorn sheep. There may be other variations of the life cycle which exist in the bighorn sheep. Prenatal transmission may also be possible. However, the present research has shown that bighorn sheep-terrestrial snail-bighorn sheep is an actual mode of transmission of *P. stilesi*. To that extent, the life cycle is now known.

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DISCUSSION

QUESTION BY DICK PILLMORE, BSF&W, COLORADO: In one of your slides, you showed one of the ensheathed infective stage larva and indicated that it had left the snail in that form. In sheep, did you ever get ensheathed larvae leaving the snail in that form?

REPLY BY MONSON: Yes, we did see several larvae with the sheath leave the snail and then exsheath.

REPLY BY SARA MCGLINCHY, CSU: We sat and watched one particular snail over an hour period and watched approximately three infective stage larvae actively migrate out of the snail's foot.

REPLY BY PILLMORE: I have recovered the infective larvae from inside the vials that I have had snails in. These have left the snails, but in no case did I ever see the ensheathed larvae come out. That's why I ask.

QUESTION BY CHARLES HIBLER, CSU: Ruth, you said that Tramisol did not show the efficacy I would like. Would you like to point out our previous discussions relevant to this. I do not want the public mis-lead that Tramisol is not an effective compound. American Cyanamid has taken Dr. Rubin and myself apart to a certain extent on this already. It is not as efficient against *Trichostrongylus* as it is against some of the other parasites, but please clarify what we discussed yesterday.

REPLY BY MONSON: The animals had a gastro-intestinal infection, *Ostertagia* and *Trichuris*. After administration of Tramisol, the animals still had *Ostertagia* and *Trichuris*. Due to some form of pre-immunity, the parasites involved may not have been the same adult worm, but different adult worms. The infections were still there after the dosage of the drug had been given.

REPLY BY HIBLER: There is no such thing as retarded development of parasitic nematodes, especially gastro-intestinal nematodes. What Ruth is trying to say is that sheep, by virtue of their eating habits, are constantly ingesting these things. *Ostertagia* goes into the abomasum, develops and comes out as a sexually mature individual. But all the rest of the *Ostertagia*, would pour into here while retarded. Therefore, when she removed the adult population of *Ostertagia*, this released the retarded population. And if you're not on your toes, if you're not examining these animals consistently, you'll miss the fact that you have wiped out one adult population and released a sub-adult population. Now I might ask you if Tramisol is effective against *Protostrongylus stilesi* -- if it will kill the adults.

REPLY BY MONSON: No.

QUESTION BY C. E. WILLIAMSON, USFS, COLORADO: Is there any indication from your studies as to whether or not an effective time can occur whereby removal of one of the hosts of this parasitic lungworm will cause a reduction in the population in a given area? For instance, where the bed grounds are infected and the land snails are infected and then by removal of the sheep, would there be a reduction in the parasite?

REPLY BY MONSON: I don't believe there would be a reduction in the parasite with reduction of the sheep. The infection will remain in the snail and the first stage larvae will remain in the droppings of the sheep. The range will not be cleared of first stage larvae each year. They will overwinter and will remain on the range. Infective larvae will remain in the snail. We have seen them in the snail for as long as six months.

REPLY BY WILLIAMSON: You mentioned that a mouflon sheep can also carry this lungworm parasite. Can domestic sheep of our western ranges also carry this?

REPLY BY MONSON: I don't know if domestic sheep would be susceptible to *Protostrongylus stilesi*. They haven't been infected with it. There is another *Protostrongylus* species that occurs in domestic sheep, *P. rufescens*, and I don't know whether or not *P. stilesi* will live in domestic sheep. Dick Pillmore has done some work with trying to infect domestic sheep but has not been able to cause infection. Maybe he can answer that better than I can.

REPLY BY PILLMORE: It's never been recorded in domestic sheep. In one instance, with a hybrid bighorn x domestic, we recovered first stage larvae over a period of time, but we were not able to recover the adult worms. At the same time, we had one mouflon ram that we repeatedly exposed but we never established an infection in it. I think that, in time, it wouldn't be surprising to have it turn up in domestic sheep, but it's not an important or a normal host.

QUESTION BY DON BAILFIELD, USFS, COLORADO: To carry Mr. Williamson's question a bit further, if we eliminated the sheep population for a number of years, could we break the cycle?

REPLY BY MONSON: Dr. Thorne from Wyoming could tell you more about this. They've kept fecal samples with first stage larvae in them which are still viable after 10 years.

REPLY BY DR. THORNE: Even longer than ten. I can't remember exactly, but it's much longer than 10. These are frozen. They are extremely hearty and I don't think it would be feasible to take the sheep off the range with the hopes of later re-introducing them and avoiding an infection. In the first place, I don't know where you'd get the sheep to start with that don't have the lungworm. In the second place, I think it would be extremely hard to assure yourself that you'd eliminated the infective larvae and the larvae there on the range. It would take quite a long time. I'd sure hate to exterminate a herd of sheep with that in mind.

QUESTION BY DOUGLAS GILBERT,CORNELL UNIVERSITY: One question, Ruth, how did you administer the snails to the sheep?

REPLY BY MONSON: Infective stage larvae in the snails were counted. Then the snails were put into gelatin capsules and fed to the sheep with a balling gun.

APPLICATION OF PHYSIOLOGIC VALUES TO BIGHORN SHEEP MANAGEMENT

by

Albert W. Franzmann, Idaho Cooperative Wildlife Research Unit, University of Idaho

ABSTRACT

The indicator species concept was used to demonstrate the application of physiologic values to bighorn sheep management. Utilizing blood urea nitrogen, packed cell volume, albumin-globulin ratio, and hemoglobin values from groups of bighorn sheep with low quality diet and good quality diet the statistical differences in means between the groups was discussed. The use of blood urea nitrogen (BUN) values to reflect protein availability to the bighorn on a particular range is proposed, and the need to pursue the indicator species concept approach to solving management and ecological problems is stressed.

INTRODUCTION

The application of physiologic values to bighorn sheep management entails the understanding of the indicator species concept (Franzmann 1970). This concept refers to a species'ability to reflect its environmental quality,or lack thereof. Since the animal is a product of its' environment (Platt et al. 1964), we should utilize the animal to gain insight into its' environment.

Direct studies of the environment have received the majority of research effort in the past and will play a continuing important role, but application of the indicator species concept to better understanding the complex interrelationships has advantages in certain situations. For example, when sampling standing forage on a range to determine the quality of forage for grazing herbivores one is confronted with major variables such as feeding behavior, forage quality variability within site and plant, and digestive capabilities and interactions. These variables can be eliminated by sampling blood from the grazing herbivore to determine the end result of grazing and/or browzing.

The bighorn sheep is an ideal species through which this concept can be demonstrated because it is a climax species (Leopold 1966) and has specific requirements to fulfill its life cycle. Physiologic values from bighorn sheep were used in this paper to demonstrate this concept and were obtained from 219 bighorns sampled from October 1969 to February 1971.

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METHODS

Blood samples taken from the juglar vein of 219 bighorn sheep were analyzed for 22 different values. The values utilized for this paper were: blood urea nitrogen (BUN), packed cell volume (PCV), albumin-globulin ratio (A/G), and Hemoglobin (Hb).

BUN values were obtained utilizing the urease type, Berthelot reaction (Biodynamics, Indianapolis, Ind.). The PCV percentage was obtained by centrifuging blood filled Pre-Cal Microhematocrit Tubes (Clay-Adams, N.Y., N.Y.) at 7400 R.P.M. for 5 minutes in a MP Readacrit Centrifuge (Clay-Adams, N.Y., N.Y.). A/G ratios were obtained from electrophoretic patterns produced from the blood serum at the Endoparasite Vector Pioneering Research Laboratory, Agriculture Research Service, Pullman, Washington. Hemoglobin values were obtained utilizing cyanmethemoglobin reaction (Biodynamics, Indianapolis, Ind.).

Poor quality diet (less than 5% protein) was received by 39 captive bighorns (Franzmann and Hebert 1971) and good quality diet (more than 15% protein) was received by 84 captive bighorns which were fed high quality alfalfa hay with a protein supplement. The protein content of the diet of the wild bighorn sheep sampled was unknown, but they all were sampled from winter populations where management measures were being practiced to prevent overuse of winter range.

RESULTS AND DISCUSSION

The differences in the mean values for BUN, PCV, and A/G between poor and good diet groups were highly significant and for Hb were significant using Student's *t* test for analysis (Table 1).

Table 1 - Physiologic value differences in bighorn sheep with diet.

Values	[a]Poor Quality Diet (39 Captive Sheep)	[b]Good Quality Diet (84 Captive Sheep)	Unknown Diet (96 Wild Sheep)
Blood Urea Nitrogen mg/100 ml	14.9**	36.9**	22.5
Packed Cell Volume %	43.4**	49.2**	45.9
Albumin-Globulin Ratio	1.37**	0.95**	1.07
Hemoglobin gm/100 ml	16.8*	18.0*	18.7

a. Less than 5% protein
b. More than 15% protein
* Significant $t_{.05}$
** Significant $t_{.01}$

The differences give us a basis from which we can potentially utilize these values to evaluate the range condition of a population of bighorn sheep.

The most significant difference between means was for BUN and this was the most useful of the 4 values in reflecting protein intake. Increase in BUN is related to protein intake (Coles 1967, Preston et al. 1965).

PCV is a reflection of the percentage of erythrocytes in blood and is a valuable technic in the clinical laboratory (Coles 1967). This value does not reflect protein intake per se, but it does reflect general condition. Where highly significant differences in PCV means occur between low and good quality diets, we must consider it a potentially useful tool in applying the indicator species concept.

A/G mean differences between the poor and good diets is a result of a higher proportion of albumin in the blood serum. This has many implications, but the possibility that it reflects an increase in a type of protein may have useful applications.

Hemoglobin, which is a measure of the oxygen carrying capacity of the blood, also reflects a character of quality to the blood. Its value in interpreting results is limited as the analysis of hemoglobin remains one of the most unsatisfactory measurements in clinical use (Coles 1967).

CONCLUSION

In summary, we have examined four physiologic values which had statistically significant differences in means between a group of bighorn sheep on low quality diet and a group on good quality diet. The point to emphasize is that this is an example of applying the indicator species concept to bighorn sheep. The quality of forage intake through the bighorn was evaluated and thereby conditions of the sheeps enviroment were considered.

To conclude that all these values are related to protein intake would be invalid, because we do not know at present what levels of these values are significant or what other variables may have a major influence on the results. We can conclude that BUN (which reflects protein intake and which had highly significant mean differences between low and good protein intake) can be used to apply the indicator species concept through the bighorn sheep to reflect its' protein utilization on a particular range.

The wild sheep physiologic values (Table 1) indicate that their forage conditions were at a level between the poor (less than 5% protein) and good (more than 15% protein) groups.

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DISCUSSION

QUESTION BY STEVE HAWKS, BLM, IDAHO: How adaptable, economically and physically, are these techniques in the field?

REPLY BY FRANZMANN: That was one of the criteria used to select the values I used. The data you saw was collected with a field testing kit with the work done right on the site. The values which require difficult laboratory procedure were not utilized because they have no value in application.

QUESTION BY JIM BAILEY, CSU: I agree wholeheartedly that we need to look at the animal more than we have to evaluate its relationship to its environment. Your evaluation of these parameters is based on three sets of animals. How else might you have evaluated whether or not you indeed have a parameter which is correlated with nutrition or physical condition? For instance, did you try to correlate parameters in your sample of wild sheep?

REPLY BY FRANZMANN: Yes. At least an analysis of variance was done for all 18 different sources of variation. On the basis of this, the first group was eliminated because it was not significant. Then we maintained significance at that level.

REPLY BY BAILEY: Correlated with what?

REPLY BY FRANZMANN: Correlated with the physiological body. The sources for variation for that - condition, sex, age, subspecies.

REPLY BY BAILEY: How did you evaluate the physical condition of the animal against these parameters? Just the three sets of animals?

REPLY BY FRANZMANN: Robinson's ten-point system of classification.

REPLY BY BAILEY: Your blood urea nitrogen values, it seems to me, could be related to more than just protein content of the diet such as I think soluble carbohydrates in the diet, might affect it and protein catabolism during weight loss might increase this. So, there are a lot of other variables besides protein in the diet that would affect that.

REPLY BY FRANZMANN: We have two curves actually that affect blood urea nitrogen. One would be based on the intake alone and then one on the animal's putting blood urea nitrogen back into the blood through the degrading process. Those things can influence it but when you have differences of 14 to 33 mg percent protein intake, you certainly have a usable value. If you are going to hold it down to a milligram or two percent you never would find anything you can use.

REPLY BY BAILEY: I don't know whether these things can be affected to this magnitude by these other factors.

REPLY BY FRANZMANN: That is why I say it is really not that important.

REPLY BY BAILEY: We have one set of data out of Colorado collected by Bob Keiss that shows high blood urea nitrogen values of animals that were dying of starvation - in some cases with available supplemented feed.

REPLY BY FRANZMANN: There is a point where the animal's tissue completely breaks down.

A DIE-OFF DUE TO PHEUMONIA IN A SEMI-CAPTIVE HERD OF ROCKY MOUNTAIN BIGHORN SHEEP[1]

by

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Wyoming Game and Fish Commission

ABSTRACT

A die-off in a semi-captive herd of 17 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) is described. Many of the deaths were caused by pneumonia and the course of the disease and gross pathology is described. Some information about the parasitic infection of several sheep involved was known prior to the outbreak. The probable lack of lungworm or poor nutrition as influencing factors is mentioned.

INTRODUCTION

Rocky Mountain bighorn sheep are host to many pathogenic parasites and microorganisms (Honess and Winter 1956, Post 1958, Howe et al 1966, and Becklund and Senger 1967). Verminous pneumonia or the lungworm-pneumonia complex has been reported as responsible for most of the mortalities in bighorn sheep (Hunter and Pillmore 1954, Buechner 1960). However, two small die-offs were investigated by Post (1962) who felt that these mortalities were due to pasteurellosis rather than verminous pneumonia. He also suggested that historic rapid die-offs were indicative of a virulent microorganism rather than the usually slow and debilitating effects characteristic of parasitism. Inadequate and poor quality feed has been mentioned as an important factor predisposing bighorn sheep to disease (Honess and Winter 1955).

The purpose of this paper is to describe a rapid die-off which occurred in a small confined herd of bighorn sheep. The available information indicates that lungworms and inadequate feed were of little or no importance in this die-off.

DIE-OFF DESCRIPTION

In late November and early December 1970, mortalities occurred in a herd of 17 bighorn sheep held in a 60-acre pasture at the Wyoming Game and Fish Commission's Sybille Big Game Research Unit. The pasture is on the north slope of a rugged mountain side. The predominant vegetation consists of western wheatgrass (*Agropyron smithii*), Sandberg bluegrass (*Poa secunda*), Junegrass (*Koleria cristata*), big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and mountain mahogany (*Cercocarpus montanus*). In addition to natural forage, the

[1]A contribution of Federal Aid in Wildlife Restoration Project, Wyoming FW-3-R.

sheep were supplemented with high quality third cutting alfalfa hay, and pellets consisting of ground corn, ground oats, pure bran, linseed hulls, and molasses. The grain pellets contained 20,000 units of vitamin A per pound.

The herd was composed of a mature ram approximately 8 years old, 2 each 2-year-old rams, 10 mature ewes, and 3 lambs. The mature ram and 4 ewes had been trapped and transported to Sybille as adults in 1964; 3 mature ewes were acquired in the spring of 1969; a 2-year-old ram and a mature ewe were released in September 1970; a 2-year-old ram, a 2-year-old ewe, 2 yearling ewes, and 3 lambs were born within the pasture.

On the morning of November 23, the mature ram was observed to be ill. Breathing was labored, and a rattling sound was audible when he was approached. That same afternoon he was discovered dead and he was necropsied the following day. On the 24th, the 2-year-old ram born at Sybille was observed ill, and on the 25th two mature ewes from the 1965 and 1969 transplants were discovered dead. Neither ewe was suitable for necropsy due to postmortem changes and having been fed on by coyotes. The ill 2-year-old ram was found dead on November 26, and was necropsied on the 27th. During the next 2 weeks sheep with symptoms of pneumonia continued to die, but none suitable for necropsy were located.

Six of the 17 sheep survived. These were the 2-year-old ram and ewe released in September 1970, a lamb born in 1970, a 2-year-old ewe, and 2 other mature ewes, one from the 1969 release and the other from the 1964 release. The lamb was the only surviving animal that had been observed to be ill.

PATHOLOGY

At necropsy the mature ram weighed 195 pounds, pellage was good, and body condition was excellent with much stored body fat present. Postmortem drainage of blood tinged fluid from the nostrils was extensive. A few assymetrical subcutaneous hemorrhages were present. The atlantal and mandibular lymph nodes were swollen and juicy, and the prescapular and axillary nodes were extremely hemorrhagic. The apical lobes of the lungs and ventral portions of the other lobes were very consolidated and undergoing red hepatization. The remaining portions of the lungs were congested and edematous, and there was a large amount of blood and foam in the trachea and bronchi. Although a single nodule about 5 mm in diameter, resembling a lungworm nodule, was located near the dorsal margin at the right diaphragmatic lobe, no lungworms were detected by a careful dissection of the bronchi. There was a weak fibrinous adhesion between the left diaphragmatic lobe and the parietal pleura. The pericardial fluid was red and slightly increased in volume. Superficial cardiac blood vessels were engorged and the heart was soft and flabby. Mediastinal lymph nodes were enlarged and juicy. The kidneys were soft and pulpy, and the splenic pulp was soft and juicy.

A *Pasteurella* sp. closely resembling *P. multocida*, a *Streptococcus* sp. and a *Bacillus* sp. were isolated from the lungs. The *Bacillus*, and *Staphylococcus epidermidis* which was recovered from blood were thought to be contaminants.

Upon necropsy, the two-year-old ram was found to be in good body condition and weighed 125 pounds. Postmortem changes were advanced and only tne heart and lungs were examined. There was an increased amount of blood tinged fluid in the pleural cavity and pericardial sac. The heart was soft and flabby. The lungs were extremely consolidated with the primary changes following a ventral distribution. The dorsal portions were congested. No lungworms were detected in the bronchi, but several small nodules were present along the dorsal aspect of the diaphragmatic lobes. A *Pasteurella* sp. was also isolated from the lungs of this ram.

Pasteurellosis was diagnosed as the cause of death in the two rams which were necropsied. Several other sheep that later died were observed coughing and debilitated in a manner similar to the two rams, but coyotes devoured their remains before they could be necropsied. It is felt that some of the other 9 sheep lost may have been killed outright by coyotes because they were observed healthy on one day, and on the next, portions of their devoured carcass were discovered.

DISCUSSION

Inadequate feed was not thought to be involved in this die-off. Range conditions were fair, supplemental feed was provided, and the 2 sheep necropsied were in excellent body condition. Other sheep which were observed before death appeared to also be in good body condition.

Because of previous lungworm studies and incidental parasite examinations, the parasitic burden of some of the sheep involved was known. A fecal sample from the mature ram was examined on July 22, 1969 and found to be free of parasitic larva and ova. On July 5, 1969 the ewes released into the pasture that date were treated with tetramisole, a drug which shows promise as a lungworm control agent in bighorn sheep. Fecal samples collected on July 22 and on August 28, 1969 for some of these treated sheep showed elimination or reduction of lungworms and gastrointestinal nematodes. One of the two ewes found dead on the 25th of November was negative for lungworms on both July 22 and August 28, 1969. Another of the ewes which died during the epizootic was one of the treated sheep. Thus it is known that at least 3 of the sheep which died, the mature ram and 2 ewes, were apparently free from or carrying a low load of lungworms during 1969. Although these fecal examinations were made over a year prior to this pneumonia onset, it is doubtful if these adult sheep could have acquired a sufficient lungworm infection to have been important in producing pneumonia. The two yearling ewes were also checked for parasites as lambs in August 1969, and both were passing moderate numbers of lungworm larvae. One of these sheep died and one survived the die-off.

Provided that lungworms and poor range conditions were not involved, two possible factors which might have initiated this die-off should be mentioned: (1) it is possible that the number of sheep in the pasture (17) had exceeded the number of suitable well sheltered bedding sites within the pasture and that crowding was taking place. This may have facilitated rapid transmission of a pathogen; (2) a second possible suggestion is that coyote harassment and attempted predation was taking place before the die-off started and that nighttime activities of hunting coyotes may have been sufficient stress to initiate pneumonia. There are probably just as many unknown important factors and any of those mentioned or unknown could have been enough to initiate the die-off individually or in combination.

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DISCUSSION

QUESTION BY CHARLES HIBLER, CSU: What was the weather condition when this outbreak occurred? Did you have a turn of inclement weather?

REPLY BY THORNE: We discussed this and we don't feel it was important. We did have slightly colder weather. It was our first cool spell. It was not a cold spell. We did have one snow. Weather is a possible factor, but we didn't feel that it was that great.

REPLY BY HIBLER: Of the sheep that survived, did you examine these sheep for *Pasteurella*?

REPLY BY THORNE: No, we didn't. We didn't want to catch them or upset them any more than necessary.

QUESTION BY BILL BRADSHAW, USFS, WYOMING: The western range is short of phosphorous as most stockmen know, and they supplement the feed or put the phosphorous in salt. I wondered if you thought that might help the sheep.

REPLY BY THORNE: I haven't done any work on that. We do normally salt our sheep at Sybille. Colorado has done some work with phosphorous. I think it is something which should be looked into. It could be a factor in some of the die-offs or diseases we have had. Perhaps somebody from Colorado would know more about this than I do.

REPLY BY GEORGE POST, CSU: I'd just like to make a comment on this. This is one of the things I was trying to bring across. They do need to know some of these things like what is the phosphorous requirement of bighorn sheep and we just cannot find out with wild-ranging sheep. We can keep some phosphorous blocks out there and maybe after five years we'll have some inconclusive evidence. We need to be able to hold these animals in captivity to be able to handle them, to be able to say this is the phosphorous requirement.

This pneumonia complex keeps breaking into any studies we attempt. It is a real tough situation.

REPLY BY HIBLER: Tom Thorne is highly qualified to do necropsy work to determine the actual cause of death of these animals. I would like to make a plea to these other states to have highly qualified individuals do postmortem examinations so that a complete and thorough postmortem examination is done. Wyoming, of course, has an individual highly qualified to do that. I think Idaho does too. Some of the rest of us don't, except CSU has a bunch of people if we can get them stirred up to do it.

QUESTION BY MILT FRAN, BSF & W: I'm not disputing your diagnosis of *Pasteurellosis*. I believe at that time, late October, there was an outbreak of EHD sweeping across North Dakota and into Montana.

REPLY BY THORNE: We had it in Wyoming, too.

REPLY BY FRAN: Was any screening done on this outbreak for viral agents such as closely associated blue-tongue virus?

REPLY BY THORNE: No, there wasn't. That is the point George brought out. We should be checking these sheep for viral agents and as you mentioned, for mycoplasma.

REPLY BY FRAN: Did you see any lesions on the heart that suggested this?

REPLY BY THORNE: No, I didn't. Of course we don't know what the pathology would be in sheep, but I didn't see anything to indicate anything like EHD. Actually, this die-off was about a month later than the EHD die-off. The EHD die-off occurred in extreme northeastern Wyoming but we did have at least one deer brought into Sybille for necropsy in October. You are right. Viruses ought to be checked but they were not in this case.

THE PNEUMONIA COMPLEX IN BIGHORN SHEEP

by

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The declining bighorn sheep population in the United States and Canada is the result of many things. One major decimating factor has been encroachment of historic ranges by man and domestic animals. Another major catastrophic factor has been lung diseases. Both are well documented. The latter may be assumed to be one of the results of the former.

Major catastrophic die-offs from disease have been said by many researchers to have been caused by pneumonias of one form or another and, in the case of the early part of this century, major losses in the western United States were attributed to scab (Ward 1915). The scab was presumably *Sarcoptic* mange of domestic sheep. There is some doubt in my mind about the validity of scab as being the true cause of these losses. Reports of the incident stated "sheep died in such numbers that their bodies clogged small streams." A man who was in the back country of Idaho at this time once heard my description of pasteurellosis in these animals and saw color photographs of the gross symptoms. He then told me that "this was what the insides of sheep thought to be dying of scab looked like -- they seemed to be rotten inside very shortly after death."

The cause of many of these decimating losses among bighorn sheep is lost to us forever because complete bacteriological, virological and parasitological studies were not made. The written accounts are all that is available to us today. We must take these written words at face value and attempt to use them for finding answers to present day problems.

We do know there is much documented evidence that pneumonias are very prevalent in bighorn sheep. These animals appear to be more prone to lung ailments than to any other single disease factor. We know that most of our bighorn sheep populations are not plagued to any great degree by predation, accidental deaths attributed to living in precipitous habitats, etc. (Honess and Frost 1942, Moser 1962, Smith 1954). These factors do take their toll, but the pneumonia complex appears to be of prime importance.

Nearly each of the major writings on bighorn sheep in the last 50-75 years note pneumonia problems as a mortality factor. Some of these make a summation of symptoms and give thoughtful diagnosis of the cause of mortalities. Many of these give inconclusive evidence of the correctness of the diagnoses.

The pneumonia complex we speak of in bighorn sheep may be defined as the relationship of the various pathogenic organisms in the lungs and respiratory tract, to the pathology in the specific organ in which they are found. We know of two major entities being present in bighorn sheep respiratory tracts: the various bacterial species and the various nematode species. The *Mycoplasma* have been isolated from captive bighorn sheep - not from wild ranging bighorn sheep (Woolf et al. 1970). Attempts have been made to isolate viral organisms from bighorn sheep mortalities. Results have always been negative. We can only postulate the presence of viral pathogens and *Mycoplasma* as being responsible for some pneumonic complications in these animals in the wild state.

We do know much about the various bacteria isolated from organs of the respiratory tract of these animals. We also know much about the lung nematodes specific to these animals.

The bacterial and the nematode entities have probably been associated with bighorn sheep for eons. No doubt the nematodes came onto this continent with the ancestors of present day bighorn sheep. We can trace this back to similar species of lung nematodes found today in wild sheep of Asia (Boev 1950). The original source of the bacterial entities is more difficult to trace with certainty. Some of these bacteria are similar or identical to bacteria found in domesticated sheep or other domesticated animals throughout the world. Similar or identical *Pasteurella* and *Corynebacterium* species can be found in domestic sheep or cattle. These organisms can also be bound in elk or pronghorn antelope.

Species of bacteria other than the genus *Pasteurella* or *Corynebacterium* have been isolated from normal and pneumonic bighorn sheep. Some of these belong to the genus *Staphylococcus*, *Streptococcus*, *Nisseria* and *Diplococcus*. The relationship of these to the pneumonia complex in bighorn sheep is largely unknown.

Some authors have referred to the pneumonia complex in bighorn sheep and leave the reader to believe the major cause is lung nematodes of the genus *Protostrongylus* (Forrester and Senger 1964, Beuchner 1960). These parasites must be taken into consideration in studying the pneumonias of bighorn sheep. They probably are not an all-encompassing cause of the problem though.

There are two recognized species and one species of questionable recognition of the genus *Protostrongylus* in bighorn sheep on our continent. These nematodes appear to be specific to the bighorn sheep species of North America. One or the other or both species are found in most wild ranging bighorn sheep. All animals in some flocks harbor these lung nematodes. I have never found a bighorn sheep that did not shed *Protostrongylus* first stage larvae in their feces. Sometimes collection of feces for several consecutive days was necessary to prove that the animal was infected.

There appear to be at least three pneumonia types in the pneumonia complex of bighorn sheep. The first type I will discuss is the very acute, very devastating pneumonia associated with *Pasteurella* infections. This pneumonic syndrome very often terminates rapidly into septicemia. Once septicemia develops, the animal's death is usually inevitable. This type of pneumonia may be brought on by the normal presence of *Pasteurella* bacteria in the respiratory tract and some type of stress; physical, physiological, psychological. The presence of animals which have been so stressed and are now shedding virulent (possibly capsulated) *Pasteurella* in nasal and throat discharges may also be a source of infection. The infection develops rapidly, causing acute consolidation and hepaticization of lung tissue, highly hemorrhagic nasal turbinates and trachea, and invasion of the blood stream from these areas. The organisms spread rapidly throughout the body causing extreme cyanosis of all organs and tissues. *Pasteurella* (usually either *P. multocida*-like or *P. hemolytica*-like) organisms can be isolated from almost all body tissues at this time. Death usually occurs very quickly after septicemia develops (Post 1962).

A second type of pneumonia is associated with presence of lung nematodes. This usually develops as a chronic condition. The lung nematodes cause tissue reaction around the site where the worm occurs (either in parenchymal tissue or attached to the lining of the bronchioles). Tissue reactions involving *P. stilesi* in the parenchymal tissue include alveolar collapse, loss of alveolar structure and scarring. Female *P. stilesi* release eggs which soon hatch into first stage larvae. Eggs that die before hatching, for one reason or another, and first stage larvae which die, for one reason or another, cause much tissue reaction. Some cases show increases in phagocytic leucocytes, formation of giant cells (sometimes referred to as foreign body cells) and fibrocytic invasion. Living larvae do not appear to cause these tissue reactions to any great degree. Living larvae wander through the lung parenchyma until they reach open alveoli or very small bronchioles. They may irritate bronchiolar linings to some extent, especially so if they die and disintegrate at this time. Affected bronchioles may show thickening of mucosal linings and increased mucous exudate. The exudate and larvae move out into larger bronchioles and to bronchi where they are swept from the respiratory tract.

Presence of *P. rushi* in the bronchioles or bronchi do cause some irritations to mucosa which in turn causes increased mucous exudate. First stage larvae of *P. rushi* are picked up in mucous and swept from the respiratory tract. The productive cough of verminous pneumonia may be associated with presence of excessive amounts of mucous and first stage larvae being removed in this way.

Terminal verminous pneumonia could be associated with large numbers of lung nematodes which cause parenchymal tissue destruction and scarring, inability of the animal to cope efficiently with its environment, loss of body weight to emaciation in some cases and a racking productive cough. Death usually occurs as a slow debilitating process.

A third type of pneumonia may occur from other bacteria (*Corynebacterium* sp., *Staphylococcus* sp., *Streptococcus* sp., *Diplococcus* sp., *Nisseria* sp. or others). Certain of these may cause purulent abscesses in lung tissue. This type of pneumonia is usually chronic to sub-acute in nature. The disease usually develops slowly by destruction of alveolar and broncheolar structures. These structures are replaced by masses of polymorphic and lymphocytic leucocytes, sometimes plasma cells and giant cells. This is a typical inflammatory response. Progression of this type of pneumonia, sometimes referred to as bronchial pneumonia, causes loss of normal lung function as well as symptoms of presence of bacteria and their toxins. If death occurs, terminal symptoms are labored and shallow breathing, a productive cough and general appearance of illness.

Understanding the entire pneumonia complex in bighorn sheep requires a knowledge of these three types of pneumonia because presence of one type may not be there without evidences of the other. Pasteurellosis symptoms in the lungs of these animals is usually accompanied by signs of verminous pneumonia. Bronchial pneumonia is also usually accompanied by signs of verminous pneumonia. Certain literature references to pneumonia symptoms in bighorn sheep mortalities indicate that usually two and sometimes all three types of pneumonia were present in the animals. This is much of the reason why recorded diagnostic information on pneumonia in bighorn sheep is so confusing. Add to this the possibility that *Mycoplasma* and viral organisms may also be complicating factors and the observer or diagnostician may be doubtful of the major cause of mortality. I have seen very few cases of pneumonia in bighorn sheep which I felt were a disease syndrome with uncomplicating factors.

Examination of the pneumonia complex in bighorn sheep with the above in mind will show the complicated nature of the disease. Holding of bighorn sheep in captivity so that this complicated disease can be studied experimentally is not possible at the present time. Usually spontaneous pneumonia or pneumonia-septicemia interferes with the study. Antibiotics used to control the syndrome alter the animal so that it loses its value as an experimental animal. We need a laboratory animal with a physiological similarity to bighorn sheep in order to solve problems. Attempts to infect domestic sheep with the *Protostrongylus* species have failed (Post 1958, Post and Winter 1957). Therefore, this animal cannot be used as a direct corollary to the bighorn sheep to measure the contribution of lung nematodes to the pneumonia complex. Development of the unique syndrome of pasteurellosis in domestic sheep is difficult because the same behavioral and psychological stresses cannot be placed on a domesticated sheep as would occur to a wild or semi-wild bighorn sheep. Our greatest need, then, is to find a method of holding relatively normal bighorn sheep in captivity. Only then will we be able to give careful and controlled attention to the diseases that plague these animals, to normal biochemistry and to all the biological, physical and behavioral factors which make this animal unique to its environmental niche on our planet.

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DISCUSSION

QUESTION BY C. E. WILLIAMSON, USFS, COLORADO: With herd removal of bighorn can the lungworm life cycle be interrupted successfully so that a clean herd can be restored to that area?

REPLY BY POST: There have been several tests to try to remove the lungworm from bighorn sheep. One of our speakers this afternoon will mention Tramisol but we still haven't found a good drug to completely remove the lungworm from bighorn sheep. This is a good objective. When we do transplanting operations we must have something so we can put a clean herd back into a historic range.

QUESTION BY DICK PILLMORE, BSF & W, COLORADO: I agree with most of what you said, that it is a pneumonia complex, but in the same herd you can have a whole spectrum from the acute to the chronic situations showing up. I think George can remember the animals that Glen Eyrie had in Colorado Springs that had acute infections where the animals were still fat with a lot of edema in the lungs. Others had great abcesses and some, particularly lambs, had very heavy lungworm infections. We really had the whole spectrum.

REPLY BY POST: That means it is a pneumonia complex. When you get all three of them you should not call it just a lungworm-pneumonia complex, should you? You should call it a pneumonia complex.

DISCUSSION FOLLOWING PANEL

COMMENT BY PARRY LARSON, G & F, NEW MEXICO: In regard to base levels in phosphorous, a good many western states are, from a livestock standpoint, in acknowledged phosphorous-deficient zones. Did any of you who are doing work on this get base levels for phosphorous? Do we know what the normal status is in bighorn? Is it related to phosphorous-calcium ratios as they normally establish in domestic livestock? Is this kind of work being done or can it be done?

REPLY BY GEORGE POST, CSU: There has been a little done in the past here in Colorado. Robert Streeter, a Ph.D. candidate about two years ago, worked on the Buffalo Peaks herd. He did calcium-phosphorous ratios on plants that he collected in bighorn sheep ranges and he tried to correlate these with demography to some extent. But again, he didn't have anything on requirements of the sheep itself.

REPLY BY LARSON: I was interested because we were working three or four years ago on pronghorn and were taking some spring blood samples. We were trying to get vitamin A, carotin, and calcium:phosphorous ratios. We sent them to CSU and we got levels which were extremely high compared with normal levels of sheep or livestock. This seems like a terrific opportunity for the talents of the people we have here. It is something that can probably be evaluated from field samples and we could know something about seasons or, any time we wanted to get samples, to see if things like vitamin A levels or calcium-phosphorous levels are probable deficiencies.

REPLY BY POST: Of course vitamin A is very fragile. It would be very difficult for you in New Mexico to take samples and send them here for analysis. Calcium and phosphorus, yes, field samples can be sent in for data.

We especially need this on normal animals. Our big problem is that the only time we get our hands on an animal is when it is sick. Also, if we put a fairly normal animal under confinement he also becomes sick. We use antibiotics on him and then he is no longer a normal animal. If we could get normal, wild sheep samples, this would be one way of building up knowledge. If we use a Cap-chur gun on an animal it takes him five or six minutes to go down. Is he normal? Consider some of the things that happen to an animal when he is frightened. The spleen squeezes up, putting new blood into circulation - blood that has been stagnating in the spleen. A new shot of adrenelin comes in.

Consider a trapped animal. You trap him at 4:00 in the morning or just at daylight and you don't get your hands on him for half an hour. He is not 100% normal either. This is our real problem. We don't have normal animals to work with and we don't have access to normal animals.

COMMENT BY AL FRANZMANN, UNIVERSITY OF IDAHO: I want to follow up on that. This is the whole object of the study I have been doing - to try to get some baseline values of phosphorous. In all the wild sheep, almost 100, the phosphorous level very seldom went above 4 milligrams percent which is about half of what domestic sheep would hope to have. Not only that, our calcium:phosphorous ratios were 3:1. We studied a group of 80 captive sheep which were on good nutrition. The diet was supplemented with protein and free choice minerals, not only calcium-phosphorous, but also trace minerals. We got values that we expect in domestic sheep. So we can relate to our domestic species in this case and get a pretty good idea of what we should expect on bighorn.

REPLY BY POST: These wild animals that you were using, were they exercised before you got your blood samples?

REPLY BY FRANZMANN: Yes. Most of them were in some of the higher excitability classes. It so happened that there are mineral excitability classes as well as blood urea nitrogen excitability classes. But this was not statistically significant in affecting calcium-phosphorous levels.

REPLY BY POST: This was kind of strange because when you exercise an elk, its serum phosphorous just goes down. A group of elk were being worked in a trap. I was taking blood samples at intervals so I could get an age classification and a sex classification. I took my first sample when the group was very fresh in the trap and my last sample when they had been in for an hour or so. We could just see this nose-dive in phosphorous with exercise. By the time the last one came through, he didn't have enough phosphorous to hold him on his feet. This would be a state of shock and in a state of shock like this, the phosphorous was the only thing that really showed up significantly. In the early part of the day the animals had 11 to 12 milligrams percent, but this dropped to 2 milligrams percent in the one that collapsed under this exercise stress.

REPLY BY FRANZMANN: How many individuals?

REPLY BY POST: There was a series of 12; one taken over a period of about an hour or hour and a half.

REPLY BY FRANZMANN: We did the same thing with sheep using M-99 which produces no excitement phase. Later samples were taken after handling, after being held overnight and after two weeks. We found the same levels throughout. You can only report what you find. I am sure when you reach a certain level you get this change that is effected because you are in a condition of extreme stress. These are things that we have to measure, though.

COMMENT BY DARYLL HERBERT, OF BRITISH COLUMBIA: I have been monitoring phosphorous in plants and animals - in bighorn sheep - for a year now. I monitored the cycle in the winter range plants every month from the growing season through the following growing season. I also did this in alpine range plants. I found adequate phosphorous levels according to NRC requirements for domestic cattle and sheep which I feel are probably higher than we can use for bighorn sheep. I found levels in winter range plants of 2600 to 2800 ppm. This declined throughout the year to about 500 ppm the following spring prior to growth. The subalpine and alpine plants range from about 2000 ppm in medium phenological stages of subalpine growth to over 3000 ppm until September. This appeared adequate for lactation. It was above the lactation levels for domestic sheep so I am sure it was above the lactation levels for bighorn sheep.

We monitored blood phosphorous levels throughout the winter from September through the following spring. The phosphorous at that time ranged from about 800 ppm in September down to about 500 ppm throughout the winter. This is below any winter requirements that anybody else has found, notably Watkins and Hoax (?) in New Mexico in the 1930's and 40's. We didn't find very drastic changes in the blood phosphorous. They ranged from between 4 and 7 milligrams percent which, again, is supposedly normal for domestic sheep. After the one-year period we also fed the high quality, pelleted ration which contained about 6600 ppm phosphorous. This brought the blood phosphorous level up to almost 10 milligrams percent. So this correlates well from the high level to the low level. I think that eventually I missed out on part of the year's cycle with the blood phosphorous, but I think that we can get a good correlation between the blood phosphorous and the forage phosphorous so that we can use it as a field method. I haven't found that the bighorn sheep is deficient or unable to get sufficient phosphorous from the range, at least in British Columbia.

COMMENT BY STEVE HAWKS, BLM, IDAHO: Has anything been done as far as investigating the bighorn sheep and parasite problems, especially lungworm, from an evolutionary point of view? Have they evolved in such a way as to prevent elimination of the host?

REPLY BY GEORGE POST, CSU: If you are going to have the worm, you must have the host. If you don't have an adequate host, the worm isn't going to be here either. You can search the literature on where the parasite came from. It probably came over with the early sheep that came over the Bering Strait to Alaska. Somehow it has been able to survive in the bighorn sheep during all these eons of time. It's been able to adapt and this, of course, is the indication of a successful parasite.

REPLY BY HAWKS: How about this excitement factor? It seems that this pneumonia complex problem really crops up during a stress. Maybe the parasite has developed itself not to become virulent until the stress factor reaches a certain point.

REPLY BY POST: This is what Sara McGlinchy tried to bring across. She tried to find a way to measure lung damage so that you know how much damage is suffered by sheep at 13,000 ft. What percent of the lung can be damaged without impairing the health of the individual? An animal at 5,000 ft. could probably get by on 1/3 of one lung. Human beings do this. At 13,000 ft. you have got to have more lung capacity than that. Every time you do anything to disrupt this lung capacity, whether it is lungworm or something else, this makes it incapable of surviving. In Alaska, where sheep are ranging at 2000 ft. they won't have the same problem as far as quantitative lung damage.

COMMENT BY TOM THORNE, G & F, WYOMING: I think, as George mentioned, they evolved together. I don't think we have any indication at all that lungworm is going to wipe out its host. I think it limits them and in some cases is pretty damaging, but if you consider all bighorn sheep I don't think it will ever wipe them out. I think it would be other factors much more important than lungworm that would wipe out the bighorn sheep.

Concerning stress, in Wyoming we have closely examined many sheep where we felt stress was directly involved and never have we incriminated or felt lungworms were important in a stress pneumonia. I am not trying to discredit lungworms. I feel they are important. The lungworms may help stress pneumonia to get started. The actual stress pneumonia does not require lungworms to kill sheep. It is generally a factor. *Pasteurella* seems to be most commonly involved, but who knows, there may be a virus or something else. The sheep die far too fast for a parasite. I have seen them show symptoms in the morning and die in the afternoon.

We have great difficulty in determining what is stress. Sheep on range look like the most calm animals in the world, especially some herds on winter ranges. You can walk around them and drive around them and they show very little concern. We can catch and put them in a trough and they don't look frightened at all. They look far more relaxed than any other wild animal which has been in captivity for a day or two, but I think inside, psychologically and physiologically, they are screwed up even though they don't show it. I don't think lungworms are involved in stress pneumonia.

SECTION III

RESEARCH TECHNIQUES

ESTIMATING PLANT COMPOSITION OF WILD SHEEP DIETS

by

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ABSTRACT

The composition of recognized leaf fragments from the digestive tracts of wild sheep and the fecal pellets of wild sheep may be quantified by a microscope technique. The frequency of recognized plant fragments in forage fed to domestic sheep and the frequency of recognized plant fragments in the feces indicated that digestion did not greatly change the relative frequency of plant epidermal characteristics.

INTRODUCTION

A microscope identification technique for classifying fragments of leafy material eaten by herbivores that thoroughly masticate their food was described by Baumgartner and Martin (1939) and the technique was later refined by Dusi (1949). Sparks and Malechek (1968) found a quantification scheme so that they could predict a 1:1 relationship between relative density of recognized fragments and the dry weights of foodplants in hand compounded mixtures. Recent studies have shown that by using new slide preparation techniques practically all food-plants passed through a leaf-eating herbivore could be recognized in the feces (Storr 1961, Williams 1969, Free et al. 1970). Since there is little or no digestion of the epidermis that is encased in cutin there are recognizable leaf fragments in the feces even though the mass (weight) of a fragment may have been changed during digestion.

Several papers have been recently published on the potential for estimating the botanical and dry weight composition of herbivore diets from the microscopic examination of feces (Croker 1959, Dusi 1949, Free et. al. 1970, Hegg 1961, Hercus 1960, Kiley 1966, Stewart 1967, Storr 1961, 1963, 1964, 1968, Ward 1969, Williams 1969). Casebeer and Koss (1970) found the food selectivity measured from fecal and stomach-content analyses of 4 African herbivores provided similar results when the diets were almost entirely grasses. The diets of fossil sheep and goats and diets of wild sheep from Alaska, Iran and Colorado, are being determined from a microscopic examination of feces in the Composition Analysis Laboratory at Colorado State University but no one has published on the accuracy of the tecnhique for estimating dry-weight percentages of plants in the diets of sheep.

The objective of this paper is to report on the accuracy of the fecal examination technique being used at the Composition Analysis Laboratory and to publicize the value of this technique for studying diets of wild sheep.

STRATEGIES

A premise upon which this paper is based is that the digestion and fragmentation of plant leafy material in wild sheep is identical (or nearly so) to that of domestic sheep. Several unpublished observations strongly support the idea that the leafy material of one species of plant relative to leafy material of other species of plants change weight and fragment similarly during digestion in a wide variety of large-bodied herbivores. The second premise is that there is about a one-to-one relation between the relative density of recognized fragments in the forage-fed domestic sheep and the dry weights of the plants in the forage samples. The third premise is that if there is high fidelity between the species and relative percent densities of recognized fragments of plants in paired diets and feces samples of domestic sheep, then it is practical to use fecal samples from wild sheep for estimating the percentage of dry weights of plants in their diets.

MATERIALS AND METHODS

Forage samples were collected from lightly grazed blue grama rangeland in eastern Colorado in mind-June, late July, early September and mid-December to represent spring, summer, autumn and winter types of plants in diets. Columbia wethers were fed the four forage types. The sheep feces were then collected from metabolism cages.

The forage samples and the fecal samples were ground in a Wiley mill through a 0.5 mm screen. Each sample was thoroughly mixed to develop randomness for subsampling. The grinding appears to reduce any species differences for fragmentation due to chewing and digestion so that the mean size of particles of different species of plants were similar in each sample. The material used for microscope slides was washed over a 0.1 mm screen to insure mixing and to remove the small fragments. Ten microscope slides were prepared for each sample according to procedure outlined by Sparks and Malechek (1968). The material used for making slides was not stained and was only treated with clearing (Hertwig's) and mounting (Hoyer's) mediums. The four forages and four composited samples of sheep feces were then examined for the frequency of recognizable plant fragments for estimating the relative percent density (RD) of each species of plant for each kind of sample.

A reference collection was made that included each of the 20 species of plants in the forage samples. The appropriate slides of leaf, stem, flower and seed were prepared for each species. The separate parts of each plant were placed in a Waring blender with enough hot water to at least cover the blades. After two minutes at high speed, the contents of the blender were poured into a 0.1 mm mesh screen and washed. Reference slides were made directly from this material, following the same procedure as for the forage and fecal samples, but applying more material to the slides.

Each species of plant was identified in the sample when a fragment was observed that matched the material on a reference slide.

The RD of recognized fragments of plants in each of the forage and fecal samples was estimated by observing 20 systematically located fields on each of the ten slides with a compound binocular microscope at about 100 power magnification. The occurrence of each recognized species of plant in each field was recorded. Average percent frequency was computed for all plant species present in the samples. The RD, calculated as the number of recognized fragments of a species expressed as a percentage of the total number of fragments of all species (Curtis and McIntosh 1950) was calculated for each plant species.

The forage samples averaged 86, 90, 96 and 99 percent grasses and grasslikes (8 species) for the spring, summer, autumn and winter periods, respectively. There were 12 species of forbs and shrubs in the four samples whose dry weights varied from as high as 4% to only a trace.

Indices of RD's for each species of plant fragment between seasonally paired forage and fecal samples of the sheep were calculated by Kulczynski's mathematical index of similarity (Osting 1956):

$$SI = \frac{2w}{a + b}(100), \text{ and by}$$

a standard deviation index (Watt 1968)

$$I = \sqrt{\frac{\Sigma\ (d)^2}{n - 1}} \quad .$$

In Kulczyski's index, w = the least RD of a species of plant in the paired forage-feces comparisions and a + b equals the % RD in the forage plus the % RD in the feces. This index would equal 100% if the mean RD values of plant fragments in forage and feces were identical.

A low I (standard deviation index) value between paired samples can be used to indicate a tendency for the RD compositions to be similar. "I" is calculated by the sum of the squared differences in RD of each plant species compared in the pair of samples. Imagine that we superimpose, on the forage and feces samples within which fragments of plants are distributed, a grid of RD values for recognized plant fragments. The grid will contain large RD values or small RD values, whichever value is obtained from the microscope technique. The RD value of a plant in each kind of sample is calculated, and the

$$\frac{\Sigma\ (\text{RD's in forage} - \text{RD in feces})^2}{n - 1}$$

is obtained as a sum of the differences of RD's of plant species between samples being compared. The denominator, n, is the number of plant species on which the mean RD is based. Thus I is the standard deviation of RD of plant fragments about the mean RD difference and if I = 0 then RD characteristics of the samples are identical.

RESULTS AND DISCUSSION

The indices of similarity (SI) and standard deviation (I) both indicated that the RD's of fragments of species of plants in the food and feces of the sheep was very similar.

Table 1 - The indices of similarity and indices of standard deviations for recognized fragments of plants between the food and feces of domestic sheep during feeding tests in the laboratory.

Season	Index of Similarity	Index of Standard Deviation
spring	91%	3%
summer	89%	3%
autumn	90%	2%
winter	92%	2%
Overall mean	91%	2.5%

There were small differences in the estimated percent dry weight of the species of grasses found in the forage samples and the % RD's in fecal samples obtained from the sheep that had consumed the forage. The similarity of the % RD's in the sample pairs for the grasses is within the technique errors that might occur. Forbs and annual plants made up only a small part of the forage during the four seasons. The epidermal fragments of forbs were not found in the feces as readily as were the grass fragments. Additional work done since this research was completed suggests that if these fecal samples had been soaked in hot water before the microscope slides were made the cuticular fragments of these fragile plants would have been more easily recognized in the slides made from the sheep feces.

It is concluded that foodplants making up more than 5% of the diets of wild sheep could be satisfactorily identified and quantified by the microscope examination of 200 fields of a composite sample of feces from any season of the year. The variance between % dry weight of ingested plants and the % RD of recognized fragments in the feces is within the practical needs for research and management of wild sheep herds.

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DISCUSSION

QUESTION BY PARRY LARSON, NEW MEXICO, G & F: You determine that this method is accurate by feeding a known ration and then seeing if you could sample fecal pellets and obtain the diet in the ration. How many vegetative species were in the known diet?

REPLY BY HANSEN: About 15 to 20 species were in the diet and probably six of them were making up 95% of the diet. We fed this ration to domestic sheep, then collected the feces of the sheep and examined the feces by the microscope technique. This is one of the schemes we have used to determine how good the technique is.

Ecologists usually figure that when an index of similarity is 85 or above, your two samples are very much alike. We got values that averaged about 90 or 91 in similarity so we are confident that this is an excellent technique.

REPLY BY LARSON: It appears so. I wondered whether this is a sample with only 5 or so diet items in it, but if you have 15 or 20 species, this could be quite similar to an actual range diet.

REPLY BY HANSEN: This was an actual range diet because the material that we fed to the sheep was collected from cattle that were esophageal fistulated. The material that the cattle chewed off and dropped into a bag through their esophageal fistula is the material that we fed to these sheep.

QUESTION BY BEN ALBRICKSON, USFS, NEVADA: Dr. Hansen, could you obtain samples from the field from bedding grounds of sheep and accurately determine their diet?

REPLY BY HANSEN: Oh, yes.

REPLY BY ALBRICKSON: How old could the material be that you used?

REPLY BY HANSEN: We've examined the fecal pellets from fossil bighorn sheep which were 15,000 to 30,000 years old. We have also examined the fecal pellets of some fossil mountain goats from the Stanton Cave in Arizona. These are fecal pellets that have been preserved because they have been kept dry. We come up with some weird determinations, but it worked.

One of the problems was that we didn't have reference material from that particular age. We called one epidermal fragment a species of plant that shouldn't be in this country. The plant supposedly wasn't introduced here until 1870. We think it was just a similar plant. If we had adequate reference material from that area, we could probably know what it was.

QUESTION FROM WAYNE SANDFORT, C & F, COLORADO: Dick, I might ask you a question as relates to time on analysis. Provided basic reference material, how many samples from all the states and provinces represented here today could you analyze?

REPLY BY HANSEN: The big problem is having adequate reference material so that you don't make mistakes on what you observe under the microscope. An adequate reference collection of plants from the given area where you are going to study the diet is absolutely necessary. On the research and studies we have done in the past, we collect all the reference plants we can and we make slides of them. Then we go to the laboratory with the diets of these leaf-eating herbivores and we start trying to identify what was in the diet. You always find species of plants that we didn't collect. This might be because the life cycle of the plant only lasted for two or three weeks and we weren't in the field when it was obvious. Frequently we will find mosses, lichens or liverworts which we don't usually associate with the diet. These are interesting, but they probably don't make up too much of the diet of the large herbivores. We find just about everything they eat.

QUESTION BY GENE DECKER, CSU: Dick, concerning your food habits studies of the bighorn herd that you are going to be working on, are you going to work with fecal samples?

REPLY BY HANSEN: Yes.

REPLY BY DECKER: Over what period are you going to gather these samples, how many are you going to gather, and are you going to try to isolate the fecal samples per individual or per herd or per area? What are the mechanics of your approach?

REPLY BY HANSEN: Jeff Todd, who is a graduate student with the Cooperative Wildlife Research Unit, will actually collect the samples. It's a difficult job to convince experienced biologists that you don't need to study each fecal pellet or each fecal group to have an estimate of the diet of a herd of sheep. So what Jeff and I are going to do is take one fecal pellet from each group and put them together. They we run our microscopic analysis on the composited sample. We think this represents the diet of the bighorn sheep more closely than if we had individual sheep records. We know for a fact that one day an animal is not going to be eating the same thing he eats on the next day. If you are worried about that, you get into statistical hang-ups on what your data means.

Jeff tries to collect fecal samples in such a systematic random manner that his collection actually represents the fecal pellets of the herd of sheep. He is so conscious about this work that he gives the technicians one pellet from each pellet group and he keeps each of the pellet groups carefully separated and documented so that every one is available if there is some reason that we should have to go back and look at them individually. This can be done but it might make the workload so great that we might not get on with the job and get the work done that really needs to be done.

REPLY BY DECKER: Are you taking samples from fresh pellet groups daily, weekly or monthly?

REPLY BY HANSEN: Jeff has determined that collections at six very critical phenological stages in the year will probably represent the bighorn sheep diet the best. So over approximately a four day to a week long period he observes the sheep eating and when he sees a sheep defecate he runs over and grabs it. Maybe not immediately, but he marks it on a map so he knows which groups are fresh and which groups aren't. He collects 50 fecal pellet groups per collection period.

It's very important to get pellets that come from the bighorn sheep. There are deer feeding with the sheep and it appears almost impossible to tell the pellets of deer and bighorn sheep apart, with 100% accuracy or even 80% accuracy.

If you went into the breeding grounds of bighorn sheep to collect your pellets for comparing its diet with what is available in the area where it has been feeding, you might be just as misled as if you did the same thing in an elk study because you have to make sure that the diet you compare is being compared with the feeding area, not the bedding area, and not the defecation area. You must put these kinds of constraints into your experimental design so that the diet is actually representative of what you want to have it represent.

QUESTION BY GENE DECKER, CSU: How long does it take to analyze this material?

REPLY BY HANSEN: For example, from a place like the shortgrass prairie where my technicians are very familiar with the plant species that occur there and have examined diets and plant mixtures and even litter mixtures, I think they can go through about 50 complex samples in a week's time or less. If you run into some unknowns, it takes longer.

However, if you go into a new area where you have to learn the reference material and run down the unknowns, you might spend two or three weeks or a month learning the reference material before you can even begin. Generally, the technicians spend a day or two reviewing the reference slides before they actually read the diet slides. This constant relearning and memorizing has to be done before they can do a precise and accurate job.

QUESTION BY JERRY LIGHT, USFS, CALIFORNIA: What would you think about sending your pellet groups? This is such a big job and we haven't got much time to do it ourselves and to train ourselves.

REPLY BY HANSEN: This would be all right if we had some way to pay the technicians. Right now, we are analyzing samples from all over the grassland areas on our grassland biome study. We sometimes steal a little bit of time to look into some of these real interesting things like fossil mountain goats and fossil bighorn sheep but we are overloaded with requests for this kind of help.

AN INEXPENSIVE METHOD OF MARKING LARGE NUMBERS OF DALL SHEEP FOR MOVEMENT STUDIES

by

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ABSTRACT

A device for spraying Dall sheep with colored dyes from an aircraft has been developed to assist researchers in obtaining information about the movements of the sheep. Inadequate movement data have always been a major obstacle to population dynamics studies of mountain sheep in rugged wilderness areas. Now large numbers of Dall sheep can be safely and economically marked with brilliant dyes anywhere in their range. During tests in 1970 in the Mackenzie Mountains, Northwest Territories, 111 Dall sheep were marked with dyes dropped from a Super Cub aircraft during 13 sorties. Each sheep was marked at a cost of about $5.00. The device employed to deliver the dyes was a standard Sorenson crop spraying tank with a modified quick-release valve. When the aircraft was used on a short, rough airstrip, the tank carried up to 45 Imperial gallons of a clothing dye-water-isopropyl alcohol mixture. The dye was released about 10 feet above bunched sheep at 75 mph indicated air speed. The sheep were marked in September, and some were found again still well colored in November, February and March.

THE PROBLEM

A problem common to most of us who have studied mountain sheep in wilderness areas is that of marking the sheep to document their seasonal movements. That information is a basic ingredient of successful studies of sheep demography.

The well known techniques of drugging and trapping sheep so that they can be marked have proven to be too slow, inflexible, and expensive in the vast, rugged Mackenzie Mountains wilderness where I work. We tried immobilizing Dall sheep with a syringe-firing weapon from blinds at mineral licks. That operation tied down two men at each mineral lick for lengthy periods of frustrating inactivity. With the low sheep density in that area and failures inherent to that technique, costs averaged about $70 per sheep.

We designed a portable trap to capture Dall sheep at mineral licks, but it was also expensive because the traps had to be checked daily by boat. That method also involved two men. During the past two summers, we caught an average of one sheep each day at the cost of about $60 per sheep. I preferred trapping to drugging because there were no known sheep fatalities and the men could engage in other projects since the traps were triggered by the sheep themselves.

Both methods of capturing sheep were inflexible since they were most effective at mineral licks. I needed marked sheep in other areas of the mountains, but unfortunately I knew of no mineral licks suitable for trapping operations in the other areas.

A PARTIAL SOLUTION

THE METHOD

We have successfully experimented with aerial spraying of dyes on Dall sheep to determine their seasonal movements. During our tests in September, 1970, we used two aircraft: a Cessna 180 and a Piper Super Cub. The faster Cessna was used to spot groups of sheep in gently rolling alpine tundra, and then it returned to our base camp. While the dye was being pumped into the Sorenson tank on his aircraft, the Super Cub pilot was given 1:250,000 scale maps showing the locations of the sheep. Both planes then headed for the sheep, the Cub pilot to apply the dye and the Cessna crew to watch and photograph the action.

Once a group of sheep was located, the Super Cub pilot made a low pass (about 100 feet above the ground) over the sheep to cause them to run in a tight group. He would then circle for his second pass. This time he would approach the sheep at about 75 mph (indicated air speed) with the engine relatively quiet at low rpm. When he was just behind the last sheep and about 10 or 15 feet above them, he would release the dye. The sheep usually kept running in a straight line and would not scatter until the plane passed beyond them. The pilot would "follow through" on his pass and not turn until he was well beyond the sheep.

The pilot of the Cub and the crew of the Cessna would then inspect, photograph, and count the marked sheep. Their location was plotted on a 1:250,000 scale topographic map.

THE MATERIALS

The Tank

In 1969 the late Stan Burrell, a skilled mountain pilot, Vern Rehbein, an aircraft engineer, and I designed and tested a valve and quick release mechanism that was installed in a 75 (Imperial) gallon Sorenson crop spraying tank normally used on a Piper Super Cub aircraft (Fig. 1). The valve was a 12-inch diameter hole cut into the bottom of the tank around which a 20-inch section of 12-inch diameter tire inner tube was glued and bolted. To close the valve, the tube was folded forward under a steel strap just in front of the hole (Fig. 2). The strap was connected to a tension buckle, clamped tight manually (Fig. 3), and released by the pilot with a Bowden cable. The cap to the standard filler tube was left off to supplement the air vent tube during the sudden release of marking fluid (Fig. 4).

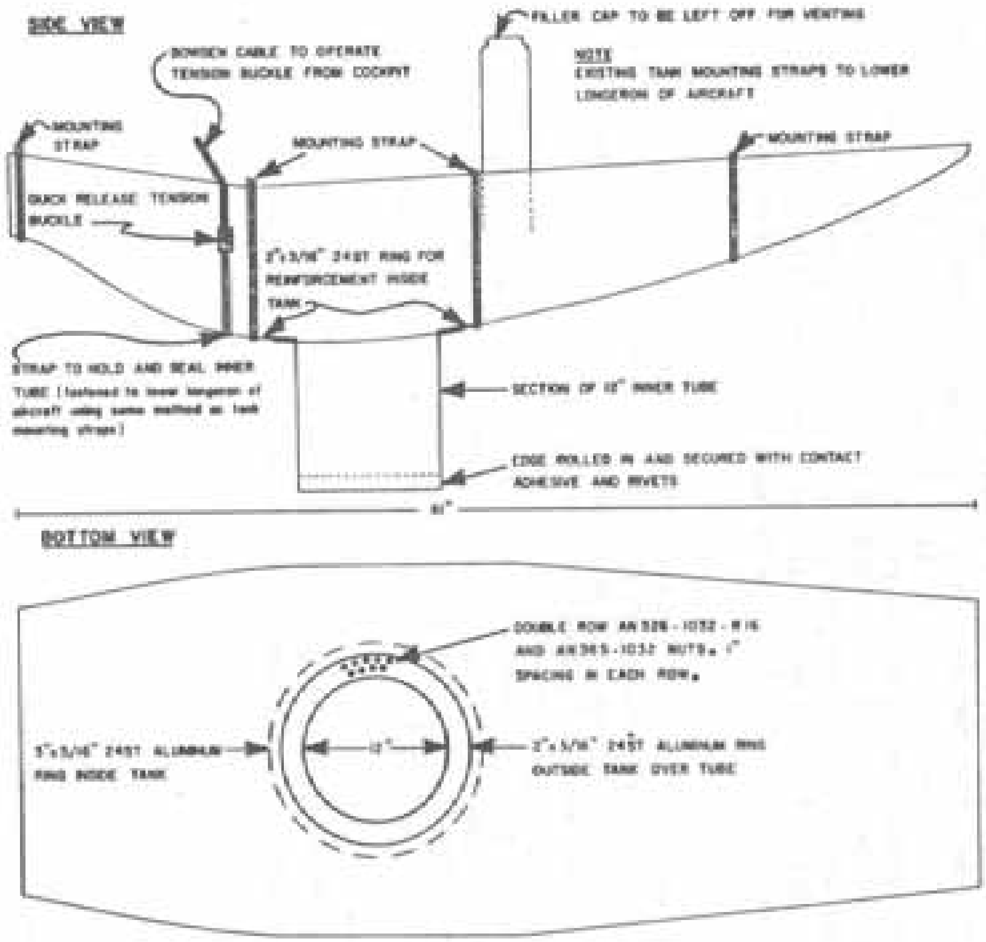

Figure 1 — Ninety gallon(U.S.) Sorenson tank for Piper PA-18-150 aircraft, modified for spraying dye on Dall sheep in the Mackenzie Mountains, Northwest Territories.

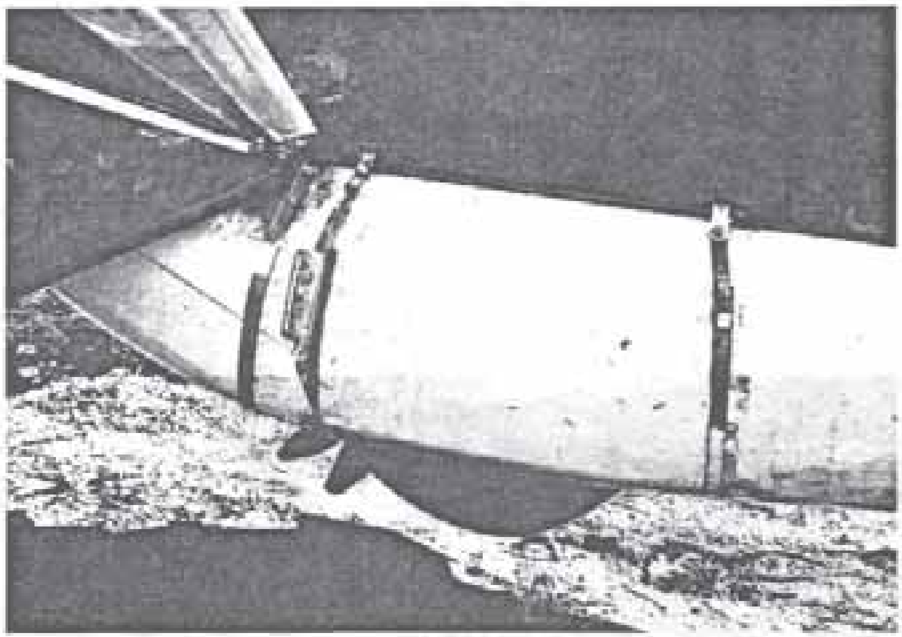

Fig. 2. View of left side of modified Sorenson tank mounted on a Piper Super Cub. The inner tube valve can be seen bulging with the weight of the dye solution. The Bowden cable leads forward from the quick-release buckle on the strap clamping the valve shut.

Fig. 3. View of Sorenson tank mounted on Super Cub showing the Bowden cable leading forward into engine cowling. The air vent tube from the tank can be seen leading up to window.

Figure 4. View of the left side of the Sorenson tank showing the filler tube. The cap to the filler tube has been left off to supplement the air vent tube.

The Plane

The Sorenson tank was held to a Piper Super Cub crop-spraying aircraft by steel straps clamped to the plane's lower longerons. Other aircraft could be used for marking sheep, but the Super Cub was best because it was the only plane rated for agricultural work that could be used on the short, rough airstrips we constructed in the mountains. The Cub lifted up to 40 (Imperial) gallons of fluid in the tank from a 1100 foot-long airfield at 3500 feet elevation.

The Super Cub could also slow down safely to 60 mph (indicated air speed) or less during a straight approach to a group of sheep to be marked. Generally, the Super Cub is an excellent aircraft for low altitude mountain flying (Simmons and Robertson 1970).

The Marker

For aerial marking by the technique described above, a non-toxic solution was needed that would not injure the sheep but would penetrate the dense pelage to the skin and remain easily visible for long periods. Non-toxic clothing dye solutions had been used successfully on desert bighorn sheep (Hansen 1964, Simmons and Phillips 1966), so I decided to try the same markers on Dall sheep.

The two dyes I have used are made by Cyanamid of Canada Ltd. (635 Dorchester Blvd. West, Montreal 101, Quebec): Calcocid Blue AX Double and Calcocid Scarlet 2 R.I.L. (The same dyes can be purchased in the U.S.A. from the Dyes Department, American Cyanamid Company, Bound Brook, New Jersey). Of the two dyes, the red seemed best for marking Dall sheep since it withstood fading better than the blue. Initially, however, the blue was more brilliant a color than the red. The powdered dyes were mixed according to the following ratios:

Scarlet 2 R.I.L.: 8 oz. powder/gal. liquid
Blue AX Double: 13 oz. powder/gal. liquid

The powders were stirred into a warm solution of 50% water and 50% isopropyl alcohol. The solution was heated so that the dye powders would dissolve more readily (Fig. 5). The alcohol was used primarily to permit the solution to penetrate the oily pelts of the sheep, but it also kept the liquid in the valve tube and in the tank from freezing.

The Results

Dall sheep can be marked from an aircraft in the Mackenzie Mountains in a safe, flexible, economical manner. They can be marked from the air in large numbers in a short period of time. The marks will last until the following molt, enabling investigators to plot the movements of the sheep for periods up to ten months, depending on how long the marks resist weathering. The white coats of the sheep, the gently rolling alpine tundra the sheep inhabit, and their habit of bunching defensively when approached by a fixed wing aircraft are factors that spell success for such a technique.

In 13 sorties, 111 Dall sheep were well marked with dye over 25% to 90% of their bodies. Usually over 50% and sometimes 100% of the sheep in each group sprayed were well marked. The group sizes ranged from 5 to 20 sheep. During that operation, each sheep was marked at an average cost of $5.00.

Red-dyed sheep were seen from aircraft in October, November, February, and March of 1970 and 1971. Blue-dyed sheep were seen from an aircraft in November, 1970, but by March, 1971, the blue dye was not visible from the air. Several sheep that had been dyed blue were collected in March. Their horns and hair bases were still blue, but the colors could only be seen within a few feet of the sheep.

DISCUSSION

ADVANTAGES

The short amount of time needed to mark Dall sheep is a major advantage of this technique. Under ideal conditions, over 100 sheep could be marked in three days.

The cost of $5.00 per sheep is inexpensive when compared with the cost of marking sheep in wilderness areas by other methods. This cost may be reduced in areas of greater accessibility where aircraft charter fees and the costs of transporting fuel, dyes, and alcohol are less.

Initially, both dyes showed up very well on the white coats of the Dall. By using a different color in each of several small, widely spaced areas, an observer can follow group composition changes and long-distance movements of the sheep. By using photographs of the marked animals, the observer can follow individual sheep marked with distinctive patterns of dye.

The three pilots I employed during tests of the dye spraying technique last year considered the required maneuvering of the dye-loaded Cub to be safe and well within pilot and aircraft capabilities. The experienced crop dusting pilot who flew the Super Cub enjoyed the work and found it far less hazardous than his normal duties. Approaches to the sheep and exit patterns involved no sharp turns or steep angles of pitch, and there was no violent reaction by the plane to the release of the dye.

Compared with the stresses placed on drugged and trapped sheep, the stress on the sheep caused by aerial dye spraying may be minimal. The entire operation from the first pass to the release of the dye was usually over in less than five minutes. The terrain was not precipitous, so the sheep did not injure themselves while running. Once the aircraft climbed to an altitude of about 500 feet above ground level, the sheep stopped running and often stood still or milled around. An indication that the aircraft did not abnormally frighten the sheep was that they did not change their normal reaction patterns to subsequent overflights.

DISADVANTAGES

Through a haze of personal prejudice, there appears to be one major weakness in this system, and that is the ephemeral nature of the dye itself. Tests on the dyes made in southwestern Arizona in the summer showed that the colors faded badly in the brilliant sunlight and were not readily discernible three months after the dyes were applied. Due to the short day length in the Mackenzie Mountains after the September application of dyes, the colors remained visible much longer. That may not be the case with dyes applied in June because of the long daylight hours.

In any case, the marks are entirely lost by the time of the next molt. For this reason, our dye-spraying efforts will continue to be supplemented by a program of trapping and permanently marking Dall sheep.

The method described above is restricted in flexibility only by terrain type. Sheep should not be marked in rugged terrain because of the increased potential for injury to the animals and to the pilot. However, gently rolling alpine tundra habitat abounds in the Mackenzie Mountains and is preferred by sheep in nearly all areas.

OTHER USES OF THE AERIAL DYEING TECHNIQUE

In June or July, 1971, we will mark Dall sheep in a small sample area and then wait a week or more for the groups of sheep to intermingle and change composition. Then we will return and count marked and unmarked animals from the air in the same area. By applying a modified Lincoln Index formula (Bailey 1951), we hope to estimate the population in that area as well as the confidence limits of our estimate.

There may be other animals that can be usefully marked with dyes from the air. We have discussed with the Game Management Division of the Northwest Territories Government the possibility of marking the light-colored Peary caribou in the arctic islands so that their movement patterns may be studied. Quick drying dyes sprayed from an aircraft may also be used to mark polar bear. The technique is applicable to any light-colored large mammal on which non-toxic dyes will show up, especially animals like caribou and Dall sheep that can be sprayed as a group, in situations where economy and flexibility are desired.

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DISCUSSION

QUESTION BY BILL CRUMP, G & F WYOMING: I have a comment relative to this technique. We have used it to mark antelope for migration and distribution studies in Wyoming and have found it very useful. It has become a common technique in areas where we have to determine definite movements. We have been using the nyanzol dye and I was wondering if you might have been using the same.

REPLY BY SIMMONS: No. I was under the impression that the nyanzol dye would irritate the membranes around the eyes and nose. Since we are drenching the animals, this was something we wanted to avoid.

REPLY BY CRUMP: We had used it with some experimental animals at the Sybille Research Unit before we went into application from air. We did not discover any irritation. We have used this method with antelope and found it a very interesting and useful method.

REPLY BY SIMMONS: You spray this with boom sprayers, don't you?

REPLY BY CRUMP: We have modified these since the original report came out. We now use a massive dose drench.

REPLY BY SIMMONS: What kind of tank do you use?

REPLY BY CRUMP: A tank very similar to yours with a very large apparature. We release the whole load at one time.

REPLY BY SIMMONS: This is a black dye?

REPLY BY CRUMP: We have used black mostly.

REPLY BY SIMMONS: How long does it last?

REPLY BY CRUMP: We have marked them in the fall. It lasts until the shedding begins in the spring. There is difficulty in telling black marks from hair that is about to be shed and is dark in appearance.

REPLY BY SIMMONS: I have heard that they have used this technique in Saskatchewan but I know that they were using the crop spraying booms to spread a fine mist.

REPLY BY CRUMP: We did this first but we went to large hole in the bottom of the tank to release the dye in large quantities.

QUESTION BY GENE DECKER, CSU: What other colors did you use, Bill?

REPLY BY CRUMP: We have tried reds and blues. Black seems to work best because of the light color of the antelope itself. There is a need for improvement in the materials for a more residual effect.

QUESTION BY JOE TRLICA, CSU: When you dump the entire load over the 50 yard area, what is the effect of the dye and the alcohol mix on the vegetation? Are you actually getting a killing of this strip?

REPLY BY SIMMONS: I don't know. I haven't considered whether the isopropyl in the dye mixture might harm plants. We're usually dumping it on the lichen, moss association and on a lot of bare soil. Does anyone here have any ideas on this?

REPLY BY TRLICA: I have an idea that the alcohol mix might be killing vegetation even though the dye itself might not be harmful. You might want to check some of these strips.

QUESTION BY AL WHITAKER, G & F COLORADO: Has any interaction been noted between marked and unmarked animals or lack of such interaction?

REPLY BY SIMMONS: We have watched marked animals mixing in with unmarked animals but I haven't been able to detect any reaction. This is the same type of deal that we get with permanently marked animals like the critter you saw with ear streamers and collars and so on. After the initial shock of seeing this monster coming at them with flopping ear tags, etc., there is very little reaction. They are well accepted it seems.

REPLY BY WHITAKER: Any reaction noticed at the breeding time?

REPLY BY SIMMONS: I just started this last year so I didn't really comment on that with any assurance. Intuitively, I feel it will not have any effect. Chuck, did you notice any effect on dyed sheep on the desert game range when we dyed sheep? (Answer not recorded). I didn't notice any effect and we watched the sheep during the breeding season. Unfortunately, during the breading season in the northwest territories it is dark as the ace of spades, so we do not get too many good observations.

REPLY BY WHITAKER: Have you considered marking the horns of big rams with a dye such as this?

REPLY BY SIMMONS: Yes, but we have gotten a lot of static from the outfitters. I would like very much to mark adult rams, to paint their horns and everything else, but we have to avoid this. I think that in some areas I am going to mark adult rams with dye and of course this would drench their horns too. The color seems to be absorbed by the horn, at least with the dyes I am using. It really doesn't stand out too well, but of course the paint would.

I had another comment on reaction. You may have noticed in the pictures that we had sheep bedded down in the background while we were marking sheep in the foreground. This young ewe was turned loose while the others were bedded down. She ran right towards them. The others looked at her and got up, then turned and ran up the hill and left this one in the dust. Later we saw this same individual feeding peacefully with unmarked animals.

QUESTION BY WAYNE SANDFORT, G & F COLORADO: From a Rocky Mountain bighorn and desert bighorn point of view, what dyes or marking materials would you recommend?

REPLY BY SIMMONS: As I said, Chuck used different dyes than I used. I am using clothing dyes from American Cyanamid. I have listed the dyes and the addresses in the paper. It depends on the application method. We were using a spray at a waterhole. I am not sure that you would even want to use this method on desert bighorns since there is such a little area to mark and your country is so rugged. Also, your Rocky Mountain bighorn habitat is so rugged that I think you would end up losing the pilot, the plane and the sheep.

THE USE OF M99 ETORPHINE AND ACETYLPROMAZINE IN THE IMMOBILIZATION AND CAPTURE OF FREE RANGING ROCKY MOUNTAIN BIGHORN SHEEP[1]

by

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Wyoming Game and Fish Commission

ABSTRACT

Seventeen of 22 attempts to capture free ranging Rocky Mountain bighorn sheep were successful using M99 etorphine in combination with acetylpromazine administered via projectile syringes. Four attempts were unsuccessful because of incomplete drug injections. There was one mortality which was caused by a drug underdose followed by excess violent struggling and shock.

INTRODUCTION

The immobilization of 22 free ranging Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) using M99 etorphine and acetylpromozine was attempted from April, 1969 through December, 1970 on the Wyoming Game and Fish Commission Whiskey Basin Game Winter Range near Dubois, Wyoming. The objectives of the immobilization attempts were to evaluate the effects of the immobilizing drugs and antagonists, to capture bighorn sheep for research purposes and transplantation and to provide physiological data (Franzman and Thorne 1970).

M99 etorphine is a thebaine derivative which is chemically related to morphine (Amer. Cyan. 1966), but has narcotizing and analgesic activities many times those of morphine (Harthorn 1966). Its action is on the central nervous system. The drug has been used effectively on a wide variety of wild mammals (Wallach 1969). Acetylpromazine is a phenothiazine derivative tranquilizer which is rapidly absorbed and produces central nervous depression at a low dosage. M285 cyprenorphine and M50-50 diprenorphine are also thebaine derivatives developed as specific antagonists for M99 (Amer. Cyan. 1966).

MATERIALS AND METHODS

The immobilizing drugs were administered in combination using automatic projectile syringes and a CO_2 powered Cap-chur gun (Palmer Chemical and Equipment Company, Inc., Douglasville, Georgia). The automatic projectile syringes ranged from 3 to 5 cc in size. The sheep were darted, as nearly as possible, in the hindquarters at ranges of 15 to 30 yards. The sheep, which were on the winter range at the time of immobilization, were darted from a vehicle or by approaching

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[1] A contribution of Federal Aid in Wildlife Restoration Project, Wyoming FW-3-R.

slowly on foot. All sheep were standing when darted and none were pursued prior to darting. Barbed syringes were used on only two sheep; collared syringes were used in all other cases. Immobilizing drug concentrations were 1 mg/cc and 2 mg/cc for M99 and 10 mg/cc for acetylpromazine. The antagonists were administered in concentrations of 2 mg/cc for M285 and 4 mg/cc for M50-50 using a hypodermic syringe.

Immediately following capture each sheep was given an intramuscular injection of 750,000 units benzathine penicillin G, 750,000 units procaine penicillin G and 1,250 mg dihydrostreptomycin and a combined parainfluenza-3 vaccine and *Pasteurella* bacterin. An eye ointment was placed over the cornea for protection of the eye. The sheep were placed in a dark, enclosed crate covering a pickup bed as soon as they began to regain coordination and strength following administration of the antagonist.

RESULTS AND DISCUSSION

Of the 22 immobilization attempts, 17 (77%) were successful and resulted in the capture of sheep. Four of the five attempts which were unsuccessful were felt to be due to incomplete drug injection and the fifth unsuccessful attempt was due to a mortality. The drug dosages and sheep reactions in the 17 successful attempts are given in Table 1.

The sheep did not seem to be markedly frightened when hit by the projectile syringe, except when barbed syringes were used. The sheep would generally run as long as the syringe remained imbedded. One ram ran approximately a quarter of a mile until a barbed syringe fell out. All other sheep ran a distance of 5 to 150 yards. They were not frightened by the report of the CO_2 rifle and did not seem to associate it or the shooter with the projectile syringe hitting them. Maximum effective range was about 30 yards, and precautions were taken to keep the CO_2 rifle from becoming too cold to fire effectively.

Most of the individuals returned to feeding shortly after they were darted, and some continued eating after they had gone down. Generally the first visible sign of drug effect was mild ataxia which took the form of an unsteady gait or uncertain stance. The first signs of reaction to the drug occurred an average of 3 minutes, with a range of 2 to 5 minutes, after injection. Ataxia generally progressed rapidly until the sheep would lie or fall down. Some went down on their knees first and then lay down. Most were able to remain in sternal recumbency. Many of the sheep continued to eat during the entire period of ataxia, and a few continued to eat even after they went down. The onset of ataxia did not seem to alarm the individuals, and other sheep in the herd payed little attention to the drugged animals. Immobilization time (given as the time from darting until the animal was in hand) ranged from 4 to 40 minutes with an average of 9.4 minutes. If the one ewe which required 40 minutes (Table 1) is not considered, the average immobilization time was 7.5 minutes. After a sheep was down it was not approached until one-half to 2 minutes elapsed. There did not seem to be any difference in reaction to the drugs between males and females.

Table 1. Sex, age, weight and drug dosages used in the capture of 17 free-ranging Rocky Mountain bighorn sheep using combined M99 and acetylpromazine.

Sex	Age	Weight (lb)	M99 Mg	M99 Mg/lb	Acetylpromazine Mg	Acetylpromazine Mg/lb	Immobilization Time (Min.)[A]	Antidote[C] M285(Mg)	Antidote[C] M50-50(Mg)	Reversal Time (Min.)
F	3	---	3.0	----	10	----	6.5	7.5	---	0.5
F	Mat.	---	2.5	----	10	----	4.5	7.5	---	1.0
F	2	---	2.5	----	10	----	4.5	7.5	---	0.5
F	4	---	3.0	----	10	----	40.0[B]	9.0	---	1.0
M	1	---	3.0	----	10	----	7.0	8.0	---	0.5
M	2	---	3.0	----	10	----	12.0	8.0	---	1.0
F	2	100	3.0	.030	8	.080	5.0	---	9.0	0.3
M	3	122	3.0	.025	8	.066	7.0	---	9.0	0.3
F	3	105	3.0	.029	7	.066	7.0	---	9.0	1.0
F	4	106	3.0	.028	7	.066	4.0	---	9.0	1.0
F	3	114	3.0	.026	10	.088	7.0	---	9.0	0.3
F	4	130	3.0	.023	10	.077	15.5	---	9.0	0.5
M	1	111	3.0	.027	10	.090	5.0	---	9.0	1.3
M	2	---	3.0	----	7	----	20.0	---	9.0	0.3
M	1	114	3.0	.026	7	.061	6.0	---	9.0	0.8
M	1	---	3.0	----	7	----	8.0	---	9.0	0.3
M	1	119	3.0	.025	7	.059	8.0	---	9.0	0.8
Average:		113	2.9	.027	8.2	.073	9.4	---	9.0	0.66

A Immobilization time given is the time required to capture the sheep after it was darted.
B This ewe had to be pursued 500 yards before she was captured.
C In all cases approximately two-thirds of the antidote dosage was administered intravenously and the remainder intramuscularly.

About one-half of the sheep did not seem to be concerned when approached and handled by their captors. The others made efforts to escape such as feeble struggling, running on the front or all four knees for a short distance, or running in one instance about 500 yards. Once captured, the sheep either did not struggle or struggled only slightly.

When immobilized, the reaction of the sheep to the drug depended upon the degree of narcosis. Respiration was generally slow and shallow. A few of the sheep displayed clonic convulsions of the neck and back muscles. Nystagmus was present in some. Excess salivation and bloating were not problems. Some of the drugged subjects displayed pronounced chewing and grinding of the cheek teeth. The grinding of the teeth, which was audible and visible from short distances, often took place before immobilization.

M285 was administered at 2-1/2 to 3 times the M99 dosage, and M50-50 was administered 3 time the M99 dose. With both antagonists 2 times the M99 dose was given intravenously and the remainder intramuscularly. The average reversal time (time required for an animal to be able to struggle or stand) was about 40 seconds with a range of .3 to 1.3 minutes. The intramuscular injection of antagonist was given to prevent any latent or prolonged effects of the M99 which might occur. The sheep remained sedated for several hours due to the effect of the tranquilizer used.

The single mortality occurred in a 2-year-old ram weighing 152 pounds. This animal was dosed with 3 mg M99 and 10 mg acetylpromazine. Ataxia was first observed in 4.5 minutes and the subject went down in 6 minutes. Immobilization was far from complete and the ram regained his feet and was pursued for an additional 10 minutes before being captured. The sheep was able to struggle violently and four personnel were required to carry it toward the pickup. While being carried to the pickup, approximately 20 minutes after capture, the sheep died. Rectal temperature was 107.4F at the time of death (normal for immobilized sheep is 101.5F). Necropsy revealed that death was due to shock, stress, and injuries suffered while struggling to regain freedom. Approximately, one fourth of the ram's lung capacity had been destroyed by lungworms (*Protostrongulus* sp.) which may have contributed to his death by reducing reserve capacity and strength.

In retrospect, it was felt that this death could have been prevented in either of two ways: once the sheep was observed to be incompletely immobilized, no further attempt should have been made to capture him; or once he was captured, additional M99 should have been administered to achieve complete immobilization and prevent struggling. The former of these two methods would probably be the most suitable.

The wide safety margin of the M99 and acetylpromazine combination and the availability of a fast acting M99 antagonist make this a very satisfactory method of capturing free ranging Rocky Mountain bighorn sheep. The induction time is reasonably rapid, and adverse side side effects are minimal. Capture with this method avoids most of the effects of stress, exhaustion, and possible injury associated with trapping. The primary disadvantages are the limited range and accuracy of the Cap-chur gun, and difficulties in keeping the darted animal in sight until immobilization occurs.

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DISCUSSION

QUESTION BY WAYNE SANDFORT, G & F, COLORADO: It is my understanding that M-99 isn't generally available for use. Is this true? How can you get it?

REPLY BY THORNE: It is not readily available. M-99 is a narcotic related to morphine. A narcotics permit is required to dispense it. You are not required to have a narcotics license to use it. The drug is still in experimental stages. The company that puts it out, American Cyanamid, is hard to work with and they are getting more difficult. I think this is because they imported their supply from England and they are running out. They are not sure there is enough money in it to produce it for wildlife work. There are problems in getting it, but if we are persistent enough they will give it to us. They charged us for the first time for the last batch. They charged, I believe, $87 for 60 milligrams. I don't consider that to be too expensive. I would rather they gave it to me in 1 milligram per cubic centimeter dose or concentration and I don't like that, so I'd rather they concentrate it a little more if they are going to charge for it. I feel this is a good enough drug and I wouldn't use any other drug on sheep.

QUESTION BY AL WOOLF, RACHELWOOD: I'll add to that. It is apparently more difficult now with the new forms. They don't really consider it a narcotic, but they put it on a Schedule 1 of the Narcotics and Dangerous Drug Act. (There is now a new bureau under the Department of Justice.) In addition, using M-99 would require that a research proposal for the use of the drug be sent to the Department of Justice and you would need a permit in your own name to be able to use it. I think that one of the drawbacks of some of the game departments in getting it would be its access.

REPLY BY THORNE: That must be relatively new because I didn't know of it, although I have a narcotics permit, I have not been using it. I have the University dispense it to me on their narcotics permit. So, I may have trouble getting it next time, but if I can get it, I certainly would use it over any other drug for sheep.

The big problem is to avoid exerting the sheep or any other animal because that will kill them. Overdose them rather than underdose them because you are much safer on an overdose. That is hard to understand for those of you who have used succinylcholine where the dose is so critical.

REPLY BY WOOLF: Over the past three years we have immobilized maybe a couple hundred animals of different species and maybe 25 or 30 of these were bighorns - some of them repeated attempts, some of them on mouflon, some on hybrids.

The only animal that we have ever killed with M-99 is one that we intentionally tried to kill. This was a white-tailed deer. I don't think you can overdose an animal with M-99. We killed with an underdose and it died in much the same way that your sheep did. Had we wanted to save the animal early in the game, we probably could have done so.

We gave it a light dose. This struggling is very characteristic of a light dose because you don't get a complete immobilization. The animal laid there and started hyperventilating, breathing rapidly and shallowly. If we had given it the antagonist to reverse it, the animal would have been fine or had we given more M-99, it would have been fine.

By the way, I give it intravenously in a case like this and it very rapidly immobilizes them thoroughly. Or you can give a tranquilizer but it would have to be given intravenously for an extremely rapid affect. In the case of this deer we did nothing. We just wanted to watch it to see what would happen. It had reached a point of excitement and hyperventilation so that it died of respiratory alkalosis (?) in about three hours. This is probably why your sheep died. Giving it something else might have done it. Probably, just letting it go wouldn't have.

REPLY BY THORNE: He was relaxed enough. I had the tranquilizer in it and I don't believe he'd have been in any trouble if we had let him go. I won't use M-99 on deer anymore. I don't feel it is a good drug for deer. It's good for elk, moose and sheep. I haven't tried it on antelope yet so I don't know on them.

QUESTION BY TONY MORRIS, GRADUATE STUDENT CSU: Have you ever used crossbows? In South Africa we need a much larger dose than you can deliver in a small projectile when working with rhinos and elephants.

We have modified the crossbow to deliver a large dart. The effective range is between 60 and 100 yards and it is very accurate. These guns just wouldn't do. We shoot them from helicopters. We use M-99 for everything except carnivores. We also include the tranquilizer in the initial dosage. When we get to the rhino or elephant we inject half the antidote. This wakes it half up and we stand the animal half up and load it into the truck.

Have you had trouble with the weight of the dosage with larger animals here?

REPLY BY THORNE: We haven't used the crossbow in Wyoming. We have one but it has a broken string and I haven't gotten around to fixing it. We used the 32 gauge shotgun that has the 22 caliber modifier. We use that on the larger animals in Wyoming. Two weeks ago, after my air rifle quit working, I killed a sheep with the 32 gauge shotgun. I shot a mature ewe with the smallest charge at about 20 yards. We hit her just perfect in the hind leg behind and perhaps a little above the knee. My assistant thought the dart had bounced out. The sheep ran off, laid down and went through the symptoms of being drugged. We caught and loaded it. The sheep was doing fine. We painted its horn and give it antibiotics. I just started giving the antidote and she started fading. I couldn't raise a vein in the neck or leg. In desperation, I put it in the lung but by then she was gone.

We opened the sheep up and she was full of blood. The dart had entered the hind leg, had penetrated clear into the mass of the hind leg. Then it turned and went behind the femur, went up and forward, passed into the abdomen just under the skin and just under the udder, went into the abdominal cavity and then penetrated into the pregnant uterus. This punched a hole about the size of my finger in the uterus and she bled to death through this hole. During pregnancy, the uterus of course, is extremely gravid.

I have decided not to use the shotgun any more on sheep and if I can't get my air rifle working, I probably won't shoot a sheep. The shotgun with the 22 blank modifier is better than the old type using the blank shotgun shell, but it is still unreliable. One will go out hard and the next one easy.

I think your crossbow could be used well in Wyoming on our larger animals such as moose. Of course you cannot use the air rifle on moose and we have a little trouble getting into range of moose, even with our shotgun.

REPLY BY MORRIS: Any bow-driven projectile does not have the shock power. A hunting arrow kills through hemorrhage not through shock power. Whatever hits the animal, even from a pretty powerful bow, hasn't got shock which will do damage.

QUESTION BY AL WHITAKER, G & F, COLORADO: Is there a possibility of using M-99 in a powdered form?

REPLY BY THORNE: The very first samples I got were in a powdered form. I think the people in Africa are lucky because, unless it has changed, they can get it in a powdered form. I wish we could work with the English company instead of the American company on this. I use the powder to mix concentrations of up to 4 milligrams per cubic centimeter and it was great. Now they dilute it. Apparently it is more expensive to produce in the powdered form. Hopefully, if enough of us who use it keep asking for it, maybe we can get it. It will preserve longer in a powdered form and you can make it up into your own concentrations.

In Africa, they will actually use the tranquilizer in some cases as the diluent. I was using a cubic centimeter promazine base for ten milligrams. I could mix a couple of milligrams of the M-99 with the tranquilizer rather than using a sterile saline or diluent fluid and come up with a total volume of only 1 cubic centimeter. This would have everything I would need to capture a sheep.

REPLY BY WHITAKER: Might this be injected in a powdered form?

REPLY BY THORNE: There are a couple of companies that are experimenting right now with possibilities of administering drugs in powdered forms. Apparently they are having fairly good luck. Again, their problem is acquiring the powdered form. One company is using a syringe. The other, a hollowed out bullet.

REPLY BY WHITAKER: Have you used succostrin on sheep at all?

REPLY BY THORNE: No, I haven't. Some people have and it can be used, but they have had a higher mortality rate than I have had. I like M-99 so much better on any animal except a deer that I think it is what we ought to use.

ANALYSIS OF WINTER HABITAT BY MULTISPECTRAL REMOTE SENSING

by

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ABSTRACT

Remote sensing will prove to be a valuable tool for mountain sheep researchers in the near future. Multispectral sensing is the process of collecting and interpreting information from electromagnetic energy detected from a scene in several discrete wavelength bands from the ultraviolet, visible, and infrared regions. This technique can be used for evaluating important characteristics of bighorn sheep habitat, specifically the winter range, since this may be the time of greatest population stress. A description of the technique of multispectral sensing is given, along with a brief explanation of a method for automatically interpreting the sensor data by computer. Automatic interpretation of multispectral data has been done over a 12 square mile area in Yellowstone National Park with an overall accuracy of 86 percent correct identification of eight different mountain terrain types (Smedes et al. 1969). The success of the Yellowstone experiment suggests using a similar approach over bighorn sheep habitat to evaluate habitat characteristics considered important for maintenance of herd populations. Although present multispectral remote sensing surveys are costly, it might be possible to obtain data through other agencies which have collected imagery over bighorn habitat areas for other purposes. Imagery might also be collected on a cost share basis by several agencies, each with a specific interest in the data and target area. Multispectral imagery will soon be collected from satellite and will be available to researchers at a much lower direct cost than data obtained from aircraft. As remote sensing data collecting systems improve, and as interpretation techniques become more advanced, higher quality data will be available at increasingly lower cost.

Remote sensing is the process by which materials on the ground are recognized and mapped from a remote location by their reflection or emission of electromagnetic energy. Methods currently being developed in the field of remote sensing promise to be a valuable asset to mountain sheep researchers needing rapid analysis of terrain and vegetation features of winter and summer habitats. The technique of multispectral sensing and computerized image analysis is briefly discussed, and a study in Yellowstone National Park using these methods is reviewed. Application of remote sensing methods to the analysis of bighorn sheep winter range is suggested, as populations may often be under great stress during the winter months.

I am indebted to Dale Hein and Eugene Decker for initial suggestions pertaining to this paper, and I wish also to express my appreciation to Lee Miller, Alex Cringan, and James A. Smith for their advice and assistance in reviewing the manuscript.

MULTISPECTRAL REMOTE SENSING TECHNIQUES

Visible light represents only a small portion of the total electromagnetic spectrum, which ranges from very short wavelength gamma rays to very long wavelength radio waves (Fig. 1). Photographic sensors are capable of utilizing only that portion of the spectrum immediately adjacent to and including the range of human vision, extending short distances into the ultraviolet and infrared wavelengths. A recent development in photographic sensors is the multiband camera which simultaneously uses several lenses, each filtered to sense electromagnetic energy only in one discreet portion of the photographable spectrum. A simultaneous multiple set of images of the same scene is the result, and differences in character of the energy reflected from objects in the scene may be utilized by comparing the objects in each of the narrow wavelength band images produced. This is much the same method used in mapping materials on the ground with color film, but is not limited to one single wide spectral interval as with color film.

A much broader portion of the electromagnetic spectrum can be utilized by other non-photographic sensors. One important such instrument, called a multispectral scanner, measures levels of incoming energy in a number of discreet segments of the electromagnetic spectrum, called spectral or wavelength bands, over the range of .3 to 15 micrometers ($10^6 \mu m$ = 1 meter). This device collects data by rotating a mirror-telescope combination which scans the scene by sweeping out strips along the ground perpendicular to the line of flight (Fig. 2). At an instant of time the mirror receives energy from a spot along its current scan line called the instantaneous-field-of-view. The incoming energy is averaged over each instantaneous-field-of-view. Current scanners produce an instantaneous-field-of-view of 1 to 3 feet in diameter at 1000 feet above terrain, and sweep out scan lines 1000 feet wide. Successive scan lines are swept out as the plane advances forward, resulting in the coverage of a continuous strip of terrain 1000 feet wide below the aircraft, flying 1000 feet above terrain. The incoming energy received by the scanning mirror and telescope at each instant is directed into a prism or into a grating where it is broken up into a continuous wavelength spectrum. Discreet portions of this spectrum, called wavelength bands, are sensed by detectors which convert the energy received into electrical currents which are then recorded as parallel tracks on magnetic tape, each channel on the tape corresponding to a wavelength band in the sensor.

A schematic diagram shows the instrument response, where each vertical bar represents the level of energy sensed in each of the wavelength bands (Fig. 3). A curve is defined by these different energy levels measured in each wavelength band, and is called a

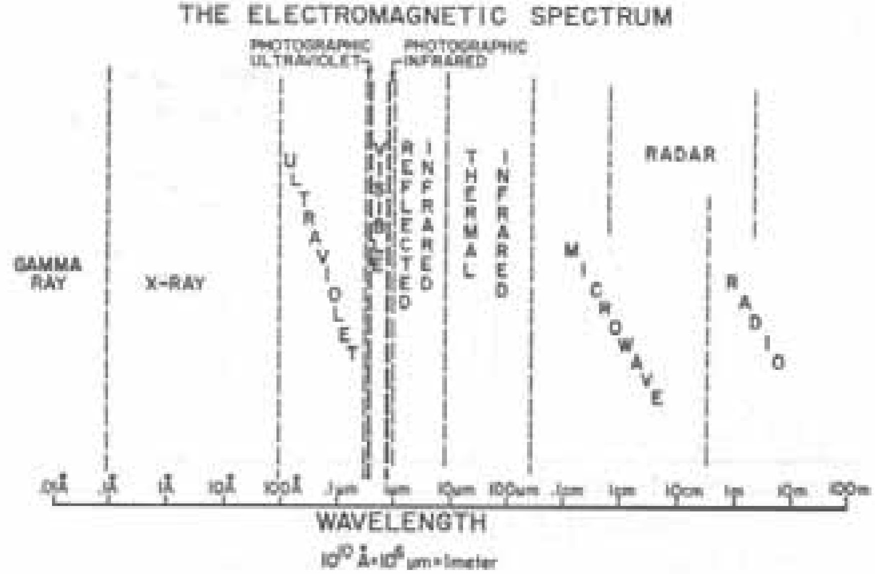

Fig. 1 ILLUSTRATION OF RELATIVE NARROWNESS OF THE VISIBLE PORTION OF THE ELECTROMAGNETIC SPECTRUM. Compare the visible band with the entire electromagnetic spectrum, from gamma rays to long wavelength radio waves. Note that wavelength is shown on a logarithmic scale.

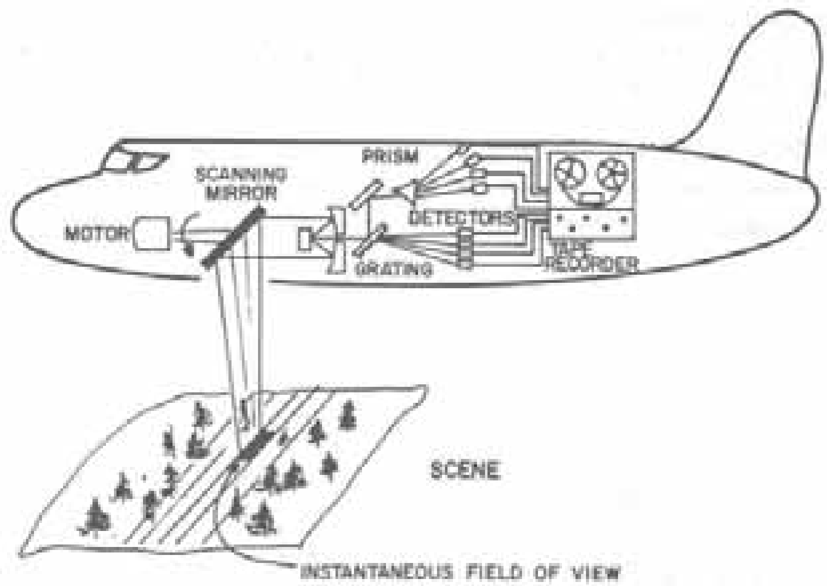

Fig. 2. SCHEMATIC DIAGRAM OF A MULTISPECTRAL SCANNER IN OPERATION. A rotating mirror and reflective telescope combination sweep out successive strips along the ground perpendicular to the line of flight, called scan lines. At any one instant on a given scan line the scanning mirror receives and averages energy from a spot in the scene called the instantaneous-field-of-view (IFOV). The energy received from each IFOV is broken down into a number of discreet wavelength bands by optical dispersing elements. The energy levels in each band are converted to electrical currents by detectors, and recorded on respective channels on magnetic tape for each successive IFOV sensed by the scanner. (Courtesy of Willow Run Laboratories, University of Michigan).

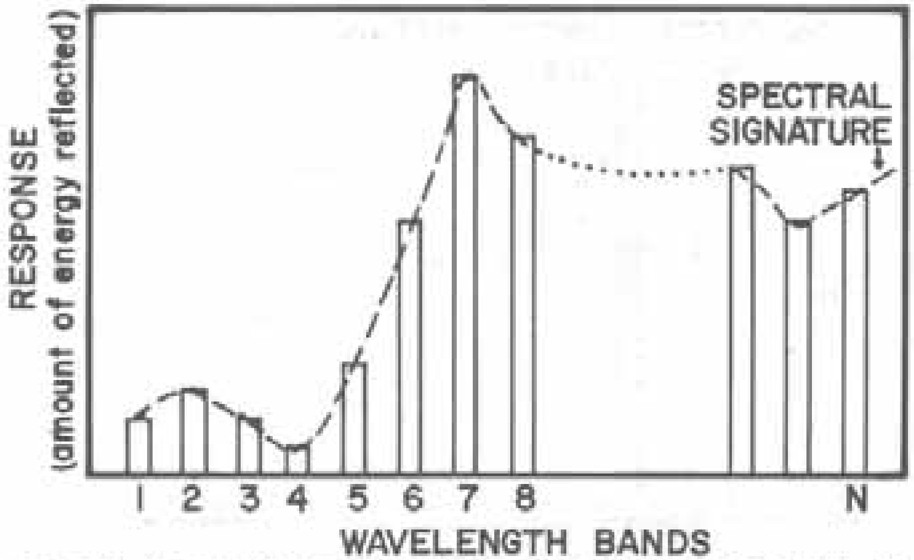

Fig. 3. GRAPHIC ILLUSTRATION OF SCANNER RESPONSE AS RECORDED ON MAGNETIC TAPE. Each vertical bar represents a wavelength band over which simultaneous data was collected. Bar height represents recorded detector output, which is directly proportional to the amount of energy received from the scene in that particular wavelength interval. The curve formed by the energy levels of all bands is the spectral signature received by the scanner for the instantaneous field-of-view currently being sensed. N = 12 channels for a multispectral scanner widely used at the present time. (Courtesy of Willow Run Laboratories, University of Michigan).

SPECTRAL SIGNATURES OF SOME GENERAL LAND COVER TYPES

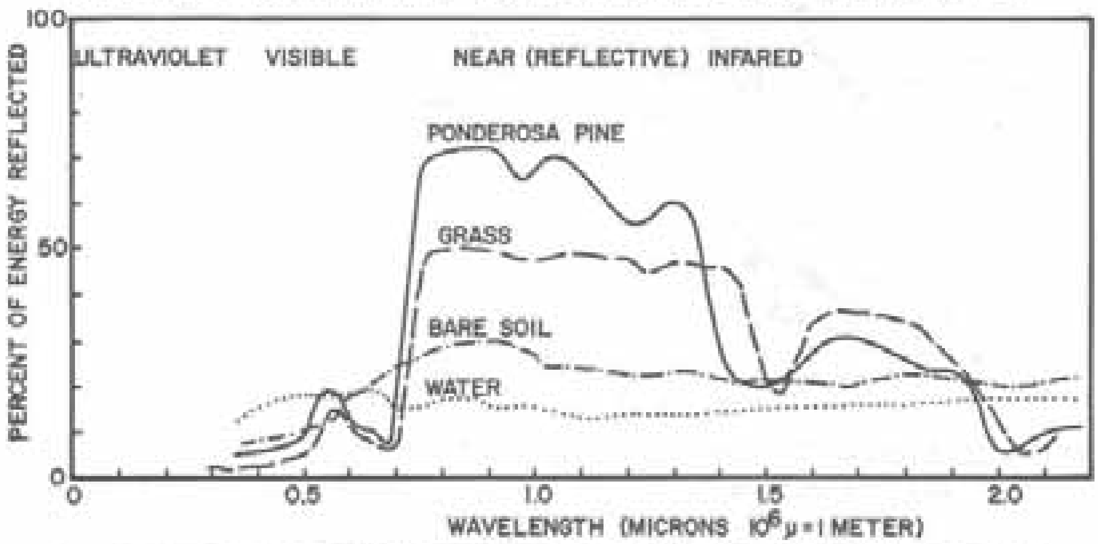

Fig. 4. SPECTRAL SIGNATURES OF SEVERAL MATERIALS COMMONLY FOUND IN WESTERN MOUNTAIN TERRAIN. Percent energy reflected, called reflectance, shown on the vertical scale is a ratio of the energy received from the scene to the energy incident upon the scene. Multispectral scanners measure only the energy reflected back from the scene, and in order to calculate reflectance the incident solar radiation must be simultaneously measured. (Courtesy of D. Earing, 1968).

wavelength or spectral signature. Every material has its own characteristic spectral signature, some being more similar or different than others (Fig. 4). The recorded levels of energy in the several wavelength bands of the multispectral scanner approximate spectral signatures. Different materials in the scene can be identified from the data after determining their spectral signatures. This is done by a computerized analysis technique known as spectrum matching in the following manner.

1. Decide what objects in the scene are to be identified, and go to the site on the ground to visually inspect and photograph typical examples of these objects and areas. No matter how sophisticated remote sensors become, there is no substitute for accurate ground truth data.

2. Collect multispectral imagery of the site at the optimal time of day and season, and also obtain aerial photographs of the area if no previous air photos are available.

3. On the air photos locate objects which are representative of those chosen to be identified in the prior ground inspection reconnaissance. Locate these same objects and areas in the multispectral scanner data and determine the scanner response at these locations (i.e. the spectral signature) for each object and area.

4. Store the spectral signatures for each of the objects in the computer.

5. Have the computer go through all the scanner data along the flight line point by point, comparing the spectral signature at each unknown image point with the known spectral signatures determined above and representing the objects to be identified. If the signature of the unknown point matches a catalogued known signature, have the computer print out our appropriate identifying symbol at the location of the unknown point, on the computer line printer.

6. Repeat this process for all unknown image points in the scanner imagery. The final result is the computer printout of the identified points, called a recognition map (Fig. 5).

The multispectral scanner has a distinct advantage over photographic sensors in that it utilizes a much broader portion of the electromagnetic spectrum for making identifications. Spectral signatures determined by the multispectral scanner are longer curves, and therefore the potential for differentiating them is increased. New multispectral scanners are currently being tested which utilize more and more wavelength bands, and the total portion of the spectrum covered is continually increasing, which will make it possible for the process of pattern recognition to make very subtile distinctions between objects appearing similar to the human eye and camera in the visible band.

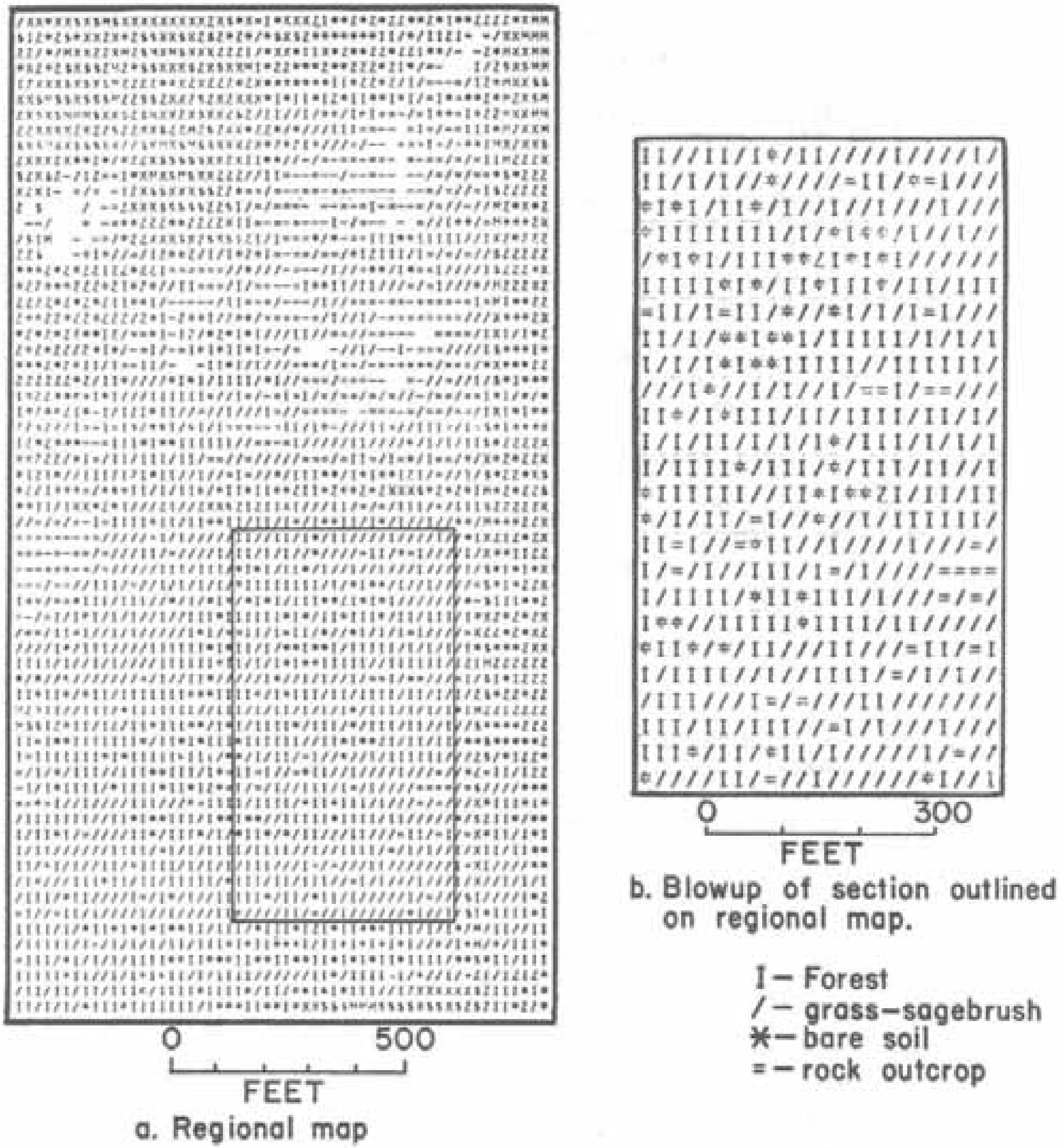

Fig. 5. HYPOTHETICAL EXAMPLE OF A RECOGNITION MAP OF MOUNTAIN TERRAIN. A blowup of a portion of the regional map illustrates a possible land classification into four different terrain types. Symbols on the regional map other than I, /, *, or =, might represent other terrain types not classified in the enlargened region, such as snowfields, water, bog, etc.

EXPERIMENTAL APPLICATION OF THE PATTERN RECOGNITION PROCESS

A study of the effectiveness of computerized image analysis was completed recently on 12-band multispectral data collected over a 12 square mile area with 1800 feet of relief in northcentral Yellowstone Park (Smedes et al. 1969). Computer analysis was carried out in the manner described above to map eight terrain types, namely bedrock exposures, talus, vegetated rock rubble, glacial kame, glacial till, forest, bog, and water. Shadows cast by cliffs and cloud cover were also readily recognized. Overall accuracy of the results using four optimum wavelength bands of the 12 available bands was 86% correct identification of all image points. A recognition map of a portion of the 12 square mile area is shown in Figure 6.

Even though automatic image analysis techniques are still presently in the experimental stage with a few problems yet to be worked out, the success of the Yellowstone study suggests that a similar approach be applied to mapping bighorn sheep habitat. Human interpretation of air photos, although presently more accurate than automatic computer image analysis, is time consuming, tedious, and subjective. Computerized interpretation is much faster, less subjective, and can be repeated frequently in time, which is not possible with human interpretation.

APPLICATION TO HABITAT STUDY

Terrain types which are of importance to wintering herds of mountain sheep could be rapidly mapped in a manner similar to that employed in the Yellowstone study and the results used as an aid in making timely management recommendations. Examples of terrain types that represent winter sheep habitat in Colorado that might be mapped are rock outcrops, talus, vegetated rock rubble, snow, grass slope or meadow, sagebrush and grass, bare soil, lakes, and streams. However, the terrain types chosen will vary with geographic location, and within the same areas there might be variance among researchers as to what terrain types are of greatest significance to the maintenance of bighorn sheep populations. Rapid computer analysis of multispectral scanner imagery would enable several interpretations to be made of the same habitat area essentially simultaneously, allowing comparisons of different combinations of habitat factors.

Analysis of terrain types comprising bighorn sheep winter habitat and mapping by the proposed method have a number of potential applications. Range quality could be determined, perhaps by using a numerical index which is a ratio of grass to bare soil and rock. The greater the percent grass cover, the higher the quality of the range. Present multispectral sensors are capable of distinguishing vegetated areas containing as little as 20% difference in exposed bare soil. Thus when grassy areas are overgrazed to the extent that 20% more bare soil is exposed, a change in range quality can be detected, from the point of view of quantity of grasses present.

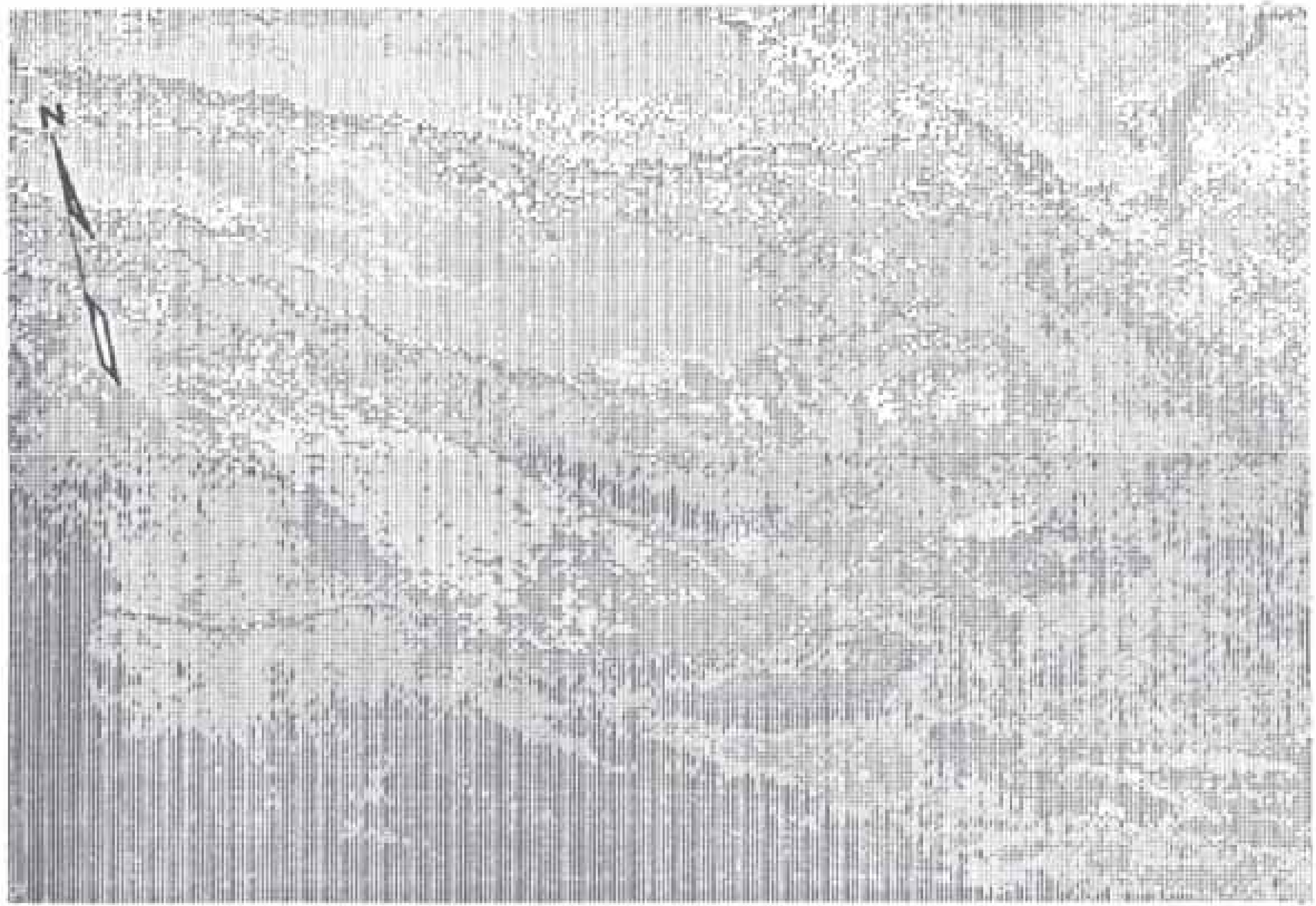

Figure 6. Recognition Map of a Segment of the Yellowstone Study Area (Courtesy of H. W. Smedes, 1969)

Symbols representing terrain classes are:

· Bedrock exposures	H. Shadows
$ Vegetated rock rubble	8 Talus
- Glacial till meadows	= Glacial kame meadows
: Bog	/ Forest
W Surface water	(Blank) Other

More intense habit study might lead to a better understanding of the lungworm life cycle by indicating a relationship between the incidence of carrier snails and particular habitat types or conditions. Perhaps the snails are found in certain definable areas from which the sheep could be exclosed, or the areas might be treated for the extermination of the lungworm.

Rapid analyses of ranges where transplants are proposed might indicate the chances for transplant success. Furthermore it may be necessary at times to quickly appraise areas for transplants if mountain sheep should become available on short notice from overpopulated herds in other locations.

In early 1972 the ERTS-A (Earth Resources Technology Satellite) will be orbiting the earth, collecting 4-band multispectral data completely covering North America every 18 days. The four wavelength bands to be used in the ERTS-A scanner were simulated in the experiment previously described (Smedes et al. 1969) to classify the eight terrain types in the Yellowstone study area, with an overall result of 80% correct identification, as opposed to the 86% accuracy obtained by using the optimum four wavelength bands from the aircraft scanner. The ERTS-A will be capable of resolving data elements of 230 feet in diameter (one acre) at an altitude of 500 nautical miles (Goldberg 1969), but in spite of this, relatively coarse instantaneous-field-of-view changes in vegetation condition over bighorn sheep habitat could be monitored nearly twice monthly, when cloud free. ERTS-B, to be orbited a year later than ERTS-A, will contain a similar scanner, but with an additional wavelength band in the thermal infrared. The manned Skylab missions in the mid to late 1970's will carry multispectral scanners capable of resolving 1/2 acre, and will utilize even more wavelength bands. Within five years it is probable that higher resolution sensors with a greater number of wavelength bands will be available for use in natural resource inventory programs. The ERTS-A satellite data will be made available to researchers who have submitted proposals to the National Aeronautics and Space Administration which are approved but not necessarily funded by NASA. Data might also be obtained through research projects sponsored by government agencies which have already made arrangements with NASA for procuring the satellite data.

At present, multispectral data collected by aircraft has much better ground resolution than orbital data, and is being collected over more and more of the Rocky Mountain West, as scanners become available to more organizations. Cooperation with other researchers and agencies interested in collecting multispectral data in or near mountain sheep habitat can make such imagery available at reasonable cost. As data collecting techniques have become more sophisticated and more costly the importance of cooperation between researchers for maximum economy and benefit becomes apparent. Researchers in most fields, including wildlife management, are presently in a position where emphasis should be placed on communication and cooperation, to take advantage of modern technology, rather than on independent study of their own disciplines.

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DISCUSSION

QUESTION BY WARREN KELLY, USFS CALIFORNIA: Is there any possibility of determining species of grasses with this method?

REPLY BY ROOT: I seriously doubt it. The field of view that we can look at is probably not small enough that we can isolate certain species and tell what their curves look like.

There is a project which is part of the International Biological Program which involves a spectral radiometer. This is a ground instrument that produces the spectral curves or the signatures that we are talking about. This radiometer can be focused on a particular species. We could look at, say blue grama, and get a curve for blue grama. It might be possible that you could match data in the air with the curve on the ground. We have problems in that we are looking at it from the ground. The angle of illumination might be a little different. The atmospheric conditions if we are flying over it might cause some interference. There might be possibilities but my answer right now is no, it cannot be done.

REPLY BY KELLY: I question whether or not you could get very good results on range quality unless you could determine species of range grasses which would be more prefereable to different species of animals.

REPLY BY ROOT: This is a good point. What I was really trying to refer to here more than anything is the idea of how much bare soil is showing through. If there is an area which the sheep do like and they do graze it heavily, then more and more bare soil will show through if they have to graze in that particular area. As the condition of the range deteriorates, we might be able to detect this.

QUESTION BY GENE DECKER, CSU: How available is the satellite information?

REPLY BY ROOT: It hasn't been collected yet, so that is a hard question to answer. I am sure that a well thought out research proposal from a University would be considered, but there will be red tape.

QUESTION BY KELLY: Is this the same satellite that they are going to use to determine some of this pollution that exists around the world?

REPLY BY ROOT: I am not sure offhand, but I would think so.

DISCUSSION FOLLOWING PANEL

QUESTION FROM DALE JONES, USFS, NEW MEXICO: I don't have any surefire method of censusing game, but I did have an opportunity to talk with a retired military man. He claims that right now the service has infra-red or another heat sensitive type films that he feels will someday be used to count wildlife. It will differentiate between species by heat emission, respiration rate and quite a few other things. He claims that right now they can tell you where just about every one of the humans are in Viet Nam, down to sex, creed and color. I am not so sure that the day of counting big game isn't too far off. Then I don't know what we are going to use for an excuse.

REPLY BY RALPH ROOT, CSU: I'd like to make a comment on that. A study has already been done using an infra-red scanner for censusing big game in Michigan. This was the same plane that flies the 12 channel scanner that flew the thermal infra-red scanner. It flew over a game preserve where there were roughly 100 deer which had been previously censused by ground methods. They were then counted by the thermal imagery. They show up as little white spots. The hotter the object is, the whiter it looks. The count from the air was as accurate or possibly more accurate than the one from the ground because a lot of the deer were in swamps or in other areas inaccessible to ground counting. I might add a word of caution. The conditions for this were ideal. There was an 8 inch snow cover and there were very uniform atmospheric conditions. It couldn't have been better.

Snow cover is very important because it allowed a very large difference between the background and the animal. In other words, a greater temperature differential will more readily be seen. In bighorn sheep studies, especially in Alaska where we are counting white Dall sheep against white snow, it might be of some benefit to census with infra-red scanners.

REPLY BY LYMAN NICHOLS, G & F ALASKA: We already tried it. I had an opportunity last year to run a test with a Daedalus scanner. We were trying initially to find whether we could locate moose in timber. I tried over a known number of moose in enclosures under a number of different conditions in the winter where the background was below freezing. I tried it at night, early in the morning and during the day. We could not differentiate them from the background at all in the timbered areas. We were able to pick out moose in the open during the day when they were actually reflecting the sun's heat.

I tried it over sheep and caribou. The sheep were right out in the open tundra before the sun came up. It was a cold background with everything very even. We flew right over the sheep but couldn't see a thing on the film.

Northern species are apparently so well insulated from the cold that they are not radiating enough heat to be detectable.

COMMENT BY RICHARD HANSEN, CSU: I would like to plead with everybody to devise methods which make work more efficient. But when it comes to these spectral signatures, which we will undoubtedly start to use in the future, I hope we have something besides grass and trees to put into the computer scheme. I think we need to put in the important factors that concern the productivity of the animal that we wish to perpetuate. These include the food sources as well as other protective sources. This is going to require people to go back and get down to the nitty gritty of actually measuring what species of plants are present and how much of each is present and the same with the diets. I hope when we do get to a computerized scheme of spectral scanning, the important things will be present.

COMMENT BY AL WOOLF, RACHELWOOD PENNSYLVANIA: In regard to censusing, I must make one comment concerning infra-red film. There is no such thing as an infra-red film that detects heat, nor will there be one. Infra-red film has just that narrow little band in the spectrum that he showed you. This is not heat-sensitive. In some items you get a color distinction but not in all. We are trying this with white-tailed deer and different films. There is no easy solution to censusing in sight right now.

In regards to thermal scanning even with something like deer, it's not a multi-spectoral scanning. We are just searching for the heat response. They can select the signature they want to record. How about if you have a deer lying there and he suddenly gets up and walks away? Are you going to pick up the bed and the deer? These types of problems exist.

In addition, in most cases, it's a real difficult interpretive job to look at this imagery and know what you are getting. It takes a real skilled person to do it.

COMMENT BY JERRY LIGHT, USFS, CALIFORNIA: Those of us who work for the United States Government have an opportunity to utilize, for training purposes, the photo labs of the Air Force. This has been done by some of us already. Those of us that haven't been doing it out to try it.

COMMENT FROM BRUCE GILL, G & F COLORADO: We've been working in cooperation with Dick Driscoll of the Rocky Mountain Forest and Range Experiment Station. We are concerned with how to census dead deer in Middle Park. The first question we ask is can you see a deer carcass using remote sensing techniques? We were flying over some experimental areas with colored infra-red anyway so we salted the area with carcasses at known locations. I put some under sagebrush, so they were partially covered by the crown, and some in the open. We were able to locate every carcass we put on the flight line. Not only were we able to locate the carcasses, but we could tell this year's dead deer from last year's because as the animal's decay, the nutrients that are leached out of the carcass are picked up by the plants. These show up as a pink ring around a two year old or older carcass. Now we are in the process of testing remote sensing against a known number of carcasses under a variety of conditions. Unfortunately, you cannot get the age structure of dead deer with remote sensing.

COMMENT BY H. DENNISON PARKER, G & F COLORADO: We have been trying for two years to get radiometer ground truth data to determine the delta T or temperature contrast which exist between mule deer and various objects in the background: snow, vegetation, rock and bare soil. All I can say at this point is that the technique would work quite well if you have 100% snow cover and I mean literally 100%. That is a limitation we cannot count on.

Further analysis will show what delta T's we can expect under various conditions. Next winter we hope to participate in a study to try a flight over the Middle Park area to test some of the results of this radiometry data. At the present time, we are doing statistical analysis on the delta T's that exist and the change of delta T's that exist as a function of environmental conditions to determine what is the best time to fly.

There is no question, theoretically or practically, that a body which differs from its background by a couple of degrees centigrade can be detected by the equipment we now have. The question is, as the man from Alaska eluded to a few minutes ago, is the delta T dependable when the animal has, for instance, the heavy insulation in the wintertime? I can't say it is at this time. We are still working on it.

Jim Yoakum

SECTION IV

MANAGEMENT PROBLEMS, PROCEDURES AND NEEDS

AN ECOLOGICAL VIEW OF BIGHORN HABITAT ON MT. SAN ANTONIO

by

Jerome T. Light, Jr., Wildlife Biologist
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ABSTRACT

The Mt. San Antonio bighorn range came under an environmental impact analysis resulting from a request to expand the Mt. Baldy Ski Resort. A team of Forest Service and California Department of Fish and Game Wildlife biologists and students spent approximately 12 months in the survey area observing bighorn and surveying their habitat. A resultant graphic analysis of interpretive base maps and valued overlays of the habitat component, the bighorn use component and the human use component leads to some inescapable conclusions.

1. Bighorn use does not occur in significant amounts where vegetation and terrain features are of low value.

2. Bighorn use does not occur where human use is heavy.

3. High-value habitat used heavily by humans is excluding bighorn use.

There still remains the job of gaining more data on bighorn behavior. Such data will provide the basis for improving Forest Service Management directives relative to maintaining to bighorn habitat.

REVIEW

The ecological analysis of the San Antonio bighorn range began as an impact survey for a proposed extension of the Mt. Baldy ski development on National Forest land in the San Gabriel Mountains in Southern California. This particular bighorn range was inventoried in 1965 and a habitat management plan now provides general recommendations for maintenance of the bighorn habitat.

The San Gabriel Mountains overlooks 9 million people in the Los Angeles - San Bernardino Basin. Approximately 100,000 are skiers, and at least as many others, have other recreational use desires, but all express concern for the bighorn.

In response to the ski area proposal, the San Bernardino National Forest prepared a preliminary impact survey (12/31/69) recommending an environmental impact survey. Part of which includes an intensive study of the bighorn and its habitat.

The objective of this report is to describe the first year's results of using interpretive base maps and valued overlays to show bighorn key areas, their habitat, past impact on bighorn by human use and summarize bighorn behavior observed while in their range on San Antonio Mountain.

THE STUDY AREA

The study area includes eight square miles of the East fork of San Gabriel River to the West and the North fork of Lytle Creek watershed to the east. The study area embraces Mt. San Antonio (Mt. Baldy) the highest of the San Gabriel Mountains. Elevation of the study area ranged from 2500 feet to over 10,000 feet. The San Gabriel Mountains consists primarily of the Pelona Schist, a geologically young rock type.

METHODS

The bighorn impact survey team under the direction of the Cajon District Ranger consisted of two Forest Service Wildlife Biologists, two California Department of Fish and Game biologists, and three students from local universities.

The survey team mapped and recorded all bighorn, their behavior, travel routes and concentration areas each month during a 12-month period in the study area. The team members strived to spend as much consecutive time as possible in the field with bighorn during the spring, summer, and fall months. Except for the winter months all travel in the study area was on foot. During the winter, approximately 24 hours were spent in helicopter observing the winter range and more inaccessible areas.

Quantitative data was recorded on (1) a Habitat Analysis form and (2) a Bighorn Observation form. Each form was tested in the field for completeness relative to obtaining all obvious habitat factors and to obtain all obvious facts relative to bighorn behavior in various habitat and environmental situations. The quantitative data is presently being transferred to a medium that will provide systems analysis to isolate significant (1) habitat factors relative to bighorn use and (2) bighorn behavior situations relative to human activity.

The Forest Service involved numerous interested groups as observers which included local Sierra Club Chapters, Colleges and the local Wildlife Society Chapter.

THE BIGHORN HABITAT

The following describes the graphic study process in which base maps and three-valued overlays were used to arrive at a single three-valued overlay model of Bighorn Habitat in the study area.

TERRAIN

The three-valued overlay on Terrain is a slope study based on importance to bighorn. It was generally found throughout the study that bighorn favored narrow promentories in or adjacent to cliffs or escarpments. Bighorn concentrations were encountered only under these circumstances.

The rating criteria for terrain is as follows:

Low - Slopes from 0 - 30 percent usually not adjacent to or more than 150 yards from escarpment or steep slopes.

Moderate - Slopes from 0 - 60 percent usually adjacent to or surrounded by escarpments which are within 50-150 yards.

High - Slopes 60 percent or more with promentories in or within 50 yards of escarpment.

The three-valued overlay for Terrain now describes its influence on bighorn use in the study area.

VEGETATION

Vegetative types in the study area were delineated on a vegetation base map. The vegetative types were then described in three values relative to their importance to bighorn.

High Bighorn Value

Escarpment Chaparral

This type is characterized by cliffs, narrow promontory ridges and slide areas. The vegetative composition includes primarily mountain mahogany (*Cerococarpus* sp), scrub oak (*Quercus dumosa*) and numerous annual grass species.

The chaparral escarpment type is influenced by the terrain characteristic and includes plants favored by bighorn and for this reason is rated High.

Timberland Chaparral

This type has a 5-10 percent overstory of Jeffrey pine and 30-60 percent understory of mountain whitethorn (*Ceanothus cordulatus*), chinquapin (*Castenopsis* spp), scrub oak, coffeeberry (*Rhamnus californica*), elderberry (*Sambucus* spp) and numerous forbs and grass including the buckwheats. Because of the high density and composition of desirable forage plants this type is of High value to bighorn.

Escarpment

This type is generally steep and barren in appearance. In the major draws are many small "mini-meadows" or wet meadows at water seeps.

The greater area contains sparse but highly preferred vegetation such as mint (*Monardella* spp), heuchera (*Heuchera* spp), oceanspray (*Holodiscus* spp), narrowleaf mahogany (*Cercocarpus* spp), and a variety of buckwheats (*Eriogonum* spp). The type is High value to bighorn.

Moderate Bighorn Value

Alpine Conifer

This type includes limber pine and lodgepole pine with an understory with 5 to 10 percent vegetation with chinquapin and barren rock rubble. The type is of Moderate value to bighorn.

Alpine Barren

This type includes 80-95 percent rock rubble with vegetation which includes the buckwheats, mint, heuchera, oceanspray and perennial grass species. This type contains preferred forage and is of Moderate value to bighorn.

Conifer

This type is usually on north- and east-facing slopes with a 40-60 percent overstory consisting of Jeffrey pine, sugar pine, incense cedar, liveoak, white fir and bigcone Douglas fir. The understory (5-10 percent) consists of narrowleaf mahogany, mountain whitethorn (*Ceanothus cordulatus*), perennial grass and eriogonum species. Vegetative composition is of Moderate value to bighorn.

Low Bighorn Value

Wash

A rock rubble and debris filled channel which changes annually with each hydrologic wash. The type is usually void of vegetation and for this reason is of Low forage value for bighorn.

Chaparral

This type is found in the lower elevation. Vegetation consists primarily of shrubs such as chamise (*Adenostoma fasiculatum*) chaparral whitethorn (*Ceanothus leucodermis*), scrub oak (*Quercus dumosa*), and birchleaf mahogany (*Cercocarpas betuloides*). Vegetation is usually quite dense (70-90 percent) and a natural barrier to bighorn, and for this reason it is rated Low.

The three-valued overlay for vegetation now shows a vegetative influence on bighorn use in the study area.

WATER

Water drainage patterns in the study area are indicated on the Drainage Base Map. This information cannot be interpreted in the three-valued overlay system. All yearlong water sources are rated High for bighorn.

TERRAIN - VEGETATION - WATER

By combining the valued overlays and map of terrain, vegetation and water we now have a bighorn habitat component overlay for the study area. The three-valued overlay model of the bighorn habitat was prepared by laying the terrain, vegetation and water valued overlays over a light table to delineate (1) combinations of only high valued areas as High, (2) any combinations of low, moderate or high valued areas as Moderate and (3) combinations of only low valued areas as Low. Later this combined three-valued overlay will be combined with bighorn occurrences.

BIGHORN OCCURRENCE IN THE STUDY AREA

Bighorn observed by helicopter and while on foot were recorded and mapped along with their concentrations and routes.

The Bighorn Occurrence Base Map shows the extent of the concentrations in the study area. The travel routes indicate direction of travel from winter range and on into the summer.

Bighorn Use was then delineated on a three-value overlay which shows the current use as light, moderate and heavy.

Light - Bighorn trailing may be found but they do not regularly trail through or concentrate in the area.

Moderate - Bighorn travel through regularly with small concentrated use areas with 10-20 sheep-days per acre along trails between heavy use areas.

Heavy - Bighorn concentrations are extensive and are linked together along routes. Bighorn use is over 20 sheep-days per acre. During the proper season bighorn can usually be found in these areas.

Bighorn observations were recorded and mapped by seasons as follows:

"Winter" (Winter - Early Spring)	12/16 - 4/15
"Spring" (Late Spring)	4/16 - 6/15
"Summer" (Late Spring - Summer)	6/16 - 9/15
Fall	9/16 - 12/15

Winter use was generally below 6000 feet. Spring use remained in the lower rugged canyons for the ewes in lambing while the rams and other barren and young ewes picked the south-facing slopes up to the 9000 foot elevation. Lambing generally occurred in May. By June and July the ewes with young head for and occupy the top of their range on San Antonio Mountain. Rams were small bands throughout the range. During the fall months bighorn rams gathered to rut on Pine Mtn. Ridge, in Cattle Canyon, North Fork of Lytle Creek, Middle Fork of Lytle Creek and West Fork of San Antonio Canyon.

The survey was temporarily halted in late Fall of 1970,and for this reason it is assumed that after the first heavy winter snows the bighorn return along the same routes back to the winter range. To what extent this assumption is valid will be determined this coming winter (1971).

By combining the three-valued overlay of bighorn habitat (terrain - vegetation - water) with the overlay of Bighorn Use we found that there were many similarities which basically indicated that the high valued habitat coincided with the heavy bighorn occurrence in most of the areas.

Those areas of high bighorn habitat value that registered light in bighorn occurrence were then studied to find out why bighorn use was light. In most cases we found that the past bighorn use, shown on the Historic Bighorn Use Overlay, coincided closely with the high valued areas shown in the Bighorn Habitat Overlay. An example is the Baldy Notch area where a ski area complex now exists. Gardner (1918) wrote that bighorn were once quite common in the area between Telegraph Peak and Mt. San Antonio. During the ski area's development which began in 1955, many bighorn were observed. Now on rare occasions bighorn rams appear on the line of sight perimeter from the center of this extensively cleared and developed winter and summer recreation area. A human influence on bighorn use of its habitat is now becoming apparent.

HUMAN INFLUENCES IN THE STUDY AREA

Man's influences on bighorn behavior has only partially been evaluated in the study area. We know where bighorn were and are now.

Throughout the study, the observers encountered numerous bighorns and took notes of their behavior responses. A general consensus of these responses were that bighorn ewes with lambs would not tolerate human advances to within 100 yards as would the individual ewes and rams. The individual ewes and rams could be approached to within 20 yards before they moved away. Bighorn out of cover retreated to cover at a quick pace. Ewes with lambs were by far the most intolerant especially when the observer was within or over their cover element.

A Human Influence overlay was developed to describe the intensity of human use along trails and centers of activity in the study area. This overlay has three values of human use which are as follows:

Light - 0-100 visitor days per year.

Moderate - 100-500 visitor days per year.

High - 500+ visitor days per year.

Much of the human influence had its beginning in 1955, when the public's attention was drawn to the Baldy Notch ski resort and later the Sierra Club cabin as a summer retreat. Human use which followed occurred during April to October. Approximately 1900 visitor days were registered from Baldy Notch and approximately 900 visitor days from the Sierra Club cabin in 1970. These two areas direct summer visitors to the top of Mt. San Antonio.

Comparative analysis of the valued overlays of present bighorn occurrence, human influence and historic bighorn use indicates a change in bighorn use patterns which was apparently molded through the years by human influences. Large areas of bighorn habitat which are suitable for bighorn occupancy have been vacated by the bighorn.

DISCUSSION

A graphic analysis of the habitat component, the bighorn use component and the human use component leads to some inescapable conclusions:

1. Bighorn use does not occur in significant amounts where vegetation and terrain features both are of low value.

2. Bighorn use does not occur where human use is heavy.

3. High-value habitat used heavily by humans is excluding bighorn use.

It would appear that the many documented cases of bighorn tolerance to human influence occur primarily in those areas where human visitation is relatively infrequent. There are many recorded instances of single visitors and small groups passing through bighorn country where the bighorn show little stress. On the other hand, there are noted instances when one or more human visitors cause the bighorn to flee the area. Apparently, occasional human visitors are tolerated but continual human visitation creates stress conditions and the bighorn begin to avoid these areas of heavy human visitation (habitation).

The best example of this is the San Antonio Canyon, Baldy Notch, Sierra Club Cabin bowl complex where high habitat components exist but bighorn use is light. In double checking this finding the study showed (from historic records in the area taken before the Baldy Notch development and in times when visitor days were appreciably less) that this was in fact a heavy bighorn use area. Because the bighorn have only gradually disappeared from the area as human use increased, the change was not too noticeable, and reports have painted a more optimistic picture than is now warranted.

The actual degree of tolerance as measured in human visitor days may never be known and will probably vary from place to place. Norman Simmons of the Canadian Wildlife Service, formerly with the Desert National Wildlife Range and the Kofa Game Range in Nevada, feels that the stress shown by mountain sheep is in direct relationship to the abundance of other habitat components. That is, where there are abundant food and water supplies in close juxtaposition with high value escape terrain a great deal more human disturbance will be tolerated.

The Mt. San Antonio area, while comparing favorably with other ranges in Southern California, nowhere near approximates the food abundance seen in places like the Sandia Mountain Tramway on the Cibola National Forest. The Rocky Mountain bighorn (a different sub-species), which has been noted as quite tolerant of man, generally occurs in ranges at northern latitudes where rainfall is more abundant and heavy stands of grass clothe the steep escape terrain which they inhabit.

CONCLUSION

The findings of the Bighorn Environmental Analysis indicate that bighorn can tolerate only limited amounts of human disturbance before they are driven from their home ranges. There are still gaps in our information which we hope to fill this summer, fall, and winter. This data will be refined and more bighorn behavior data will be analyzed. With this data we will have a better basis for recommending management directives where the maintenance of bighorn in their habitat is of primary concern.

HABITAT MANAGEMENT FOR THE DESERT BIGHORN

by

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ABSTRACT

Habitat management for desert bighorn is maintaining or improving food, water, cover, and space for wild sheep in the southwest. Severe competition now exists in many ranges of the bighorn; consequently, wildlife managers need to more effectively manage both the bighorn and its habitat. Management plans should and can be cooperatively accomplished to improve herd populations and habitat conditions. Many pristine ranges do not contain bighorns, although the ranges await transplant ventures. Some ranges are deficient in quantity or quality of water and/or forage. This paper lists tried and tested techniques to re-establish bighorn populations and improve habitat conditions for native bighorns.

INTRODUCTION

When white man first came to North America, bighorns (*Ovis canadensis*) inhabited most of the lands in the southwest (Buechner 1960). However, today, less than one-tenth of these pristine ranges produce bighorns. Relentless yearlong hunting, competition with domestic livestock, and the decrease of available habitat due to human use, were all factors contributing to this drastic reduction in populations during the century from the 1850's to the 1950's. Man was, therefore, the responsible factor for the bighorn's decrease. But, man is learning how to take better care of wildlife populations and environmental conditions; consequently, the last two decades have witnessed increased herds in areas where they were formerly extirpated. The question facing us today is--can or will man continue the present trend of increasing desert bighorn herds and improving habitat conditions? The objective of this paper is to identify and document ways this can be accomplished. The actions of man in future years will determine whether this will be done.

RECENT MANAGEMENT ACCOMPLISHMENTS

Wildlife management is the science and art of changing habitats and wild animal populations to achieve human goals (Giles 1969). Today's knowledge of management emphasizes the need for a systematic "plan" to inventory physical and biotic data, analysis findings, document recommendations, and periodically evaluate results. Agencies such as the Forest Service and the Bureau of Land Management recognize the need for this management systems approach and each have administrative manuals outlining guidelines, methods and procedures, commonly referred to as "Habitat Management Plans" (Bureau Land Management 1968).

A recent survey disclosed Habitat Management Plans (hereafter referred to as "HMP's") have been completed and implemented in California and Nevada (Schneegas 1964; Light, Zrelack and Graham 1966; Light, Winter and Graham 1967; Myers 1969; and Warburton 1969). Other plans have also been completed, but copies have not always been readily available to the public as the HMP's cited above.

The two major methods of habitat management challenges for the future are: (1) herd re-establishments into presently unoccupied historic ranges, and (2) maintaining or improving food, water, cover, and space for bighorns.

RE-ESTABLISHING UNOCCUPIED RANGES

Buechner (1960) outlined the probable distribution of bighorns in the United States prior to the advent of the white man. He likewise mapped the present distribution which is less than one-tenth of the original distribution.

Today's wildlife managers have developed successful techniques of capturing and translocating bighorns (Yoakum 1963). Over 25 transplants have been made in six states. Some of the earlier transplants were not too successful, but more recent ventures have resulted in well established herds. The first transplant from British Columbia to Oregon resulted in a 200 percent herd increase in five years (Deming 1961). Within ten years, the herd had increased sufficiently to warrant a limited hunt, thereby resulting in a recreation return far earlier than many sportsmen dreamed.

One reason for the more favorable recent transplants has been the ability to capture large groups (20 or so animals) of sheep and moving the entire captured herd. There may be a behaviorism factor here in moving a herd group as opposed to attempts to collect a number of individuals.

New and improved techniques are also assisting in transplant ventures. Nevada's 1969 experiences (Tsukamoto 1970) are a good example of how a large herd can be captured today and transported with few, if any, mortalities.

The re-established herd of California bighorns in Oregon has a most notable record. This nucleus herd of 23 sheep was started in 1954. Since then the herd has multiplied to the extent that five bands have been transplanted to other areas and a total of four successful hunting seasons have been conducted to date. In addition, the herd has provided many recreation days to the public who enjoy trips to the transplant site to view the returned wild sheep.

IMPROVING HABITAT CONDITIONS

Habitat improvement projects to date have centered mainly around water developments and vegetation manipulation.

Projects to improve water quantity have been the most frequently used habitat improvement technique. Natural water holes and spring improvement work are methods described in detail by Halloran and Deming (1956); Weaver, Vernoy and Craig (1959); and Baker (1969).

Today, the wildlife manager is faced with making decisions and providing recommendations for waters developed primarily for human use. Frequently, a small additional unit to a pipeline or water facility can provide much needed water for wildlife. It, therefore, behooves the wildlifer to be acquainted with these procedures as well as to design water developments specifically for wildlife welfare. Further specifics regarding water developments beneficial to wild animals may be found in Chapter 14 of the Wildlife Management Techniques (Yoakum and Dasmann 1969).

Forage manipulation projects to increase desirable plants for bighorns have been very limited. Only one such project is known. This was a vegetation-type conversion from a dominant juniper-pinõn community to a mixed browse, forb and grass type near Hawthorne, Nevada. The area was first chained and later seeded. It is now a successful project and transplanted bighorns thrive on the increased desired succulent forage.

Since desert bighorns are primarily grazers (Barrett 1964, Yoakum 1964), it appears that type conversion from habitats dominantly trees or browse to mixed communities of grass, forbs and browse is a highly desirable habitat improvement technique. Yoakum's (1964) studies substantiate that bighorns utilized forage in quantities of 59.5% grass, 32.0% forbs and 8.5% browse on the Silver Peak Range in Nevada which has a vegetative composition of 22% grass, 4% forbs, and 74% browse.

Another example of preferred forage class use was reported by Dr. Charles Hansen (personal communication) who noted that bighorns made greater use of grasses in old wildfire burns than adjacent abundant browse ranges. Based on this knowledge, the Bureau of Land Management in Las Vegas, Nevada has zoned certain high density bighorn ranges as areas of no wildfire control, thereby allowing nature to convert browse communities to more productive forbs and grasses preferred by native bighorns.

For the wildlife habitat manager seriously concerned with manipulating vegetation for the benefit of bighorns or other wildlife, the publication entitled "Restoring Big Game Range in Utah" (Plummer, Christensen, and Monson 1968) is highly recommended. The authors have been responsible for improving over 120,000 acres. The "10 Basic Principles" stated in this book provide principles and practices that are applicable to practically any set of circumstances in North America. Here is the most important single publication to any manager seeking knowledge on techniques of game range rehabilitation. The reader may also wish to consult other publications for methods of improving forage. Two recommended sources are: (1) Chapter 14 of "Wildlife Management Techniques" (Yoakum and Dasmann 1969), and (2) "The Ely Chain" (Cain 1971).

DISCUSSION

Today, there is a challenge to the wildlife manager to increase bighorn populations. The public desires more recreation days use of bighorns to enjoy observing, to photograph, or to harvest.

To meet this challenge, the wildlife manager should first place priority efforts in restocking historic ranges now unoccupied. It is true that not all pristine ranges are suitable for transplants today, but many are, and each suitable range should be stocked at the earliest possible date. It is estimated that the present bighorn population in the southwest could be possibly doubled if these efforts were actively pursued.

Projects can and should be accomplished to increase quantity and quality of water or forage for bighorns. But no such major project should be accomplished prior to completion of a thorough Habitat Management Plan. No funds for improvement projects should be approved unless the project's feasibility has been thoroughly investigated and justified. In most cases, tested and proven techniques to improve waters or forage are known.

The year 1971 witnessed the First North American Wild Sheep Conference on an international basis. Each attending nation discussed the problems of too few wild sheep today compared to a century ago. And each stressed the paramount problem of the impact an exploding human population will have on native bighorn habitat. Yet, in many regions, the bighorn population, through professional wildlife management, is better today than it was 20 years ago. This indicates man can properly take care of wildlife and the environment.

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DISCUSSION

QUESTION BY JOHN RUSSO, ARIZONA G & F: Jim, I was interested in what you had to say about the amount of territory that is not being utilized today that is historic range and I agree with you. But as I look at this habitat and mentally inventory it, I find that a lot of this is in the realms of BLM, Forest Service, State agencies and private land which we really can't do too much about because that almighty dollar has a big hook on it. When you start to throw domestic livestock off this country, somebody is going to scream. Now, you have been with the BLM long enough, give me a solution?

REPLY BY YOAKUM: Sure, Johnny, I've known you long enough to talk to you directly. I don't know your state well enough to make recommendations, but I know Nevada well enough to know that when the Indians were there, practically every mountain range in the state had bighorn sheep. On this day, less than 1/3 of it is occupied by bighorn sheep. I know that now we have management planning systems in which we have identified major ranges and have asked for bighorn sheep to be transplanted in those ranges. I have said that in many of those ranges there is no conflict with livestock. There were days when there was conflict with livestock. Let's live for today. Let's not live for tomorrow. There was conflict with diseases and parasites with livestock. Domestic sheep are going off the land at the present time at a tremendously accelerated rate. There is less and less of a problem. There are ranges in central and northern Nevada, as well as parts of California, Oregon and Idaho where there are no domestic animals whatsoever and there is no major conflict with any endemic species. The agencies are requesting the re-introduction of native bighorn sheep.

REPLY BY RUSSO: This is true. Of course I have to speak of Arizona and quite often I get myself into trouble by sticking my neck out and saying things I probably shouldn't. I think we've talked about this often enough in past meetings to sympathize with each other, but you can see what is happening.

We have Lake Havasu City. The McCulloch Corporation has stepped in there and has developed a beautiful city. Of course these people are demanding to move back into this mountain range. If you had flown over this country several years ago and fly over it now, you might have a tendency to "puke with pride."

You go a little further into this and you'll find that we are gradually being pushed out of the Colorado River area because of access roads that are being demanded. We have roads that are being put right through some of our best bighorn sheep areas. This certainly is pushing these animals back.

We have recently investigated what has happened to the bighorn sheep in the Superstition Mountains. At one time we had sheep there but they are no longer there. This is the Tonto National Forest. In visiting this area a month ago, we found that the grass cover in that country looked about like this floor. There are cattle all over. We had a promise from the BLM in Arizona that any place where we have wild sheep they will remove domestic sheep. But there is no promise here that they will remove domestic sheep from where we used to have bighorns so we could think of putting bighorns in. This is the problem we run into.

REPLY BY YOAKUM: Yes Johnny, Arizona and Southern California have problems that I don't think I'll ever be able to answer. But the world is not all that bad. I might leave this group with the feeling that people are problems, but hell, we're part of them and we can't get rid of them. We're going to live with them. It's not all that bad.

I'll cite you the other case which is good! When I went to Oregon 10 or 15 years ago there wasn't a sheep in the state and there hadn't been for 20 years, although 2/3 of Oregon used to have bighorn sheep. They brought in 20 from British Columbia and in five years increased by 200%. That particular herd has now produced enough for 5 successful transplants within the state. They are working on 3 more. They have even brought them to Nevada. They are thinking of sending them to other states. They are hunting them now. So these are places where, I am sure Johhny, we can't answer all the problems. But there are places where we can do the job too!

REPLY BY RUSSO: And I'm sticking with it, too!

HUMAN DISTURBANCE AS A LIMITING FACTOR OF SIERRA NEVADA BIGHORN SHEEP

by

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ABSTRACT

The only native bands of California bighorn sheep (*Ovis canadensis californiana*) remaining in the United States are found on several small areas in the Sierra Nevada. Recent studies conducted by the Inyo National Forest indicate these small bands have suffered a decline over the past two decades. During this time span, the major impact on the sheep ranges has been the great increase in recreational use. Bighorn sheep numbers have apparently decreased on ranges that have been subject to large increases in human use. Statistical data are not available to support this hypothesis; however, field observations indicate the relationship does exist.

Bighorn sheep population in the western states experienced a large decline in numbers starting with the gold rush era and continuing through the turn of the century. Many wildlife scientists think this decline was mainly caused by human encroachment on bighorn sheep ranges. Buechner (1960) stated that excessive hunting, forage competition with domestic livestock, scabies disease and loss of key winter ranges to human development were the major factors causing the early decline among bighorn populations. Van Den Akker (1960) listed military uses of bighorn ranges, construction of barriers across migration routes and upsurping of water holes for human uses as additional factors responsible for bighorn sheep losses. Human disturbance and loss of habitat due to urban development are the greatest threats to the continued survival of desert bighorn in the Santa Rosa Mountains of Southern California (Blong 1967).

The human disturbance factors mentioned above are normally apparent and lend themselves to measurement and evaluation of their effect on bighorn populations. The effect of the mere physical presence of humans on bighorn sheep is more intangible and very difficult to evaluate; however, many feel it can be detrimental to bighorn sheep in certain cases. It is frequently stated that bighorn sheep require living space that is subject to a minimum of human disturbance (Wilson 1969, Monson 1966, Nelson 1966). On the other hand, bighorn sheep have been reported living in close association with humans such as in Death Valley (Welles and Welles 1961) and the Buckskin Mountains near Parker Dam on the Colorado River (Nelson 1966).

The possible adverse effect of human disturbance on bighorn sheep in the Sierra Nevada was mentioned by Dixon in 1936. He felt that the increase in recreational camping on the bighorn summer ranges was one of the major limiting factors of the bighorn sheep in the Sierras (Dixon 1936). Jones (1949) thought bighorn sheep in the Sierra Nevada required the solitude provided by the wilderness environment as part of their habitat needs. He cited the disappearance of bighorn from the Humphreys Basin area following a sharp rise in human use.

It appears that bighorn sheep response to contact with humans is quite variable. Bighorn reactions to human contacts in one area may not apply to bighorn-human contact in a different location.

BACKGROUND

Prior to the arrival of white man, California bighorn sheep (*Ovis canadensis californiana*) were present in scattered abundance along the Sierra Nevada crest northward through the Cascade Range and lava beds of Northern California, through Oregon and Washington into British Columbia. By the early nineteen-thirties the only surviving members of this subspecies of bighorn remaining in the United States were found in scattered bands in the Sierra Nevada. The early decline in numbers was due to illegal hunting, scabies disease, and forage competition with domestic livestock (mainly sheep).

Wildlife conservationists became alarmed by the drastic reduction of the Sierra Nevada bighorn populations. In 1941, a sanctuary was proposed to protect part of the remaining bighorn sheep and their habitat. Due to lack of concrete data regarding the actual status of the bighorn numbers, the sanctuary proposal was abandoned (Cronemiller 1941).

The first detailed study of the California bighorn sheep in the Sierra Nevada was conducted by Fred L. Jones during the summer of 1948. He located five ranges occupied by bighorns between Monache Meadows and Convict Creek. These were called the Mt. Langley, Mt. Williamson, Mt. Baxter, Birch Mountain and Convict Creek ranges (Jones 1949). The estimated number of California bighorns remaining in the Sierras was placed at 390 animals (Jones 1949).

CURRENT STATUS

The California bighorn sheep was classed as a rare animal in the United States in 1966 by the U.S. Fish and Wildlife Service's Committee on Rare and Endangered Wildlife.

The U.S. Forest Service is responsible for managing wildlife habitat on National Forest land. Of particular concern is the habitat of any species currently classed as rare or endangered. The Inyo National Forest administers more than ninety percent of the habitat that supports the remaining California bighorns native to the Sierra Nevada. Since 1967 the Forest has conducted field surveys on the five ranges described by Jones in 1949 to gather information on vegetative conditions on both summer and winter ranges. Data on bighorn distribution and number were obtained to compare with the status reported in 1949 (Jones 1949).

Evaluation of the data collected from the surveys shows California bighorn ranges are generally in satisfactory condition (Dunaway 1970). Despite good range conditions the total numbers of bighorns appear to have declined over the past two decades. The largest losses have occurred on the Convict Creek, Birch Mountain and Mt. Langley ranges. Bighorn numbers on the Mt. Baxter and Mt. Williamson ranges, although somewhat lower than those reported in 1949, have remained fairly stable. The total number of California bighorns remaining in the Sierra Nevada is estimated at 215 animals. Table 1 presents a summary of the current population estimates compared to those reported by Jones in 1949. Figure 1 shows the locations of the populations.

Table 1 - Status of California Bighorn Sheep on the Inyo National Forest, 1949 and 1970

Range	Area, Sq. Mi.	1949 1/	1970
Convict Creek	35	25	0
Birch Mountain	20	15	0
Mt. Baxter	75	135	95
Mt. Williamson	65	125	75
Mt. Langley	155	90	45
	350	390	215

1/ Data from Jones, 1949

DISCUSSION

The normal factors that limit the size of wildlife populations are operating at a low level among the California bighorn in the Sierra Nevada. Losses to illegal hunting are no longer a threat to the bighorn sheep. Excellent patrol by wardens of the California Department of Fish and Game and the difficulty involved in locating the sheep have discouraged poachers. Some natural predation no doubt occurs; however, it is thought that predation is not significant in limiting the population size. No predator kills have been located during the past four years or have any been reported by other people who hike the areas occupied by bighorn. Domestic livestock have not grazed on the bighorn ranges for many years. Domestic sheep, once a serious forage competitor with bighorn on the alpine summer ranges, no longer graze in the areas occupied by bighorn. Several cattle allotments are located along the broad alluvial fans at the base of the eastern Sierra scarp. These allotments adjoin the bighorn winter range at several points; however, there is no overlap due to the extremely rugged terrain occupied by the sheep. It is doubtful competed with the California bighorn on the winter ranges.

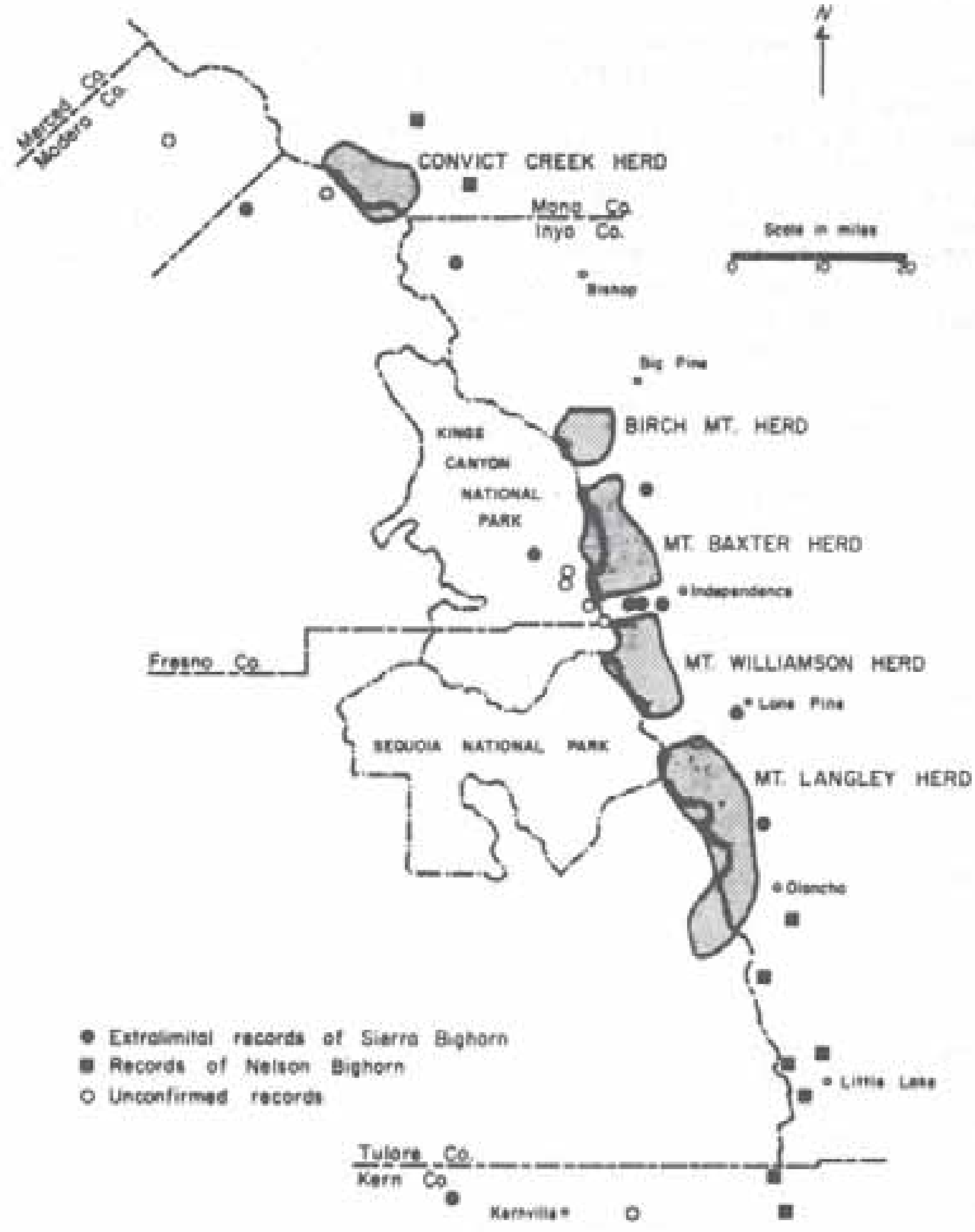

Figure 1. Distribution of California bighorn sheep in the Sierra Nevada in 1948. (From Jones, 1949).

Mule deer (*Odocoileus hemionus inyoensis*) and tule elk (*Cervus nannodes*) browse on winter ranges that are adjacent to several of the bighorn winter ranges but there is very little overlap between the two areas. At times bighorn move down onto the fringe area between the two winter ranges for the respective animals. There is some forage conflict in this narrow fringe area as all three animals use browse to a high degree during the winter months. At the present time the intensity of forage conflict among mule deer, tule elk, and California bighorn in these fringe areas between their winter ranges is well within acceptable limits. (Dunaway 1970).

Disease and parasites are not causing any significant losses of California bighorns at the present time. All the sheep observed in the field during the past four years have appeared to be in excellent condition. Fecal pellet samples collected from the winter ranges of the Mt. Baxter and Mt. Williamson bighorn herds were examined for internal parasites. Eggs and larvae of both lungworm (*Protostrongulus* sp) and threadnecked worm (*Nematodirus filicollis*) were found but at very low levels of occurrence (McCullough and Schneegas 1966, Dunaway 1970a).

When viewed individually the above factors probably have very little effect on limiting the bighorn populations in the Sierra Nevada. The combined effect is more significant but it is still probably not an effective population depressant. The current situation on Sierra Nevada bighorn ranges is similar to that reported by Jones in 1949 with one exception, that is the great increase in human use on these sheep ranges.

Recreational use of National Forest lands has increased at a rapid rate during the past twenty-year period. This large increase in use is readily apparent on the seventeen National Forests in California. The Report of the Chief of the Forest Service for 1969 states the total recreational use on all National Forests, National Grasslands, and other lands administered by the Forest Service for the year 1969 was more than 162 million days 1/. Of this National total over 45 million visitor days (28%) were reported in California.

The Inyo National Forest ranks in the top three recreational use Forests in California. Recreational use pressures on the Forest resources has more than tripled during the past two decades. In 1950 total recreational use on the Forest was approximately 1.2 million visitor days. Forest statistics for 1970 show this use at more than 4.6 million visitor days. This upward trend in use has occurred in the wilderness areas on the Forest where the major portions of the California bighorn ranges are located.

1/ Recreation use of National Forest land and water which aggregates 12 person-hours, may entail 1 person for 12 hours, 12 persons for 1 hour, or any equivalent combination of individual or group use.

Not only has the number of people using the wilderness increased but the mode of travel has changed. Prior to the fifties the most common method of travel in the Sierra high country was by horse with pack mule. This type of locomotion channeled the flow of people along the main trail network that traverses the Sierra Nevada high country. Human intrusion on alpine ranges occupied by California bighorn was at a low level. Foot travel was not strange to the Sierra at this time; however, hikers were generally in the minority among the back country recreationists. The early nineteen-sixties signaled a change in the method of travel in the wilderness. Hiking with a backpack became more popular as a way to see the high Sierra country. Today the major use of the wilderness is by hikers. The advantage the foot traveler has over the horseback rider is the ability to travel cross-country. Traversing through difficult terrain and mountain climbing are popular uses of the wilderness. One of the results of the change in the style of travel has been to place people in ever-increasing numbers on the rugged alpine bighorn ranges that were previously rarely visited by humans.

There are several areas in the Sierra where the relationship between heavy human use and absence of bighorn sheep can be seen. The five bighorn ranges first described by Jones (1949) have conspicuous gaps between them. These gaps were areas of high human use. For example, the gap between the Mt. Baxter and Mt. Williamson ranges contains Kearsarge Pass. This pass has been one of the favored routes across the Sierra crest for many years and receives extremely heavy human use. Mount Whitney is located in the gap between the Mt. Williamson range and the Mt. Langley range. Scaling the summit of the highest peak in the 48 states has been a popular event for many years. In 1970, approximately twenty-five thousand people hiked the Mount Whitney Trail from the trailhead at Whitney Portal on the Inyo National Forest.

All three bighorn ranges that have suffered losses in numbers of sheep have received major increases in recreational use. In contrast, the Mt. Baxter and Mt. Williamson ranges have not been exposed to this surge of recreationists seeking a wilderness experience. The California bighorn numbers for these two ranges have remained fairly stable over the past twenty-year period. There is no statistical data to prove the relationship between increased human use and decreased bighorn numbers in the Sierra Nevada; however, the relationship appears to be real.

CONCLUSIONS

California bighorn populations in the Sierra Nevada have been at a low level for many years; however, the apparent loss of sheep numbers on three of the five occupied ranges during the past twenty-year period may place the subspecies in jeopardy. Continued losses may lead to the eventual extinction of the native stock of bighorn present in the Sierra. Although difficult to prove, it appears that human disturbance may be a major factor that limits the bighorn in the Sierra. It is realized that the most obvious conclusion can be completely wrong but we do not have the luxury of large bighorn populations on which to test a variety of assumptions. Land managers charged with the responsibility of administering the natural resources must be aware of the needs of the bighorn sheep and make every effort to perpetuate the species. Only through awareness of the problems facing the bighorn and consideration for habitat needs in land management decisions will the California bighorn sheep remain as part of the native fauna of the Sierra Nevada.

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DISCUSSION

QUESTION BY EUGENE DECKER, CSU: Would you tell us about the Forest Service proposal for a zoological area that resulted from your field study?

REPLY BY DUNAWAY: At last week's Desert Bighorn Council meeting we reported on a proposed zoological area that will be set up for the express purpose of perpetuating the California bighorn in the Sierras. We have taken the ranges for the two largest herds, the Mt. Baxter and the Mt. Williamson herds, and we have tried to delineate the exterior boundaries to include all the ranges for these two herd units. We have proposed setting these two areas up as zoological areas. The main objective is to provide the needs of the California bighorn sheep. The major part of these two areas is located in the John Muir wilderness. The key sections of the winter ranges are located on the eastern scarp of the Sierra at the lower section of the John Muir wilderness. This amounts to slightly more than 4000 acres. We have sent this proposal into the regional office for classification of the area into a "California Bighorn Sheep Zoological Area."

One of our main administrative objectives for the area will be to limit human use. For example, we will maintain existing trails that go through these two areas at the barest minimum. We will not construct any new trails within these two units. In certain segments of each unit, human use will be definitely controlled. Use will be limited to the major trails only and camping will not be allowed.

We worked closely with Sequoia and King's Canyon National Parks on setting up these two areas. They have classified their particular areas on the western side of the Sierra crest, where some of the California bighorns find summer ranges, as Class 4 lands. This amounts to roughly 61,000 to 65,000 acres which adjoins our proposed zoological area. Once these are established I believe we will be able to have a more definite control on the human use factor on these two areas.

REPLY BY DECKER, CSU: How have the wilderness advocates, the Sierra Club, etc., reacted to this proposal which would curtail their activities?

REPLY BY DUNAWAY: Surprisingly, they are in full support. I first considered this concept about a year ago. I sent out quite a few letters of inquiry to various persons to see what they thought about setting up such a unit. We were concerned about the reaction of the Sierra Club. They are one of the main users of the John Muir Wilderness area. One of the sections of the Sierra Club, the Sierra Peak section, spend the majority of their time climbing peaks along the Sierra crest. They have what they call the Sierra Peaks badge which is their ultimate goal. They have to climb 50 peaks to get the badge. Several of these are within our proposed zoological area. Mount Williamson, for example, is one of their favorite areas and is used in their basic mountaineering training. Their base camps may have 150 to 200 persons for a weekend. Of course, we had to consider this. I met with the Sierra Peaks section twice explaining the problem of human disturbance. Surprisingly, the Sierra Peaks sections backed it 100 percent. They took the initiative and curtailed all their base camp use and all their wilderness outings in these two areas for the 1971 period. I was quite gratified when they did this. Of course, it was something they really couldn't turn down.

We held two public meetings during January 1971. One was in Bishop and one was in Pasadena. The public has universally endorsed our proposals to protect some of these real key areas for bighorn habitat. I have a file of 450 letters from the general public. Of these, only two are against our proposal. The rest fully agree to it.

THE WIND RIVER BIGHORN HERD - A NEW APPROACH TO SHEEP HABITAT MANAGEMENT

William Crump, Game Division Supervisor
Wyoming Game and Fish Commission, Lander

Wildlife managers have always recognized the importance of critical game ranges in sustaining bighorn sheep herds. A sheep herd in western Wyoming near the small town of Dubois was stabilized and substantially increased by furnishing critical winter range through a series of land acquisitions, land trades and agreements on land use with the Bureau of Land Management, United States Forest Service and private landowners. This paper is presented to point out what can be done with a sheep herd through this type of program and may be of benefit to other states and localities in planning programs to maintain or increase bighorn sheep populations.

DESCRIPTION OF AREA

The area in which the program was initiated lies along the Northeast slopes of the Wind River Mountains in West Central Wyoming. The critical sheep winter range lies between 7,500 and 10,000 feet in elevation. During mild winters, the winter ranges are extensive while they become quite limited during periods of heavy snow cover.

The principal range lies on windswept ridges and rims along the Torrey Creek and Jakey's Fork Creek drainages. These are ancestral ranges for bighorn sheep as evidenced by Indian pictographs and archaeological discoveries of tools used by Indians constructed out of bighorn sheep horns and old Indian trap sites located in the area. The lower extremes of the sheep range are characterized by low snowfall, windswept ridges, steep canyon rims for escape cover and desirable grass vegetation. An old burn on forested lands within the range occurred in 1931 and further furnished some 3,000 acres of generally open range land. The land status consists of some private lands and lands administered by the Bureau of Land Management, U. S. Forest Service and the Wyoming Game and Fish Commission.

EARLY STUDIES ON SHEEP RANGE

Several research studies were conducted in the middle 1950's to evaluate sheep populations and determine factors limiting populations. Approximately 300 to 400 sheep were using the entire range at this time. Their distribution was highly localized on one rim of Jakey's canyon with extremely limited forage available over most of the area due to competition with domestic livestock, principally horse use. Lamb survival was very low, between 5 and 10 lambs per 100 ewes. At that time, it was recommended that our department acquire by purchase some of the critical private lands lying adjacent to BLM and USFS lands.

LAND ACQUISITION PROGRAM

Two critical land purchases were made in the Whiskey Mountain area lying between Jackey's Fork Creek and Torrey Creek. The first purchase in 1954 consisted of some 1,668 acres of deeded land and some additional state lease land and isolated tracts of BLM land. This purchase was primarily made for a winter elk range. In 1957, an extremely important sheep winter range of 1,661 acres of deeded lands was purchased and added to the original lands obtained in 1954. These two acquisitions were obtained for approximately $147,000 and are worth many times that amount today if placed on the market. A series of land trades were completed in which lower lands of little wildlife value were exchanged for additional private lands adjacent to important rim areas highly preferred by sheep. One Forest Service land permittee voluntarily relinquished a horse use permit along a critical rim area. Additional sheep forage was reserved on Forest Service and Bureau of Land Management lands through a cooperative agreement and habitat management plan initiated by all three agencies -- the Wyoming Game and Fish Department, the U. S. Forest Service and the Bureau of Land Management.

Efforts to acquire and reserve winter range in this area for sheep extended over a period of some fifteen years and involved many individuals. Private landowners, and personnel of the Bureau of Land Management, United States Forest Service and Wyoming Game and Fish Department are to be commended on their efforts to reserve sufficient winter forage for bighorn sheep. These efforts resulted in land acquisitions, land trades and management of agency lands to primarily increase and benefit bighorn sheep.

COOPERATIVE AGREEMENT & HABITAT MANAGEMENT PLAN

A cooperative agreement was signed in 1969 among the Wyoming Game and Fish Department, the United States Forest Service and Bureau of Land Management. This agreement was a formal declaration of the importance of this range for bighorn sheep with the following objectives:

1. to improve the habitat and forage conditions within the area for bighorn sheep
2. to maintain the population of bighorn sheep in balance with the forage production potential of the area
3. to maintain the area in public ownership for public purposes
4. to determine and implement the most practical and economical plan of administration to eliminate unnecessary duplication of effort, travel and supervision.

A formal habitat management plan was signed in December of 1970 among the three agencies. It was prepared by a small committee of technical personnel with representatives from each agency. The plan defined the area of concern and had four principal objectives:

1. to produce optimum forage for wildlife, primarily wintering bighorn sheep
2. to obtain a better distribution of bighorn sheep over the range
3. to minimize competition among domestic livestock, other wildlife species and bighorn sheep
4. obtain a better understanding of the ecological needs of this sheep herd.

Specific items in the habitat management plan include methods of population control, fence construction for protection of range, continued production and use studies to evaluate range conditions, use and competition, timber harvest practices, plans for additional land acquisition and exchanges, access developments, temporary road closures and techniques for habitat management evaluation.

PROGRAM RESULTS

The effect of the total acquisition and management program has been impressive. Today, some 8,500 acres of winter range are primarily managed for bighorn sheep, and they have responded. Within the Whiskey Basin Winter game range, sheep have increased from an estimated 300 animals in 1955 to approximately 700 animals today with a total wintering herd estimated at nearly 1,000 animals. Lamb survival has increased from approximately 6 lambs per 100 ewes in 1956 to between 30 and 50 lambs per 100 ewes, depending on winter conditions. Table 1 illustrates the hunter harvest from this area over a fifteen-year period. A total of 555 animals have been taken through legal hunter harvest. An active program of live-trapping and transplanting of sheep was initiated to control populations. A total of 468 sheep have been removed from this range since 1956. Data on annual catch and sex and age classes of animals live-trapped are illustrated in Tables 2 and 3. Live-trapped animals have been used to re-introduce bighorn sheep into ancestral ranges or supplement existing herds in other sections of Wyoming. Through cooperative efforts, additional animals have been delivered to South Dakota, Utah and New Mexico.

Another benefit of forage improvement has been desirable changes in sheep distribution. Today there is a general uniformity of distribution over much of the winter sheep range where it previously was highly concentrated. It has been necessary to increase elk harvests in the winter range area to minimize their competition with bighorn sheep. The competition from other wildlife species, such as mule deer and moose, have been of little significance to sheep.

Additional public benefits have been achieved in this program, including fishing access to lakes and streams, improvement of forage conditions for other species of wildlife and assurance of public access to large public land areas on the adjacent Shoshone National Forest.

Table 1. Hunter Harvest of Bighorn Sheep from South Dubois Herds, 1956-1970

Year	Sex & Age Restriction	No. Permits	Harvest
1956	3/4 curl	36	20
1957	3/4 curl	48	20
1958	3/4 curl	36	14
1959	3/4 curl	40	18
1960	3/4 curl	52	22
1961	3/4 curl	64	28
1962	3/4 curl	76	34
1963	3/4 curl	132	34
1964	3/4 curl	132	41
1965	sheep either sex & 1/2 curl	136	77 (includes 8 ewes)
1966	either sex and 1/2 curl	144	77 (includes 12 ewes)
1967	1/2 & 3/4 curl	116	38
1968	1/2 & 3/4 curl	116	50
1969	3/4 curl	116	35
1970	3/4 curl	116	47
		Total	555

Table 2. Bighorn Sheep Numbers Removed by Live-Trapping - South Dubois Herds, 1956-1971

Year	Number
1956	8
1957	35
1958	26
1959	5
1960	6
1961	0
1962	0
1963	22
1964	80
1965	86
1966	71
1967	18
1968	0
1969	12
1970	76
1971	23
Total	468

Table 3. Sex and Age Classes of Bighorn Sheep Numbers Removed by Live-Trapping from South Dubois Herds, 1956-1971

Females		Males	
Lambs	78	Lambs	72
1 yr.	22	1 yr.	31
2 yr.	34	2 yr.	15
3 yr. & Older	205	3 yr.	7
Total	339	5 yr.	3
		6 yr.	1
		Total	129

Total animals removed 468

CONCLUSIONS

A habitat improvement program for bighorn sheep can and has worked on a specific bighorn herd in Wyoming. It required effort and persuasion on the part of Game and Fish Department personnel and cooperative efforts on behalf of agency personnel--but was accomplished. The net effect of available critical winter forage has resulted in substantial herd increases and higher productivity rates.

As bighorn herd populations increase, it becomes important to provide adequate methods of population control. With each increase in forage afforded by land acquisition or forage reservations, the herds increased. They also distributed themselves over the total winter range more equitably. Live-trapping and transplanting has been the method chosen in this instance to control populations and will have to be a continuing and regular practice to control herd size.

It is hoped this paper will stimulate other states and sections of Wyoming with similar situations to improve bighorn sheep populations through a course of cooperative land acquisition and forage reservation.

DISCUSSION

QUESTION BY BILL RUTHERFORD, G & F, COLORADO: When do your lamb losses occur?

REPLY BY CRUMP: We figured the major lamb losses occurred from about the first part of the winter in November and December through the spring period. We attribute much of it to predation because of malnutrition. We were getting the lambs, and they were living through the summer period. We ran weekly ewe-lamb ratio counts during the summer. We didn't notice, in this particular area at that time, the die-off in late summer that has been experienced here in Colorado.

QUESTION BY EUGENE DECKER, CSU: Where were the lambing grounds in relation to that wintering ground?

REPLY BY CRUMP: Just above the area. In this particular portion, the very steep slopes along Jakey's Fork, at what we call the Three Sisters Rocks. There are very steep cliffs here. The lambing grounds are at the very top of these cliffs. This is adjacent to the winter range and during a light winter, it would have been used as winter range.

QUESTION BY GUS SWANSON, CSU: Did you also provide as good a winter forage in the areas where sheep were released?

REPLY BY CRUMP: No. In some of the areas, for instance Laramie Peak, we have quite a good sheep habitat in an ancestral range. We have put quite a number of sheep in there. They have shown encouragement. We have had seasons in there for the last several years. We have areas where we do not have any major competition. We have some other areas in the state that need a program like this very badly. We need to coerce the Forest Service, BLM, and private landowners into a similar program. Sheep ranges are so few in relation to deer ranges or elk ranges that we hope to encourage this in other areas. I think it is a very workable program, and it is successful.

REPLY BY SWANSON: You spoke of the fire in 1931 as being so fortunate. Are you planning fires especially for management?

REPLY BY CRUMP: Well, I think Ladd Gordon handled that pretty well in his article in New Mexico Wildlife. I think he has some real strong points. We have frequently over-protected the forest as far as wildlife is concerned. I can think of nothing that is more of a wildlife desert than some of the heavily timbered forests in northern Idaho.

Incidentally, the fire of 1931 was not planned. It was the result of a whiskey-making expedition. This was back in prohibition days. Apparently, their distilling fire got away from them.

The fire did enhance the range. There is no question about that.

QUESTION BY BRUCE GILL, G & F, COLORADO: You mention your lamb-ewe ratios were about 5 to 10 lambs per 100 ewes before your acquisition program. What are your lamb-ewe ratios now?

REPLY BY CRUMP: It depends on the severity of the winter and other factors. We typically will have from 30 to 50 lambs per 100 ewes now. We will see yearlings all over that herd next winter.

QUESTION BY C. E. WILLIAMSON, USFS, COLORADO: Concerning your transplants of sheep where you put them on top of existing herds, how do you compare the success of this with transplanting to empty areas?

REPLY BY CRUMP: We have attempted in several areas to supplement populations of bighorns. We did it in the Bighorn Mountains on the Eastern Slope. We did it out at Lander where we were working with marginal herds. They have not been as successful as plants in direct ranges where sheep were absent. I don't think that you can really have a cause and effect relationship here. In most of the areas in which we have diminished in total sheep populations, the sheep are practically gone from them. We are just working with remnant herds. We have some other major factors that are keeping these populations down: timbering practices, grazing, water, things of this nature.

I don't think we have been as successful in areas where we have supplemented. We have quite a number of areas we intend to introduce sheep into.

QUESTION BY JOHN RUSSO, G & F, ARIZONA: In the past, Wyoming has contributed quite a bit to disease and parasite studies. What mortality have you experienced in your trapping?

REPLY BY CRUMP: Our mortality is relatively low, less than 3 percent. This covers the trap site and also holding in pastures for later release. There is such a thing as TLC (Tender Loving Care) which you cannot have too much of. This is not always evident. It's something that I think is important in handling any animal, lots of TLC.

QUESTION BY JOHN RUSSO: Have you had any opportunity to study some of these lambs for lung conditions and this sort of thing?

REPLY BY CRUMP: Incidentally, every sheep in Wyoming has lungworm. We don't worry about it.

QUESTION BY STEVE HAWKS, BLM, IDAHO: How did you solve the problems of sheep distribution?

REPLY BY CRUMP: We did it in several different ways. Protection from livestock and subsequent regrowth caused shifts in distribution. Removal of sheep by trapping also had an effect. We also used a progressive salting program, one of the few salting programs that worked. We moved the salt a little each year to draw sheep to other areas.

QUESTION BY JACK GRIEB, G & F, COLORADO: You have a habitat management plan for this area. What does your harvest plan look like? What are your goals and objectives?

REPLY BY CRUMP: Our harvest is going to evolve around 3/4-curl sheep. This really doesn't affect the population much. In order to control the population increase in the area, we are going to have to depend on intensified trapping and transplanting. The general public is more receptive to a trapping and transplanting program providing you get it through. This is extremely important. If you notice some of our figures, we haven't done too well in some years, depending on weather conditions, depending on how much elk bother us and other things. Our principal objective is to keep this herd at about the level we have now. We hope that with the construction of this fence this coming summer on the BLM ridge, that we will acquire another 1060 acres of land that will further re-distribute these sheep so we will have better distribution.

COMMENTS BY GUS SWANSON, CSU: I would like to comment that we had some very significant papers here that have illustrated a gradual solution to a very important need in the wildlife field--that is to have experiments. We have done so much work, of many different kinds, of the descriptive or observational type. It is very rare in the wildlife field that we have investigations which actually involve experiments. This was brought out very clearly by Peter Larkin who recently visited CSU and spoke on the future of research in the natural resources area. I would like to emphasize the privilege we have had in hearing the first paper by Lyman Nichols in which he described a real experiment, where he had control, a population which was not hunted, and two populations in similar environments which were being hunted at two different levels. This type of study in the wildlife field is so rare that it needs emphasis.

Then, I would like to congratulate Mr. Dunaway also on what looks like might be an experiment if it goes through. I would like to suggest that there be a control as well as your effort to modify your present heavy use. It would be so much more conducive to us five or ten years from now if there was a control as well as the experiment.

CLOSING COMMENTS BY EUGENE DECKER, CSU, CONFERENCE CO-CHAIRMAN

During the past two days, we have heard and discussed a series of presentations concerning a group of magnificent wild animals, the wild sheep of North America. We have learned much about the status, problems and programs related to sheep management in various parts of the continent. In several cases, the reports were encouraging, resulting from successful action programs which have increased sheep populations and/or restored them to former ranges. As a result, the recreational hunting opportunities also have improved.

However, I feel that there are two major problems encountered in wild sheep management that must be overcome. The first is that sheep are considered a "minor" game animal in many areas. We professionals must strongly influence our administrators and governing bodies to assign a high priority to the sheep and their habitat. Deer, elk and livestock now are receiving the major considerations in wildland usage. It is time that the sheep be given a fair portion of range and space resources. This must be done if the sheep are to be maintained and hopefully increased. I feel that there is no better qualified group anywhere than you here today, to accomplish this needed change.

The second problem I see is the "hang-up" of many managers and administrators that "we don't know enough yet." I contend that we already know enough about sheep to better manage them than we are now. The animals need positive action programs now, not at some indefinite time in the future. We do know many management projects that will benefit sheep. I urge all of you to implement such programs.

If we can work to overcome these problem areas, I predict that the status of the wild sheep will be improved in many areas by the time of our next conference.

APPENDIX A

Registrants - North American Wild Sheep Conference

April 1971

Agency Abbreviations: G&F, State Game and Fish Agency; BLM, Bureau of Land Management; USFS, U. S. Forest Service; BSF&W, Bureau of Sport Fisheries and Wildlife; NPS, National Park Service; CWF, Colorado Wildlife Federation; CSU, Colorado State University; USU, Utah State University

Albrechtsen, Ben
USFS
Nevada

Andrews, Arch
G&F
Denver, Colorado

Bailey, James A.
CSU
Fort Collins, Colorado

Bear, George
G&F
Fort Collins, Colorado

Bielefield, D.
USFS
Colorado

Blaisdell, James A.
NPS
Danville, California

Blumberg, R.
G&F
Lake City, Colorado

Boone, John
Denver, Colorado

Bradshaw, W. W.
USFS
Laramie, Wyoming

Braley, Joseph

Bumstead, Roger S.
USFS
Missoula, Montana

Buttery, Bob

Butts, David B.
NPS
Estes Park, Colorado

Chura, Nicholas J.
Laurel, Maryland

Clark, Vern Robert
G&F
Montrose, Colorado

Coghill, Cliff
G&F
Gunnison, Colorado

Cooley, Frank
G&F
Colorado Springs, Colorado

Crane, Don
G&F
Saguache, Colorado

Crawford, Courtney
G&F
Walden, Colorado

Crump, W. I.
G&F
Lander, Wyoming

Cruse, J.
USFS
Denver, Colorado

Dado, Joseph F.
CWF
Arvada, Colorado

Dalton, Christine
Logan, Utah

Dalton, Larry B.
USU
Logan, Utah

Decker, Eugene
CSU
Fort Collins, Colorado

Dillinger, Ken
G&F
Idaho Springs, Colorado

Dunaway, David J.
USFS
Bishop, California

Elkins, Mark
G&F
Estes Park, Colorado

Eustis, George P.
Colo. Rocky Mtn. School
Carbondale, Colorado

Evans, Robert
G&F
Denver, Colorado

Franzmann, Albert W.
Univ. of Idaho
Moscow, Idaho

Gaufin, D. M.
USFS
Ogden, Utah

Gilbert, Douglas L.
Cornell
Ithaca, New York

Gilbert, Paul
G&F
Hot Sulphur Springs, Colo.

Gill, Bruce
G&F
Kremmling, Colorado

Gordon, Paul

Gorsuch, George
USFS
Colorado

Graham, Hatch
USFS
San Bernardino, Calif.

Greene, A. F. C.
USFS
Denver, Colorado

Greiman, H.
USFS
Montrose, Colorado

Grieb, Jack
C&F
Fort Collins, Colorado

Gruell, George
USFS
Jackson, Wyoming

Hansen, Charles
NPS
Death Valley, Calif.

Hansen, Richard M.
CSU
Fort Collins, Colorado

Hardman, Billy
USFS
Colorado

Hawks, Steve
BLM
Salmon, Idaho

Hebert, Daryll
U. of B. C.
Vancouver, B. C.

Hepworth, Leland
USU
Logan, Utah

Hickey, Bill
Kamiah, Idaho

Jamsheed, Rasheed
G&F
Meshad, Iran

Jones, Dale
USFS
Albuquerque, New Mex.

Jones, W.

Keiss, Bob
G&F
Fort Collins, Colorado

Kelly, Warren
USFS
Placerville, Calif.

Kowalski, Gerald
CSU
Fort Collins, Colorado

Larsen, W.
Denver, Colorado

Larson, Parry A.
G&F
Albuquerque, New Mexico

Latimore, Robert E.
USFS
California

Lee, Philip

Light, Jerome T.
USFS
Spring Valley, Calif.

Martinez, Jerry
USFS
Gunnison, Colorado

McGlinchy, Sara
CSU
Fort Collins, Colorado

Metherell, Jake
NPS
Cedar City, Utah

Miller, Robert E.
Fitzsimons Hospital
Denver, Colorado

Monson, Ruth
CSU
Fort Collins, Colorado

Morris, Dale

Morris, A.
CSU
Fort Collins, Colorado

Morton, Allen
USFS
Wyoming

Mullen, Larry
USFS

Mumma, John
USFS
Eagar, Arizona

Myers, Gary
G&F
Denver, Colorado

Neider, David
McCall, Idaho

Newman, John

Nichols, Lyman
G&F
Anchorage, Alaska

Oldenmeyer, John
BSF&W
Denver, Colorado

Olson, Perry D.
G&F
Colorado Springs, Colo.

Pillmore, Richard E.
BSF&W
Lakewood, Colorado

Post, George
CSU
Fort Collins, Colorado

Putnam, Jack
Museum of Nat. History
Denver, Colorado

Radtke, Robert E.
USFS
Hales Corners, Wisc.

Reichert, Chuck
G&F
Meeker, Colorado

Riger, Eleanor
Tomorrow Entertainment
New York, N. Y.

Roper, Laren
G&F
Kremmling, Colorado

Russo, J. P.
G&F
Phoenix, Arizona

Rutherford, William H.
G&F
Fort Collins, Colorado

Sandfort, W. W.
G&F
Denver, Colorado

Scheffler, Eike G.
G&F
Edmonton, Alberta, Canada

Schuett, Walt
G&F
Monte Vista, Colorado

Senteney, Paul
USFS
Durango, Colorado

Shepherd, Harold R.
G&F
Fort Collins, Colorado

Simmons, Norman M.
Canadian Wildlife Service
Fort Smith, N. W. Territory

Smith, Jack
USFS
Colorado

Spillet, Juan J.
USU Coop. Unit
Logan, Utah

Steinhoff, H.
CSU
Fort Collins, Colorado

Stevens, D.
NPS
Estes Park, Colorado

Swanson, Gustav A.
CSU
Fort Collins, Colorado

Swope, Harold M.
G&F
Fort Collins, Colorado

Thorne, Tom
G&F
Laramie, Wyoming

Tully, Bob
G&F
Denver, Colorado

Verner, Jon E.
USFS
Pueblo, Colorado

Von Barby, Hans W.
CWF
Evergreen, Colorado

Wallmo, O. C.
USFS
Fort Collins, Colorado

Wevers, Victor
USFS
Colorado

Williamson, C. E.
USFS
Colorado

Wills, Dale
USFS
Fort Collins, Colo.

Woodward, Harry R.
G&F
Denver, Colorado

Woolf, Alan
Rachelwood
New Florence, Pa.

Yoakum, James D.
BLM
Reno, Nevada

Zbylski, Joseph R.
U. S. Army
Denver, Colorado

Zgainer, Mike
G&F
Del Norte, Colorado

ZoBell, Rex S.
BLM
Cheyenne, Wyoming

APPENDIX B

NORTH AMERICAN WILD SHEEP CONFERENCE PROGRAM

April 14th, 1971

PANEL: MANAGEMENT AND CURRENT STATUS
Moderator, Warren E. Kelly (Desert Bighorn Council) Wildlife Biologist, Eldorado National Forest, Placerville, California

The Dall Sheep and its Management in Alaska. Lyman Nichols, Regional Game Biologist, Alaska, Department of Fish and Game, Anchorage

The Desert Bighorn in Arizona. John P. Russo, Chief of Game Management, Arizona Game and Fish Department, Phoenix

Bighorn Sheep Management in New Mexico. Parry A. Larson, Area Game Manager, New Mexico Game and Fish Department, Albuquerque

The Bighorn Sheep in Colorado. Wayne W. Sandfort, State Game Manager and William H. Rutherford, Wildlife Researcher, Colorado Division of Game, Fish and Parks, Denver

PANEL: PHYSIOLOGY AND PATHOLOGY
Moderator, Dr. Douglas L. Gilbert, Professor of Wildlife Science, Cornell University, Ithaca, New York

Development of a Protective Bacterin Against Pasteurellosis in Bighorn Sheep. Peter Nash, Graduate Assistant, Colorado State University

Effects of Protostrongylus stilesi in Bighorn Sheep. Sara McGlinchy, Graduate Research Assistant, Colorado State University

The Life Cycle of Protostrongylus stilesi in Bighorn Sheep. Ruth Ann Monson, Graduate Research Assistant, Colorado State University

Application of Physiologic Values in Bighorn Sheep. Dr. Albert W. Franzmann, DVM, Research Fellow, Idaho Cooperative Wildlife Research Unit, University of Idaho, Moscow

A Die-off Due to Pneumonia in a Semi-captive Herd of Bighorn Sheep. Dr. Tom Thorne, DVM, Research Veterinarian, Game and Fish Research Laboratory, Wyoming Game and Fish Commission, Laramie

The Pneumonia Complex in Bighorn Sheep. Dr. George Post, Department of Fishery and Wildlife Biology, Colorado State University

BANQUET - "*Wild Sheep Studies in Iran* ." Eugene Decker, Assistant Professor, and Gerald J. Kowalski, Graduate Research Assistant, Department of Fishery and Wildlife Biology, Colorado State University

April 15th, 1971

PANEL: RESEARCH TECHNIQUES.
Chairman, H. B. Mitchell (Northern Wild Sheep Council) Regional Wildlife Biologist, British Columbia Fish and Wildlife Branch

Estimating Dry Weight and Plant Composition of Wild Sheep Diets. Dr. Richard M. Hansen, Department of Range Science, Colorado State University

An Inexpensive Method of Marking Large Numbers of Dall Sheep for Movement Studies. Norman M. Simmons, Wildlife Biologist, Canadian Wildlife Service, Ft. Smith, Northwest Territory

The Use of M-99 Etorphine and Acetylpromazine in the Immobilization and Capture of Free Ranging Bighorn Sheep. Dr. Tom Thorne, DVM, Research Veterinarian, Game and Fish Research Laboratory, Wyoming Game and Fish Commission, Laramie

Analysis of Winter Habitat by Multispectral Remote Sensing. Ralph R. Root, Graduate Research Assistant, Department of Watershed Sciences, Colorado State University

PANEL: MANAGEMENT PROBLEMS, PROCEDURES AND NEEDS
Chairman, Jack R. Grieb, Chief of Game Research, Colorado Division of Game, Fish and Parks, Fort Collins

An Ecological View of Bighorn Habitat on Mt. San Antonio, California. Jerome T. Light, Jr., Wildlife Biologist, Cleveland National Forest, San Diego

Habitat Management for the Desert Bighorn. Jim Yoakum, Wildlife Biologist, Bureau of Land Management, Reno

Human Disturbance as a Limiting Factor of Sierra Nevada Bighorn Sheep. David J. Dunaway, Wildlife Biologist, Inyo National Forest, Bishop, California

The Wind River Bighorn Herd, a New Approach to Sheep Habitat Management. Wm. I. Crump, District Game Division Supervisor, Wyoming Game and Fish Commission, Lander

Presentations of "Jonas Bighorn Trophy" for outstanding paper. Jack H. Jonas. Denver Jonas Brothers