DESERT BIGHORN COUNCIL

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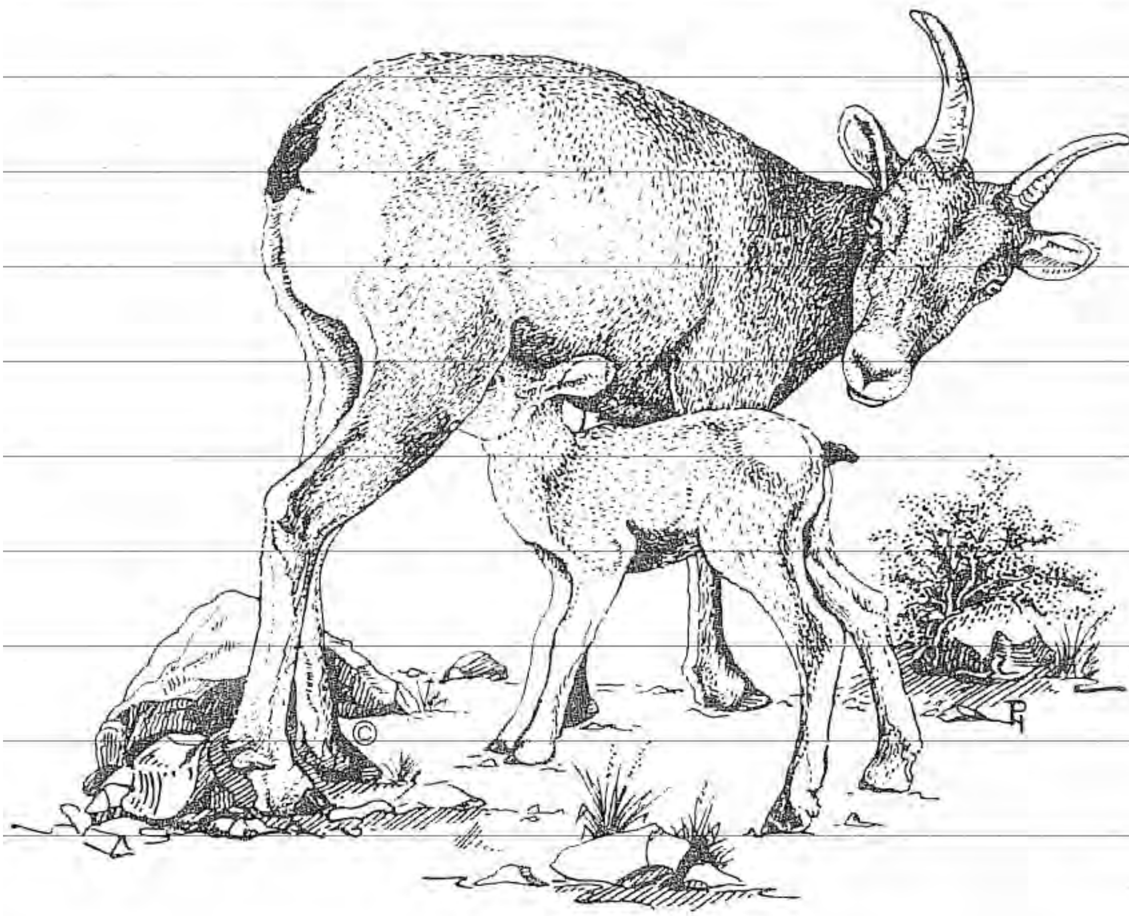
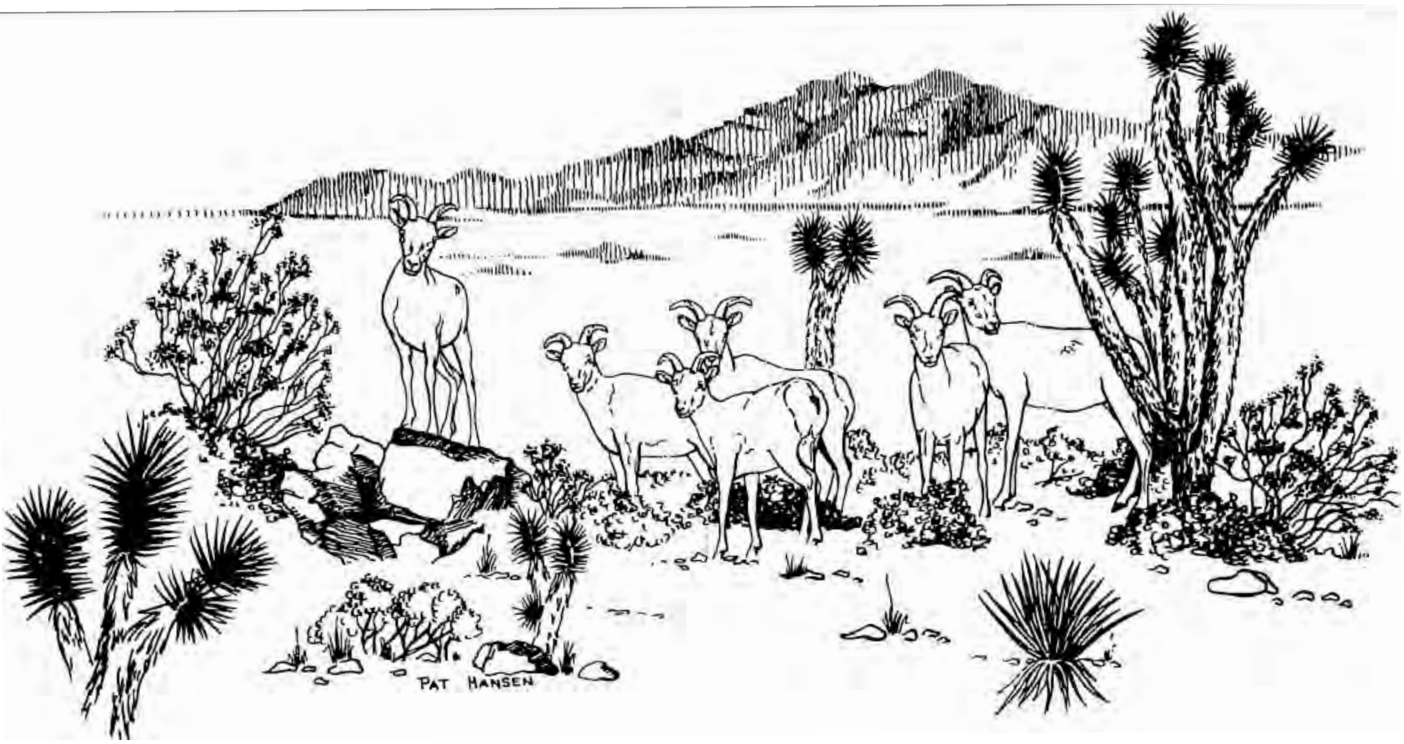


$5.00

1982

Desert Bighorn Council
1982 Transactions

A Compilation of Papers Presented
At the 26th Annual Meeting,
April 7-9, 1982, Borrego Springs, Calif.



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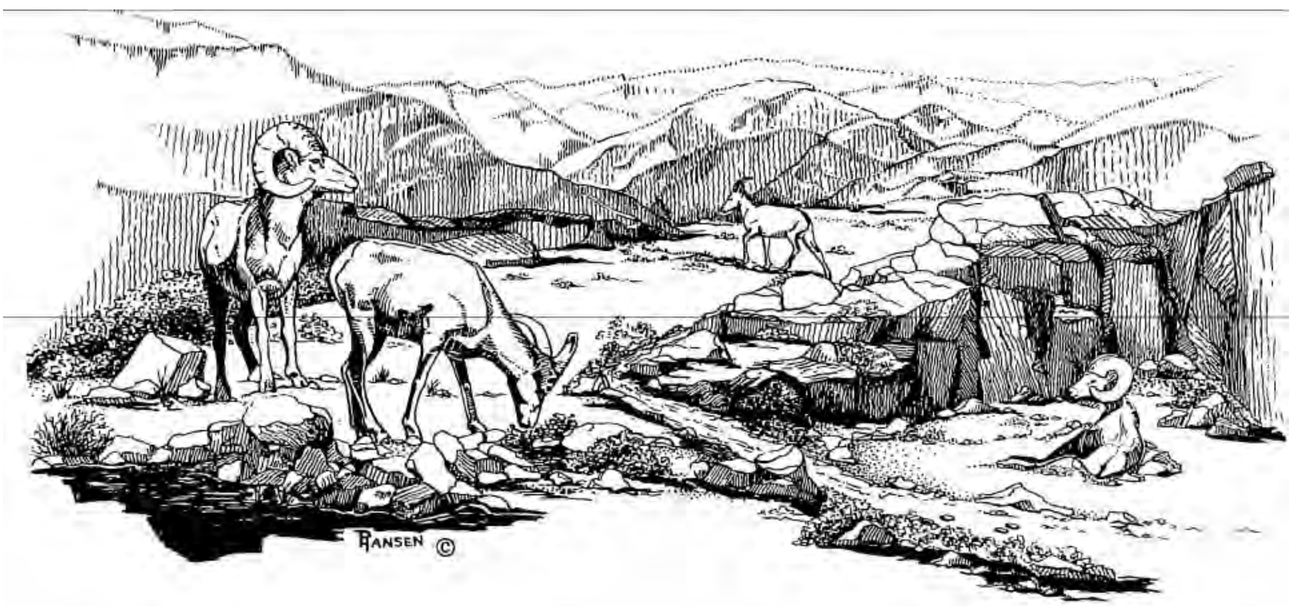

Bighorn Illustrations by Pat Hansen

Typesetting & Layout by Shersten Zoller

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1958	Yuma, Arizona	Gale Monson and Warren Kelly	
1959	Death Valley, California	M. Clair Aldous	Fred Jones
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1961	Hermosillo, Sonora, Mexico	John Van den Akker	Ralph Welles
1962	Grand Canyon, Arizona	James Blaisdell	Charles Hansen
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1964	Mexicali, Baja Calif., Mexico	Rudolfo Hernandez Corzo	Charles Hansen
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1966	Silver City, New Mexico	Cecil Kennedy	John P. Russo
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1968	Las Vegas, Nevada	Ray Brechbill	John P. Russo
1969	Monticello, Utah	Ralph and Buddy Welles	W. Glen Bradley
1970	Bishop, California	William Graf	W. Glen Bradley
1971	Santa Fe, New Mexico	Richard Weaver	Tillie Barling
1972	Tucson, Arizona	George W. Welsh	Doris Weaver
1973	Hawthorne, Nevada	Warren Kelly	Doris Weaver
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1976	Bahia Kino, Mexico	Mario Luis Cossio	Lanny Wilson
1977	Las Cruces, New Mexico	Jerry Gates	Peter Sanchez
1978	Kingman, Arizona	Kelly Neal	Peter Sanchez
1979	Boulder City, Nevada	Bob McQuivey	Peter Sanchez
1980	St. George, Utah	Carl Mahon	Peter Sanchez
1981	Kerrville, Texas	Jack Kilpatric	Peter Sanchez
1982	Borrego Springs, California	Mark Jorgensen	Rick Brigham

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1960 Ralph and Florence Welles, U.S. National Park Service, Death Valley, California
1962 Oscar V. Deming, U.S., Bureau Sport Fisheries and Wildlife, Lakeview, Oregon
1965 John P. Russo, Arizona Game and Fish Department, Phoenix, Arizona
1966 Charles Hansen, U.S. Bureau Sport Fisheries and Wildlife, Las Vegas, Nevada
1968 Steve James, Jr., Fraternity of the Desert Bighorn, Las Vegas, Nevada
1969 M. Clair Aldoux, U.S. Bureau Sport Fisheries and Wildlife, Fallon, Nevada
1974 The Arizona Desert Bighorn Sheep Society, Inc.
1978 Fauna-Silvestre, Mexico City, Mexico
1979 Robert P. McQuivey, Nevada Dept. of Fish and Game, Las Vegas, Nevada

HONOR PLAQUE:

1968 Nevada Operations Office, Atomic Energy Commission, Las Vegas, Nevada
1969 Pat Hansen, Bighorn Illustrator Specialist, Death Valley, California
1972 Inyo National Forest, Bishop, California
1973 Lydia Berry, Clerk-Stenographer, Desert National Wildlife Range, Las Vegas, Nevada
1979 Jim Blaisdell, National Park Service, Seattle, Washington
1980 Society for the Conservation of Bighorn Sheep, Upland, California
1981 Dr. Thomas D. Bunch, Dept. Animal, Dairy, and Veterinary Science, Utah State Univ., Logan
New Mexico Dept. of Game and Fish
Dr. Grant Kinzer, New Mexico State University
1982 Maurice 'Bud' Getty, California State Parks, Sacramento CA
DBC Ewes

AWARD OF EXCELLENCE:

1975 Gale Monson, Desert Museum, Tucson, Arizona; Lowell Sumner, Glenwood, New Mexico

REVISED PROCEDURES FOR CAPTURING AND RE-ESTABLISHING DESERT BIGHORN

Lanny O. Wilson and Charles L. Douglas, Editors
and the Technical Staff, Desert Bighorn Council

New techniques developed since 1973 necessitated a revision of the guidelines for capturing and re-establishing desert bighorn (Wilson et. al, 1973, which were adopted by the Technical Staff of the Desert Bighorn Council, and circulated upon request to agencies or interested persons.

These revised procedures were developed after reviewing and analyzing virtually all successful and unsuccessful desert bighorn capture and re-establishment programs to date. By following these guidelines, capture and re-establishment programs should avoid the problems of unsuccessful operations and benefit from those that were successful.

RATIONAL FOR CHOOSING BETWEEN DIRECT RELEASE OR RELEASE INTO AN ENCLOSURE

The rising cost of equipment, supplies and manpower necessitates that agencies select the most cost-effective method for re-introductions of desert bighorn. There are 3 choices: (1) a release directly into the selected habitat, (2) a release into a permanent enclosure, or (3) release into a temporary enclosure. Each method has its advocates, and each has inherent problems.

The original Guidelines for capture and re-introduction of bighorn advocated that transplanted bighorn be released into an enclosure. It was felt that bighorn need to become familiar with a new habitat, or with each other, and required "imprinting" on water sources and escape terrain. Enclosures also have been used as a means of propagating bighorn. When only a limited number of animals can be transplanted, an enclosure serves to allow reproduction and increase in herd size prior to release into a new habitat.

Reintroductions of desert bighorn have become more frequent since the early 1970s, and since then considerable progress has been made in improving means of capture, in better immobilization drugs, and in handling and treatment procedures. In addition, extensive experience has been gained with groups of bighorn transplanted into enclosures and into direct release situations.

Enclosures have the following positive attributes:

1) An enclosure permits bighorn to become familiar with a given location and, thereby, may deter widespread dispersal when they are released.

2) A permanent enclosure provides an area where bighorn can be propagated.

3) A permanent enclosure provides a space where predators can be removed and largely excluded.

4) An enclosure allows animals to be studied.

5) A temporary enclosure is more cost effective than a permanent structure. The materials also can be used again at another site.

Permanent enclosures have the following negative attributes:

1) Bighorn tend to become concentrated at densities far above the highest densities known in nature (7 bighornlsq. mi.).

2) Dense concentrations of bighorn tend to have poor survival and to reproduce below optimum levels, even with supplemental feeding.

3) The results of extended confinement indicate stress is almost certainly operative, although it has not been studied and evaluated. Pen raised bighorn appear to be less robust and more susceptible to capture stress than wild sheep.

4) Diseases and injuries are commonplace, and may decimate the herd (e.g. Black Gap, Zion, Lava Beds).

5) Predators may gain entrance and kill animals that cannot escape them (e.g. Black Gap, Hawthorne).

6) Young born in an enclosure probably will not learn predator avoidance behavior. (e.g. 70 of 80 bighorn released from the Black Gap enclosure were killed by mountain lions, Winkler, 1977).

7) Predators often become more of a problem than they would be under more natural conditions. Predator control measures often are required during enclosure of sheep and prior to their release.

8) Fencing materials, maintenance of the enclosure, and personnel involvement require a large financial investment. A large enclosure constructed by Arizona Dept. of Fish and Game in the Virgin Mtns. cost about $80,000.

9) Permanent enclosures have not been demonstrated to be cost effective. In some cases, keeping bighorn in an enclosure has not resulted in a viable reintroduction.

Direct release of bighorn into selected habitat has the following advantages:

1) It is expedient and cost-effective.

2) Stress is reduced by returning bighorn to natural habitats within a short period of time after capture.

3) Young born in the wild mature with predators being part of their experience and, thereby, develop proper avoidance strategies.

4) Predator control measures may not be required.

5) Diseases and minimal reproduction do not result from overcrowding.

6) Various expenses such as predator control, exclosure construction and maintenance, supplemental feeding, and treatments for disease and injury are reduced.

Direct release of bighorn has the following disadvantages:

1) Although bighorn usually stay within the general vicinity of a release site, or eventually return to it, exploratory wanderings may result in their selecting other areas, which could lead to fragmentation of the group.

2) If bighorn are not equipped with radio-telemetry collars and monitored after release, it is almost impossible to know the outcome of the transplant. Exploration of a new area by bighorn may make them difficult to locate even if they have radio collars.

3) If transplanted bighorn die, they often are difficult to locate, and it usually is not possible to determine the causes of death.

4) A larger number of bighorn (i.e. 20 or more) is necessary for direct release into suitable habitat than is required for an enclosure (12).

There is evidence that direct release of bighorn into suitable habitat has many positive attributes. More state fish and game agencies are turning to direct release because of its cost effectiveness in relation to enclosures. Nevada, California, Arizona and Idaho recently have used this method. Nevertheless, in some cases enclosures may be chosen for propagation because of special circumstances. Temporary enclosures have been used with success in New Mexico; such enclosures avoid the high costs of permanent structures while incorporating many of the benefits of direct release and enclosure situations.

SITE SELECTION

It is vital to determine whether potential reintroduction sites have or have not supported bighorn in the past. If there is no evidence of historic bighorn use, the habitat probably is unsuitable and a transplant would be unsuccessful. Old documents, reports, and journals of early pioneers may document the historic bighorn ranges, and should be thoroughly researched. Historic use areas generally are known, but the full extent of seasonal ranges usually is not well documented. For example, summer ranges adjacent to water sources where desert bighorn tend to concentrate are usually much better known than winter or intermediate ranges. One must be careful not to conclude that an historic use area was occupied throughout the year when, in fact, it may have been occupied only seasonally.

To the degree possible, factors responsible for the decline or loss of an historic population(s) should be documented and then it should be determined if these factors still prevail. Factors responsible for declines or extirpation of desert bighorn populations include occupancy of the range by miners or livestock, diseases and parasites introduced by domestic livestock, changes in vegetation resulting from livestock grazing and climatic changes, barriers to migration such as net wire fences, road construction, canals, urbanization, loss of water sources and illegal hunting. Some diseases, such as contagious ecthyma, can remain dormant in an area for as long as 20 years (Lance 1980). Bighorn should not be penned nor released on land being grazed by domestic livestock. If livestock graze adjacent land, a buffer zone should intervene between those lands and sheep habitat.

It must be determined whether dominant plant communities that existed in the historic area(s) are the same that exist today or whether such vegetation could be re-established. Most bighorn populations are associated with "open" plant communities in areas of climax or subclimax vegetation (Geist 1971). Subclimax communities resulting from fires or other natural disturbance often are preferred. Plant communities can be changed by heavy livestock grazing or protection from fire, e.g. sagebrush (Artemisia spp.), mesquite (Prosopsis spp.), junipers (Juniperus spp.) or other shrubs can invade or become more dense, thereby changing plant species composition and density. Such areas may be restored to more natural conditions by prescribed burning or spraying. However, in some cases, topsoil may have been lost to the extent that climax plants could not become re-established even if the invading species were eliminated.

iong-term cooperative agreements which define management practices between the land and wildlife administrators must be secured to insure the probabilities of successful re-establishment and the long-term welfare of the re-established bighorn population. Cooperative agreements are mandatory when one or more entities are involved in management of the habitat and another is responsible for management of wildlife. Cooperative agreements should address livestock grazing policy on lands adjacent to proposed release sites, particularly if an enclosure is considered. The possibilities of misunderstandings will be reduced if management responsibilities of all agencies are clearly defined. This is particularly important where personnel changes within agencies may occur.

SELECTION OF AGE CLASSES TO BE TRANSPLANTED

Theoretically, animals having the greatest reproductive potential and the longest life expectancy, are optimum for transplanting. Young sheep have a longer life expectancy, are easier to handle, and are more adaptable to change than older animals. Young bighorn immobilize faster, and are less likely to go into shock than older animals. They usually quiet down faster when placed with other bighorn and, therefore, are less likely to be injured. Although young animals may enhance the success of a transplant, the effects on the parent population also must be considered.

Ewe Selection. Ewes two years old and older are almost impossible to age accurately in the field. Removal of old ewes from a herd has the least effect on the parent population (Leslie 1980). Removing young ewes has the greatest negative effect on the parent population, but is optimum for the transplanted group. A selection of random age groups is intermediate between the extremes, and serves to provide mature ewes for young ewes to learn from, while conserving the parent population. A random selection of all ewe age classes is recommended as being the best strategy for a transplant group.

Ram Selection. Rams usually can be aged accurately by counting horn rings. Young rams are preferable to older rams for transplants because they tend to stay with the ewes and not wander. It also has been shown that yearling rams are capable of fertilizing receptive ewes. Selection of young rams avoids problems encountered with transporting old rams or with holding them in a mixed group.

Group Selection. Generally all bighorn for a transplant should be captured from one herd. Bighorn are highly social animals that tend to associate with others in small groups. Recent studies with marked bighorn have shown that the only lasting social grouping among desert bighorn is the ewe-lamb pair. Other bighorn move freely between groups and, thus, there is little group integrity over time (Leslie 1977, Leslie and Douglas 1979, Chilelli and Krausman 1981, J. Witham, pers. comm). Considerable effort should be made not to separate ewe-lamb pairs.

If individuals from different herds are gathered into a larger transplant group, a temporary enclosure may be called for until the bighorn become familiar with one another. Otherwise, a release into the habitat might result in fragmented groups. There is not unanimity of opinion on this point, nor is there adequate data to support any opinion.

A minimum of 12 bighorn should be released in enclosures and a minimum of 20 in areas of extensive habitat, with a ratio of 1 ram per 3 ewes. These recommended numbers are based on results of bighorn releases throughout the Rocky Mountain Region. Releases of 20 or more bighorn have been the most successful.

The 1 ram to 3 ewe ratio helps reduce probabilities of inbreeding in the initial release. More than 1 ram to 3 ewes could result in excessive fighting between rams, or undue harassment of ewes by rams during the breeding season. In fall captures, adult ewes will have been bred, and will contribute lambs of both sexes to the group.

Approximately every 5 years during the first 20 years of a re-establishment program, an adult ram of the same subspecies but from a different population should be released with the re-established population. Inbreeding can become a detrimental factor in the long-term welfare of a population, especially if it remains small (fewer than 50 animals); thus a population's base should be large enough to insure genetic vigor.

RELEASE SITE OR ENCLOSURE SITE SELECTION

The release site should provide a variety of vegetation types and topography that contains broken rocky outcrops for escape and lambing. Water is the major limiting factor in desert bighorn habitat; therefore direct release should be made as close to permanent water and rugged escape terrain as possible. Experience in Nevada has shown that direct released bighorn quickly find and use most water sources within the release area (Bob McQuivey, pers. comm.). A temporary or permanent enclosure should contain a permanent water source. In some cases, local conditions may dictate that the water source be a man-made guzzler.

Enclosures should be located on high ground with good drainage, having breaks in terrain consisting of rocky outcrops and areas of cover. Bighorn acclimate to new habitats more readily if they have areas of steep, rocky outcrops (escape terrain) into which they can retreat when alarmed. Escape areas probably will be used as lambing areas, because they give bighorn a sense of security.

Areas of flat or rolling terrain normally do not have rocky outcrops. Thus, the bighorn's hooves may grow too long and sore feet and/or infections can result. This occurred with captive bighorn at the Desert Game Range.

Ewes of many wild bighorn populations, particularly Rocky Mountain bighorn and some desert bighorn, have shown a high fidelity to lambing areas (Wilson 1968; Thorne et al. 1979; Sandoval, pers. comm.). Therefore, if a paddock area with good lambing ground characteristics is selected, it could remain a focal point for the population after the paddock fence has been removed.

In more northern areas, where seasonal or elevational distributions may change during the year, bighorn should be introduced in an enclosure located on winter range having rough, precipitous terrain (lambing grounds). The selected winter range should be free from concentrations of other large ungulates, such as deer, elk, cattle, domestic sheep, horses, burros, etc. Competition for food, water, cover and space could be critical.

Clumps of brush or trees, rock ledges and/or rock overhangs can afford protection and thermal cover to bighorn during storms and periods of extreme cold or heat.

Enclosure sites should provide natural year-round forage, but supplemental feeding and salting may be necessary. Desert bighorn must have natural year-round forage. It also is important to keep animals in prime condition to reduce the potentiality of disease and/or parasite infections.

Captive bighorn are not able to move to different locations during periods of stress, such as droughts or periods of excessive cold and/or heavy snowfall. Therefore, supplemental feeding should be considered in a re-establishment plan. Supplemental foods should closely approximate the bighorn's native foods insofar as possible.

Salt should be made available as enclosure areas may be deficient in one or more minerals or trace elements. Selenium often is deficient in young volcanic soils and in other areas. The lack of selenium can result in white muscle disease, myopathy and reduced immune response (D. Jessup, pers. comm.). Salt containing trace elements and minerals are best. Fifteen captive bighorn in Texas used 50-60 pounds of Moorman mintrate salt a month. Lamb mortality did not occur after salt was placed in the enclosure (Hailey 1962, 1964). Salt blocks may be a factor in spreading sore mouth or other diseases, therefore it is preferable to put granulated salt directly onto the ground, simulating a natural mineral lick.

Enclosures should be constructed of 2 x 4 inch welded wire, a minimum of 8 feet in height and encompass an area of 640 acres for each 25 bighorn. Welded wire is superior to woven wire and will reduce injuries to bighorn. Some bighorn ewes have died as a result of catching their horns in woven wire.

In potential wilderness areas or areas where man-made intrusions are not wanted, temporary enclosures have proven successful. Creation of a permanent holding facility can be highly visible; therefore, a temporary paddock constructed from sections of nylon nets could he developed as was done in the Big Hatchet Mountains of New Mexico (Sandoval, pers. comm.). The enclosure must be checked twice daily to release any animal(s) that become entangled in the netting. The larger the enclosure, the greater the probability the enclosed bighorn will retain their natural behavior and wild instincts.

All predators should be removed from an enclosure prior to introducing bighorn, and predators should be controlled in the area where bighorn are confined. The bottom of the fence should be buried, or if the ground is too rocky, a heavy wire stretched along the bottom on which to fasten the fencing. Electric wires (2 or more) should be installed about 12 inches out and at a right angle to the top of the woven wire. These precautions resulted in 80 bighorn being produced from an original 6 in an enclosure in Texas. No predation occurred upon the enclosed bighorn during a 14-year period. However, when the bighorn were released and a predator control program was not maintained, cougars killed approxirntely 70 of 80 sheep (Winkler 1977).

Electric wire(s) placed in the recommended position usually will keep mountain lions and bobcats from climbing over the fence. Burying the bottom of the fence reduces the probability of predators digging under it. Three desert bighorn were killed by mountain lions and 2 from unknown causes in a two-day period in an enclosure in Hawthorn, Nevada (Tsukamoto et al. 1970).

If rock jacks need to be constructed to help support fences, design the fence so that the rock jacks are outside the enclosure. Larger bighorn, especially rams, will use the rock jacks to jump out of the enclosures.

Water developments in enclosures should be designed so that water can be regulated. This will ensure that watering troughs can be maintained and cleaned to reduce disease vectors; in addition, water can be manipulated to capture bighorn for treatment or release. For example, oral medication such as tetracycline powder to help prevent pneumonia can be added to water that can be regulated. Medications administered through water reduce stress to animals as compared to capture and treatment.

All water sources should be cleaned twice yearly to reduce the incidence of disease and/or parasites.

TRAPPING TECHNIQUES

Watering sites are the only places where desert bighorn can be located with certainty. However, winter baiting has been used successfully to trap desert bighorn. One kg. of apple pomace per bighorn in combination with salt and alfalfa is used. Usually a 2-3 week period is sufficient to "hook" the animals on the bait (Schmidt et al. 1978).

Pomace from a cider mill is best, but if pomace is not available, mashed apples can be used in the following manner: Line a pit with plastic so that the juice can be drained. Pomace is placed in the pit, compacted to drive out the air, and the top of the pit is sealed with plastic--the fuller the pit the better. Daytime temperatures in the range of 10-20" C is best. Do not open for 2 weeks. Pomace will spoil in 2 days if exposed to the air. Thereafter, remove as needed. Pomace also can be bagged and frozen (Schmidt et al. 1978).

A trap having a total outside dimension of 100 ft. is about the smallest that can be used. Rectangular or semi-circular configurations can be used, depending on the site. If a drop net is used, a 70 x 70 ft. square net is recommended. Cutting the drop net into 4 quarters and fastening them together with snaps facilitates transport of the net and removal of bighorn from it.

In most cases, desert bighorn will be suspicious of a drop trap or new structures in their habitat. Therefore, a3-4 week adjustment period is required.

Traps should be constructed of posts and nylon netting, with 3 to 4 in. mesh, that is at least 8 ft. high. The Nevada Dept. of Wildlife uses a drop-gate trap that has a peripheral net suspended by metal poles placed so that bighorn cannot strike them (Cooper and McLean 1974). Safety of the animals must be a primary concern in trap design. Use of nylon netting reduces chances of injury, yet easily contains large rams.

Traps with automatic gate closing devices should be attended at all times. Trapped bighorn may panic and die of stress if not promptly removed.

Pull or drop gates should be used with permanent traps. Drop nets activated by a remote radio control or manual trip device are recommended. Such gates are simple to construct and are less likely to jam than other types. The pull-type gate can be used as a cutting gate to release unwanted animals. The drop gate can be activated by a manual trip device or activated by a solenoid.

Electromagnetic helicopter releases have been developed for drop nets that make no sound (Hibler, pers. comm.). These are preferred to blasting caps for releasing the net.

Drive net traps comprised of 14 in. mesh in 400 ft. x 9 ft. sections can be used to capture desert bighorn. Nylon netting stretched between 2 stationary end poles, and supported by A-frame poles at 10-15 ft. intervals has been used successfully in California and New Mexico (Beasom et al. 1980). Bighorn are driven into the net via helicopter. The net collapses upon contact, and entangles the bighorn. Smaller mesh netting placed behind the larger mesh facilitates capture of lambs. It generally takes 2 people for every 100 ft. of net to subdue entangled bighorn. One advantage of the drive net is that it can be removed and/or set up in about 30 minutes. Other advantages are that no baits need to be prepared and selected animals can be captured. If animals must be removed from the area to transport vehicles, they should be sedated while entangled in the net. Rompun and Atropine is safe and effective for short-term sedation.

No more than 25 bighorn should be trapped at one time. Schmidt et al. (1978) state that an experienced five-man crew can handle up to 25 animals. Smaller numbers should be captured if samples are to be taken. A small or inexperienced crew should not attempt to catch or handle more than 8-10 bighorn.

When drop nets are used, one person should be assigned to watch for badly entangled animals. Such animals should be removed first. Bighorn lying on their backs should be righted immediately. Pulling or positioning of bighorn should be done by the hind legs, not the head.

HELICOPTER AND CAPTURE GUN OR NET GUN CATCHING TECHNIQUES

Helicopters with adequate power are necessary for flying in mountainous terrain or deep canyons. The Bell Jet Ranger or Hughes 500 are adequately powered helicopters. The B-1 Bell helicopter does not have the required margin of safety and performance for such work. The door of the helicopter should be removed on the passenger side for the gunner.

A helicopter pilot highly experienced in mountain flying is mandatory. The inherent hazards in such flying warrant using only the best pilots available.

Capturing of bighorn usually should not be considered when wind velocities exceed about 5 knots, even though larger helicopters, such as the Hughes 500, can be navigated in winds exceeding 15 knots.

To reduce weight, only the pilot, the gunner, and I assistant should be allowed in the helicopter during capture flights.

The Palmer Powder rifle or the CO_2 rifle with open sights loaded with the designated charge for the projectile syringe, and fired at about a 45° angle has proven effective. Dart syringes are advanced in the barrel to the rifle's forearm to decrease velocity when a powder rifle is used. CO_2 rifles should contain new cartridges and should not be allowed to become very hot or very cold. The Paxarm rifle is preferred by some researchers because the charge can be adjusted quickly, and it is not affected by temperature changes.

Sheep tend to stop with their rumps or sides toward the helicopter if not approached too closely. Aim to hit about half-way down the rump where the white patch and brown fur meet. The hip or the rump are the best areas for dart injections, although high hits could strike the pelvis, and low hits could embed in the leg. Shooting at about a 45" angle has proven best in obtaining a good hit while reducing possible injury to the animal. Shooting should be done from distances of no more than 25-30 ft. Shooting at running bighorn increases chances of hitting them in the head, neck or flank, which may result in serious injury or death. Shooting beyond the rotor wash should be avoided, because dart trajectory is adversely affected and is unpredictable.

A projectile syringe with a ¾-in. long barb should be used. Half of the barb should be removed to help reduce tissue damage. Points longer than ¾-in. are more prone to plug, cause greater tissue damage, and are more likely to hit bone (Day 1969).

The following drugs and dosages have proven effective in immobilizing bighorn under field conditions:

1) 2 mg. M-99 (Etorphine) Potent narcotic
   15 mg. Haloanisone - Nuroleptic tranquilizer
2) 2.2 mg. M-99 (Etorphine) for ewes, 2.5 mg. for rams
   2.5 mg. Atropine - Parasympatholytic agent
   20 mg. Azaperone
3) 3.5 mg. M-99 (Etorphine)
   20 mg. Azaperone
   (R. Remington, pers. cornm.)
4) 2.4 mg. M-99 and 20 mg. Xylazine HCL (Rompun) for adult desert rams
   2.0 mg. M-99 and 20 mg. Xylazine HCL for adult ewes
   (Sandoval, pers. comm.)

5) Adult rams 5.0 mg. M-99 and 10 mg. Rompun when rams are 180-200 lbs. of body weight (Jessup, pers. comm.)

Xylazine HCL given intravenously (i.v.) or intramuscularly (i.m.) has been used to calm bighorn captured in a drop net. Multiple dosages of Xylazine HCL should not be given, because it depresses respiration and causes fast, shallow heartbeats. Dopram, in large doses (5 cc i.v., 5 cc i.m.), apparently helps reverse a "Rompun hangover" in bighorn rams. Azaperone is safer, and has not caused problems in multiple darting when used with M-99. Mortality is more likely to occur with low dosage of M-99 than with high dosages (R. Remington, pers. comm.). Atropine, given at 0.4-0.6 mg/110 lbs. body weight, has been used successfully when bighorn are captured and moved via horseback.

Experienced help in drug dosages and shooting should be sought when possible. Drug tolerances may vary within individuals, which complicates knockdown times and drug effectiveness.

Bighorn should never be run excessively or when temperatures exceed 62" F. If possible, dart the desired animal immediately after it is sighted and before it begins to run. Chasing or hazing bighorn excessively by helicopter increases the chance of shock and capture myopathy. Higher temperatures increase the chances of heat stress and death.

If necessary, darted bighorn can be approached from the same elevation or from above, and slowly herded to lower or more level areas. If the animals can be herded into more gentle terrain, the chances of injury are reduced. It is important to remember that darted bighorn have depressed heart and respiration rates. Undue herding or harassment is hazardous for bighorn. Ewes and lambs generally stop running when they reach a vertical cliff. Rams generally run short distances and try to hide. Care must be taken not to herd bighorn into fences or other obstacles that could result in their being injured.

Drugged bighorn should be approached on foot from the direction most hazardous to them in the event they should try to move. Carry a lariat and a loaded "Cap-Chur" gun when approaching immobilized bighorn; or, let one man out of the helicopter to capture and blindfold an immobilized animal. If the sheep runs, the shooter can quickly dart it again. Partially immobilized bighorn generally seek rough hazardous terrain. Each bighorn is different as is their drug tolerance. Some will not become completely immobilized. Thus, they may be able to stay just out of reach. Such animals should be darted again and marked for a double reversal dosage.

The "Cap-Chur" gun may be needed if an animal received only a partial drug dose and begins to show signs that the drug is wearing off. However, caution is advised in administering any additional drug. Nevertheless, an under-drugged animal is more likely to be lost than one over-drugged with M-99.

Once a bighorn has been drugged and it is determined that it cannot be herded to safer ground, move the helicopter away, but do not lose sight of the animal. When the drug begins to take effect, let the bighorn seek an area to lie down without harassment. Wait 1-2 minutes after the animal is down before approaching it.

Desert bighorn usually show signs of ataxia within 5-7 minutes or less after being injected with M-99. Sometimes, because of plugged needles or other causes, only a partial does or none of the drug may be injected. Therefore, if an animal shows no sign of ataxia within 15 minutes, another full drug dosage should be administered. A full drug dosage administered to a bighorn which has received a partial dosage usually will not endanger the animal. Staying too close to an injected bighorn may result in it seeking extremely rough terrain, which may result in serious injury or death. After a bighorn has been darted and goes down, locate a nearby landing area so that the animal can be reached quickly.

Radio transmitters attached to tranquilizer darts provide additional assurances of not losing darted bighorn. The bighorn is placed under less stress because the helicopter does not have to pursue it closely after it has been darted (Sandoval 1980). Some researchers are not in favor of such darts because they are expensive and the added weight can affect accuracy and penetration.

Guns which discharge nets to capture wild animals should not be used where a trapped bighorn could fall and be seriously injured. Net guns can be effective in capturing desert bighorn; however, they must be fired at a distance of approximately 10-15 ft. from the animal and extended chases usually are necessary. These are the major disadvantages of the net gun (Sandoval, pers. comm.). If situations are right, more than 1 bighorn can be captured at a time.

HANDLING OF CAPTURED BIGHORN

Once a bighorn is in hand, hold its head upright and immediately blindfold the animal. Also, insure that the animal is in a comfortable position and check it for injuries and signs of stress. Holding the head up insures that the animal does not suffocate from vomit in the air passages. Once blindfolded, bighorn tend to become more calm and to struggle less. Long wraps, such as elastic leg wraps, work well as blindfolds and have less tendency to slip off than nonelastic materials.

If bighorn are to be held at the capture site for a short time in order to attach radio collars, collect samples, etc., they should be hobbled and placed on their brisket in a normal upright position.

Body temperature of restrained bighorn should be monitored and corrective action taken if the temperature exceeds 106" F. Body temperatures can be reduced by applying cold packs to the carotid area of the neck, by pouring water on the animal, or by dipping the animal in a tank of water. Dipping desert bighorn when ambient temperatures exceed 50" F has proven effective in reducing shock. Adding toxaphene or lindane to the water will help cleanse the bighorn of ectoparasites, particularly scabies mites. However, 2 dips 10-12 days apart may be necessary to eradicate mites. When dipping bighorn, the nostrils and mouth must be covered to prevent aspiration of toxaphene.

All captive bighorn should be observed for signs of stress, such as heavy breathing, salivation, tail curled tightly over back, nystagmus, or a heartbeat in excess of 130 beats per minute. One must be sure not to count both heart sounds as a beat.

Drugged bighorn exhibiting signs of severe stress should be given 1 mg. of M 50-50 (about 1/4 reversal dose) and oxygen (mouth to mouth resuscitation or use of an aspirator) until the heartbeat is below 130 beats per minute. Bighorn showing signs of severe stress, particularly if the heartbeat exceeds 130 beats per minute, are subject to shock and can die within a few minutes. In such extreme cases, a complete reversal dosage of M 50-50 should be given. Atropine will slow and stabilize heart rate and block the effects of noradrenalin. The use of bicarbonate lactated ringers and possibly steroids via rapid intravenous infusion will greatly reduce effects of stress. Administrations of vitamin E and selenium also are recommended (Jessup, pers. comm.).

If a drugged bighorn has a high body temperature and is cyanotic, a complete reversal dosage of M 50-50 should be given i.v. immediately. If the sheep is slow to respond, Atropine sulfate and Dopram should be given as heart and respiration stimulants. If the bighorn recovers, it should not be transported, but should be released in the field at the capture site.

Bighorn should be moved from the trap to the transporting vehicle as soon as possible, and with a minimum amount of handling and noise. Some desert bighorn are susceptible to stress or shock that can result in death. Prompt movement of animals to a transporting vehicle during periods of hot weather is critical in order to avoid heat stress. Loading ramps from traps constructed of mesh wire and steel posts have resulted in injury and death to some bighorn. Bighorn do not load well from loading ramps. Ewes and small rams are particularly vulnerable to catching their horns in wire mesh and breaking their necks. An animal can best be walked to a transportation vehicle by 1 person holding up one hind leg and 2 persons grasping the horns and walking alongside the neck. Do not carry bighorn unless their backs are supported. Use a stretcher with leg holes.

Three people are needed for moving immobilized ewes (1 to carry the equipment and 2 to handle the animal). A minimum of 4 people are needed to move mature rams because of their size and difficulty in handling.

When bighorn are moved from the capture site to the transportation vehicle by helicopter, they should be moved to the helicopter as quietly and carefully as possible. Any loud noise or shouting should be avoided. If bighorn are captured in fairly gentle terrain, they can be carried by hand or walked to the helicopter by 2 people, as previously discussed, or carried on a canvas stretcher. If a bighorn is to be walked, first administer ¼ of reversal dose of M 50-50.

Bighorn captured from a helicopter should be transported: (1) by a metal stretcher or shallow box attached to the skid pipes of the helicopter on the passenger side, (2) in crates of heavy construction which can be picked up in a sling beneath the helicopter, or (3) in bags constructed of heavy gauge vinyl or nylon cargo nets slung under the helicopter. Tubular steel stretchers with nylon mesh attached by belts or straps have been used to carry bighorn to helicopters and transportation vehicles. The stretchers with the secured bighorn also can be attached to the skids of a helicopter for transporting. Rubber stretch cords attached to the stretcher or box are useful in securing bighorn for the flight to the transportation vehicle.

If a bighorn is to be transported by crate, the crate should be in place and ready to be moved to the transportation vehicle area as soon as the animal is loaded. Place the animal in the crate head first and secure the lids before the helicopter arrives.

Crates should be constructed of wood 4 ft. long x 2 ft. wide x 3 ft. high. Ropes should support the crate in the front and rear and 3 ft. below the helicopter. Slotted crates are best, as they create less air resistance in flight than solid crates and also rotate and pivot less.

Bighorn have been lost from hyperthermic shock when transported in the back of helicopters when temperatures exceed 70" F. Heavy gauge vinyl bags or nylon cargo nets slung under the helicopter are recommended.

A veterinarian should be available to assist with bighorn and to monitor them while they are in the transportation vehicle area. The presence of a veterinarian will improve the chances of saving bighorn which may go into shock. Also, a veterinarian will be able to treat diseases, parasites or injuries. The veterinarian should be experienced in wildlife capture and briefed on expected problems, emergencies and medical supplies needed at least a week prior to capture.

Bighorn should be checked at the base camp and treated for any injuries, diseases or parasites. Animals also should be tagged, administered a long-acting antibiotic, such as LA-200 or Flocillin and the M 50-50 reversal drug (twice the M-99 dosage). The blindfold should be removed before loading the animal in the transportation vehicle. Always check for injuries, disease or parasites and administer treatment(s) before the reversal drug is administered. Betadine and Furacin are good antiseptics for treating cuts; Panalog is good in dart punctures. If there are minor bone breaks, leave them alone to heal themselves. Treatment may do more harm than good. If major bones are broken, there is little chance of the animal surviving.

Tagging is necessary for future identification. Ear tags designed for domestic sheep have proved satisfactory. Neck collars with or without radio transmitters also should be put on at this time.

After the reversal drug has been administered, the bighorn should be held. The animal's head must be an upright position and it should lie on its brisket during recovery. Normally, an animal rises within 1-3 minutes after M 50-50 is administered intravenously, and within 15-20 minutes if given intramuscularly. After standing for a few minutes they may lie down again. Some bighorn flip onto their backs and it is imperative that someone be present to immediately get the animal back to an upright position. Once a bighorn begins to butt and/or paw, place it with other animals.

TRANSPORTATION

A truck or trailer with 2 compartments, 1 in front of the other, is best for holding and transporting drugged animals. Bighorn recovering from M-99 can be placed in the rear of the vehicle, but should be separate from recovered bighorn. Once recovered, the animal can join the others by being permitted to move forward. This type of operation requires less handling and, thus, reduces stress. A single compartment truck is suitable for trapped bighorn (i.e. not drugged).

Transportation vehicles (truck beds or horse trailers) should provide sufficient room for animals to lie down in comfort. Vehicles should be well vented and have padded sides. Transportation is best when temperatures are between 30" and 70° F. Wild sheep usually lie down when they are being transported. Therefore, ample room should be made available to reduce fighting and trampling. The interiors of vehicles should be kept as dark as possible.

Holes, corners, cracks, exposed nuts and bolts, or areas where bighorn can catch a horn or foot should be covered. Old pads from camp cots or floor padding from horse trailers work well as padding material. Nylon mesh net suspended 3.5 ft. above the floor of a vehicle has been used to deter animals from jumping.

Bighorn held longer than 48 hours should be fed and watered. Bighorn released 48 hourse after capture, without having been fed or watered have displayed no ill effects from such treatment. The disturbance associated with watering and feeding also can do more harm than good during a short capture period.

The exhaust system and muffler of the transportation vehicle should be checked carefully to insure that carbon monoxide cannot be drawn into an enclosed truckbed or horse trailer. Several bighorn were asphixiated in Idaho during a transplanting operation because of a hole in the top of the muffler.

If large rams are to be captured, they should be separated from ewes and lambs by a railing or slotted panel. Large rams are more excitable and prone to butting than ewes, which can result in severe injuries to smaller animals. Rompun (about 10 mg.) or Haldol, Azaperone or Acepromazine will help suppress aggressiveness in large rams when they are being transported (Jessup, pers. comm.).

Where the transportation compartment can be enclosed and high velocity winds will not be generated, it is recommended that bedding materials of good quality prairie or timothy hay be distributed 12-15 in. deep on the floor. Winds caused by moving vehicles can blow particles of dust and hay into the eyes, nostrils and throat of animals. Therefore, if the transportation compartment cannot be sealed in such a manner as to keep particles from blowing, loose bedding materials should not be used.

Prairie and timothy hay are excellent bighorn forages. Bighorn are more content if they can lie down and feed. Bighorn captured with M-99 have an uncontrollable urge to eat, and bedding materials which afford nourishment will reduce the chances of their eating tarps, netting, padding materials, etc., which could be harmful to them. Feeding bighorn also are less prone to grind their teeth.

RELEASE OF BIGHORN FROM THE TRANSPORTATION VEHICLE

Release is one of the most critical phases of bighorn capture and transplanting operations, and the one in which the greatest problems can arise. With few exceptions, released bighorn will be unaccustomed to humans, noise and wire fences. Many bighorn have had their necks broken from being spooked from a transportation vehicle at the release site and running into a wire fence. Undue noise and harassment probably has contributed to more broken legs and necks during release than at any other period during capture and transplanting operations.

When bighorn are being released into a paddock, it is advantageous to allow them to leave the transportation vehicle at their leisure. This gives them the opportunity to leave the vehicle on their own initiative and to explore their new environment. This is especially important if the bighorn have not previously encountered fences.

Allowing bighorn to leave a vehicle at their leisure also can reduce the possibilities of injury. Time permits the animal's eyes to adjust to the bright light outside of a darkened transportation vehicle. It also reduces the chances of the animals falling in their haste to get away. Usually, when one animal leaves a vehicle, the others will follow.

If bighorn are released into paddocks, large rams should be kept separate from ewes and lambs during the paddock adjustment period. If bighorn are released into small paddocks, the paddocks should be constructed so that the rams can see the ewes. Bighorn rams killed some ewes while trying to escape from a paddock in New Mexico.

When bighorn are released directly into suitable habitat, they should be encouraged to leave the vehicle at one time. This tends to keep the group together as they head for escape terrain, and is thought to help keep the group from fragmenting (Bob McQuivey, pers. comm.).

Agencies responsible for the capture and transplanting operations often want photographs of bighorn being released. If this is the case, 1 qualified photographer and not more than 2 (1 for motion pictures and 1 for still photos) should be present. The photographers then can provide duplicate prints to other agencies, the news media, etc. The Nevada Dept. of Wildlife has used observers as a human line to direct released bighorn toward escape terrain. The presence of numerous people is probably of less importance in a direct release than it is in a release into an enclosure. In an enclosure release, numbers of people present should be kept to an absolute minimum. In either case, excessive movements and noise should be avoided.

ACKNOWLEDGMENTS

Members of the Desert Bighorn Technical Staff and contributors responsible for this revision are:

Lanny O. Wilson, Chairman, USDI Bureau of Land Management
James A. Blaisdell, formerly with USDI, National Park Service (Retired)
Dr. Thomas D. Bunch, Utah State University
James DeForge, Desert Bighorn Research Institute
Dr. Charles L. Douglas, National Park Service, Univ. of Nevada. Las Vegas
Gerald Gates, New Mexico Dept. of Game and Fish
David A. Jessup, DVM, Calif. Dept. of Fish and Game
Warren Kelly, USDA, Forest Service
Dr. Paul R. Krausman, University of Arizona
Robert P. McQuivey, Nevada Dept. of Wildlife
Richard Remington, Arizona Game and Fish Dept.
Andrew Sandoval, New Mexico Dept. of Game and Fish
Dr. John L. Schmidt, Colorado State University
Dr. Juan Spillett, USDA, Forest Service
Richard Weaver, Calif. Dept. Fish and Game
George Welsh, Arizona Game and Fish Dept.

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PRELIMINARY RESULTS OF A DESERT BIGHORN TRANSPLANT IN THE PELONCILLO MOUNTAINS NEW MEXICO

Amy Elenowitz
New Mexico State University, Las Cruces

Abstract. A one year field study was conducted in the Peloncillo Mountains, New Mexico following a paddock release of 28 bighorn sheep *(Ovis* canadensis mexicana). The 20 adults were radio-collared. The transplant was supplemented twice with 6 radio-collared rams released directly into the wild. This report presents preliminary information based on 138 observations and 352 triangulation fixes recorded during the first 8 months of the study. Natural and artificial water sources were utilized. Two major use areas were established within 6.4 km (4 mi.) of the release site. Ewes separated into 3 cohesive bands. Mobility ranged from sedentary to highly exploratory whereby the distances of travel from the release site ranged from 35.4 km (22 mi.) for ewes and 43.3 km (30 mi.) for rams.

INTRODUCTION

Historically, desert bighorn *(Ovis* canadensis *mexicana)* were present in most rugged mountain ranges of southern New Mexico (Ligon 1927, Bailey 1931). Presently, only 2 remnant populations exist: the Big Hatchet and the San Andres. Their precarious status (see Watts 1979, Sandoval 1980) initiated listing of desert bighorn as a state endangered species in 1980, and the New Mexico Dept. of Game and Fish became committed to a re-establishment program. Sandoval (1978) conducted an in-depth evaluation of 16 historic bighorn ranges to determine which had transplant potential. Based on availability of suitable habitat, minimal human disturbance and unlikely invasion by exotics, the Peloncillo Mountains were chosen as the first re-establishment site.

To determine the success of the transplant, a 1 year field study was initiated in June 1980. This report presents preliminary information on water utilization, major use areas based on the first 8 months of the study, group dynamics, and movements.

STUDY AREA

The study area encompasses 202 km²(78 mi.²) in the central portion of the Peloncillo Mountains. The mountain range is narrow and long, extending northward from the Mexican border for approximately 120 km (75 mi.) along both sides of the Arizona-New Mexico state lines. Elevation ranges from 1524 m (5000 ft.) to 2112 m (6928 ft.) at Gray Peak. Tertiary volcanic rocks constitute the substrate (Todd et al. 1975) which give rise to an extensive series of vertical outcrops and cliffs.

The area is typified by spring drought (April-May) and peak summer-fall precipitation (July-October). Average annual precipitation at Rodeo, New Mexico is 27.6 cm (10.89 in.). During the study, I recorded an average 43.1 cm (17 in.) at the release site. Temperature extremes ranged from about -25.5 to +26.9° C (+17 to +106° F).

Vegetation in the study area is typical of the Chihuahuan Desert and is comprised of a desert-shrublgrass type dominated by Mescal (Agave palmeri), yucca (Yucca baccata), black gramma (Bouteloua eriopoda), and a mixed-shrublgrass type characterized by oak *(Quercus* spp.), mountain mahogany (Cercocarpus montanus), and sideoats gramma (Bouteloua curtipendula) (Sandoval 1982).

METHODS

The paddock was constructed of 2.4 m (8 ft.) high nylon mesh net and encompassed 16 ha (40 ac.) in the northern portion of the study area. To provide permanent water, an 8,535 liter (2,255 gal.) capacity rainwater catchment with an offline drinking basin was constructed (Sandoval 1981).

Bighorn were obtained from 3 populations of *O.c. mexicana.* In November 1980, 12 ewes were captured from the Kofa National Wildlife Refuge, and the North Plomosa Mountains, Arizona. In May 1981, 10 rams were captured with a linear collapsible net from a captive population at the Red Rock Wildlife Experimental Area, New Mexico. Each bighorn was examined, inoculated against bluetongue, contagious ecthyma, psoroptic scabies, and instrumented with color-coded radio telemetry collars with 2 hour mortality sensors (Telonics; Mesa, AZ). The sheep were transported by stock trailer to the release site. After the transplant, an active predator control program was undertaken; mountain lions *(Felis* concolor) were the primary target species.

On 26 June 1981, the bighorn were released from the paddock by removing approximately 244 m (800 ft.) of fence netting. The ewes had been retained for 7 months and the rams for 2. The population was supplemented twice by radio-collared rams released directly into the wild near the old paddock site. Two Red Rock, New Mexico rams and 4 Kofa, Arizona rams were released in late September 1981 and mid-January 1982, respectively.

Each bighorn was located 4-10 times each month, primarily on the ground, with a portable antenna and receiving unit. A Cessna 182 aircraft equipped with external directional and nondirectional antennas was employed about once a month when signals could not be picked up from the ground. Observational information recorded included group size, composition and activity. Locations were coded to the nearest 200 m (656 ft.) using the Universal Transverse Mercator (U.T.M.) Grid System for computer analysis of bighorn preference in relation to slope aspect, elevation and habitat type (Urquhart 1977). Information on watering habits was aided through use of 8 mm time-lapse cameras placed at selected sites. Food habits were determined by microhistological analysis of monthly fecal samples conducted at the Composition and Analysis Laboratory, Colorado State University, Fort Collins.

RESULTS

Confinement Phase

Sandoval (1981) discussed the confinement phase of the transplant. Two ewes were lost during confinement; 1 died of injuries sustained in a fall and the other died after becoming entangled in the fence netting. Of the 10 surviving ewes, 8 gave birth to lambs (5 female, 3 male) between January and March 1981.

Post-Release Dieoff. Fifty-two percent of the population died post-release. Fifteen losses were attributed to pneumonia: all 10 of the paddock-released rams, 1 wild-released ram and 4 lambs. One lamb disappeared, cause unknown. No ewes died of pneumonia but 1 was killed by a mountain lion and 1 died after becoming entangled in a fence. Refer to Sandoval (in press) for an analysis of mortality in the Peloncillos.

Water Utilization. Two categories of water sources are present in the study area: volcanic potholes and man-made units. High summer rainfall resulted in heavy utilization of potholes following the release. As the potholes dried, use of the water catchment was recorded as follows: bimonthly visits August through October, no use during the winter, and 1 trip in March. Occasional winter use of concrete and earthern dams was suggested by sign. As noted by Watts (1979), an observed high intake of prickly pear (Opuntia spp.) could have satisfied the bighorn's decreased water requirements during cooler months.

Ewe Group Integrity. The ewes and lambs organized into 3 maternal bands in mid-September, 2.5 months following the release. There was periodic interchange of members between bands as well as solitary movements, but overall there appeared to be a high degree of cohesion within bands. Some ewe pairs had particularly close affinities. However, the degree of intraspecific association still needs to be analyzed to determine significance.

Major Use Areas and Ewe Movements. The major difference between bands was the extent of their movements. The primary Band 1 of 6 ewes was the most sedentary and ranged no further than 4.4 km (2.75 mi.) from the release site. Their major use was in the Gray Peak area which radiates E-NE of the release site and encompasses approximately 23.3 km^2 (9 $mi.^2$). They resided in the western portion of the area following the release and, with onset of cooler, drier weather, gradually drifted east into higher elevations, possibly in response to the preponderance of browse plants found there. Their drifting movements could best bedescribed as punctuated, in that one slope or peak was used for a week or more at a time before another micro-area was utilized.

Band 2, comprised of 2 ewes, was more exploratory and moved up to 9.7 km (6 mi.) south of the release site. The band remained largely within the Gray Peak area until January when it became established in the Burro Pass area, which is 6.4 km (4 mi.) south and encompasses 18.1 km^2 (7 $mi.^2$). In comparison with the Gray Peak area, the terrain is more broken and precipitous, closely resembling that found in western Arizona where the ewes were obtained (A. Sandoval, pers. comm.). Therefore, familiarity may have been an attractant.

Band 3, comprised of 2 ewes and 1 lamb, named the Renegades, was highly exploratory. The band traveled 193 straightline km (120 mi.) in a 2.5 month period in isolation from the other bands. Before their exploratory moves the animals resided mainly in the Gray Peak area; afterward they settled with Band 2 in the Burro Pass area.

Long Distance Ewe Movements. On 12 September the Renegades were observed near the release site and 1 week later they were aerially located 35.4 km (22 mi.) east in the Central Animas Mountains (Fig. 1). The minimum distance across flat terrain (using Tank Mountain as a corridor) is 11.3 km (7 mi.). Five days later, the Renegades returned to the release area in the Peloncillos.

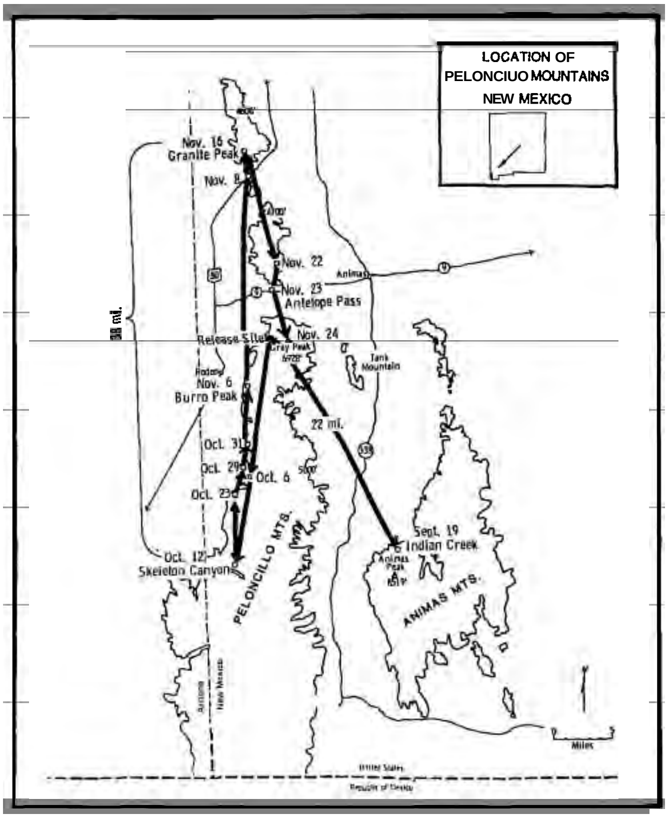

Figure 1. Movements of the Renegades (ewes 9.31, 9.68) in the Peloncillo and Anirnas Mountains, New Mexico, September-November 1981.

During the next month they moved south; after 1 known stop, they were observed in Skeleton Canyon on 12 October, 32.2 km (20 mi.) south of the release site. This canyon demarks the southernmost limit of suitable bighorn habitat in the Peloncillos. Within 2 days, the Renegades began a northward trek with 4 known stops that ended on 16 November at Granite Peak. This is 12.9 km (8 mi.) north of the release site and 61.1 km (38 mi.) north of Skeleton Canyon. A major part of the move--30.6 km (19 mi.)--was made in about a day: they began moving the evening of 6 November from Burro Peak (a moonless night) and in the morning on 8 November were seen standing in the middle of Highway 80 at Granite Pass. On one moonlit night during this period, extensive movement was indicated by significant signal fluctuations and verified by change of position the next morning.

On 17 November, the Renegades separated for the first time in 2 months. The leader began to head south, but Ewe 9.31, the mother of the lamb, did not follow. When she was next seen on 23 November, she was without her lamb. Thus, her reluctance to leave with the leader was probably due to her having lost her lamb there. This behavior pattern--attachment to the area where a lamb was lost also was observed in 2 other ewes.

The southward move of Ewe 9.31 back to the study area was observed. In the early morning on 23 November she ran across State Road 9 at Antelope Pass and jumped the 1 m high (3 ft.) boundary fence. She then alternately walked and sprinted across 4.0 km (2.5 mi.) of desert flats, stopping periodically to scout the terrain. The following day the other ewe also returned.

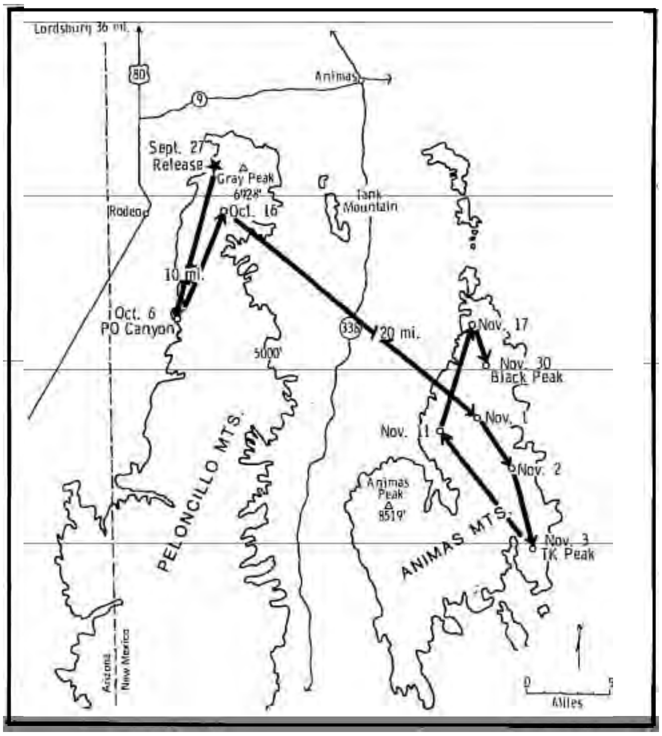

Figure 2. Movements of Meriwether in the Peloncillo and Animas Mountains, New Mexico, September 1981-March 1982.

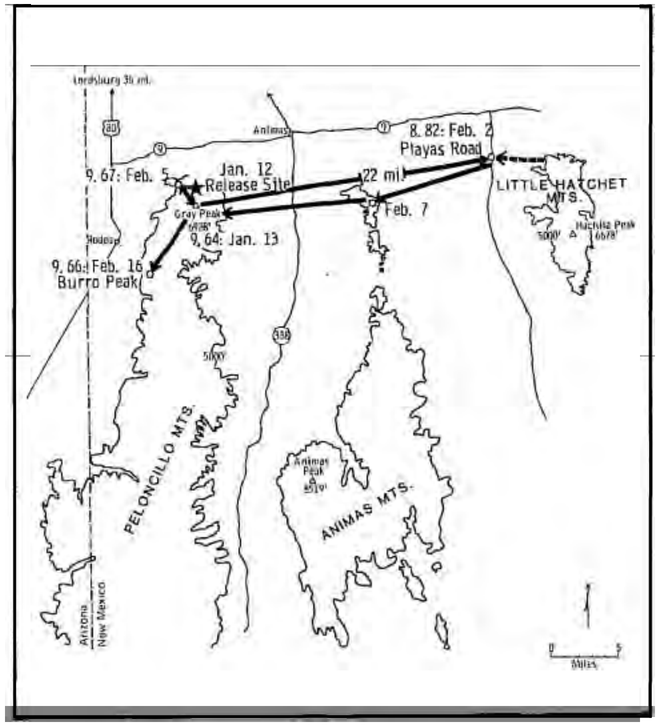

Figure 3. Movements of 4 rams (PER 8.82, PER 9.64, PER 9.66, PER 9.67) in the Peloncillo and Animas Mountains, New Mexico, January-March 1982.

Movements of the Wild-Released Rams. Of the 6 rams released into the wild, 1 ram named Meriwether, after the explorer Meriwether Lewis, was the most exploratory. Nine days following his release in late September 1981, he was found 16.1 km (10 mi.) south of the release site (Fig. 2). He then moved north, close to the release site. Two weeks later, he was located 35.4 km (22 mi.) southeast in the Animas Mountains and within 2 days he moved to TK Peak, a total distance of 48.3 km (30 mi.) southeast of the release site. Meriwether may have traveled even further south; however, by 30 November he stabilized in the Black Peak area, 35.4 km (22 mi.) southeast of the release site. He is still residing there.

In the second release of 4 Arizona rams in mid-January 1982, the rams initially stayed together but in February they dispersed individually (Fig. 3). Three remained within 9.7 km (6 mi.) of the release site but the fourth ram (PER 8.82) was highly exploratory. Three weeks following his release, he was seen by a motorist on the Playas road, 35.4 km (22 mi.) east of the release site. He was moving west which indicated that he probably was returning from the Little Hatchet Mountains. In any case, he began to return, remaining in the upper Animas Mountains for about a month, and then homed back to the Peloncillos where he met the ewes. As of March 1982, all 4 rams are associating with ewes within 3.2 km (2 mi.) of the release site.

DISCUSSION

Several post-release studies have found that transplanted bighorn initially exhibit exploratory behavior to varying degrees (McQuivey 1980, deVos 1981, Ravey 1981). This was evident in the Peloncillo transplant. The distance of travel from the release site ranged from 1.6-48.3 km (1-30 mi.) for rams and from 4.4-35.4 km (2.75-22 mi.) for ewes. The majority of bighorn were sedentary ($n = 9$; movements ≤ 2.75 mi. from the release site) versus exploratory ($n = 4$; movements ≥ 22 mi.) or intermediate between these extremes ($n = 3$; movements up to 6 mi.). The long distance movements had several elements in common: movement was rapid, occurred occasionally at night, entailed crossing highways, fences and flat terrain and was oriented in every direction but west to the Chiricahua Mountains in Arizona.

Band composition and exploratory tendencies may be related to origin of capture. All but 1 of the 6 members of sedentary Band 1 were from the Kofa National Wildlife Refuge, whereas all 4 of the ewes in the exploratory Bands 2 and 3 were from the Plomosa Mountains. Why Plomosa ewes were more exploratory than Kofa ewes is uncertain. Perhaps they had undergone periodic long distance moves in the Plomosas and so were inclined to explore in the Peloncillos. This possibility is suggested by data from Arizona. Witham and Smith (1979) cite examples of ewes crossing Interstate 10 between the Plomosa and West New Water Mountains and suggest that, under drought conditions, Plomosa ewes would be likely to move south to the West New Waters to take advantage of more permanent sources of water there.

In the long term, exploratory behavior in transplanted sheep is desirable as a means of learning the extent of suitable habitat. The social behavior of bighorn assures that such knowledge can be passed to potential future generations (Geist 1971), and would become invaluable in the event of drought or habitat alteration in the immediate release area. However, exploration could be detrimental through mortality caused by crossing fences, highways and flat terrain. This was most vividly confirmed when 1 of the exploratory ewes initiated another trek and became fatally entangled in a fence. No vehicular collisions occurred during the study but the bighorn's indifferent reactions to approaching vehicles (displayed on 2 occasions) indicate that the potential is high. The one time that a ewe was observed crossing flat terrain, she was wary, took the shortest route and used hills as travel corridors, but vulnerability to predation is still high for an animal adapted not for sustained speed, but for evading predators in precipitous terrain.

Exploration would be of no net value to a transplant if homing back to the release area did not follow. The release method--wild versus paddock release--may have influenced the homing motivation. The extensive movements of the Renegade ewes to new areas did not override their attachment to the release site and eventual return to it. It appears that their 7 month confinement in the paddock effectively habituated them to the release area. In the wild release of 6 rams, Meriwether was the only ram lost to dispersal. It is likely that he failed to home back to the Peloncillos because he never found the ewes; there was nothing to draw him back. In contrast, the other highly exploratory ram (PER 8.82) knew ewes were present and returned to the release site. The presence of an established ewe population probably discouraged one-way dispersal.

FUTURE OUTLOOK

Fifteen bighorn currently reside in the Peloncillos. Mortality to pneumonia has been the single most limiting factor. It is too early to assess the outcome of the transplant but there are encouraging signs: 1) permanent dispersal occurred in only 1 ram, 2) use of the enclosure aided habituation and induced homing in exploratory ewes, 3) the population is established in 2 use areas, 7.2 km (4.5 mi.) apart and within 6.4 km (4 mi.) of the release site, and 4) plans are in progress to directly release 10 Arizona ewes at Burro Pass in November 1982 which will facilitate interchange of individuals between use areas and reinforce the herd as a whole.

ACKNOWLEDGMENTS

Financial support was provided by the New Mexico Dept. of Game and Fish (Federal aid in Wildlife Restoration; Project No. W-84-D), the Bureau of Land Management, and contracted to New Mexico State University. Other cooperating agencies included the Arizona Game and Fish Dept. and the U.S. Fish and Wildlife Service. For their assistance and support throughout the study I thank personnel of New Mexico Dept. of Game and Fish, A. Sandoval in particular, Dr. R. Valdez, J. Holwick, and the Jesse Evans Ranch.

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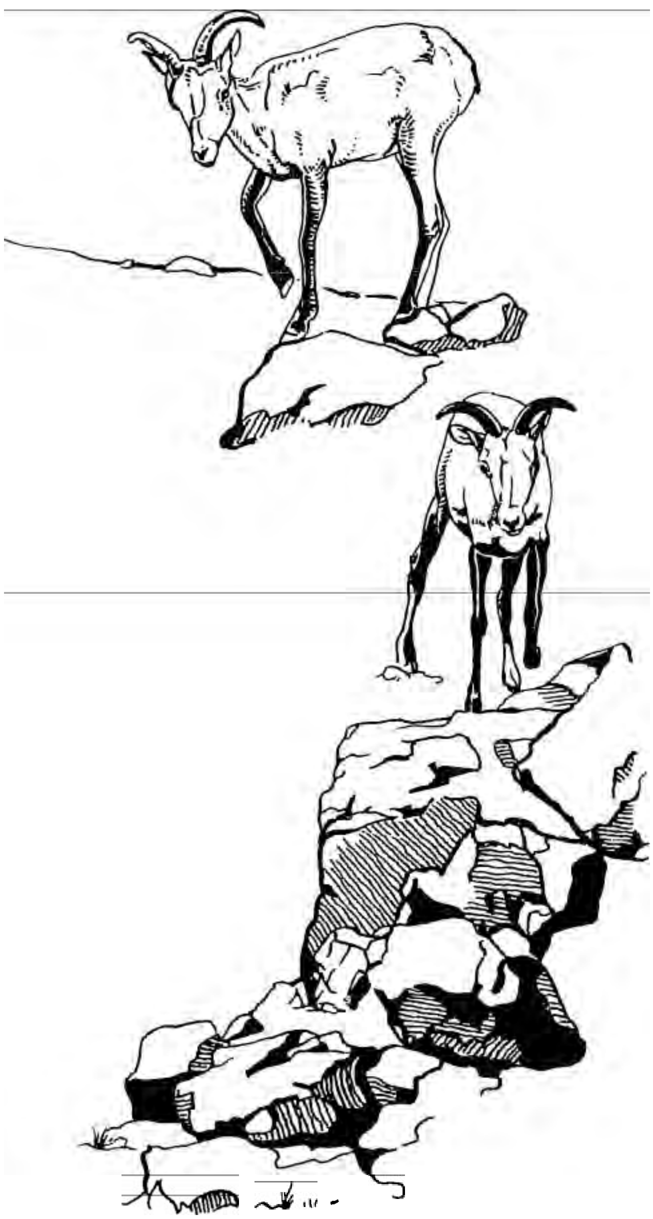

SOME ASPECTS OF POPULATION DYNAMICS OF AOUDAD IN THE HONDO VALLEY, NEW MEXICO

Khushal Habibi
Dept. of Fisheries and Wildlife
Michigan State University

Abstract. Population dynamics of aoudads were appraised in the Hondo Valley by applying 3 methods of population estimation. The average density of the animals was calculated at 6.4/km^2 in areas of heavy concentrationsyielding a population size of 500 to 600 animals in the study area. The adult male:adult female ratio was assessed as 68:100, juvenile:female 88:100, yearling:female 37:100 and lamb:female 52:100. Group size ranged from 2-63 with the majority of animals tallied in herds of 2-20 individuals. It was concluded that the aoudad population is in a state of rapid increase in the Hondo Valley.

INTRODUCTION

The aoudad (Ammotragus *lervia)* was introduced into the Hondo Valley, New Mexico, in the early 1940s with the release of 7 animals on the private game pasture of Joe McKnight. The pasture, which is about 800 ha in size, was enclosed by a 2.5 m high fence. With the increase of the herd, small numbers of aoudads escaped from the pasture annually, with 2 large escapes taking place in 1965 (approximately 100 animals) and 1977 (approximately 60 animals).

Today the aoudad is successfully established throughout the Hondo Valley and has extended its range from Lincoln to the White Ranch in the Hondo River Canyon (approximately 50 km.). The animals have dispersed southward into the Guadalupe Mountains National Park, Texas, an air distance of approximately 200 km (Dickinson and Simpson 1980).

Despite their survival and rapidly increasing numbers, a detailed study of their population dynamics has not been conducted in the Hondo Valley. Available estimates of aoudad numbers usually undergauge the actual population size.

The present study is being conducted on the Diamond A Cattle Company Ranch in the Hondo Valley as part of a doctoral research program. It attempts to appraise some aspects of the dynamics of free-ranging aoudads in the area.

STUDY AREA

The study area is situated on approximately 18,000 ha along the southern flank of the Hondo River. Topography of the site changes from steep hills close to the Hondo River drainage into rolling hills sodthward. Elevations vary from 1520 m along the river to 1800 m at the highest point in the range.

Cholla cactus (*Opuntia imbricata*) interspersed with Emory oak (*Quercus emoryi*) and squawbush (Rhus *trilobata*) dominate the top portions of the ridges. Valley slopes are covered with birchleaf mountain mahogany (Cercocarpus betuloides), sagebrush (*Artemesia* spp.) and beargrass (*Nolina* spp.). A number of grasses including various forms of bluestems (Andropogon spp.), grama grasses (Bouteloua spp.), western wheatgrass (Agropyron *smithii*), and lovegrass (*Eragrostis* spp.) cover the valley floor and slope sites. Burro grass (Scleropogon *brevifolius*) is found on overgrazed sites. Wet-season watercourses support a thin line of bushes and thickets providing a modicum of shade and cover along the gullies. Snakeweed (*Gutierrezia hecida*) is common throughout the area at all elevations.

METHODS

Methods used in estimating total numbers included total count on sampled plots (Seber 1973), Lincoln-Petersen mark-recapture estimate, and the index and control method (Caughley 1980).

Total Counts on Samples Plots. A preliminary investigation revealed that aoudads concentrate along the steepest terrain in valleys close to agricultural fields near the Hondo River. Density of the animals was sampled by dividing the area under investigation into units and counting animals on randomly pre-selected portions. The mean density on the units was taken as an estimate of the average density on sampled and unsampled units combined (Caughley 1980).

Population variance was determined from the preliminary investigation and an iterative approach was used to determine the sample size needed for the survey. It was estimated that aoudads used 96 km^2 of the range intensively. Twelve of the random plots each measuring 2.56 km^2 (1 mi.^{2}) were surveyed on foot. Distances were measured with a pedometer. Using contour lines as a guide, the boundaries of each sampling unit were found and all animals counted within the unit. Observation of animals flushed were made with a Nikon 7x35 binocular and a Bushnell 22x60 spotting scope. All animals were sexed and classified according to age class.

The Mark-Recapture Survey. A drop net was used to catch animals for marking. Numbered plastic collars were placed around the animals' necks. Thirteen animals were netted and collared on 5 trap-occasions. Two crippled females and a juvenile with deformed horns also served as marked animals which could be identified easily. After termination of the marking operation, observation of animals extended for a period of 4 weeks. The entire range used by aoudads was surveyed by foot and vehicle and a marked:unmarked ratio determined.

Index and Control. Aoudads utilize their home range in sympatry with domestic sheep. Since the number of sheep in the pastures was known, the density of aoudads was estimated by comparisons of aoudad numbers with the known density of domestic stock (Caughley 1980).

RESULTS

On the sampled plots, 37 groups totalling 209 animals were observed. The mean density of aoudads was calculated 6.4/km^2 in habitats with a high concentration of animals. The total number of aoudads on the 96 km^2 study area thus was calculated to be 615 (with 95% confidence limits ± 179).

As a result of collars becoming brittle in cold weather and constant butting and sparring among the younger animals of both sexes, 3 collars belonging to 2 juveniles and 1 lamb were retrieved in oat fields adjacent to the river which the animals frequently visited on winter nights. This reduced the number of marked animals to 13. During the "recapturing" survey 10 marked animals were observed on 25 occasions.

A total of 1002 aoudads were observed in the entire study area. The Lincoln-Petersen estimate (Bailey 1951, 1952) based on sightings of 76.9% of marked ao'udads gave a population estimate of 560 (95% confidence limits ± 184).

From October-December the number of aoudads and domestic sheep occurring in the breeding habitat of the animals were counted on repeated occasions. A total of 1780 aoudads and 2150 domestic sheep were tallied. There was an estimated 900

Table 1. Estimates of population size of aoudads on 96 km^2 in the Hondo Valley study area during 1981-1982.

Survey Type	Period	Population Estimate	95% Confidence Limits
Total counts based on sampled plots	Aug. 1981	615	436, 794
Index and Control	Oct.-Dec. 1981	745	
Lincoln-Peterson estimate	Jan.-Feb. 1982	560	376, 744

sheep in the area and if both species can be assumed to be equally conspicuous the population of aoudads was estimated as 745 (Caughley 1980).

The several estimates (Table 1) indicate that about 500-600 animals inhabit the study area. Outside the 96 km^2 study area, the aoudads use approximately 200-250 km^2 in the Hondo Valley. Moreover, a census of the McKnight game pasture (6 km south of the study area) conducted in August 1981 resulted in a total count of 200-250 animals. Thus it is estimated that the size of the entire local population in the Hondo Valley and adjacent ranches may be between 1200-1400 animals.

Sex and Age Composition. Geist (1971) states that sex ratios are most likely to be valid for the entire population if determined 2 weeks prior to the ewes entering estrus. For 1142 animals tallied during the rut, 20% were adult males, 29% adult females, 11% subadults of both sexes, 25% juveniles and 15% lambs.

Sex ratios obtained during September-October, when the main rut was in progress showed a male:female ratio of 68:100. The disparity in favor of females may be attributed to trophy hunting. Dickinson and Simpson (1979) found a ratio of 58 males:100 females in the Guadalupe Mountains. Gray (1980) reported an overall ratio of 40 males:100 females and 19:100 in the Palo Duro Canyon, Texas during 2 consecutive years.

Juvenile:female ratio was calculated 88:100, subadult:female 37:100 and lamb:female 52:100 during the rutting season. Since the study was started in July it was not possible to assess the twinning ratio from field data for 1981. However, 190 sightings of lambs during February-March 1982 showed a twinning ratio of 21.79%. Twinning is common among free-ranging aoudad populations in the southwestern United States. Fourteen females collected in 1957 in the Canadian Gorge, New Mexico, contained an average of 1.2 embryos per female; a 1.6 embryo per female ratio was obtained from 7 females autopsied in winter of 1958 (Ogren 1965) in the same area. Barrett (1980) found an average of 1.2 corpora lutea in 10 females from California in 1966.

Table 2. Number of animals in each size-sex class present per 100 adult females. Observed during the rutting season in the Hondo Valley Sept.-Oct. 1981.

Adult males	Subadults (both sexes)	Juveniles (both sexes)	Lambs (both sexes)
68	37	88	52
		140	

Comparable data on juvenile:female ratios in the Palo Duro Canyon showed a natality rate of 73:100 (Gray 1980). Barrett (1980) reported 30 juveniles:100 females for the Hearst Ranch herd in California, and Dickson and Simpson (1979) recorded a ratio of 132 juveniles:100 females in the Guadalupe Mountains. Combining juvenile and lamb ratios gives an overall total of 140 young:100 females for 1981 (Table 2). The highest fecundity rate of aoudads in the Hondo Valley suggests that fertility of the aoudads appears to be in a healthy state and exceeds the productivity ratios recorded in other release sites in the United States.

Herd Dynamics. Aside from solitary individuals, aoudad herds were classified into 4 categories (Petrides, unpubl.): 1) male herds, composed solely of adult males, 2) female herds, consisting of females with or without young and subadults of both sexes, 3) mixed herds, including adult males, females subadults and young, and 4) juvenile herds, without adults present. To avoid inconsistencies due to joining and parting of individuals, all animals in a herd were sexed and/or size-classed when they were sighted at first contact. Of 328 herds tallied, 5.59% comprised male herds with an average of 3.5 animals each. Juvenile herds accounted for 3.69%, with a mean size of 6.15 (the majority of them were seen during January and February when pregnant females abandon thg mixed herds and form small bands in isolated valleys). Female herds (N=178) which composed the largest percentage (54.27) had an average size of 7.89 animals and ranged in size from 2-45, while mixed herds accounting for 36.28% of the herds tallied had a mean size of 14.65, with a range of 2-63 individuals (Table 3). Aoudads lived predominantly in groups of 2-20 animals (Figure 1). Group composition at Camp Cooley, Texas, as studied by Solbert (1980) also ranged from 3-23 animals. Only 16 groups of over 30 animals each were tallied. These usually were seen in the evening when several groups congregated to feed in oat fields at night.

Adult rams were classified into 4 classes according to horn size (Gray and Simpson 1980). Prior to the rut, a gathering of rams took place and most were in male herds. Of 306 rams counted September-December, 35% were class I animals, 20% class II, 19% class III and 25% belonged to class IV. With termination of the rut in mid-November, larger rams gradually left

Table 3. Mean herd size of aoudad male, female, mixed and juvenile herds in the Hondo Valley tallied during August 1981-Feb. 1982.

	Male herd	SD	Female herd	SD	Mixed herd	SD	Juvenile herd	SD
No. herd	18		178		119		13	
Mean herd size	3.5	1.46	7.89	7.33	14.65	10.38	6.15	3.83
Range	2-8		2-42		2-63		2-14	

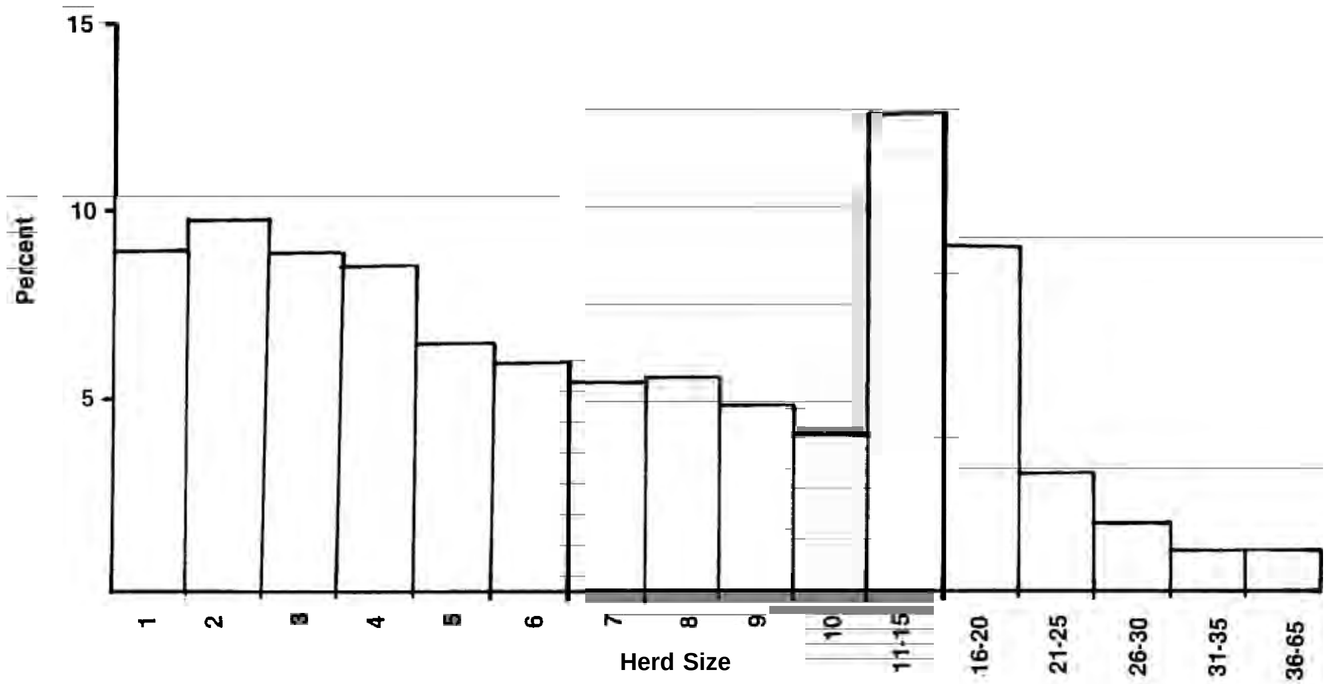

Figure 1. Herd size composition of aoudads based on data accumulated from July 1981 to February 1982 in the Hondo Valley, New Mexico.

female groups while the smaller class I rams remained in mixed herds until the start of winter (Table 4, Figure 2). A significant difference (P40.001) was found in distribution of male ratios during the rut and post-rut seasons.

CONCLUSIONS

Exotic species introduced into new environments either manage to survive and thrive or, if unable to establish themselves, die off. With evidence of continuing success, a species is said to be established (Petrides 1968). Being an aggressive competitor and capable of adjusting to new and hostile environments (Simpson et al. 1978), the aoudad has thrived in all release sites in North America. The species has extended its range extensively, occasionally dispersing long distances within a short period of time into the range of native species (Dickinson and Simpson 1980).

A frequent problem in the management of wild ungulates in relation to use of rangelands is overpopulation (Petrides 1960). A species which becomes too abundant for the range to support without undergoing deterioration is undesirable in terms of competition with domestic and native species. Although data are scant on the number of aoudads present in the Hondo Valley during past years, there are reports (Gonzales and Morrison, pers. comm.) of heavy concentrations of aoudads on the study area during 1976 which caused destruction of fences and overgrazing. In order to alleviate the problem 206 hunting licenses were issued for the Hondo Valley in 1976-77, resulting in the harvesting of 140 animals. The hunting kill since then has been light.

Table 4. Percentages of aoudad males by horn-size class (Gray and Simpson 1980) seen during the rutting and post-rutting seasons in the Hondo Valley from September-December 1981.

Period	Class I	Class II	Class III	Class IV	Total Sightings
September	26.5%	30.4%	25.5%	17.6%	102
October	32.5	10.6	18.7	38.2	123
November	44.4	20.0	13.3	22.3	45
December	60.0	22.8	8.6	8.6	35
Sept.-Dec.	35.4	20.0	19.0	25.6	305

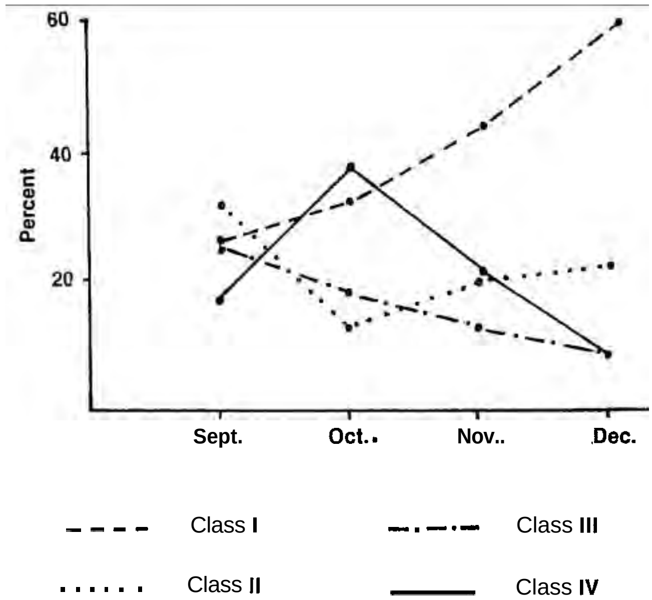

Figure 2. Percentage of aoudad rams of various age classes observed during the rutting and post-rutting seasons. With the termination of the rut the larger rams gradually abandon the breeding areas.

Aoudads in the southwestern states have a high natality rate, the ability to breed virtually year-round though with a concentration of lambs in March and April, the occurrence of some females breeding twice a year (pers. obser.; Dickinson, pers. comm.), a high twinning rate, a controlled number of predators in the habitat, and a free access to favorable range. This suggests that the aoudad population in the Hondo Valley is in a state of rapid increase. Its direct competition with mule deer (Odocoileus hemiones) and domestic sheep occurring in the same range seems likely.

ACKNOWLEDGMENTS

I would like to express my special appreciation to the Asia Foundation, Diamond A Cattle Co., the National Rifle Association and the New York Zoological Society for providing financial assistance to the project.

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ANTILEPTOSPIRAL AGGLUTININS IN SERA OF DESERT BIGHORN SHEEP

Christopher Chilelli
Marilyn Marshall
J. Glenn Songer
Dept. of Veterinary Science
University of Arizona, Tucson

INTRODUCTION

Leptospirosis is a disease affecting most mammals, both wild (Roth 1970, Collins et al. 1981) and domestic (Ellis et al. 1981). It is of most importance as a cause of abortion, infertility, and neonatal death.

The disease is caused by bacteria of the genus Leptospira. All pathogenic organisms in this genus are serovars of Leptospira interrogans (R.C. Johnson, pers. comm.). Leptospirosis is best diagnosed by isolation of the organism from the blood, liver, or brain of acutely affected animals or from the kidney or urine of chronically affected animals (Shotts 1976). A serologic test, the microscopic agglutination test (MAT), may also be used for diagnosis in conjunction with culture or when the above specimens are not available (Cole et al. 1973).

Antibodies to serovars of Leptospira interrogans have been detected in many species of wildlife, including deer (Youatt et al. 1959, Trainer et al. 1963, Reilly et al. 1962, McGowan et al. 1963), roe deer (Michna and Campbell 1970), antelope (Collins et al. 1981) and others (Broom and Coghlan 1958, Hathaway et al. 1981).

Little is known about leptospirosis in desert bighorn sheep (Ovis canadensis *nelsoni,* O.C. mexicana). Reed (1960) reported negative results on 16 serum samples from desert bighorn sheep; the plate agglutination test, which is much less sensitive than the MAT was used to evaluate these samples. There is apparently no other report in the literature of the occurrence of leptospirosis in bighorn sheep.

The purpose of this report is to present results of testing of serum specimens from 77 sheep for antibodies to L. *interrogans*.

METHODS AND MATERIALS

Bighorn sheep were captured by the Arizona Game and Fish Dept. from several geographic locations in Arizona, Lake Mead area, Black Canyon, Trigos Mountains, Castle Dome Mountains, Kofa Mountains, Plumosa Mountains, and Santa Catalina Mountains (Fig. 1). A blood sample was collected from each animal using an evacuated blood collection tube with 20 gauge 1½ in. needle. Samples were transported to the laboratory on ice; the serum was then separated and stored at $-20°C$.

Serological testing was performed using the MAT (Cole et al. 1973). Each serum sample was tested for anti-leptospiral antibodies against serovars canicola, grippotyphosa, *hardjo, icterohaemorrhagiae, pomona,* and autumnalis. Live antigens for the MAT were maintained in semisolid medium and propagated in liquid medium (Ellinghausen and McCullough 1965).

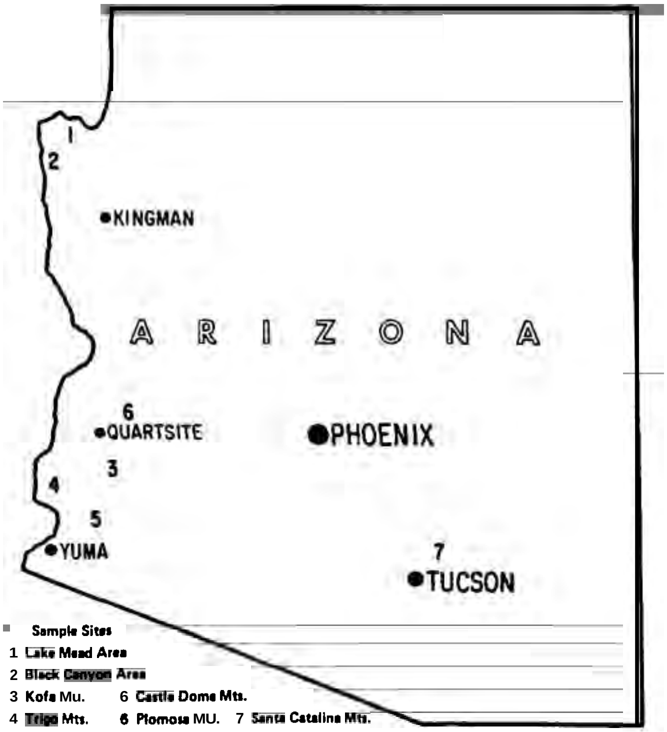

Figure 1. Sample sites of desert bighorn sheep in Arizona.

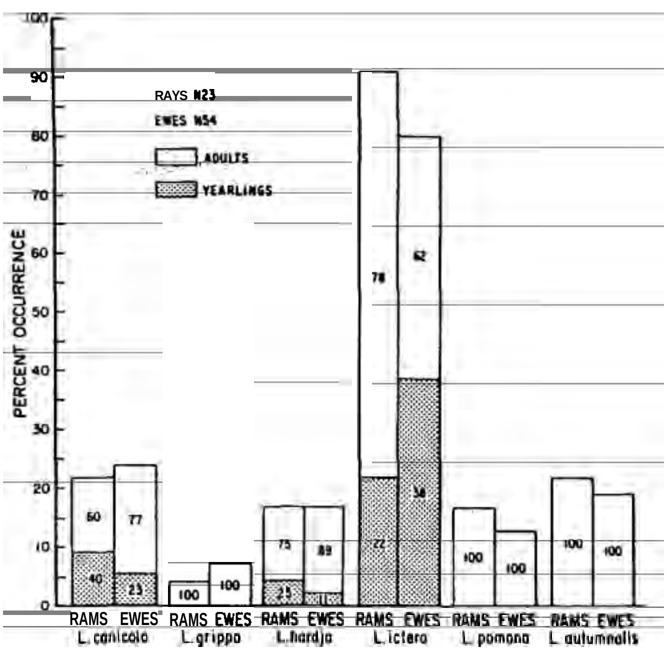

Figure 2. The percentage of titers at 1:2 of rams vs. ewes and adults vs. yearlings in seventy-seven serum samples of Arizona bighorn sheep to Leptospira interrogans.

Table 1. Agglutinating antibody titers to six serovars of Leptospira interrogans in seventy-seven Arizona desert bighorn sheep.

Titers	Antigens[1]					
	C	G	H	I	P	A
1:2	11.7[2]	6.5	16.9	83.1	14.3	20.8
1:4	6.5	-	9.1	53.2	5.2	19.5
1:8	2.6	-	6.5	20.8	2.6	9.1
1:16	-	-	2.5	9.1	-	5.2
1:32	-	-	1.3	1.3	-	1.3
1.64	-	-	1.3	-	-	-
1:100	-	-	1.3	-	-	-

[1]C = canicola, G = grippotyphosa, H = hardjo, I = icterohaemorrhagiae, P = pomona, A = autumnalis

[2]Percent of titers equal to or greater than given titer.

RESULTS

Seventy-seven serum samples were obtained: 69 were from adults (18 rams and 51 ewes) and 8 were from yearlings (5 rams and 3 ewes).

At dilution of 1:2, the following reactions were found: canicola (11.7%), grippotyphosa (6.5%), hardjo (16.9%), icterohaemorrhagiae (83.1%), pomona (14.3%), and autumnalis (20.8%). At 1:16, only reactors to hardjo (2.5%), icterohaemorrhagiae (9.1%) and autumnalis (5.2%) were found and at 1:100 only one reaction was found, this being to serovar hardjo (Table 1).

Specimens from O.c. nelsoni were found to have titers of 1:2 to canicola (24.4%), grippotyphosa (7.3%), hardjo (4.9%), icterohaemorrhagiae (85.4%), pomona (9.7%), and autumnalis (21.9%). In O.c. mexicana titers of 1:2 were found to canicola (25.0%), grippotyphosa (5.5%), hardjo (30.5%), icterohaemorrhagiae (75.0%), pomona (19.4%), and autumnalis (19.4%). Only 7.3% of the O.c. nelsoni samples reacted to icterohaemorrhagiae at 1:16 and greater. while in O.c. mexicana, 11.1% reacted hardjo, 8.3% to icterohaemorrhagiae, and 2.4% to autumnalis. One specimen from O.c. mexicana reacted to hardjo at 1:100.

A greater percentage of rams than ewes had titers 1:2 or greater to icterohaemorrhagiae (91% vs 80.0%), pomona (17% vs 13%), and autumnalis (22% vs 19%); more ewes than rams had titers 1:2 or greater to canicola (24% vs 22%) and grippotyphosa (7% vs 4%); the percent of reactions to hardjo (17%) was the same in both rams and ewes (Figure 2).

There was a greater percentage of yearling vs. adult reactions at titers of 1:2 to canicola (55.5% vs 18.8%), hardjo (25.0% vs 15.9%), and interohaemorrhagiae (87.5% vs 81.9%). Titers to grippotyphosa, pomona, and autumnalis were found only in adults.

Table 2 shows the distribution of titers by geographic location. No useful differences were found in titers among groups captured at different locations.

DISCUSSION

Others have reported that the use of serology without concomitant cultural examination of appropriate tissues can provide at best a presumptive diagnosis of leptospirosis (Hathaway et al. 1981). High titers of antibody (greater than

Table 2. The distribution of reactors by titer and geographic location of seventy-seven Arizona bighorn sheep serum samples to *Leptospira interrogans*.

Sites	Titers[2]	Antigens[1] C	G	H	I	P	A
	1:2	28.6	3.6	3.6	82.1	3.6	14.3
ake Mead Area	1:4	7.1	-	3.6	42.8	-	10.7
	1:8	-	-	-	17.8	-	3.6
	1:16	-	-	-	7.1	-	-
	1:32	-	-	-	-	-	-
28)[3]	1:64	-	-	-	-	-	-
	1:100	-	-	-	-	-	-
	1:2	15.4	15.4	7.7	92.3	23.1	38.5
	1:4	7.7	-	-	69.2	7.7	38.5
lack Canyon Area	1:8	7.7	-	-	23.1	7.7	23.1
	1:16	-	-	-	7.7	-	7.7
	1:32	-	-	-	7.7	-	-
13)	1:64	-	-	-	-	-	-
	1:100	-	-	-	-	-	-
	1:2	-	-	-	75.0	50.0	100.0
	1:4	-	-	-	25.0	25.0	75.0
ofa Mtns.	1:8	-	-	-	-	25.0	50.0
	1:16	-	-	-	-	-	50.0
	1:32	-	-	-	-	-	25.0
4)	1:64	-	-	-	-	-	-
	1:100	-	-	-	-	-	-
	1:2	9.1	9.1	54.5	54.5	18.2	9.1
	1:4	-	-	45.5	45.5	9.1	9.1
rigo Mtns.	1:8	-	-	36.4	18.2	-	9.1
	1:16	-	-	27.3	-	-	9.1
	1:32	-	-	9.1	-	-	-
11)	1:64	-	-	9.1	-	-	-
	1:100	-	-	9.1	-	-	-
	1:2	11.1	11.1	22.2	77.7	-	11.1
astle Dome Mtns.	1:4	-	-	-	33.3	-	11.1
	1:8	-	-	-	-	-	-
	1:16	-	-	-	-	-	-
	1:32	-	-	-	-	-	-
9)[3]	1:64	-	-	-	-	-	-
	1:100	-	-	-	-	-	-
	1:2	66.6	-	22.2	88.8	22.2	11.1
	1:4	22.2	-	11.1	77.7	11.1	11.1
lomosa Mtns.	1:8	11.1	-	11.1	33.3	-	-
	1:16	-	-	11.1	22.2	-	-
	1:32	-	-	-	-	-	-
	1:64	-	-	-	-	-	-
	1:100	-	-	-	-	-	-
	1:2	33.3	-	33.3	100.00	33.3	-
anta Catalina Mtns.	1:4	-	-	-	100.0	-	-
	1:8	-	-	-	66.6	-	-
	1:16	-	-	-	33.3	-	-
	1:32	-	-	-	-	-	-
	1:64	-	-	-	-	-	-
	1:100		-	-	-	-	-

C = canicola, G = grippotyphosa, H = hardjo, I = icterohaemorrhagiae, P = pomona, A = autumnalis
Percentage of titers equal to or greater than
Total number in sample

1:400) in serum of nonvaccinated animals usually indicate past or present infection with leptospira. Low titers, on the other hand, may or may not indicate that an animal has had contact with leptospira. Agglutination of leptospira in low dilutions of serum may be simply cross-reactions with antibodies actually directed toward antigens of other bacteria but shared with leptospira. It is well known, however, that antibody titers decrease after the animal recovers from the disease; in fact, sera from some cattle may have no antibody to leptospira isolated from their own kidneys (Ellis, pers. comm.).

There is essentially no agreement among workers studying leptospirosis in wild animals as to which titers are significant and which are not. Some (Trainer and Hanson 1960, Michna and Campbell 1970, Collins et al. 1981) have considered titers of 1:100 or greater to be positive, while others (Broom and Coghlan 1958, Hathaway et al. 1981) have reported as positive titers of 1:24. It is apparent that major improvements must be made in serologic methods for diagnosis of leptospirosis.

Despite the limitations of these data, they may be useful for at least 2 reasons. First, the lack of titers of antileptospiral antibody greater than 1:100 and the apparent absence of significant herd problems with abortion or infertility indicate that leptospirosis is probably not a major disease problem. Second, these data, which are apparently the first generated from study with the MAT of desert bighorn sera, provide a baseline for future studies. While low average titers for a herd are difficult to interpret, a significant increase from one sampling period to the next could indicate the need to make especially careful observations of reproduction rates in thg herd.

Further, studies should be specifically planned and executed to elucidate details of the epidemiology, pathogenesis, and diagnosis of this and other diseases affecting reproduction and fertility in bighorn sheep and other wild animals.

ACKNOWLEDGMENTS

We would like to thank the Arizona Game and Fish Department for their efforts and cooperation, and particularly Jim deVos for his close support and help on this project.

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SURGICAL **TREATMENT FOR** CHRONIC **SINUSITIS**

Robert L. Glaze
Glaze Veterinary Clinic
Kerrville, TX

Thomas D. Bunch
Dept. of Animal, Dairy and Veterinary Sciences
Utah State Univ., Logan

James W. Bates
Utah Division of Wildlife Resources
Price, UT

Chronic sinusitis (CS) induces a pyrogenic osteomyletis and osteonecrosis of the paranasal sinuses and is characteristically a terminal disease. Symptoms include weight loss, blindness, central nervous system disorders, aberrant horns and draining fistulous lesions from the horn core, sheath and frontal bone. Attempts to treat CS by trephining the infected sinus and then irrigating with antibiotics and antiseptic agents have not been effective. Sheep treated by this procedure redeveloped symptoms of CS within 3-9 months of treatment. We here describe a more radical method for treating CS that may result in a complete cure of the disease.

A Nelson's desert bighorn ewe with CS was airfreighted from southeastern Utah to the Glaze Veterinary Clinic, Kerrville, Texas following capture by chemical immobilization with M-99. The ewe arrived at the clinic within 24 hours of capture, and her vital body signs were normal. She was 7-8 years of age and weighed 90 Ibs.

The ewe was kept in isolation for 10 days prior to surgery so she could acclimate. She readily adjusted to a 12x30 foot covered stall and began to eat and drink on her first day at the clinic.

The site of the ewe's infection was in the cornual sinus of the left horn (Figure 1). An abscess 1 in. in diameter occurred at the base of the horn. The abscess had fistulated through the corium, proximal to the epikaris, and the exudate surfaced through the skin below the base of the horn.

Drugs were administered intravenously (i.v.) to induce surgical anesthesia. A mixture of 2½ cc of Acepromazirie (50 mglcc) and Ketamine (100 mglcc) produced anesthesia within 2-3 minutes. Eight mg of Atropine were given intramuscularly (i.m.) to control excessive salivation. After the ewe was anesthetized, hair was clipped from the surgical site (base of left horn and left side of frontal bone) and the exposed area was thoroughly washed twice with Betadine surgical scrub and then rinsed with undiluted Betadine. During surgery it was necessary to periodically administer Ketamine at the 100 mglcc rate to maintain surgical anesthesia.

The region around the surgical site was draped. An incision through the skin was made ½ in. proximal to the base of the horn. The horn was removed by cutting with an obstetrical wire (Figure 2). Upon removing the horn, it was obvious that the canal connecting the cornual to the frontal sinus was completely ossified (Figure 3). This condition required that we made a second section of the horn ½ in. posterior to the first so we could gain entry into the frontal sinus. After the second section was made, it became apparent that the disease had extended 2 inches further into the frontal sinus and posterior to the orbit.

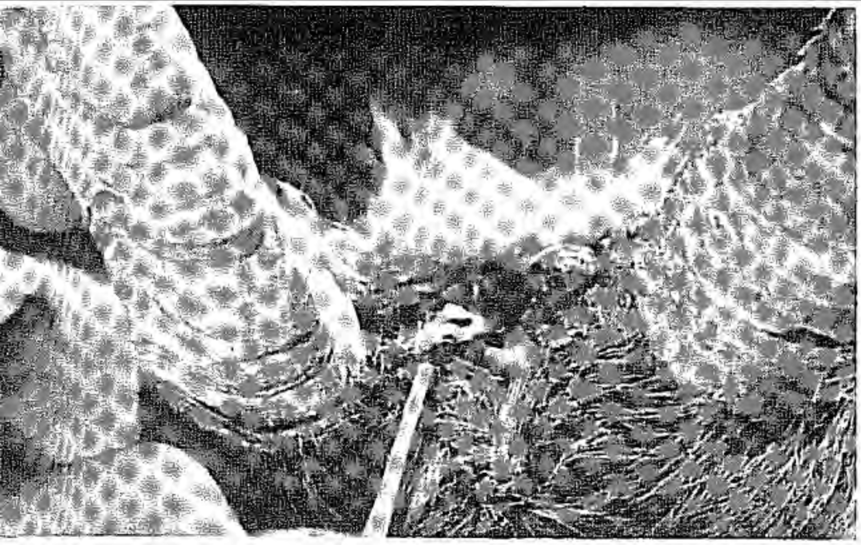

Figure 1. The base of the ewe's left horn was enlarged as a result of CS in the cornual sinus. The infection drained downward between the horn core and sheath and erupted through the skin between the bases of the horns (note pointer).

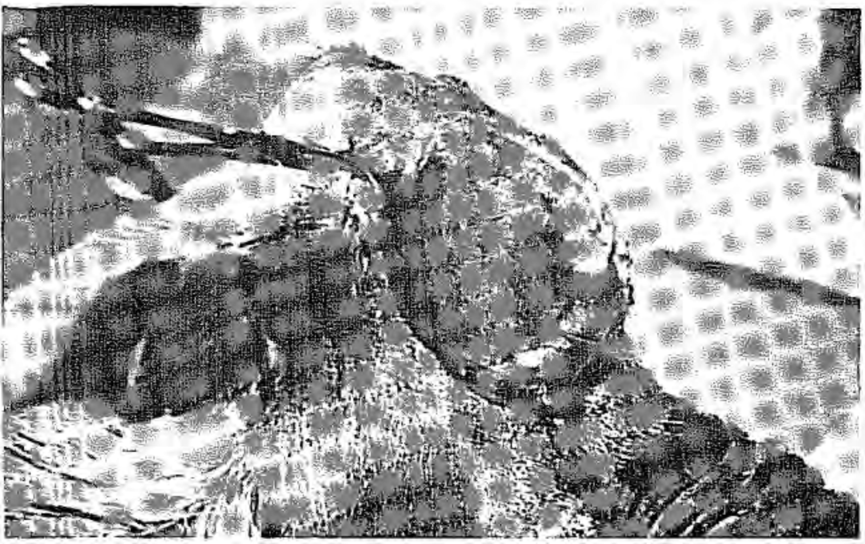

Figure 2. Infected horn is removed so the underlying frontal sinus can be treated. Wound is packed with gauze.

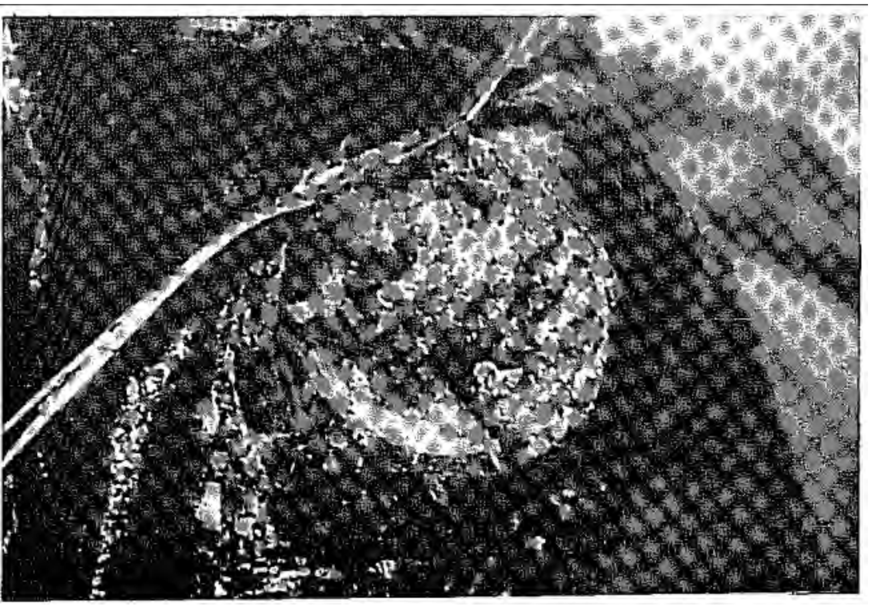

Figure 3. Extensive osteomylitis with ossification of cornual sinus.

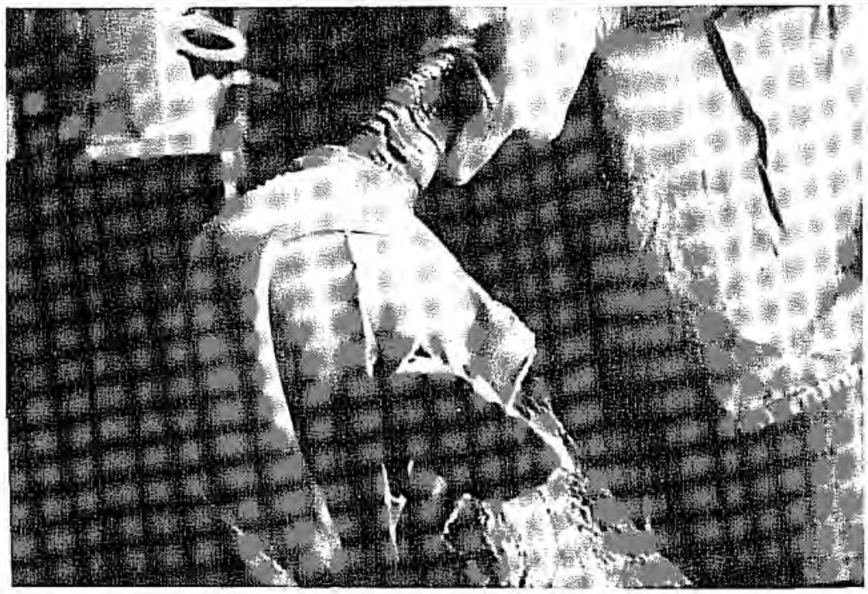

Figure 4. Bonnet-type bandage overlying packed frontal sinus.

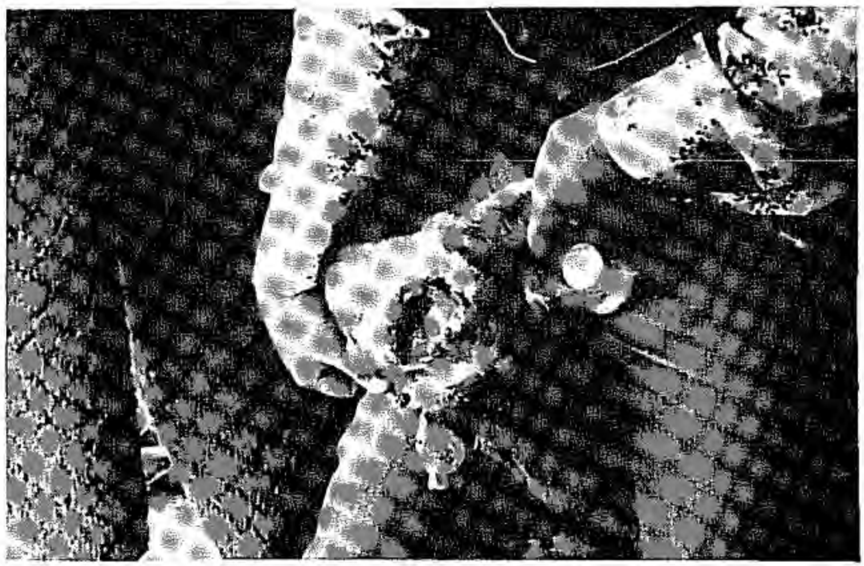

Figure 5. Removal of packing 2-3 weeks after surgery. The exposed sinus has begun to fill in and heal.

Figure 6. Four months after surgery. The opening to the frontal sinus had completely healed over.

As much of the diseased bone as could be extracted was removed from the frontal sinus. The sinus was then flushed with a water pik containing 50 mg Gentocin per 100 ml sterile saline to remove the remaining bony sequestra. The exposed sinus was then packed with sterile gauze impregnated with Penicillin, Streptomycin and Furacin. A bandage (bonnet-type) was placed over the wound to maintain the packing and to prevent contamination (Figure 4).

The entire surgical procedure took approximately 65 minutes. The ewe was ambulatory 15 minutes after she was removed trom the surgical table and began to-drink water within 30 minutes.

Post-operative treatment consisted of daily administration of 200 mg i.v. Gentocin (3 days) and 4cc i.m. (7 days) of Penicillin-Streptomycin. The bandages were changed every-other day for the first 2 weeks and twice weekly during the third and fourth weeks (Figure 5). The wound was treated with Betadine ointment and packed with sterile gauze.

Prior to surgery, a culture of the exudate revealed the presence of Pasturella *multicida*. During surgery, cultures made from the infected area revealed Staphlococcus *aureus* and Pseudomonas *aeruginosa.* Post-operative cultures taken from the treated sinus were negative, which indicated that the infection had been effectively treated.

Although 4-6 weeks of post-operative care were required following treatment, the process has demonstrated that some animals with CS are treatable and can be cured (Figure 6). In more advanced cases of CS, where the disease has progressed into inaccessible areas, surgical treatment still offers temporary relief and may prolong the life of the sheep. In either situation, surgical treatment for CS (as herein described) provides some hope for sheep that otherwise would most likely die. Animals that are cured can be returned to their native habitat, incorporated into breeding and propagation programs, or used for research purposes.

ACKNOWLEDGMENT

A contribution of the Foundation for North American Wild Sheep and the Utah Division of Wildlife Resources. Transportation costs for the ewe were paid for by the Texas Chapter of the Foundation for North American Wild Sheep.

A COMPARISON OF FOUR METHODS FOR CAPTURING BIGHORN

David A. Jessup, D.V.M.
Staff Wildlife Pathologist
California Dept. of Fish and Game
Rancho Cordova, CA

Russell Mohr
Wildlife Consultant

Bernard Feldman, D.V.M.
University of California, Davis

Abstract. Wherever bighorn occur, wildlife professionals need to increase management activities. Management activities include marking or tagging individuals in a population to study range usage, migration patterns, or reproductive success; sampling or treating diseased individuals; or removing surplus animals from healthy populations to start new herds. All such activities require capturing of animals.

Advances in pharmacology and technology have made capture and transport of bighorn feasible, although costs and capture-associated mortalities have frequently plagued bighorn management efforts. No single method of capture has proven best for all management objectives, weather conditons, habitat conditions, terrain types and herd compositions. By comparing capture success rates, morbidity, mortality and physiologic effects of various capture techniques on serum enzyme, metabolite and hormone levels, we intend to supply wildlife professionals in the western U.S. with information that will allow them to more safely and efficiently manage bighorn.

We currently are collecting data and blood samples from bighorn captured for various purposes and by various means in as many of the western states with bighorn populations as wish to participate in our study. Although we analyze the cost effectiveness of our own capture efforts, we do not propose to do this outside California. This study, funded by a grant from a private conservation organization, will include an extensive literature review of bighorn capture stress, capture myopathy and capture efforts, as well as field studies of current bighorn capture efforts and therapeutic approaches to dealing with capture-associated medical problems. When completed in 1983, results of this study will be provided free of charge to interested parties. This paper, which compares previous bighorn capture efforts in California, will illustrate the manner in which we intend to compare methods currently being used to capture bighorn in the western United States.

INTRODUCTION

Although North American bighorn numbered between 1.5 and 2.0 million at the beginning of the 19th Century (Buechner 1960), fewer than 40,000 survive today (Trefethin 1975), many in isolated populations. The value of animals lost in capture is difficult to estimate, but represents one less set of genes in a dwindling pool.

In the course of studying bighorn populations and during attempts to re-establish them in habitats from which they were extirpated, bighorn have been captured by various means. Four methods were used to capture bighorn in California between 1975 and 1981. These methods included: (1) driving animals into stationary corrals with a helicopter, (2) driving animals into portable standing nets with a helicopter, (3) baiting animals under drop nets, and (4) darting of individual animals with an anesthetic drug from a helicopter.

Capture methods were chosen for various biological, financial and political reasons. Cost per animal captured varied greatly, as did success, morbidity, and mortality associated with capture and various serum electrolyte and metabolyte levels used to measure physiologic responses to capture stress.

METHODS

Between 1975 and 1981, bighorn were darted from helicopters on several occasions. Most were released after marking and sampling. A few were removed for relocation by helicopter. One, or possibly 2, mortalities resulted either directly or indirectly from capture.

During March 1979, 7 bighorn were baited with fermented apple pulp under a drop net and captured. No chemical restraint was used. A helicopter was not needed to move the animals. In March 1980, 10 bighorn were captured in the same manner, but a helicopter was used to lower them 2,000 vertical feet from the capture site to transport vehicles. These bighorn were chemically restrained. No injuries or fatalities occurred.

During February 1980, a helicopter and a 20-man ground crew were used to herd bighorn into a stationary corral. For various reasons, only 10 of 15-17 bighorn trapped were eventually physically restrained. Of these 10, six died of capture myopathy, trauma and capture stress.

During March 1980, 21 bighorn in mountainous winter range were driven by helicopter into linear drive nets. They were first physically, then chemically, restrained by a ground crew, and finally transported via helicopter to vehicles. No morbidity or mortality occurred.

During April and November 1981, 22 desert bighorn were driven by helicopter into linear nets. After marking and sampling, each was released; none was physically restrained longer than 12 minutes. Despite high temperatures and apparent stress, 6 to 12 months of monitoring each animal has not indicated problems associated with capture.

Blood samples were taken from each bighorn captured during handling for data collection, marking and treatment. Samples were taken within one hour of capture in stoppered glass tubes, allowed to clot, centrifuged, and the serum refrigerated. Serum enzyme and metabolite values were determined by an autoanalyzer (SMA-12), after the serum had been frozen and stored at $-20°C$ for a variable period.

Serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), and lactate dehydrogenase (LDH) are enzymes found in varying concentrations in skeletal muscle, heart muscle, and liver. The first 2 enzymes also are referred to as AST and ALT, respectively.

In sheep, SGOT is found in both the liver and muscle in about equal quantities, while SGPT is found in very small quantities in muscle. LDH is found in red blood cells, brain, cardiac muscle, skeletal muscle and liver, and is slightly different in form in each organ. When damage or disfunction occurs, these enzymes are released and the speed and degree at which they rise indicate the organ and severity of damage (Duncan and Prasse 1977, Coles 1980).

Blood urea nitrogen (BUN) is a metabolic breakdown product of protein and a useful measure of kidney function. Glucose (GLU) and cholesterol (CHOL) are the soluble and easily metabolized energy forms of sugars and fats in blood. Glucose levels rise sharply when an animal is excited, due to release of adrenalin, and drop as an animal Pecomes exnaustea. Phosphorus (P) and calcium (CA) are electrolytes. Albumin (ALB) is a serum protein and part of the total protein (TP) (Sodikoff 1981).

Variables such as wages, per diem, travel expenses, and cost per hour of helicopter time were standardized to compare cost effectiveness of 4 techniques. Costs to put a skilled state or federal employee in the field vary sharply, but an average value of $10 per hour was used for the sake of comparison. The current average cost for helicopter time for a small turbine-powered ship with maneuverability, versatility, and payload capacity to capture bighorn is approximately $325 per hour (Jessup 1978). After attempting to roughly average costs and standardize success, we projected the cost at 1981 prices of capturing 20 bighorn by each of 4 methods which we used. Since injury and mortaiity to bighorn cannot be assigned monetary values, an arbitrary safety rating for each capture technique (based on our experience) is presented. This is not an actual cost per animal, but a projected comparison based on experiences with the 4 capture methods.

RESULTS

Means for serum electrolyte, metabolite and enzyme values indicate several striking contrasts (Table 1). SGOT, SGPT, and BUN were elevated significantly in drive-trapped animals. LDH was slightly elevated for all captured bighorn. Glucose was elevated in all animals. Inorganic phosphorus values were increased slightly in drive-trapped animals, and calcium values were depressed, but were somewhat depressed in all animals. Serum albumin and protein values appear to be within normal limits.

Certain general trends are demonstrated in Table 2. The costs, both in materials and manpower, for permanent corrals were high and not recoverable unless they could be reused frequently for several years. The cost of drop nets and drive nets was recoverable since they were portable and reusable. Hence, cost per animal decreased with each successive use of the equipment. Baiting a drop net site initially required a great deal of manpower in site and bait preparation, actual baiting and animal observation. If a capture site was chosen that was accessible by vehicle, helicopter time could be greatly decreased or eliminated, thus decreasing cost per, animal. In all mass capture methods, the cost of manpower was high, as more animals captured at any one time meant more manpower was needed to safely process them. Darting individual animals by helicopters was less expensive in equipment (gun vs. net), but used expensive drugs. Also, although manpower costs were greatly reduced, more helicopter time per animal was needed. When labor was free or relatively cheap, helicopter time far outweighed labor as a cost consideration. When labor was expensive, it obviously was a major cost factor.

Anytime a helicopter was used to capture or move animals, certain elements of risk were involved. Pursuit of animals is relatively more hazardous to both man and animal than slinging or transporting, and slinging or transporting is relatively more hazardous than herding. Perhaps the most critical factor was judgment on the part of the people involved in bighorn capture as to the stamina and state of exhaustion of the animals. When bighorn are excessively frightened, physically exhausted, and handled for long periods, the probability of mortality increases with all capture methods.

The number of animals physically handled by the 4 methods used was too small for statistical analysis. Conclusions drawn at this point must be considered preliminary and subject to modification as more data become available.

Table 1. Mean values of various serum enzymes used to evaluate physiologic state of captured bighorn.

	SGOT	SGPT	LDH	BUN	GLU	CHOL	P	CA	ALB	TP	Medical Compli-cations	Injuries	Mortal-ities
(a) Darting[1]													
X̄ N = 20	175.2	ND	485.3	18.5	92	64	5.2	9.2	3.9	6.3	4/22	4	1
Drive Trapping													
X̄ N = 5	686.4	225	1433	43.6	186	65	7.7	7.3	2.7	7.7	14/17	14	6
Drop Netting													
X̄ N = 16	141	1.7	513	21.6	203	71	5.7	6.9	2.66	5.8	1/17	0	0
Drive Netting													
X̄ N = 18(b)	155.7	4.2	519.1	14.6	174	84	6.5	8.7	3.1	6.5	1121	0	0
N = 18(c)	291.8	50.2	--	14.5	133	67	6.1	11.6	3.5	7.4	0122	0	0
N = 36(d) (Grand Mean)	223.8	27.2	519.1 (18)	14.4	154	76	5.6	10.2	3.3(34)	7.0	1143		
Normal Resting Domestic Sheep N► 100	307 ± 43	37.8 ± 3.4	238-440	8-20	50-80	52-76	5-7.3	11.5-12.8	2.3-3.8	6-7.9			

[1]Source: J.B. Payson, 1977

(a) = Average all individuals sampled
N = Individuals sampled
(b) = March 1980
(c) = April, November 1981
(d) = Numbers in parenthesis represent sample size

SGOT = serum glutamic oxaloacetic transaminase
SGPT = serum glutamic pyruvic transamlnase
LDH = lactate dehydrogenase
BUN = blood urea nitrogen
GLU = glucose

CHOL = cholesterol
P = phosphorus
CA = calcium
ALB = albumin
TP = total protein

Table 2. Cost Effectiveness of four methods **(a,b,c,d)** used to capture bighorn in California.

	Original Equipment Reusable[1] (Actual)	Cost of Nonreusable Equipment[1] (Actual)	Setup Man-Hours[3] (Average)	Capture Man-Hours[3] Average)	Helicopter Cost[2] (Minimum)	Cost Per Animal[4] (Minimum)	Versatility	Animal Morbidity and Mortality
a. Helicopter Darting	$1800	$1500	30	70	$6500	$540	Good	Fair
b. Drop Netting	$1200	$500	220	140	$0-1300	$265-340	Fair	Good
c. Drive into Stationary Trap	$7500	$300	220	120	$975	$609	Poor	Poor
d. Drive Netting	$2000	$400	25	120	$1950-3250	$310-455	Good	Good

[1]Equipment cost based on average of 1979-80 prices for items needed to capture 20 bighorn given average success.
[2]Bell Jet-Ranger at $325/rotor hour.
[3]Manpower at average cost of $10 per hour, including travel and per diem.
[4]Sum of columns divided by 20, does not include intangibles mentioned in text or amortization of reusable equipment

HELICOPTER DARTING

Helicopter darting required a capture rifle and accessories, which cost $600-$1400 depending on make and accessories purchased. Approximately 1.5 darts are needed per bighorn captured, as approximately 1 out of every 3 or 4 shots were missed and the dart and drugs lost. Darts cost from $12-$20 apiece, depending on make, and $120 apiece if a radio transmitter is attached. The most effective drugs used for helicopter darting of bighorn are M-99 (Etorphine) and a tranquilizer (Rompun, Acepromazine, or Azaperone). M-99 and its antagonist M 50-50 costs $72 per 20 cc vial, which is enough for about **4** animals. Thus, capture drugs cost a minimum of $35 per animal, not counting missed shots, each of which cost about $17 in drugs plus the price of the dart.

Helicopter darting is relatively expensive in terms of both reusable and nonreusable equipment. This method is conservative on manhours, requiring little setup time beyond preparation of darting and medical equipment and finding animals. Capture requires 2 individuals for an average of about 1.5 hours per animal plus an hour of helicopter rotor time. Obviously, helicopter time is the major expense with this capture method, and the inability to locate target animals rapidly increases costs. The versatility and mobility of this method also is good. Injuries to bighorn during pursuit from dart penetration, and from falls during anesthetic induction, oftentimes occur. Capture stress and myopathy, bloat and hyperthermia have also killed bighorn captured in this manner (Dalton et al. 1978, Matthews 1977), but only a slight rise in LDH and a rise in glucose resulting from capture stress occurs. These values (see Table 2) indicate only the state of the animal at the time of sampling. ,Experience and a review of the literature indicate values may continue to rise significantly for several days (Duncan and Prasse 1977, Franzmann and Thorne 1970). Hot pursuit of animals in rocky, mountainous terrain also is dangerous to the capture crew. Capture drugs are potentially lethal to humans. Experience, judgment, and the ability of the pilot and capture crew are extremely important ingredients with this capture method, both for success and animal safety. If fewer than 7 animals are to be captured and/or particular individuals selected, or recaptured, this method serves well.

DROP NETTING

Drop net capture has been used extensively on Rocky Mountain bighorn in Colorado and other states for the last several years (Spraker 1977). Due primarily to poor bait acceptance, it has been used only occasionally in California. A four-panel, 70x70 ft. drop net that clips together costs approximately $900. Outrigger poles, central pole, ground anchors and guy ropes are additional expenses, as are blasting caps, tape, electrical wire, detonator and assorted hardware. Additional nonreusable equipment such as apple pulp, salt blocks and alfalfa are used for bait. Bait preparation appears at present to be an art rather than an exact science. If animals can be baited to a flat area near a road, helicopter time is not needed. We have had net capture sites several thousand vertical feet above roads, and the expense of helicopter time needed to evacuate animals greatly offset the financial advantages of drop net capture.

Bait preparation, baiting and animal observation require several weeks of manpower. Should animals prove unreliable or nonaddicted to a bait, days of standby time may be involved. In addition, at least 2 people per animal are needed during the capture phase in order to handle bighorn rapidly and efficiently and thereby to avoid stress and associated pathology. Physiologic profiles of net-captured bighorn revealed only a small rise in LDH and a rise in glucose, both probably resulting from excitement and muscular exertion of capture. If volunteer or inexpensive labor is used, the cost of drop net capture can be reduced considerably, which also is true for all 3 trapping methods.

Drop nets require flat or gently sloped terrain with cover for blaster and handling crews. Equipment is heavy and setup is somewhat time-consuming. As baiting is the key to success, versatility and mobility of this capture method are only fair. If a large enough crew is available to rapidly and efficiently handle captured bighorn, drop net captures appear to be quite safe. If 20 or more bighorn are to be captured, if animals can be baited to optimal capture sites, and if several captures are planned in a year or two, this method appears to be the best of the four methods evaluated.

WING TRAPS

Bighorn have been driven into wing traps made of snow fence, post and field fence or wooden panel fence in Oregon and British Columbia for many years. California's only experience with this method of capture was disastrous. Animals were pursued and physically restrained for too long a period. Marked rises in SGOT, SGPT and LDH (Table 1) indicated significant muscular and/or hepatic damage. Increased BUN may have resulted from renal failure. Glucose elevations were probably due to excitement and exertion, but may have been declining in this case due to exhaustion. The morbidity and mortality figures speak for themselves: 6 of 10 bighorn handled died. Stationary traps are expensive to build, both in terms of raw materials and manpower. Such expense may be justifiable if many animals are to be trapped over a long period of time in one location. A fairly large handling crew also is required for rapid, efficient handling. Fear and excitement may cause bighorn to repeatedly hit solid fences, which can result in lacerations, fractures, exhaustion, capture stress and/or myopathy. Helicopter time expense is minimal as compared to darting or drive-netting--unless repeated drives become necessary. Mobility and versatility of stationary traps are poor. Strategic use of burlap may decrease hitting of fences. We found few advantages in using this capture method.

DRIVE NETTING

Ten 100-ft. sections of 8 ft. high, 14 in. stretch nylon mesh net costs approximately $1800. Some additional hardware, holding bags, and 10 support poles (7-to-8,l in. x 1 in. pine) per 100-ft. section of net also are needed. When efficiently packaged, setup time for drive nets is quite low. Six hundred feet can be set up by 6 people in less than an hour.

Each 100-ft. section should be anchored separately. "E" or "C" configurations, with backup sections, tend to capture more animals per drive. A moderately-sized handling crew was needed, as no more than 6 animals were ever captured during a drive. Helicopter time depended upon numbers of bighorn in an area, net configuration and efficiency, and distance of bighorn from the nets. Rotor time was minimized by using the helicopter only when the bighorn were driven, transported, or nets and crew ferried. Lack of dependence on behavior or bait acceptance made this technique quite versatile and mobile, and flat terrain is not required. This method is relatively safe, and all sizes, ages, and both sexes of animals can be captured. Table 2 reveals only an increased value in LDH and glucose, probably resulting from muscular exertion and excitement. If from 6-20 animals are to be captured per location, and the use of a helicopter cannot be avoided, mobility, variable terrain and manpower are major factors. Under these conditions this technique is superior. No bighorn capture method is foolproof or without risk. For maximum success, a combination of drop netting, drive netting and/or darting was optimal in our limited experience.

Again, the sample size in this study was too small to provide definitive results, thus, comparisons are preliminary. Other capture techniques, including drop gate trapping, net guns and telemetry darts may be investigated in the future. In addition, this preliminary work suffered from several deficiencies. Analyses for serum electrolytes and metabolites were limited to those available on a popular commercial panel. A specifically designed "stress panel" will be used to analyze newly obtained and future serum samples. This panel includes the skeletal muscle enzyme, creatinine phosphokinase (CPK), which is a good indicator of muscle damage. Elevated CPK and LDH values will be fractionated into isoenzymes to better delineate the tissue of origin. Other serum electrolytes, including chloride (CL), sodium (NA), and potassium (K), will be included, as will a complete blood count (CBC).

Serum cortisol levels will be analyzed by radioimmunoassay (RIA) by Dr. Terry Spraker at the Colorado State Diagnostic Laboratory. His work on deer indicates this hormone may be the best single indicator of stress (Spraker 1977). Whole blood selenium will be determined on each animal for which unclotted blood is submitted. Low selenium intake is known to be a major predisposing factor to white muscle disease (Underwood 1977) and possibly capture myopathy (Hebert and Cowan 1971). On some samples, serum carbon dioxide and pH will be determined immediately so serum bicarbonate and acid base balance can be calculated. Participation to date in our study of capture techniques used on bighorn, which was initiated December 1, 1982, has been encouraging. Samples from bighorn from Washington, Oregon, Utah, Arizona, Montana, and South Dakota have been submitted. Unfortunately, only serum, sometimes in small quantities, frequently was taken. This was, in part, due to communications difficulties and logistics of standardizing sampling procedures over an area as vast as the western United States. In the future, this study will supply full written instructions, all sampling equipment needed, and in some cases, individuals to assist in the collection of blood from captured bighorn. Response to initial letters and calls indicated that as many as 400 bighorn from 13 western states may be sampled during the course of the study. With continued cooperation and support of wildlife professionals, the California Department of Fish and Game and the Shikar Safari Club Foundation International, we will produce a useful and thorough comparison of methods used to capture bighorn.

ACKNOWLEDGMENTS

Dr. Bernard Feldman gave support for serum enzyme analysis and assisted in writing various drafts of this manuscript. Dr. Terry Spraker frequently shared his expertise on bighorn and capture myopathy, and hopefully will be a valuable cooperator with this project. Thanks is given to Bill Clark, Dick Weaver, Jim Banks and Karen Jones of the California Department of Fish and Game for their assistance and cooperation in various aspects of this work. Thanks also is given to Jim DeForge, Dr. Charles Jenner, and other members of the Foundation for Desert Bighorn Research for assistance in capturing, monitoring and sampling bighorn.

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SURVIVAL OF CAPTIVE BORN OVIS CANADENSIS IN NORTH AMERICAN ZOOS

Karen Sausman
Executive Director, Living Desert Reserve
Palm Desert, CA

Abstract. The survival rate was analyzed for subspecies of North American bighorn sheep housed in several zoological gardens. Complete herd histories, including birth and death data as well as causes of mortality, were collected from 7 institutions and the data were analyzed. Lambs were divided into inbred and outcross animals with animals being considered inbred if they had an inbreeding coefficient greater than 0. The rate of survival of inbred and outcrossed lambs was compared using "survival equalling 1 year" and also "survival equalling 6 months." The second analysis compared survival rate of male and female inbred lambs and male and female outcrossed animals. Age at death was compared in inbred and outcrossed lambs as were reasons for mortality. Analysis of the data for the 7 collections, located in various geographic areas and housing various subspecies, indicates that inbreeding may be a mortality factor in the captive management of North American bighorn sheep. Therefore, long-term survival of captive or isolated wild populations may depend on maintaining genetic diversity within the herds through careful selection of breeding stock in captive populations or introduction of non-related animals into isolated wild populations.

In 1972 the Living Desert Reserve in Palm Desert, California asked to become involved with the Calif. Dept. of Fish and Game in the propagation of desert bighorn sheep. An initial herd was established with an 18 month-old *Ovis* canadensis cremnobates ram caught in the Santa Rosa Mountains and one approximately 3 year-old female Ovis canadensis nelsoni brought from near the Arizona border. In summer 1973 a second wild female from the Santa Rosas was added to the group.

The first lamb was born to this group of animals in 1973 and since then 17 additional lambs have been born. Initially our success in raising lambs to maturity was excellent, with only 1 out of 5 animals dying before reaching 3% years of age. The fifth animal disappeared from the enclosure at 10 days of age and most likely was predated. Then, starting in 1977, we began to face a complete turnabout in our lamb survival even though the enclosure and the basic care was the same. Thirteen lambs were born from 1977 to the present, of which only 5 survived to 1 year of age—an average survival of only 38%. Concerned about our lamb mortality, I contacted several other institutions which maintain North American bighorn sheep.

The following is a preliminary report on survival of Ovis canadensis in captivity. There are much additional data that should be reviewed and additional information to be gotten from the data on hand. However, a presentation of the preliminary findings, hopefully, will stimulate additional questions that can be answered as the research continues.

Almost every paper that discusses the decline of bighorn sheep mentions William T. Hornaday's comment in his 1908 ***Campfires* on *Desert and Lava*** 'that captive bighorn sheep usually die of pneumonia.' His information was based on experiences of the New York Zoological Society. William G. Conway, General Director of the New York Zoological Society, was kind enough to send me their records of bighorn sheep from the early part of the century. While not particularly enlightening, they are interesting. The first record of a bighorn sheep being received in New York was on March 4, 1902, listed as a male California mountain sheep. This animal died on July 24, 1902. The second animal arrived on March 8, 1905, listed as a female Rocky Mountain sheep; the animal survived until September 4, 1905. The next animal to arrive was a male Rocky Mountain sheep, described as Ovis nelsoni from Yuma, 4 years of age in December 1912. This animal survived an additional 8 years in captivity at the Zoo. Another male arrived in early 1913. This male, described as Ovis canadensis, lived for just over a year. In March 1920, 2 Rocky Mountain sheep, 1 female and 1 male, were received. The female died in November of 1920 and the male in March 1921. However she gave birth to a wild-conceived lamb that lived for nearly a month. In 1921 the park tried again. Two male and 2 female sheep from Rocky Mountain National Park arrived in March. Both females produced lambs conceived in the wild. One lamb survived 6 days; the other survived approximately 3 months. One of the females died in 1922; the other produced a captive-born lamb in August 1922 which survived until the following May—approximately 9 months. By the end of 1922 all but 1 of the females of these 4 sheep were dead. She apparently lived by herself at the park until 1931 when a male was purchased from the St. Louis Zoo. No lambs were recorded being born to this pair. In 1936 the female died, her survival in captivity being 15 years, and in 1937 the male died. The zoo purchased 1 more female from the Calgary Zoological Society in October 1937 but she died in January of 1938 and they have not attempted to keep sheep since. In the few cases where the cause of death was listed, it was pneumonia.

At the same time New York was struggling to keep sheep alive, the National Zoological Park was described by Crandall (1964) as having exceptionally good results. The sheep were kept in a high, dry enclosure floored with natural rock and concrete. Crandall reports 20 births in the collection and a maximum longevity of 9 years and 8 months. However he does not mention how many of these 20 lambs survived. It would appear that the Living Desert Reserve, 50 years later, was not doing much better than the New York Zoological Society or the National zoo.

The International Zoo Yearbook, Vol. 20,1980, lists 106 bighorn sheep—47 males, 59 females captive in 23 collections throughout the world. Of these animals, 81 had been born in captivity (33 males, 48 females). Of those institutions, 17 consistently bred sheep in previous years. It is from these 17 that I randomly selected 6 collections in addition to my own to study the captive history of their herds. The collections were Buffalo, New York; Calgary, Alberta Canada; Denver, Colorado; San Antonio, Texas; Los Angeles, California; and San Diego (Wild Animal Park), California. In addition, some information was gathered from the Phoenix Zoo.

A total of 37 apparently unrelated animals made up the original founder stock as follows: Buffalo, NY, started with 1 male and 2 female Ovis canadensis canadensis in 1976; Calgary started with 3 male and 4 female *O.c.* canadensis in 1972, 1 male and 4 females from the wild and 2 males from the Alberta Game Farm. Denver started in 1969 with 1 male and 6 female wild-caught *O.c.* canadensis; Living Desert Reserve started in 1972 with 1 male and 2 female, wild-caught animals already mentioned; Los Angeles Zoo started in September 1976 with 3 male and 4 female *O.c. nelsoni* from the Nevada Desert National Wildlife Range's long-term captive herd; San

Diego Wild Animal Park started in December 1976 with 3 male and 2 female *O.c.* nelsoni, also a part of the herd from Nevada. Finally San Antonio, TX, started in May 1969 with 4 male and 1 female *O.c.* canadensis and *O.c. mexicana*.

These original animals were the founder stock for a total of 181 lambs—86 males, 86 females, and 9 unknown. Denver produced the most—85 animals (40 males, 39 females and 6 unknowns); San Antonio produced 23 animals (8 males, 13 females and 2 unknowns); Calgary produced 21 (11 males, 9 females, 1 unknown); Living Desert Reserve produced 18 (8 males, 10 females); Buffalo produced 13 (6 males, 7 females); Los Angeles also produced 13 (7 males, 6 females); San Diego produced 8 (6 males, 2 females). Of these 181 lambs, 67 of them or 37% were dead at less than 6 months of age.

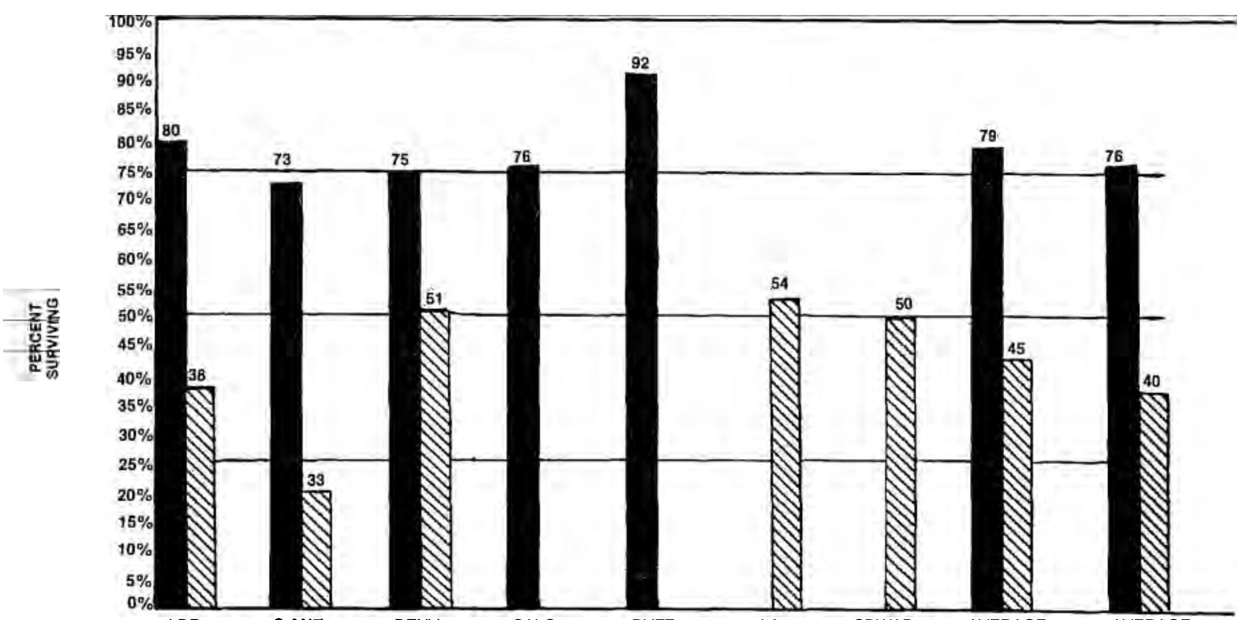
The cause of death of any captive-born animal can be divided into 2 very basic categories: (1) poor husbandry or management techniques, (2) genetic factors. The information gathered from the 7 facilities allows us to examine both of these.

DeForge et al. (1979) discussed reasons for suspecting inbreeding and genetic weakening as one of the causes of the decline of bighorn sheep in the wild. Many studies of laboratory and domestic animals have shown that inbreeding usually leads to a reduction in viability and fertility (Wright 1977, Lasley 1978). It is recognized that inbreeding causes an increase in homozygous genotypes which in turn allows for recessive deleterious effects to be manifested. It has been shown that characteristics expressed early in life, such as the 'survival after birth,' or 'growth rate to weening' are usually more severely affected by inbreeding than characteristics which develop later in life and contribute little to "fitness." Because an ever increasing number of the world's ungulate species now exist only in small populations either in the wild or in zoological gardens, some inbreeding is obviously going to occur. Several authors have been concerned about the effects of inbreeding on zoo animals (Flesness 1977, Seal **1978,** Senner 1980, Ralls et al. 1979, 1980).

'Ralls (Ralls et al. 1979) of the National Zoo studied inbreeding and juvenile mortality in several species of ungulates. She discovered that juvenile mortality of inbred young was significantly higher than that of non-inbred young in 15 of 16 species of captive ungulates studied. She found inbred animals were usually "less able" to cope with their environment than non-inbred animals. They were more susceptible to various diseases and environmental stress. She also suggested that data from natural wild populations indicate that close inbreeding has the same deleterious consequences as it does in captive herds.

Ralls then went on in 1980 to study, in detail, the effects of inbreeding in Dorcas gazelles, Gazella *dorcas.* Her study was based on data gathered on the parentage, longevity and death information on 93 gazelle calves born from 1960-1978. The calves were divided into 2 categories: non-inbred calves, those whose parents were totally unrelated, and inbred calves which consisted of those who had inbreeding coefficient of greater than 0.

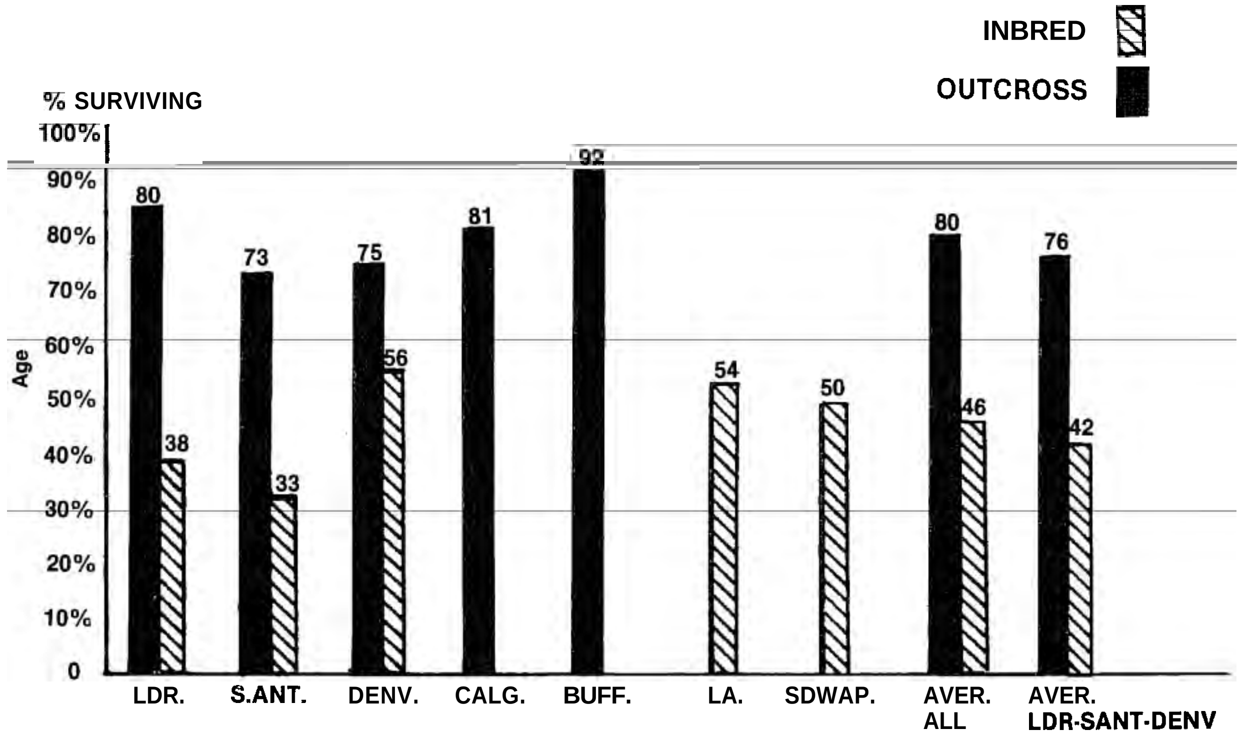
The calves were then divided into 2 categories based on longevity, those that survived less than 6 months and those that survived 6 months or more. She came to the following conclusions. The mortality rate of inbred calves was 31% higher than that of the non-inbred calves and the difference was statistically significant. Twenty-five of 42 inbred calves died under the age of 6 months versus 14 of the 50 non-bred. This



	LDR.	S.ANT.	DENV.	CALG.	BUFF.	LA.	SDWAP.	AVERAGE ALL	AVERAGE LDR-SANT-DENV
TOTAL N BORN	18 = 8.10	23 = 8.13.2	85 = 40.39.6	21 = 11.9.1	13 = 6.7.0	13 = 7.6.0	8 = 6.2.0	181 = 86.86.9	126 = 56.62.6
OUTCROSS N –	5 = 2.3	11 = 4.7	32 = 18.4	21 = 11.9.1	13 = 6.7.0	0	0	82 = 41.40.1	48 = 24.24.0
INBRED N	13 = 6.7	12 = 4.6.2	44 = 19.22.3	0	0	13 = 7.6	8 = 6.2	90 = 42.43.5	
UNKNOWN N	0	0	9 = 3. 3.3	0	0	0	0	9 = 3. 3.3	69 = 29.35.5

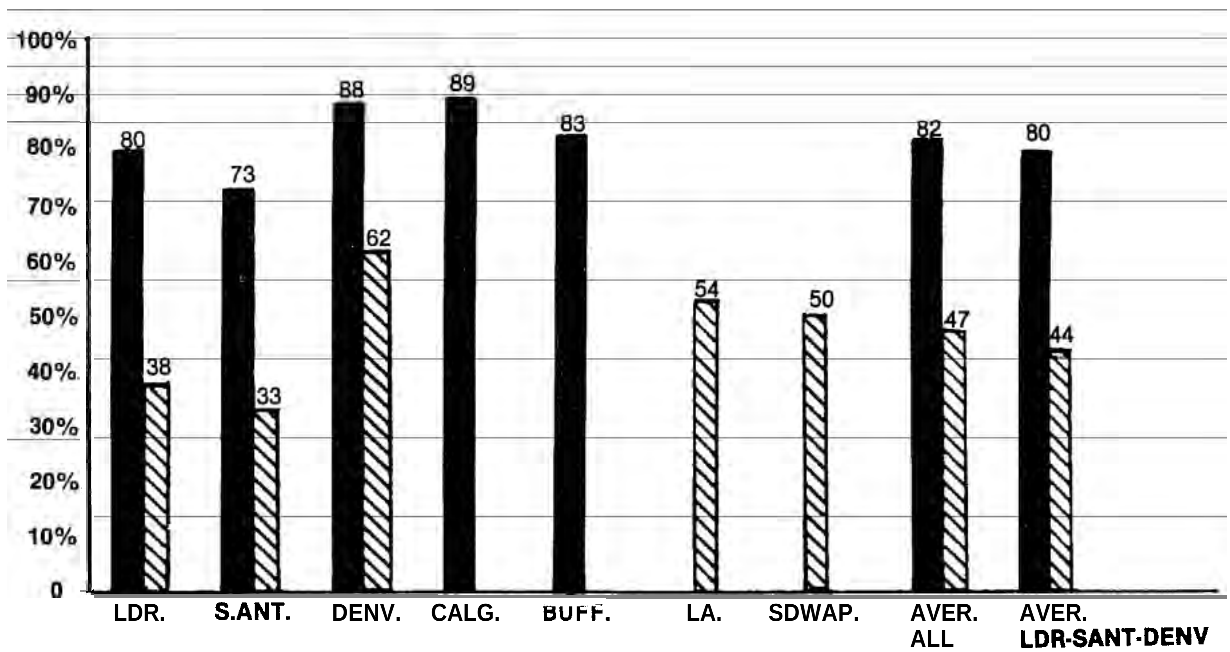
OUTCROSS = **INBRED** =

Figure 1. Survival of captive-born Ovis canadensis lambs comparing inbred and outcrossed lambs (survival = 1 year).



N = 181 lambs born = 82 outcross and 90 inbred; 9 unknown = 172

Figure 2a. Survival of captive-born Ovis canadensis lambs comparing inbred and outcrossed lambs (survival = 6 mo., N = 172).



N = 158 lambs whose exact age at death is known; 70 outcross and 80 inbred

Figure 2b. Comparing inbred and outcrossed lambs (survival = 6 mo., N = 158).

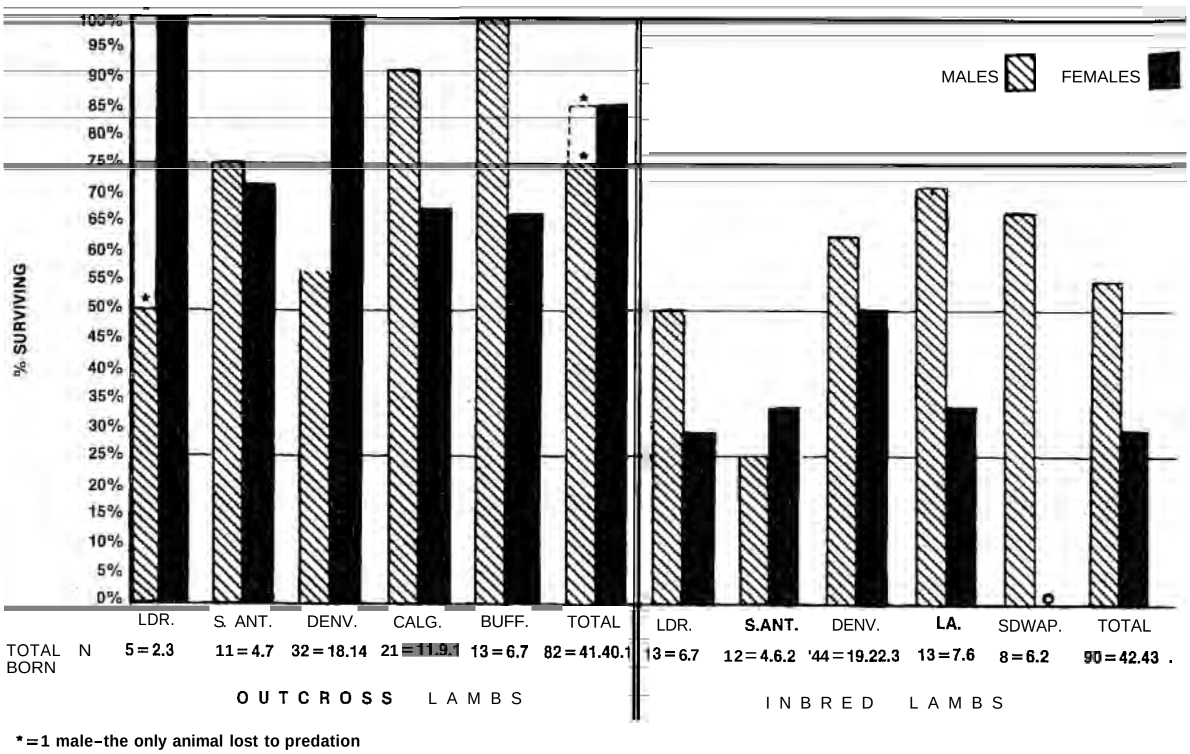


Figure 3. Survival of captive born *Ovis canadensis* lambs comparing inbred and outcrossed lambs by sex survival (survival = 1 year).

conclusion held up even after it was reviewed for potential changes in management techniques and after examining it on the basis that whether or not the calves were from primiparous or multiparous mothers.

The data on captive born bighorn sheep were examined following Ralls' methods. Review of the records of the 7 facilities allowed dividing 181 captive born lambs into inbred and outcross (non-inbred) animals. The results are striking. Figure 1 compares survival of captive born in-bred *Ovis canadensis* lambs and outcrossed lambs at survival of 1 year. The Living Desert Reserve produced a total of 18 lambs, 5 outcross and 13 inbred; 80% of the outcross lambs survived, whereas 38% of the inbred survived. San Antonio had 23 lambs born, 11 outcross and 12 inbred; survival of the outcross was 73%, survival of the inbred, 33%. Denver had 76 lambs of known parentage born, 32 outcross and 44 inbred; survival rates were 75% for outcross and 51% for inbred. Calgary had 21 lambs born, all of them outcross; their survival rate was 76%. Buffalo had 13 lambs born, all of them unrelated. There survival rate was 92%! Los Angeles had 13 lambs born, all inbred from a long-term captive herd, their survival rate 54%. San Diego had 8 lambs born of the same parentage and stock as Los Angeles; survival rate was exactly 50%. It should be noted that the San Diego and Los Angeles animals are essentially the same herd— long-term inbred animals from Nevada—and the survival rate of lambs at both facilities is almost identical. The mean survival rates for 172 lambs born of known parentage, 82 from unrelated stock, 90 inbred, show 79% survival of outcross animals, 45% survival of inbred. To reduce the possibility that husbandry techniques might affect the results, I took the percentages of only the 3 institutions that bred both inbred and outcross lambs. The statistics remain approximately the same, 76% survival for the outcross and 40% survival for the inbred. The survival rate for outcross animals was 34-36% higher than inbred. These numbers approximate Ralls' 31% differences in inbred versus outcross lamb mortality in Dorcas gazelles.

To make the comparisons match Ralls' work more exactly, Figure 2a shows the same computation for survival equalling 6 months. As you can see, there is practically no change whatsoever, 80% outcross to 46% inbred. Finally, there were 14 lambs who where known to survive until 4 months of age but were sold from the collections between the ages of 5-6 months. Figure 2b shows that if those 14 animals are removed from the population, and the sample size becomes 158 animals, the percentages still hold 82% outcross to 47% inbred. For the remainder of this paper the sample size will be based on total sample of 172 animals of known parentage.

The data were then analyzed to determine if there was any difference in sex ratio. Again survival equalled 1 year for the population of 172 lambs. According to Senner (1980) sex ratio changes during inbreeding, apparently because the male X chromosome (in mammals) is always hemizygous, independent of inbreeding. A female X chromosome pair can become increasingly homozygous with an increase in inbreeding. Therefore, males become increasingly common among survivors at higher levels of inbreeding. As can be seen from Figure 3, survival of outcross lambs was approximately equal for males and females. However inbred lambs show a distinct pattern favoring survival of male lambs with 54% of the males surviving and only 30% of the females.

Finally, the data were analyzed to compare inbred and outcross lambs by "age at death." In Figure 4 we can see that inbred lambs show a slightly higher mortality rate at each age division until 2 years of age is reached, after which differences may be statistically insignificant because of small numbers of animals remaining. Both outcross and inbred lambs show the greatest mortality during the first 6 months of life. However, by

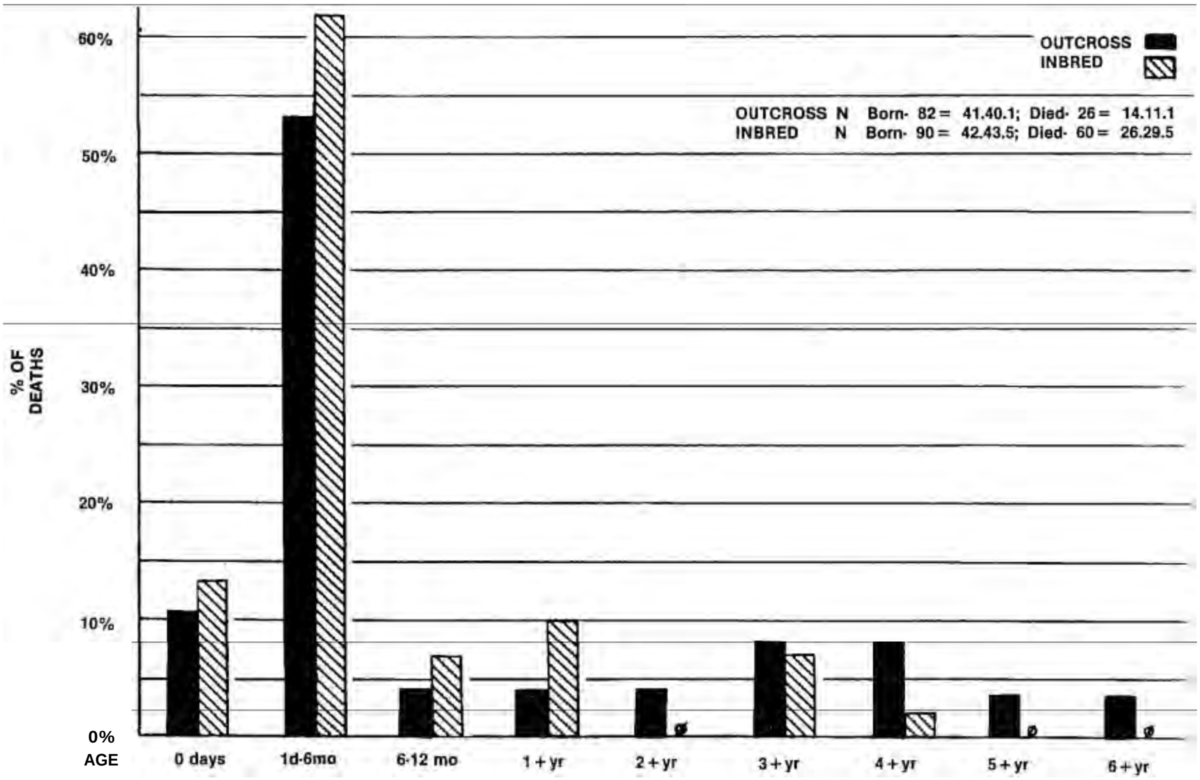


Figure 4. Survival of captive born Ovis canadensis lambs comparing inbred and outcrossed lambs by age at death.

breaking the age at death information down even further Figure 5 shows that a greater percent of inbred animals die by the end of their second month than do outcross animals, 70% versus 46%. Sheep appear to follow the same pattern as other species studied; the effects of inbreeding may be the most deleterious between 0-2 months of age ('survival after birth' and 'growth rate to weening.')

At the time of writing there were 21 outcross lambs still alive, ranging in age from 1 to 11 years with 13 individuals over 6 years of age. There is only 1 inbred animal known to be alive that is over 6 years of age. However it must be noted that of the 181 lambs born, 59 were sold out of the collections starting at 4 months of age (34 outcross lambs, 20 inbred lambs, and 4 lambs of unknown origin). Again, earlier computations indicate that even after removing these animals from the population, the resulting percentages do not fluctuate significantly. The 7 institutions represented in this study now house 42 bighorn sheep (13 males, 29 females) of which 11 are from the original founder stock (3 males and 8 females); 21 are outcrossed lambs (6 males, 15 females) and 10 are inbred lambs (4 males, 6 females).

Reviewing and comparing causes of death of inbred and outcross lambs may give an even greater understanding of the above information. Analyses of the causes of death of lambs has been started. When this information is tabulated it will be available as an addundum to this paper.

So far we have considered only the genetics of captive management. Poor husbandry and management of bighorn sheep in captivity could be contributing to high lamb mortality. By using data from 7 unrelated institutions located in various climatic areas and operated by different organizations, any bias in the data due to husbandry and management techniques should be controlled. For example, the husbandry techniques in Palm Desert, CA, and San Antonio, TX, no doubt are different. However there is no difference in the percentages of survival of inbred and outcrossed lambs in these facilities. Both facilities show at least a 40% greater survival rate for outcrossed animals than inbred. The genetics of the animals at Los Angeles and San Diego are essentially identical; both started with animals from the same long-term inbred herd, yet regardles of which facility is managing them they both show nearly identical lamb survival rates, 54% in Los Angeles and 50% at San Diego. On the other hand, facilities as diverse as Calgary, Alberta, and Buffalo, NY, breeding only outcrossed lambs show remarkable survival rates of 81% and 92% respectively.

By comparing the captive history of populations of sheep at a variety of institutions, the husbandry part of the question of whether or not sheep can be kept alive in captive situations may be answered. Apparently they can if unrelated breeding stock is used. The effects of inbreeding may be the reason for poor survival of captive born lambs in some facilities. The results presented correspond strongly with data for other ungulate species. Regardless of what facility and techniques are used, outcrossed lambs have up to 42% greater chance of survival than inbred lambs.

In conclusion I would like to relate this information to the continued survival of bighorn sheep, both in captivity and in the wild. There is strong indication that strict attention must be paid to parentage when attempting to breed sheep in captivity. Any efforts to use already captive sheep or to capture small populations of wild bighorn for captive propagation and reintroduction into the wild should be carefully controlled so as to maximize lamb production by maximizing genetic diversity of the founder stock.

The data from this paper do not suggest the minimum sized

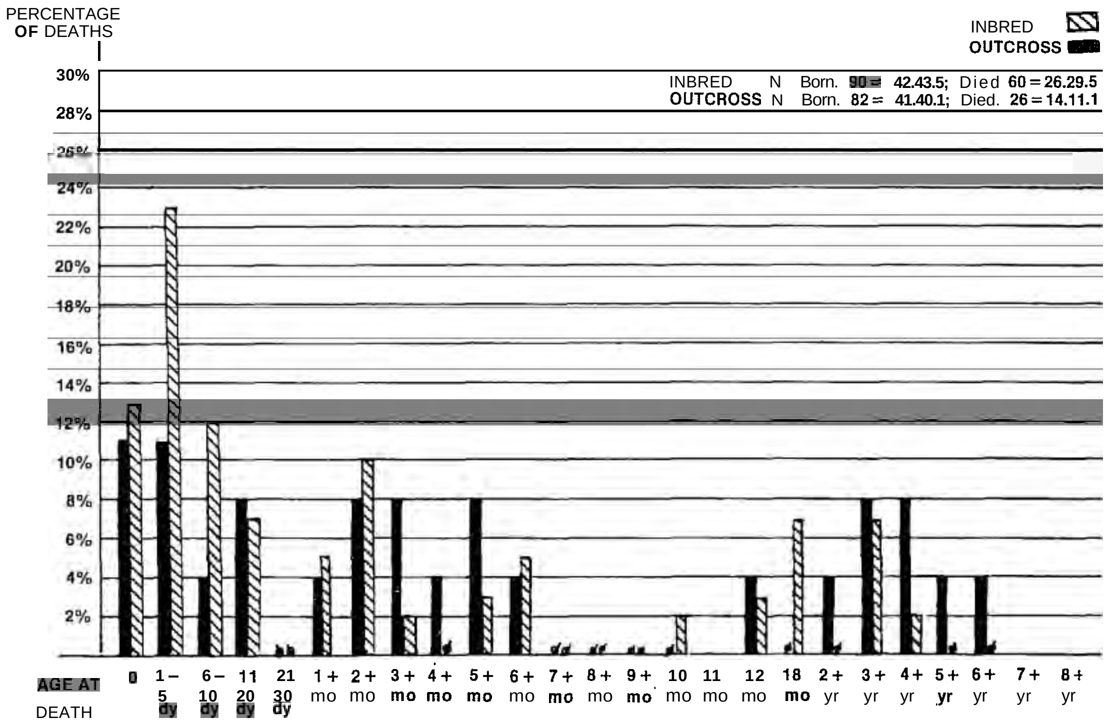


Figure 5. Survival of captive born *Ovis canadensis* lambs comparing inbred and outcrossed lambs by age at death.

founder group which would allow for enough genetic diversity to establish a self-sufficient herd. Strongly inbred lambs obviously do not survive in a captive situation. The survival of wild-born inbred lambs would theoretically be even less than that of captive inbred lambs since in a captive situation there are 2 factors which are controlled—predation and medical care. While predation may be minimal in bighorn sheep, (Allan 1980, Kelley 1980) it is a factor that captive lambs do not face. So too is the factor of medical care which may result in the survival of ill or weak captive born lambs. The data presented also suggest that effects of inbreeding on already declining herds or herds which are genetically isolated from other bighorn sheep herds may be more important than previously thought. The effects of inbreeding may be adding to high lamb mortality in certain herds of bighorn sheep such as those now being studied in the Santa Rosa Mountains. The data may even point to the necessity of manually introducing genetic diversity into isolated wild populations by shifting breeding rams from one herd to another.

During the coming months we intend to increase our sample size by analyzing additional herds from other facilities which house North American bighorn sheep. We also plan to analyze data on 'causes of death' in captive born lambs. While our current data suggest that inbreeding my have serious effects on survival of bighorn lambs, we must stress that the information presented needs additional review and should at this time be considered as "food for thought."

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LAVA BEDS WRAP-UP, WHAT DID WE LEARN?

James A. Blaisdell
National Park Service (retired)
Friday Harbor, WA

Abstract. What appeared to be a successful re-establishment of California bighorn at Lava Beds National Monument came to an abrupt end in 1980. An unfortunate set of circumstances during trapping and transplanting in winter 1980 was followed by disease a few months later which eliminated the entire population. This paper is a review of those occurrences and suggests certain precautions for future projects.

INTRODUCTION

Members of the Council and readers of the DBC Transactions know that in 1970, an interagency agreement was signed by the National Park Service, Forest Service, Fish and Wildlife Service, Bureau of Land Management and California Dept. of Fish and Game to cooperatively re-establish California bighorn Ovis canadensis californiana at Lava Beds National Monument, Siskiyou County, California. The main objective was to provide animals for transplant to historical California bighorn areas in the state as well as for Lava Beds. In 1971, 10 animals from British Columbia were placed into the 1100 acre enclosure. Through the years we had normal increases in the herds, little predation (none was documented), little harassment by man and great interest by the public. However, in 1973 our only 2 adult rams were shot and killed by 2 would-be poachers; they did not retrieve the carcasses. Those men were captured and 1 convicted (the other turned state's witness) in 1975. In 1974, 7 bighorns were lost to bluetongue, a disease of domestic animals carried by the Culicoides gnat. Normal reproduction took place each year. In 1975, another tragedy took place and probably originated from domestic animals. Sore mouth or Ecthyma struck, and we lost 6 lambs in a week's time. Yet the herd recovered. From that date on, the herd was healthy with excellent reproduction and little loss. By October 1979 there were 42 bighorn in the enclosure and the Interagency Committee decided that it was time to transplant some sheep to the South Warner Mountains of northeastern California. The capture activities would take place in February 1980. Between February and August 1980, all 42 bighorns disappeared from Lava Beds National Monument: 4 transplanted, 6 killed during capture exercises, and 32 lost to disease that may have been precipitated by trapping activities.

TRAPPING AND TRANSPLANTING

The sun did not shine anymore than it had for several days on 19 February. It rained off and on most all day. Consequently, the fields and even hilly areas of bighorn enclosure were soggy with mud. The helicopter that was to be used to drive animals into the capture pen arrived on time and the drive began. It appeared to me that during the next 2-3 hours sheep were run excessively; in addition, when sheep hid under rocks or ledges, a siren on the chopper was used that terrified the animals even more. When it became apparent that that method of capture would not work (it has worked in other places), it was given up, and ground troops took over. A line of about 30 people, strung completely across the width of the pen (about ½ mi.), attempted to drive animals from the north boundary to the catch-pen, a distance of about 3 miles. Even with the help of the'helicopter, few of the animals could be driven. Most came back through the line. Eventually, 14 bighorn entered the capture corral. Four of those escaped back into the pen by jumping and actually climbing over the 8 ft. board fence. Several were cut and hurt during their escape attempts, and lambs were trampled by the terrified adult animals. Now remember, it is the same day and the mud was worse than that morning. An attempt to get one of the trucks up the ¼ mile of road to the trap area failed miserably. The truck was freed eventually from the mire, after many minutes had been wasted and the bighorn were beating themselves up in the pen. This precluded fast handling and processing of the animals, and each one had to be carried by 3-4 workers all the way to the gate, a quarter mile away. Most were carried upright although several were carried upside-down before the men could be otherwise instructed. The result of this entire operation, from early morning until nearly dark, was that 5 animals died while being processed by veterinarians and others involved, and another was too sick to be released in the Warners; she died shortly afterward. Of 14 animals captured, 4 were released in the Warner Mountains, 4 escaped back into the pen, and 6 perished.

DISEASE

In 1977 Dr. Ted Kistner, Oregon State Univ. veterinarian, resigned from the interagency committee, stating that blue tongue, sore mouth or hoof rot (all domestic animal diseases) were a great danger to bighorn in the enclosure. His recommendation was that a change in livestock allocation, or preferably a buffer zone fence be used to keep livestock and bighorn apart. The Forest Service felt they could not cut the allottee's acreage; this was probably politically correct, at least. Funds for implementation of the second suggestion apparently were unavailable to any of the agencies. We respected Dr. Kistner's knowledge and advice, yet the animals had already survived blue tongue and sore mouth; perhaps we thought they could survive anything. But we must admit, painfully, Dr. Kistner was right. I wonder why we didn't go to The Society for the Conservation of Bighorn Sheep for help? In the past they had come through magnificently with monetary assistance. Another thought, too late. Who would have thought a totally new disease would make its way in? Sometime between July 1-25, 1980 all of the remaining animals in the pen were counted dead or were missing and presumed dead. The California Dept. of Fish and Game diagnosed the cause as Pasteurella pneumonia, probably passed through the fence from domestic sheep (not proven). We do know that between April 16 and the first week in July, domestic sheep were observed either adjacent to the fence or very near to it on at least 8 occasions.

Well, blame will not bring back the Lava Beds bighorn, yet something should have been done to keep the livestock, infected or not, away from the enclosure. There is no law that stipulates that a livestock owner or even a range management agency must report to other animal managers and neighboring lands stewards of the presence of disease or parasites in their herds, wild or tame. A recent newspaper article (The Denver Post, Jan. 5, 1982) is a good example of this subject. Let me paraphrase several paragraphs: A mysterious, blinding eye disease has spread to a second herd of bighorn sheep in Yellowstone National Park; park officials said that as many as 23 sheep have died; some of them shot by park rangers as they wandered blind along roads. Laboratory tests indicated that the eye disease may be related to pink eye, a disease common among domestic cattle, but no absolute confirmation has been made. Dr. Norman Swanson, Wyoming's state veterinarian said "Pink eye isn't a reportable disease in Wyoming. Farmers and ranchers experience it with their livestock every year; untreated, it can blind animals." Idaho's state veterinarian, W.G. Nelson, said that "We will do nothing unless ranchers begin reporting problems."

CONCLUSION

What did we learn from 10 years of work with bighorn at Lava Beds? If we can make our mistakes known to other re-establishment planners, and with use of the Technical Staff's publication, Trapping and Transplanting Guidelines, this failure or tragedy if you will, can be transformed into something of a success; maybe it was not a failure if the knowledge gained can be utilized by others. Probably most of the points I will make are well known to most of you. Let's get them down on paper so no one makes those errors again!

One of the preliminaries before planting bighorn in an area where livestock or bighorn previously existed should be a check for presence or layover of disease; the Guidelines suggest this already. This was done at Lava Beds only partially. Bighorn history was studied and it was found that elimination of Lava Beds bighorn was caused by one or more things: rough winters, poaching, horses, cattle, sheep competition, and disease. I always suspected it was a combination of the latter 2. It would be difficult to determine causes back in 1912, but we can certainly check out future transplant sites more recently vacated by bighorn. A check of the soil and of pellets of bighorn, deer and domestic sheep could be useful.

I suggest strongly that bighorn never be planted to an area or even directly adjacent to an area inhabited by livestock. Domestics almost always harbor disease detrimental to bighorn.

Be certain that all agencies, organizations and individuals involved in a transplant operation are willing to go all the way, doing all it takes to make a success of the program. If it takes a change in stock allotment or a buffer zone to keep livestock away from the bighorn, this must be done or the project will fail. You must find a way to do it.

Don't over-harass the animals. Driving bighorn long distances is too tiring for the animals. Also make sure you can get the vehicles and equipment to the holding area. If a helicopter must be used (I'm not certain it always must be), forget the siren or other frightening devices. The animals are under enough stress already.

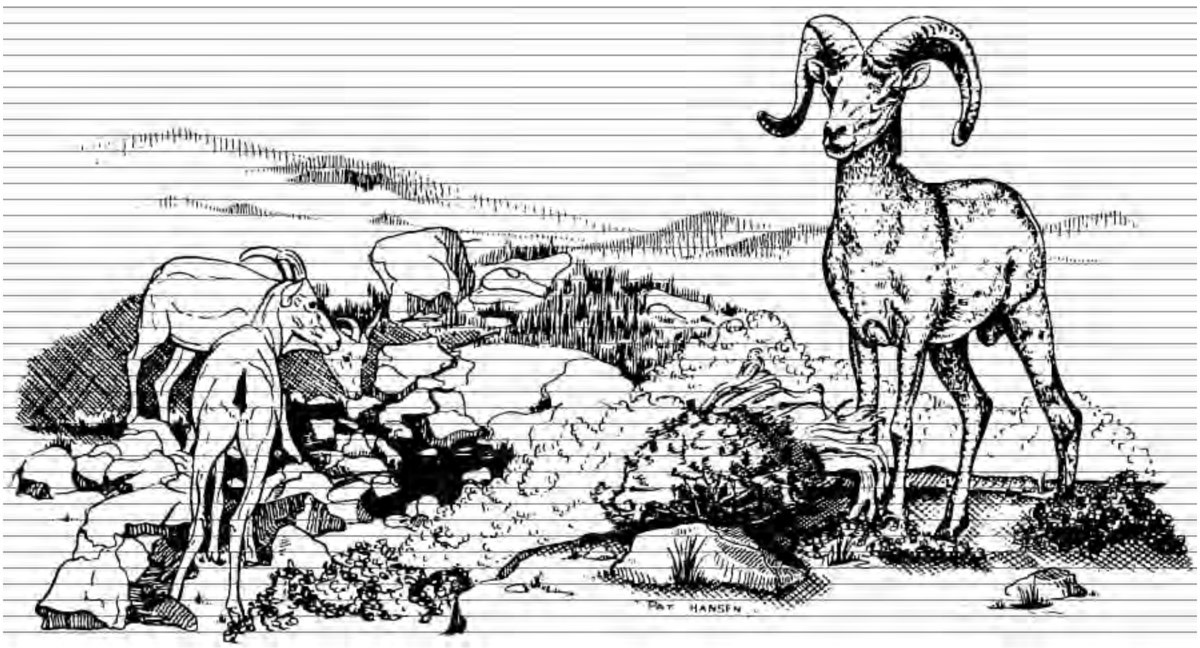
Be certain that you have a well-designed and well-built capture and holding pen. The one at Lava Beds was not; there were too many angles, gates, and no top. Netting sides would have prevented injuries and escapes; a drop net would be even better.

If the weather cooperates, the animals are easily driven and trapped. A minimal amount of handling for placing radio-collars, taking blood and parasite samples, weighing, measuring and temperature-taking is an absolutely necessity. In the Lava Beds case, much of this should have been dispensed with. They were tied up too long, including the long carry from the pen. Someone on the scene should be assigned to make this decision according to the situation.

Good biological data were collected during the 10 years. For instance, we documented that both males and females can and will breed at 1½ years of age; however, this was not the general case. We also discovered quite by accident and after spending considerable dollars that those animals liked their home. The rams, especially, liked to escape from the pen in the spring. They returned voluntarily if there was a natural way to get back in. One year, we chased 2 rams for a week on foot, by airplane, and by helicopter; we had absolutely no luck driving them back, and they were given up for lost. A few days later they were back inside! Finally we learned, much to our pleasure, that people who viewed the herd from the roadway enjoyed the experience.

REFLECTIONS

These opinions are, of course, mine. I was present on the project from the very beginning in 1966 up to the time of the trapping and transplanting effort in 1980. In my heart, I feel that there was no need to lose the Lava Beds herd of bighorn. All they needed was a little space and freedom from domestic animals. If, in the future, some of you bighorn workers want to become involved in a transplant program, and if you don't want to have that heavy-hearted feeling every time you think back upon it, I suggest you pay heed to what we've learned at Lava Beds National Monument.



DESERT BIGHORN LAMB AND ADULT-YEARLING DIETS FROM WESTERN ARIZONA

Rick F. Seegmiller
Dept. of Zoology
Arizona State University, Tempe

Robert D. Ohmart
Center for Environmental Studies
Arizona State University, Tempe

Abstract. We hypothesized that diets of lambs and adult-yearling desert bighorn sheep *(Ovis canadensis mexicana)* would differ due to different time-energy constraints imposed by differences in body and mouth sizes; these we presumed would allow lambs to forage more selectively than adults and yearlings. Diets (determined by fecal analysis) of each age class were compared during 2 summers, 1974-1975, and 1 spring, 1975. Results followed the hypothesis during both summers, but not during spring. The relatively high abundance and quality of forage during spring promoted interage dietary similarity, apparently by reducing the advantage that lambs had over older and larger sheep in foraging selectively. As desert forage either died (annuals) or entered dormancy (perennials), summer diets of both age classes became dissimilar, with lambs relying primarily on 2 relatively uncommon desert shrubs, and adults and yearlings relying primarily on 2 relatively common shrubs and cultivated Bermuda grass (Cynodon dactylon).

INTRODUCTION

Diets of desert bighorn sheep have been studied throughout the Southwest (e.g., Halloran and Kennedy 1949, Halloran and Crandell 1953, Russo 1956, Welles and Welles 1961, Barrett 1964, Deming 1964, Yoakum 1964, 1966; Hansen and Martin 1973, Brown et al. 1977, Walters and Hansen 1978, Walker 1978, Walker and Ohmart 1978, Seegmiller and Ohmart 1981), but only Brown et al. (1976) have specifically examined the diet of lambs. In the latter study, the diet of lambs was not compared to that of older age classes under the same regime (area, season, and year) of available forages, and thus studies assessing possible differences in forage selection are lacking.

Differences in the selection of forage between lambs and older bighorn sheep would have important implications to habitat managers. The young of ungulates, including desert bighorn sheep, sustain a relatively high mortality during the first year of life (Murie 1944, Taber and Dasmann 1957, Caughley 1966, Hansen 1967) and it has been hypothesized that high juvenile death rates are influenced largely by the relative shortage of a high quality, nitrogenous food supply (White 1978). Extreme aridity and unpredictability of rainfall and plant production in western Arizona accentuate the problem of lamb survival.

Our major premise for expecting dietary differences between lambs and adults or yearlings stemmed primarily from 2 bodies of literature. The first was from studies documenting dietary differences between naturally sympatric ruminant species (e.g., Talbot and Talbot 1962, Lamprey 1963, Gwynne and Bell 1968, Mackie 1970, Jarmen and Sinclair 1979, Hanley 1980). The second was from papers correlating dietary differences in ruminants to body size, mouth size, and the ratio of rumen volume to metabolic body weight (Hungate et al. 1959, Hofmann 1968, Bell 1970, 1971; Jarmen 1974, Hanley 1980).

Body size has a positive correlation with the amount of energy and nutrients that a ruminant requireslunit time (Kleiber 1961, Moen 1973), and mouth size generally has a positive relationship to body size. Body and mouth sizes together determine the degree of forage selectivity that is physically possible for a ruminant within its time and energy constraints (Bell 1970, 1971; Jarmen 1974). This is because plants are a heterogenous food source, which is due to a great variability in the size, abundance, and nutritive quality between and within different plant tissues (i.e., leaves, stems, young and mature growth).

Optimal foraging theory (e.g., Emlen 1966, MacArthur and Pianka 1966, Schoener 1971, Westoby 1974, Pulliam 1974, Charnov 1976, Pyke et al. 1977, Andersson 1978, Sih 1980) predicts that an animal maximizes fitness by selecting a diet that both maximizes the intake of energy and nutrients and minimizes the time and energy spent searching for food. Thus, due to the heterogeneity of plants, a ruminant must forage selectively to harvest the highest quality dietlunit time, i.e., the optimal diet. A ruminant with larger body and mouth sizes generally has less time and ability to be as selective as a smaller ruminant and must sacrifice some forage quality to obtain the quantity of food required.

The ratio of rumen volume to metabolic body weight (body weight to the three-fourths power) in a ruminant is a measure of the relative efficiency by which cellulose can be digested (Hungate et al. 1959, Short 1963, Haniey 1980). The larger the ratio, the more adapted a ruminant is to a diet high in cellulose (low digestibility). Forage high in cellulose can be retained and fermented longer in a proportionately larger rumen than in a proportionately smaller one.

Lambs are considerably smaller in body and mouth sizes than adults or yearlings, but rumen volumes of desert bighorn at various ages are not known. Data from domestic sheep (*Ovis aries;* Wardrop and Coombe 1960, Church et al. 1962, Purser and Moir 1966) and white-tailed deer (Odocoileus *virginianus;* Short 1964) indicated that the adult ratio of rumen volume to metabolic body weight was reached at about 1.5 to 2 months of age. The pattern of rumen development in the lambs of desert bighorn sheep may be comparable and we have assumed that the ratio was not a major variable potentially affecting interage dietary differences.

Evolution of those 3 trophic-related morphologies,have reduced interspecific competition between naturally sympatric ruminants, but they also may have reduced intraspecific competition between age classes and dimorphic sexes. We hypothesized that diets of lambs would differ from diets of adults and yearlings due to smaller body and mouth sizes in lambs; these we presumed would impose different time-energy constraints on foraging and thereby permit lambs to forage more selectively than adults or yearlings. We tested this hypothesis by comparing lamb and adult-yearling diets during 2 summers, 1974 and 1975, and the spring of 1975.

STUDY AREA

The study area is in western Arizona in the southeastern end of the Bill Williams Mountains, which lie north of the Bill Williams River and east of Lake Havasu. The mountains are fractured and support sparse vegetation characteristic of the Colorado Desert (Jaeger 1957). Precipitation in Parker, Arizona (40 km southwest of the study area) averages 97 mm annually, most of which (55 mm) occurs in winter and spring (November-March; Sellers and Hill 1974). Bermuda grass was cultivated in fields operated by the Planet Ranch along the Bill Williams River. Otherwise, perennial grasses throughout the area were very scarce. A band of riparian vegetation bordered the Bill Williams River.

Desert bighorn on the study area are a remnant population, totaling approximately 17 (4 adult rams, 7 adult ewes, 3 yearlings, and 3 lambs) during spring 1975. At least 3 lambs were present through summer 1974, but only 1 of 3 lambs produced during spring 1975 survived past June. Mortality in adults or yearlings was not documented. A more detailed description of the area and the desert bighorn population are reported in Seegmiller and Ohmart (1981).

METHODS

Diets were measured by microscopic analysis of discernible plant fragments in fecal material. Lamb and adult-yearling pellet groups were collected monthly during June through August 1974 and 1975, and during March through May 1975.

Lamb pellets were first encountered and collected during mid-March when lambs were about 1.5 months old. They could be distinguished readily from those of adults or yearlings by their smaller size through August (lambs about 6 months old), but after this period they were not consistently distinguishable. Adult and yearling pellets could not be separated by size. Pellet groups were estimated to range in age from freshly deposited to a few weeks old. Only pellets observed being voided or with dark, shiny surfaces or moist centers were collected.

Lamb pellet groups were milled individually and equal weights from each group were pooled to produce monthly composite samples. Lamb diets were determined monthly from analysis of lamb pellets only, but adult-yearling diets were not determined separately. Rather, the adult-yearling monthly diets were calculated from monthly diets of both lambs and the total bighorn population (Seegmiller and Ohmart 1981). This was possible because the bighorn population diets were measured from monthly composites of 16 adult-yearling pellet groups and 4 lamb pellet groups. Adult yearling diets were computed using the equation $x_i = (5a_i - b_i) \div 4$, where x equals the percentage of plant species i in the adult-yearling diet; a equals the percentage of plant species i in the total bighorn diet; and b equals the percentage of plant species i in the lamb diet.

Twenty microscope slides were made from each monthly composite of pellets and 20 microscope fields were located on each slide, yielding 400 fieldslmonth. Frequency of occurrence of the fragments of each plant species was recorded for each monthly composite and converted to percent relative density, which is reported to approximate percent dry weight in the diet (Sparks and Malechek 1968). The monthly results were averaged to assess seasonal differences in diets. Preparation of fecal and reference plant slides and other details of the technique are described elsewhere (Seegmiller and Ohmart 1981).

The Spearman Rank Correlation Coefficient (r_s; Siegel 1956), a nonparametric test, was used to assess statistically the degree of association between lamb and adult-yearling diets each season. A significant association or correlation ($P<0.01$) indicates the diets are statistically alike, whereas $P>0.05$ indicates they are not. The test is about 91% as powerful as the strongest parametric correlation and was used to avoid the assumptions of parametric statistics.

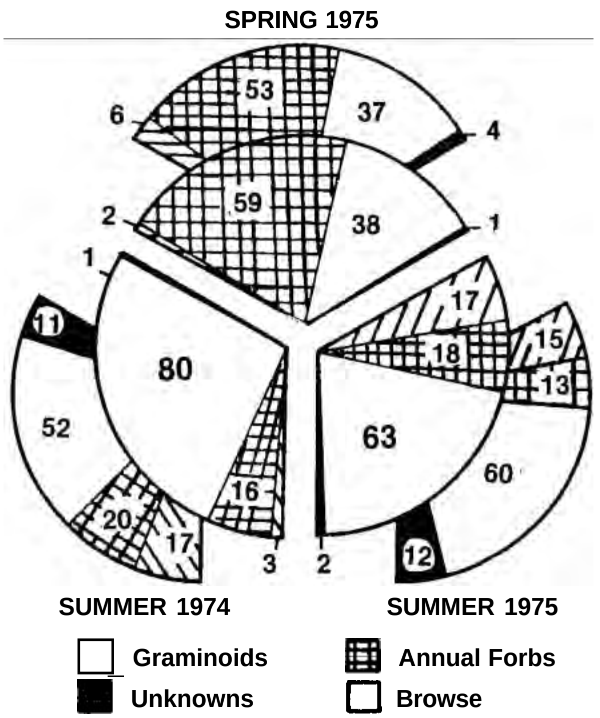


Figure 1. Percent composition of major forage types in desert bighorn lamb and adult-yearling diets during 2 summers, 1974-1975, and 1 spring, 1975, western Arizona (inner circle, lambs; outer circle, adults and yearlings).

RESULTS

Composition of graminoids, annual forbs, and browse between lamb and adult-yearling diets were similar during each season (Fig. 1). Lamb and adult-yearling spring diets were dominated by annual forbs, followed by browse and grasses. During both summers the lamb and adult-yearling diets were composed primarily of browse, followed by forbs and grasses.

The proportions of plant species in the lamb and adult-yearling diets had an insignificant correlation during both summers ($P>0.05$; 1974 $r_s = -0.33$, $N=16$; 1975 $r_s = 0.13$, $N=17$), but had a significant correlation during spring ($P<0.01$; $r_s = 0.73$, $N=17$; Table 1). Both lamb and adult-yearling spring diets were dominated by desert annual forbs, Indian wheat (Plantago insularis) and forget-me-not (Cryptantha spp.) and by one of the most common desert shrubs, white bursage (Ambrosia dumosa). Collectively, these species comprised 52% and 48% of lamb and adult-yearling spring diets, respectively, from a total of 46 plant species utilized by each age class.

During both summers, lambs fed primarily on the desert shrubs globe-mallow (Sphaeralcea spp.) and desert lavender (*Hyptis emoryi*) from a total of 28 plant species utilized in 1974 and 35 species in 1975. In addition, plant(s) in the Cruciferae and the desert shrub white ratany (Krameria *grayi*) were eaten in significant amounts in 1974, whereas Bermuda grass and the riparian tree, velvet mesquite (Prosopis *velutina*) were major food items in 1975. In the respective years, those plant species comprised 75% and 56% of summer lamb diets.

Adult-yearling diets during both summers were dominated by Bermuda grass and little-leaf palo verde (*Cercidium microphyllum*). The latter is a small tree common throughout the area. Few other plant species stood out as major dietary items in summer; however, Indian wheat and creosote bush (Larrea *divaricata*), a common shrub on the area, were important food plants in 1974, while creosote bush, staghorn cholla cactus (*Opuntia* acanthocarpa), and velvet mesquite were important in 1975. Collectively, these species comprised 43%

and 42% of the 1974 and 1975 summer adult-yearling diets, respectively, from a total of 34 and 37 species utilized, respectively.

DISCUSSION

Because lamb and adult-yearling desert bighorn sheep operate under different time-energy constraints imposed by differences in body and mouth sizes, we hypothesized that if both foraged optimally, lambs would forage more selectively than adults or yearlings. Thus, we expected their diets to differ, despite the fact that the mother-young bond kept them within the same habitats. The results of this study'supported the hypothesis during both summers, but not during spring (Table 1).

Desert plants grew and reached their annual peak abundance and quality in spring (Hanley and Brady 1977), following winter and spring rainfall. Consequently, sheep seldom ventured out of desert habitats from March through May (Seegmiller and Ohmart 1981). During spring, new growth of desert forage apparently was of sufficient size, abundance, and nutritive value to reduce the advantage that lambs had over adults and yearlings in selectively foraging; thus, within the limited time available to satisfy their energy requirements, adults and yearlings were able to harvest a composition of food items similar to that harvested by lambs.

Summer had hot, dry weather which caused desert plants to cease growth and either die (annuals) or enter dormancy (perennials), thereby reducing nutritive value (Cook 1972, Hanley and Brady 1977), size, and abundance of the highest quality plant parts. The increased differences in diets were attributed primarily to those phenological changes. Adults and yearlings, having higher energy and nutrient requirementslunit time, apparently were prevented from consuming the smaller and more widely scattered food items of highest quality in the same proportions as lambs. Lambs selected primarily the relatively uncommon shrubs, globe-mallow and desert lavender, which probably maintained relatively high nutritive values; adults and yearlings, not being able to forage as selectively as lambs, relied primarily on the highly abundant little-leaf palo verde, creosote bush, and cultivated Bermuda grass.

Table 1. Desert bighorn lamb (L) and adult-yearling (A-Y) diets during summer (June-August) 1974-1975, and spring (March-May) 1975 in western Arizona. Numbers represent percent relative density of plant fragments in fecal material. Numbers in parentheses indicate numbers of pellet groups. Trace amounts (tr) are◄1%.

	Spring		Summers			
	1975		1974		1975	
Plant Species	**L (20)**	**A-Y (48)**	**L (35)**	**A-Y (48)**	**L (17)**	**A-Y (48)**
GRASSES AND SEDGES						
Cynodon dactylon	1	4	2	16	11	15
Other species[a]	1	2	1	tr	6	tr
ANNUAL FORBS						
Cruciferae	3	4	7	1	6	1
Cryptantha spp.	13	10	4	5	6	2
Plantago insularis	29	31	4	9	5	5
Other species[a]	14	6	1	5	tr	4
BROWSE AND CACTI						
Ambrosia durnosa	10	7	2	4	2	5
Cercidium microphyllum	1	1	1	11	6	9
Haplopappus spinulosus	5	4	tr		tr	2
Hyptis ernoryi	8	4	27	4	10	3
Krarneria grayi	1	1	6	tr	1	3
Larrea divaricata	tr	4	1	7	tr	6
Opuntia acanthocarpa	1	2	2	2	3	6
Prosopis velutina	tr	tr	4	5	9	6
Sphaeralcea spp.	4	tr	35	6	26	5
Other species[a]	7	14	2	13	6	15
UNKNOWNS	1	4	1	11	2	12
TOTAL	100	100	100	100	100	100
NUMBER OF SPECIES	46	46	28	34	35	37

[a]Species comprising 4% *or less of the diets during each season: GRASSES AND SEDGES -Aristida adscensionis, Scirpus americanus, Sorghom sudanense, Tridens spp., Triticum aestivum; ANNUAL FORBS - Amsinckia*

MANAGEMENT IMPLICATIONS

Significant dietary differences during summer between lamb and adult-yearling desert bighorn sheep documented in this study have important management implications. The young of desert bighorn sheep sustain relatively high mortality, despite lambs being able to forage more selectively than older sheep. Perhaps the main reason is that lambs have considerably higher energy and nutrient requirementslunit body weight, due to both smaller body size (Kleiber 1961) and a very rapid rate of growth (Moen 1973). Thus, lambs require a food source with a considerably greater concentration of energy and nutrients than do older sheep. Lower survival in lambs, therefore, can be expected during years of drought that yield low forage quality and availability.

To maximize productivity and survival of desert bighorn, habitat managers must develop land-use guidelines designed to maximize availability of the highest quality and most preferred plant species during the most nutritionally critical season. In the arid ranges of western Arizona, the critical season generally occurs during early summer, because plants that grew in spring have either died or entered dormancy and lambs are still small and growing rapidly; the severity of this period is enhanced following a relatively dry winter and spring. Examples of possible ways to improve forage conditions and lamb survival are: (1) restrict livestock grazing, and other human-induced disturbances, on ranges used by bighorn nursery bands during summer; (2) expand the range available to nursery bands during summer by improving the number and distribution of watering sources within the drier bighorn habitats; and (3) provide supplemental food that is high in nitrogen and digestibility at key watering sites during summer. The latter example may seldom be justifiable economically, except for critical populations during exceptionally severe conditions.

The data and theory on ruminant forage selection presented in this paper also suggest that the adult males and females of ruminants, sexually dimorphic in size, may have different diets. Differences in forage selection promote differences in habitat selection in ruminants (Hanley 1980) and may provide an explanation for the spatial segregation observed between male and female ruminants during certain seasons (Geist and Petocz 1977, King and Smith 1980, Morgantini and Hudson 1981). Further studies of forage selection in ungulates should be designed to assess these potentially important interage differences in diet.

ACKNOWLEDGMENTS

Sandy Pinkerton and Julie Wen analyzed the fecal samples and Cindy D. Zisner typed the manuscript. Duna Strachen prepared the figure and Susan M. Cook and Jane R. Durham made helpful suggestions during prepartion of the manuscript. We are grateful to these persons and many others. The research was supported by Bureau of Land Management Contract No. 52500-CT4-270.

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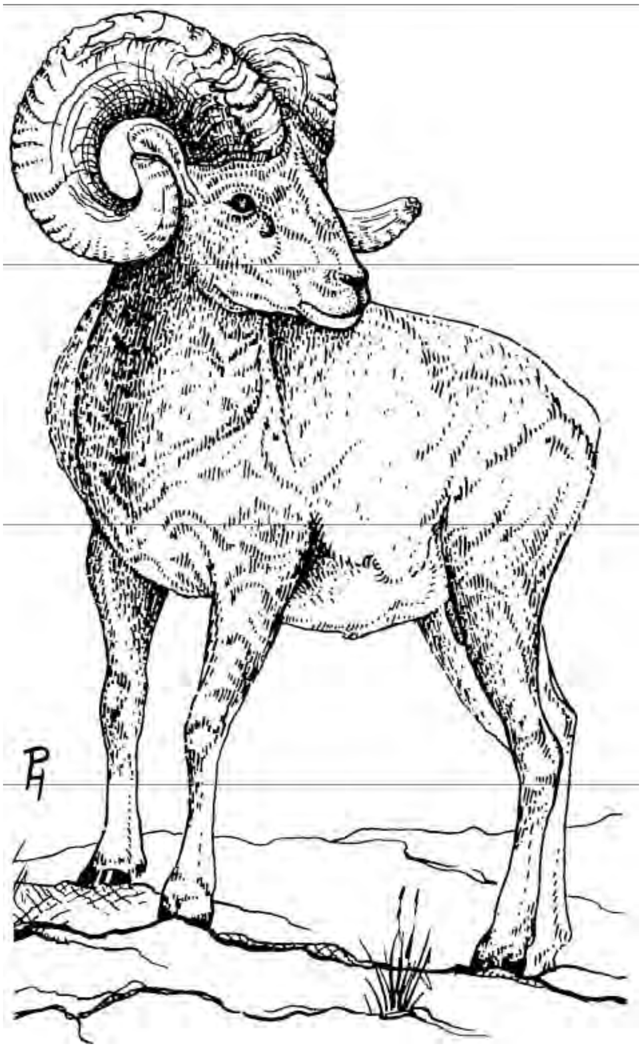

AGE AND WEIGHT RELATIONSHIPS OF DESERT BIGHORN SHEEP CAPTURED IN ARIZONA DURING 1981-82

Richard Remington
Arizona Game and Fish Dept.
Yuma, AZ

Abstract. During 1981-82 a total of 70 weights were taken of desert bighorn sheep captured in Arizona for transplant purposes. A total of 41 live weights were taken of bighorn from northwestern Arizona (Ovis canadensis *nelsoni)* and 38 weights were taken of bighorn from southwestern Arizona *(Ovis* canadensis rnexicana). This report investigates implications of age and weight of bighorn in relation to aerial captures using the immobilant Etorphine (M-99) with a tranquilizer (Azaperone). Analysis of data failed to show significant agelweight relationships in response to drug reaction times or time of total immobilization. Discussion is presented on agelweight relations of rams and ewes from the two Arizona locations and with weights of desert bighorn available from the literature.

INTRODUCTION

The Arizona Game and Fish Department has captured free roaming desert bighorn sheep since 1955. Capture techniques have varied from mechanical trap captures to the current method of darting bighorn from a helicopter using Etorphine (M-99) in combination with a tranquilizer (Azaperone) (deVos and Remington 1981).

At the completion of Arizona's 1980 bighorn sheep captures the Department analyzed the records of 165 desert bighorn sheep captured in Arizona since 1977. It was found that, in general, rams had longer drug response times and times to complete immobilization than did ewes (deVos and Remington 1981).

In an analysis of mortality that occurred within these 165 captures it was noted that the majority occurred within prime age rams. It was suggested that these mortalities may be attributable to an underdose of the narcotic Etorphine (Dr. R. Lange, 1980 pers. comm.).

Prior to 1981-82 live weights were not taken of desert bighorn captured in Arizona. Handling and total time of immobilization were minimized in an effort to reduce capture myopathy (Spraker 1977) and other physiological stress (Winegardner et al. 1977). The excellent survival rate of bighorn captured in Arizona between 1977-1980 justified increased handling time which permitted the collection of the live weight measurements used in this investigation.

This investigation was undertaken by the Department to determine if relationships exist between age and live weights of desert bighorn sheep. Relationships have been shown between horn length and body weight of Barbary sheep (Gray and Simpson 1979). However, data on Dall sheep indicate horn length is not an indicator of body weight (Bunnell 1978).

This investigation also was undertaken to determine relationships of age and weight to the current capture techniques used by the Department. It was felt that current dosages of Etorphine may be inadequate for complete immobilization of heavier bodied bighorn.

Therefore, if a confident estimation of the weight of a bighorn sheep could be made by age, and relationships do occur between age and body weight, then drug dosages could be altered to ensure more rapid immobilization, reducing the total time of immobilization and lowering chances of mortality from an underdose of Etorphine.

MATERIALS AND METHODS

Ninety-nine desert bighorn were captured in Arizona during 1981-82. These sheep were captured for various releases within the states of Arizona, New Mexico and Colorado. All sheep were captured using a Palmer C02 powered long range projector and firing a 4 cc Palmer dart into the fleshy rump area of the bighorn. The dart was fired by game department personnel from a Bell Jet Ranger III helicopter. Each dart contained 3.7 mg M-99 (Etorphine) and 20 mg Azaperone. Details of capture and handling techniques were described by deVos and Remington (1981).

Table 1. Ages and weights of bighorn sheep captured in Arizona during 1981-1982.

Age	Sample Size	Range kg	$\bar{x}$ Weight	(lsd)
BLACK MOUNTAIN COMPLEX				
Ewes				
1	1		36.7	
2	5	34.9-64.9	44.3	(14.0)
3	9	37.2-57.2	44.3	(6.3)
4	11	38.6-87.1	52.7	(13.4)
5	4	45.8-62.6	53.5	(8.7)
$\bar{x}$ 3.4	N = 30		48.4	
sd 1.0			11.4	
Rams				
2	5	35.4-47.2	42.0	(5.0)
3	2	57.6-78.5	68.0	(14.8)
4	2	60.8-71.7	66.2	(7.7)
5	1		60.3	
7	1		81.2	
$\bar{x}$ 3.3	N = 11		56.4	
sd 1.6			15.8	
KOFA COMPLEX				
Ewes				
1	2	43.1-44.5	43.7	(1.0)
2	1		55.3	
3	1		47.6	
4	4	44.9-64.9	50.8	(9.5)
5	3	42.1-65.3	57.2	(5.1)
6	3	47.2-66.7	56.2	(9.8)
7	1		68.0	
9	1		58.5	
$\bar{x}$ 4.5	N = 16		53.8	
sd 2.1			9.5	
Rams				
1	1		34.5	
2	3	55.8-56.7	56.4	(0.5)
3	3	44.5-61.2	53.8	(8.6)
4	1		72.1	
5	2	64.9-78.9	71.9	(9.9)
6	2	70.3-91.2	80.7	(14.8)
8	1	–	77.1	
$\bar{x}$ 3.9	N = 13		3.0	
sd 2.0			15.1	

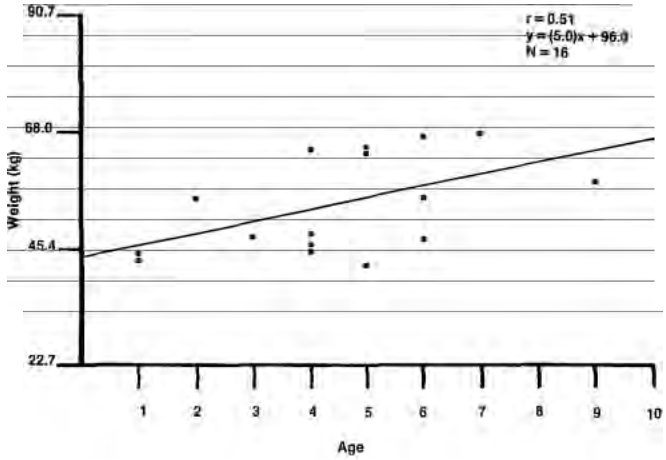

Figure 1. The relationship of weight to age in 16 bighorn ewes from the Kofa Mountains, Arizona.

At the base camp the condition of each sheep was initially determined. If sheep appeared to be in stress or mild shock, they were immediately given an intravenous injection of M 50-50 (Diprenorphine), placed in a transportation trailer, and vital signs monitored. No weights were taken from these sheep. However, in most cases sheep arrived at the base camp in stable condition and additional time was taken to collect data before reversal.

The age of each sheep was determined by characteristics described by Hansen (1965) and by horn annuli (Geist 1966). Ages were estimated to the nearest year. Weights of individual sheep were taken on a Howe Richardson platform scale upon which a 122 cm x 53 cm x 36 cm box had been constructed and placed over the platform to support live sheep. All weights were recorded to the nearest pound.

RESULTS

Live weights were recorded for 70 bighorn captured during 1981-82. The total is comprised of 41 sheep (30 ewes; 11 rams) *(O.c. nelsoni)* from northwestern Arizona, and 29 sheep (16 ewes; 13 rams) *(O.c. mexicana)* from southwestern Arizona. Table 1 outlines ages and weights of bighorn captured during this period.

Live weights of ewes taken from both Arizona locations are highly variable and show little correlation with age. Black Mountain ewes displayed a poor relationship ($r = 0.38$) between age and weight, while Kofa ewes showed a slightly higher value ($r = 0.51$) (Figure 1). A Wilcoxin-Mann-Whitney rank sum test was used to test for significant differences of weights between sexes and locations. Kofa ewes were heavier than Black Mtn. ewes ($p = 0.039$) although this difference may be due to sampling biases. The average age of ewes weighed from the Black Mtn. complex is one year less than from the Kofa complex. Quick field aging of ewes which have completed tooth replacement becomes more difficult with increasing age. Placing an adult ewe within a specific year class will not be without error. Attempting to age adult ewes past 4 years of age continues to add error to analysis. A more realistic model may include a 4+ year class. No significant (p►.10) difference was found between weights of Kofa ewes reported by Russo (1956) and those taken during 1981-82.

Black Mountain rams were significantly (p = 0.038) heavier than ewes from the same area. The average age class of captured rams and ewes was similar, with somewhat more variation of ages shown in rams than ewes. Ram weights within each year class are consistantly higher than ewe weights. A similar significant (p = 0.08) difference is found when comparing weights of Kofa complex rams to ewes, although the average age of rams weighed from the Kofa complex is somewhat less than ewes captured in the same area. Individual year class weights of rams, with the exception of one year, remain consistently higher than associated ewe weights from the Kofa complex.

Agelweight relationships of rams from the Black Mountain complex (r = 0.78) and Kofa complex (r = 0.81) show a much closer relationship than that found in ewes. Also when all rams are considered, a high (r = 0.80 correlation is shown (Figure 2). No significant (p = .154) difference was found between weights of individual rams from the Black Mountains and the Kofa complex. McQuivey (1978) found no significant differences in ram weights from southern and central Nevada. In addition, no significant (p►.10) difference was found between ram weights reported from the Kofa Mountains by Russo (1956) and those taken during 1981-82.

Multiple linear regression was used to determine relationships of age and weight with capture chronology recorded during 1981-82. In this investigation chase time is defined as the length of time from initial observation to drug injection. Response time is defined as the time from drug injection to the time of first recognizable signs of ataxia. Immobilization time is defined as the time from drug injection to the time the sheep is unable to stand and has become completely ataxic. Table 2 shows chase, response and immobilization times of each year class of bighorn captured.

Previous investigations of captures of desert bighorn sheep using Etorphine (M-99) have shown chase, reaction and immobilization times to be greater for rams than for ewes (deVos and Remington 1980). It was speculated by these authors that larger body size, coupled with increased chase times, would have an additive effect on time of complete immobilization.

Results of this investigation (in all cases) failed to show significant correlations of agelweight relationships to time of initial drug response or to time of complete immobilization. Irregardless of sex, age, and location, live weights of bighorn sheep captured in Arizona during 1981-82 showed poor (r = 0.25) correlations to time of complete immobilization. Rams appear to have a predictable time to immobilization in relation to chase and to a greater degree initial response time from drug injection. Rams from both locations show considerably less variations in age weight relations than ewes. Individual variations of drug response time is greater for ewes than rams, thus predictability of complete immobilization time for ewes is not confident. It is apparent that greater amounts of variation to drug response times and times of immobilization of the bighorn captured during 1981-82 in Arizona is due to variations other than those investigated in this report.

DISCUSSION

Live weights of bighorn from the 1981-82 Arizona captures do not differ significantly from weights of northern and southern Arizona bighorn rams. McQuivey (1978) also reported that no significant difference was found in field dressed weights of bighorn in southern and northern Nevada. McQuivey (1978) also reported that dressed weights of rams harvested in Nevada were less than reported by Russo (1956). Hansen (1965) reported that by one year of age rams from the Desert Game Range weighed between 52.5 and 59 kgs while ewes of the same age weighed from 41 to 50 kgs. This is somewhat heavier than the single 1 year old ram weighed from the Kofa Mtns. during 1981-82. Weights of one year old ewes taken in Arizona ranged from 36.7 to 44.5 kgs; this is somewhat lighter than reported by Hansen. Aldous and Devan (1958) weighed 26 rams from the Desert Game Range which averaged 70.8 kgs and ranged from 57.6 to 59.4 kgs. This is greater than the average weights of rams taken during the 81-82 Arizona sheep captures. However weights of 15 trapped ewes reported by Aldous and Devan (1958) averaged 43.8 kgs and ranged from 33.6 to 51.7 kgs which is less than weights reported from the Kofa Mtns. by Russo (1956) and less than weights taken of ewes from the 1981-82 Arizona captures.

Hansen and Deming (1980) in reviewing bighorn weights described in Clark (1964), Russo (1956), and Hansen (1965), state the combined data suggest a large adult desert ram would weigh about 90.7 kg and an average ram would weigh about 81.6 kg. The average adult ewe would weigh about 48 kg and range from 33.6 to 57.2 kg. Weights taken during this investigation suggest average ewe weights are greater than those given by Hansen and Deming (1980). Weights of rams taken during 1981-82 captures were consistent with the summary made by Hensen and Deming (1980).

McQuivey (1978) reported finding significant differences in field dressed weights of Nevada bighorn rams harvested in spring and in fall months. The average field dressed weights

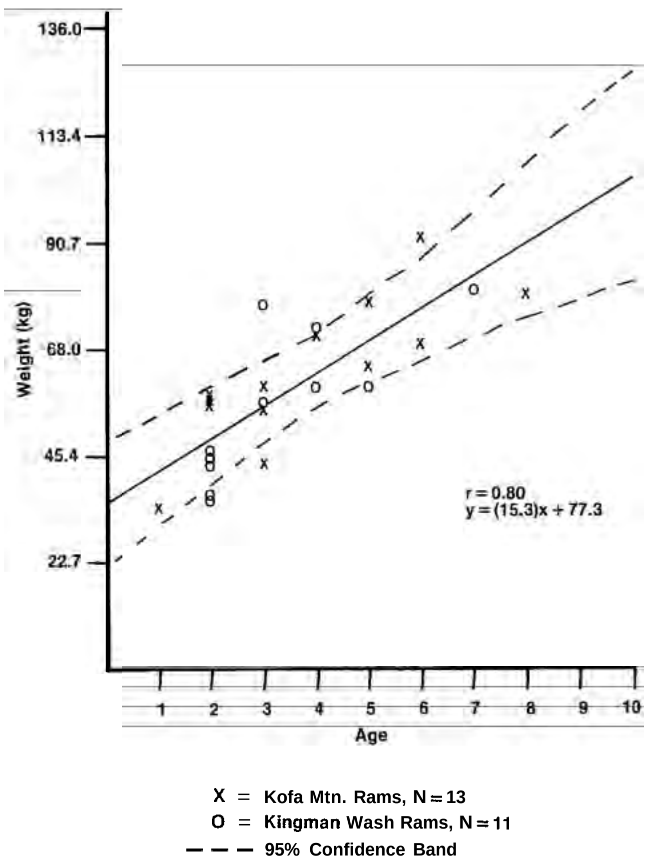

Figure 2. The relationship of weight to age in bighorn rams from the Black and Kofa Mtns., Arizona

of rams harvested in Nevada during October thru December was 48 kg, while the average field dressed weights of rams harvested during April was 62.6 kgs. McQuivey (1978) suggested stress of rutting activity in addition to poorer range conditions may be responsible for this difference. Rutting activity in southwestern Arizona begins in late June and early July and continues into November (L. Smith et al. 1978-80). Poorer range conditions are expected during fall months than in spring, however fall flushes of vegetation can be produced from late summer rains, indicating fall range condition may be better than summer drought months (L. Smith et al. 1978-80). It may be assumed that this condition would also apply to bighorn elsewhere in Arizona. Spring weights of Arizona bighorn rams may be 30% greater than the November thru January weights recorded during this investigation. Ewes collected by Russo (1956) during April and May averaged 13% higher in body weight than those collected from October thru December.

Table 2. Chase, response, and immobilization times for bighorn rams and ewes of different age classes, from the Black and Kofa Mtns., Arizona.

Sample Size	Age (yrs.)	$\bar{x}$ Chase (min.)	$\bar{x}$ Response (min.)	$\bar{x}$ Complete Immobilization (min.)
		Black Mountain Complex Ewes		
1	1	5	–	7
5	2	3	4.6	7
9	3	7.2	5.2	5.7
11	4	3.1	5.7	8.0
4	5	4.5	3.0	5.5
$\bar{x}$	3.4	4.4	5.1	6.9
sd	1.0	4.2	1.8	2.9
		Black Mountain Complex Rams		
5	2	1.3	4.7	6.7
2	3	5.0	6.5	13.0
2	4	5.0	4.0	8.0
1	5	5	5	6.0
1	7	–		–
$\bar{x}$	3.3	3.4	5.1	7.8
sd	1.6	2.4	2.0	4.4
		Kofa Mountain Complex Ewes		
2	1	4.0	6.0	10.5
1	2	8	4	6
1	3	4	3	5
4	4	7.5	5.0	10.5
3	5	3.7	4.0	11.7
3	6	3.7	4.3	12.0
1	7	2		32.0
1	9	4	7	10
$\bar{x}$	4.5	4.8	4.8	11.8
sd	2.1	2.4	1.9	7.3
		Kofa Mountain Complex Rams		
1	1	6	6	6
3	2	4.8	10.3	12
3	3	8	3.0	5.0
1	4	8	12	–
2	5	3.5	3	6.5
2	6	12.5	7.0	12.0
1	8	2	5	5.5
$\bar{x}$	3.9	6.7	6.7	8.4
sd	2.0	3.5	4.4	4.4

Weights of Arizona rams taken during the 1981-82 captures show a high correlation of weight to age. This suggests rams continue to gain weight in relation to age throughout much of their adult life. Harvested rams from Nevada were found to gain weight through 5 years of age with a slight decrease in weight after 10 years of age (McQuivey 1978). McQuivey suggested that this is probably due to increasing horn size during early years and poorer body conditions in over-mature animals. Other investigations (Anderson et al. 1974) have suggested that mule deer bucks continue to gain weight through life, while females achieved a constant weight at about 8 years. It was also shown that males gain weight faster than female mule deer (Anderson et al. 1974). Rams captured during this investigation were necessarily biased toward younger ages. Sufficient weights of older age rams are not available to confirm losses of body weight in over-mature bighorn.

Poor correlations were found between ages and weights of desert bighorn in relation to current capture techniques used by the Arizona Game and Fish Department. Differing responses seen in Arizona bighorn captures are probably due to variables beyond the scope of this investigation. Ambient temperature during captures may slow rate of drug absorption. Bighorn captured when ambient temperatures are low enough to warrant closing of epithelial capillaries (when bighorn would be attempting to conserve body heat) would slow rates of absorption of intramuscular injections of both the immobiliant and tranquilizer. Site of drug injection would cause differing rates of drug abosorption. Individual variations in physiology of each sheep also may cause variations of drug responses. Variations in manufactured capture equipment (powder charges, lubricant, guns, etc.) may all play a role in varying the reaction and immobilization times.

As captures of free roaming bighorn sheep continue in Arizona, investigations will be made to increase the efficiency of current capture techniques and live weight projections of rams and ewes.

ACKNOWLEDGMENT

Acknowledgements are made to Pittman-Moore Inc., Clinical Research, Washington Crossing, N.J. for their continuing supply of Azaperone being used in Arizona.

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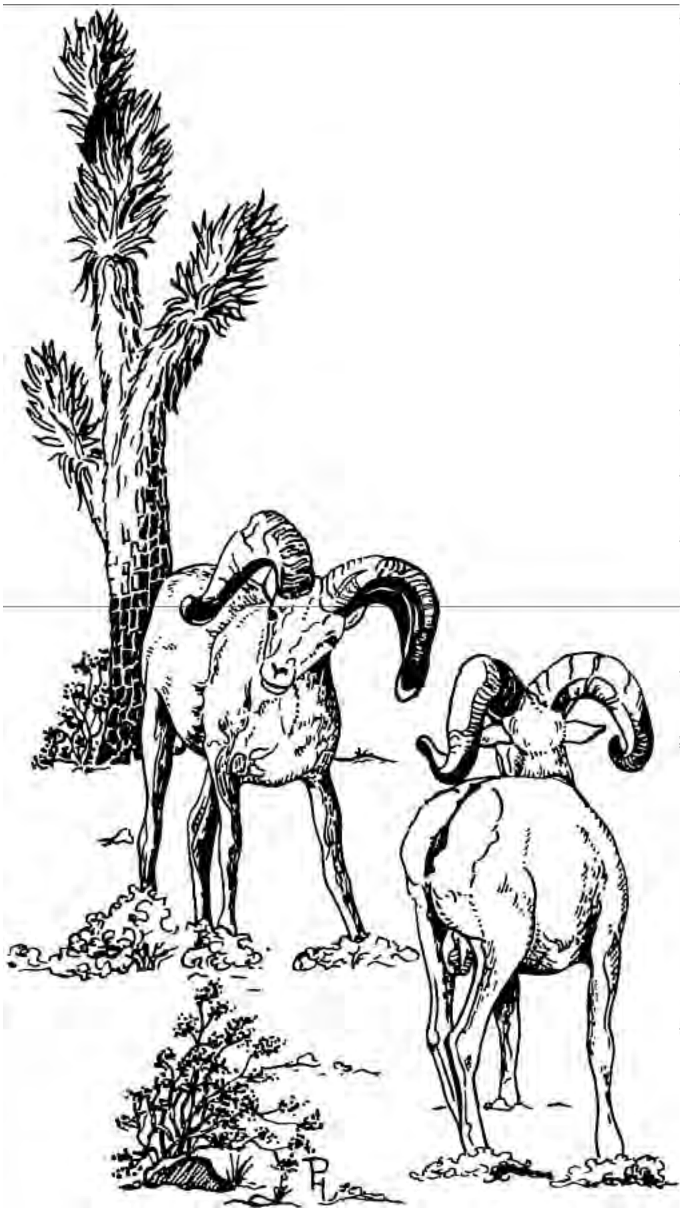

THREE-YEAR OBSERVATION OF PSOROPTIC SCABIES IN DESERT BIGHORN SHEEP FROM NORTHWESTERN ARIZONA

George W. Welsh
Arizona Game and Fish Department
Kingman, AZ

Thomas D. Bunch
Dept. of Animal, Dairy and Veterinary Sciences
Utah State University, Logan

Abstract. Psoroptes ovis was first observed in Nelson's bighorn sheep from the Black Mountains and Lake Mead area of northwestern Arizona in 1979. Occurrence was monitored through 1981. Visual examinations and ear scrapings were used in evaluating sheep that were live-captured or harvested during the hunting season. The prevalence of Psoroptes scabies in live-captured sheep was 0.25, 0.25, and 0.00 for the years 1979-1981, respectively, and was higher in rams. The severity of ear lesions was also greater in the males. The prevalence in harvested rams was 0.23, 0.44, and 0.07, respectively, for the years 1979-1981. The severity of the ear lesions was highest in 1980. Aerial surveys in the Black Mountains during May of 1981 showed a decrease in total sheep numbers and a drop in the ewellamb ratio from surveys taken in 1979 and 1980. A 1982 survey showed a reverse in the downward trend, with an increase in lamb production. In the Lake Mead area, there was a slight decrease in the ewellamb ratio during 1981. Differences in total sheep numbers between years 1979-1982 are most likely a bias inherent in the sampling technique. The population decline and increased prevalence and severity of Psoroptes scabies was believed to be related to drought and declining range conditions. Live-captured sheep in 1980 had poor body condition. Results of the 1981 survey suggest that the population decline may have resulted from death of sheep infested with Psoroptes mites, since the prevalence of scabies was the lowest in 1981.

INTRODUCTION

Scabies epizootics in bighorn sheep have been noted by observers for more than 120 years (Honess and Frost 1942, Hornaday 1901, Packard 1946, Seton 1929, Wright et al. 1933, Hansen 1967, Carter 1968, Decker 1970, Mortan 1970, Lange et al. 1980). Some of these epizootics have been associated with rapid population declines and extirpation from many ranges (Honess and Frost 1941, Hornaday 1901, Packard 1946, Lange et al. 1980), whereas others were not associated with herd decline (Carter 1968, Decker 1970). Lange et al. (1980) alluded to the fact that the recent scabies epizootic in the San Andres National Wildlife Refuge in southern New Mexico may have resulted in a population decline of more than 50%. Although they found few specimens for autopsy, the remains of a young ewe that had been dead less than 2 weeks had the most severe ear lesions seen to that date. Their alternative hypothesis for the decline was mass emigration of the sheep from their native range.

As a result of the decline in the San Andres' population, the Arizona Fish and Game Department undertook a survey to determine whether their populations of desert bighorn were infested with Psoroptes. In 1979, Psoroptes *ovis* was identified in Nelson's desert bighorn sheep from the Black Mountains and Lake Mead area of northwestern Arizona (deVos et al. 1980). This population has been monitored during the last 3 years and the results of those surveys are presented herein.

MATERIALS AND METHODS

Nelson's desert bighorn sheep inhabiting the Black Mountains and Lake Mead area of northwestern Arizona were studied by examining animals captured with the immobilizing drug, M-99, and by examining animals harvested during the hunt. Ear scrapings were taken from the external auditory meatus to the distal end of the ear. Scrapings were analyzed at the USDA Livestock Insects Laboratdry, US Dept. of Agriculture, Kerrville, Texas, and at the Department of Entomology, University of Arizona, Tucson. Ears of sheep that had lesions of exfoliated epidermis were given a subjective score of 1-10 depending on the extensiveness of the lesion. A score of 1 indicated a lesion with little exfoliation, whereas a score of 10 represented extreme exfoliation with crusted serous exudate that contained hairs loosened from the follicles, and blockage of the meatus with dark waxy material and sluffed cells.

A helicopter survey during 1979-1982 established population structure and numbers.

RESULTS

During 1979, 3 of 12 (0.25) live-captured sheep had Psoroptic lesions. The occurrence of lesions was higher in males (1 out of 3 rams); in ewes, lesions were observed in 1 of 9. The lesions were confined to the inner surfaces of the ears and were more extensive in rams. During 1980, the prevalence of Psoroptic lesions was 0.25 in 8 captured sheep, and was observed only in rams. The lesions were extensive (scale 8,10); the external surface of the ears of one ram was void of hair and had a reddish, serum-crusted epidermis. In 1981, 51 sheep were captured and none exhibited Psoroptic lesions.

The prevalence of Psoroptic lesions in hunter-harvested rams in 1979 through 1981 was 0.23, 0.44 and 0.07, respectively, (Table 1). The severity of the lesions was notably higher during 1980, with most rams receiving a rating of 10.

The mites were identified as Psoroptes ovis at the USDA Livestock Insects Laboratory, Kerrville, TX.

Table 2 compares population structures and numbers for 1979 through 1982. Total sheep numbers peaked in 1980 in the Black Mountains and then declined by 38 percent in 1981. A decline was also noted in the Lake Mead area, but the high numbers in 1982 suggest this was due to a sampling error. The lamblewe ratio for 1981 was considerably lower in the Black Mountains and declined from a May average of 0.52 in 1980 to 0.29 in 1981. An increase to 0.35 was observed in October of 1981, which would have been higher if the survey had been taken during May. There was no significant change in the ewellamb ratio in the Lake Mead area.

DISCUSSION

Nelson's desert bighorn in the Black Mountains and Lake Mead area of northwestern Arizona were first observed to have Psoroptes ovis in November of 1979. Psoroptes mites may have been present in this population prior to 1979; however, no attempts were made to survey scabies in Arizona bighorn until attention was drawn to the serious implications of the epizootic that occurred in the San Andres National Wildlife Refuge in 1978 (Lange et al. 1980).

The sheep captured in 1979, with one exception, were judged to be in fair to excellent body condition. During 1980, a notable decline in body condition had occurred, with several sheep being judged as poor, and none as excellent. A drought which began in the survey area in April of 1979, and subsided in March of 1981 was considered the primary cause for reduced body condition. As body condition declined during 1980, the severity of ear lesions increased concomittantly. A higher prevalence of Psoroptes was observed in rams harvested during 1980.

We presume that the population decrease from May of 1980 to

Table 1. Comparative prevalence of Psoroptes scabies in Nelson's desert bighorn rams harvested during the 1979,1980, and 1981 hunting season in the Black Mountains and Lake Mead areas of northwestern Arizona.

Year		Hunting Unit	No. of Rams	Severity of Scabies*	Prevalence
1979		15A & B	5	2	0.20
		15C North	6	2, 10	0.33
		15C South	1		0.00
		15D	1		0.00
	$\overline{X}$				0.23
1980		15A & B	8	1, 10, 10	0.38
		15C North	5	5, 10, 10	0.60
		15C South	3	5, 10	0.67
		15D	2		0.00
	$\overline{X}$				0.44
1981		15A & B	6		0.00
		15C North	4		0.00
		15C South	2	1	0.50
		15D	2		0.00
	$\overline{X}$				0.07

'Scale: (1) slight exfoliation to (10) extensive exfoliation of expidermis, serous exudate bearing hairs loosed from the follicles and blockage of meatus.

Table 2. Population census of Nelson's bighorn sheep in the Black Mountains and Lake Mead areas of northwestern Arizona from 1979-1982.

Month	Year	Rams	Ewes	Lambs	Lamb/Ewe Ratio	Total Number
Black Mtns.						
May	1979	92	211	87	0.41	390
May	1980	117	260	134	0.52	511
May	1981	79	182	52	0.29	313
Oct.'	1981	102	126	44	0.35	272
Lake Mead						
May	1979	32	151	80	0.53	263
May	1980	87	235	109	0.46	431
May	1981	60	164	65	0.40	289
May	1982	120	314	134	0.43	568

'Survey conducted during the rut

May of 1981 principally involved those sneep with Psoroptes mites. After the population declined, the prevalence of Psoroptes scabies dropped from 0.25 to 0.00 in captured sheep and from a 1980 high of 0.44 to 0.07 in rams harvested during the 1981 hunt.

The decline in the ewellamb ratio in the Black Mountains was attributed to poor body condition of the ewes. Two ewes in poor body condition had lambs during January and February of 1981 that weighed approximately 4 lbs., whereas a ewe in good body condition had a lamb weighing 8 lbs. The birth weight for Nelson's desert bighorn lambs average approximately 8 lbs. (Monson and Sumner 1980).

We believe the Psoroptes scabies outbreak in the Nelson's desert bighorn sheep of northwestern Arizona was enhanced by a combination of the 1979-1981 drought and 1980's high population density. Once sheep began to decline in body condition, the prevalence and severity of ear lesions increased. When the population decline occurred, the prevalence of Psoroptic scabies was drastically reduced within the remaining population. Assuming the decrease was a result of a die-off, then the greatest mortality must have occurred among sheep suffering simultaneously from malnutrition and Psoroptes scabies.

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DESERT BIGHORN SUMMER MORTALITY IN SOUTHWESTERN ARIZONA, 1979

James H. Witham
Dept. Fishery and Wildlife Biology
Colorado State University, Fort Collins
Richard R. Remington
Arizona Game and Fish Dept., Yuma
E. Linwood Smith
E.L. Smith and Associates
Tucson, AZ

Abstract. Mortality of 14 desert bighorn sheep (Ovis canadensis rnexicana) in the Plomosa and Buckskin Mountains, Arizona, was discovered during June-August, 1979. A review of those deaths on an individual basis did not indicated that a general population die-off occurred. An unusual instance of group mortality involving 5 mature rams is discussed.

INTRODUCTION

Fourteen dead or dying desert bighorn sheep were discovered in the North Plomosa and Buckskin Mountains in southwestern Arizona betrween 21 June and 7 August, 1979. Those animals were found in conjunction with the desert bighorn research program sponsored by Southern California Edison Company and the Buckskin Mountains Central Arizona Project waterhole study. Initial concern of biologists and the press focused on the possibility of a massive die-off of bighorn within those ranges. This paper documents information regarding this series of mortalities.

STUDY AREA AND METHODS

The North Plomosa Mountains are 30 km ENE of Blythe, California. An estimated 96-126 bighorn (Arizona Game and Fish unpublished data) inhabit this range which has been artificially isolated by construction of Interstate 10. The Buckskin Mountains sustain an estimated herd of 60-80 bighorn (Arizona Game and Fish unpublished data) and are 20 km NNE of Parker, Arizona. The 2 mountain ranges are separated by 20 km of flat, alluvial plain. Both the Buckskin (Campbell and Remington 1979) and the North Plomosa Mtns. (Witham and Smith 1979) have been previously described.

Ten carcasses were found in advanced stages of decomposition and were examined in the field. Maximum daily temperatures during June-August 1979 ranged from 40.5-48.9 °C, promoting rapid decomposition. Two fresh carcasses and 1 sick lamb were transported to the Bar S Animal Clinic, Wickenberg, Arizona, for necropsy. Tissues from those animals were sent to the University of Arizona Veterinary Science Pathology Laboratory, Mesa. One additional lamb carcass was flown directly to the pathology laboratory for necropsy.

Dried rumen contents were collected from 5 decomposed ram carcasses and sent to the Composition Analysis Laboratory, Colorado State University, for microscopic analysis. Those data were expressed as percent relative density of discernible plant fragments (based on 100 fields per sample). Ages of the rams and lambs were estimated from horn annuli (Geist 1966) and physical characteristics (Hansen 1965), respectively.

RESULTS

The first mortality was an adult ewe found 21 June in the Buckskin Mountains. The ewe was alive when located but died before being transported to the Bar S Animal Clinic. Necropsy revealed that the thoracic cavity of the ewe was filled with greenish-yellow fluid and that the liver was unusually hard and light in color.

A desiccated month-old lamb was discovered 27 June in the Buckskin Mtns. The carcass had not been dismembered by scavengers. The lamb's rear legs were twisted behind the head in an unnatural position. Two fractures were evident when the hide was removed. The left mandible was crushed in the diastema between premolars and incisors. A separation in the lumbar vertebrae immediately anterior to the pelvic girdle accounted for the abnormal position of the rear legs. It was unlikely that fractures were sustained during a fall as the lamb was located near the top of a mesa.

A sick lamb was observed 5 July at the Central Arizona Project Buckskin tunnel. The animal remained stationary when approached. The emaciated month-old male lamb coughed repeatedly and had clear mucoid exudate draining from the nose and mouth. It was transported to the Bar S Clinic and was administered antibiotics until its death on 15 July. The pathology report indicated (1) right eye appeared to have cataracts, (2) left eye had corneal pannus, (3) entire apical and cardiac lobes, and anterior ventral half of diaphragmatic lobe were consolidated and purple; right apical lobe had a 3x4x2 cm abcess with thick dirty yellow exudate of creamy consistency; cut sections of lung parenchyma exuded the same exudate, (4) Providence sp. and Proteus sp. were isolated from intestine and liver, all other cultures were heavily overgrown with contamination; Proteus sp. and Providence sp. were not considered disease producing organisms in this case. The diagnosis indicated that the lamb had bronchopneumonia with abcessation.

On 13 July, the carcass of a 9-year-old ram was found near a Plomosa Mountain waterhole, which had dried between 7-9 July. The carcass was fresh and showed no evidence of bloating; it was transported to the Bar S Clinic for necropsy. The ram appeared in good physical condition with substantial fat deposits in the abdominal cavity. The whole weight of the carcass was 60 kg (132 lb.), substantially less than expected for a 9-year-old ram in southwestern Arizona. Comparatively, weights of 3 mature bighorn rams (5 years +) collected by Russo (1956) during 18 June-12 August 1953, in the Castle Dome/Kofa Mountains ranged from 78-91 kg (171-200 lb.). The tightly drawn hide on the ram's head, and the presence of 5 visibly dehydrated live sheep 20 m from the carcass, lend credence to the supposition that dehydration was a factor in the death of this animal. Lung, heart, kidney and skeletal muscle tissues were sent to the pathology laboratory; however, postmortem degeneration was too advanced for meaningful interpretation.

A 3-year-old ram was found 21 July at the same site of the previous 9-year-old ram. This ram was lying on its side and was extensively bloated. Blowfly larvae were present in the carcass. The horn sheaths were missing, having been removed by a hiker on 18 July. When contacted, the hiker stated that the ram appeared to have been dead for 2-3 days prior to 18 July.

The most unusual incident in this series of mortalities was discovered on the afternoon of 21 July. Carcasses of 5 mature rams were found in a large cave 2.8 km from the site of the previous 2 rams. Ages of the 5 rams were estimated at 6, 6, 8, 9 and 12 years. Two rams were found leaning against each other at the front of the cave. The remaining 3 rams were 10, 13, and 25 m deeper in the cave. The cave is the largest in the Plomosa Mountains measuring about 9x6 m at the entrance and about 30 m deep. The cave floor was composed of a 15 cm layer of dust and powdered bat guano.

Those carcasses and the 3-year-old ram found earlier in the morning appeared to be at a similar stage of decomposition. There was no evidence of gunshot wounds or burns that may have been caused by lightning. The animals were bloated, large blowfly larvae were present, hair was beginning to slough, the skin on the exposed sides of the animals was drawn and desiccated, and horn sheaths were easily removed from the cores. Effects of recent fighting were evident on 3 rams. The thin layer of muscle overlying the nasal bones was torn and severely bruised. Nasal bones on 2 rams were stained by hemorrhaging. Although the 5 rams were at a similar stage of decomposition, they may not have died simultaneously. We are reasonably confident that the 5 rams died at least within several days of each other during 7-15 July.

Rumen contents from these rams were removed several weeks later for analysis (Table 1). The delay in rumen content collection may have biased results in favor of less digestible forage. Four plant species were common to all samples, 3 having been previously identified as typical June-August forages of Plomosa bighorn sheep. Microscopic analysis of 57 fecal pellet groups collected during summer have shown relatively high frequencies of occurrence for cactus (26%), *Hilaria* rigida (37%), and Sphaeralcea ambigua (60%) (Smith and Witham unpublished data). The 4th plant common to all samples was

Table 1. Percent relative density of discerned fragments from desert bighorn sheep rumen samples collected from 5 dead rams found in a Plomosa Mountain cave, 21 July 1979.

Forage	Ram 1	Ram 2	Ram 3	Ram 4	Ram 5
Aristida	T				7
Bromus					T
Carex		2			
Hilaria	2	4	6	2	12
Muhlenbergia			4		T
Poa	2				T
Sporobolus cryptandrus	T				
Acacia	16	39	62	50	44
Allium					T
Artemisia[1]	T	T			
Astragalus	1	T			1
Atriplex		2			
Cactus	56	28	16	22	14
Cercocarpus[1]			1	2	5
Ephedra		10	3	8	9
Krameria					1
Oenothera	1				
Sphaeralcea	2	5	6	9	1
Yucca	14	6			1
Unknown and seeds	3		1		

[1]Genus not known from Yuma County, AZ

T value <1 percent relative density

Acacia sp. which was found at a high percent relative density in each stomach ($\bar{x} = 42\%$, range 16-62%). These values were higher than expected based upon the frequency of Acacia sp. in our June-August fecal samples (1157=2%). However, the presence of Acacia sp. is consistent with the direct observations of Russo (1956) who ranked Acacia *greggii* as important forage utilized by bighorn on the adjacent Kofa Game Range.

Discovery of the rams in the cave prompted the Arizona Game and Fish Department to conduct a helicopter survey for additional mortalities in the Plomosa Mountains. Two lamb carcasses were located during a 3-hour flight on 31 July.

The first lamb was observed on a ledge and body fluids were draining from the carcass. Cause of death of the 4-month lamb was not evident when the animal was retrieved in early August. The second lamb was a female aged at 6 months. The carcass was fresh and without bloat. A reddish-yellow foamy exudate drained from the nose. Muscles of the left shoulder appeared to be damaged. The lamb was immediately flown to the pathology laboratory; necropsy indicated that: (1) a nasal bot was present in the ethmoid sinuses on the right side, (2) an extensive pneumonic process involved the entire right lung and cardiac and apical lobes of the left lung; lung tissue was swollen, firm, and dark red-purple; a cut section showed a variegated color pattern from red to dark blue or purple, (3) alveolar lumens were filled with inflammatory cells; some viens and venules were thrombosed; fibrin and cellular exudate was found in the lumen of some bronchioles, (4) there was extensive abcessation of the left shoulder involving subcutis and muscles, exudate was creamy in consistency and red-tan in color; inflammation of subcutis extended from the shoulder to the mid forelimb area, (5) tissue cultures were overgrown with contamination, and (6) diagnosis was a severe fibrinopurulent bronchopneumonia with extensive cellulitis and abcess in the left shoulder to mid forearm region.

The last dead bighorn sheep that were observed during this period were the remains of a ewe and lamb found 7 August. The sun-bleached bones were scattered on a ledge and were found fortuitously while observing live sheep. The lamb was exceptionally small and may have been unborn when the ewe died. In any case, the lamb was too young to survive without maternal care. It is likely that these sheep died during winter or spring, 1979.

A 2x4 contingency table was used to test the hypothesis that no significant difference existed between the sex-age composition of the observed Plomosa mortalities and expected values from a helicopter survey estimate of Plomosa herd composition (53 rams:100 ewes:40 lambs:16 yearlings) (Arizona Game and Fish unpubl. data). Mortality was not found in similar proportions to the structure of the population, and indicated that adult ram carcasses were found at a significantly higher ($p < 0.05$) rate than other cohorts.

DISCUSSION

The months of June-August are recognized as a period of stress upon desert bighorn sheep in the Plomosa and Buckskin Mountains. Temperatures are maximum while water availability and forage quantity and quality decline. Concomitant is the potential for social stress as herd density increases around limited water sources, and energy demands are elevated at the start of the breeding season in mid-June. Those factors may negatively affect physiological condition of individual sheep and increase mortality. Data collected between October 1977 and July 1981 in our study area support that contention; 76% of 25 fresh carcasses have been found during June-August (unpubl. data).

The 14 bighorn mortalities found in 1979 were discovered during the course of 2 research projects in separate mountain ranges. The large number of man-hours spent in areas of high bighorn density during a period of maximum climatic and behavioral stress, undoubtedly increased the probability of finding carcasses that normally would have remained undetected. It is possible that these efforts simply resulted in a more complete documentation of typical summer mortality.

Discovery of 5 adult rams in a cave should not be obscured by the other, seemingly more typical, mortalities. The circumstances of this incidence of group mortality are unique relative to other examples (Monson 1965) because of the freshness and similar stage of decomposition of the carcasses when found; however, cause of mortality was not identified.

Catastrophic all-age die-offs of bighorn sheep have been observed recently in *O.c.* canadensis (Fuerstein et al. 1980), *O.c. californiana* (Lava Beds National Monument) (R. Weaver pers. comm.), and *O.c. mexicana* (Snyder 1980). Discovery of 14 dead and dying bighorn in southwestern Arizona during summer of 1979 generated widespread speculation as to the magnitude of losses. A review of those mortalities on an individual basis, the sex-age ratio of the carcasses, and subsequent helicopter surveys indicated that those deaths were not part of a general population die-off.

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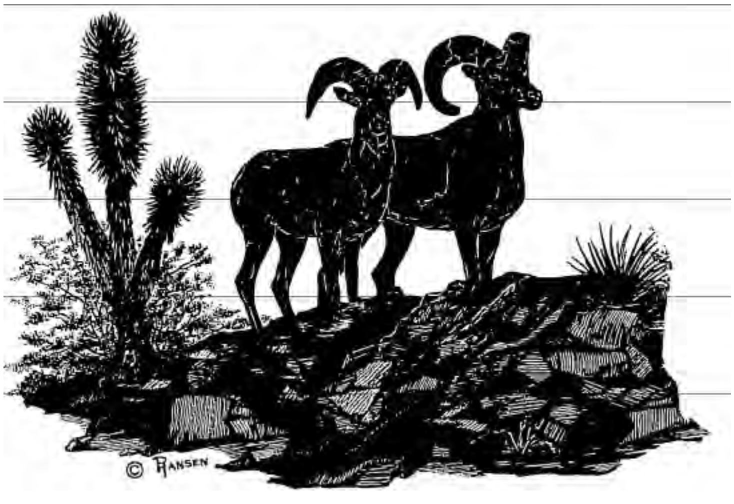

EVALUATION OF BIGHORN SHEEP HABITAT

Stephen A. Holl
U.S. Forest Service
Fontana, CA

Abstract. Habitat evauation models to determine the quantity and quality of bighorn habitat are described. The quantity of escape terrain required by ewes is a linear relationship, $Y = 0.179X - 1.43$; where Y equals the estimated population size and X the hectares of escape terrain. Habitat quality is determined using a model termed PATREC. This model also defines management activities needed to enhance sheep habitat.

INTRODUCTION

It is axiomatic that wildlife habitat is composed of food, water, cover, and space. Likewise, it has been well documented that habitat requirements change with respect to season, activity, sex, and age of a species. A major challenge to wildlife managers is to determine the amount of habitat necessary to support a population, and the ability to predict the effects of different land management strategies on that population. Information of this nature is frequently required to evaluate the effects projects, activities or other disciplines might have on bighorn populations, establish management actions for a population, or evaluate potential transplant sites.

Previous attempts to develop habitat evaluation techniques for bighorn *(Ovis* canadensis) (Ferrier and Bradley 1970, Hansen 1980), have dealt solely with desert populations. Both techniques rely heavily on the availability of water, which may not be a necessity during all seasons (McQuivey 1978). Neither technique allows for seasonal changes in foraging strategies and thermal requirements. Additionally, neither technique provides estimates of population sizes or densities supported by a given range.

Recent advances in wildlife habitat evaluation techniques have provided some stimulating results (Thomas 1979, Verner and Boss 1980, Russell et al. 1980). In California, an interagency effort, The Wildlife Habitat Relationships Program (Salwasser et al. 1980) is developing similar techniques. Some efforts of this group are being designed to estimate population characteristics based on habitat components and their condition. The objective of this report is to describe a habitat evaluation technique currently being developed for use on bighorn *(O.c. nelsoni)* inhabiting the San Gabriel Mountains.

THE STUDY AREA

The San Gabriel Mountains are a portion of the Transverse Range separating the San Joaquin Valley and Mojave Desert from the Los Angeles Basin. Elevations range from approximately 233 m to 3,333 m. At least 12 major vegetation types have been described for this range (Hanes 1976). Typically, on cismontane slopes, chaparral is dominant at lower elevations, with oak woodlands in the narrow canyon bottoms and on north aspects. Mixed conifer and yellow pine forests occur from approximately 1,800 m to 2,500 m. A subalpine forest, characterized by lodgepole pine *(Pinus* murrayana) ranges up to approximately 3,160 m. Above this is an alpine dwarf scrub community characterized by several varieties of buckwheat *(Eriogonum* spp.). A population of bighorn, currently estimated at 735 animals (Holl and Bleich 1981), occupies the eastern end of the range. Winter range densities are approximately 12-13 bighorn/km^2. Winter ranges are between 1,000 m to 1,900 m. Summer ranges may extend to 3,333 m elevation. Both resident and migratory animals inhabit these mountains. Additional information describing this population is available (Gardner 1918, Robinson and Cronemiller 1954, Weaver et al. 1972, Light and Weaver 1973, DeForge 1980).

METHODS

Eight winter ranges used by the bighorn population were selected for study. Designation of winter ranges was based on Weaver et al. (1972) and DeForge (1980). Boundaries of winter ranges were defined as those areas where 95 percent of the observations were made during the past 7 years of winter helicopter surveys. The size of each winter range and 7 habitat variables: elevation, percent slope, aspect, distance to water, and percent cover of herbaceous, chaparral, and tree associations were mapped on 1:24,000 topographic maps and aerial photographs. Additionally, the amount of escape terrain, defined as slopes greater than 60 percent and dominated by rock outcrops, was mapped.

Information concerning seasonal habitat requirements of bighorn and habitat characteristics in the San Gabriel Mountains was obtained from previous studies (Light and Weaver 1973, DeForge 1980) and work currently in progress (Holl et al. 1979). Winter range population sizes are empirical estimates based on Weaver et al. (1972), DeForge (1980), and current work. Ewe populations were determined from the empirical estimates and mean rams:100 ewes:lambs ratios. It was necessary to assume that winter range populations were stable and at carrying capacity.

Criteria and assumptions constraining the selection of an evaluation technique were:
a) It would be sensitive to inherent variability present among natural populations;
b) It would be simple to use;
c) It would produce an estimate of population size.

RESULTS AND DISCUSSION

Eight winter ranges, their estimated size, amount of escape terrain, population sizes, and number of ewes were used in the analysis, Table 1. Winter ranges varied in size from 185 to 1,165 hectares and the estimated amount of escape terrain ranged from 32 to 385 hectares. Estimated mean population sizes ranged from 10 to 130 bighorn.

Quantity **of** habitat. The relationship between total population size and amount of winter range is curvilinear (Figure 1). Thus, population size does not increase in direct proportion to the amount of habitat available. This is expected since as the area increases, so does the number of habitat types. Some of these types may not be suitable for bighorn, and thus, not all will be used. The relationship shows, however, that approximately 245 hectares of winter range are required to support a minimum population of 10 bighorn.

It is well documented that escape terrain is a necessary habitat component for bighorn, particularily ewes (Sandoval 1979, Hansen 1980, Geist and Petocz 1977, Wehausen 1979, and others). When the estimated ewe population size was regressed on acres of escape terrain, the relationship was linear and significant ($P < 0.01$), with a y-intercept of approximately one (see Figure 1). The resultant equation shows that without escape terrain there should not be any ewes, and the size of the ewe population is directly proportional to the amount of escape terrain available. The model also indicates that approximately 60 hectares of escape terrain are needed to support approximately 10 ewes.

Table 1. Estimated size, amount of escape terrain, population size, and number of adult ewes for eight winter ranges in the San Gabriel Mountains.

Winter Range	Total Hectares	Hectares Escape Terrain	Estimated Population	Rams:100 Ewes:Lambs	Estimated Ewe Population
Middle Fork	312	156	35	118:100:29	14
South Fork	715	286	80	59:100:33	42
Day Canyon	490	32	10		0
Deer Canyon	185	67	15	55:100:21	9
Cucamonga Canyon	650	65	100	204:100:21	31
Barrett-Cascade	440	101	30	100:100:32	13
Cattle Canyon	1,035	372	130	56:100:29	70
East Fork	1,165	385	130	55:100:34	72

The model does not show that a ewe population will be present if sufficient escape terrain is available. There obviously are other habitat components that must be present to support a population. Nor would I expect this model to work for all bighorn populations. For instance, the slope of the regression line should be less for desert populations owing to their inherently lower densities. However, I believe the principle is applicable to other bighorn populations.

Quality of habitat. Habitat quality is dependent on the amount, condition, and juxtaposition of habitat components necessary to support a given population. The evaluation of habitat quality requires a knowledge of the habitat components required by a species and a standard with which these components can be compared. It often is difficult to evaluate a particular situation or area, because we are not always aware of interactions between habitat components, and habitat components are not always uniformly distributed within and between areas.

To evaluate potential and existing habitat quality in the San Gabriel Mountains I selected a recently developed system, termed PATREC (Cling 1979, Russell et al. 1980). PATREC is an acronym for pattern recognition, which employs Bayesian Probability Theory to provide quantitative answers. The output of a PATREC model provides a quantitative response analogous to: "Based on my experience and knowledge, and given the habitat components and conditons just described, the probability the area is high quality habitat is . "

Basically, PATREC utilizes the habitat conditions associated with high population densities in an area, and the habitat conditions associated with low population densities, as standards of habitat quality. The system is most accurate where objective data are used; however, where there are data missing, subjective determinations may be substituted.

A PATREC Model requires three components: (1) an estimate of the probability an area will have a high or low density population (prior probability), (b) a list of habitat attributes associated with bighorn sheep, and (c) the probability a habitat attribute is associated with high or low population densities (conditional probability).

The model developed from data collected in the San Gabriel Mountains has 7 habitat attributes and high density habitat has 17 sheep/km^2 (Table 2). The model includes both abiotic

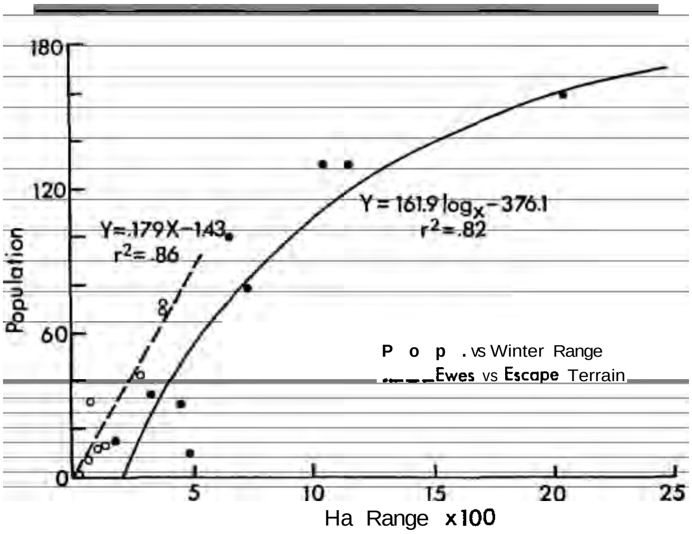

Figure 1. Regression analyses of estimated population size on size of winter range and estimated number of ewes on amount of escape terrain.

Table 2. The PATREC habitat evaluation model developed for the San Gabriel Mountains.

Habitat Attributes	Conditional Probabilities High	Conditional Probabilities Low
1) Area is below 6,000 ft. elevation	.60	.40
2) More than 60% of the area has aspects between 130-230" from north	.60	.35
3) Water is available within 150 yards of escape terrain	.80	.65
4) More than 35% of the area is a birch leaf mountain mahogany association	.60	.20
5) Percent of the area within 150 yards of escape terrain having a shrub canopy cover less than 35%		
a) less than 25%	.20	.40
b) 25 to 50%	.30	.35
c) more than 50%	.50	.25
6) Trees occupy of the area		
a) less than 30%	.60	.20
b) 30-50%	.30	.25
c) more than 50%	.10	.55
7) Grasses and forbs comprise more than 5% cover	.70	.35

Population Density Standards: High = 17/km^2; Low = 6/km^2

Prior Probabilities: P(H) = High = .60; P(L) = Low = .40

and biotic attributes, of which the first six normally can be ob- tained from topographic and vegetation maps and aerial photographs.

Computations to provide an output are quite simple and can be done by hand, using a small calculator or a computer. Once he required inventory data are gathered from an area they are used in the following equation:

(Bayes Theorum)

$$P_{(H/ID)} = \frac{P(H) \times P_{(ID/H)}}{P(H) \times P_{(ID/H)} + P(L) \times P_{(ID/L)}}$$

Nhere $P(H_{ID})$ is the probability that the area supports a high density population, based on the inventory data. P(H) and P(L) are the probabilities of having a high or low density area, respectively (prior probabilities). And, $P(ID_H)$ and $P(ID_L)$ are the probabilities the inventory data have a high or low density potential, respectively (conditional probabilities).

he following will serve as an example. An imaginary area, Bighorn Canyon, has been inventoried and attributes are met or 1, 3, 5b, 6b, and 7. Attributes 2 and 4 were not met. First, the probabilities that the inventory data for the given area have high or low density potentials are calculated. Notice, when an attribute is not found, both conditional probabilities are sub- racted from 1.

$$P(ID_H) = (.6)(1-.6)(.8)(1-.6)(.3)(.3)(.7) = .0048$$

$$P(ID_L) = (.4)(1-.35)(.65)(1-.2)(.35)(.25)(.35) = .0041$$

Substituting these data into equation:

$$P(H_{ID}) = \frac{.0048(.6)}{.0048(.6) + .0041(.4)} = .63$$

rom these data we would conclude the probability that Bighorn Canyon supported a high density population (17 heep/km²) was .63. The model also provides insight into some management options which are available to improve the area. Although habitat attributes 2 and 4 were not met, it is unlikely hat management could change these. However, attributes 5b nd 6b can be managed; thus, the probability that Bighorn Canyon would support a high density population could be in- reased.

CONCLUSIONS

he first model, a linear regression equation, predicts the umber of ewes in an area based on the amount of escape ter- ain present. It also showed that in the San Gabriel Mountains minimum of 60 hectares of escape terrain on winter ranges re necessary to support 10 ewes. The second model, ATREC, determines the probability that an area will support a igh or low density population.

hese models demonstrate that population parameters can be etermined based on the quantity and quality of habitat vailable to bighorn. Using both models, a trained biologist an predict the approximate size of the female portion of a opulation and whether or not it will be a high or low density opulation.

lthough data used in developing these models were collected 'om the San Gabriel Mountains, I believe they are applicable to existing and potential populations throughout the Transverse Mountain Range. The principles employed in developing these models should be applicable to other ranges supporting bighorn. Used in combination, the models can identify specific management actions which will enhance bighorn habitat, or identify and evaluate potential transplant sites.

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AN EVALUATION OF THE EFFECTS OF RECREATIONAL ACTIVITY ON BIGHORN SHEEP IN THE SAN GABRIEL MOUNTAINS, CALIFORNIA

Kathleen Hamilton
Cooperative National Park Resources Studies Unit
University of Nevada, Las Vegas

Stephen A. Holl
U.S. Forest Service
Fontana, California

Charles L. Douglas
Cooperative National Park Resources Studies Unit
University of Nevada, Las Vegas

Abstract. The effects of human disturbance on bighorn sheep *(Ovis canadensis nelsoni)* was studied in the San Gabriel Mountains, California. The hypothesis that bighorn were abandoning habitat receiving high levels of human use was tested.

Bighorn using the Narrows mineral lick in South Fork Lytle Creek were not displaced by the presence of people in the canyon. The greatest proportion of sheep use of the lick and people use of the canyon occurred during midday hours. There was no correlation between numbers of people using the canyon and numbers of bighorn using the lick. Frequency of people traveling near the lick was important since sheep did not use it when people were in the immediate vicinity. Bighorn did not avoid the lick; they used it only when no humans were in the immediate vicinity.

The presence of large numbers of hikers on the Devil's Backbone trail, located in sheep summer range, did not cause sheep to abandon adjacent habitat. There was no significant difference in sheep distribution between the Devil's Backbone trail (heavy recreational use) and the Cucamonga Peak trail (light recreational use).

INTRODUCTION

The San Gabriel Mountains are inhabited by the largest population of bighorn sheep *(Ovis canadensis nelsoni)* in California (Weaver et al. 1972). Population estimates for the past 7 years (1976-82) have ranged from 665 to 740 sheep (Holl and Bleich 1982) with a mean of 702. The mountain range is bordered on the south by the Los Angeles - San Bernardino Basin, one of the most heavily populated metropolitan areas in California. A major portion of the San Gabriel Range is public land under administration of the U.S. Forest Service. In 1981, the Angeles and San Bernardino National Forest were ranked fifth and second, respectively, in national use and received a total of 11,452,000 visitor recreational days (1 RVD = 1 visitor in the forest for 12 hours or 12 visitors in the forest for 1 hour).

Because of the large amount of recreational activity in the San Gabriels, researchers have expressed concern for possible adverse effects on the bighorn population. Light (1971), using overlays of habitat components, concluded that heavy human use of high quality bighorn habitat was excluding bighorn and, therefore, bighorn could tolerate only limited amounts of human disturbance before they would be driven from their home range. Weaver et al. (1972) felt that increasing numbers of hikers would lead to a decrease in sheep utilization of areas adjacent to trails. Light and Weaver (1973) determined that humans and bighorn were mutually exclusive and developed a set of guidelines designed to minimize bighorn/human interactions. In a 1980 study of the San Gabriel bighorn herd, DeForge postulated that the population was regulated by stress imposed by negative stimuli sheep received from encounters with humans and that sheep would avoid areas of human activity to minimize those encounters.

The hypothesis that sheep are abandoning areas of heavy human use was tested by determining (1) whether the presence of people are adversely affecting bighorn use of a point (or localized) resource such as a mineral lick, (2) whether the high number of hikers on foot-trails in sheep summer range caused abandonment of nearby habitat.

The study was part of the San Gabriel Bighorn Sheep Project, developed by the U.S. Forest Service and California Fish and Game to determine habitat and resource requirements, population dynamics, distribution, and effects of humans on bighorn sheep in the San Gabriel Mountains.

STUDY AREA

The study was conducted at selected sites in the San Gabriel Mountains, located in Los Angeles and San Bernardino Counties of southern California. The range extends 100 km (63 mi.) on an east-west axis with an average width of 32 km (20 mi.). The range is characterized by steep rocky slopes with narrow ridgetops. The shallow rocky soils are derived from decompos-

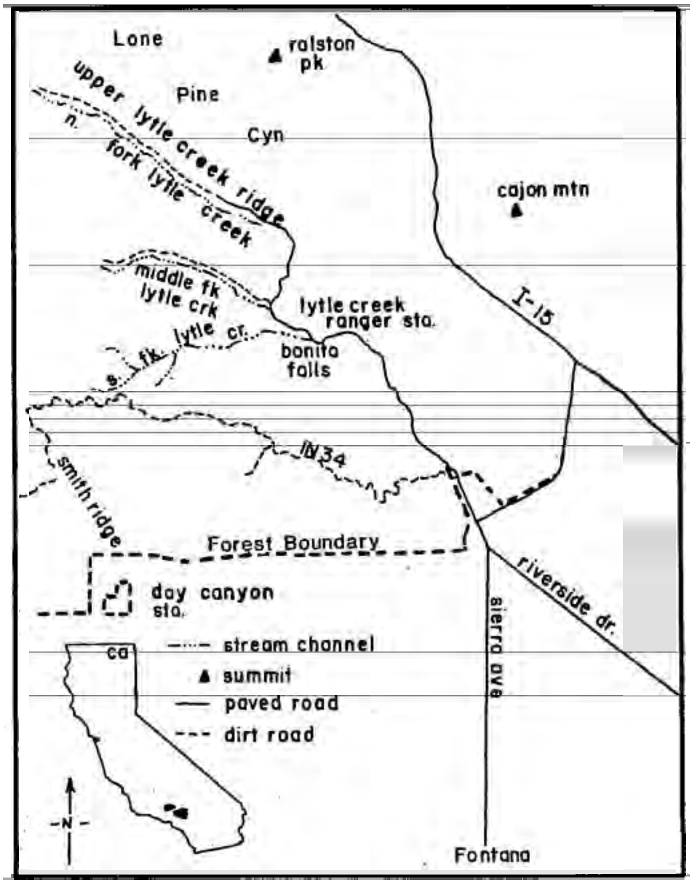

Figure 1. Map showing location of South Fork Lytle Creek in the San Gabriel Mountains, California.

ed granite, and are highly friable (Sharp 1972). Climate in the study area is classified as Mediterranean, resulting in hot dry summers and mild wet winters (Bailey 1966). Elevations vary from approximately 550 m (1800 ft.) in the foothills to 3067 m (10,064 ft.) on the highest peak, Mt. San Antonio.

Bighorn sheep inhabit the eastern portion of the San Gabriel Range. Winter distribution of bighorn varies from 914 m to 1828 m (3,000-6,000 ft.). Summer distribution varies from 914 m to 3,067 m (3,000-10,064 ft.). For a more detailed description see Weaver et al. (1972), De Forge (1980), and Holl and Bleich (1982).

The two mineral licks studied are located in South Fork Lytle Creek (Fig. 1). The major plant community on southern aspects is chaparral. Vegetation on northern aspects and drainages is oak woodland interspersed with big cone Douglas-fir (Pseudotsuga macrocarpa). Vegetation along the creek is riparian, dominated by white alder *(Alnus rhombifolia).*

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The mineral licks used by sheep in South Fork Lytle Creek are characterized by gray, clay-like soils associated with exposed seeps. Chemical characteristics of the licks were reported by Holl et al. (1980). The Narrows lick is located approximately 0.25 mile from the mouth of the canyon at 975 m (3,200 ft.) elevation, on the cliff face just above the north bank of the creek. This part of the canyon is easily accessible to people and is thus subject to regular recreational use. The second mineral lick, the Buck Point lick, is located approximately 2.5 miles from the mouth of the canyon. The lick is not associated with the creek, but occurs near seeps on the north canyon wall, which is barren of vegetation. Due to precipitous terrain, human travel into the area is difficult, resulting in minimal recreational use.

Two hiking trails, traversing sheep summer range (Weaver et al. 1972), were used to help determine whether high numbers of hikers were affecting sheep (Fig. 2). The Cucamonga Peak trail is located in the Cucamonga Wilderness. The trail starts from the trailhead near the Joe Elliot Memorial Tree, goes up to Cucamonga Peak and continues to Icehouse Saddle, where it branches into three other trails. Access to the trail head is from the San Sevaine truck road. The part of the trail used for the study was from the trail head to Cucamonga Peak. Elevation is approximately 1,890 m (6,200 ft.) near the trail head, to 2,682 m (8,800 ft.) at Cucamonga Peak.

Vegetation from the trail head up to 2,440 m (8,000 ft.) was primarily yellow pine forest. From approximately 2,440 m to Cucamonga Peak dominant tree species were limber pine *(Pinus flexilis)* and lodgepole pine (P. *contorta).*

A wilderness permit is required prior to entry into the Cucamonga Wilderness. Entry into the area by people is restricted during summer months due to a fire closure which affects the access road and a portion of the trail.

The Devil's Backbone trail is one of 4 trails leading to the top of Mt. San Antonio ("Old Baldy"). The trail, from the trail head near the ski lift area to the top of Mt. San Antonio, was used for the study. Elevation ranged from 2,621 m (3,600 ft.) at the trail head to 3,065 m (10,064 ft.) at the top of Mt. San Antonio. The characteristic vegetative community from the trail head to approximately 2,895 m (9,500 ft.) is subalpine forest. Vegetation above timberline is characteristic of alpine fell-field.

Hiking trails leading to Mt. San Antonio are open for recreational use throughout the year.

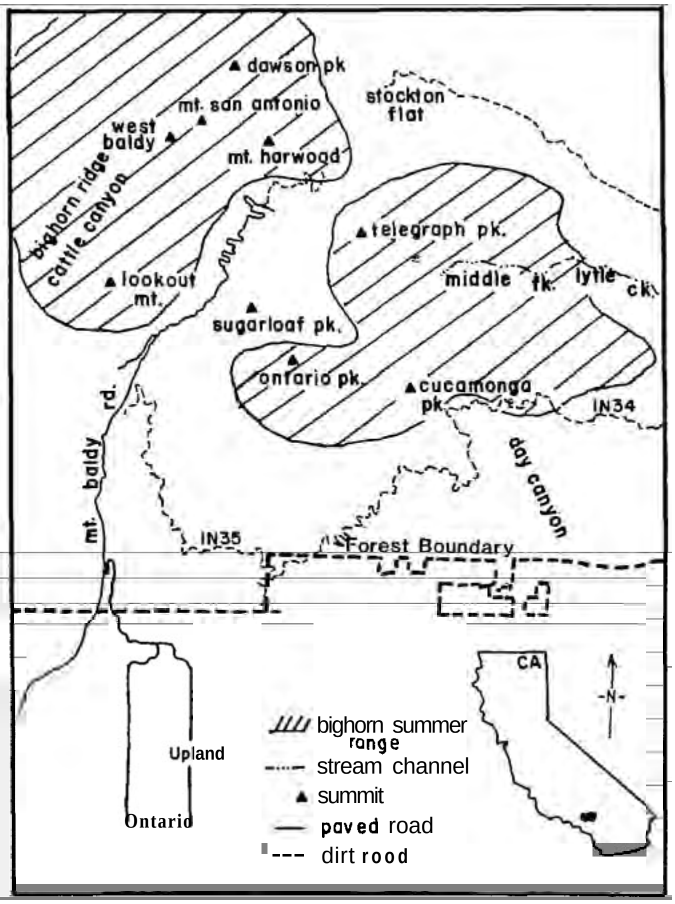

Figure 2. Map showing the location of Mt. San Antonio and Cucamonga Peak in bighorn summer range, San Gabriel Mountains, California.

METHODS

Bighorn use at the mineral licks was monitored to determine differences in use and activity periods. The Narrows lick is in an area subject to human disturbance, whereas the Buck Point lick is in an area receiving little or no disturbance.

Bighorn use of the mineral licks was monitored by direct observation from behind natural blinds and with the use of time-lapse cameras. The blind at the Narrows lick was situated on a small knoll approximately 125 meters from the lick. Bighorn use at the Buck Point lick was monitored from the side of a cliff in the Buck Point area of the San Sevaine truck road (Road 1N34). The blind was approximately 500 m from the mineral lick. The mineral licks were observed during August 1980 and from June through September 1981. They were monitored once each 10 days for a total of 15 observation periods per lick. Observation periods were from dawn to dusk.

A time-lapse camera was installed at the Narrows lick, but inaccessibility of terrain prevented camera use at the Buck Point lick. Time-lapse cameras have been used for bighorn research by Helvie (1972), Constantino (1973, 1974), and Douglas (1976). The time-lapse camera system was similar to that used by Helvie (1972), and consisted of a Super 8 movie camera, Kodachrome II color film, an intervalometer, and an electric eye that activated the camera during daylight hours. The intervalometer was set to expose a single frame of film every 60 seconds. Each film cartridge lasted for approximately 4 days. Camera records were made twice monthly in September 1980 and during the summer of 1981. The camera was placed ap-

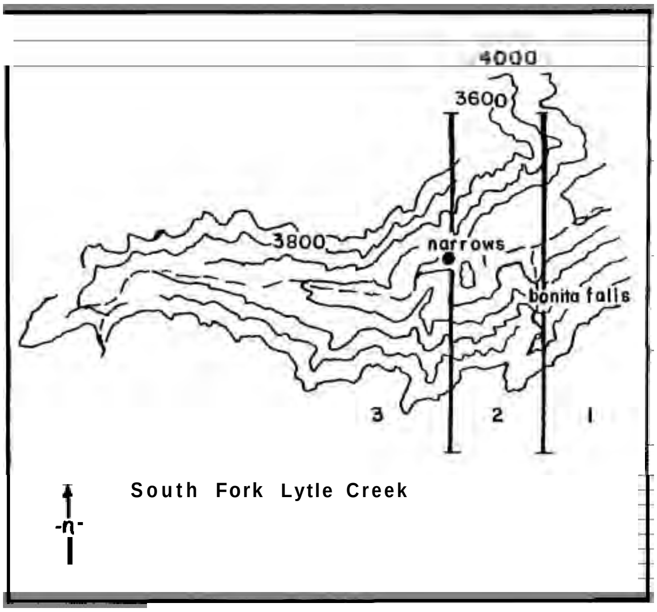

Figure 3. Map of lower South Fork Lytle Creek divided into 3 sections for accuracy in recording recreational use. Section 1 includes that area from the mouth of the canyon to Bonita Falls; Section 2 includes that area upstream from Bonita Falls to the Narrows mineral lick; Section 3 includes the area upstream from the mineral lick.

proximately 125 meters from the Narrows lick. It could not be placed closer for fear of vandalism.

Direct observations were made with the aid of binoculars and a variable power spotting scope. Data collected by direct observation included time of day sheep visited the lick, duration of visit, group composition, and age classes. Sex and age classes were identified following Geist (1971a). Data collected by time-lapse photography included time of day sheep visited the lick and duration of visit.

Recreational use in the lower portion of South Fork Lytle Creek was recorded while monitoring the Narrows mineral lick. For accuracy in recording, the canyon was divided into 3 sections (Fig. 3). The first section included that area from the mouth of the canyon up to and including Bonita Falls. The second section was upstream from Bonita Falls and included the Narrows mineral lick. The third section was that part of the canyon upstream from the Narrows mineral lick. Data collected on recreational use of the canyon included: number of individuals entering the canyon, time and duration of visits, and where the majority of time was spent.

Two trails, the Devil's Backbone and the Cucamonga Peak trail, were monitored to help determine whether high numbers of hikers in sheep summer range were causing bighorn to avoid suitable habitat. The number of people using the Cucamonga Peak trail is low during summer months due to a fire closure which includes the access route to the trail head and a portion of the trail. The number of people using the Devil's Backbone trail is not regulated. The trail is open for use throughout the year and is subject to use by large numbers of hikers.

Each trail was hiked 3 times per month during the summer of 1981. Locations of bighorn were recorded while hiking the Cucamonga trail from the trail head to Cucamonga Peak, and Devil's Backbone trail from the trail head to the top of Mt. San Antonio (see Fig. 4 and 5). Due to the small sample size of bighorn observations obtained in 1981, sightings recorded for these trails by other researchers on the San Gabriel Bighorn Sheep Project were included in the data analysis. Bighorn sightings were recorded on topographic maps and the distances between bighorn and the nearest point on the trail were determined.

The amount of human use of the Cucamonga Wilderness was determined from records of Wilderness Permits maintained by the San Bernardino National Forest. Numbers of hikers using the Devil's Backbone, and other trails leading to the top of Mt. San Antonio, were obtained from the Angeles National Forest. These estimates are based on the use of trail head registers.

RESULTS

Bighorn use at the Narrows mineral lick was compared to use at the Buck Point lick. A total of 226 bighorn were observed using the licks. Sixty-five sheep at the Narrows lick and 78 sheep at the Buck Point lick were sighted from observation blinds. During 32 days of time-lapse camera use at the Narrows lick, 83 sheep were recorded using it. Two ewes with marking collars were observed at the Narrows lick. The ewes

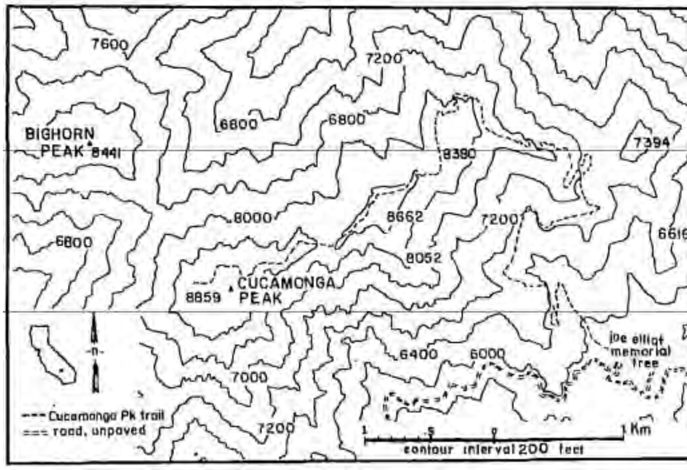

Figure 4. Map of the Cucamonga Peak trail in the Cucamonga Wilderness, San Gabriel Mountains, California. The dotted and dashed line is the Wilderness Boundary. Cucamonga Peak is in the Wilderness Area.

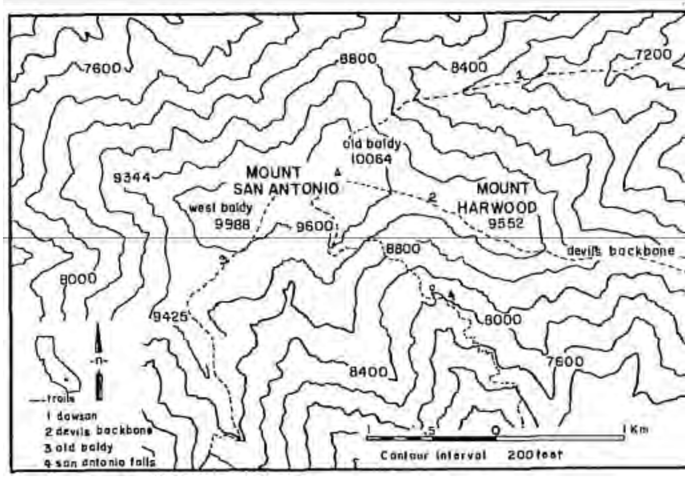

Figure 5. Map of Mt. San Antonio in the San Gabriel Mountains, showing the location of the 4 trails to the top of the mountain.

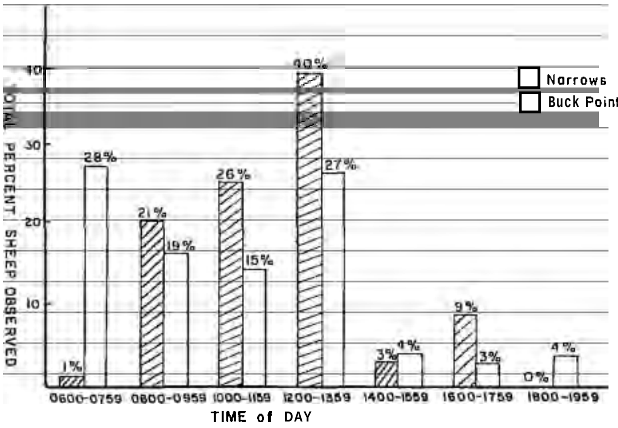

Figure 6. The percentage of bighorn sheep use at the Narrows and Buck Point mineral licks, South Fork Lytle Creek, occurring within a day, per two hour increment.

had been collared during a previous study by DeForge (1980). These ewes never were observed at the Buck Point lick.

There was a difference in the time of day sheep used the mineral licks (Fig. 6). Twenty-eight percent of sheep use at the Buck Point lick occurred between 0600 and 0800 hours; at the Narrows lick only 1% of sheep use occurred during that time. Four percent of sheep use at Buck Point occurred between 1800 and 2000 hours, but no sheep were observed using the Narrows lick during that time. A chi-square analysis was used to test for a difference in time of use between the two licks. A significant difference was found ($p \blacktriangleleft .001$). The significance was due to a greater number of sheep ($n = 22$) using the Buck Point lick during early morning (0600-0800 h), while only 2 sheep used the Narrows lick during that time. The significance was also due to the 4 sheep observed at the Buck Point lick during late afternoon (1800-2000 h). No sheep were observed at the Narrows lick during that time.

Duration of individual bighorn visits to each lick also was compared. Individual sheep used the Narrows lick for 22 minutes, the Buck Point lick for 25 minutes. There was no significant difference between time spent at the two licks ($t = .714$; $df = 131$).

During the study, 48 groups (186 persons) were observed in lower South Fork Lytle Creek from the time of arrival in the canyon until time of departure. The majority of people (51%) hiked to Bonita Falls, in Section 1 (see Fig. 3). Fourteen percent of the people hiked only as far as Section 2, and most stopped near the mineral lick. The remaining 35% hiked upstream from the lick, usually crossing it to get upstream. Thus 49% of the people visiting the canyon traveled within close proximity to the mineral lick. People never were observed at the Buck Point mineral lick.

The greatest proportion of use of the canyon by bighorn and people occurred during midday (Fig. 7). Forty percent of sheep use at the Narrows mineral lick ($n = 59$), and 52% of people use of the canyon ($n = 82$), occurred between the hours of 1200 and 1400. There was a significant difference between the time people were in the canyon and the time bighorn used the lick (chi-square $p \blacktriangleleft .005$). This difference was due to fewer sheep using the lick between the hours of 1400 and 1600, in comparison to the number of people using the canyon during these hours.

Simple linear correlation (Zar 1971) was used to determine. whetherthere was a relationship between the number of sheep and the number of people, per day, using lower South Fork Lytle Creek. There was no significant correlation between the number of sheep in the canyon and the number of people observed in the canyon per day ($r = .345$; $df = 4$); nor was there a significant correlation between the number of people in the canyon and the number of bighorn using the lick per day ($r = .419$; $df = 4$). The number of people crossing the lick and number of sheep using the lick were tested, and again, no correlation was found ($r = .124$; $df = 6$). Since total numbers of people in the canyon did not seem to affect the number of sheep using the lick, linear correlation was used to determine whether there was a relationship between the number of groups of people walking across the lick at the time of greatest sheep use (1000-1400 h) and the number of sheep using the lick during that time. There was no significant correlation ($r = .460$; $df = 6$).

Although the number of people crossing the lick did not seem to affect sheep use of the lick, the frequency with which people crossed it did have an effect. Bighorn never were observed using the lick when people were at the lick or directly upstream from it. The least amount of time before bighorn were observed using the lick after a group passed by (regardless of the number of people in the group), was one hour.

The Cucamonga Peak trail was subject to a lower level of human disturbance than the Devil's Backbone trail. Twenty-four persons used the Cucamonga Peak trail during June through September 1981 (Table 1). It is the only trail leading to the top of Cucamonga Peak. In comparison, an estimated 6,400 persons used the Devil's Backbone trail. Four trails, including the Devil's Backbone, lead to the top of Mt. San Antonio. During the summer of 1981 an estimated 14,775 persons used these trails. The total number of persons in the entire Cucamonga Wilderness Area (Table 1) during this time was 1,992.

Bighorn distribution near the Devil's Backbone and Cucamonga Peak trails was compared (Fig. 8). A total of 20

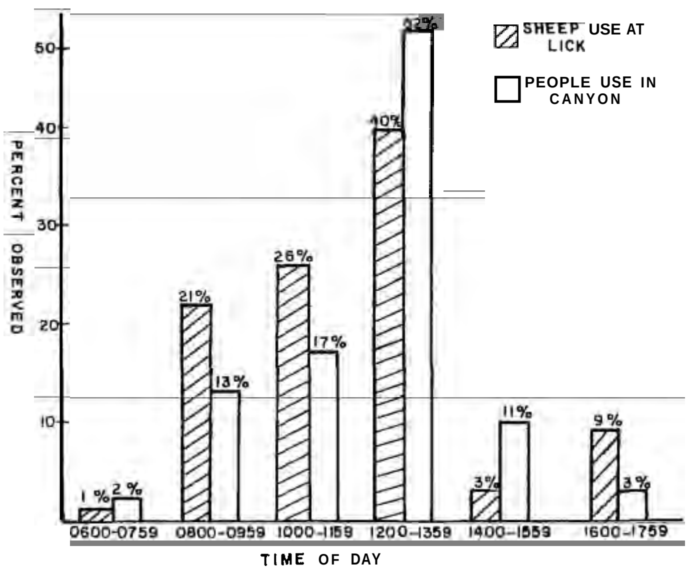

Figure 7. The percentage of bighorn sheep use at the Narrows mineral lick and human use of the lower part of South Fork Lytle Creek occurring within a day, per two hour increment.

Table 1. Recreational use of hiking trails on Mt. San Antonio and Cucarnonga Peak in the San Gabriel Mountains, California, June through Sept. 1981.

Location		Number of People
Mt. San Antonio[1]		
Devil's Backbone trail		6,401
Bearflat trail		5,106
San Antonio Falls trail		2,978
Dawson Peak trail		290
Mt. San Antonio	total trail use	14,775
Cucamonga wilderness*		
Cucarnonga Peak trail		24
Cucamonga Peak	total trail use	24
Cucarnonga Wilderness Area	entire area	1,992

[1]Numbers of persons on the Mt. San Antonio trails are from U.S. Forest Service estimates based on the use of the trail head registers.

[2]Numbers of persons in the Cucamonga Wilderness are from U.S. Forest Service records of Wilderness Permits.

groups of sheep was observed at distances of 0 to 200 meters from the Cucamonga Peak trail. Sixteen groups were observed at distances of 0 to 200 m from the Devil's Backbone trail. Distribution of sheep was expressed as the number of groups observed in each 50 m increment (to 200 m) from the trails. The maximum distance of 200 m from the trail was chosen because visibility from the Cucarnonga Peak trail was poor at distances greater than 200 m. The habitat around the Cucamonga Peak trail was well forested; in comparison, the Devil's Backbone trail, which traversed subalpine forest and alpine fell-field, was in fairly open country and visibility from this trail was good. Eighty percent of all bighorn observations from the Cucamonga Peak trail were within 200 m from the trail. The farthest distance sheep were observed from this trail was 1150 m.

A chi-square analysis was used to determine whether there was a significant difference between trails in the distribution of sheep. There was no significant difference (p►.10).

DISCUSSION

According to Geist (1971b) if mammals are harassed enough they will learn to minimize encounters with humans by reducing activity to areas, habits, and times of day where encounters with humans are minimal. If the presence of people in South Fork Lytle Creek were adversely affecting sheep at the Narrows mineral lick one or more the the following might occur, depending upon the intensity of the disturbance: (1) sheep would abandon use of the mineral lick, (2) sheep would use the lick ony during the time of least human use of the canyon, (3) sheep would use the lick only during days when people were absent, or only when present in low numbers, (4) sheep would spend less time at the lick.

The extent to which the presence of people affects bighorn is influenced by topography of the area and the manner of approach by humans. If the presence of humans is fairly predictable, and if harassment is kept to a minimum, it is possible for sheep and humans to coexist (Geist 1971b, MacArthur et al. 1982). The majority of recreational use in South Fork is in the form of picnicking and day-hiking. People using the area remain in the canyon bottom, below sheep, minimizing the reaction of sheep to their presence. MacArthur et al. (1982) found the heart rate for sheep feeding on slopes was significantly lower than when the same animals were feeding in open meadows. Sheep approached from above show a greater response than when approached from below (Hicks 1977). Bighorn in South Fork Lytle Creek never were observed being approached from above by humans.

Approximately one-half of the people using the canyon travel within the immediate vicinity of the Narrows lick. The majority of use occurs during midday, which is also the peak time of mineral lick use by sheep. To date there is no evidence that sheep have shifted mineral lick use to a time when fewer people are in the canyon, nor is there evidence that the duration of a visit to the Narrows lick is less than the duration of lick use per visit at an undisturbed lick. Correlations between the number of people in the canyon and number of sheep using the lick were insignificant, but the frequency of people traveling in the vicinity of, and directly upstream from the lick did have an effect on lick use. It would appear that bighorn have adapted to the presence of people in the canyon by waiting until the lick was free of disturbance before using it, but otherwise were not disturbed by the presence of people.

Recreational use of trails in sheep summer range did not appear to cause avoidance of nearby habitat. There was no difference in the distribution of sheep between trails. Summer range on Mt. San Antonio is used by ewes and lambs. Summer range in the vicinity of Cucarnonga Peak is used by rams, ewes, and lambs (DeForge 1980, Holl and Bleich 1982). Researchers found that ewes with lambs were more wary than rams (Weaver and Light 1973, Wehausen 1980). Thus, ewes with lambs should be more sensitive to human disturbance.

In addition to the 6,400 persons using the Devil's Backbone trail, there are 3 additional trails on Mt. San Antonio which means that the probable level of recreational use in the summer range is 14,775 people per summer (Table 1). Estimates of the number of people using trails on Mt. San Antonio can be considered conservative since they are based on records from trail head registers and not everyone using the trail may have registered. There were instances during the study when the supply of paper at the register was exhausted. Records of the number of people using the Cucarnonga Peak trail are more ac-

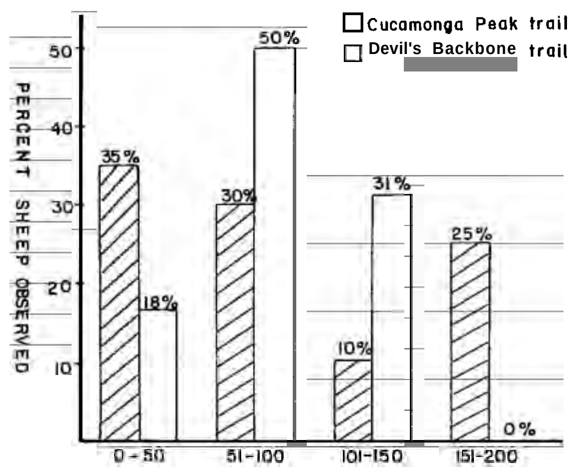

Figure 8. The distribution of bighorn sheep from the Cucarnonga Peak and the Devil's Backbone trail, San Gabriel Mountains, California. The trails traverse sheep summer range.

curate because a Wilderness Permit is required before entry into the area. Although the access road is closed during the fire season, a few people may use the trail illegally.

The effect of trail use in sheep summer range also has been studied in the Sierra Nevada. In an area receiving considerable use by backpackers and packtrains, Hicks and Elder (1979) concluded that hiker foot-trails did not affect sheep movement in bighorn summer range. They also found that bighorn-human encounters were not adversely affecting the bighorn population.

Light and Weaver (1973)found that intense recreational activity and bighorn occupancy of an area were mutually exclusive and considered Mt. San Antonio an area of heavy recreational use. In light of our results, it would seem that if sheep are displaced, under present conditions, the displacement is temporary.

ACKNOWLEDGMENTS

This study is the result of a cooperative agreement between the University of Nevada, Las Vegas, the U.S. Forest and California Fish and Game.

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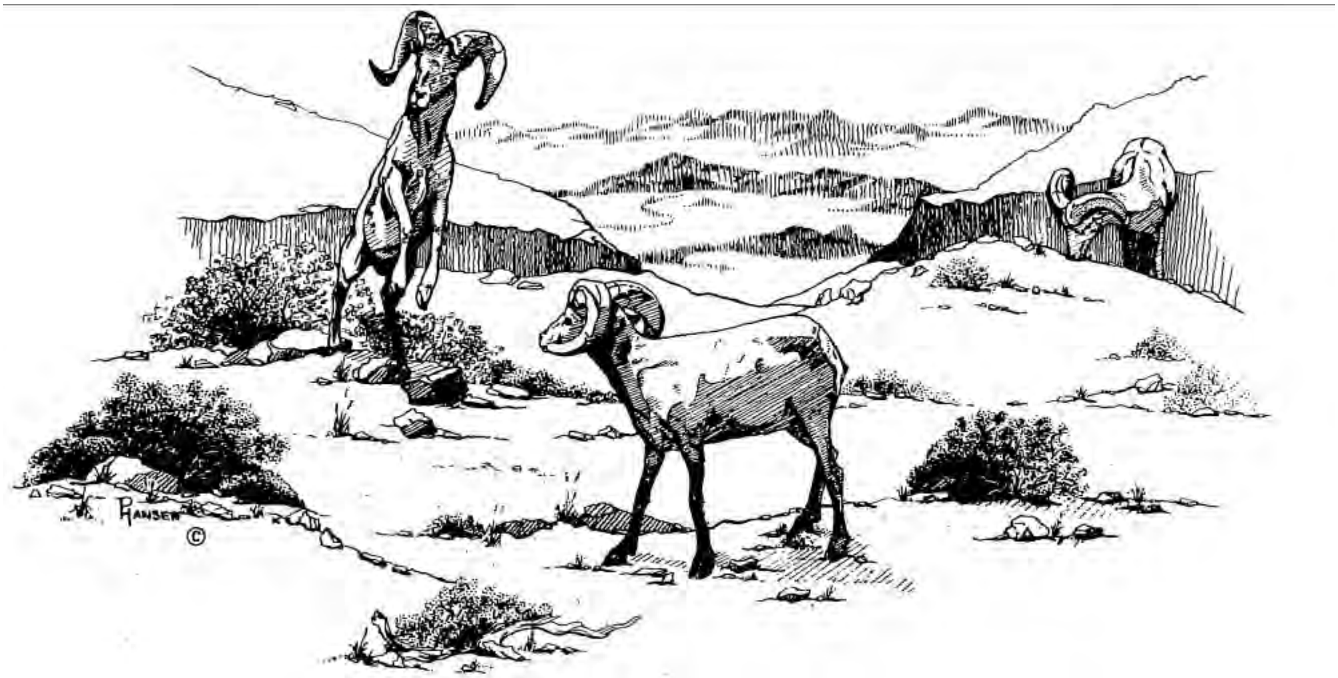

VOLUNTEER PARTICIPATION IN CALIFORNIA WILDLIFE HABITAT IMPROVEMENT PROJECTS

Vernon C. Bleich
California Dept. of Fish and Game, Hemet
Lester J. Coombes
California Dept. of Fish and Game, Chino
Glenn W. Sudmeier
Society for the Conservation of Bighorn Sheep
Hesperia, CA

Abstract. In 1969, interested conservationists and the Department of Fish and Game founded the Volunteer Desert Water and Wildlife Survey to assist the Department with wildlife management activities in the desert regions of southern California. Between July 1, 1969 and June 30, 1982 members of the Survey contributed 11,533 man-days of labor, 788,145 vehicle-miles, and $169,795 worth of other goods and services to the Department of Fish and Game. Total cash value of these contributions is well over $1,000,000. It has taken a substantial amount of effort to direct this program over the past 13 years, but the returns have more than compensated the Department for its investment. Additionally, the public relations value to the Department has been substantial, and the communication which occurs among persons participating in the volunteer program allows a greater understanding of wildlife management principles by persons from many diverse backgrounds.

The term "volunteer" is defined by Webster as "one who enters into or offers himself for any service of his own free will." In that sense, volunteers have been of service in several aspects of wildlife management in California for a number of years.

Wilbur (1978) recently reported on the valuable contributions made to the California condor (Gymnogyps *californianus)* management effort by interested citizens. That is a loosely knit program, but does include a well coordinated annual two-day count. Participants submit individual sightings of condor on record cards during the remainder of the year.

In parts of California, sportsmen's groups or other conservation organizations occasionally organize "clean up" days at various Department facilities (Anonymous 1982). While popular, these .affairs usually occur only annually, and generally are restricted to state or federally operated waterfowl areas or other Department lands.

More recently, the Department of Fish and Game reorganized and revitalized its reserve warden program (Replogle 1981). Opportunities for public participation in the program, while a significant factor in strengthening already strained patrol efforts, are not great. The program is extremely selective, and rigorous testing and background investigations are involved. It is estimated that only 100 reserve wardens will be available for service by the end of 1982. Therefore, this program, while important, offers only a limited opportunity for public involvement in Department activities.

One area within the Department's scope where large numbers of volunteers have been able to contribute significantly to a wildlife management program has been the Department of Fish and Game's Habitat Development Project (Federal Aid Project W-26-D) in the deserts of southern California (Massie 1975; Carpenter 1976; MacKenzie 1977). That project is responsible for all habitat work in southern California in which Department participation is involved. Within the Department's southern California administrative area (Region 5) are 15,133,520 ha, much of it desert. Within this area are nearly 1,400 small game guzzlers, over 500 springs, and 36 big game guzzlers. In addition to maintaining these facilities, numerous opportunities for Departmental personnel to participate in other activities including additional water development, brush manipulation for mule deer *(Odocoileus* hemionus) habitat improvement, and marsh management activities, such as pothole blasting, to create nesting habitat for waterfowl.

HISTORY

In 1969, a group of persons concerned about the future of desert wildlife met with Department personnel to set up a volunteer program which would allow all interested persons the opportunity to participate in wildlife management activities in the desert. The meeting was requested by the Southern and Inland Councils of Conservation Clubs, representing several thousand sportsmen, and the Society for the Conservation of Bighorn Sheep. The purpose of that meeting was to explore ways to carry out programs recommended by Dick Weaver and his cohorts, who conducted the first and only intensive investigation on the status of mountain sheep (*Ovis* canadensis) in California. Weaver (1973) recommended numerous options aimed at improving conditions for mountain sheep in California, but lack of manpower was a major factor limiting the Department's ability to carry out those recommendations. After lengthy discussions at the initial meeting, those present agreed that a program using volunteer labor could be effective in improving conditions throughout the desert for mountain sheep as well as many other wildlife species. This program was designated the Volunteer Desert Water and Wildlife Survey (hereafter referred to as the Survey). Several subsequent meetings among those involved in the program resulted in a series of objectives for the program, and on the means of accomplishing those objectives.

SCOPE

Participants in the Survey are involved primarily in four aspects of wildlife habitat management: (1) water hole surveys, (2) small game guzzler maintenance, (3) spring development and maintenance, and (4) the construction and maintenance of artificial big game watering devices, or big game guzzlers (Massie 1975).

On a continuing basis, volunteers collect data relevant to wildlife populations in numerous desert mountain ranges. These counts are conducted over a three-day period during the most inhospitable time of the year, usually early July in the southern California desert, when daytime temperatures routinely exceed 50 °C. During this hot period, many species are concentrated near waterholes, and the physiological stresses imposed by high temperatures assure the observer that the majority of wildlife in the vicinity of a waterhole will use it during a given 3-day period. It is through these surveys that many of the Department's wildlife biologists are kept appraised of wildlife population trends occurring in their geographic areas of responsibility. This is especially true for populations of mountain sheep, which are so sporadically distributed throughout the desert mountain ranges that they are difficult to monitor, and particularly when such activities seldom are included in a biologist's annual work plans.

A second major activity of the Survey has been the routine inspection and maintenance of the Department's small game guzzlers. Nearly 1,400 of these units are found in southern California, most of them in the desert. While many persons have a slightly negative impression of off-road vehicle operators, it is very important to note that members of off-road vehicle clubs have been primary participants in this aspect of the volunteer program. Over 50 off-road vehicle clubs have accepted the responsibility of maintaining a large number of the small game guzzlers located throughout the desert. Participants in this program are provided with maps to the various sites, instructions on how to inspect the guzzlers and estimate wildlife use, and the materials necessary for the repair of these units should that be necessary. Repairs generally consist of patching cracks in the water collecting surfaces using roofing compound and fiberglass tape, which allows water to flow over the cracks and into the storage tank.

By far the most difficult part of this work is locating the guzzler, and sometimes 70% of the time required for a repair job is involved in just looking for the site. Many of the volunteers participating in this aspect of the Survey are interested in off-road driving for pleasure, and they have the time, appropriate equipment, and desire to do this work. Inspections and required repairs are done by volunteers on their own time schedule, after they have received proper orientation.

The third major activity in which members of the Survey participate is the ongoing spring development and maintenance program. Work on desert springs located in remote areas has created considerable interest among volunteers, particularly among a number of hunter-oriented sportsmen's groups.

Development of a desert spring may involve the use of a number of techniques, including hand-labor, explosives, prescribed fire, and even horizontal-well technology (Weaver et al. 1959, Biswell and Schultz 1958, Coombes and Bleich 1979, Bleich et al. 1981). Hand-work is by far the most tedious and common method used by volunteers in spring development work. Tools and material generally are back-packed into the site, which may take as long as 5 hours to reach.

A typical desert spring development involves construction of an underground box in which water is collected, and a drinker which makes that collected water available to wildlife. One very importantaspect of this program is that once a spring has been developed, periodic inspections and minor maintenance are necessary to assure that the water it is producing remains available to wildlife.

By far, the most popular aspect of the Survey has been our ongoing big game guzzler program. The first 5 big game guzzlers, resembling giant quail guzzlers, were constructed in the 1950s by the Department's habitat development crew, and were located primarily to benefit burro deer (Odocoileus *hemionus eremicus)* in southeastern California. In 1965 a new style unit was constructed in the Santa Rosa Mountains in an effort to provide permanent water in a part of that range used only seasonally by mountain sheep.

Since 1971, 30 additional big game guzzlers have been constructed, using volunteer labor, throughout the southern California desert. These recently constructed devices have been located primarily at sites recommended by Weaver (1973) to benefit populations of mountain sheep. The exceptions are 3 guzzlers constructed recently in the Riverside Mountains to provide permanent water sources for burro deer inhabiting that mountain range.

Extensive preparation is involved in a project of this magnitude. A site must be located, usually by helicopter, and it must be inspected on the ground. Environmental documents must be completed, and an agreement reached with the land-owning agency to allow the project to proceed. Then all necessary tools, materials, and heavy equipment must be transported to the site, prior to the arrival of the volunteers.

Once the volunteers are at the site, individuals are organized into work teams, and equipment is taken to one of 5 work areas, each supervised by a Project employee. The first major work area is the dam site. A rebar framework is drilled into the bedrock and a special filter is attached to a 50 mm pipe running through the base of the dam. Concrete is then mixed and relayed in buckets to the site, where it is used, along with large rocks, to construct a small masonry dam.

The 50 mm galvanized pipeline, or pickup line, leading from the dam to the tanks, is the second work area. Pipe is cut to size and threaded, and then connected together. Where necessary, it is supported by rebar inserted into holes drilled into the canyon walls, often in precarious places.

The third work area involves the installation of the water storage tanks. An area is leveled by rock fill, and then a concrete slab is poured to form a solid, level base on which the tanks rest. The tanks are rolled into place, positioned, and then plumbed. The fourth work area centers around the installation of a float valve regulated drinker, which is connected to the water storage tanks by an 18 mm galvanized pipeline.

The final work area involves the construction of an exclosure around the drinker to preclude access by range cattle *(Bos taurus)* and feral asses *(Equus asinus)* and yet allow native species access to the water. Fortunately, such fences have been necesary at only a few of our projects.

ACCOMPLISHMENTS

As shown above, the members of the Volunteer Desert Water and Wildlife Survey have been active participants in the Department's Wildlife Habitat Development Project. Just how active they have been is surprising.

Between July 1, 1969, and June 30, 1982, members of the Survey contributed substantially to the Department's ability to maintain and enhance desert water sources, and to the Department's knowledge of population trends of several desert wildlife species. During that period, they donated 11,533 man-days of labor, drove 788,145 miles in order to do that labor, and interested individuals and agencies donated $169,795 worth of goods and services to the Department. These figures are conservative, because they are taken from annual reports compiled by the project leaders, and include only those activities actually reported by the volunteers (Massie 1970-77, Bleich 1978-82).

Interest in the program has been-very consistent over the past 13 years, with contributions of labor fluctuating about a long-term mean of 890 man-days per year. Contributions of vehicle-miles have fluctuated about a long-term mean of 61,000 mileslyear, and materials and other services contributed have fluctuated about a long-term mean of $13,000/year.

In cash value to date, the Department has received well over $1,000,000 worth of goods and services from members of the Survey. Using the conservative values of $50 per man-day for labor, $25 daily per diem, and $.15 per mile driven, and including the materials and other services contributed, the total cash value is $1,152,992. When put in the simplest terms, the Department has received an average of 4.0 man-years of help per year, including transportation and travel costs, for 13 straight years.

When we consider just what has been accomplished by members of the Volunteer Desert Water and Wildlife Survey over the past dozen years, it is impressive. Between 1969 and

1982, our records indicate that volunteers performed maintenance on or inspected big game guzzlers a total of 339 times; performed maintenance on or inspected 920 small game guzzlers; developed and maintained 80 springs; inspected and reported on 542 other springs; and constructed 30 big game guzzlers.

Although the actual physical labor performed and total miles driven are impressive figures, and desert wildlife have benefited tremendously from the efforts of individuals involved in the Survey, perhaps one of the most important aspects is the opportunity that the Survey presents for persons from many different walks of life to join together and work toward a common goal. The backbone of the Survey has always been the hunting sportsman, but volunteers come from many walks of life, with varying interests and backgrounds, and the communication that occurs among these people is impressive.

During volunteer projects, protectionists are able to discuss philosophies of wildlife management with avid hunters and other consumptive sportsmen, and both groups learn to work together. These people often discover that their preconceived and stereotyped opinions about each other have to be changed. An additional very important benefit is that the Survey provides an opportunity for Department of Fish and Game personnel to work alongside the volunteers, which presents one of the best opportunities that employees have to sell the Department's programs and to create support for the Department and its objectives.

PROBLEMS

Although the Survey has been highly successful and has resulted in a large number of benefits both to the Department and to desert wildlife, administration of it has not been easy. Annually, the Project is faced with an inadequate budget to see it through the year and Project personnel wonder whether or not the Project will be eliminated in the next budget crisis. Additionally, it is very difficult to properly supervise all aspects of the Project with our limited staffing, and supervision and guidance are of paramount importance if a volunteer program is to be successful. Furthermore, the rising price of gasoline has cut substantially into the number of off-road vehicle clubs actively participating in the small game guzzler maintenance program, and more and more clubs are requesting a reassignment of guzzlers which are located closer to the metropolitan areas where most of them live.

RECOMMENDATIONS

Many well qualified people are looking for meaningful ways to participate in wildlife conservation activities (Smith 1974). The problems of organizing and training the volunteers generally are more than compensated for by the amount and quality of the labor performed. In addition, there are many indirect benefits to wildlife programs which result from a better informed, more involved public (Smith 1974).

The Volunteer Desert Water and Wildlife Survey, a long-term, relatively intensive and highly successful program, has demonstrated that large numbers of persons can be of great value when given the opportunity to utilize their skills and when such a program appeals to their interests. The guidance and supervision necessary to coordinate such a program should, however, not be underestimated.

In this era of decreasing revenues and increasing workloads, it is possible that volunteers may become important sources of labor in many other aspects of natural resource management. Administrators are encouraged to investigate the opportunities for such volunteer involvement and, where practical, to integrate members of the public into conservation programs.

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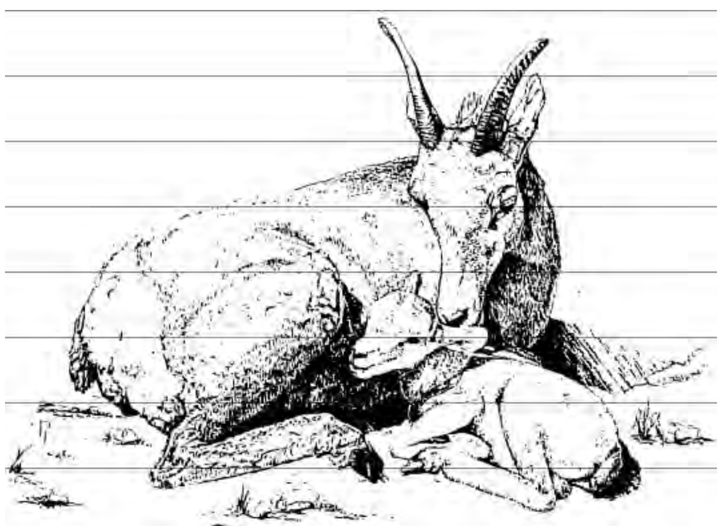

AN ILLUSTRATED GUIDE TO AGING THE LAMBS OF MOUNTAIN SHEEP *(Ovis canadensis ssp.)*

Vernon C. Bleich
California Department of Fish and Game
Hemet, CA

Abstract. Photographs of known age male and female mountain sheep are presented to help observers insure more accurate estimates of parturition dates.

INTRODUCTION

This illustrated guide is designed to allow more accurate estimates of the ages of mountain sheep lambs than previously had been possible by relatively inexperienced personnel. The need for such a guide became apparent in 1976, during a ground survey of mountain sheep in the Santa Rosa Mountains, California. Observers during that survey were provided only with crude line drawings of 2 and 4 month old lambs; therefore, the vast majority of lambs seen were classified as either 2 or 4 months old. Because of the theoretical as well as practical value of knowing the ages of young animals in a population, this guide was prepared to assist observers.

Two sheep were utilized in compiling this guide: the male was born 10 March 1977, and the female was born 16 March 1977. Both are the progeny of adults held captive at the Living Desert Reserve, Palm Desert, California. For all practical purposes, both lambs are the same age.

Because of the large amount of individual variation inherent in any population of wild animals, the guide will only assist with estimating the ages of lambs. Some subjective judgement must be used in assigning age classifications; however, the accuracy of estimates by inexperienced personnel should be improved markedly over what it would have been without this guide. Users should have no trouble sexing lambs over 4 months of age by using horn morphology. With younger animals, the only sure way is to observe the genitalia.

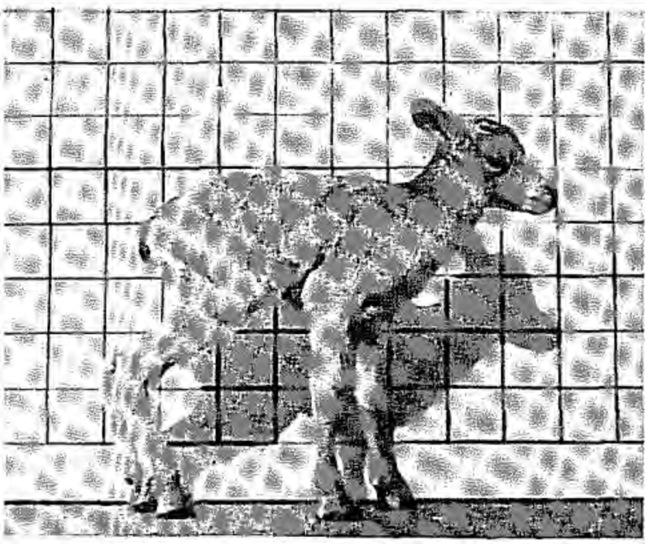

Figure 1. Two day old lamb, sex unknown

With respect to Figures 1-19, the photograph of the one day old lamb is against a scale of three-inch squares. With the exception of the 1 and 2 month old lambs, all other photographs are against a scale of four-inch squares. The 1 and 2 month old lambs were photographed against a block wall, and the distance between the grout lines on the wall is 4 inches. A yardstick is provided as an additional scale in these photographs.

Because Hansen (1965) and Hansen and Deming (1980) have provided very good descriptions of most month classes of lambs through the age of 1 year, that material is not repeated here. In the interest of economizing on costs and space, readers are referred directly to those papers for detailed written descriptions.

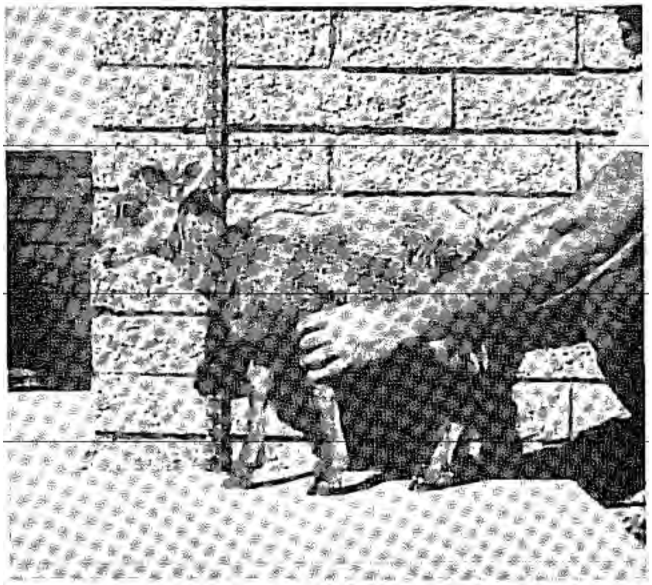

Figure 2. One month old male lamb; at this age female lambs appear nearly identical to males.

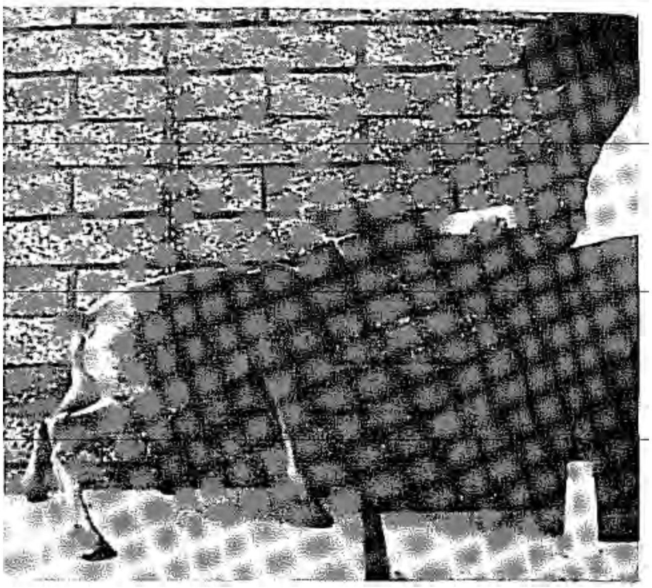

Figure 3. Two month old male lamb; unless genitalia observed, it still is nearly impossible to distinguish sexes at this age.

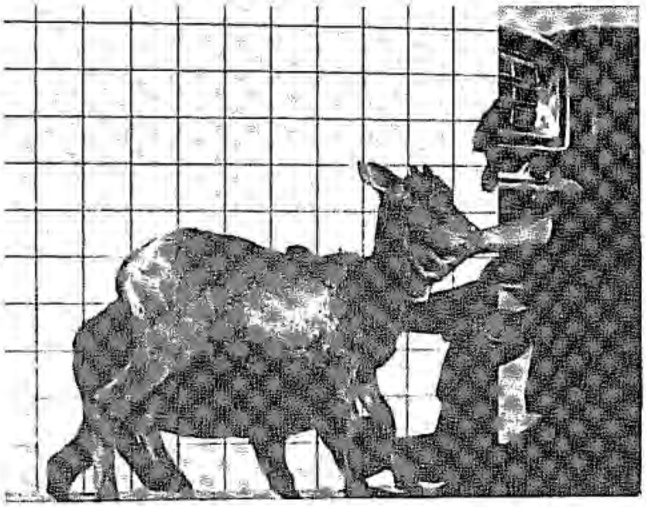

Figure 4. Three month old male lamb.

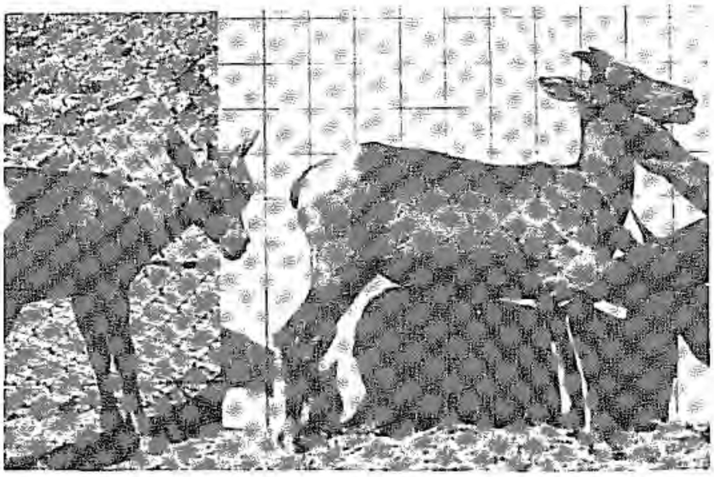

Figure 5. Four month old female lamb (left) and male lamb. By this age, it is possible for observers to distinguish sexes solely by horn morphology.

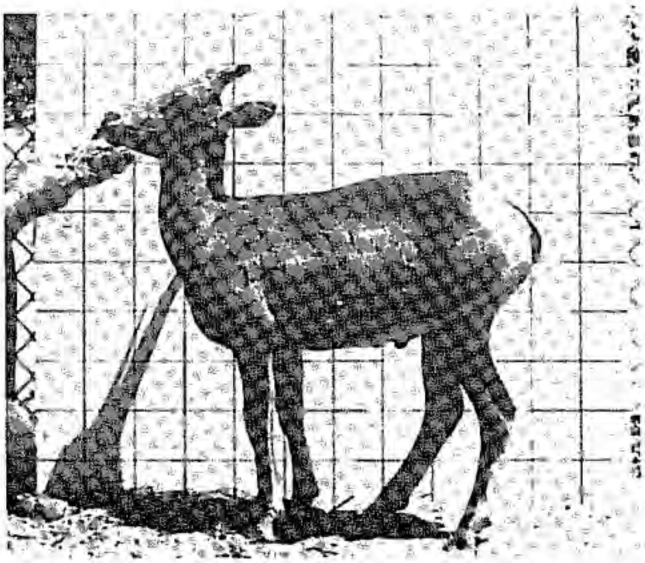

Figure 6. Five month old male lamb

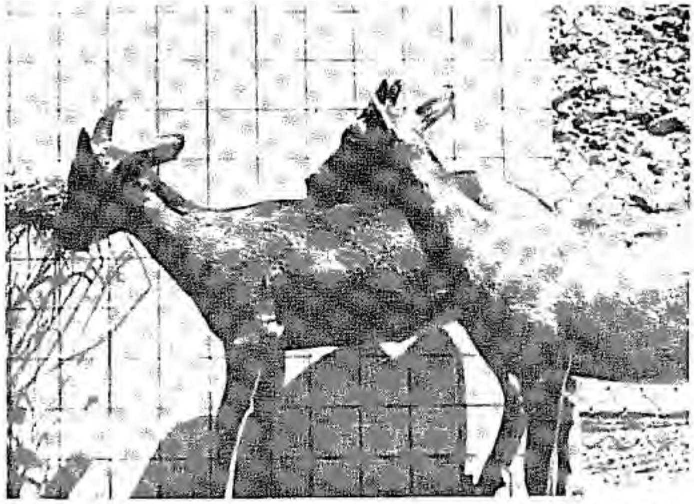

Figure 7. Five month old male lamb (left) and female lamb.

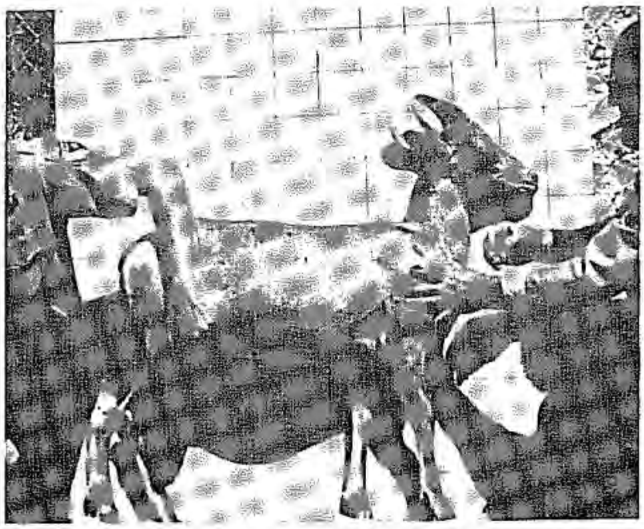

Figure 8. Six month old male lamb

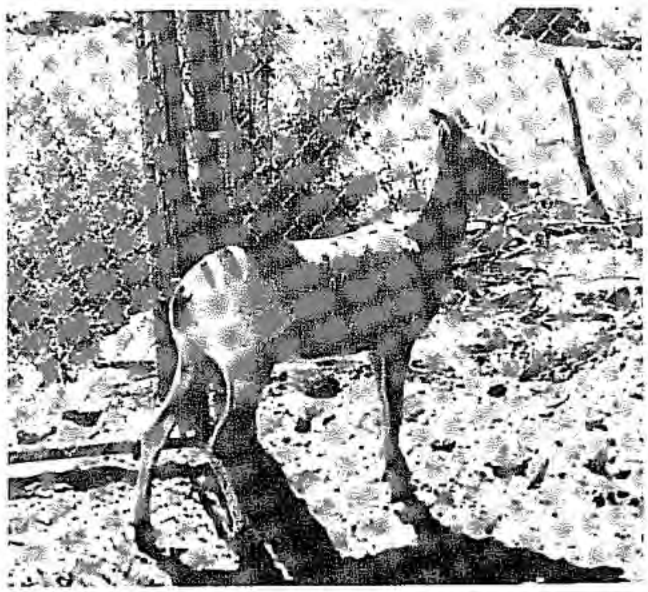

Figure 9. Six month old female lamb; note slighter build, obvious by this age, when compared to male.

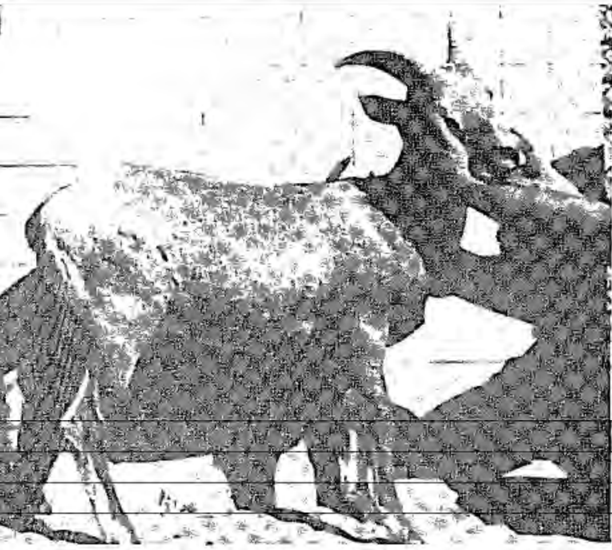

Figure **10.** Seven month old male lamb

Figure **13.** Eight month old female lamb (left) and male lamb; note continuing differentiation of body con. formation.

Figure **11.** Seven month old female lamb (left) and male lamb.

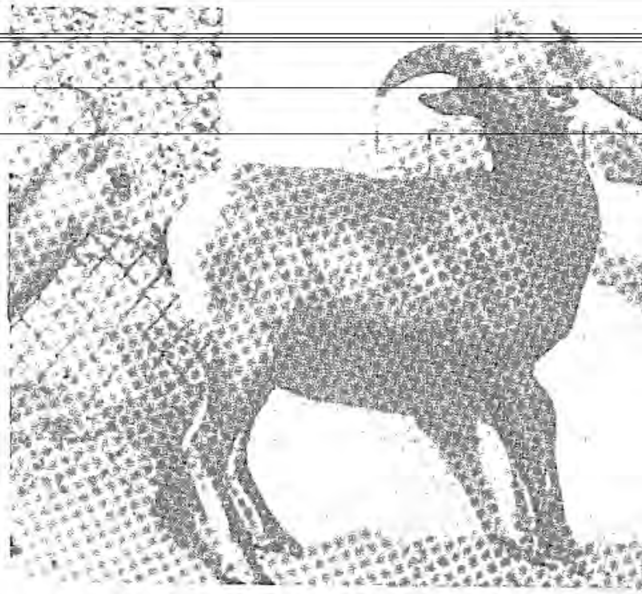

Figure **14.** Nine month old female lamb (left) and male lamb.

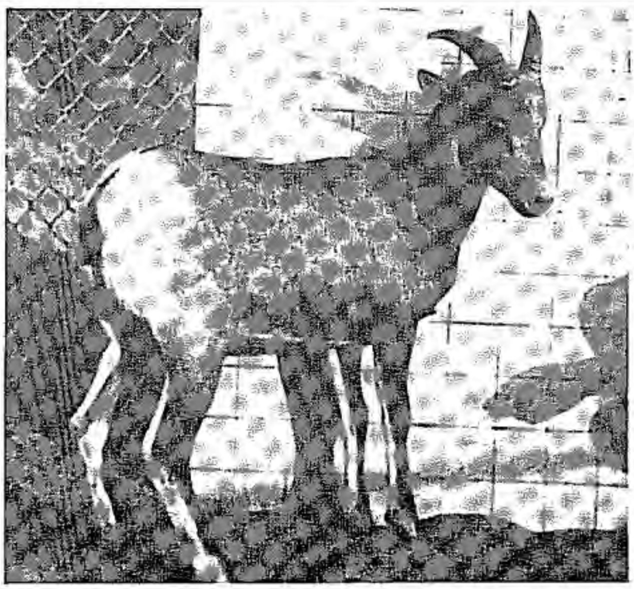

Figure **12.** Eight month old male lamb

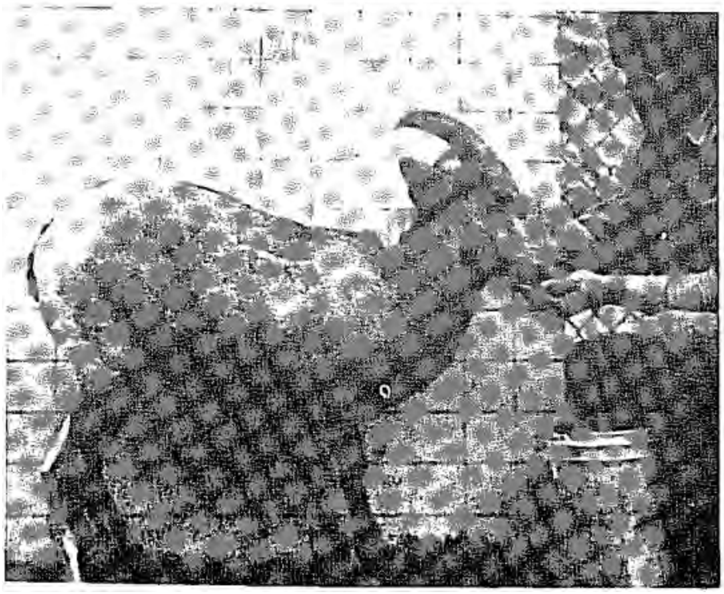

Figure **15.** Ten month old male lamb

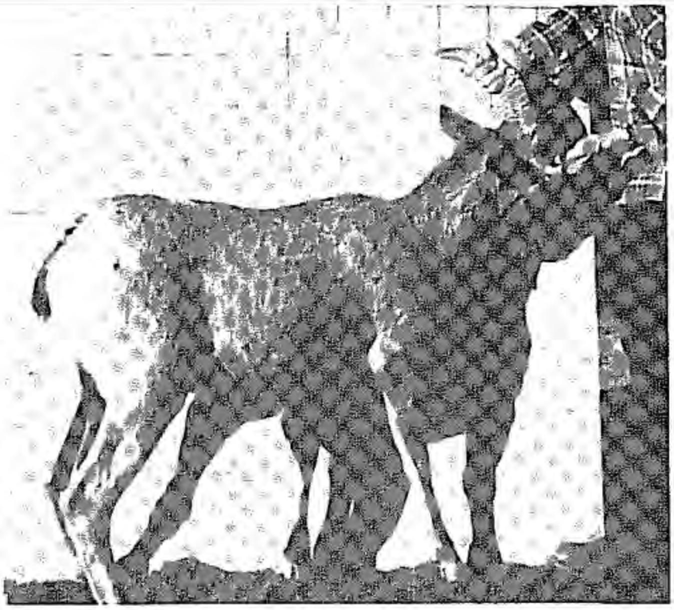

Figure 16. Eleven month old male lamb

Figure 17. Eleven month old female iamb (left) and male lamb

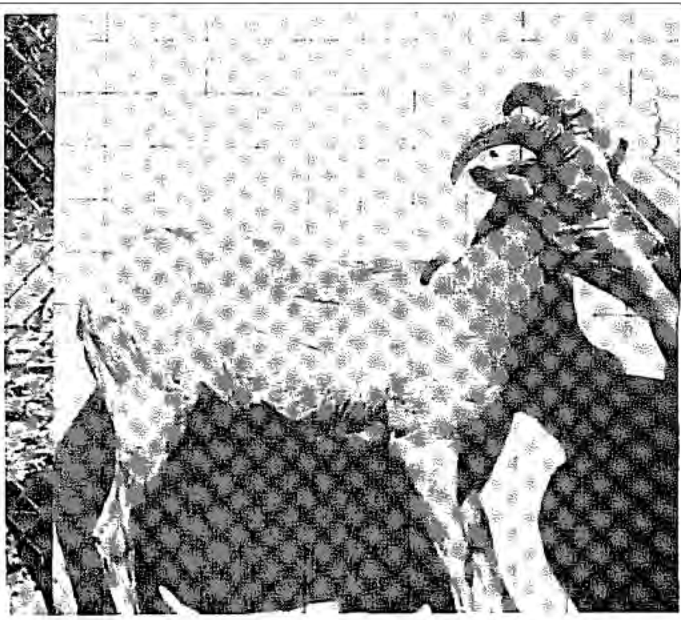

Figure 18. Twelve month old (yearling) male lamb.

Figure 19 Yearling female (left) and male; note obvious differences in horn morphology, conformation, and facial structure.

Hicks (1978) and Cunningham (1982) utilized a draft of this guide during researches on mountain sheep (Ovis canadensis cremnobates) Inhabiting the In-Ko-Pah and Jacumba Mountains. California, and their evaluations of its usefulness were most encouraging. Similarly, Robert Celentano (pers. comm.) has used it satisfactorily to age mountain sheep lambs (Ovis canadensis *nelsoni)* in the Sacramento and Turtle Mountains, California. Numerous other Department of Fish and Game and Bureau of Land Management personnel found it to be useful during the survey conducted by Celentano (pers. comm.).

The figure of the one-day-old lamb is from Demlng (1955). Robert Claybrook contributed substantially to this project, and the cooperation of Karen Sausman is appreciated. Stan Cunnlngham, Lorln Hicks and Bob Celentano are acknowledged for field testing this guide, and for providing valuable comments. Thls is a contribution from California Federal Ald in Wildlife Restoration Project W-26-D, "Wlldlife Habitat Development."

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HORIZONTAL WELLS FOR MOUNTAIN SHEEP: DESERT BIGHORN "GET THE SHAFT"

Vernon C. Bleich
California Dept. of Fish and Game
Hemet, CA

Abstract. Horizontal well technology, long used in the livestock and construction industries, recently has been applied to the management of wildlife habitat. Horizontal wells are an effective method of developing water supplies in arid regions, where more traditional methods may not be adequate. Development costs do not differ greatly from more traditional techniques, although the initial investment in machinery is relatively high. Because mountain sheep have declined in areas which historically had adequate water supplies, but which are now deficient in water, more widespread application of this technique is encouraged to improve habitat conditions for that species.

INTRODUCTION

Horizontal wells are constructed by drilling a horizontal or slightly inclined hole into a slope, installing a casing and pickup screen, and grouting the casing to prevent the tapped water from flowing around the casing instead of through it. The prinicipal differences between horizontal wells and traditional vertical wells, aside from their relative positions, are (1) all horizontal wells drain by gravity, (2) they generally require specialized drilling equipment for construction, and (3) their location generally depends upon the presence of a slope, into which the well is drilled (Summers 1973).

Until recently, subsurface water was made available for wildlife by using hand tools and occasionally explosives, or by the removal of phreatophytes (Biswell and Schultz 1958; Halloran and Deming 1956, 1958; Mahon 1971; Weaver et al. 1958, 1959, and others). Indeed, Weaver et al. (1958, 1959) concluded that hand tools were the most important items used in developing springs for wildlife use. Although traditional development techniques remain important, the application of horizontal well technology to a vigorous water development program offers many opportunities to increase water flows in areas previously dismissed as impractical or impossible to improve. An expanded version of this paper, emphasizing development methodology, will appear in The Wildlife Society Bulletin, 10(4), 1982.

Development with hand tools has several basic flaws: (1) it is not possible to control water flow from the spring, (2) a variable flow may be inadequate to generate enough water to create a surface source, and (3) the exposed spring water and spring area are readily susceptible to contamination. The horizontal well eliminates these disadvantages.

Wildlife occasionally has benefited from horizontal wells developed for domestic livestock. However, horizontal well methodology only recently has been applied specifically to the management of wildlife habitat, and its future appears promising (Coombes and Bleich 1979). Unfortunately, this technique is not well known, and only rarely has it been applied to improving wildlife habitat.

METHODS

Site selection is one of the most difficult and important steps in the development of a successful horizontal well. The driller must evaluate a number of parameters, including (1) the distribution of phreatophytic vegetation, (2) the presence of historical springs and seeps, and (3) the presence of an appropriate geological formation (Welchert and Freeman 1973). Although the importance of site selection cannot be overemphasized, the presence of these factors does not necessarily guarantee a successful well. A detailed account of the above requirements is provided by Welchert and Freeman (1969, 1973, 1976), Coombes and Bleich (1979), and Bleich et al. (in press).

The development methodology for horizontal wells has been detailed elsewhere (Welchert and Freeman 1969, 1973, 1976; Bleich et al. in press), and won't be discussed here because of space limitations.

COSTS

Development costs of horizontal wells do not differ greatly from costs associated with more traditional spring development techniques. The initial cost of the machine, however, is high. At present, the cost of a good, dependable horizontal well drilling machine and associated equipment is approximately $12,000. While fiscal constraints may preclude purchase of this type of equipment by agencies not fortunate enough to already own one, drilling contractors are available to develop horizontal wells for wildlife purposes.

The Department of Fish and Game has maintained records on the cost of materials for only 6 of 19 wells which have been attempted (Table 1). The average cost of materials per well, including materials irretrievably committed during the development process, and estimated costs for maintenance and expendable materials was $240. Welchert and Freeman (1969) reported an average expenditure of $50 per well for plumbing materials. This cost, when corrected for inflation (Casey 1980), is $128 per well and is comparable to the $152 per well spent by the Department of Fish and game when the costs of concrete and maintenance are ignored (Table 1).

Manpower requirements during operation of the horizontal well machine are no more than would be expected during more traditional development efforts. Although one man can operate the machinery and complete a horizontal well, this is not recommended. Because of the safety hazard involved in operating sophisticated machinery of this type, 2 persons should be present at all times, particularly in remote areas.

Development costs and manpower requirements escalate

Table 1. Cost of materials for six horizontal wells developed by the California Department of Fish and Game.

Item	Average Amount	Average Cost
2 in. casing	62 feet	$112.00
1.25 in. pickup pipe	20 feet	25.00
plumbing parts	1 reducer 1 valve	15.00
cement	4 sacks	28.00
other'		60.00

Total cost per well. ***$240.00***
Cost of plumbing materials per well. **$152.00**

'expendable materials, equipment maintenance, etc.

rapidly if helicopter transport of the machinery is necessary. At current rates, helicopters with an external lift capacity adequate to safely transport each 390 kg half of our drilling machine cost approximately $350 per rotor-hour. Helicopters capable of moving the machine in one piece are extremely expensive, ranging from $700 to over $1,000 per rotor-hour. It must also be remembered that helicopter ferry costs must be included when calculating the cost of helicopter transport. Sites in remote locations may not be practicably developable using horizontal well technology because of the extreme costs involved in just getting the equipment into and out of the site.

Manpower costs are increased when transporting equipment by helicopter, because it is necessary to have at least 6 people present to assist with the disassembly and reassembly of our equipment before and after helicopter transport, if the machine must be moved in 2 pieces. Of course, only 2 persons need remain on site during the development process; however, additional personnel are required when removing the machine from the site, for reasons pointed out above. Again, if the site is remote, commitments in manpower and time can become substantial.

Welchert and Freeman (1969) reported an average development time of 32.2 hours per producing well, of the 45 wells on which they maintained records. Although we did not maintain records of total development time per well, it is estimated that each of the wells the Department has developed to date has averaged approximately 40 hours of drilling, a figure not greatly different than that reported by Welchert and Freeman (1969).

DISCUSSION

Several advantages make horizontal well technology a desirable water development alternative. First, horizontal wells greatly increase the success rate in spring development, particularly in arid regions where historical water sources may have dried up. Second, the horizontal well provides a method of controlling the amount of water flowing from a spring, reducing water waste, which is advantageous especially in extremely arid regions. Third, the spring area is not readily subject to contamination, thus providing a sanitary water supply. Fourth, horizontal wells are relatively inexpensive to develop, except when equipment must be transported by helicopter. Maintenance costs are low, and there are no operational costs. Finally, there are no moving parts (aside from a float valve and a vacuum relief valve) in a horizontal well system. The chances of mechanical failure are extremely low, an important consideration in remote regions.

One species that has benefited particularly from the application of horizontal well technology is the mountain sheep (Ovis canadensis). Although ecotypes of mountain sheep inhabiting desert regions have evolved physiologically efficient methods of maintaining water balance (Turner 1973), they require free water (Blong and Pollard 1968). Weaver (1973) documented the disappearance of mountain sheep from several areas in California now deficient in water, but which historically had adequate water supplies. Indeed, the recent general drying trend of the California deserts likely is a factor in the disappearance of surface water at historical springs, and may have contributed to the exptirpation of mountain sheep in several desert mountain ranges. Even with horizontal well technology, it may not be possible to restore adequate surface water at every historical spring. However, we have developed a list of sites where the application of this technique seems realistic, and we have implemented a successful water development program.

In addition to mountain sheep, we have used this technique successfully to make water available for such big game animals as wapita *(Cervus* elaphus), mule deer *(Odocoileus hemi*-onus), and pronghorn (Antilocapra *americana).* Other game species that have benfited include sage grouse (Centrocercus *urophasianus),* chukar *(Alectoris* chukar), California quail (Lophortyx *californicus),* Gambel's quail (Lophortyx *gambellii),* mountain quail (Oreortyx *pictus),* and mourning dove *(Zenaidura* macroura). Additionally, numerous species of nongame birds and mammals benefit from the production of water at historical sites, or from the production of water at sites which historically had not even produced a surface flow.

Clearly, populations of mountain sheep and other game and nongame species will benefit from the wider application of horizontal well technology, which is a valuable, cost effective technique, readily applicable to wildlife habitat management programs.

ACKNOWLEDGMENTS

I thank the Southern California Safari Club for donating a horizontal well drilling machine to the California Department of Fish and Game. W.T. Welchert and W.C. Fairbank gave freely of their time and provided several obscure references. R.A. Weaver, C.S. Edon, P.W. Gelfand, S.A. Holl and R.T. Bowyer reviewed an earlier version of this paper, and their assistance is appreciated. This paper is dedicated to the memory of the late Morris P. "Andy" Anderson, of the California Dept. of Fish and Game, who fully realized the potential of horizontal well technology'as a wildlife habitat improvement technique, and actively encouraged its application. This paper is a contribution from California Federal Aid in Wildlife Restoration Project W-26-D, "Wildlife Habitat Development."

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ECOLOGICAL INVESTIGATIONS INTO HIGH LAMB MORTALITY

James R. DeForge
Joan E. Scott
Desert Bighorn Research Institute
Palm Desert, CA

Abstract. The health and current population trends of peninsular desert bighorn sheep *(Ovis* canadensis cremnobates) in the northern Santa Rosa Mountains were studied with the aid of nineteen collared bighorn sheep in the northern Santa Rosa Mountains. High lamb mortality over the last six years has cut this population in half. Pathologic evidence indicates lambs have been dying of pneumonia; serologic evidence indicates that parainfluenza-3, bluetongue viruses, and possibly epizootic hemorrhagic disease and contagious ecthyma viruses, were initiating factors to the pneumonia. Changes in seasonal weather patterns, predation, interaction with deer and cattle, and human impact were possible stressors contributing to the lambs' increased susceptibility to pneumonia.

INTRODUCTION

Within the Santa Rosa Mountains, Riverside County, California, lives the peninsular desert bighorn sheep (Ovis *canadensis* cremnobates), classified as RARE by the California Fish and Game Commission since 1972. Bighorn were numerous in the Santa Rosas since prehistoric times (Grinnell and Swarth 1913, Barret 1965, Weaver and Mensch 1970). The population was estimated at 350 in 1953 (Jones et al. 1957) and 500 in 1970 (Weaver and Mensch 1970).

However, high lamb mortality has occurred since 1977. The following are lamblewe ratios from California Fish and Game fall helicopter counts of the entire Santa Rosa range (Fish and Game files):

Year	Lamb/Ewe Ratio	
1977	71100	
1978	91100	
1979	211100	
1980	241100	(only 1 lamb observed north of Hwy. 74)
1981	121100	
1982	101100	

In 1982, only 5 lambs were observed in the Santa Rosa range; four of these were seen in the study area north of Highway 74. Survival of 26 lambs per 100 ewes is needed to maintain stable populations of desert bighorn (McQuivey 1978). Heavy losses over extended time periods prompted concern among managers and conservationists. If this trend continues, very few young and prime breeding age ewes will be left in this population.

Poor lamb survival has been a major concern in many bighorn populations, including those of the neighboring San Jacinto Mountains and Anza Borrego area. Only sketch information is available for the San Jacinto Mountains, but conservationists have noted declines in numbers of bighorn counted in recent years, and a Fish and Game helicopter count in August 1980 found a lamblewelyearling ratio of only 10110015. Similar ecological circumstances may be present in these adjacent areas, and since ram movement may facilitate interactions between those areas and the Santa Rosas, the potential for disease transmission exists.

STUDY AREA

The study area is the northern portion of the Santa Rosa Mountains, Riverside County, CA (Fig. 1). Land ownership within the study area is basically a checkerboard pattern, with even sections administered by the Bureau of Land Management and odd sections privately owned; two areas are managed by the California Department of Fish and Game. The study area is within a state game refuge, established in 1917 primarily for protection of bighorn.

The bighorn range on the transmontane side of these mountains where desert slopes represent the westernmost extension of the Colorado Desert. Annual precipitation averaging 129 mm (5.2 in.) of rain is concentrated in November to March and in August and September (Zabriskie 1979; weather records of Boyd Deep Canyon Research Center, Palm Desert). Soils in the study area are mostly of granitic origin. There is much faulting, steep scarps and eroded canyons, resulting in a desirable terrain for bighorn. Bighorn are found between 150 m (500 ft.) and 1160 m (3800 ft.). Dominant plant species in bighorn habitat include creosote bush (Larrea ***tridentata),*** brittle-bush *(Encelia farinosa),* burro-weed (Ambrosia *dumosa),* desert trumpet *(Eriogonum inflatum),* century plant (Agave *deserti),* and cholla cactus *(Opuntia* acanthocarpa).

METHODS

Field studies began in February 1981. In May 1981, 13 free-ranging bighorn were captured, sampled and released. Twelve of these were captured with 1000 feet of 8-ft. high 16-in. stretch mesh standing linear net. These animals were selectively driven into the nets by helicopter, with no tranquilizer drugs used. One ram was captured by chemical immobilization from a helicopter using a projectile syringe containing **5.4** mg Etorphine (M-99) and 6 mg Rompun. The Etorphine was reversed with an i.v. injection of 10 mg Diprenorphene (M50-50). Five captive bighorn at Living Desert Reserve, Pa!m Desert, CA, also were sampled. This herd is located in the foothills of the Santa Rosas and has suffered similar high lamb mortality. These penned animals were captured by hand with the use of a linear net. Two of these animals were injected with 10 mg Rompun as a tranquilizer.

In November 1981, 7 of those free-ranging bighorn sampled in May and 6 additional bighorn were captured, sampled, and released. Nine of the free-ranging bighorn were captured in November by moving them with helicopter into linear nets. Four were chemically immobilized from a helicopter using projectile syringes containing 5 mg Etorphine, 10 mg Rompun, and 2 mg Acepromazine for rams and 4 mg Etorphine, 7 mg Rompun, and 2 mg Acepromazine for ewes. All immobilizations were reversed with Diprenorphine at twice the concentration of Etorphine used. Also in November, 5 bighorn were sampled from the Living Desert Reserve, 4 of which had previously been sampled in May. Two of these animals were caught in linear nets and injected i.m. with 10 mg Rompun. The other 3 were chemically immobilized from the ground using projectile syringes containing 4 mg Etorphine and 7 mg Rompun for adult ewes and 3 mg Etorphine and 5 mg Rompun for an 8 month old female lamb.

All captured animals were blindfolded, hobbled, and physically examined. Rectal temperatures, respiration and pulse were monitored as indicators of stress. Blood, hair, nasal and

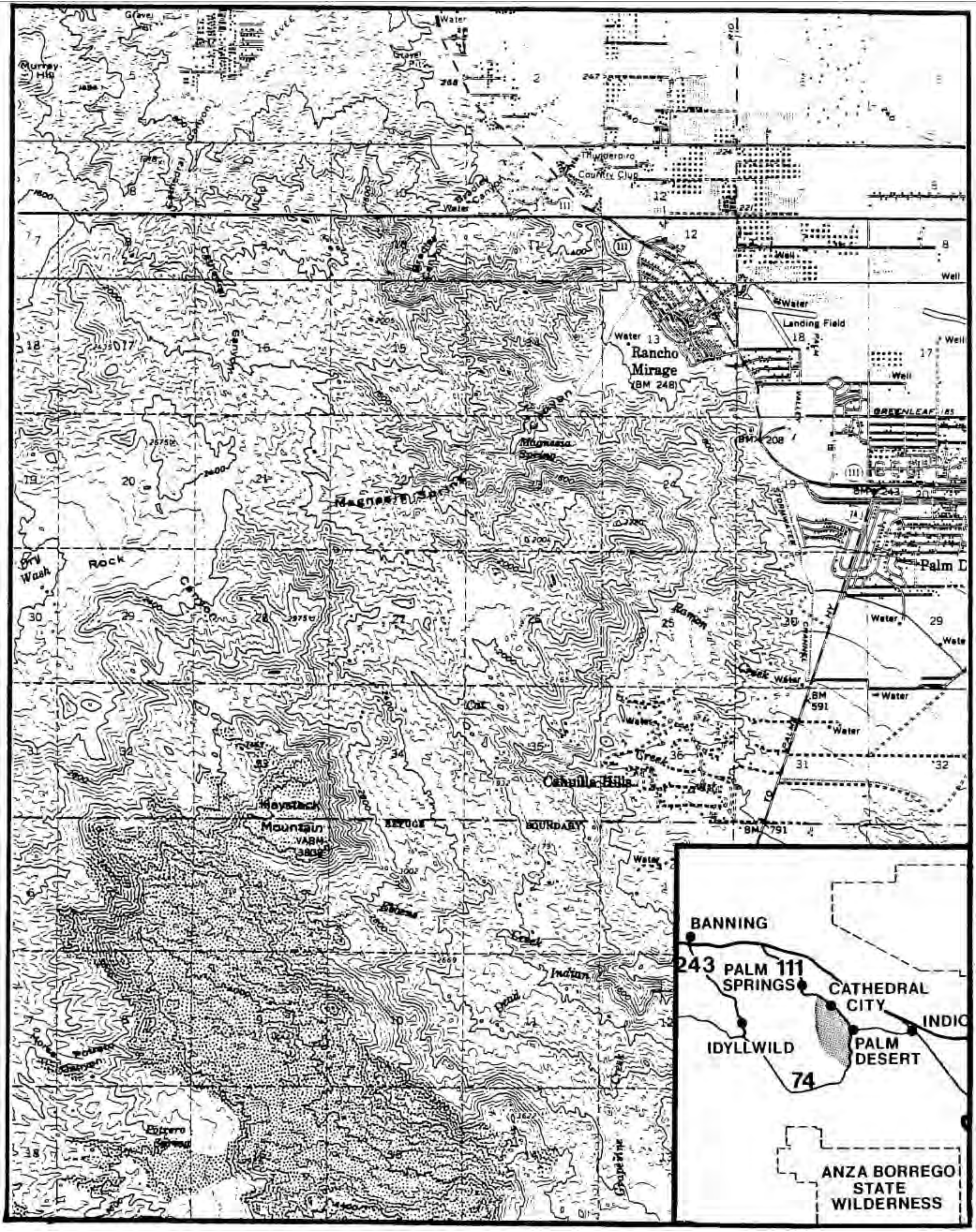

Figure 1. Topographical map of study area in northern portion of the Santa Rosa Mountains, California. Inset shows relationship of study area to nearby towns.

/aginal swabs, and fecal samples were collected. Vitamin E-Se and antibiotics were administered. Numbered aluminum ear-:ags were applied. Radio or ribbon collars were attached to all 'ree-ranging animals. Animals captured in November were given parenteral killed virus parainfluenza-3 vaccine, killed 'our-strain bluetongue vaccine, and two-species *Pasteurella* bacterine.

Blood was collected from each animal by jugular puncture for disease studies, hematology, and blood chemistry. Blood for hematology and blood chemistry was sent to A & E Clinical Veterinary Laboratory, Los Angeles, CA, from animals sampled in May and to Veterinary Reference Laboratory, Anaheim, CA, from all other animals sampled. Methods of analysis of diseases in the population are reported elsewhere (DeForge et al. 1982).

As the result of the 2 captures, 19 animals were fitted with color-coded collars (5 rams and 14 ewes), and 14 of these collars (10 ewes and 4 rams) carried radio telemetry transmitters. Bighorn were tracked primarily on foot, but with limited fixed wing or helicopter aerial monitoring. Sightings and telemetry readings were plotted on maps daily. Data were recorded on lamb/ewe ratios and behavior, movements, predation, feeding habits, nutrition, rutting behavior and timing, human impacts, disease, mortality, etc.

Field data for study of nutrition and food habits of this population have been collected. However, this portion of the study is not completed and will not be reported here.

RESULTS

Adult Population. The bighorn population in the study area numbered 150 animals as recently as 5 or 6 years ago. Ratios from field studies and helicopter surveys of collared to uncollared animals indicate that today the adult population consists of 60-70 animals (45-50 ewes, 15-20 rams). Adult bighorn were observed showing clinical signs of illness (respiratory difficulty, coughing, and nasal discharge), but during this study a major die-off of adult animals has not occurred. Fresh carcasses from one yearling ram and one adult ram were found in the study area. The adult ram is the only collared animal to have died. Thus this population decline appears to be the result of high lamb mortality over a number of years.

Lamb Mortality. It is assumed from our field observations and other studies that most ewes of reproductive age are bred and become pregnant (Turner and Hansen 1980). When the Bradley lambing area was first visited in mid-February 1981, 9 lambs were seen with 14 ewes. Lambs continued to be observed, but the majority were always young, indicating that they were dying before reaching a few months of age. Most lambs were born by mid-May. By the end of June 1981, only 2 lambs remained. One was male lamb #5791 that was captured with his mother #5784 on May 1, 1981. Both animals were blood-sampled, given antibiotics, eartagged, and released. The mother also had been radio-collared.

On July 31, 1981, a sick one-week-old female lamb was found alone at Lower Magnesia Spring. It was obvious that she would not live long without care, so she was removed from the range. Examination indicated pneumonia and an infected prolapsed eye. Treatment was initiated, but she died 9 days later.

During July 1981, lamb #5791 grew progressively weaker and was monitored closely. He died in the field on August 4, 1981, and was removed for postmortem examination, leaving one lamb left alive in the study area.

On August 29, 1981, another new lamb was observed. This male lamb was approximately 2 weeks old, so was born very late in the season (mid-August). The lamb seemed ill periodically, but at other times appeared normal. She was last observed on November 4, again leaving one lamb left in the study area.

On October 3, 1981, a previously unobserved ram lamb, approximat'ely 6-7 months old, was sighted in the study area. It was assumed that he wandered into the area, possibly from the nearby Deep Canyon area. He seemed to be without a mother, and was not seen regularly with any particular ewe. He appeared ill periodically, with a recurring darkened crusty chin, but he continues to survive.

Thus, for 1981, only 1 female lamb survived from those born in the study area, and one more ram lamb apparently entered the study area. Therefore, the 1981 lamblewe ratio for the study area was 41100, a declining trend if extended over time.

In 1982, 14 ewes were collared before lambing season. Closer monitoring of parturition and maternal care was possible than during 1981. The first lamb observed was born in early February, but this was the only one observed until the last week of February, when approximately 6 were born. Most lambs were born by mid-May.

On June 5, 1982, a 2% month old male lamb was observed in moribund condition, showing depression, nasal discharge, foamy salivation, droopy ears, inability to feed, unwillingness to move, and excessive drinking of water. On June 6 he was captured unharmed by use of a Telonics experimental net capture gun fired hand-held from a helicopter. His condition was diagnosed as pneumonia, so severe that he was not expected to live. However he was put on massive antibiotic treatment and appears to have recovered. It is anticipated that he will be returned to the wild soon. His recovery gives hope that other sick lambs can be treated and saved until such time as this disease complex can be understood and management applied.

On June 15, 1982, a one-day-old male lamb of radio-collared ewe #6106 died. The carcass was removed for necropsy. The lamb's mother was the same ewe that had a lamb late last August, which she also lost.

Of the 14 ewes collared in 1982, one still has her lamb as of mid-October. Another collared ewe was observed less frequently, but was last seen with her lamb. Three collared ewes may have had a lamb for a short time, because they were observed either with extended udders, or with a group where one lamb could not be positivley associated with the collared ewe. Six collared ewes had lambs and lost them. Three collared ewes never were seen with lambs.

At least 4 lambs (all female) are still alive in the range as of mid-October from the 1982 lamb crop. A helicopter count of the area on October 17, 1982 gave a lamblewe ratio of 111100, indicating 5 or 6 may survive. Lamb survival through October, 1982 is better than for 1981, but the lamblewe ratios both years are below that needed to halt the population decline.

During both years, lambs were observed that were suspected of being ill, but signs were often inconclusive. Lambs causing the most apprehension were those that were hardest to see, because the mothers kept them high in steep terrain. Many recordings were made of "lethargic lambs, resting in the shade with droopy ears." In retrospect, those were the lambs that seemed to disappear. Lambs also were seen to cough, to sneeze, and some had nasal discharges. If approached, these same lambs would scamper up a steep scarp on their mother's heels as if they were perfectly healthy, making it difficult to single out critically ill lambs.

If an uncollared ewe was seen without a lamb, it was often not known if she previously had one, so losses to uncollared ewes could go unnoticed. During lambing, research was most often centered around lambing areas, so daily lamb/ewe ratios were biased. Ewes that lost lambs usually left these areas. Collared ewes gave the only good indicator that lambs were dying, but even that was not always immediately evident. Ewes with lambs form nursery groups, and it was sometimes difficult to tell which lamb belonged to which ewe. One ewe often babysat the nursery while the others went for water or food, so observation of a ewe without her lamb was not always an immediate sign that she had lost it. In addition, even a healthy population loses lambs, so loss of a few was not an immediate danger signal. It therefore became obvious that by the time the problem was documented, the loss was already heavy.

Few lamb carcasses were found fresh enough for necropsy to determine cause of death. It was hoped that dead lambs of collared ewes would have been more easily located. In spite of many efforts to find missing lambs, carcasses seldom were recovered. Small fragile lamb bodies usually were destroyed quickly by the combination of hot desert temperatures and predators. Often only small bone fragments remained.

Group Protection of Lambs and Fostering. On several occasions protection of a few remaining sick lambs by a ewe group was observed. The following case documents group protection, as well as fostering of a lamb.

Ewe #5784 was captured with her lamb #5791 on May 1, 1981. The mother was radio-collared and the lamb ear-tagged, so close monitoring was possible. There is little doubt that the ewe was the natural mother of this lamb. When captured, the lamb was approximately one week old, and it followed right on the ewe's heels. When released, to the distress of researchers, lamb and ewe went in different directions. Six hours later they were observed together, the lamb inside a small cave, the ewe in front of her. For the next 2½ months the ewe was always with the lamb, nursing and caring for it.

The last week of July, both ewe and lamb started showing signs of pneumonia. From that time on, the lamb was seen most often in the company of several uncollared ewes, although the mother was usually not more than 500 meters away, but sometimes not in sight of the lamb. The group of ewes seemed to try to protect the sick lamb. On two occasions, researchers attempted to approach the sick lamb for examination and possible capture. Those 4 uncollared ewes observed researchers alertly, and stayed near the lamb, seemingly in attempt to get the lamb to move off with them. As researchers got closer, the ewes eventually left, but they returned within minutes to look for the lamb. Both times the lamb did finally flee before researchers could approach closely. On one of these occasions the natural mother was with the 4 uncollared ewes, but the other time she was not in sight and presumably did not know of the incident.

One of the uncollared ewes became the lamb's foster mother. The lamb was observed nursing from this ewe at 3 months of age. Even when the natural mother appeared to regain some of her strength, she seemed to play a secondary role in this lamb's care. The lamb was now under the care of the foster mother, with both ewes seeming to accept their new roles. No adverse behavior was every observed between the natural mother and the foster mother.

The lamb eventually died in the field from pneumonia, and when the carcass was found a few hours after death, the foster mother, the natural mother, and 2 uncollared ewes were standing nearby. They watched as the dead lamb's body was carried out of the field.

It should be noted that, as a rule, maternal care of a lamb seemed to be excellent. This case appeared to be a unique situation where the natural mother became so ill that she was physically unable to care for her offspring. Although other cases of lamb fostering were not noticed, group protection of lambs seemed common.

It is not believed that lamb fostering has been recorded elsewhere in wild bighorn. Ear-tagging the lamb at capture made possible documentation of this behavior.

Disease. Pathologic studies indicate that a pneumonic process has been killing lambs of the Santa Rosa Mountains, and serological studies give evidence that a combination of Parainfluenza-3 and bluetongue viruses, and possibly epizootic hemorrhagic disease and contagious ecthyma viruses, are initiating factors (DeForge et al. 1982). This does not preclude the possibility that other stressors such as nutrition, interspecific competition, predation, changes in seasonal weather patterns, human impacts, etc. may also have been important initiating factors triggering this pneumonia complex.

Blood Chemistry and Hematology. The mean, standard deviation, and range of hematologic and blood chemistry values for all clinically normal bighorn sampled are given in Tables 1 and 2 respectively. These values will be used as normals for future studies here, given similar capture and blood collection methods. Tables 1 and 2 also give established normals for domestic sheep (Schalm et al. 1975, Kaneko 1980) and hematologic and blood chemistry results from 2 groups of desert bighorn *(O.c. nelsoni)* from Utah (McDonald et al. 1981). Indication is made on tables where means are not significantly different at the 5% level. For comparison, it should be recognized that Utah Group I was captured by drop net (no immobilization drugs used) and was physically stressed from capture; Utah Group II was captured by chemical immobilization with Etorphine from a helicopter. Additionally, Utah Group I received supplemental feed.

Although the Santa, Rosa population has disease problems, most bighorn examined were clinically normal, and hemagrams and blood chemistry values generally did not indicate a diseased condition. This reflects the fact that disease problems involve the respiratory tract and not abdominal organs, and also that adult animals seem to withstand the disease, whereas lambs die.

Glucose and white blood cell counts in desert bighorn appear to increase with stress of capture and dampen with chemical immobilization tranquilizers. Leucocyte differential appears to vary from domestic sheep normals, with higher neutrophil and lower lymphocyte percentages. Stress and excitement causing corticosteroid release would explain this difference.

Alkaline phosphatase and total protein levels were high due to inclusion of lambs and yearlings in samples. Data for adults were within normal ranges of domestic sheep.

Blood urea nitrogen (BUN) can be indicative of nutritional level. Data therefore have more meaning if separated into captive and free-ranging, as captive sheep ate little natural vegetation. Data indicate the free-ranging bighorn were adequately nourished.

Bighorn serum electrolyte levels differ from domestic sheep. Significance of this is unknown, but may be related to exertion of capture.

During the study, 2 clinically ill lambs were removed from the field, as reported earlier. Blood for hemagrams and blood chemistry was collected from both lambs. The abandoned 1 week old female lamb with pneumonia and an infected prolapsed eye had white blood cells elevated to 28,400/mm³, with neutrophils comprising 86%, indicating infection and stressed condition. Other values were within normal ranges. The lamb died 9 days after capture.

The second clinically ill lamb tested was the 2½ month old male with severe pneumonia. White blood cells were increased to 27,700/mm³, with neutrophils comprising 84%. BUN was increased to 78 mgldl and creatinine to 3.8 mgldl, indicating kidney malfunction. Glucose was elevated to 172 mb/dl probably due to the excitement and exercise of capture. As reported, this lamb is recovering.

One ram died 10-14 days post capture. Serological studies indicated exposure to several diseases in the range. White blood cell and red blood cell counts were lowered to 5,600/m³ and 8,3000,000/mm³ respectively. This may indicate active viral intection, but also may be a reaction to capture drugs. Alkaline phosphatase was raised to 805 U/1 indicating possible hepatic disease, and phosphorus was lowered to 3.3 mgldl, a possible indication of poor diet. Serum glutamic oxaloacetic transaminase (SGOT) was elevated to 865 U/1, which could indicate exertion or capture stresslmyopathy. However, Spraker (1977) reports much higher SGOT levels in bighorn with capture myopathy.

One ram reacted adversely to tranquilizing drugs, and it was speculated that he may have had some disorder which did not allow his system to detoxify the drugs. He appeared emaciated, but was at the end of the rut, when rams often are lean. Immobilization drugs have a stronger affect on ungulates when body weights are lowest and physical conditions are poorest (Jacobsen et al. 1976). He had high levels of creatinine (3.1 and 3.4 mgldl; blood was collected twice), high levels of total bilirubin (0.5 and 0.3 mgldl) and very low glucose levels (69 and 36 mgldl. This could indicate liver or kidney disease, dehydration, or malnutrition. This ram actively rutted ewes during 1982, and appeared healthy.

Predation. On four different occasions coyotes *(Canis latrans)* were seen stalking bighorn lambs. Each time lambs appeared to make narrow escapes, but pursuit was not always terminated while these interactions were in view of the observer. Therefore, the end result on two occasions could not

Table 1. Hematologic values from this study, desert bighorn in Utah, and domestic sheep.

	This Study[a] $\bar{x} \pm s$	(n)		Domestic Sheep Normals[b] $\bar{x} \pm s$ (range)		Utah Group I[c] $\bar{x} \pm s$ n=11		Utah Group II[c] $\bar{x} \pm s$ n=16	
White Blood Cells ($10^3/mm^3$)	6.5 ± 2.8	(39)	a[d]						
(w/Chemical Immobilization)	4.2 ± 1.6	(10)	b					4.7 ± 1.1	b
(wlo Chemical Immobilization)	7.2 ± 2.7	(29)	ac	8 (4-12)	c	10.8 ± 1.4			
Band Cells (%)	0.10 ± 0.38	(39)	a	rare		3.0 ± 2.7		0 ± 0	a
Segmented Neutrophils (%)	54.9 ± 16.5	(39)	a	30.0 (10.50)		63 ± 13.6	a	62 ± 18.7	a
Lymphocytes (%)	40.6 ± 16.1	(39)	a	62 (40-75)		26 ± 10.5		34 ± 17.8	a
Monocytes (%)	1.8 ± 1.6	(39)	a	2.5 (0-6)		5 ± 3.2		1 ± 1.9	a
Eosinophils (%)	2.6 ± 2.7	(39)	a	5.0 (0-10)		2. ± 2.2	a	2 ± 2.9	a
Basophils (%)	0 ± 0	(39)	a	0.5 (0-3)		0 ± 0	a	0 ± 0	a
Red Blood Cells ($10^6/mm^3$)	10.1 ± 2.0	(39)		12.0 (9-15)				9.0 ± 0.9	
Hemoglobin (gldl)	15.9 ± 2.1	(39)		11.5 (9-15)	a			12.3 ± 1.6	a
Packed Cell Volume (%)	43.8 ± 6.1	(39)		35.0 (27-45)	a			35 ± 3.9	a
Mean Corpuscular Volume (fl)	44.2 ± 6.4	(39)		34.0 (28-40)					
Mean Corpuscular Hemoglobin (pg)	16.2 ± 1.8	(39)		10.0 (8-12)					
Mean Corpuscular Hemoglobin Concentration (gldl)	36.9 ± 2.1	(39)		32.5 (31-34)					

[a]Peninsular desert bighorn (Ovis canadensis cremnobates) from the Santa Rosa Mountains, California

[b]Schalm, O.W., N.C. Jain, and E.J. Carroll. 1975. Veterinary hematology. 3rd Ed. Lea and Febiger, Philadelphia, PA.

[c]McDonald, S.E., S.R. Paul, and T.D. Bunch. 1981. Physiologic and hematologic values in Nelson desert bighorn sheep. J. Wildl. Dis. 1:131-134.

[d]If the means from any 2 groups of sheep for the same hematologic value are followed by a common letter, there is no significant difference between these means at the 5 percent level.

be positively documented. In each of these attacks, a pair of coyotes was involved.

On June 23, 1981, a lamb was found dead. It had been hamstrung, the right ear torn off, and the skull had a puncture wound similar to that which would be caused by a canine tooth. A coyote was feeding on the carcass when found. A few hours before, the lamb was sighted alive with a ewe.

On June 12,1981, a coyote was seen coming up a ridge toward 3 ewes which were feeding approximately 6-9 m (20-30 ft.) apart. Apparently the coyote could not see the ewes. When the ewes spotted the coyote, they faced him and held visual contact until the coyote cowered and circled away. The ewes showed no observable fear of the single coyote, even at a distance of 6-8 m (20-25 ft.).

On October 17,1982, an adult ewe was observed cornered on a vertical scarp by 3 coyotes. It appeared that this ewe had sought protection from the coyotes by scaling the vertical cliff. However, she had only one exit from the cliff which the coyotes were guarding, so she was virtually trapped. The observer's presence frightened off the coyotes.

Table 2. Blood Chemistry values from this study, desert bighorn in Utah, and domestic sheep.

	This Study[a] $\bar{x} \pm s$	(n)		Domestic Sheep Normals[b] $\bar{x} \pm s$ (range)		Utah group I[c] $\bar{x} \pm s$ n = 11		Utah Group II[c] $\bar{x} \pm s$ n = 16	
SGOT[d] (U/l)	258.7 ± 154.7	(40)	a[f]	307 ± 43	a	284 ± 110.0	a	328 ± 280.7	a
SGPT[e] (U/l)	51.0 ± 36.7	(40)	a	38 ± 4	a				
Alkaline Phosphatase (Ull)	521.1 ± 679.6	(40)	a	178 ± 102	b	372 ± 204.2	a	191 ± 77.3	ab
(Lambs & yearlings only)	1380.3 ± 1217.0	(7)							
(Adults only)	338.8 ± 299.1	(33)	a						
Cholesterol (mg/dl)	60.7 ± 24.4	(40)	a	64 ± 12 (52-76)	a	61 ± 10.2	a	70 ± 20.4	a
Glucose (mg/dl)	126.2 ± 31.5	(40)	bc	68.4 ± 6.0 (50-80)					
(w/Chemical immobilization)	104.3 ± 35.0	(10)	ab					98 ± 28.5	a
(wlo Chemical immobilization)	133.4 ± 27.2	(30)	c			226 ± 38.2			
Blood Urea Nitrogen (mg/dl)	19.6 ± 8.2	(40)	ab	(8-20)		21 ± 5.1	a	16 ± 5.2	bc
(Captive only)	28.9 ± 5.9	(14)							
(Free-ranging only)	14.5 ± 3.3	(26)	c						
Creatinine (mg/dl)	1.9 ± 0.5	(40)	a	(1.2-1.9)		1.9 ± 0.1	a	1.9 ± 0.3	a
Total Bilirubin (mg/dl)	0.22 ± 0.11	(40)	a	0.23 ± 0.09 (0.1-0.42)	a	0.9 ± 0.3		0.3 ± 0.2	a
Total Protein (g/dl)	7.1 ± 0.9	(40)	abc	7.2 ± 0.52 (6.0-7.9)	ab	6.6 ± 0.7	cd	6.5 ± 0.9	d
(Lambs & yearlings only)	6.4 ± 0.9	(7)	bd						
(Adults only)	7.3 ± 0.9	(33)	a						
Albumin (g/dl)	3.6 ± 0.4	(40)	a	2.7 ± 0.19 (2.4-3.0)	b	3.6 ± 0.1	a	2.9 ± 0.5	b
Globulin (g/dl)	3.6 ± 0.9	(40)		4.4 ± 0.53 (3.5-5.7)					
Albumin/globulin ratio	1.1 ± 0.3	(40)		0.63 ± 0.09 (0.42-0.76)					
Calcium (mg/dl)	11.0 ± 1.3	(40)		12.16 ± 0.28 (11.5-12.8)		10.0 ± 0.4		9.8 ± 0.9	
Phosphorus (mg/dl)	5.4 ± 1.8	(39)	a	6.4 ± 0.2 (5.0-7.3)		5.5 ± 2.3	a	3.6 ± 0.8	
Sodium (megll)	153.0 ± 6.7	(40)		(139-152)					
Potassium (megll)	5.4 ± 0.9	(40)		4.8 ± 0.4 (3.9-5.4)					

[a]Peninsular desert bighorn (Ovis canadensis cremnobates) from the Santa Rosa Mountains, California.

[b]Kaneko, J.J., ed. 1980. Clinical biochemistry of domestic animals. 3rd Ed. Academic Press, New York.

[c]McDonald, S.E., S.R. Paul, and T.D. Bunch. 1981. Physiologic and hematologic values in Nelson desert bighorn sheep. J. Wildl. Dis. 1:131-134.

[d]Serum glutamic oxaioacetic transaminase

[e]Serum glutamic pyruvic transaminase

[f]If the means from any 2 groups of sheep for the same blood chemistry value are followed by a common letter, there is no significant difference between these means at the 5 percent level.

It must be assumed that coyotes at times have been successful enough in sheep predation for stalking behavior to be reinforced. This success is probably most often on lambs when attacks are attempted by 2 or more coyotes. If lambs are carrying infections and being weakened by pneumonia, coyote predation may play an important role in lamb mortality. It is not clear whether death from coyotes is occurring to healthy animals, to sick animals that eventually would have died, or to animals that were only temporarily weakened by infection and would have otherwise recovered.

It should be noted that ewes visited waterholes in summer most frequently midday from 1030 to 1430 h, especially when accompanied by young lambs. This could have been a behavioral reaction to avoid predators.

Although bobcats *(Felis rufus)* are present in the bighorn range and were seen on several occasions, no sign of interaction with bighorn was recorded.

Golden eagles *(Aquila* chrysaetos) were observed on a number of occasions in the study area. Allen (1939) considered eagle predation on lambs a significant mortality factor, and Ober (1931) and Kennedy (1948) observed eagle predation on sheep. On two different occasions, an eagle was seen soaring high over a group of ewes and young lambs, then diving down to within approximately 5 m (16 ft.) of them. On both occasions the ewe stayed alerted to the eagle, maintaining visual contact until the eagle was approximately 150 m (500 ft.) away or out of sight. The ewes stood still with the lambs protected under them or close to their side.

Weather. Precipitation data from Boyd Deep Canyon Research Center, Palm Desert (Table 3) are presented from June to the following May, since this probably reflects precipitation as it relates to the effect of vegetational response on lambing season. Since 1977 when high lamb mortality began in the Santa Rosas, there have been both wet and dry summers, both wet and dry winters, and both wet and dry years overall. No clear correlation can be discerned between precipitation and lamb mortality. However it is possible that during the wet years of 1976177 through 1979180, *Culicoides* sp. gnats became established or increased in numbers, resulting in the spread of *Culicoides*-transmitted bluetongue virus.

Monthly mean maximum temperatures since 1977 show no consistent variation from the 20 year average (Table 4; weather records from Boyd Deep Canyon Research Center, Palm Desert), indicating that ambient temperatures did not contribute to lamb mortality in most years. The only exception was 1981, which averaged 4°C (7°F) warmer than the 20 year average, higher than all recorded years since 1961. During 1981, lamb losses were extremely high (only 1 lamb survived from 45-50 ewes in the study area). Field observations indicated that bighorn, particularly lambs, were stressed by high ambient temperatures. Monthly maximum temperatures averaged over 40°C (104°F) for June, July and August of that year, and this long hot period probably increased stress on the remaining lambs.

Water. A shortage of water is a problem for bighorn in many desert mountain ranges. Blong (1965) expressed concern over diminished flow of springs in the Santa Rosas, "very likely due to wells recently drilled in the area."

During this study, water always was available in Magnesia Canyon from intermittent natural springs and in Bradley Canyon from man-made drinkers for bighorn. However, all springs in Magnesia Canyon have been known to go dry in years past (Richard Weaver, pers. comm.).

Two man-made water sources are available for bighorn in Bradley Canyon. The Thunderbird Waterspout or Spring was built in 1965 by residents of Thunderbird Ranch Estates. More recently another resident of Thunderbird recessed a bathtub in the ground (Thunderbird Tub) that automatically stays full of water. Both water sources were used regularly during summer months. In addition, bighorn use other water man has inadvertently made available. In Bradley Canyon bighorn have hit their horns on PVC irrigation systems bordering their habitat, getting water from leaks that result. Also at the bottom of Cathedral Canyon, bighorn sign was found around irrigated palm trees surrounding a city watertank.

The Thunderbird Spring is filled by continuously flowing

Table 3. Monthly precipitation (mm) from Boyd Deep Canyon Research Center, Palm Desert, California. Data are presented from June to the following May, since this more closely reflects precipitation as it relates to the effect of vegetational response on lambing season.

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	TOTALS: SUMMER STORMS[a]	WINTER STORMS[b]	SEASON TOTAL
20 yr. average	0	9	15	13	6	14	14	20	17	14	4	3	37	85	129
1974175	0	1	0	1	26	0	21	0	4	4	27	0	2	82	84
1975/76	0	T[c]	T	3	1	13	8	0	64	7	4	35	3	132	135
1976177	0	1	0	159	23	5	4	27	5	4	T	2	160	68	230
1977178	0	1	94	5	0	0	29	110	19	58	2	0	100	216	318
1978179	0	1	10	5	2	46	36	47	34	22	0	T	16	187	203
1979180	0	90	42	T	0	1	1	67	113	29	5	5	132	211	353
1980131	0	9	0	1	0	0	1	15	12	39	0	6	10	67	83
1981182	T	0	0	22	3	0	3	32	18	17	9	5	22	73	109
1982183	0	2	2												

[a]July to September

[b]October to March

[c]Trace

waterspout, which keeps water fresh for bighorn, but also promotes a heavy growth of arrowweed (Pluchea sericea). Bighorn seemed to fear the heavy cover and often watched the spring for an hour or more before going to drink. The arrowweed was burned in Spring 1982 with aid of the fire department. Afterward, use of the spring changed dramatically, with bighorn showing no hesitation as they came to water.

Range and Movements. All collared ewes in the study area appear to be from one contiguous herd. All have been spotted throughout ewe range (Figure 2). Also, 3 animals captured in 1977 in Magnesia Canyon by Turner and Payson (1982) are still in this herd, and those bighorn they captured in Carrizo and Deep Canyon in 1977 never were observed in the range of this herd. Therefore, intermingling between this herd and the Deep Canyon herd is doubtful. Little bighorn use has been observed in the Carrizo Canyon and Dead Indian Canyon areas, where bighorn were numerous as recently as the 1970s.

Although the 45-50 ewes in the study area are one herd, they were not always found together, but were found in smaller groups of 1-19 animals. Little group fidelity was observed within smaller bands, with mixing and intermingling between smaller groups occurring regularly.

Ewe groups (ewes, lambs, and immature rams) did not migrate between a summer and a winter range, but concentrated in different sections of the range during different seasons (Figure 2). This related to seasonal requirements for a type of terrain or proximity to a needed resource.

In hot summer periods, when hill vegetation was dry, sheep were dependent on water and/or green vegetation and could be found with regularity in Bradley Canyon at Thunderbird Waterspout and Tub, along Magnesia Spring, and in Cathedral Canyon where and when it was wet. Often sheep were there for green forage, and were seen feeding in washes and near or occasionally in planted yards. In 1981, bighorn were highly dependent on these waterlgreen forage areas from mid-May until the beginning of October; in 1982 from mid-April until mid-September.

When the weather started to cool, precipitation increased, and plants started to green up, sheep were less dependent on permanent water sources and were found more in the high country. They left Bradley Canyon almost completely and were found more often southwest of Cathedral Canyon near Dunn Road, on the back of Bradley Peak, and on the large mountain mass between Magnesia Spring and Ramon Creek. This period started in September/October and lasted until lambing began in February.

During this time ewes used the fullest extent of their range. On 2 occasions in mid-January 1982, collared ewes were spotted just off Hwy. 74 near Vista Point (Section 18) close to Deep Canyon. However, they returned to the herd ewe range soon, possibly even that day. Although this is a separate herd, occasional visitation to the range of the other herds does occur.

As parturition approached, ewes moved to more precipitous terrain. The steep scarp of Bradley Peak appeared to be a favored lambing area, but lambing also was documented north of Cat Canyon in Section 26, north of Lower Magnesia Spring in Section 14, and along steep cliffs above lower Cathedral Canyon. Lambing started in February, and most were born by mid-May. In April/May ewes started visiting permanent water sources. Young lambs were left in steep terrain, while older lambs followed the mothers to water.

Mature rams had a wider range than ewes (Figure 3). During the rut they were concentrated in the ewe range--from mid-June to mid-November 1981, but not until mid-July 1982.

After the rut, mature rams were in ram bands, usually concentrated higher in the range, north and east of Haystack Mountain, in upper Cat Canyon, the mountain mass between Magnesia Spring and Ramon Creek, and in Grapevine Canyon. However, an occasional mature ram might be sighted anywhere in the range, as they seem to wander freely. It has been speculated that rams may range to Deep Canyon or to the San Jacintos, but data are not available to prove or disprove that hypothesis. No telemetry readings on any collared rams were received from those areas. One ram came into the ewe range during the 1981 rut with darkened horns as if he had been in a burned area, and the closest burned area was the San Jacinto Mountains.

It should be noted that ranges reported here were those observed over a 20 month period only. If water availability was different, as in years when Magnesia Canyon went dry, areas of bighorn concentration would most likely alter, especially in summer months.

Interaction with Cattle and Deer. Both southern mule deer *(Odocoileus hemionus fuliginatus)* and domestic cattle *(Bos* taurus) were present in higher country within the ram range. Low densities of all 3 species in these areas suggest that competition for water or forage did not exist between these species and bighorn. However, viruses that seem to be predisposing bighorn lambs to bacterial pneumonia could be carried by these ungulates. Overlap of ram range with these ungulate populations is a possible route of infection for the bighorn population. Blood serology studies need to be conducted on these species to determine whether they play a role in the bighorn disease complex.

Human Impact. The increasing human population of the Coachella Valley and subsequent encroachment into bighorn habitat has caused concern among bighorn managers (Blong 1965, Weaver and Mensch 1970). The bighorn habitat is

Table 4. Monthly mean maximum temperatures (degrees Celsius) from Boyd Deep Canyon Research Center, Palm Desert, California.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	YEAR AVG.
20 yr. average	18	21	22	26	30	36	39	38	35	30	23	19	28
1976	22	21	23	26	33	39	39	39	32	30	26	21	29
1977	18	25	21	29	27	38	40	38	33	32	26	21	29
1978	17	19	23	25	32	39	41	39	35	33	22	16	28
1979	14	19	22	28	31	38	40	36	39	32	23	22	29
1980	17	21	22	26	30	36	39	38	35	30	23	19	28
1981	23	26	25	32	34	42	41	42	38	29	27	23	32
1982	18	22	21	27	33	34	38						

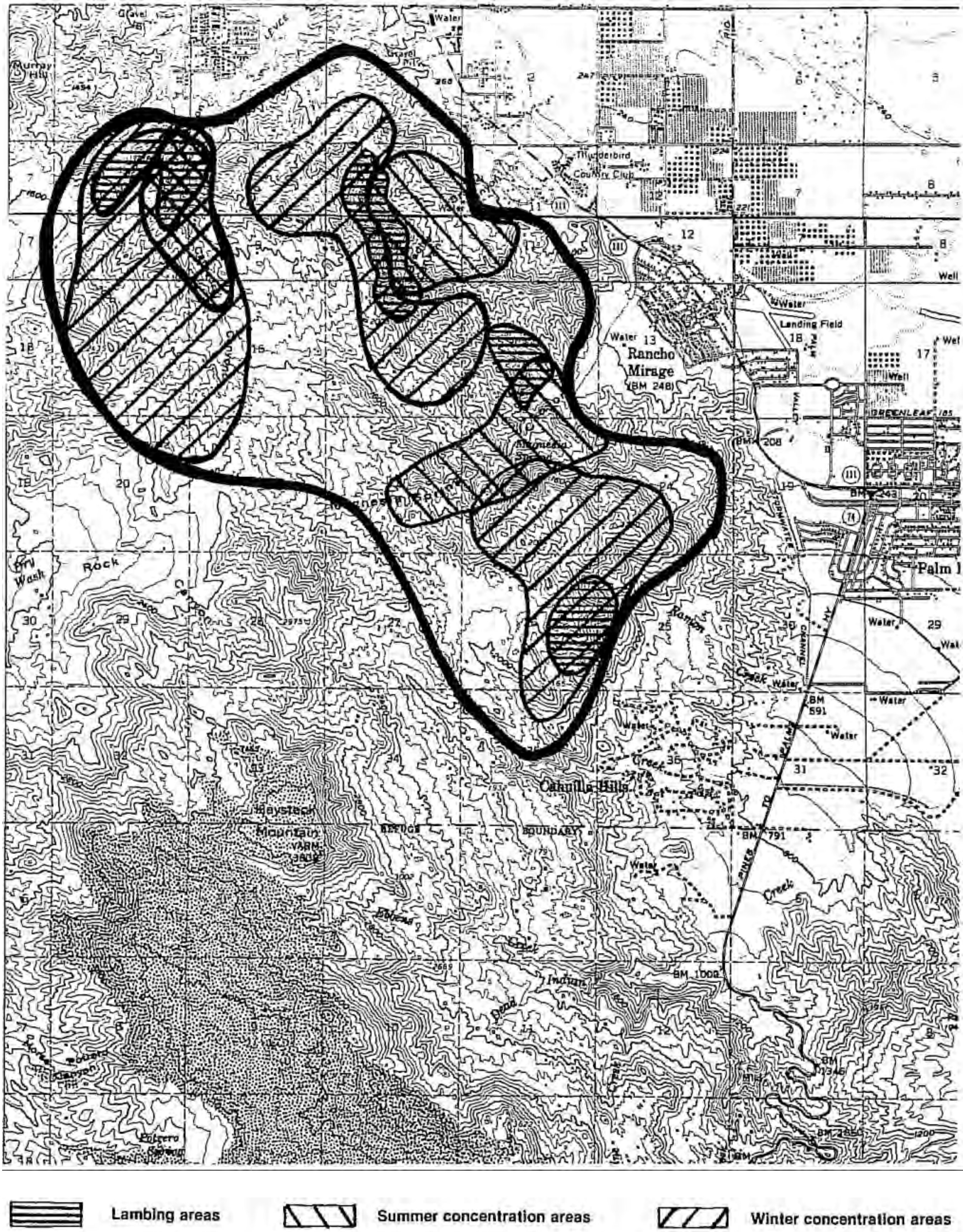

Figure 2. Range of ewes in study area in northern portion of the Santa Rosa Mountains, California (heavy line). Ewes could be found in ewe range at any time of year, but concentrated in different sections during different seasons.

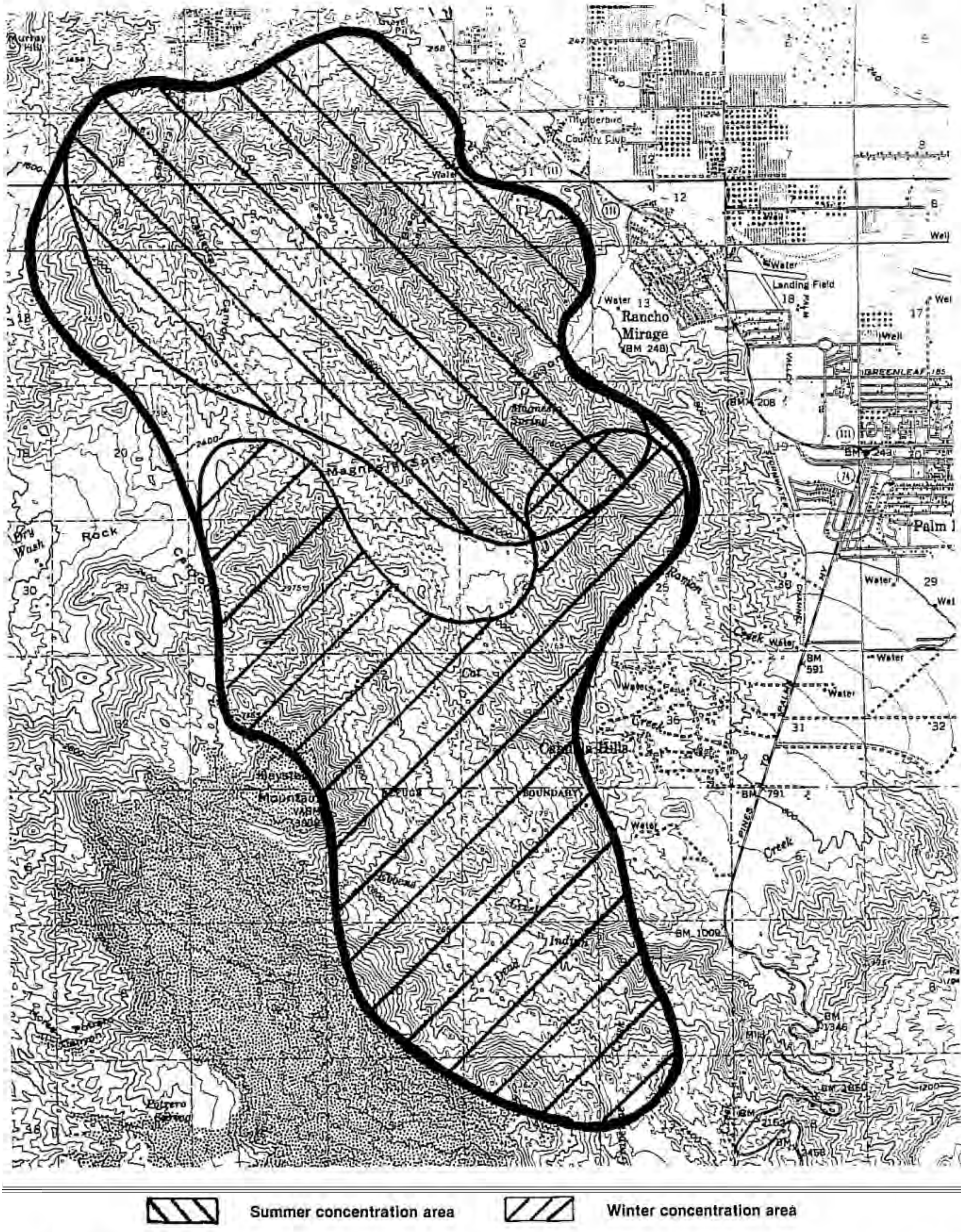

Figure 3. Range of rams in study area in northern portion of the Santa Rosa Mountains, California (heavy line). Rams could be found anywhere in ram range at any time of year, but concentrated in different sections during different seasons.

bordered by residential areas, and there is constant pressure for increased development. Human encroachment can affect bighorn distribution and numbers (Jorgensen 1974, DeForge 1972, 1976, 1980).

Bighorn reactions to man are a product of man's behavior towards bighorn (DeForge 1980, 1981). Varying bighorn responses to humans were observed. In the Bradley Canyon area, Thunderbird Ranch Estates border the bighorn range and bighorn have become somewhat accustomed to the residents. A unique situation exists here in that there is apparently little adverse bighornlhuman interaction. The residential area is under 24 hour guard, restricting public access and thus free play in this canyon. As a result, there has been very little human use of the hills behind these homes. Bighorn used this canyon regularly during summer months and were seen to feed adjacent to or in residents' yards. It should be noted, however, that many of these homes were not occupied during summer.

In 1965 Thunderbird residents built a drinking system for bighorn less than 100 meters from homes (Thunderbird Waterspout or Spring). In 1981 bighorn watered regularly on a nearly daily basis at the Thunderbird Waterspout from May through September, which apparently has been the pattern for years. The same pattern was observed in May and June 1982, but in July 1982 heavy construction for flood control began in the canyon, lasting throughout the summer months. Bighorn altered their use of this canyon and water source to primarily weekend use, when construction was not occurring. Yet construction was concentrated on the far side of the canyon, 200-500 m away from the spring, and did not restrict the bighorn's movements into the spring or activity on the spring. Thus the change in this canyon's environment due to noise and vision of human occupancy appeared to be the only reason for this behavioral change.

It appears that human intrusion and development can alter the movements of this population and could be another cumulative stressor contributing to disease susceptibility.

CONCLUSION

The bighorn population in the northern Santa Rosa Mountains has declined from 150 to 60-70 animals in the last 5 or 6 years. High lamb mortality has occurred since 1977. Pathologic evidence suggests a pneumonic process has been killing lambs, and serological evidence suggests that a combination of parainfluenza-3 and biuetongue viruses, and possibly epizootic hemorrhagic disease and contagious ecthyma viruses may be initiating factors to this pneumonic process. Predation, changes in seasonal weather patterns, interaction with other ungulates, and human impact could also be important factors in these losses. If high lamb mortality continues over the next few years, this population will show an even sharper decline, as most ewes in this range are at the upper end of their life expectancy. Bighorn have all but disappeared from nearby Carrizo Canyon, a very important watering area just a few years ago, as well as from Dead Indian Canyon, once a popular lambing area. In the Fish and Game fall survey of the Santa Rosa Mountains in October 1982, only 1 lamb was counted south of the study area, demonstrating the seriousness of the situation.

Bighorn problems are not limited to the Santa Rosa Mountains. Entire populations of 16 mountain ranges in California have been lost in the last third century (Weaver 1979, DeForge et al. 1981). These losses have gone virtually undocumented. Only through continued research on declining populations like the Santa Rosas can the problems be identified and action be taken to correct this situation, thus insuring the bighorn's future.

ACKNOWLEDGMENTS

The Desert Bighorn Research Institute is attempting to determine reasons for high lamb losses in the northern Santa Rosa Mountains. The Institute supports 2 full-time biologists on the project. In addition, numerous volunteer hours are donated by other Institute researchers. The authors greatly appreciate the efforts of the Institute's researchers and members.

Cooperating with the Institute in this study are the California Department of Fish and Game, the San Diego Zoo, the Living Desert Reserve, and the Los Angeles Zoo. We appreciate use of facilities at Palm Desert Pet Hospital and P.L. Boyd Deep Canyon Research Center, Palm Desert. Special thanks go to Dr. David Jessup, Calif. Dept. of Fish and Game, and Dr. Charles Jenner, Desert Bighorn Research Institute, for technical advice, assistance and review of manuscript. We also appreciate the advice and assistance of Richard Weaver, Calif. Dept. of Fish and Game; Karen Sausman, Living Desert Reserve; and Steve Segreto, Desert Bighorn Research Institute. We appreciate the assistance of Dr. Deborah Bernreuter, Veterinary Reference Laboratory, on blood chemistry and hematological analysis. We thank Richard and June McClung, Desert Bighorn Research Institute, for generosity and use of facilities. This research was funded by grants and donations from the Rogers Foundation, Mzuri Safari Foundation, Foundation for North American Wild Sheep, Shikar Safari, Annenberg Fund, Inc., and numerous contributions from private individuals.

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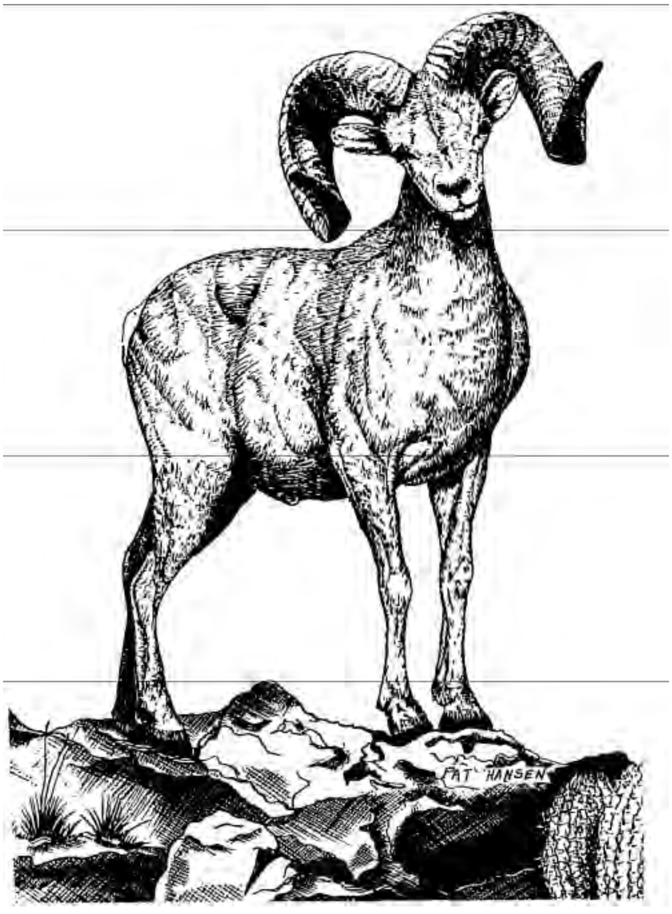

DISEASE INVESTIGATIONS INTO HIGH LAMB MORTALITY OF DESERT BIGHORN IN THE SANTA ROSA MOUNTAINS, CALIFORNIA

James R. DeForge
Desert Bighorn Research Institute
Palm Desert, CA

David A. Jessup, D.V.M.
California Dept. of Fish and Game
Rancho, Cordova, CA

Charles W. Jenner, D.V.M.
Joan E. Scott
Desert Bighorn Research Institute

Abstract. Nineteen free-ranging and 6 captive peninsular desert bighorn sheep were examined and tested for exposure to selected disease agents. Four diseased lambs provided pathological data. It was determined that a pneumonic process has been killing the lambs of the northern portion of the Santa Rosa Mountains. Serological evidence indicated that parainfluenza-3 and bluetongue viruses, and possibly epizootic hemorrhagic disease and contagious ecthyma viruses were probable initiating factors to the pneumonia. None of these viruses were isolated from captured bighorn or from carcasses of bighorn lambs.

INTRODUCTION

Peninsular desert bighorn, *Ovis* canadensis cremnobates, inhabit the Santa Rosa Mountains, Riverside County, CA. High lamb mortality has occurred here since 1977, reducing the size of this population (see DeForge and Scott 1982). Of particular concern was the area north of Hwy. 74, where only 1 lamb was recorded in the Fish and Game 1980 fall helicopter count (CDF&G files). Although population fluctuations do occur, these losses over this extended period of time prompted great concern among managers and conservationists alike. Since February 1981 researchers of the Desert Bighorn Research Institute have been studying ecological reasons for high lamb losses in the northern Santa Rosa Mountains. This work is being conducted in close collaboration with the California Dept. of Fish and Game. A large portion of this study was an investigation to determine whether diseases were a factor in these high lamb losses.

For a description of the study area, see DeForge and Scott (1982).

METHODS

Field observations began February 1981. Thirteen free-ranging bighorn were captured in May 1981, 12 with drive nets and 1 by chemical immobilization. The animals were examined, and blood, hair, nasal and vaginal swabs, and fecal samples were collected. Vitamine E-Se and antibiotics were administered. Radio or ribbon collars were attached, and the animals were released. Five captive bighorn at the Living Desert Reserve, Palm Desert, CA, also were sampled at this time.

In November 1981 a second capture was conducted to look at changes in serum antibody levels and to radio-collar additional animals. At that time 7 of the free-ranging bighorn previously sampled in May and 6 additional free-ranging bighorn were captured by drive nets or chemical immobilization, sampled, collared, and released. Five bighorn were again sampled from the Living Desert Reserve, 4 of which also had been sampled in May. Each animal handled received vitamine E-Se and long-acting antibiotics and was vaccinated against parainfluenza-3, two species of *Pasteurella,* and 4 strains of bluetongue with killed vaccines.

Whole blood was collected from each captured animal by jugular puncture and transferred into sterile tubes for serology and heparinized tubes for virus isolation. Whole blood was allowed to clot for 2-5 hours at room temperature, then centrifuged for 15 minutes for serum separation. Serum was distributed to several labs for serological testing to determine prevalence within this population of antibodies to parainfluenza-3 (PI-3), bluetongue (BT), epizootic hemorrhagic disease (EHD), contagious ecthyma (CE), infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD), ovine progressive pneumonia (OPP), toxoplasmosis, anaplasmosis, and brucellosis, as listed in Table 1. When possible, more than one laboratory and/or test was used to verify results.

Four lambs found by field researchers provided significant pathologic data.

Lamb #1: A male lamb approximately 1 week old was captured along with his mother on May 1, 1982. He was ear-tagged, sampled, and released. Antibiotics were administered as standard capture procedure. He started showing clinical signs of respiratory disease in mid-July, and was monitored closely by researchers. On August 4 he died in the field. The carcass was collected and necropsied approximately 8 hours post mortem. Blood was collected for serology at necropsy. Tissues were examined at the CDF&G Wildlife Investigations Laboratory (WIL), Rancho Cordova, CA.

Lamb #2: An approximately 1 week old female lamb in moribund condition with a prolapsed right eye was found abandoned at lower Magnesia Spring on July 31, 1981. The eye was treated, antibiotics were given, blood was collected for serology, and radiographs were examined for signs of pneumonia. Personnel at the Living Desert Reserve bottle-fed and closely monitored the lamb during the next 9 days. On several occasions food was supplemented with intravenous feedings. On August 6 the lamb was given parenteral PI-3 killed vaccine and four-strain BT killed vaccine. The lamb was found dead the morning of August 9, 1981, and necropsy was performed. Tissues were sent to WIL for histopathology.

Table 1. Laboratories and test methods for disease studies on bighorn sheep sampled in the north end of the Santa Rosa Mountains during 1981.

DISEASE	LABORATORY	TEST METHOD
Parainfluenza-3	Calif. Dept. of Food & Agriculture Veterinary Laboratory Services, San Bernardino, CA	Serum Neutralization
	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	Serum Neutralization
Bluetongue	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	AGID[a] & Virus Isolation
	Dr. Osborn, University of California, Davis	AGID & Virus Isolation
	National Veterinary Services Laboratory, Ames, IA	AGID & Complement Fixation & Virus Isolation
Epizootic Hemorrhagic Disease	National Veterinary Services Laboratory Ames, IA	AGID & Complement Fixation & Virus Isolation
Contagious Ecthyma	National Veterinary Services Laboratory, Ames, IA	Complement Fixation
Leptospirosis (5 serotypes)	Calif. Dept. of Food & Agriculture Veterinary Laboratory Services, San Bernardino, CA	Plate Agglutination
Anaplasmosis	Calif. Dept. of Food & Agriculture Veterinary Laboratory Services, San Bernardino, CA	Card Agglutination
Toxoplasmosis	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	Passive Hemaglutination
Ovine Progressive Pneumonia	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	AGID
Brucellosis	Calif. Dept. of Food & Agriculture Veterinary Services Laboratory, San Bernardino, CA	Plate Agglutination
Infectious Bovine Rhinotracheitis	Calif. Dept. of Food & Agriculture Veterinary Services Laboratory, San Bernardino, CA	Serum Neutralization
	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	Serum Neutralization
Bovine Virus Diarrhea	Washington Animal Disease Diagnostic Laboratory Washington State University, Pullman, WA	Serum Neutralization

[a]Agar Gel Irnrnunodiffusion

Lamb #3: A 2½ month old male lamb was captured on June 6, 1982, by use of a hand-held net gun fired from a helicopter. This animal had been under close observation for over 30 hours precapture showing clinical signs of depression and pneumonia. The lamb was stabilized and treated with fluids and antibiotics. Blood was collected for serology, and radiographs were taken and examined. The lamb was transported to the San Diego Zoo Veterinary Hospital on June 7, where virus isolation was attempted from nasal wash, nasal swab, transtracheal wash, and heparinized blood (buffy coat). The lamb remained at the San Diego Zoo Veterinary Hospital for 5½ weeks, where he was treated with Carbenicillin and Gentomycin and nebulized with Vicks Vapostream and Mucomyst through the early periods of his recovery. He was transferred to the Los Angeles Zoo on July 14 for further observation.

Lamb #4: A male lamb was born to radio-collared ewe #6106 on June 14, 1982, and observed by researchers that afternoon and the morning of June 15. The lamb appeared healthy. The afternoon of June 15, researchers returned to find the lamb had just died. The carcass was collected and transported to the San Diego Zoo Veterinary Hospital for necropsy, histopathology, virus isolation, serology, and bacteriology.

RESULTS

During the 1981 lambing season only 1 lamb (female) survived to yearling age from the 45-50 ewes in the study area, and one more lamb (male) apparently entered the study area, giving a lamb/ewe ratio of 4/100. In 1982, at least 4 lambs (female) are known still alive as of mid-October, and a helicopter survey on October 17, 1982, gave a lamb/ewe ratio of 11/100, indicating 5-6 may still survive. Monitoring is continuing to document any further mortality of the 1982 lamb crop.

Results of serological tests are given in Table 2. In May, 77% of the tested free-ranging bighorn had high titers (median titer 1:128) to PI-3 and another 15% were suspect (low titers or different results from different labs). In November, 69% of the free-ranging bighorn had a significant titer to PI-3 (median titer 1:32) and another 8% were suspect. Of the captive bighorn, 80% of those tested in May were suspect to PI-3, and 40% of those tested in November were seropositive (median titer 1:16, both periods). Of those sheep tested in both May and November, titers to PI-3 fell from May to November. Therefore, this disease appeared more active in the herd before May. Exceptions to the declining titers were 2 captive rams that were vaccinated with a killed PI-3 virus vaccine to test its effectiveness for bighorn. Predictably, their titers increased by November.

BT seropositive results did not change from those animals that were sampled in both May and again in November, so data from both captures are presented together. Of the the 19 free-ranging individuals tested, 47% were seropositive. Of the 6 captive bighorn, 83% were seropositive and the other 17% suspect. BT virus was not isolated from any of the samples, but research has shown it is difficult to isolate from known positive animals. Work on domestic livestock and mule deer indicates the virus is usually detectable in the host for less than 2 weeks (Jessup 1982).

The percentage of seropositive samples to EHD again did not change from those individuals sampled both May and again in November, so again the data from both captures are presented together. In the free-ranging bighorn, 79% were seropositive, and in the captive bighorn 100% were seropositive. The antigenic properties are similar for EHD and BT. BT positive animals will react positively for EHD antibody; however, EHD positve animals do not cross react for BT antibody. In 1977, Turner and Payson (1982), found 27% of examined bighorn in the Santa Rosas seropositive to EHD, but their results are inconclusive, as all bighorn reacting to EHD reacted to BT as well. If we eliminate any of the results from this study that could be cross reactions to BT, 32% of the free-ranging bighorn and 17% of the captive bighorn still show evidence of exposure to EHD. EHD virus could not be isolated from any of the samples.

The serologic results for CE changed from May to November, so the data are presented separately for the two periods. In May 54% of the free-ranging bighorn tested were seropositive (median titer 1:40) (+ 8% anticomplementary) and 60% of the captive bighorn were serpositive (median titer 1:20). In November 92% of the free-ranging bighorn and 60% of the captive bighorn were seropositive (median titer for both 1:10).

All samples from May were seronegative for Leptospira spp., but in November 20% of the captive bighorn and 23% of the free-ranging bighorn were seropositive, with highest titer to *L. canicola* in all samples. The median titer was 1:64 for the free-ranging bighorn and 1:32 for the captive bighorn. Serologic results for *Anaplasma* remained the same from those individuals tested in May and again in November, with 84% of the free-ranging bighorn and none of the captive bighorn seropositive. All bighorn in May were negative to Toxoplasma,

Table 2. Seropositive results from bighorn in the Santa Rosa Mountains. In May and again in November 1981, 13 free-ranging and 5 captive bighorn were sampled. Some of the same animals were sampled both times (7 free-ranging, 4 captive). When the serological results did not change in individual animals sampled both in May and again in November, data are combined to calculate percentages seropositive. Where serological results did change in individuals sampled both in May and again in November, data are separated for calculation of percentages seropositive.

	FREE RANGING	CAPTIVE
PI-3		
May	77%	
(+ suspect)	(15%)	(80%)
November	69%	40%
(+ suspect)	(+8%)	
BLUETONGUE	47%	83%
(+ suspect)		(+17%)
EHD	79%	100%
w/o possible BT cross rxns	32%	17%
CE		
May	54%	60%
(+ AC)	(+8%)	
November	92%	60%
LEPTOSPIROSIS		
May	0%	0%
November	23%	20%
ANAPLASMOSIS	84%	0%
TOXOPLASMOSIS		
May	0%	0%
November	8%	
(+ suspect)		(40%)
OPP	0%	0%
BRUCELLOSIS	0%	0%
IBR	0%	0%
BVD	0%	0%
(suspect)	(5%)	

but by November 8% of the free-ranging bighorn had low titers and 40% of the captive bighorn showed titers at a suspect level. Serum antibodies were not detected against Brucella abortus, OPP virus, or IBR virus. Five percent of the free-ranging bighorn showed suspect titer levels to BVD; samples from captive bighorn were seronegative to BVD.

Fecal samples revealed no lungworm ova (Baermann technique). Whole blood direct selenium analysis indicated adequate levels of selenium ($\bar{X} = .455$ ppm). No pathogens were cultured from nasal or vaginal swabs. No confirmed signs of chronic frontal sinusitis or scabies were observed.

The following data were obtained from the 4 diseased lambs listed above.

Lamb #1: When sampled at approximately 1 week of age, this lamb had a colostral antibody titer to PI-3 of 1:256, and to CE of 1:80, and was seropositive to BT and EHD viruses and *Anaplasma.* It was seronegative to *Leptospira,* Brucella abortus, Toxoplasma, IBR virus, BVD virus, and OPP virus. At death 3 months later the lamb was seronegative to all these organisms. Severe chronic bacterial pneumonia was diagnosed as the cause of death, with the right and left anterior lobes of the lung adhered to the ribs. About 90% of the 3 lobes of the right lung was hepatized with only the most distal diaphragmatic lobe of normal texture. Only about 30% of the left lung appeared to have normal tissue, most of that in the ventral diaphragmatic lobe. Mononuclear cuffing and hyperplasia of bronchial epithelium indicating longstanding respiratory disease was present as well as acute necrotinizing and suppurative lesions. The animal showed marked splenic germinal center depletion indicative of immune suppression.

Lamb #2: Radiographs taken immediately post capture indicated severe pneumonia, and serum collected was positive to BT and EHD viruses as well as Toxoplasma. Seronegative results were obtained to IBR, BVD, and PI-3 viruses as well as to *Leptospira,* Brucella abortus, and Anaplasma. The prolapsed right eye was probably from an injury and not necessarily related to the respiratory infection. At necropsy, parietal and pleural adhesions of the anterior ventral lobes of the lungs were noted. The anterior ventral lobes were consolidated and contained purulent material in the alveoli and bronchioles. Areas around the consolidation were hemorrhagic and tissues were crepitant. Histopathology confirmed diagnosis of pneumonia with lesions suggesting upper respiratory disease preceding bacterial overgrowth and lung tissue destruction.

Lamb #3: At capture the lamb was seropositive to CE virus (1:40 titer), and seronegative for IBR, BVD, PI-3, BT, and EHD viruses. Radiology indicated severe pneumonia. Clinical signs of illness were depression, foamy salivating mouth, and nasal discharge. No virus was isolated, but a mixed bacterial flora that included Pasteurella spp. was cultured from the nasal passage and trachea. Under heavy antibiotic treatment, the animal's lungs have cleared. This lamb developed papular and erosive lesions on the lips, dental pad, and gingival mucosa 12 days post capture. Scrapings were submitted for electron microscopic examination and inoculated into cell cultures for virus isolation, but no virus could be cultured or revealed. Sera collected two weeks and one month post capture were positive for BT, suggesting that the oral lesions were due to BT. The lesions have since cleared.

Lamb #4: The necropsy showed good nutritional status with large quantities of perirenal and cardiovascular brown fat and subcutaneous fat deposits. There appeared to be only 10% of functional lung present, this located in the apical lobe of the left lung. The lungs appeared to have never expanded properly, and the animal died of anoxia. Blooc collected at necropsy was seropositive to BT virus and seronegative to IBR and BVD viruses. *Escherichia* coli only was recovered from cultures of liver, lung, and trachea, a probable postmortem invader.

DISCUSSION

The above postmortem results provided conclusive evidence that the lambs in the north end of the Santa Rosa Mountains were dying of pneumonia. Adult bighorn had been observed showing clinical signs of pneumonia (respiratory difficulty, coughing, and nasal discharge), but while most adults appeared able to live with the disease, the lambs could not survive.

Pneumonia has often been diagnosed as the cause of bighorn deaths, but the etiology is often unclear (Hailey et al. 1972, Hibler et al. 1972, Parks et al. 1972, Spraker 1977, Spraker and Hibler 1977, Foreyt and Jessup 1982). Pasteurella spp., the most common and pathogenic bacteria isolated from bighorn, are probably normal inhabitants of the upper respiratory tract of healthy animals, but when they successfully invade the lower respiratory tract, they are pathogenic (Spraker 1977, Dyer 1982). Bacterial pneumonias are usually secondary to the damage caused by a primary agent or combination of agents such as a virus, microplasma, parasitic lungworm, or environmental stressors. With no evidence of parasitic lungworm infection in these animals, we suspected a virus or combination of viruses and environmental stressors predisposed the lambs to the bacterial pneumonia. Stressors can act to lower the bighorn's resistance to disease by producing excessive levels of cortisol that suppress the immune system.

Samples were tested for exposure to 3 common bovine respiratory diseases: PI-3, BVD, and IBR. These respiratory viruses acting alone are only mildly pathogenic, but they compromise the pulmonary defense mechanisms, allowing invasion of the lower respiratory tree by the upper respiratory flora (Heuschele 1981, Salsbury 1981, Dyer 1982). This study and a serological survey of this same bighorn herd in 1977 (Turner and Payson 1982) indicated that BVD and IBR were not problems in this population. However, the high percentage of seropositive results and high titer levels to PI-3 virus indicate that PI-3 could be a factor in this lamb mortality. In 1977, no serologic evidence of PI-3 virus activity was found (Turner and Payson 1982), indicating recent introduction of the disease organism into the Santa Rosa bighorn population.

PI-3 virus destroys the mucocillary cells that line the lower respiratory tract, hindering the clearance of infective agents (Heuschele 1981, Salsbury 1981, Dyer 1982). Originally thought to be mainly a disease of cattle, PI-3 has recently been found to be common in wild and domestic sheep worldwide (Salsbury 1981, Lehmkuhl and Cutlip 1982), and when coupled with stress and bacteria it can trigger a high incidence of fatal pneumonia in both lambs and adults (Salsbury 1981). PI-3 virus has been isolated from Rocky Mountain bighorn *(O.c.* canadensis) dying of pneumonia (Parks et al. 1972) and samples seropositive to PI-3 have been found in Rocky Mountain bighorn populations (Parks and England 1974; Charles P. Hibler, pers. comm.). as well as in the desert bighorn population of the San Gabriel Mountains, California (DeForge 1980). But prior to 1981, no other herds of bighorn sampled in California had shown exposure to PI-3 (Jessup, unpubl.).

PI-3 virus is also believed to act as an immunosuppressant (Dyer 1982) and could be acting to compromise the lambs' defenses to pathologic agents. Lamb #1 showed marked splenic germinal center depletion indicative of immune suppression. Serum from this animal showed high colostrol antibody response to PI-3, CE, BT, and EHD viruses as well as to Anaplasma at 1 week of age, but at death was seronegative to all these organisms. This could indicate an active PI-3 infection and subsequent suppression of the humoral immune response or an inability to build antibody response after receiving the maternal antibody in the colostrum.

The high serologic response from our samples to BT and EHD viruses indicated that pneumonia of this bighorn population could also be related to one of these two closely related viruses. Both viruses may be associated with pneumonia, and clinical signs in bighorn probably could not be differentiated in the field from other causes of pneumonia. BT has been documented as a primary cause of pneumonia in bighorn sheep (Robinson et al. 1967). Both of these diseases are non-contagious and insect borne, but while BT is common in both domestic and wild ruminants (Trainer 1970), EHD has been documented mainly in deer populations (Trainer and Karstad 1970). When Turner and Payson (1982) surveyed this same bighorn herd in 1977, they found seropositive results for EHD from 27% of samples and for BT from 36% of samples. BT has been diagnosed in bighorn losses in the Lava Beds National Monument, California (Blaisdell 1975), in New Mexico (Robert E. Lange, pers. comm.), and in Texas (Robinson et al. 1967, Hailey et al. 1972).

In cattle BT has been shown to cause abortions and malformities in calves, and at birth 50% of calves of infected heifers have detectible BT virus (Luedke et al. 1977). Since some collared ewes never were observed with lambs, we suspected abortions and/or birth defects with subsequent death occurred in this population. As an example, lamb #4 died at 1 day of age, seropositive to BT virus and with lungs that did not properly inflate. Had the mother not been observed the day of parturition she might have been considered barren.

No change in seriologic results for BT between May and November in this study or between January and June in the 1977 study (Turner and Payson 1982) could indicate that there is no specific BT season in the study area. The usual BT vector, Culicoides variipennis, may survive in this relatively frost-free climate year-round. Breeding habitat for *Culicoides* sp. gnats consists of warm shallow water, high in organic matter. Increased populations of gnats could be expected in unseasonably wet years, as occurred in the study area from 1976177 through 1979180.

Entomologists from the Coachella Valley Mosquito Abatement District, investigating the possible gnat vectors in the study area in November 1981, found *Culicoides* variipennis ssp. sonorensis as well as C. *brooklyni.* Other possible vectors they found were the closely related Leptoconops knowltoni, L. werneri, and L. foulki and black flies of the family Simuliidae (Mike Wargo, pers. comm.). BT virus isolation from these vector species was attempted at Cooperative Veterinary Extension Service, Berkeley, California, but yielded negative results.

CE is an infectious dermatitis of sheep and goats caused by a pox virus that produces painful lesions primarily on the gums, lips, and teats. Affected ewes will not allow nursing, and lambs may starve to death, become prey, or die of secondary disease and malnutrition. CE has been documented in Rocky Mountain bighorn in Colorado (Lance et al. 1981) and western Canada (Samuel et al. 1975). A yearling ram in the study area had a recurring darkened crusty chin that could be indicative of CE. Turner and Payson (1982) suggested that the low level serologic response to CE in 1977 in 80% of the free-ranging bighorn they tested in the Santa Rosas indicated a chronic antigenic challenge. This study further confirmed that possibility.

The low percent of seropositive results to *Leptospira* spp. may indicate a problem of marginal significance in the Santa Rosas. In 1977 Turner and Payson (1982) found 18% seropositive results to Leptospira. Pathologic effects of this disease have not been documented in bighorn.

Toxoplasma and Anaplasma infections usually only cause low grade infections in sheep, and most cases are subclinical. We do not expect these diseases to be debilitating factors in bighorn.

October lamb survival figures for 1982 were better than the previous year, but the lamb to ewe ratio is already below the absolute minimum fall ratio of 26 lambs per 100 ewes needed to maintain a stable population (McQuivey 1978). It cannot be demonstrated that direct intervention was totally or partially responsible for the 1982 increased lamb survival. Nevertheless, direct intervention in the form of capture, sampling and treatment did not result in increased mortality of captured bighorn, and continued testing and treatment should be included in future efforts to insure the survival of this population.

CONCLUSION

We present here pathologic evidence that a pneumonic process has been killing the lambs of the Santa Rosa Mountains, and serological evidence that the combination of PI-3, BT, EHD, and CE viruses may have been initiating factors to this pneumonia. This does not preclude the possibility that other stressors such as nutrition, interspecific competition, predation, changes in seasonal weather patterns, human impacts, etc. may also have been important initiating factors triggering this pneumonia complex.

ACKNOWLEDGMENTS

The authors greatly appreciate the assistance and cooperation of the California Department of Fish and Game, San Diego Zoo, Los Angeles Zoo, Palm Desert Pet Hospital, Living Desert Reserve, P.L. Boyd Deep Canyon Research Center, and the researchers and members of the Desert Bighorn Research Institute. This research was funded by grants and donations from the Rogers Foundation, Mzuri Safari Foundation, Foundation for North American Wild Sheep, Shikar Safari, Annenberg Fund, Inc., and numerous contributions from private individuals. Special thanks go to Drs. Phil Robinson and Werner Heuschele, San Diego Zoo, for technical advice and assistance.

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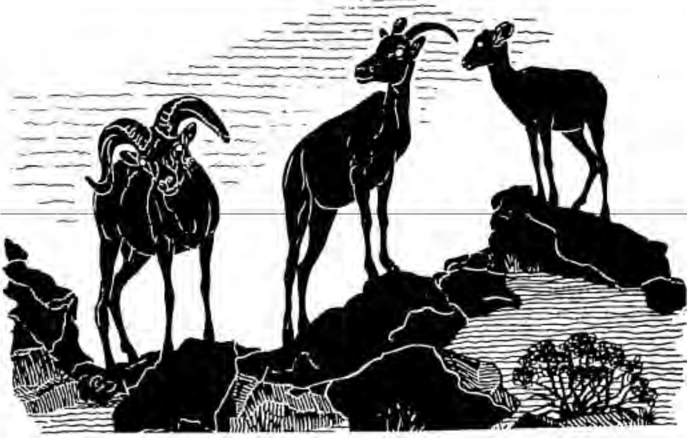

FOOD HABITS OF FERAL BURROS AND DESERT BIGHORN SHEEP IN DEATH VALLEY NATIONAL MONUMENT

Tim F. Ginnett
Charles L. Douglas
Cooperative National Park Resources Studies Unit
University of Nevada, Las Vegas

Abstract. Food habits of sympatric feral burros *(Equus asinus)* and desert bighorn sheep (Ovis canadensis nelsoni), were determined monthly during 1980 in the Cottonwood Mountains of Death Valley National Monument. Analysis of feces indicates that burros and bighorn sheep utilize many of the same forage taxa, resulting in a moderate degree of dietary overlap. Bighorn sheep maintained constant proportions of browse, grasses, and forbs in their diets year-round. Seasonal use of individual forage taxa, however, was subject to wide variation. Burros, contrastingly, were found to switch from a predominantly browse diet in winter to a diet consisting mainly of grasses during summer. Forb use by burros remained at a constant low level year-round. Burro use of individual forage taxa followed the same seasonal trends as the variations in browse, grass, and forb categories. It is postulated that potential for forage competition exists, and that due to their more highly opportunistic pattern of feeding, burros should be expected to outcompete desert bighorn sheep if a competitive situation were to exist.

INTRODUCTION

"Except for most of the ocean, the wilderness is in retreat or is being changed in character. In another thousand years most of the world's surface and much of its fresh water will have been altered and fashioned by man or at any rate covered with living communities of plants and animals profoundly different from what they were even a few hundred years ago."

These words written by Charles Elton (1958)summarize one of the greatest problems facing modern conservation biologists, the rapid spread or invasion of organisms introduced by man into native ecosystems. Yet in the more than 20 years since these words were written, there is still a paucity of quantitative information on the effects of many of these introductions on native ecosystems.

The relatively recent introductions of the domestic donkey or burro into the southwestern U.S. represents one such example. The Death Valley area, in particular, supports the largest concentration of feral burros in the United States. The burro population within Death Valley National Monument rose from an estimated 800 animals in 1968 to over 2100 in 1980 (USDIINPS 1981). Concurrently, the desert bighorn sheep population declined from an estimated 915 animals in 1961 (Welles and Welles 1961)to ca. 520 animals in 1976 (USDAINPS 1981). Since burros and desert bighorn occupy many of the same habitats within the monument, park managers there have become increasingly concerned about possible effects of burros on the native bighorn sheep.

Among other things, burros have been accused of competing with bighorn for forage (e.g. Dixon and Sumner 1939, McMichael 1964, St. John 1965, Mensch 1970), and are thus presumed responsible, in part, for the recent declines in bighorn populations. The previously cited examples, however, based their conclusions on circumstantial evidence and/or incomplete data. Seegmiller and Ohmart (1981) published the first rigorously quantitative study detailing burro and bighorn interactions. While they were unable to state that competition was occurring between burros and bighorn, they concluded that the species exhibited considerable niche overlap and that if resources were to become limiting, burros would be favored in the resulting competition. Their study area in Arizona was very unlike Death Valley however, having an essentially unlimited water supply, and nearby agricultural fields which the animals commonly foraged in. To our knowledge, no quantitative information exists demonstrating forage competition between burros and bighorn sheep. Competition, however, is well known to be difficult to demonstrate in the field (Pianka 1974).

This study compares seasonal food niches of desert bighorn sheep and feral burros in one area of Death Valley National Monument in an attempt to evaluate the potential for forage competition between the two species.

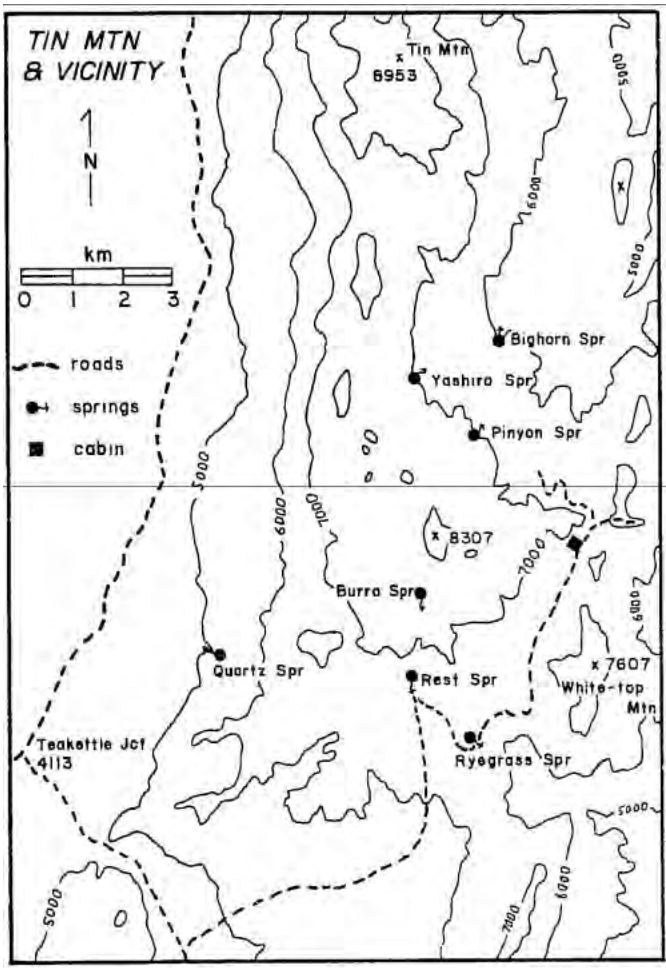

Figure 1. Map of the study area showing permanent water sources and prominent landmarks. Contour interval equals 1000 ft.

DESCRIPTION OF THE STUDY AREA

The study area was located in the northern end of the Cottonwood Mountains of Death Valley National Monument, California. The area stretches south for approximately 16 km from the summit of Tin Mtn., ca. 9 km east from the Teakettle Junction road, and covered approximately 150 km^2 (Fig. 1).

Geologically, the Cottonwoods consist of Paleozoic marine sediments of a wide range of ages which are underlain by Precambrian metamorphic and sedimentary formations. Scattered intrusions of Tertiary age granites are also present (USDIINPS 1981).

The mountains rise abruptly on the western side, forming an extremely steep escarpment, and descend in a somewhat gentler fashion on the eastern slope. The topography varies from flat alluvial drainages, through rolling hills, to vertical limestone cliffs as much as 160 m in height. The majority of the area is extremely steep and rugged. Elevations range from 1253 m at Teakettle Junction to 2729 m at the summit of Tin Mtn. The study area is bisected by a northwest-southeast running ridge averaging ca. 2450 m in elevation. The northern portion forms a basin which drains easterly, through Bighorn Gorge, into Death Valley. The southern area drains to the west into Racetrack Playa and Hidden Valley. Seven permanent, year-round water sources exist in the study area (Fig. 1). Quartz Spring is enclosed by a fence which allows bighorn access but excludes burros. Rest Spring is similarly fenced but neither species is known to use it. Burro Spring is heavily used by burros and is only used occasionally by bighorn. All other springs are heavily used by both animals. During winter and after summer thundershowers, water is available in temporary catchments, and in several ephemeral seeps.

Plant communities on the study area include Creosote Bush scrub, Shadscale scrub, Sagebrush scrub, Pinyon-Juniper woodland, and Desert wash (after Munz 1974).

MATERIALS AND METHODS

Attempts were made to collect up to 20 fecal samples for each species, once each month throughout 1980. Fresh bighorn samples were available only for a total of eight months, including January, and June through December. Fresh burro feces were gathered every month except February. Table 1 lists the sample sizes obtained each month.

Table 1. Number of fecal collections from individual animals analyzed each month during 1980.

	Bighorn	Burro
January	4	7
February	-	-
March	-	13
April	-	20
May	-	17
June	9	20
July	20	20
August	20	17
September	20	19
October	18	16
November	7	16
December	11	20
Total	109	185

Burro feces were collected over several widely separated portions of the study area. To ensure freshness, burro feces were collected while still moist. Freshness of bighorn samples was ensured by repeatedly visiting three areas known to be used by bighorn and removing new pellet groups from within fixed collection areas. When the freshness of a sample was ambiguous, it was removed from the collection area to reduce any chance of sampling error. Fresh bighorn samples were occasionally available elsewhere on the study area. Samples were dried in an oven at ca. 60°C for several days and stored in paper sacks until analyzed. Analysis was accomplished by microhistological technique (e.g. Storr 1961, Sparks and Malechek 1968, Free et al. 1970, Hansen 1971). Each fecal sample was analyzed singly rather than compositing samples as is usually done (e.g. Korfage et al., Tilton and Willard 1981). Each sample was analyzed using the method of Sparks and Malechek (1968), except that a Nomarsky interference contrast microscope was used to count fragments. Occasionally, two or more species of the same genus were not completely separable by fecal analysis and were therefore lumped by genus. These include *Ephedra nevadensis* and *E. viridis, Phacelia frernontii* and *P. valis-morte, Penstemon floridis* and *P. fruticiforrnis, Brornus rubens* and *B. tectorurn,* and several species each of *Stipa* and *Eriogonum.* In addition, an undetermined number of the family Asteraceae are lumped at the family level because they possess very similar floral parts (i.e. pappus bristles, palea, etc.).

RESULTS

Burro Diets. Forty-eight taxa were identified in burro feces. A minimum of 2 additional species were present but were unidentifiable due to a lack of reference material. Table 2 shows the number of taxa used by burros on a monthly basis. The number of taxa used by the population increased from a low during January to a high during July and declined thereafter. This was due to the increased availability of forbs during early summer. The number of taxa found in individual fecal samples, however, showed no seasonal trends. A Kruskal-Wallis test, performed on the mean numbers of taxa in individual burro diets, yielded only a weak significant difference ($P = 0.049$) between months. In addition, individual bur-

Table 2. Numbers of forage taxa found monthly in feral burro feces during 1980.

Month	Pop. Use	$\overline{X}$ Individual	S.D.	n	% of Pop. Use
January	19	10.57	2.44	7	53.55
March	22	10.31	1.81	13	46.86
April	21	10.00	2.43	20	47.62
May	27	11.29	1.87	17	41.81
June	25	9.90	2.00	20	39.60
July	30	10.85	1.96	20	36.17
August	26	10.18	2.48	17	39.15
September	24	9.32	1.81	19	38.83
October	23	9.69	2.75	16	42.13
November	25	9.75	2.56	16	39.00
December	22	8.85	1.39	20	40.23
Annual	48	10.02	2.26	185	20.85

Table 3. Diets of feral burros in the Cottonwood Mountains during 1980. Numbers represent percent composition.*

Forage	JAN	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Atriplex confertifolia	51.13	37.73	31.78	6.08	4.11	2.11	13.34	36.65	45.37	38.29	52.97	29.14
Cowania mexicana	6.93	9.86	7.95	6.83	1.68	2.50	1.04	1.49	2.54	1.12	6.54	4.41
Kochia americana	6.29	18.09	10.77	2.51	0.52	2.27	1.25	0.91	1.09	1.61	0.30	4.06
Coleogyne ramosissima	1.01	7.75	4.68	3.56	0.21	1.83	0.16	-	1.11	0.46	2.71	2.13
Yucca brevifolia	1.43	1.16	0.70	-	0.05	0.19	0.44	1.56	1.71	1.93	1.29	0.95
Ephedra spp.	0.30	2.08	2.99	3.08	0.63	1.31	0.60	1.14	1.77	0.92	1.85	1.52
Artemisia spinescens	-	0.84	1.30	0.19	-	0.03	0.16	0.29	0.30	1.30	0.61	0.46
Eurotia lanata	-	0.50	1.16	0.85	1.22	2.09	9.74	7.14	10.06	15.12	2.98	4.60
Other browse	0.82	2.74	1.04	0.77	0.20	0.77	0.29	1.10	2.06	0.98	0.72	1.08
Total browse	67.91	80.75	62.37	23.97	8.62	13.10	27.02	50.28	66.01	61.73	69.97	48.35
Aristida glauca	-	0.08	-	0.03	0.79	0.23	1.21	1.59	0.97	5.18	3.18	1.20
Sitanion jubatum	7.75	1.68	6.14	47.67	35.26	49.43	41.40	29.84	20.28	18.72	14.82	24.82
Hilaria jamesii	0.22	0.08	0.12	0.75	11.38	9.51	17.32	8.56	3.84	3.76	2.98	5.32
Oryzopsis hymenoides	0.97	3.32	10.76	16.84	18.98	7.66	4.71	2.98	1.64	1.04	1.22	6.36
Bromus spp.	0.52	1.58	13.83	2.08	5.87	0.19	0.72	0.11	0.36	0.74	0.49	2.41
Stipa spp.	0.52	0.41	0.46	1.79	2.25	0.97	0.45	0.11	0.67	1.11	0.92	0.88
Other grass	0.14	-	0.29	0.37	1.00	0.03	0.04	0.11	0.12	0.06	-	0.20
Total grass	10.05	7.15	31.60	69.53	75.53	68.02	65.85	43.21	27.94	30.61	23.61	41.19
Sphaeralcea ambigua	0.69	0.33	1.23	0.40	0.70	12.73	2.03	0.98	0.55	0.31	0.43	1.85
Other forbs	0.30	0.16	0.23	0.52	3.65	0.35	0.52	0.46	0.24	0.24	0.06	0.61
Total forbs	0.99	0.49	1.46	0.92	4.35	13.08	2.55	1.44	0.79	0.55	0.49	2.46
Unknowns	21.06	11.62	4.58	5.56	11.48	5.75	4.60	5.07	5.26	7.10	5.92	8.00

'Partial list only. A complete list is available from either author ros used less than half the number of taxa used by the population during most months.

Table 3 lists the most important species occurring in burro diets. Burros were primarily browsers during winter months but switched to a diet consisting mainly of perennial grasses during spring and summer. This switching coincided with the start of plant growth during spring. Forbs constituted a small part of the diet with a small peak in use occurring in July. Atriplex confertifolia was the most heavily consumed browse species during most of the year. Eurotia lanata was used mainly during fall, reaching peak utilization in November, and declining thereafter. Usage of *Cowania mexicana* was highest during late winter, declined steadily during the year, and rose again in December.

The first grasses to be used heavily by burros in spring were the annual Bromus spp., which have the earliest growth phenology of any major forage plant on the study area. It cures early, however, and is essentially unused after July. By May, *Sitanion jubatum* is the most commonly consumed grass and forms the major grass component of the diet for the rest of the year. *Oryzopsis* hymenoides and *Hilaria jamesii* are the other two most heavily used perennial grasses, with *Oryzopsis* showing a peak in usage during June and *Hilaria* usage peaking in August. There was no observable difference in phenology of *Oryzopsis* or *Hilaria.* Both were cured by mid-July.

While a number of forb species were represented in burro diets, including species of Mentzelia, Chaenactis, and Phacelia, Sphaeralcea *ambigua* was the only forb species of great importance, forming over 10% of the diet during July.

Table 4. Numbers of forage taxa found in desert bighorn sheep diets during 1980.

Month	Pop. Use	$\bar{X}$ Individual	S.D.	n	% of Pop. Use
January	23	13.75	2.06	4	59.78
June	24	10.89	1.90	9	45.38
July	31	12.55	2.50	20	40.48
August	30	13.10	2.36	20	43.67
September	28	12.45	2.63	20	44.46
October	25	12.56	2.23	18	50.24
November	20	12.14	1.07	11	60.70
December	22	11.55	1.81	12	52.50
Annual Diet	44	12.41	2.29	109	28.20

Bighorn **Diets.** Forty-four taxa were identified in bighorn fecal material. The unidentified fraction contained a minimum of 3 species. Numbers of taxa ranged from 31 during July to 20 during November (Table 4). Regression of the number of taxa used by the population versus sample size indicates that the fluctuation observed is significantly related to sample size ($r^2 = .72$). This indicates that during at least some months sample sizes were too small to obtain a complete listing of taxa forming the diet. In general, however, relatively few taxa ac-

Table 5. Diets of desert bighorn sheep from the Cottonwood Mountains during 1980. Numbers represent percent composition.*

Forage Taxa	JAN	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Atriplex confertifolia	3.39	3.61	4.91	6.87	6.81	16.26	9.87	23.43	9.39
Cowania mexicana	3.56	6.00	1.18	1.10	0.47	0.86	7.14	0.84	2.64
Yucca brevifolia	1.37	0.36	0.48	0.90	1.49	1.26	-	1.81	0.96
Cercocarpus intricatus	28.44	12.78	11.62	17.64	14.69	14.61	1.28	7.10	13.54
Ephedra spp.	6.26	23.33	24.96	10.78	6.82	5.91	8.38	7.36	11.73
Artemisia spinescens	1.99	0.54	0.53	1.32	3.63	2.80	4.09	1.41	2.04
Eurotia lanata	10.26	0.90	11.10	15.15	19.26	19.30	19.24	11.13	13.29
Other browse	2.15	3.47	3.40	11.91	0.81	0.18	1.91	1.54	1.92
Total browse	57.42	50.99	58.18	55.67	53.98	61.18	51.91	54.62	55.51
Aristida glauca	4.22	0.18	2.51	2.16	4.16	10.81	19.07	16.21	7.42
Sitanion jubatum	4.63	12.08	5.02	5.62	8.15	6.67	5.42	4.05	6.45
Hilaria jamesii	0.78	0.54	20.76	21.75	25.41	7.98	6.64	5.23	11.14
Oryzopsis hymenoides	1.56	8.94	2.18	5.19	2.13	1.95	2.78	1.25	3.25
Bromus spp.	1.37	3.49	0.32	0.59	0.56	1.20	0.64	1.11	1.16
Poa nevadensis	0.19	3.64	0.48	0.51	0.51	0.28	3.65	1.25	1.31
Stipa spp.	24.45	7.37	1.07	3.43	1.54	4.90	4.31	13.65	7.59
Other grass	0.19	—		0.24	0.13	0.06	—	—	0.08
Total grass	37.41	36.20	32.34	39.49	42.59	33.85	42.51	42.75	38.40
Spaeralcea ambigua	0.59		1.72	0.91	1.21	1.78	-	0.28	0.81
Other forbs	0.38	6.12	2.44	1.96	1.19	1.85	0.63	1.40	1.92
Total forbs	0.97	6.12	4.16	2.87	2.40	3.63	0.63	1.68	2.73
Unknowns	4.18	6.72	5.30	2.01	1.03	1.37	4.96	1.67	3.41

'Partial list only. A complete list is available from either author count for the majority of the diet; therefore any taxa not found are probably of minor importance. A similar analysis with data from burro diets yielded no such correlation. As was found with burros, individual bighorn used a lesser number of forage species than the population as a whole. The mean-monthly number of taxa in individual bighorn diets did not change significantly throughout the year (Kruskal-Wallis test, $P = .22$).

The seasonal fluctuations in browse, grass, and forb usage are shown in Table 5. Usage of the 3 categories did not change markedly with season. Bighorn sheep were primarily browsers, with grass usage being next in importance. Sheep consumed relatively few forbs, the peak use occurring in June.

While use of the 3 forage classes did not change seasonally to any great degree, usage of individual forage species within each class exhibited wide seasonal variation. Cercocarpus *in-tricatus* formed the largest proportion of the annual diet. Usage was highest during January, declined steadily throughout the year, and rose again in December. Use of *Atriplex* confertifolia showed an opposite pattern of usage to that of Cercocarpus. The lower use occurred in January, increasing to a high in December. Ephedra spp. formed less than 10% of the diet for most of the year but increased to ca. 25% of the diet in June and July. Use of *Eurotia* lanata was highest during fall months, with lesser usage occurring during winter and spring.

Hilaria jamesii formed the largest proportion of grasses in the annual diet. *Hilaria* was followed in order of importance by *Stipa,* Aristida, Sitanion, Oryzopsis, Poa, and Bromus spp. As was seen with browse, no predictable seasonal trends in grass use are apparent. *Hilaria* was lightly used during winter but was heavily used during summer months. *Stipa* usage followed an opposite pattern, with usage being highest in winter and lowest during summer. Use of Aristida followed a trend similar to that described for A. *confertifolia.* The other grasses mentioned each formed less than 10% of the diet during each month.

Niche Overlap. Dietary niche overlap was caluclated two ways. The first overlap estimate is simply calculated as the number of shared forage taxa, expressed as a percent of the total number of taxa used by both burros and bighorn. Since this method does not take into account differing proportional usages of each taxa, a second estimate was calculated which takes proportions into account. The index used was the percentage similarity index (PS, Whittaker 1975). PS is calculated by summing the lesser of the paired values for each forage taxa in the diets of desert bighorn sheep and burros. Seegmiller and Ohmart (1981) used this index to compare bighorn and burro diets in Arizona; thereby data from this study can be compared directly with their data.

Table 6. Percent taxa in common and PS values for 1980 bighorn sheep and burro diets

Month	Total # Taxa	# in Common	% in Common	PS
January	27	14	51.85	17.35
June	35	14	40.00	34.78
July	38	23	60.53	28.24
August	33	23	69.70	51.76
September	35	17	48.57	39.97
October	31	17	54.84	46.25
November	27	18	66.67	46.94
December	28	16	57.14	44.86
Annual Diet	55	37	67.27	41.14

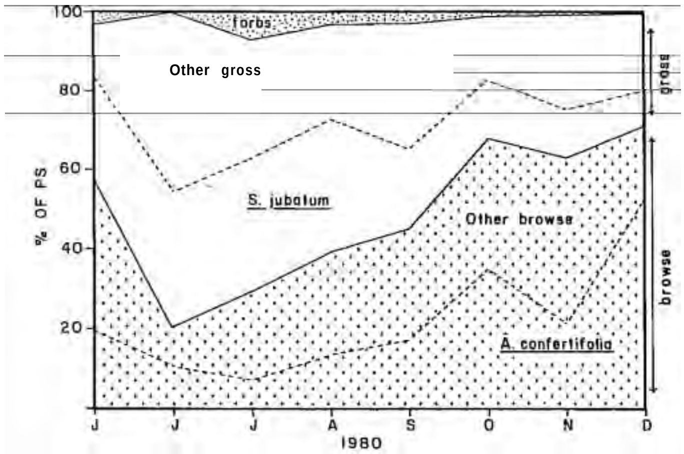

Figure 2. Percent contribution of browse, grasses, and forb categories to observed PS values for eight months during 1980.

A total of 55 forage taxa were identified in annual diets of burro and bighorn sheep collectively. Of these, 37 (67.3%) were used in common. Table 6 lists numbers of taxa found collectively in diets of both species, the number and percent used in common, and PS values for each month that data were available. Similarities based on numbers of shared taxa are consistently greater than PS values.

Figure 2 illustrates the relative contribution of browse, grass, and forb categories to PS. Forbs were lightly utilized, and therefore accounted for only a small proportion of the niche overlap. Common use of grasses contributed the most to niche overlap during spring and summer, while overlap in browse use accounted for the largest proportion of PS during fall and winter. Roughly 50% of niche overlap during any given month was due to common use of 2 species, *Sitanion jubatum* and Atriplex *confertifolia.*

In order to further identify the relationships of monthly bighorn and burro diets, an agglomerative, hierarchical, weighted pair-groups cluster analysis (Mueller-Dombois and Ellenberg 1974) was applied to the data. The clustering algorithm used was PS. The intention here is not to classify the diets into real clusters on the basis of similarity, but rather to examine both inter- and intraspecific patterns in diet similarity. In Figure 3, data are arbitrarily broken into clusters at the 60% similarity level for ease of viewing. The results indicate that bighorn diets are more similar to each other at all times of the year than they are to any monthly burro diet. Spring and summer burro diets were slightly more similar to bighorn diets than they were to burro diets from other times of the year. Within each species, there appears to be a strong temporal component to diet similarity with adjacent monthly or seasonal diets being more similar to each other than non-adjacent months.

DISCUSSION

Information on burro food habits is scant, particularly for California populations. Browning (1960) analyzed 20 stomach samples taken during fall and spring in Death Valley and found that burros consumed 51% browse, 10% grasses, and 39% forbs. In fall and winter stomach samples from Death Valley, Douglas (unpubl. data) found burros to use 55.2% browse, 24.2% grasses, and 20.6% forbs. Woodward and Ohmart (1976) in the Chemehuevi Mtns. of California, found an annual diet consisting of 61.1% browse, 3.9% grasses, and 30.1% forbs. Other studies have also found burros to be browsers (Seegmiller and Ohmart 1981, Moehlman 1974). Hansen and Martin (1973) and Walters and Hansen (1978) found burro diets in the Grand Canyon to consist of 61% and 70% grasses respectively. McMichael (1964), Seegmiller and Ohmart (1981), and Woodward and Ohmart (1976) have shown forbs to be important components of burro diets during spring.

The above information, with the data from this study, suggests that burros are opportunistic in their feeding habits, utilizing whatever forage may be available to them (Browning 1960), possibly having a preference for grasses (Hansen and Martin 1978) or forbs, depending upon availability.

Although a number of papers have been published on desert bighorn food habits (e.g. Hansen and Martin 1973, Brown et al. 1977, Smith et al. 1977, Mensch 1970, McMichael 1964), only a few have dealt with seasonal changes in the diet (Barrett 1964, Seegmiller and Ohmart 1981). As Browning and Monson (1980) have recently reviewed desert bighorn food habits, only a few pertinent comparisons will be made here. Seegmiller and Ohmart (1981) found bighorn to be browsers throughout most of the year, switching to a predominantly forb diet during March and April. They also reported light use of grasses and postulated that this was due to low availability. Other studies have shown sheep to be primarily browsers (Walker and Ohmart 1978, Russo 1956). Conversely, Brown et al. (1975, 1977) reported bighorn from central and southern Nevada to be mainly grazers, consuming up to 81% grasses. Their sample set, however, consisted primarily of rams taken during fall hunting seasons and do not represent an adequate estimate of annual diets of sheep. Due to the extreme variability in diets of bighorn sheep between sites, few generalizations can be made about their feeding habits except that they apparently have the ability to exist on a wide range of available forages.

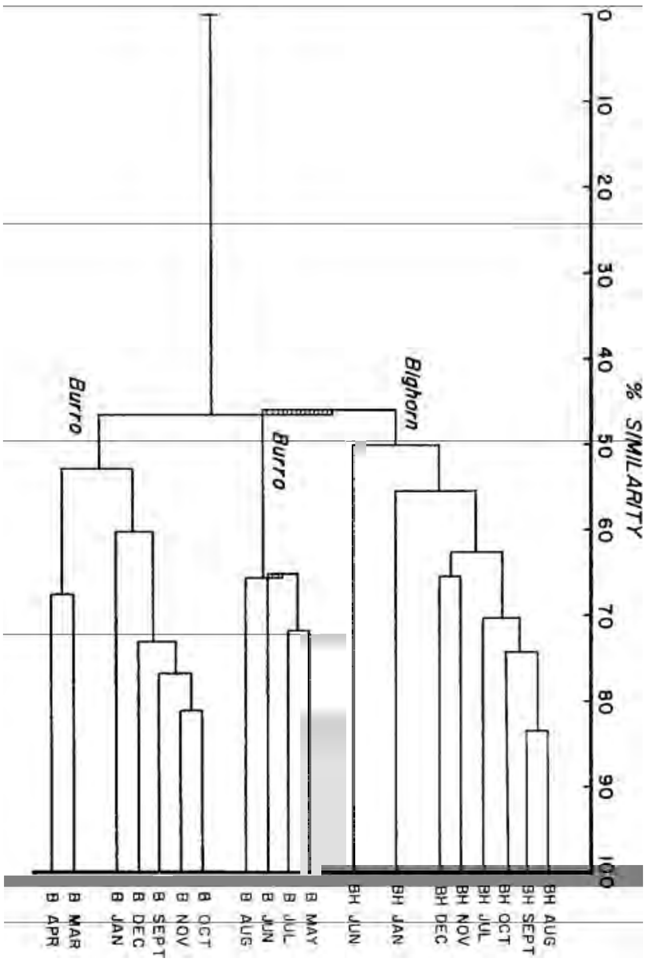

Figure 3. Dendrogram depicting the results of a cluster analysis of monthly desert bighorn and burro diets during 1980. (BH, bighorn; B, burro).

Two or more species exhibit niche overlap if there is common use of one or more resources. The presence of overlap has often been taken as being indicative of a competitive situation, particularly in literature pertaining to desert bighorn sheep and feral burros (McMichael 1964, St. John 1965). Niche overlap by itself, however, does not necessarily imply competition. Depending on the resource in question, niche overlap can be taken both as evidence for or against the existence of competition (Colwell and Futuyma 1971). The degree of niche overlap can be indicative though, of the potential for a competitive interaction were the shared resource to become limited. In order to document the existence of competition between two species, the following facts need to be established: (1) existence of past or present niche overlap, (2) the limiting nature of the resource in question, and (3) depression of the reproductive potential of one or both populations.

Feral burros and desert bighorn in the Cottonwood Mountains exhibit overlap in their food niches. As it is not known which factors presently limit bighorn and burro populations in Death Valley, no definitive statement on forage competition is possible. If, however, as White (1978) has postulated, most herbivore populations are limited by the amount of available nitrogenous forage, then the potential for competition may be very high.

Burros outnumber bighorn on the study area by at least a factor of two. In addition, since burros are not restricted to giving birth during one time of the year as are desert bighorn, they are likely to have a higher reproductive potential than are bighorn. Finally, because of their typical equid digestive system, burros are theoretically capable of existing on lower quality forages than could a ruminant. This could be an enormous competitive advantage in an arid environment which is characterized by frequent years of low forage production and low forage quality. For these reasons, we feel that the feral burro should be expected to outcompete desert bighorn in most situations, and should be removed as quickly as possible from habitats also occupied by (or potentially occupied by) desert bighorn sheep.

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INTERACTIONS BETWEEN DESERT BIGHORN SHEEP AND FERAL BURROS AT SPRING AREAS IN DEATH VALLEY

William C. Dunn
Charles L. Douglas
Cooperative National Park Resources Studies Unit
University of Nevada, Las Vegas

Abstract. Use of springs by desert bighorn sheep (Ovis canadensis nelsoni) and feral burros (Equus *asinus)* was examined as part of a study on resource partitioning between these species. Spring use by ewe groups was almost entirely restricted to a spring not used by burros while ram group use was not affected by the presence of burros. The number of burros present affected sheep use of springs, although the impact varied with different intensities of burro use. Evidence also suggests that temporal shifts in drinking times of bighorn may occur at springs used by burros. The potential adverse impacts of limiting use of springs by ewe groups are discussed.

INTRODUCTION

Since May 1980, a study examining resource partitioning between sympatric feral burros (Equus *asinus)* and desert bighorn sheep (Ovis canadensis nelsoni) has been conducted in the Cottonwood Mountains of Death Valley National Monument. One aspect that has been studied closely is the mutual use of water sources during hot summer months.

Previous studies have shown that springs are an essential part of desert bighorn habitat during the summer months. Turner (1973) found that desert bighorn are unable to meet their water requirements without free water during the hottest portion of summer. Blong and Pollard (1968) noted that ewe groups visited waterholes at least every other day during hot months in the Santa Rosa Mountains, although ram groups did not water as often. Welles and Welles (1961) stated that conditions other than high temperatures that increased summer waterhole use by bighorn included increases in insolation, aridity, rate of surface evaporation, and for rams, heightened metabolism during the rut.

A decrease in desert bighorn home range usually coincides with an increased need for free water. Simmons (1969) and Blong and Pollard (1968) found that ewe groups usually restricted their movements to within 1 mile of water during mid- and late summer, although ram groups occupied larger home ranges until the rut began. Hansen (1965) and Olech (1979) found that this increased time spent near water sources made them focal points for social and maintenance activities.

Various researchers also have found that use of water by feral burros increases during the summer months. Norment and Douglas (1977) reported a positive correlation between water stress and lack of movement by burros in summer months.

McMichael (1964) and Seegmiller and Ohmart (1981) also found burros concentrated nearer to water sources during summer months.

This close proximity of both species to water sources increases the opportunity for interactions in areas of sympatry. Many researchers have asserted that increased use of water sources by feral burros has been detrimental to bighorn (Dixon and Sumner 1939, Weaver 1959, Weaver 1973, Jones 1980, Mensch 1970). Conversely, Welles and Welles (1961) and McMichael (1964) did not find any direct evidence of competition at water sources. However, all of these studies suffered from a lack of quantitative data to support the findings. This paper is an attempt to quantitatively assess the effect water use by feral burros has on bighorn sheep. The data collected were used to test the following hypotheses:

Hypothesis 1.
There is no difference between the amount of bighorn use at springs not used by feral burros and amount of bighorn use at springs used by both species.

Hypothesis 2.
The number of feral burros present at a spring does not influence the use of the spring by bighorn.

Hypothesis 3.
There is no difference between time of day bighorn use springs that are used only by bighorn and time of day bighorn use springs that are shared with burros.

STUDY AREA DESCRIPTION

Location. The study area is located in the northwestern corner of Death Valley National Monument, CA (Figure 1). It encompasses approximately 150 km^2.

Physiography. The Cottonwood Mountains are a block-faulted range located at the southwestern margin of the basin and range province (NPSIUSDI 1981). They contain paleozoic limestone, dolomite, siltstone, shale, quartzite, and calcareous sandstone (McAllister 1952). The paleozoic rocks have been deformed over time by thrust faults, folds related to the thrusts, normal faults and small intrusions (McAllister 1952).

The northern part of the Cottonwood Mountains rises abruptly from Racetrack Valley, forming a precipitous west face that extends from Tin Mountain to Lost Burro Peak (Figure 2). The southern part of this face is dissected by 3 steep-walled canyons.

Rolling terrain dominates the topography from the vicinity of Ryegrass Spring, northward to Yashiro and Bighorn Springs, and includes a large basin encompassing Yashiro, Bighorn, Sheepwater, and Pinyon Springs which drains eastward into Bighorn Gorge. North of the basin, limestone cliffs as high as 120 m dominate the physiognomic relief culminating at Tin Mountain.

Elevations range from 1253 m (4113 ft.) at Teakettle Junction to 2730 m (8953 ft.) at Tin Mountain with a mean elevation of 1889 m (6200 ft.).

Vehicular access into the study area is limited to a dirt road from Teakettle Jct. to White Top Mountain and a small spur road to an abandoned mine near Lost Burro Peak.

Flora. The study area supports 5 major vegetation types: creosote-scrub in the lower elevations, atriplex-scrub in the

Figure 1. Location of study area.

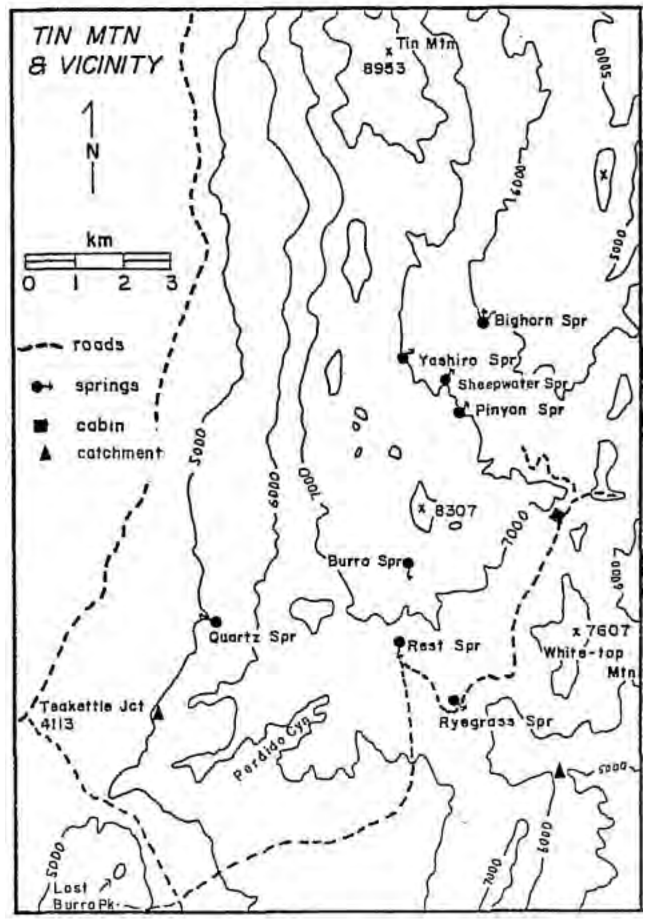

Figure 2. The Tin Mountain study area, showing springs and major landmarks.

mid-elevational areas, sagebrush-shadscale in the high basins, sagebrush and pinyon-juniper in the higher elevations.

Climate. From October 1980 through March 1982, annual precipitation ranged from 13.4 cm at 1524 m to 20 cm at 2435 m. Peak periods of precipitation occurred from March through May and September through November 1981, and February through March 1982. Precipitation was almost nonexistent in June and July of 1981, although it increased in late August and September due to a series of thundershowers.

Mean summer temperatures ranged from 21°C at 2435 m to 28°C at 1524 m. High temperatures recorded during the summer were 33°C at 2435 m and 41°C at 1524 m.

Water Sources. Data on spring use by feral burros and desert bighorn were obtained from 4 springs in the study area (Figure 2).

1) Quartz Spring is located at an elevation of 1550 m (5100 ft.) in a small canyon at the base of the precipitous west face. The canyon is formed by steep north and south slopes and a sheer west slope that rises to an elevation of 2072 m (6800 ft.). The canyon mouth opens to the west. A burro exclosure was constructed around Quartz Spring in 1975 to prevent its use by feral burros; thus Quartz Spring acted as a control for sheep in the study of spring use.

2) Pinyon Spring consists of 2 large seeps coming out of a sandstone hillside. They are located in a small draw at 2194 m (7200 ft.) elevation that is surrounded by scattered pinyon pines. Numerous small canyons are located to the south, while a large basin extends northward to Yashiro Spring.

3) Yashiro Spring is a seep located at an elevation of 2133 m (7000 ft.) at the southern tip of one of the limestone escarpments that extends to Tin Mountain. A large flat basin is located to the south and east.

4) Bighorn Spring also is a large seep located at an elevation of 1828 m (6000 ft.) at the southern tip of the easternmost limestone escarpment. Rolling terrain dominates the topography to the south and east. A broad wash originating at the spring extends northeast.

MATERIALS AND METHODS

To collect data on spring use, time-lapse cameras were placed at Pinyon, Yashiro, and Bighorn Springs. Data collected at Quartz Springs were obtained from 6 days of direct observations, supplemented with 3 days of time-lapse photography. The time-lapse camera system employed was similar to that described by Constantino (1973) and Helvie (1972). It consisted of a Minolta D-4 Autopak movie camera connected to an intervalorneter and a photoelectric cell. The photoelectric cell turned the system on in the morning and off at dusk. The intervalometer allowed 1 frame of film to be exposed per minute. A 50-ft. roll of film could collect approximately 4% days of data. Spring use data were collected at the 4 springs during the following periods of 1981:

Pinyon	Yashiro	Bighorn	Quartz
8-13 to 8-16	7-18 to 7-22	7-18 to 7-23	7-23 to 7-27
8-22 to 8-25	7-28 to 8-2	7-29 to 8-1	9-7 to 9-9
	8-30 to 9-2	8-13 to 8-17	

In all, more than 24,000 minutes of data were collected from all the springs.

Each roll of film was analyzed on a Kodak Ektagraphic MFS-8 analyzing projector (Eastman Kodak Co., Rochester, NY) which allowed viewing of individual frames. Data recorded from each frame included number of burros and bighorn present, number of each species drinking, sex and age group of all burros (adult, yearling, foal) and bighorn sheep (ram age class, ewe, yearling and lamb).

RESULTS AND DISCUSSION

Evaluation of Methodology.

Two major problems plagued the collection of data during this study. First, the cameras stopped functioning at each of the springs at least once. Because of this, data collected at each spring were not collected at exactly the same time period as at other springs. We do not believe this altered the results substantially since weather conditions remained fairly constant throughout the duration of the study and all data were collected after lambs were weaned and before the rut began. Second, the cameras filmed only a limited area around each spring because of limitations in the field of vision. Consequently, the numbers of burros in the immediate vicinity of the spring may have been under-represented in the data analysis.

The hypotheses tested were essentially one-tailed, testing whether or not burros were affecting spring use by bighorn sheep but not testing whether bighorn sheep were affecting spring use by burros. There are 3 reasons for this. First, Quartz Spring had long been an important water source for bighorn but use decreased to almost nonexistent levels by 1971, whereas burro use showed a concomitant increase. Second, many previous researchers have suggested that the presence of livestock and/or feral burros adversely affect sympatric bighorn sheep (see Wilson 1968, Russo 1956, Buechner 1960, McQuivey 1978, Ferrier and Bradley 1970, McMichael 1964, Jones 1980, Morgan 1971). Although most of the evidence is circumstantial, the recurring pattern of decreasing range use by bighorn sheep, when domestic or feral livestock are introduced strongly support conclusions about probable adverse impacts on bighorn by livestock. Third, the emphasis of national park management is towards preservation of native species. The time constraints of the study necessitated con-

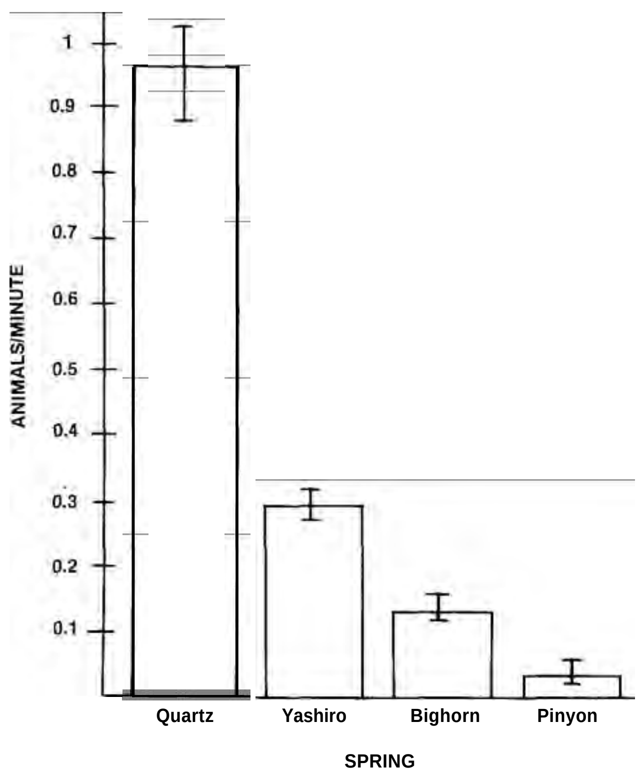

Figure 3. Amount of bighorn sheep use at each spring. 95% confidence intervals are shown.

centration on possible adverse impacts of the introduced species, the feral burro.

Hypothesis 1: Differences in Bighorn Use of Springs

Figure 3 shows the means (animalslminute) and 95% confidence intervals for use of each spring by bighorn sheep. Since the 95% confidence intervals of the means do not overlap, a significant difference in use between springs is demonstrated. Bighorn use was inversely related to burro use of springs but the correlation was not significant ($r = -0.43$, $p > 0.05$).[1] When Quartz Spring, the control for sheep, is included in the analysis it can be seen that there is twice as much use by sheep at Quartz Spring than at all other springs combined (Figure 4). The difference in use between Quartz Spring and the combined springs is significant (non-overlapping confidence intervals).

This dramatic increase in use at Quartz Spring is largely accounted for by use of ewe groups. Ewe group use at the 3 springs also used by burros was almost nonexistent. The highest use by ewes at any of those 3 springs was by 6 ewe groups (1.6 ewes/group) over 11 days of recorded use. At these springs, ewes were negatively affected by burro use ($r = -0.87$, $0.1 > p > 0.05$) and almost all use by ewes (97%) occurred when burros were not present. When Quartz Spring is included in the analysis, the negative effect of burros on spring use by ewe groups is even more pronounced ($r = -0.95$, $p < 0.05$).

[1] It is important to realize that the small sample size of springs (4) tested for this hypothesis greatly weakens correlation tests. Significant correlation coefficients can still be considered valid if t-tests verify that the coefficients are significantly different from zero (A. Yfantis, pers. comrn.). All significant correlation coefficients were found to be significantly different from zero.

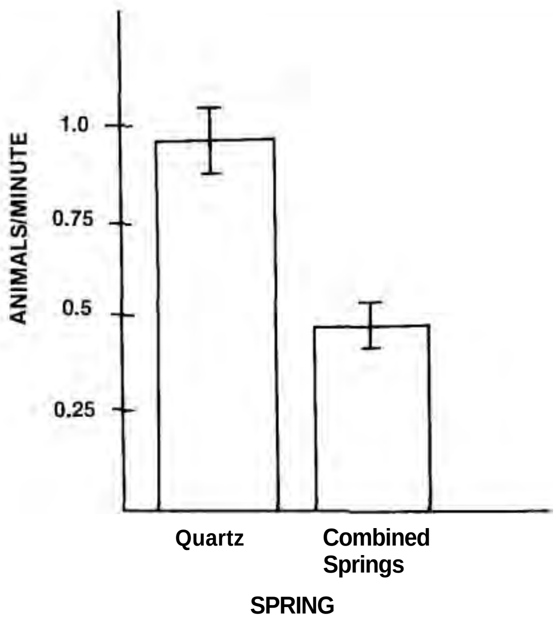

Figure 4. Comparison of Bighorn sheep use at Quartz Spring and at the other springs also used by burros. 95% confidence intervals are shown.

Ram use of springs was not negatively affected by the presence of burros ($r = 0.14$, $p > 0.05$), although differences in use between springs were significant (non-overlapping confidence intervals). The greatest amount of use by rams (55%) at any of the 4 springs occurred at Yashiro Spring. Only 12% of the total use was recorded at Quartz Spring.

That ram group use is actually greater at those springs mutually used by burros and sheep, and ewe group use is substantially less than at Quartz Spring (control for sheep), suggests that burro usage of springs negatively affects use of springs by ewe groups but may not affect ram group use.

If this is true, ewe groups and feral burros should also exhibit spatial segregation in range use. Three radio-collared ewes had home ranges around Quartz Spring or on the precipitous west face of the study area (Figure 5). Feral burros occupied home ranges around Burro and Ryegrass Springs or around Bighorn and Yashiro Springs (Figure 6). No part of the ewe ranges extend into areas occupied by feral burros during the summer months. In addition, more than 70% of sightings of unmarked ewes were in areas unoccupied by burros.

Conversely, the home range of the 4 year old radio-collared ram occupied a much larger area than any radio-collared ewe, and included Bighorn and Yashiro Springs (Figure 7). In addition, more than 50% of the sightings of unmarked rams were in areas occupied by feral burros. These data support the alternative hypothesis suggesting that the presence of feral burros limits spring use and range use by ewes but perhaps not by rams.

Differential behavior of ewe and ram groups also supports the

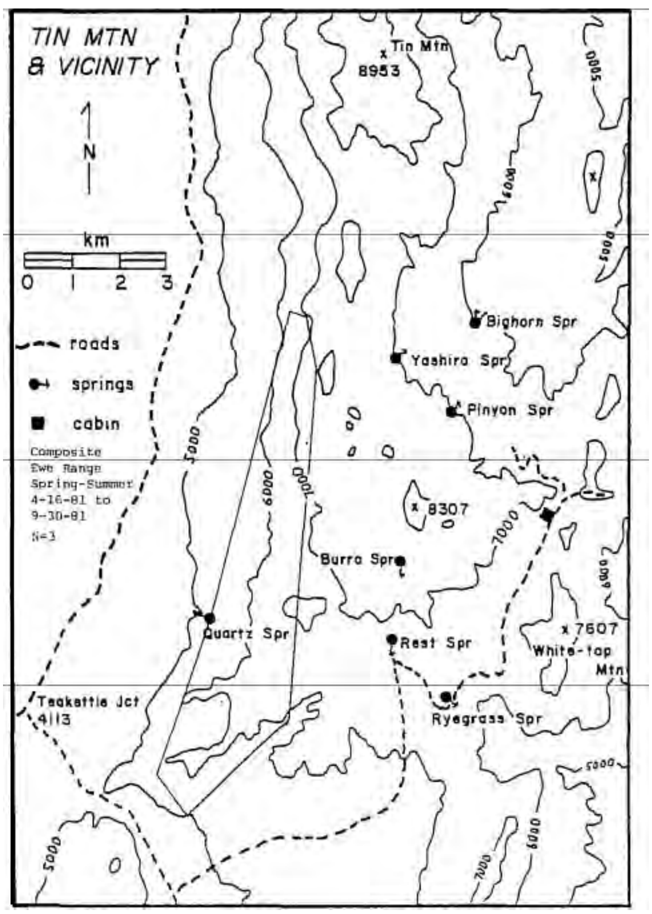

Figure 5. Composite summer range of radio collared ewes.

alternative hypothesis. If feral burros are adversely affecting bighorn by limiting use of springs by ewes, it may simply be due to their presence at the springs, since we never witnessed any outward antagonistic behavior between burros and bighorn during the 2-year study. If, indeed, burros do not normally act antagonistically towards the sympatric bighorn, one would suspect that ewes groups would have become accustomed to the presence of burros at springs during the approximately 90 years that they have coexisted (Hansen, DVNM files). Apparently they have not done so.

Ewe groups, especially ewes with lambs, were inclined to be more cautious than ram groups and took to flight sooner. This behavior pattern also was found by several other researchers (Hamilton, pers. comm.; Wehausen 1980; Hicks and Elder 1979; Light 1971). In addition, Light (1971) noted that increased human visitation to certain areas eventually caused bighorn to avoid those areas. Likewise, increased frequency of burro visitation to springs and increased numbers of burros present in the spring areas may result in substantial reductions in spring use by ewes.

Factors other than the presence of burros could influence the amount of spring use by bighorn sheep. The following discussion examines some of these factors.

1) Climate. Climatic difference between Quartz Spring at 1559 m and the higher elevations of Bighorn, Pinyon and Yashiro Springs could influence frequency of spring use by bighorn in some years. Although mean temperatures and average high temperatures for July, August, and September 1981 were higher at Quartz Spring than in the basin where the other springs are located, differences were not significant

Table 1. Monthly temperatures (°C) at Quartz and Pinyon Springs.

Quartz			
July	32.6	24	28.3
August	31	22	26.5
September	26.1	17.6	21.9
			$\overline{X} = 25.5$
Pinyon			
July	30	15.3	22.6
August	30.4	16.6	23.5
September	26.6	12.2	19.4
			$\overline{X} = 21.8$

($x^2 = 0.626$, p►0.01) (Table 1). Likewise, precipitation records during 1981 (Table 2) indicate that Quartz Spring received less moisture than the basin but the difference was not significant ($t = 2.218$, p►0.05). Consequently, we do not feel that climatic difference between the 2 areas explains the greater frequency of use at Quartz Spring which is 3 times greater than at the next most used spring.

2) Water Requirements.

a) Peak Usage: Frequency of use by ewe groups and ram groups also will vary according to individual water. re-

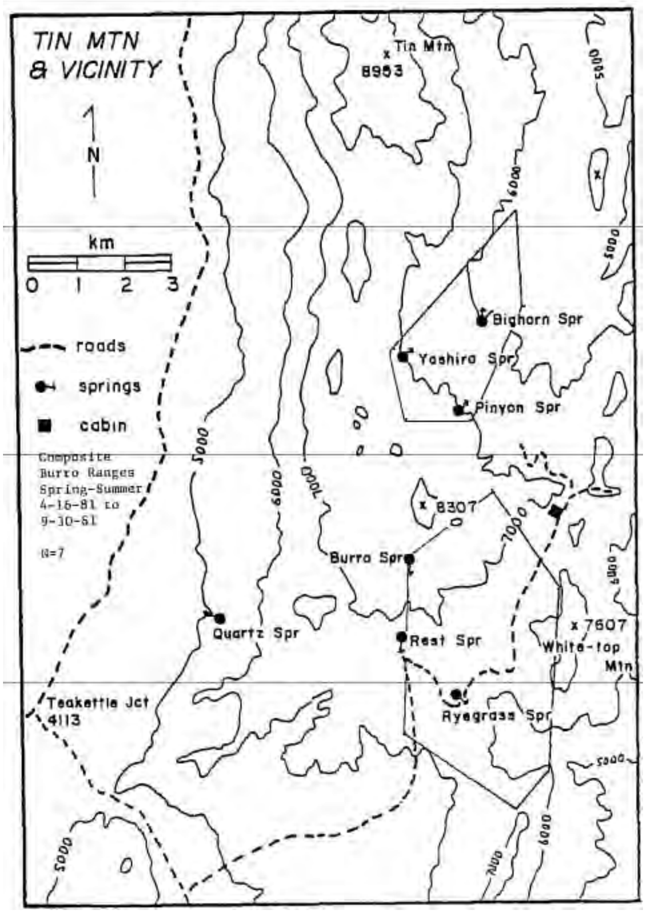

Figure 6. Composite summer ranges of radio collared burros.

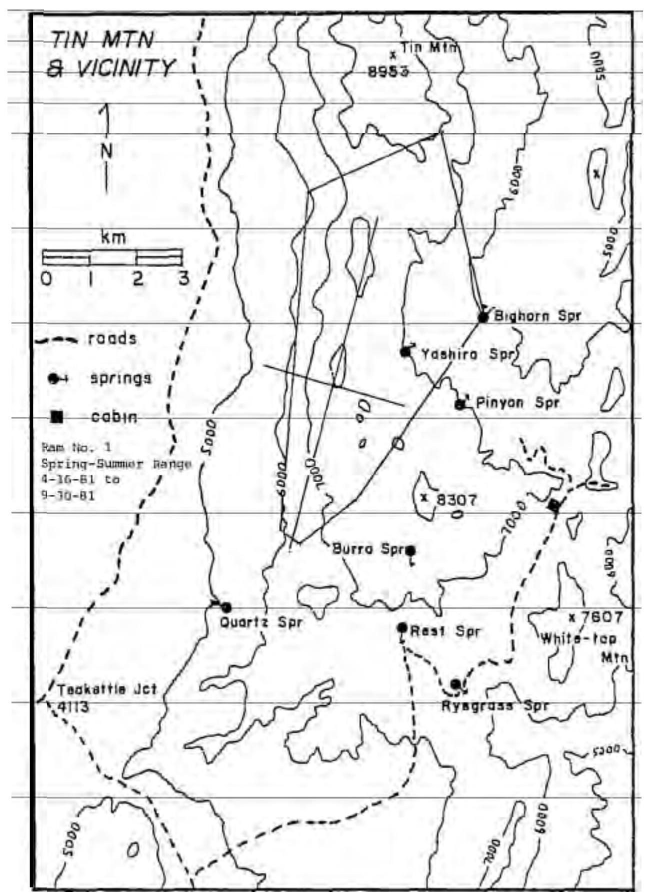

Figure 7. Home range of Ram No. 1 (Axes of 95% probability ellipse are shown.

Table 2. Monthly precipitation **(cm)** at Quartz and Pinyon Springs.

Month	Quartz Spring	Pinyon Spring
1980:		
November	3.81	4.83
December	0.15	--
1981:		
January	0.15	0.05
February	0.15	0.96
March	5.82	5.79
April	--	1.73
May	1.42	2.46
June	--	--
July	0.20	--
August	0.48	0.76
September	0.91	2.08
October	--	0.33
	$\bar{X}=0.44$	$\bar{X}=0.6233$

quirements. McQuivey (1978) found ewes with lambs most frequently at water holes in the River Mountains of Nevada during June to mid-July, while rams were seen most often from late July through August. These periods correspond with the time of highest moisture stress: ewes are nusing iambs in early summer and rams are active in the rut in late summer. The lesser ewe group use of Yashiro, Bighorn, and Pinyon Spring may have been due to lesser water requirements. The sampling period corresponded with what is commonly considered to be the beginning of the rutting period (although spatial segregation between ewe and ram groups suggests that it had not started yet), but after the nursing period for lambs.

b) Physiological Differences: As previously stated, bighorn are able to survive without free water for up to 5 days (Turner 1973). Behaviorally, bighorn reduce physiolgical stress by a reduction of activity during hours of peak isolation (Turner 1973) and seek protection in shallow caves and shaded overhangs (Leslie and Douglas 1979). Bighorn are able to concentrate urine to almost 4 times the concentration of sea water and to a lesser degree are able to reabsorb water from their feces (Turner 1973).

Conversely, Moehlman (1974) observed many individual burros watering daily, and females with young foals were observed drinking 2 to 3 times daily. The feral burro has a greater need for free water than bighorn because: (1) behavioral adaptations to reduce heat gain are not as well developed as in desert bighorn, (2) the amount of feces burros produce is greater than that of desert bighorn, (3) the water content of the feces is higher than bighorn, (4) urine flow is greater than bighorn and is much less concentrated (Schmidt-Nielsen 1964, Turner 1973). If burros are not affecting bighorn, low usage by bighorn should occur at every spring, instead of the differences observed.

3) Potential for Use. Bighorn use of springs may be less at springs also used by feral burros because the potential for use is less. If surrounding habitat is unable to support many sheep, then the spring will receive less use by sheep. Evaluation of habitat using Hansen's method (Hansen 1967) indicates that habitat surrounding Bighorn, Yashiro and Pinyon Springs is comparable in quality to the habitat surrounding Quartz Spring. All areas are rated as important to bighorn. The only major difference was that there was a significantly greater density of grass in the vicinity of Quartz Spring ($x^2=332$, p◄0.01). Since grass is an important component of the diet of bighorn sheep (Ginnett 1982, Wilson 1968, Welles 1965, Brown et al. 1977), the greater density of grasses around Quartz Spring may be conducive to greater sheep use of the surrounding habitat. This dietary component would be especially important to the health of the reproductive segment of the population. However, Ginnett (pers. comm.) felt that results of the transect data were not conclusive as to which area had higher quality vegetation.

4) Quality of Water. A reduction in use of certain springs by bighorn could be due to difference in quality of water. Large amounts of dissolved salts and other minerals in spring water

Table 3. Results of the testing of Hypothesis 2: The number of feral burros present at a spring doesldoes not influence use of the spring by bighorn sheep.

	NUMBERS OF BURROS PRESENT			
Spring	Burros42 vs. **Burros►2**	Burros43 vs. **Burros►3**	Burros44 vs. **Burros►4**	Burros45 vs. **Burros►5**
Combined (Yashiro, Pinyon, and Bighorn Springs)	Not Significant (U=80, p►0.05)	Significant (U=120, p◄0.05)	—	---
Yashiro	Not Significant (U=105, p►0.05)	Significant (u=138, p◄0.05)	—	—
Bighorn (U=131, p◄0.05)	Significant (Burros►2 has more bighorn use than Burros◄2)	Not Significant (u=102, p◄0.05)	Not Significant (u=105.5, p◄0.05)	Significant (u=120, p◄0.05)
Pinyon	Not Significant (u=58, p◄0.05)	Not Significant (u=95, p◄0.05)	Significant (u=111.5, p◄0.05)	---

could reduce the palatability of the water to sheep. Because of time constraints of the study and inaccessibility of the springs, water quality was not evaluated. Data on salt tolerance of bighorn are currently unavailable, therefore, it would be difficult to interpret effects of dissolved solutes in spring water on sheep.

Hypothesis 2:
The Relationship Between Numbers of
Burros and Sheep Use of Springs

This hypothesis was tested on the premise that sheep use of springs mutually used by burros and sheep might be reduced significantiy by the presence of a certain number of burros.

At Bighorn Spring, a significant decrease in sheep use occurred when 5 or more burros were present (Mann-Whitney, $u = 120$, $p < 0.05$), while at Pinyon Spring, a significant decrease in sheep use occurred when 4 or more burros were present (Mann-Whitney, $u = 132$, $p < 0.05$) (Table 3). Sheep use at Yashiro Spring was decreased significantly when only 3 or more burros were present (Mann-Whitney, $u = 138$, $p < 0.05$). if data collected at springs used by both burros and bighorn are combined, sheep use decreased significantly when 3 or more burros were present (Mann-Whitney, $u = 29.5$, $p < 0.05$).

That sheep use at Bighorn Spring does not show a significant decrease until higher numbers of burros are present there than at any of the other springs is probably related to the length of time burros were present rather than to the numbers of burros that visited the spring. There were rarely more than 5 burros present at Bighorn Spring at any one time, but those animals remained for longer periods (often entire days) than observed at any other springs. Consequently, bighorn that drank there had to do so in the presence of 4 to 5 burros.

Conversely, the possible reason sheep use at Pinyon Spring does not decrease significantly until at least 4 burros are present probably is related to the numbers of burros that visited the spring. During the study, more burros usually were observed at Pinyon Spring than at Yashiro or Bighorn Spring.

That the null hypothesis (numbers of feral burros present at a spring does not influence spring use by sheep) was rejected at each individual spring as well as when spring data were combined suggests that numbers of burros present at a spring affects sheep use. The results also indicate that the effect of burros on sheep use of springs varies in different areas due to differences in densities of burro and bighorn populations. Bighorn use of springs decreased substantially when there were more than 3 or 4 burros present.

Hypothesis 3:
Differences in Daily Spring Use Patterns of Bighorn

This hypothesis was tested on the premise that if sheep use of springs was limited by burro use of springs, there might be a temporal shift in drinking times by sheep. It presupposes that burros are affecting bighorn use of springs, which is suggested by evidence presented for Hypothesis 1. The data from each spring used by both bighorn and burros were tested individually against sheep use data collected at Quartz Spring, where sheep were unaffected by burros. It was assumed that the pattern of use at Quartz Spring was normal for undisturbed sheep.

Because of a paucity of data for Pinyon Spring, no comparison was made between sheep use at this spring and at Quartz spring. At Bighorn Spring, the pattern of use differed significantly from that at Quartz Spring (Kolmogorov-Srnirnov (Siegal 1965); $k_d = 8$, $p < 0.05$), whereas the pattern of use at Yashiro Spring did not differ significantiy from that at Quartz Spring (Koirnogorov-Smirnov (Siegal 1965); $k_d = 5$, $p > 0.05$) (Figure 8).

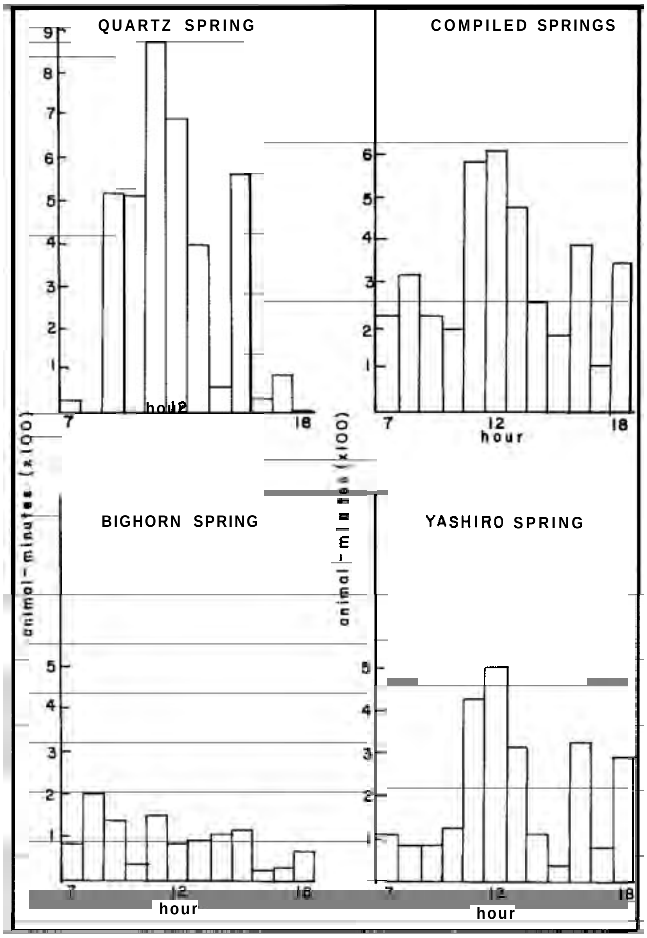

Figure 8. Daily patterns **of** bighorn use at various springs.

To test if burros are affecting bighorn use patterns, it is important to examine how much burro and bighorn use patterns differ at each spring. If the presence of burros limits spring use by bighorn, one would expect the greatest amount of bighorn use to occur when burro use is least. At Yashiro Spring, a low period of bighorn use occurs from 0700 to 1000 hours (Figure 9). This corresponds to high burro use from 0800 to 1000. The greatest sheep use occurs during 1100 to 1300 hours. Burro usage is concomitantly decreasing during this period although the second highest amount of burro use during the day occurs at 1100. Other periods of high sheep use occur at 1600 and 1800 hours. Although burro use is high at 1600, it is low at 1800. These data suggest that, at best, there may be a weak relationship between decreasing sheep use and increasing burro use at Yashiro Spring.

At Bighorn Spring, sheep use tends to be steady throughout the day, although use is somewhat heavier in the morning (Figure 10). Likewise, burro use is fairly steady throughout the day. If burros cause a shift in bighorn spring use patterns at Bighorn Spring, the steady use throughout the day by burros may be influencing the steady use by bighorn. Low periods of burro use that occurred at 0700 and 1800 were not periods of high bighorn use. Yet, the large difference in daily use patterns between sheep use at Bighorn Spring and Quartz Spring suggests that bighorn may be affected by the presence of burros.

Even if a difference is strongly demonstrated in diurnal use patterns by sheep at Quartz Spring as compared with springs mutually used by burros and bighorn, it might not necessarily be due to the presence or absence of burros at the

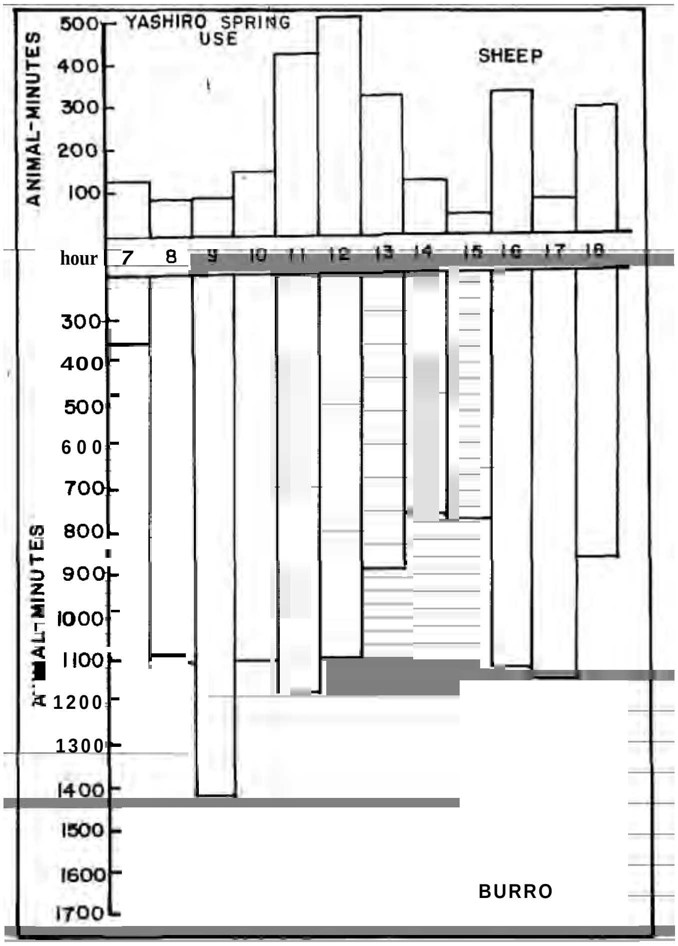

Figure 9. Comparison of burro and bighorn daily use patterns at Yashiro Spring.

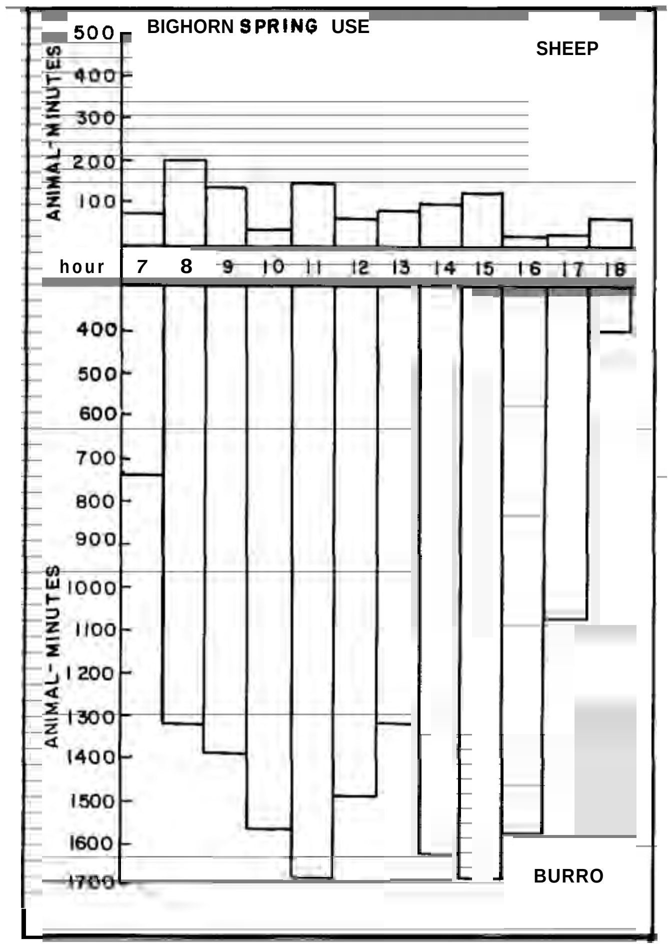

Figure 10. Comparison of burro and bighorn daily use patterns at Bighorn Spring.

spring. There are several other possible factors. First, although sheep drinking at these springs are all from the same herd, variation in time of drinking may be due to variation among individuals or variation among groups of sheep. Second, during the course of the study, we rarely noted bighorn coming into Quartz Spring Canyon before the sun was shining directly into it. Since the sun reaches Yashiro and Bighorn Springs approximately one hour earlier, a change in time of spring use could occur. Third, danger of predation, which may be greater at certain springs than at others, could influence daily use patterns.

CONCLUSION

Sales (1974) states that resource overlap (like that demonstrated by mutual use of springs by burros and bighorn) does not necessarily demonstrate that competition has occurred during the coexistence of 2 or more species. Likewise, Colwell and Futuyma (1971) state that percent overlap and amount of competition are not necessarily equivalent. Instead, Colwell and Futuyma (1971) propose that niche shifts (i.e. changes in a species' pattern of resource use) are evidence of competitive interactions. Sales (1974) differentiates between mean resource overlap for all potentially interacting species and competition-free overlap, the amount of resource overlap between 2 or more species in the absence of competition. If mean resource overlap is less than competition-free overlap, then strong evidence for competition exists. In other words, a limitation of resources to one or both species is demonstrated. Bighorn habitat surrounding Yashiro, Bighorn, and Pinyon Springs seems to be of as high quality as the habitat surrounding Quartz Spring, and yet Quartz Spring receives twice as much use by bighorn as the other springs combined. This suggests that mean resource overlap between burros and bighorn, particularly ewe groups, is not as great as competition-free overlap would be. This is especially true if one considers that sheep use at Quartz Spring was virtually nonexistent immediately prior to construction of the burro exclosure. Competition, therefore, seems to be demonstrated in the limitation of spring use, not because of a shortage of the resource (as all springs flowed freely throughout the year), but by limited availability of the resource to the sheep. If it is true that the presence of burros at springs is enough to limit ewes, especially ewes with lambs, in their use of the springs, then a form of interference competition seems to have been at work during their coexistence. This is in agreement with Merrill's (1982) interpretation of the Darwinian concept of competition in that the emphasis on competitive interactions is on the contest and not on the resources.

Since burros were first introduced into the area at least 90 years ago (Hansen, DVNM files), we believe that if competition occurred between bighorn and burros during their coexistence, it probably has already taken place. The result is the allopatry that is most evident now between ewe groups and burros. The ewe group niche has shifted (Diamond 1978) to a "refuge from competition" (Jaegar 1974) in the vicinity of Quartz Spring.

The potential adverse impacts of limiting use of springs by ewe groups because of burro use may extend well beyond limitations in the availability of water. The reproductive capacity of the herd may be severely limited in several ways. First, ewe groups that still range in the vicinity of Pinyon, Bighorn, and Yashiro Springs may be limited in the amount of water they can consume because of apprehension in approaching a spring and remaining there for long periods when burros are present. This potential decreased intake of water could result in decreased milk production during the nursing period which could eventually lead to lower lamb survival, thereby inducing a decline in the population.

Second, limiting use of range by ewe groups to the vicinity of Quartz Spring may place limitations on nutrient intake. An increase in use of the available vegetation could potentially decrease the nutritional quality if the number of animals exceeds the carrying capacity of the range. It has been demonstrated in several studies that nutritional quality of vegetation is strongly correlated to reproductive success (Caughley 1970, Verme 1965, Cowan 1950, Taber 1956, Severinghaus and Tank 1964). It follows that the hypothesized limitation of food resource due to range constriction could lead to a decline in the sheep population.

Frankel and Soule (1981) state that interspecific competition has never been proven to be a direct cause of extinction of a group of animals, although it can be a contributing cause. The bighorn of the Tin Mountain area may in fact be in danger of extinction. Soule (1980) found that an ungulate herd must have an effective population number of at least 50 animals to keep the inbreeding rate to less than 1% per generation. Fewer breeding adults would result in increasing homozygosity, a loss of much of the herd's capacity to adapt to changing conditions, and possibly its demise. To calculate the effective population number of the Tin Mountain herd, Franklin's (1980) coefficient for determining effective population size for herds with an uneven sex ratio was used:

$$Ne = \frac{1}{\left(\frac{1}{4Nm} + \frac{1}{4Nf}\right)}$$

where
Ne = the effective population number
Nm = the number of males in the herd
Nf = the number of females in the herd

Assuming the herd contains a maximum of 70 animals (Sanchez, DVNM files) of which there are 18 breeding rams and 30 breeding ewes (calculated from a 60:100 ramlewe ratio), the Tin Mountain herd is found to contain 44 breeding adults, less than the effective number needed to minimize the inbreeding rate to 1% per generation. With only 44 breeding adults, approximately 1/4 of the genetic variation would be lost in 20 generations (Soule 1980). It is unknown how long the Tin Mountain herd has had an effective breeding population of less than 50 animals. If coexistence with burros has contributed to the reduction in the effective number of bighorn, then a large amount of the heterozygosity of the herd may already have been lost.

While data presented in this paper suggest competition may have been a process in the coexistence between these 2 species, final proof can only be provided when the current mean resource overlap is proven to be less than competition-free overlap. That will require removal of the burros and subsequent monitoring of the response of the sheep. One would expect that if competition had occurred during the coexistence of the burros and bighorn, an increase in population size and range use by ewe groups and possibly ram groups could occur. Yet a recognizable ecological release by bighorn may not occur for several years because (1) bighorn are not very exploratory and do not colonize new areas readily (Geist 1971), so range use may not increase immediately, and (2) possible overbrowsing by burros resulting in a lowering of vegetational quality may contribute to low reproduction for the bighorn herd until a marked improvement in vegetation occurs.

ACKNOWLEDGMENTS

We thank Thomas Hardy and Evangelos Yfantis, Univ. of Nevada, Las Vegas, for assistance in data analysis, and the Death Valley Natural History Assn. for financial assistance.

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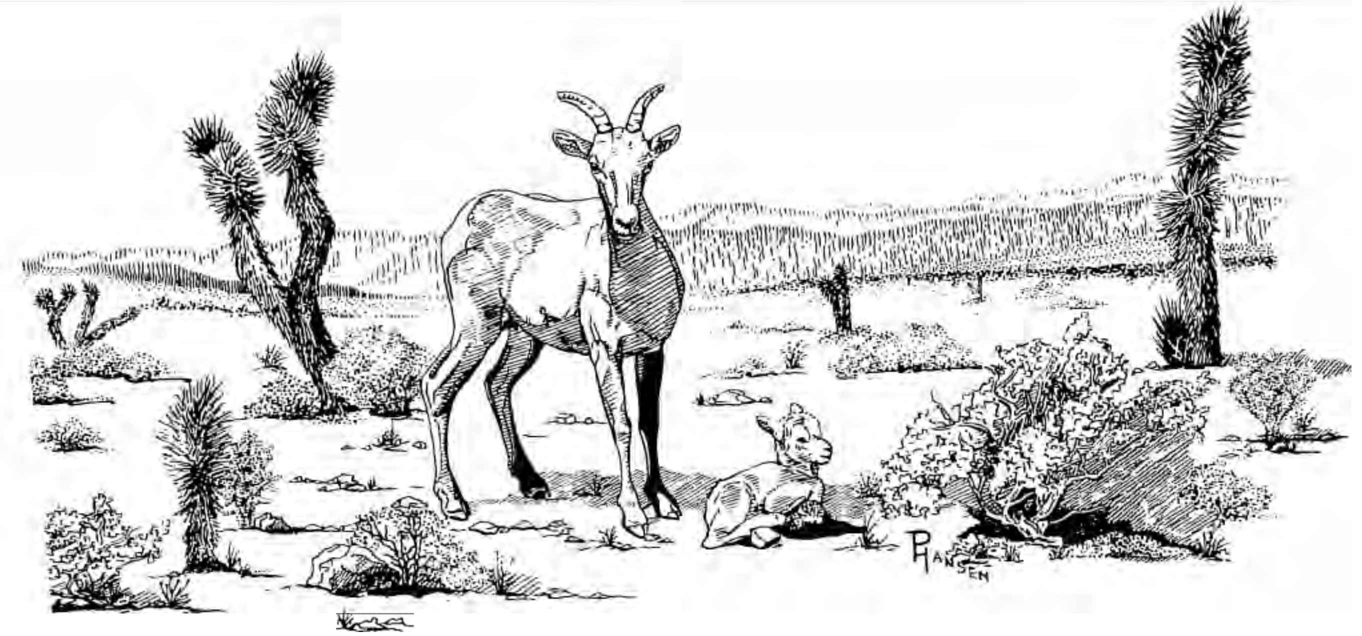

SIMULATED DEMOGRAPHY OF THE RIVER MOUNTAIN HERD

David M. Leslie, Jr.
Cooperative Parks Studies Unit
Oregon State University, Corvallis

Charles L. Douglas
Cooperative National Parks Resources Studies Unit
University of Nevada, Las Vegas

Abstract. The simulation model that was first presented by Leslie (1980) was modified to include an empirically-based regression formula capable of altering annual lamb survival as it depends on herd density and precipitation patterns. The model also was made interactive, which greatly increased the ease with which an operator can assess various management options regarding herd reductions. Based on existing demographic data and past management activities in the River Mountains, it was possible to simulate, with some confidence, population trends from 1973 on. Proposed reductions for summer 1982 were evaluated.

INTRODUCTION

Desert bighorn sheep, *Ovis canadensis nelsoni,* in the River Mountains, Nevada, are "harvested" at an unprecedented rate. Live-trapping of the population has provided over 100 sheep for transplants to Utah and Colorado and within Nevada (McQuivey 1980, 1981). Such intensive management requires equally intensive research to monitor potentially detrimental demographic changes in the River Mountain herd. A simulation model was developed by Leslie (1980) to aid managers in synthesizing existing demographic data and in establishing reasonable "harvesting" strategies.

The data base for the River Mountain herd is extensive (Cooper and McLean 1974, Leslie 1977, 1978,1980; Leslie and Douglas 1979, 1980, 1981; McQuivey 1978, McQuivey and Leslie 1976, and others), but is far from complete. For example, demographic insight on ewe survival is largely lacking (Leslie 1980). The original model did not account for climatic variables thought to influence lamb production and survival in low elevation ranges in southern Nevada, and that was thought to be the most serious limitation of the resulting simulations (Leslie 1980). If empirical observations from the River Mountains could account for the effects of climate on secondary production, the realism and utility of the model would be greatly strengthened (Leslie and Douglas 1981). Douglas and Leslie (in prep.) reported that 87% of the observed variability in lamb survival in the River Mountains could be accounted for by fall precipitation (53%) and herd density (34%). It was noteworthy that a density-independent factor had the greatest effect on annual lamb survival.

This report is designed to update the original model (Leslie 1980) and to summarize simulations that have been conducted since the inclusion of a regression formula that describes annual lamb survival. Those interested should refer to Leslie (1980) for a detailed description of the model; it is not repeated here.

MODEL STRUCTURE

The original model was discrete and included 22 variables that influenced the demographic character of the simulated population (Leslie 1980). Unless otherwise mentioned, the original structure of the model, input data (e.g., ram and ewe survival, fecundity, etc.), assumptions and limitations have remained unchanged from the first paper (Leslie 1980).

The most significant change in the model was inclusion of the following regression formula describing the relationship between annual lamb survival, precipitation, and herd density (fecundity remains fixed):

$$Y = 0.109X_1 - 1.268X_2 + 1.451,$$

where Y is lamb survival, X_1 is previous fall precipitation in inches, and X_2 is herd density. Each year of a simulation, lamb survival is recalculated using the current level of independent factors.

One of the main purposes of the model is to provide realistic answers, based on existing population statistics, to a wide range of questions regarding herd reduction via live-trapping. For example, "If we remove 40 sheep, 10 rams and 30 ewes, with such-and-so age structure, what will be the effect on productivity in the following year?" And since we know that fall precipitation is an important determinant of lamb survival, we may further ask, "What if this removal is followed by 1 or 2 years of sub-normal fall precipitation?" Given the wide range of possible age structures, numbers removed and levels of precipitation, a vast assortment of such questions are possible.

To make the model more flexible in that regard, it was made "interactive." After the program is compiled (i.e., made ready to run on the computer) and basic demographic data (e.g., survival and fecundity) entered, the operator is presented with a series of questions. The answers provide additional input data on the particular management strategy to be employed. The following questions appear on the computer terminal and must be answered before the program will run.

1. Enter number of years for simulation: 35 maximum

Comment: The program is designed to simulate any number of years up to 35. Actually, 35 is arbitrary. If more are desired, it can be arranged by changing the control card in the program.

2. Enter 1 to use random precipitation generator.
   Enter 2 to input "X" precipitation values.

Comment: This provides a yearly value for fall precipitation (X_1) that is used along with density (X_2) to predict annual lamb survival. If "1" is entered, the appropriate number of yearly values of fall precipitation (i.e., the number of years chosen for the simulation in Question #1) are randomly generated by the compiler in the computer. The program was written to generate values within the range of observed precipitation in the River Mountains. If "2" is entered, the operator can choose whatever values desired and input them directly. This option gives flexibility in manipulating high, low or intermediate rainfall patterns.

3. Enter year of transplant or "CR" to continue.

Comment: "CR" stands for carriage return. If no removals are desired, the operator hits carriage return on the terminal. If a removal is to be conducted, the operator indicates the year in which it is to occur. For example, it may have been set up such that fall precipitation is above normal in years 1,2 and 3, and then below normal in year 4. The operator may be interested in examining the effects of a reduction under conditions of low rainfall and presumably low lamb survival. The operator simply enters "4", and animals will be removed in that year of the simulation.

4. **Enter ten age classes for ewes then rams for Year "X".**
Comment: If "4" had been entered above, "X" here would read "4". Here, the operator enters the number of animals removed from each of 10 age classes for both ewes and rams. This is a powerful tool for it allows an evaluation of the effects of age-specific removals on subsequent reproductive output of the simulated population. Population responses vary dramatically and depend on the ages of females that are removed, relative to fecundity (Leslie 1980).

5. **Enter year of transplant or "CR" to continue.**
Comment: If another removal is desired, enter the year and Question #4 will be repeated. This will go on indefinitely, unless the carriage of the terminal is returned, at which time the simulation will begin. Output is printed immediately below.

SIMULATIONS AND RESULTS

Leslie and Douglas (1981) noted that results from simulations with the lamb survival regression were less clear than those reported by Leslie (1980), due to oscillations in population size. However, the pattern of population change with annual fluctuation in lamb survival was more realistic based on empirical observations from the River Mountains (Leslie and Douglas 1979, McQuivey 1978). Given a fixed schedule of adult survival and fecundity (Leslie 1980) and randomly varying levels of fall precipitation, the simulated population fluctuated around 250 animals, which represented the assumed carrying capacity of the River Mountains (Fig. 1). The synergistic effects of herd density and fall precipitation largely determined the magnitude of population change. For example, in Year 6 of the simulation, relatively high herd density and very low fall precipitation perpetuated the greatest decrease in population size (Fig. 1). Conversely, low herd density and exceptional fall precipitation in Year 12 resulted in the greatest increase in population size (Fig. 1). Simulations of this sort were conducted for up to 75 years, and the demographic behavior of the population remained oscillatory around 250 animals. Significantly, age structures of rams and ewes never stabilized due to those oscillations, which exemplified the strong and stochastic effects of climate on population demography. Tendencies of the population to increase or decrease, indefinitely, were checked by the density-independent and -dependent character of the regression model that determined lamb survival.

In an attempt to mimic changes in the River Mountain population that might be expected as a result of herd reduction, a series of simulations were conducted using observed levels of fall precipitation and actual numbers of sheep removed from 1973-1980. No age-specific data on females that were removed were available; therefore, it was assumed that removals were made up of a random selection of females from all age classes. Such removals appear to be the most pragmatic for both the source population and transplant group (Leslie 1980). The realism of the simulations was verified, in part, by the parallel nature of simulated and observed lamb survival (Fig. 2). Both were very similar between 1973 and 1980; the divergence in 1981 remains unexplained (Fig. 2). It should be noted that the simulated levels of lamb survival in 1978-1981 were more liberal than observed levels; therefore, results regarding population response to removal must be considered liberal as well. In other words, if lamb survival was actually lower, but other input data accurate, population increase after reduction would be slower than predicted by the simulations.

Once the simulated population satisfactorily mimicked demography and management of the River Mountain herd from 1973-1981, it was possible to address various reduction strategies that were being considered for summer 1982, varying total numbers, age structures and fall precipitation regimes. Three simulations were conducted; the totals to be removed in 1982 ranged from 40-80 animals. The composition of all removals was 60% female and 40% male. Ewes were removed randomly from all age classes, but only males less than 5 years of age were selected. Additionally, fall precipitation was set at a low level immediately after the reductions, but allowed to fluctuate normally after that.

According to the simulations, the River Mountain herd has been decreasing since 1976 (Fig. 3). The most precipitous decline occurred in 1980 as a result of the removal of 40 animals from the population and relatively low fall precipitation during the previous year. By 1982, the size of the population was 188 sheep (Fig. 3). Estimates that were prepared annually by the Nevada Department of Wildlife (R.P. McQuivey, pers. comm.) did not parallel the trajectories in Fig. 3, but rather, they followed lamblewe ratios in Fig. 2. A probable reason for that divergence may be the starting number of

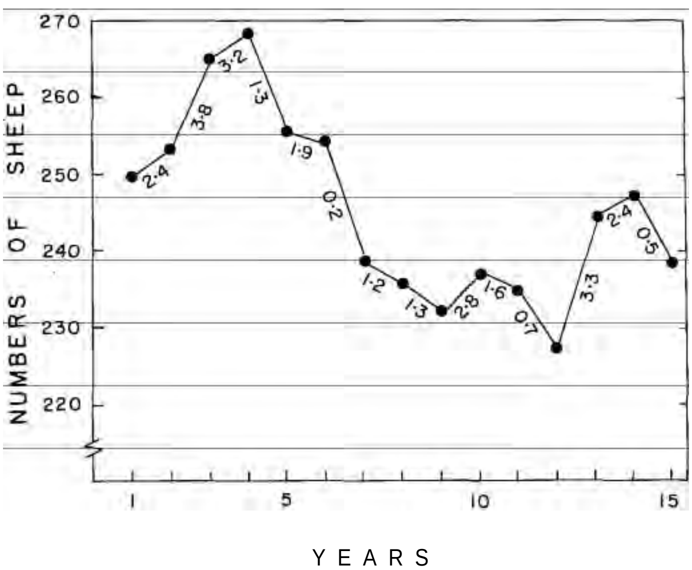

Figure 1. Simulated population fluctuations of the River Mountains herd, as related to fall precipitation.

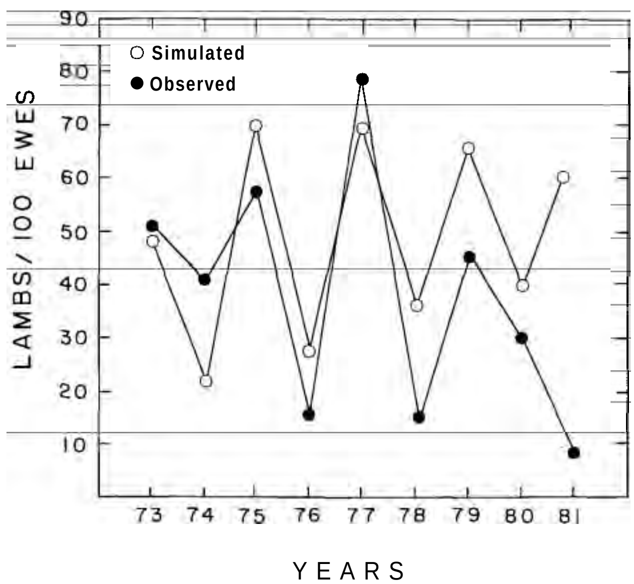

Figure 2. Comparison of observed and simulated lamb survival in the River Mountains bighorn herd.

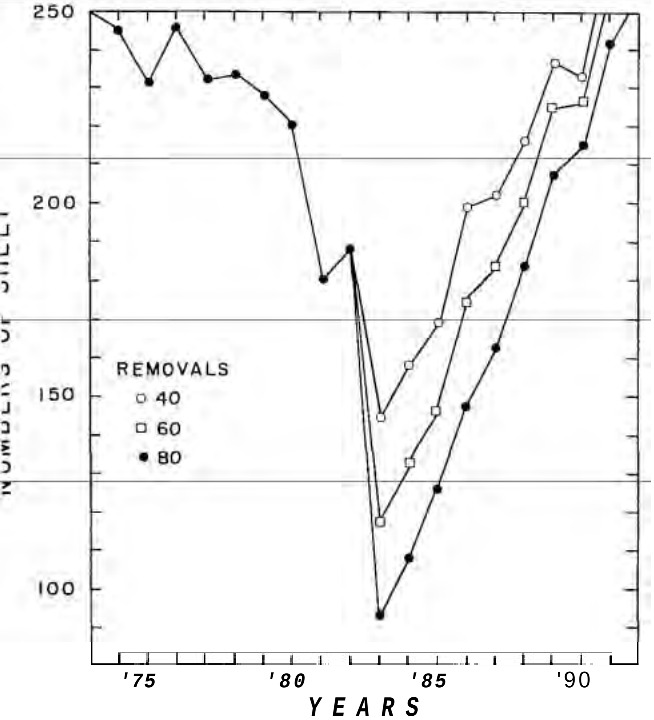

Figure 3. Simulated removals of 40,60, and 80 bighorn from the River Mountains, and the projected population recovery rates.

sheep in the simulations relative to the actual number in the River Mountains. At any rate, the size of the simulated population compared to NDOW estimates may be of secondary value from a management perspective. What are important are the trends that result from continued herd reduction in the River Mountains, and our ability to accurately assess them.

Removals of 40, 60, and 80 sheep decreased population levels proportionately (Fig. 3). As suggested by Leslie (1980), a substantial reduction in density was not the only requisite to favor rapid population increase. Favorable precipitation (i.e., a density-independent effect) must also occur and operates simultaneously with density to enhance population increases. Variability in those effects were observed in 1989-1990 of the simulations (Fig. 3). Population response under the same fall precipitation regimes was different depending on density. Trajectories in Fig. 3 indicated that the River Mountain herd will take up to 8 years to recover its 1973 size, assuming normal precipitation.

A possible limitation to results in Fig. 3 remains the fixed schedule of adult survival. If adult survival is enhanced at low densities and with favorable precipitation patterns, as is lamb survival, population increases after reduction would be more rapid. No empirical data are available to verify that for desert bighorn sheep, but similar effects have been noted for Soay sheep, O. aries (Grubb 1974) and African buffalo, Syncerus *caffer* (Sinclair 1974). However, Caughley (1977) noted that for species with a low r_m, recruit survival is more dependent on the number of adults in the population than is adult survival. Bighorn sheep have a low rate of increase (Buechner 1960, Woodgerd 1964). Yearly increments of increase that were simulated for the River Mountain herd after removals (Fig. 3) compare favorably to population growth at low densities observed for California bighorn, *O.c. californiana*, on Hart Mountain, Oregon (Voget and Hansen 1380) and for Rocky Mountain bighorn, *O.c.* canadensis, on Wildhorse Island, Montana (Woodgerd 1964). Thus, fixed adult survival may not have influenced results in a significant manner.

CONCLUSIONS

The River Mountain herd offers a unique and unprecedented opportunity to resolve some vital management questions and to add considerable knowledge to our understanding of population demography of desert bighorn sheep. Intensive monitoring of this population is mandatory to verify effects of continued herd reduction, so that it is not simply sacrificed for the sake of creating "x" number of new herds throughout the Southwest.

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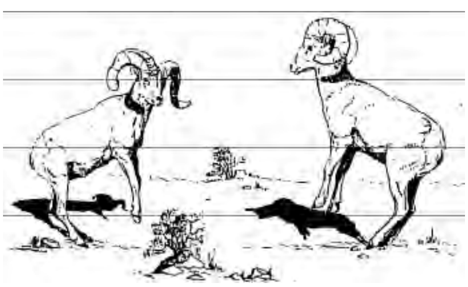


THE DESERT BIGHORN COUNCIL– THE FIRST 25 YEARS

Warren E. Kelly
Humboldt National Forest
Elko, NV

Abstract. The Desert Bighorn Council has been in existence for 25 years. The first meeting of the Council was held in Las Vegas. Three years later, we had developed a Constitution and Bylaws. In our 25 years we have published 25 transactions containing about 500 technical papers. The Council has presented several awards for outstanding accomplishments and it has memorialized its members who have died. The Council has prepared a book about the life history of the desert bighorn and contributed to a book about the wild sheep in North America, published by the Wildlife Management Institute. Two attempts have been made to force the Council to merge with the Western Association of Game and Fish Commissioners. Other proposals have been made to merge the Council with other bighorn groups. So far the Council has maintained its own autonomy.

The Desert Bighorn Council (DBC) had its beginning in Las Vegas in the spring of 1957 when biologists from the U.S. Fish and Wildlife Service, National Park Service and the Nevada Fish and Game Commission met to discuss the existing knowledge of the desert bighorn sheep. Clair Aldous, Gordon Fredine, Wally Wallace, Al Ray Jonez, and Warren Kelly attended this meeting. The review of existing literature didn't take long. About the only publication of a scientific nature on desert bighorn in existence at that time was the results of John Russo's work in southwestern Arizona during the early 1950s.

Gordon Fredine made the comment that most of the information on desert bighorn was still unpublished and stored in the minds and diaries of the people that were working on sheep at that time. He suggested we have a meeting of all persons currently working with the desert bighorn. The states of Texas, New Mexico, Arizona, Nevada, and to a lesser extent, California, were active in bighorn programs. Also personnel at the San Andres, Kofa, Cabeza Prieta and Desert Game Ranges and at Death Valley National Monument were conducting bighorn investigations. The first meeting of biologists doing research and gathering management data on desert bighorn was held in September of 1957. Twenty-seven people attended that meeting. The meeting was given the name of the Desert Bighorn Sheep Council. The agenda consisted of status reports from each state, refuge and park or monument. Unstructured discussions were conducted on such topics as water requirements, breeding and lambing periods, lamb survival, herd composition, seasonal food requirements, territory of individuals and bands, burro-bighorn competition, hunting, censusing techniques, and sign reading. Each discussion was recorded and the tape was transcribed and printed in the Transactions. After papers and discussions we had our first business meeting. Two questions were asked the group: was the meeting a success and shall the meetings become an annual affair? The answers were a unanimous "yes!"

The second meeting was held in Yuma during the first week in April. Again, that year we had a small group and nearly everyone at the meeting presented a paper. The program chairman had requested papers on specific subjects such as water developments, trapping and tagging, lungworm infections, water requirements and daily movements. Our field trip was an overnight affair to the Kofa Game Range.

In 1959 we met in California's Death Valley National Monument. This is where the Desert Bighorn Council actually came into being. At our business meeting we formally adopted the name Desert Bighorn Council as our official title. At this meeting a committee was appointed to prepare a Constitution and Bylaws for approval at the next meeting of the Council.

The Constitution and Bylaws were approved at the 1960 meeting in Las Cruces, New Mexico. In this governing document there are four objectives:

1. To provide for the exchange of information...through meetings and published transaction.
2. To stimulate and coordinate studies in all phases related to desert bighorn.
3. To provide a clearing house of information among all agencies, organizations and individuals...through the appointment of work committees.
4. To function in a professional advisory capacity, where appropriate, on local, national and international questions involving the management and protections of the desert bighorn,' and to adopt such measures as shall tend to promote the advancement of knowledge concerning bighorn and the long-range welfare of these animals.

In the last objective you may have recognized the origin of the words on our letterhead, which reads "Established to promote the advancement of knowledge concerning bighorn and long-range welfare of these animals."

During these first 25 years, have we satisfied any of these objectives? Let's take a look. At our first meeting we decided that we would hold our meetings in different places each year. We would then have an opportunity to visit other bighorn areas, visit with other biologists and observe their problems first hand, observe existing and proposed trapping and transplanting sites and generally make the Desert Bighorn Council Meeting a well-rounded annual training session. Since 1957 we have met in 22 different places and have had outstanding field trips. Our membership has been between 100-150 people since our first 3 or 4 meetings. We have published 25 transactions of our meetings and there has been an average of 20 papers in each transactions. The Council has prepared 2 management guidelines, one on trappping and transplanting and the other on habitat requirements of desert bighorn. The Council has prepared several resolutions relative to the introduction of exotic ungulates, the San Gorgonio Wilderness, the regulation and control of public use on public land, feral burros, and to permanently mark legally taken bighorn trophy heads.

In 1960 the Council presented its first Trophy Award to Ralph and Buddy Welles for their work at Death Valley National Monument. Since then Trophy Awards have been presented to Oscar Demming, John Russo, Charles Hansen, Steve James, Clair Aldous, the Arizona Desert Bighorn Sheep Society, the Mexico Forestry and Wildlife Department, and to Bob McQuivey. Honor plaques have been presented to the Nevada Operations Office of the Atomic Energy Commission, Pat Hansen, the Inyo National Forest, Lydia Berry, Jim Blaisdell, and the Society for the Conservation of Bighorn Sheep. In 1975 the Council presented an Award of Excellence to Gale Monson and Lowell Sumner, editors of The Desert Bighorn.

In 1964 the Mexican Forest and Wildlife Department presented the Silver Ram to the Council at the 8th Annual Meeting in Mexicali-San Felipe, Baja California, Mexico. The Mexicans intended this trophy to be given as an award. Since there was no way we could duplicate the Silver Ram for all future awards recipients, the Council voted to keep the Silver Ram as a symbol of the Council. It would be passed from chairman to chairman and would be on the podium at each meeting.

In 1962, Winn Banko, using the same argument that Gordon Fredine used in 1957, proposed that the Council members compile a book on the life history, ecology and management of the desert bighorn. This idea was approved and the Technical Staff was appointed and charged with the task of overseeing the completion of the book. Gale Monson and Lowell Sumner took on the task as editors. The editors worked with the sixteen authors to prepare 22 chapters and the book **The Desert Bighorn** was finally published in 1980.

In June of 1974, 17 Desert Bighorn Council members met with 61 other biologists and administrations at a workshop about North American Wild Sheep in Missoula, Montana. The workshop was sponsored by the Wildlife Management Institute. The proceedings were published in a book titled **The Wild Sheep in Modern North America.** Approximately one-half of the book relates to reports and management recommendations for the desert bighorn.

In 1964 the Desert Bighorn Council began a practice of dedicating transactions to members who had died. The first was Sr. Luis Macias, Director of the Mexican Forestry and Wildlife Department. Others were John Reed, Cecil Kennedy, Bun Morgan, Jake Metherell, Bill Graf and Bill Cooper, John Ebersole and Dick Smith who died in an airplane accident with Chuck Hansen. Chuck, Bill, John and Dick were doing an aerial bighorn survey when their accident happened. All of these people were dedicated to their profession and to the protection and preservation of the desert bighorn.

On 2 occasions efforts were made to force the Desert Bighorn Council to become integrated into the Western Association of State Game and Fish Commissioners. On each occasion the Council resisted these efforts. The reasons for opposing this proposal were (1) only administrators and a favored few would attend the meetings; (2) biologists actually working on bighorn would lose the opportunity to visit other bighorn areas; (3) possibly the greatest loss would be to the local Fish and Game Biologist-Conservation Officer-Game Warden in such places as Bishop, Monticello, Kingman, Las Cruces or Kerrville; these communities aren't on the Western Association's meeting list; (4) we would have to gain permission from the parent organization prior to taking any action. I believe the Council exhibited its maturity in dealing with pressures brought on by a relatively few members of the Western Association.

We have had proposals to merge with other bighorn groups either permanently or on a one year in five basis. On each occasion the Council has voted to maintain its own integrity. During the first 5 years of the Council we heard comments such as: We will soon exhaust the amount of data for papers; or, due to lack of data we will have to meet every two years or so; or, we should merge with other bighorn groups so we won't run out of data for papers; or, no new studies of desert bighorn will be initiated. So far none of these dire predictions have occurred. The number of papers has remained consistent with past years and the quality and diversity of the subject matter has gotten better. The Council has encouraged research and the Technical Staff has reviewed study plans; the most recent was Jim DeForge's project. Sometime soon the Council may be financially able to sponsor research through the Charles Hansen Memorial Fund.

The Desert Bighorn Council has been a leader, pusher, counselor and even occasionally an activist to meet and exceed the objectives as set forth in the Constitution and Bylaws.

You all know that Las Vegas is a gambling town. Five people took a chance back in 1957 and the desert bighorn came out the winner. I hope they can be winners during the next 25 years.

REPORT OF THE FERAL BURRO COMMITTEE

Steven D. Kovach, Chairman
Natural Resources Management Branch, Western Division
Naval Facilities, Engineering Command
San Bruno, CA

Abstract. Activities concerning feral burros by such agencies as the Bureau of Land Management (BLM), National Park Service (NPS), U.S. Navy, and U.S. Fish and Wildlife Service are reviewed.

NEVADA

Both the BLM and Nevada Department of Wildlife agree that there are no major feral burro problems in or adjacent to desert bighorn ranges. This does not imply that there are not problems, particularly around water sources.

NEW MEXICO

The court fight continues between animal protection groups and the NPS over feral burro removal operations at Bandelier National Monument. The appeal by protection groups is still in court.

ARIZONA

During Fiscal Year (FY) 1981, the BLM removed 899 burros. The majority of these came from the Yuma area. During the FY 1982 most burro removal activity has occurred in the Black Mountains outside Kingman. By April 1982 a total of 300 burros had been removed. The goal is 600 animals. Up until January helicopters and cowboys were used to herd burros into corral traps. The next phase will utilize water traps. The feral burro population within the Black Mountain area is 1800 animals (estimated). The BLM's management plan for the Black Mountains calls for leaving 400 burros as a managed herd. Plans for FY 1983 include continuing the efforts in the Black Mountains, plus removal of some animals from the Hualapai and Aquarius Mountains. At Grand Canyon National Park, no burros have been sighted recently.

CALIFORNIA

The BLM has continued its burro removal program within the California Desert Conservation Area (CDCA).The Environmental Impact Statement (EIS) for the CDCA called for all feral horse and burro removal to be completed by FY 1985. During FY 1981, 1,500 burros were removed from the Saline Valley area. During FY 1982 (through April) 500 more burros were removed from the same area. The goal for FY 1892 is 1620 animals to be removed from the CDCA area.

In the Inyo Mountains, Dr. John Wehausen's surveys indicated no burro activity. More importantly, bighorn sheep were found to be occupying areas previously used by burros. Dick Weaver, California Department of Fish and Game Bighorn Project Leader, suggested that the BLM's extensive burro removals from Saline Valley created a void which was filled by the burros in the Inyo Mountains.

There has been much confusion over the events at China Lake concerning control of feral burros: here is a brief review. In early 1980 the Navy and BLM entered into a Memorandum of Understanding which allowed the BLM to live-capture burros from the airfield operations area. The removals were conducted like other BLM roundups except that the Navy paid for the whole operation. From March 1980 through January 1981, 258 burros were removed. During this time period numbers of burros occupying the area actually increased, however--not decreased. Due to the safety requirements for aircraft and personnel at China Lake and the nearby community, the Naval Weapons Test Center command opted for "emergency direct reduction." During 2 weekends in March 1981, 3 shooters eliminated 649 burros. Most of these animals were field necropsied, and results indicated the burros were starving. Because of its actions, the Navy was sued by a group of animal protection interests. A settlement provided for no additional shooting, and allowed the animal protection groups to live-capture burros from the airfield and adjacent area. Between June 1981 and February 1982 the animal groups removed 606 burros. During the entire 22 month period, total removal efforts resulted in 1513 burros removed from a 275 square mile area, a density of 5.5 burros per square mile. In May 1981, the Navy released its draft EIS for feral burro management at China Lake. The preferred alternative was total removal by shooting. Fifty-eight comments were received: the majority opposed shooting and opted for live removal. The final EIS was released in November 1981: due to public response and pressure, the selected alternative was an 18-month period of live-removals followed by shooting the remaining animals. The Navy and BLM have another Memorandum of Understanding for live-removal: between January and May of 1982 and 1983, BLM personnel will utilize corral traps; between June and December of both years, water traps will be used. The Navy will pay BLM $50 for each burro so gathered. Once the burros are delivered to the local fair grounds, a consortium of 6 animal protection groups will assume responsibility for feeding, branding, veterinary care, transportation to private adoption centers, and rent for the fair ground facilities. No estimate of costs has been (or will be) provided by the consortium. Removal of burros under this plan started in February 1982 and by April 1982, 643 burros had been removed, 143 ahead of schedule. An estimated 4,000 remained to be gathered.

At Death Valley National Monument, the NPS each August conducts an aerial survey of burros in the monument. The annual increase in burro population numbers is 15%. The 1981 population count was 2,501 animals actually seen. During winter 1981-82, burros were discovered to have crossed the Valley floor at the southern end of the Black Mountains. About 45 desert bighorns live in the area. In November 1981, the EIS for Death Valley Burros was released. Over 200 comments were received. Many of the comments actually preferred the direct control (shooting) option over the extensive and costly live removal alternatives. There is no estimate on when the final EIS will be released.

OTHER ITEMS

During FY 1981 the BLM proposed to raise adoption fees for horses to $200 and for burros to $75, plus transportation costs. The increase was delayed from 1 October 1981 until 2 January 1982. Many fewer animals have been adopted under the new fees, but more revenue has been taken in.

The costs of gathering or controlling burros has been and is tremendously variable. NPS estimated that Fund for Animals spent in excess of $1,000 per burro to remove over 600 burros from Grand Canyon National Park. The BLM in Arizona estimated their live trap costs (including use of helicopter for herding) at $310 each in 1977 and $350 each in 1982. The Navy estimated live trap costs at China Lake at $550 per animal, and direct control costs at $50 each (and if the helicopter and crew costs are eliminated, the figure drops to $12 per burro.

In Nevada, PhD candidate Greg McMahon has been experimenting with what aircraft are best for counting feral horses. Data are very preliminary, but a B-1 helicopter was found to be best, followed in order by a Piper Super Cub, the Cessna 180, then Cessna 206. Based on marked-unmarked animal ratios, the Super Cub gave only a 5% error from a B-1; the Cessna 180 was about 35% less efficient than the Super Cub, and the 206 Cessna was poorest for counting horses.

STATUS OF DESERT BIGHORN SHEEP IN TEXAS--1982

Jack Kilpatric
Texas Parks and Wildlife Department
Marfa, TX

Historically, desert bighorn sheep occupied most of the arid mountain ranges in the Trans-Pecos region of Texas, that portion of the state which lies west of the Pecos River. The number of sheep in the early 1880s was estimated at 1,500 animals. Prior to that time, principal contact with man had been limited to the Indians and Spanish who had left no significant or lasting impact on the bighorn sheep.

The year 1881 marked the beginning of a series of events which led to the total extinction of the native Texas bighorn sheep. This was the year the railroad came through Van Horn, Texas, lying right in the heart of the best bighorn range. A year later, the Hazel Silver Mine was opened between the Beach, Baylor, and Diablo Mountains. These mountains contained the largest herds of bighorn sheep, and would subsequently be known as their last stronghold. Railroad crews and miners employed hunters to supply them with meat. Bighorn sheep were a part of their diet.

Market hunters also moved into the mountains around Van Horn, Texas, following the declineof the buffalo herds and the coming of the railroads. These hunters would work at their trade all winter while the weather was cold enough to keep meat. They would haul their meat, which consisted of deer, antelope, and bighorn sheep, to Van Horn by the wagonload to be loaded on refrigerated rail cars and shipped north to markets. This unregulated slaughter of bighorn sheep continued until 1903, when hunting of bighorns in Texas was prohibited.

By this time, the bighorn sheep herds in other parts of the Trans-Pecos had been nearly extirpated due to the encroachment of man. Domestic sheep were brought into these areas mainly because most of the ranges had good water resources. The impact of domestic sheep on the wild bighorn populations resulted in the demise of the bighorn in Texas. Factors such as food competition, net wire fences and domestic diseases and parasites took a heavy toll on bighorn populations.

In 1938, domestic sheep ranchers began stocking the last stronghold of Texas bighorn range. By 1941, the total number of Texas bighorn was estimated at only 150 head.

In 1945, the Texas Legislature established the Sierra Diablo Wildlife Management Area as a sanctuary for the last remaining bighorn sheep. No attempt was made to manage the sheep, however, and the herd continued to decline. In 1955, the population was estimated at 25 sheep, all in the Sierra Diablo Mountains. The last observation of native sheep in Texas was in 1960, when 2 ewes were sighted by department personnel in Victorio Canyon in the Diablo Mountains.

After it became apparent that the native Texas bighorns were in danger of extinction, efforts at reintroducing bighorn sheep to former ranges in Texas began. The project was a significant pioneering effort in the transplanting and propagation of bighorn sheep in the United States, and has continued uninterrupted since its initiation in 1954, except for the year 1981 when legislative funding was dropped. The project has had its ups and downs throughout the years, and cannot be considered a complete success. One of the most outstanding contributions of the project has been to further the knowledge of practical bighorn sheep management in Texas.

Through an agreement between the U.S. Fish and Wildlife Service, The Boone and Crockett Club, The Wildlife Management Institute, and the Game and Fish Commissions of Texas and Arizona, the reintroductory project was initiated in 1954 to restore the desert bighorn sheep to huntable numbers in Texas. A 427 acre brood pasture was constructed on the Black Gap Wildlife Management Area. Actual trapping and transplanting operations were conducted on the Kofa Game Range in Arizona during 1957, 1958 and 1959, and resulted in 16 sheep being released in the Black Gap pasture. Initially, 10 of these sheep did not survive. From the remaining 3 rams and 3 ewes, which began reproducing in the pasture in 1960, the herd steadily increased to an estimated 68 head in 1970. In January 1971, 20 bighorns were released from the pasture to range free on the Black Gap Wildlife Management Area. A total of 16 lambs were produced by the free ranging and penned sheep in 1971. The original 3 rams and 3 ewes produced 84 offspring.

In the fall of 1971, the brood herd within the Black Gap enclosure suffered its first major setback when 18 sheep were found dead. Necropsies revealed that the probable cause of the die-off was initiated by nutritional stress, brought about by poor range conditions and the rigorous breeding season. Disease organisms isolated were pneumonia and bluetongue. Losses of other sheep during this period were likely, as an extensive survey of the pasture in the summer of 1973 revealed only 4 rams, 6 ewes and 6 lambs. Several skeletons of sheep were found.

Shortly after this first major setback, the Parks and Wildlife Department began to cut back on their intensive predator control programs which had been conducted since the construction of the Black Gap pasture. In 1975, the predator control program was stopped altogether for a period of approximately 1 year. Losses of bighorn sheep within the enclosure to mountain lions and bobcats were common. The moratorium on predator control was subsequently modified to permit limited trapping activities specifically designed to protect the remaining sheep within the brood pasture. In addition, an 18 inch extension at a 45" angle was added to the brood pasture fence. It was hoped that this improvement along with limited predator control measures would alleviate the problem of mountain lions entering the pasture.

In January 1977, 6 ewes were captured by Department personnel in Mexico and released into the Black Gap pasture. Two of these ewes did not adapt to enclosure and died. In spite of the limited predator control and the extension on the fence, predators contined to plague the Black Gap pasture. From 1975 through 1977, a total of 21 sheep were killed by mountain lions and bobcats in the Black Gap pasture. This made it virtually impossible to continue propagation efforts.

An additional 600 acre brood pasture was completed in 1977 on the Chilicote Ranch in Presidio County by private funds and labor provided by the King Ranch, Inc. A total of 4 ewes and 3 rams were placed in the enclosure in 1977-78. The removal of these sheep from the Black Gap pasture virtually ended the propagation efforts at that location, as only 2 rams were left in the enclosure. One of these rams has subsequently escaped through a hole in the fence.

Since the Chilicote brood pasture was built and stocked with sheep, the herd has increased to 12 adults. Predation was blamed for the relatively slow increase in these sheep. One lamb was definitely killed by a mountain lion, and 1 ewe died of old age. Other losses have not been identified primarily because the Parks and Wildlife Dept. had no sheep project in fiscal year 1981. The project was reinitiated in 1982, however, and more time will be devoted to the Chilicote brood pasture facility in the future.

Concurrent to the propagation attempts at Black Gap and Chilicote Ranch, efforts to reintroduce bighorns to the Sierra Diablo Mountains were underway. In 1970, an 8 acre holding pen was constructed on the Sierra Diablo Wildlife Management Area. A total of 3 rams and 5 ewes from the Black Gap pasture were placed in this pen during the period of 1971 to 1978. From this nucleus a total of 7 sheep were released to range free in the Sierra Diablo Mountains in 1973, and 7 more were released in January 1979. These free ranging sheep have been estimated to number at least 25 head.

In November 1979, 5 ewes were delivered to the then empty Sierra Diablo holding pen from Arizona in a cooperative wildlife exchange between Arizona and Texas wildlife agencies. In late January and early February 1980, 2 lambs were born in the pen from these ewes. In March 1980, 1 ewe and her lamb were found dead. The ewe's death was related to her inability to adapt to the enclosure. The other lamb was observed to be sick. He was transported to the Glaze Veterinary Clinic at Kerrville for tests, where he later died. The cause of death was diagnosed as Contagious Ecthyma or Soremouth. This was the first incidence of disease in the Sierra Diablo holding pen since its construction. The other 4 ewes were removed from the pen in an effort to determine if the sheep were carriers of Soremouth. One ewe died in the capture attempt. The remaining 3 ewes were transported to a holding pen on the Kerr Wildlife Area. One ewe died shortly after arrival at the Kerr Area from enterotoxemia and another recently died of old age. The 1 remaining ewe is now being maintained at the Glaze Clinic, Kerrville.

Also at the Glaze Clinic is a ewe which was found to produce a lamb each year in the Sierra Diablo pen but would not lactate. With her are 2 of her offspring, a ram and a ewe, which have been hand raised. Attempts are being made to determine if the inability of the ewe to lactate is genetically transmissible by utilizing the techniques of backcrossing and inbreeding to concentrate any possible genetic deficiencies. All 4 of the sheep at the Glaze Clinic are being observed as a control group in the bighorn sinusitis study being conducted there.

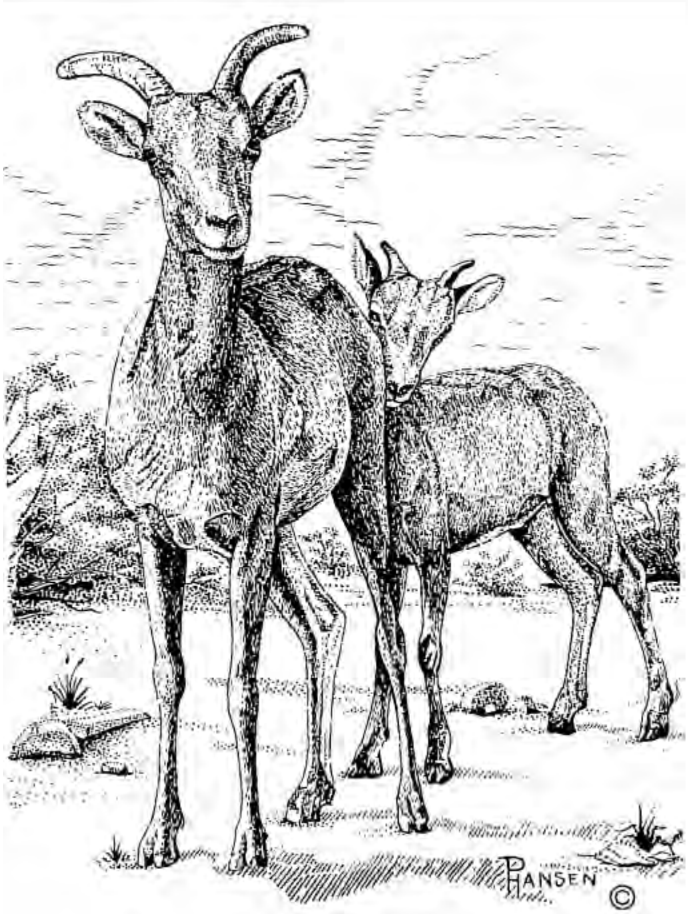
The free ranging sheep from the 1971 release of 20 head at Black Gap thrived for the first 2 years. Most of the ewes located adjacent to the brood pasture and good lamb crops were reported. However, as the predator control program went, so did the sheep. As we were losing sheep inside of the pasture to mountains lions, we were also losing sheep outside of the pasture. Occasionally, some of the survivors of these sheep are still seen in the area, but are estimated to number between 5 to 10 head. If there had been other sheep to supplement the original release annually, possibly this project would have been successful.

As stated, several things have been learned from the reintroductory attempts:

1. Bighorn sheep can be propagated successfully in enclosure situations. Very high lamb crops can be expected. This is important to Texas, because there is not a source of sheep readily available for free release.
2. Bighorn sheep propagated in a brood pen can adapt readily to the wild. This is evidenced by the successful releases in the Sierra Diablo Mountains in 1973 and 1979.
3. Adequate nutrition is a key factor in limiting losses to disease in an established herd of penned sheep.
4. A certain percentage of wild transplanted sheep (52% to date in Texas) will not adapt to a pasture or pen situation: stress involved with the failure to adapt will promote poor nutrition and susceptibility to disease.

5. A total commitment to predator control is necessary to protect a penned herd of bighorns or a newly released herd. It is foolish to assume that any prey species can flourish when it is in a situation where there are more predators than prey. Also, penned sheep are easier prey because of the confinement.

Based upon past experience, Texas is preparing to embark on a full scale effort to establish a sizeable herd of bighorn in the Sierra Diablo Mountains by supplementing the struggling, but successful, releases already made there. Brood pen facilities are planned at Sierra Diablo Wildlife Management Area which should produce 25 to 30 lambs each year. The initiation of this endeavor, however, depends upon legislative or private funding and the ability to obtain sufficient ewes to stock the brood pens. Once it is demonstrated that a viable herd of bighorns can be established in the Sierra Diablo Mountains, other suitable mountain ranges will be stocked with sheep produced from the Sierra Diablo brood pens.



DESERT BIGHORN ON BLM LANDS IN SOUTHEASTERN UTAH

Michael M. King
Gar W. Workman
Dept. Fisheries and Wildlife
Utah State University, Logan

Abstract. In 1980, the U.S. Bureau of Land Management contracted Utah State University to study the ecology of desert bighorn sheep on BLM lands in southeastern Utah. Objectives of the study included determining movements and habitat utilization, feeding habits, effects of mining, recreation, and livestock activities, and collecting disease and physiological information. Progress as it relates to the above objectives is presented.

INTRODUCTION

Nelson's bighorn *(Ovis canadensis nelsoni),* native to the rugged mountain and canyon country of North American deserts, is one of the most highly regarded animals for consumptive and nonconsurnptive purposes. As a component of arid and often fragile ecosystems, it requires close management as our human population expands its realm of influence into bighorn sheep habitat for energy exploration and development, livestock operations, and recreation activities. Expanded human use in bighorn habitats necessitates research to determine ecological requirements of bighorn so those critical components may be protected and conserved. Only by these means wil bighorn persist in desert environments.

Wilson (1968), Irvine (1969), Bates et al. (1975), and Dean (1977) studied the ecology of Nelson's bighorn in southeastern Utah. These studies provided baseline information on distribution and abundance, population trends, movements, feeding habits, and other general life history characteristics. Although these studies provided much needed data for wildlife and land managers, many questions remained unanswered. These early studies, with the exception of Bates et al. (1975), did not have the luxury of telemetry equipment. As a result, much time was spent searching for sheep rather than observing sheep and their interactions with the environment. Bates et al. (1975) used telemetry equipment, but all locations were from fixed-wing aircraft so intensive ground observations were not made.

Since these early studies, mining and recreation activities have fluctuated, while livestock uses have remained about the same. However, the data available on sheep ecology are minimal. To update the data for bighorn sheep in southeastern Utah, the U.S. Bureau of Land Management has funded a long-term study on desert bighorn ecology to assist them in formulating their land use planning system, livestock grazing environmental statement, and for the best possible management of the desert bighorn and its habitat under the multiple use concept.

The objectives of the study are to determine the extent of bighorn movements, habitat utilization, feeding habits, effects of mining, recreation, and livestock activities, and to collect physiological and disease information. This paper reviews the progress of the study to date.

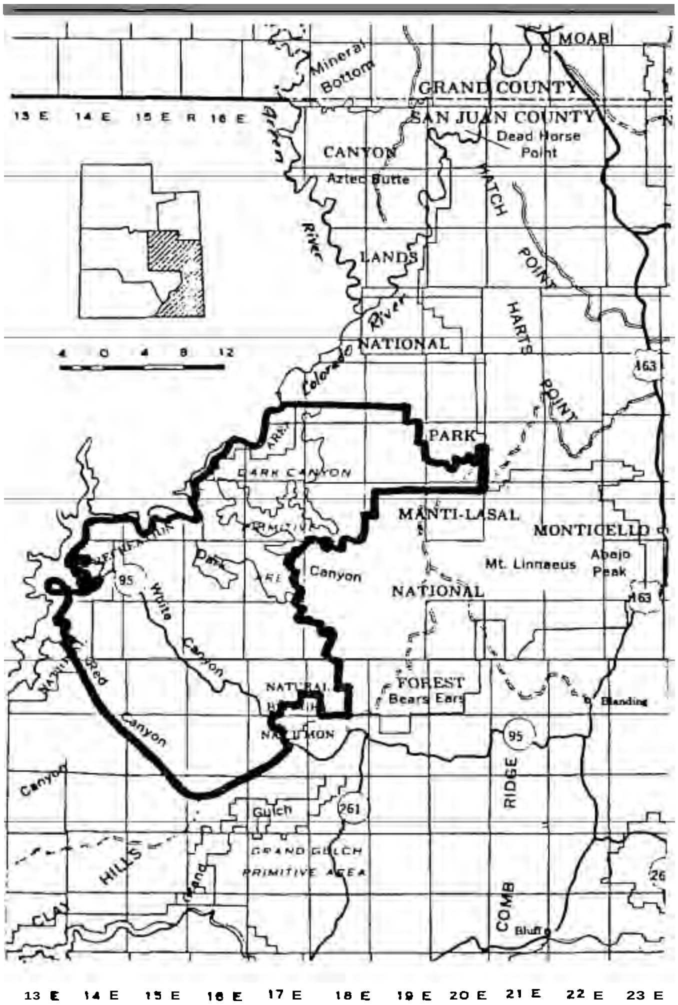
METHODS

Study Area. Immediately south of Canyonlands National Park in Southeastern Utah, the Bureau of Land Management administers extensive acreages of public land that provide suitable habitat for desert bighorn sheep (Fig. 1). This area is composed of some of the most rugged desert terrain found anywhere in the U.S. Topography throughout the area is rough and broken and not easily accessible to human use. Talus slopes and boulders are common throughout the canyons, with many slopes exceeding 100% grades. Elevations range from 3400 feet on the shores of Lake Powell to 7000 feet on many of the mesa tops.

Plant communities in the study area are typical of the Upper and Lower Sonoran Life Zones (Wilson 1968).

Annual average rainfall in the area is 9 inches and temperatures range from 0"-40°C.

Procedures. In order to monitor sheep movements, habitat utilization, feeding habits, and other life history characteristics, 7 bighorn sheep (2 ewes, 5 rams) were captured and fitted with Telonics radio transmitters in February, 1981 by the Utah Division of Wildlife Resources. Sheep were immobilized from a Hughes 500D jet helicopterwith M-99 (Etorphine), fitted with collars, administered the antagonist drug M50-50 (Diprenorphine), and released. Since that time, sheep have been located and observed at least twice per month from the ground, and at least once per month from a fixed-wing aircraft. Each time sheep were observed, habitat type, feeding



Portion of Moab District 06, 1976, USDI/BLM

Figure 1. BLM desert bighorn study area.

habits, general behavior characteristics, and response to disturbances were recorded.

Disease information was collected when sheep were captured and collared. Blood samples were taken from sheep and analyzed to detemine incidence of several diseases. Sheep were examined externally to determine if sheep were infected by parasites or sinusitis.

RESULTS AND DISCUSSION

Movements. Ram 65, a 1½ year old when collared, was relatively static in his movements from February-September 1981. During that time, his home range was estimated to be 2.5 mi^2. He was found in association with 3 mature ewes and their lambs during this time. With the onset of the rut in October, he left his summer range and associates and moved to an area 3 miles to the west where he is now located. This fall-winter movement extended his home range size to 8.8 mi^2. During fall-winter he was associated with several different adult rams and ewes. However, as the mature rams left the area in January and February 1982, he remained with the ewes.

Ram 75, also a 1½ year old, was relatively static in his summer movements. His home range size from February to September was approximated at 4.5 mi^2. He was associated with several different ewes during this period. During fall-winter he moved considerably more than in the summer. Though he used the same areas, he expanded his range into several new areas. His overall home range size was estimated to be 13.5 mi^2. He was found in association with several different sheep during this period, but did not leave the ewes.

Ram 85, a 2½ year old when collared, moved considerable distances during February-September 1981. His home range was approximated to be 10.5 mi^2. This ram was not sighted until September at which time he was found killed by a mountain lion *(Felis concolor).*

Ram 135, a lamb when collared, also moved considerable distances from February-September 1981. During summer, he ranged 8.3 mi^2. He was seen in association with 2 different ewe groups, however he associated most often with other young rams. During fall-winter, ram 135 moved into several new areas. The increased movement extended his home range to 19.0 mi^2. This home range extension is attributed to his movement from ewe groups with mature rams as they left ewe groups after the rut.

Ram 155, also a lamb when collared, spent the summer associated with a group of mature ewes and their lambs. During this time his home range was estimated to be 7.0 mi^2. The fall-winter range was very restricted compared to summer movements. He used an area of 1.3 mi^2 within the summer range.

Ewe 115, a mature ewe, moved little during the entire field season. During summer, she had a home range size of 1.8 mi^2 during which time she was primarily alone. During the fall-winter period, she expanded her range little and used essentially the same areas. Her home range expanded to 2.4 mi^2 during this period and she was observed with several different ewes and rams.

Ewe 145, a mature ewe, ranged over considerable area during the period from February-September 1981. Her home range size during this period was 9.4 mi^2. She associated with 5 other ewes and their lambs and occasionally ram 135 and other small rams. During fall-winter, her movements were restricted to a smaller portion of the summer range, using an area of 4.0 mi^2. During this time, 1 large ram was seen in association with her group.

A complete list of home range sizes for all sheep during summer and fall-winter periods is contained in Table 1.

Table 1. Approximated home range sizes for radio-collared desert bighorn sheep in southeastern Utah.

Sheep#	Sex	Age	Home Range Size (mi²) Summer	Fall-Winter	Total
R65	M	1½	2.5	6.3	8.8
R75	M	1½	4.5	10.5	13.5
R85	M	2½	10.5	---	10.5
R135	M	lamb	8.3	15.2	19.0
R155	M	lamb	7.0	1.3	7.8
E115	F	mature	1.8	2.4	3.5
E145	F	mature	9.4	4.0	10.2

Habitat Utilization. There are essentially 4 major categories of habitat in the area. Mesa tops, talus slopes, benches, and valley floors and flats are common throughout the area. Sheep were observed in all habitat types, however, the steep talus slopes received heaviest use (59% of all observations, Table 2).

Feeding Habits. Direct observations of feeding behavior were recorded from June-December 1981 (Table 3). Forage use by bighorn was determined by recording frequencies of use of different plant species at various feeding stations. Use of a culm of grass, leaf or stem of a forb, or leader or leaves of shrubs or trees constituted one instance of use. Instance of use was recorded for each sheep in the group being observed at 2 minute intervals for as long as the sheep could be observed. At least 150 observations were made each month for a total of 2879 total observations. During June-September, browse species dominated the diets of sheep (76.0%), with grasses and forbs being less significant. During October-December, browse species were again chief diet items (70.3%), however grasses in the diet increased to 27.9%. The observed increase in use of grasses is attributed to utilization of new growth stimulated by significant fall rains.

The Bureau of Land Management (San Juan Resource Area, Monticello, UT) had bighorn fecal samples analyzed to determine diet composition for winter-spring periods for 1979 and 1980 (Table 4). The results of these analyses also suggest the importance of browse in bighorn diets.

Effects of Mining, Recreation and Livestock. These 3 aspects have been particularly difficult to evaluate to this point of the study. Recently, uranium ore prices have dropped significantly, virtually eliminating all mining from the area. Recreation within the area is sporadic, however, 3 major accesses to Lake Powell are in the study area and receive frequent use by fishermen and boaters. Hikers and hunters also frequent the area.

Cattle operations in the area may have a signifcant impact on sheep populations. The study area serves as winter range for 3 cattle allotments. However, cattle are not moved into sheep habitat until November so little data were collected during the past year. This aspect will be examined more fully in the present phase of the study.

Disease Information. As sheep were captured, blood samples were collected for analyses to determine if sheep were infected by various diseases. The results of these analyses showed that captured sheep were not infected with Brucellosis, Leptospirosis, or Anaplasmosis. However, 4 of 18 sheep captured showed positive Blue Tongue titers, indicating they had been exposed to the disease at some time.

Table 2. Desert bighorn sheep use of different habitat types in southeastern Utah.

Habitat Type	Number of Observations	% Total
Talus slopes	142	59.2
Benches	65	27.1
Mesa tops	17	7.1
Valley floors	16	6.6
Total	240	100.0

Table 3. Diet composition for desert bighorn sheep in southeastern Utah, 1981 (determined by 2879 observations of 166 feeding sheep).

Sample Size	Season	% Grasses	% Browse	% Forbs
n = 628	June-Sept.	18.3	76.0	5.7
n = 2251	Oct.-Dec.	27.9	70.3	1.8

Table 4. Results of bighorn sheep fecal material analysis conducted by BLM for winter 1979-80 and 1980-81.

Sample Size	Year	% Grasses	% Browse	% Forbs
n = 150	1979-80	5.3	76.4	18.3
n = 150	1980-81	17.2	30.5	52.3'

'Contains 17.7% unknown forb seed, thought to be mustard

Sheep were also examined to determine if they were infected with sinusitis or scabies mites. Two young rams were infected with scabies but no cases of sinusitis were discovered.

The reported results of this paper are from the first phase of a four-phase study funded by the Bureau of Land Management. Future efforts will concentrate on continued definition of critical areas and aspects of bighorn ecology in southeastern Utah so that biologically sound managment decisions can be made to protect and manage desert bighorn to increase their chances of survival in Utah.

ACKNOWLEDGMENTS

Special acknowledgment is extended to the personnel of the Bureau of Land Management, Utah Division of Wildlife Resources, and Utah State University who have actively participated in planning and initiating the study. This study would not be possible if it were not for the support financially and in kind they provide.

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MOVEMENTS AND MORTALITIES OF DESERT BIGHORN OF THE SAN ANDRES MOUNTAINS NEW MEXICO

Richard Munoz
U.S. Fish and Wildlife Service
Las Cruces, New Mexico

Abstract. Movements and mortalities of 25 radio-collared desert bighorn sheep (Ovis canadensis mexicana) of the San Andres Mountains were documented from 9 December 1980 to 1 March 1982. This report details results of work accomplished from 1 April 1981 to 1 March 1982 to evaluate the effectiveness of treatments for a severe psoroptic mite (Psoroptes ovis Hering) infestation. Of 25 sheep fitted with radio-collars, 9 were killed by mountain lions (Felis concolor) and 1 died of an undetermined disease. Two transmitters no longer are emitting signals.

Radio-collared sheep were located during an aerial survey on 26 and 27 October 1981. Thirty-eight sheep (8 lambs, 21 ewes, 9 rams) were observed, which amounts to a lamb/ewe/ram ratio of 38:100:43. Of the total sheep observed, 53% (n = 20) were uncollared.

INTRODUCTION

Studies were conducted during 1981 and 1982 on the San Andre Mountains to document movements and mortalities of 25 radio-collared desert bighorn sheep (Ovis canadensis *mexicana*) and to evaluate effectiveness of treatments for a severe psoroptic mite (Psoroptes ovis Hering) infestation (Sandoval 1979,1980). The background of this study was detailed by Sandoval (1981) and Munoz (1981).

METHODS AND MATERIALS

Methods utilized during telemetry work were described by Munoz (1981). An aerial survey was conducted on 26 and 27 October 1981 from a Bell 206 Jet Ranger helicopter. Two observers were utilized, and sheep were counted by first locating radio-collared animals on the assumption that uncollared sheep would be in the vicinity of collared sheep (Sandoval 1979). Total survey time was 3 hours and 25 minutes.

RESULTS AND DISCUSSION

Mortality. Ten of 25 sheep originally radio-collared died during 1981. Nine sheep (6 ewes, 3 rams) were killed by mountain lions (Felis concolor) and one died of an undetermined natural cause. San Andres sheep lost to mountain lion predation from December 1980 to March 1982, represent 24% of the known bighorn population and 36% of the radio-collared sheep. At this level, lion predation represents a severe limiting factor to the San Andres herd. All but 2 of the sheep mortalities caused by lions occurred within a 3 month period beginning 1 January 1981 and ending 1 April 1981. The last sheep lost to mountain lion predation was killed on 24 March 1982.

Blaisdell (1961) stated that, "Lions will kill bighorn; it seems to me that it is the degree to which they kill, and the influence the predation has on the total population which should concern us." Incidents of mountain lion predation of desert bighorn sheep were recently reported by McCutchen (1978) and Jorgensen and Turner (1975). However, predation by mountain lions has not been reported as a limiting factor in the sense that predation outweighs all other potentially limiting factors. Hornocker (1970) found lion predation to be insignificant on a herd of Rocky Mountain sheep in Idaho and attributed this to the close knit group behavior of the herd. The estimated population for Hornocker's study area was 125 sheep, compared to an estimated population for the San Andres Mountains of 40 sheep. Average group size in 45 observations made during 1981 was 3 with a standard deviation of 2. Sandoval 1979) reported average group size in the San Andres Mountains was 5.9 during 1976. It may be that predation pressure increases in situations where density of sheep decreases to the point that group size is not large enough to provide adequate detection of lions. In the San Andres Mountains, the reduction of the sheep herd by scabies infestation in 1979, may have contributed to the problem of increased lion predation.

Predator control was conducted by New Mexico Game and Fish and Animal Damage Control personnel throughout 1981 and 1982. During this time, 38 mountain lions were removed by three trappers in the San Andres and Oscuros Mountains.

Movements. Average distance between extremes of home ranges for 18 ewes was 8 km (4.97 mi), with a standard deviation of 3.94 km (2.45 mi). For 7 rams, average distance between extremes of home ranges was 19.1 km (11.8 mi), with a standard deviation of 15.3 km (9.5 mi).

Sheep generally remained in 5 distinct herds; however, intermingling of herds occurred on several occasions. A pilot from White Sands Missile Range observed 21 sheep in one herd on 9 June 1981. This sighting coincided with telemetry documentation of the mixing of 2 of the 5 herds in the same area of this observation.

Population Structure. Thirty-eight sheep were observed (8 lambs, 21 ewes, and 9 rams) during an aerial survey of the southern portion of the San Andres Mountains on 26 and 27 October 1981. This amounts to a lamb/ewe/ram ratio of 38:100:43. Since 1941, the lamb/ewe/ram ratio has ranged from 92:100:175 to 21:100:31, with an average of 51:100:72 (Sandoval 1979). Two lambs observed earlier during 1981 were not counted during the aerial survey. The minimum percentage of productive ewes was 48 percent. No indications of recurrences of psoroptic mite infestation were observed.

CONCLUSION

Lion predation is the major limiting factor (used here as the factor that outweighs all others in the extent to which it reduces the rate of population increase) of the San Andres bighorn sheep population at this time. This probably resulted from the decrease of sheep group size during the 1979 scabies infestation. The decrease in group size probably increased the vulnerability of sheep to lion predation. No indications of a recurrence of psoroptic mite infestation were noted throughout 1981. Production during 1981 was good despite stress associated with treatments for psoroptic mite infestations. Predator control conducted by New Mexico Game and Fish and Animal Damage Control personnel reduced predator losses during the latter part of 1981. Production during 1982 should be higher than in 1981 due to the decrease of lion predation and to the cessation of treatment for psoroptic mite infestation.

ACKNOWLEDGMENTS

This project was a cooperative effort involving the New Mexico Department of Game and Fish, White Sands Missile Range, and the U.S. Fish and Wildlife Service. I would like to especially thank Andy Sandoval who was helpful in all phases of this study.

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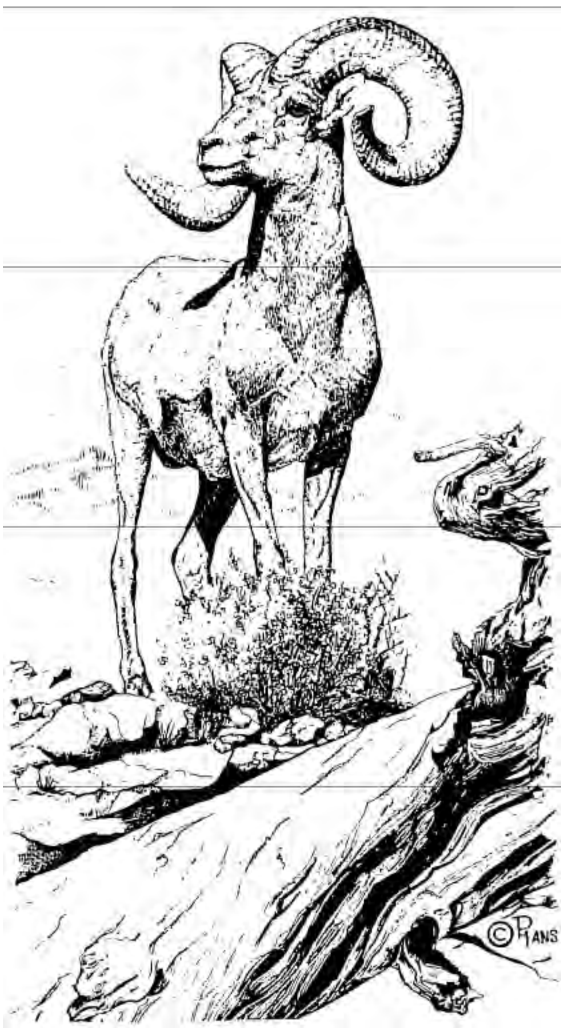

ARIZONA BIGHORN SHEEP STATUS REPORT--REVIEW OF PAST 25 YEARS

Paul M. Webb
Arizona Game and Fish Department
Phoenix, AZ

Since this is the 25th anniversary of the Desert Bighorn Council, the following is a capsulated review of desert bighorn management and progress in research and transplanting since 1957.

John Russo (1956) wrote a book on desert bighorn in Arizona. Russo's study was initiated in 1950 and continued through 1957. As a result of the efforts of this sheep biologist, the following was known about desert bighorn in Arizona:

1. Historical distribution
2. Present distribution
3. Estimated population
4. Most habitat requirements
5. Life history
6. Mating behavior and reproduction
7. Food habits
8. Competition from cattle, burros, and deer
9. Inimical factors
   - A. Man's activities
   - B. Poaching
   - C. Predators
   - D. Disease
10. Needed management practices
    - A. Survey techniques
    - B. Water development
    - C. Hunting
    - D. Transplanting
    - E. Feral animal control
    - F. Controlled grazing

Much of the findings of Russo still stand today.

SURVEYS

By 1957, waterhole surveys were an annual event in bighorn ranges in Arizona. Mechanized technology had not yet caught up with sheep survey efforts. During the next 10 years, however, surveys were gradually increased throughout the state and included boat surveys along the Colorado River and, most importantly, helicopter surveys. Helicopter surveys are now the primary means of locating, counting, and classifying bighorn sheep.

The helicopters used originally were Bell supercharged models 43G-3B. However, after a number of close calls and an accident that resulted in a death, surveys are now done with the more powerful and efficient Hughes 500 or Bell 206 (Jet Ranger) helicopters.

Bighorn surveys are still best accomplished in some areas by waterhole counts, by walking (especially during lambing), by some vehicular surveys, and by some boat surveys.

Survey data are used to determine population information and to annually assess reproductive trends. The number of rams counted and estimates of their ages are the primary means of determining numbers of hunting permits.

HUNTING

Hunting began in 1953 as part of Russo's study. Initially, hunts were recommended to examine animals for disease and parasites and to give hunters an opportunity to harvest "surplus" rams. By 1957, 115 hunters had harvested 49 rams, with an average hunter success of 43%.

Since 1957, permit numbers increased each year to a maximum of 90 in 1962 and 90 in 1965. Since 1972, permit numbers have been gradually reduced reaching a low of 45 in 1981. The reason for the reduction was because hunter success had increased from about 30-35% in 1962 to over 75% since 1976. The same number or more bighorns were being harvested by fewer hunters.

After 29 bighorn seasons (1953 to 1981) 1,775 hunters have harvested 896 rams for an average hunter success of 50% (Table 1). All hunts have been conservative and nothing indicates that hunting under the present intensity has harmed any bighorn population.

WATER DEVELOPMENT

Water has been developed and will continue to be developed specifically for bighorn throughout the state. It is one management tool recommended by the Bureau of Land Management and U.S. Forest Service in any habitat management plan. Next winter, the Arizona Desert Bighorn Sheep Society hopes to celebrate their 100th water development project for sheep in cooperation with the Arizona Game and Fish Department.

TRANSPLANTING

Trapping operations were initiated in Arizona in 1955 on the Kofa Game Refuge. This was instigated by the desire of Texas to obtain bighorn. A cooperative plan was developed whereby Texas paid all trapping costs and any sheep trapped were to go to both Arizona and Texas. By 1957, only 4 sheep were safely transplanted to Texas.

Trapping was done in the hot, dry summer months around waters that bighorn were known to use. High mortality occurred initially; when tranquilizing drugs were used, mortality was reduced but was still high.

After 1957, capture operations continued around waterholes in the dry, summer months and enough sheep were captured to fulfill Texas' needs and to start on Arizona's needs.

Arizona constructed a 112 acre enclosure near Aravaipa Canyon. Eight sheep were released in this enclosure between 1958 and 1960. By 1964, for one reason or another only 2 rams were left.

Capture efforts then turned to the use of Cap Chur equipment and the use of various drugs. The drug M-99 (Etorphine) proved to be the most satisfactory. In 1968, 2 ewes were successfully captured on the ground with this method. Both were taken to Aravaipa.

With a good means of delivering the drugs via the Cap Chur rifle, attention then turned to the helicopter as a means of locating the sheep and getting close enough to "dart" them. This first proved successful in 1971 and 3 ewes were captured for Aravaipa; 3 more were captured for Aravaipa in 1972.

This then has been the history of the development of trapping techniques for bighorn in Arizona. The helicopter-Cap Chur rifle method has been responsible for most of our capture work since. The exact number of sheep captured in Arizona by this method is unknown at this time, but at least 321 sheep have been captured since 1977 for various purposes--transplanting and special studies.

CURRENTPROBLEMS

Disease has been identified as a problem. A better understanding of the relationship of disease commonly found in bighorn sheep and in livestock is needed. Livestock that are introduced into bighorn ranges during winters of good annual plant production should be checked for disease.

Some populations of bighorn sheep have virtually disappeared in the last 10 years. Current low populations should be studied to determine the cause.

Habitat continues to deteriorate because of man's activities and occupation, e.g., powerlines, highways, urbanization, military activities, canals, and winter visitors encroaching on habitat.

Survey efforts are becoming too costly. With helicopters renting at approximately $300 per hour, an alternate means of survey may have to be initiated.

Table 1. Summary of Arizona bighorn harvest.

Year	Permits Authorized	Hunters Afield	Harvest	Percent Success
1953*	20	20	10	50
1953*	17	17	10	59
1954	20	19	12	63
1955	20	20	5	25
1956	20	19	6	32
1957	20	20	6	30
1958	40	37	18	49
1959	65	62	19	31
1960	80	80	24	30
1961	85	84	26	31
1962	90	89	27	30
1963	81	79	31	39
1964	78	76	25	33
1965	90	83	42	51
1966	84	84	35	42
1967	84	83	31	37
1968	81	77	47	61
1969	86	84	42	50
1970	79	76	39	51
1971	85	81	31	38
1972	74	74	35	47
1973	71	68	38	56
1974	63	62	41	66
1975	60	57	35	61
1976	61	61	46	75
1977	57	57	50	88
1978	58	54	45	83
1979	59	59	47	80
1980	50	50	39	78
1981	45	43	34	79
Total	1,823	1,775	896	50

'Two hunts in 1953.

Low lamb survival is found during most years. This needs to be identified and the causes determined.

DIRECTION

Arizona will continue to monitor sheep populations and hold conservative hunts.

The aggressive transplanting program of the last few years will be rested for at least 1 year. A need exists to analyze what has been accomplished to provide direction to future transplant programs. During the next year firm priorities will be established for areas identified as potential transplant areas.

Disease affecting bighorn sheep will continue to be monitored and studied through blood collection, analysis of fecal droppings, scabies investigations, and other methods.

A study may be initiated to determine what has caused some sheep populations to drop so drastically in the last 10 years.

CURRENT STATUS

During 1981-82, bighorn surveys produced a total of 1,258 bighorn sheep observations. Bighorn surveys were conducted on the ground and with the aid of helicopters. Of 1,258 bighorn classified, 370 were rams, 624 were ewes, and 208 were lambs. Also, 56 yearlings were classified. Calculated sex and age ratios are 59.3 rams to 100 ewes to 33.3 lambs.

As in the past years, Arizona again conducted a conservative bighorn hunt. Statewide, 45 permits were authorized for the 1981 bighorn sheep hunt, a decrease of 5 permits from 1980. Permits issued in 1981 were distributed over 20 hunting areas. For the 45 permits, 2,535 applications were received, an average of 56 applications for each bighorn permit. Total applications were comprised of (72%) resident and (28%) nonresident applicants. During the 1981 bighorn hunt, 43 hunters hunted 293 days to harvest 34 rams for a 79% hunter success, comparable to that of the last several years (Table 1). Ages of bighorn sheep harvested ranged from 4-10 years and averaged 6.9 years on a statewide basis. Green Boone and Crockett scores ranged from 120-118 to 180-318 and averaged 159-6/8. The Aravaipa herd (our 1st transplant) was hunted for the 2nd year. One ram was harvested. The herd here is estimated at 100 bighorn sheep.

TRANSPLANTING PROGRAMS

Arizona was again active in capturing and transplanting. Jim deVos (1982) summarizes these efforts in the Virgin Mountains, Goat Mountains, and Redfield Canyon. A brief discussion on the Mule Shoe Ranch release and the Rocky Mountain sheep in eastern Arizona follows.

In November 1980, 12 sheep (9 ewes and 3 rams) were released into a 300 acre enclosure at the Mule Shoe Ranch located in the southern portion of the Galiuro Mountains of south-central Arizona. In 1981, a supplemental release of 9 (6 ewes and 3 rams) was placed in the enclosure.

Four mortalities were recorded from the 1980 release--3 ewes and 1 ram. Also, a ram is missing. At times, it seems to be a matter of speculation as to just why these sheep are retained in an enclosure. Some sheep seem to wander in and out at will. One yearling ewe and one adult ewe escaped the enclosure shortly after their release in 1980. These 2 ewes, and 1 of the ewe's lamb, were located approximately 9 kilometers south of the enclosure. One of the ewes was found dead shortly after the lamb was born. Recently, the other ewe and a yearling ram (the lamb?) were found inside the enclosure. The current population of sheep in the enclosure is 3 adult males, 3 yearling rams, 11 ewes, and 2 lambs.

Twenty Rocky Mountain bighorn have been released in the Blue River area of eastern Arizona. Currently, winter surveys have produced sightings of 31 sheep--7 rams, 19 ewes, and 5 lambs.

RESEARCH

The Arizona Game and Fish Dept. has a livestock-bighorn sheep interaction study in the Aravaipa Canyon area of south-central Arizona.

Private and federally funded research projects involving desert bighorn sheep are presently ongoing within Arizona. A desert bighorn sheep study initiated and funded by Arizona Public Service and Southern California Edison Electric is going into its 5th year. This research project is designed to determine the impacts that powerline construction has on sheep population in the New Water, Plomosa, Dome Rock Mountains, and the northern portions of the Kofa Game Refuge. Data on home range, seasonal movements, and lamb mortality of bighorn have been documented.

Another study involving desert bighorn sheep and mule deer movements is presently in its 3rd year. This research project is being funded by the Bureau of Reclamation to determine movements of bighorn sheep and mule deer in relation to the Granite Reef Aqueduct portion of the Central Arizona Project near the Little Harquahala and Harquahala Mountains.

A study was initiated in 1981 in the Santa Catalina Mountains just north of Tucson to ducument habitat use by radio-collared sheep in relation to human activities and urban encroachment, to document vegetative community preference by these sheep, and to obtain information on population parameters using mark-recapture techniques. Currently 11 sheep have been radio-collared. The study is a cooperative program between the Coronado National Forest and the Arizona Game and Fish Department.

PRELIMINARY REPORT ON FOUR FREE RELEASES OF DESERT BIGHORN IN ARIZONA

James C. deVos, Jr.
Arizona Game and Fish Department
Phoenix, AZ

Abstract. Four free releases of desert bighorn sheep were conducted during the fall of 1981. Two releases were in northwestern Arizona, consisting of a total of 41 Ovis canadensis nelsoni. Two releases, one of which was a supplement, were in the southeastern portion of the state, consisting of 26 *O.c. mexicana*. Sheep were captured from a helicopter, transported and held in a temporary holding facility up to 12 hours. In general, ewes have moved short distances from the release site and appear to have established use areas. Rams have moved greater distances, but also are staying in the area of the release sight. Considerable herd interchange within releases has occurred. Lambing has occurred in all of the transplants.

INTRODUCTION

During the past 200 years, both populations numbers of, and the occupied range of desert bighorn sheep (Ovis canadensis) in North America have declined (Buechner 1960). There are many educated guesses as to why; two common ones are range degradation by domestic livestock, and diseases introduced by livestock. Advances in veterinary medicine have ceduced the occurrence of many common devastating livestock diseases. Improved grazing practices have in some cases resulted in improved range conditions. As a result, some areas where desert bighorn were extirpated are now suitable as reintroduction sites.

In recognition of the need to reintroduce sheep into suitable habitat, the Arizona Game and Fish Department (AGFD) officially recognized the need for transplants in its bighorn sheep strategic plan (AGFD 1980). Two transplants took place in 1980 (deVos et al. 1981). During November and December 1981, 41 bighorn sheep (*O.c.* nelsoni) were released into the Virgin Mountains (20 Sullivan Canyon, 21 Buck Springs) in northwestern Arizona, 16 bighorn sheep (*O.c.* mexicana) were released into Redfield Canyon in southeastern Arizona. Two supplemental releases were made, one to Muleshoe Ranch (9, *O.c.* mexicana) and one to Goat Mountain (10, *O.c.* mexicana). Transplants also were made. This is a preliminary report on the Virgin Mountain, Redfield Canyon, and Goat Mountain releases.

METHODS

Selection of release sites resulted from investigations conducted by AGFD, Forest Service (USFS) and Bureau of Land Management (BLM) St. George, Utah District biologists. Factors evaluated included: topography, present livestock use patterns, range conditions, availability and distribution of free water, and potential human interaction. Based upon these criteria, Virgin Mountain, Goat Mountain and Redfield Canyon were selected as suitable release sites.

Bighorn were captured by darting from a helicopter. Both a Cap-Chur long range projector and a Paxarm MK24 capture rifle were used. Animals were darted with 4cc Cap-Chur darts using 3.5 mg of Etorphine (M-99) plus 20-25 mg Azaperone. Bighorn were transported from the capture site to a base camp in a 9 ft. square net. Upon arrival at camp, animals were checked for physical well-being, stabilized, (if necessary) and injected with a reversal dose of Diprenorphine (M50-50). After reversal, they were placed in a darkened horse trailer until transported to the release site (deVos and Remington 1980).

A 15 x 25 ft. woven wire and burlap holding pen was constructed at all release sites to reduce post release scattering. Sheep were held overnight in all cases except at Buck Springs, where they were held for approximately 1½ hours until sunset when they were released.

Post-release monitoring was accomplished using a TR2 receiver (Telonics Inc., Mesa, AZ). Aerial tracking was accomplished by using various fixed wing aircraft equipped as described by LeCount and Carrell (1979).

RESULTS

Sullivan Canyon: This release consisted of 20 sheep, 10 (6 ewes, 4 rams) of which were radio-collared. On the first flight, which was made on December 8, 1981, 27 days after the release, all but 1 sheep was relocated. Distance ewes traveled from the release pen varied from 0.0 to 3.5 miles. Ram movements varied from 1.3 to 3.6 miles. Since the first radio location ewes have stayed in the vicinity of the release site; however, 1 ewe has moved over 11 miles to the northeast and stayed in that area. Rams have moved greater distances than ewes, especially recently. On the last flight in early March 1982, rams were located as far as 10.9 and 22.4 miles from the release site; the latter location was in Nevada.

Of interest is the amount of travel that occurred between radio locations. The period between locations did vary; however, it is possible to gain insight into the amount of pioneering that occurred. For 7 sheep located on the first and second flight, the mean distance between these 2 points was 3.0 miles. Between the second and third flight this mean distance increased to 4.3 miles. After the third flight movement decreased steadily throughout the end of February. The wide movements of 2 rams on the last flight resulted in this figure almost tripling (1.0 to 2.6). This decrease in movement was especially noticeable for ewes and probably was the result of early pioneering by all sheep and subsequent selection of lambing sites by some ewes. A summary of movement data is found in Table 1.

Buck Springs: This release consisted of 21 sheep, 10 (6 ewes, 4 rams) of which were radio-collared. Aerial radio-tracking began on December 8, 1981. On this flight, all but 1 animal was relocated. The distance that ewes traveled from the holding pen ranged from 1.0 to 2.3 miles. Mean distance traveled for ewes was 1.9 miles. Rams were located closer to the release site; the greatest distance traveled being 1.0 miles. The mean was 0.9 miles. Through the end of March 1982, the greatest distance that a sheep was located from the release site was 3.3 miles (2 year old ram).

As expected from the lack of widespread movements, distances traveled between locations were small. The mean distance between the first and second flight was 1.2 miles. This measurement varied little on subsequent flights. Both ewes-and rams were often located less than 0.5 miles from the previous site (see Table 1).

Table 1. **Movement data from 1981-82 wild released bighorn sheep in Arizona**

	Sullivan Canyon (Virgin Mountains)		Buck Springs (Virgin Mountains)		Painted Cliffs (Goat Mountain)		Redfield Canyon	
	♂	♀	♂	♀	♂	♀	♂	♀
Distance (miles) from Release on First Location (X)	1.8	2.0	0.9	1.9	1.4	1.2	2.5	3.6
Greatest Distance (miles) from Release Through 3-31-82	22.4	11.6	3.3	2.8	4.8	5.2	20+	6.7
Distance (miles) from Release on Latest Location (X)	9.7	5.4	1.8	1.5	3.1	1.2	5.6	1.9

Painted Cliffs: This transplant was a supplement to the Goat Mountain release made in 1980. The actual release site was approximately 5 miles west of the 1980 holding pen. At Painted Cliffs, 10 sheep were transplanted; 6 (3 rams and 3 ewes) were fitted with radio-collars. On December 1, 1981, the first relocation flight was conducted. This was less than 2 weeks after the release and most animals were near the release site. By the end of December, all but 1 animal had moved to Goat Mountain at least once. Only 1 ewe stayed at or near Painted Cliffs through March 1982, apparently lambing in the area. Pioneering in this group has been limited. The greatest distance moved by an individual was 6.2 miles from the release pen.

The amount of movement between locations has been minimal. Ewes often have been found less than 1 mile from their previous location. One ram has moved considerably between locations. He often has been 3-4 miles from the previous sightings. The other 2 rams have moved only short distances between locations (see Table 1).

Redfield Canyon: Rain and winds hampered the success of this release, resulting in only 16 sheep being released. Eight (2 rams, 6 ewes) of these were fitted with radio-collars. The small number of rams released dictated that 2 additional rams be released. This was done in January 1982. On December 8,1981, 1 week after the release, the first aerial location was collected. Three radio-collared ewes had moved over 4 miles from the holding pen. The 2 rams had moved between 2-3 miles. Subsequent flights found most animals moving back to the general area of the release. By the third flight (January 5,1982) all but 1 sheep was within 2 miles of the release site. For ewes, this pattern continued through the last flight (March 31,1982). Only occasionally would a ewe be found over 3 miles from the release site.

The 2 rams that were released with the original group remained very near the release site until mid-February. At that time, these rams together, moved to the west across a broad, open valley. By mid-March they were nearly 8 miles to the west. They split up and continued west across the valley up to 15 miles to the west. The 2 rams released in early January have stayed in the vicinity of the release site (see Table 1).

Discussion: It is too early to draw firm conclusions from the data that have been collected to date. There are, however, trends that are beginning to be observed. In all cases, ewes are remaining in the general area of release site. Only 1 ewe has traveled over 10 miles from the holding pen and most have remained within 5 miles. With a few exceptions, rams have stayed near the release site. Only 3 rams have left the area where they were translocated. In past releases, a single ram or pair of rams moved great distances in March, only to return with the onset of the rut period. It is probable that this will be the case for the rams that have moved.

There are other signs that lead to guarded optimism. All of the releases have had ewes lamb in the area since the transplant. Many of these ewes have joined into nursery bands in areas which appear particularly suitable for this purpose (available free water, precipitous terrain, abundant forage).

ACKNOWLEDGMENTS

Three of these transplants were funded by sportsmen's groups with genuine concern for the propagation of wild sheep. The Foundation for North American Wild Sheep provided the funding for the Virgin Mountain transplants ($24,000). The Arizona Desert Bighorn Sheep Society funded the Redfield Canyon release ($25,600). Special thanks go to Dr. Tom Boggess, DVM (ADBSS) and Lloyd Zeman (FNAWS) for their efforts in securing these funds. Without this positive expression of support for Arizona's sheep management program, these transplants would not have taken place, and desert sheep would be the worse for it.

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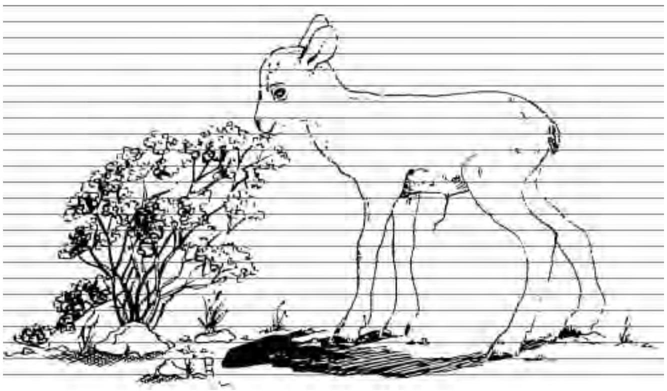

STATUS OF BIGHORN SHEEP IN NEVADA--1981

Robert P. McQuivey
Nevada Department of Wildlife
Reno, NV

Abstract. Aerial inventory of 13 mountain ranges in Nevada during September and October of 1981 resulted in the classification of 1,056 desert bighorn sheep (Ovis canadensis nelsoni) with a ratio of 52 rams and 16 lambs per each 100 ewes. The 1981 hunting season provided a near record harvest of 65 rams for a hunter success rate of 72.2%. Transplant efforts using the drop net trap resulted in the relocation of 20 animals from the Black Mountains of Clark County to the Stillwater Range of Churchill County, Nevada. The Mormon Mountain die-off appears to have run its course with in excess of 100 animals surviving the catastrophe.

The desert bighorn sheep program in Nevada, which is partially funded by federal aid funds through the Pittman-Robinson Act, continues to focus on an intensive annual helicopter inventory, a closely monitored harvest program, and an aggressive reintroduction project. Other facets of sheep management in the state include public relations, interagency coordination, water developments, mortality documentation, and law enforcement. All of the programs in Nevada are designed to increase abundance and distribution of the species and to provide recreational opportunities.

HELICOPTER SURVEY RESULTS

A total of 66.9 hours of survey time was expended during September and October of 1981 as a means of inventorying 13 mountain ranges in the state which support bighorn populations. The observation of 1,056 animals represents 15.8 sheep sighted per survey hour, the lowest observation rate recorded in 5 years. Results of the 1981 survey are presented in Table 1.

The observation rate was reduced during 1981 because of adverse weather conditions which include high winds, the widely scattered distribution patterns of most populations which was a result of early green-up, and the relative lack of lambs in the sample due to high summer mortality. The observation of only 16 lambs per 100 ewes is the lowest recorded since aerial surveys were initiated in 1969. The low recruitment rate was a result of above average population levels in most areas coupled with poor range conditions during the critical summer months.

The population age structure as measured by estimated ram ages suggested that 42% of the animals are between 1 and 3 years of age, 28% between 4 and 6, with 30% 7 years of age and older. These data show a balanced herd and further suggest that recreational harvest is not having a significant impact on the population dynamics.

THE MORMON MOUNTAIN HERD

A catastrophic die-off of unknown origin occurred in the Mormon Mountains of Lincoln County, Nevada during the fall months of 1980. Hunters found in excess of 35 recent mortalities during the one month season and reported that many animals were coughing heavily. Samples collected from dead animals showed a high degree of pneumonia in the lungs of most individuals in addition to extremely poor body condition in a few.

Aerial surveys conducted during February of 1981 and again during September of 1981 indicate that although lamb survival was minimal during the past year, the adult mortality has stabilized. Lamb survival during the February survey showed 16 lambs per 100 ewes (1980 Cohort); whereas, the September

Table 1. Record of desert bighorn sheep observed during September and October of 1981 as a result of annual helicopter inventories.

Mountain Range	Survey Time	Total Observations	Number of Ewes	Number of Lambs	Number of Rams	Ratio Ram/Ewe/Lamb
Mormon Mountains	8.6	111	75	6	30	40/100/08
Meadow Valley Range	6.1	56	31	11	14	45/100/36
Pahranagat Range	5.4	2	1	1	-	---
Arrow Canyon Range	5.0	100	51	12	37	73/100/24
River Mountains	2.8	199	119	9	71	60/100/08
McCullough Mtns.	7.1	36	18	2	16	89/100/11
Highland Range	2.0	31	24	2	5	21/100/08
Pintwater Range	3.4	37	19	4	14	74/100/21
Sheep Range	16.8	297	180	28	89	49/100/16
Desert Range	1.8	37	21	3	13	62/100/14
East Desert Range	1.8	65	41	4	20	49/100/10
Las Vegas Range	3.8	46	25	9	12	48/100/36
Stonewall Range	2.3	39	25	9	5	20/100/36
Totals	66.9	1,056	630	100	326	52/100/16

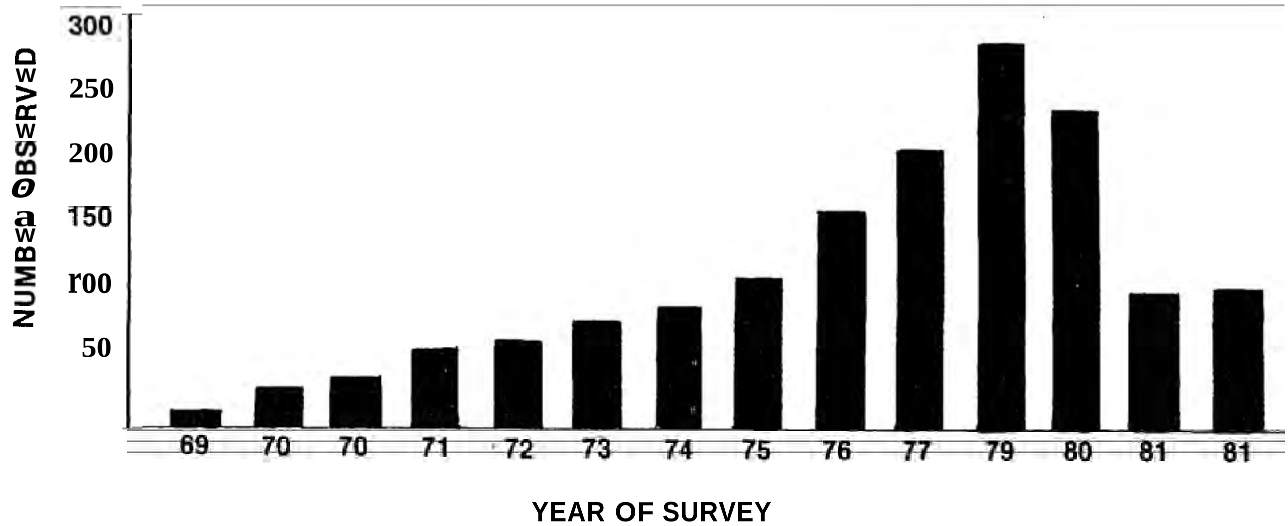

Figure 1. Record of bighorn sheep observed on the Mormon Mountains during helicopter surveys between 1969 and 1981.

survey showed only 8 lambs surviving per 100 ewes (1981 recruitment).

Data from the Mormon Mountain herd which are based largely on aerial inventories since 1969 show a classic example of a large animal population which increased dramatically in a relatively short time and then crashed to a very low level (Figure 1). Continued sampling during the next few years should provide some much needed information on the recovery rate for such a population.

HUNTING AND HARVEST TRENDS

A total of 90 bighorn sheep tags were available during the 1981 season in Nevada comprised of 80 regular resident, 9 regular nonresident, and 1 special bid tag which sold for $21,050. Resident applications totaled 1,177 (147 applications per tag) and ranged from a low of 10 applications for 3 tags in one area to a high of 166 applications for 7 tags in a more popular hunt unit. Nonresident applications totaled 569 for an average of 63 per available tag. The nonresident applications represented a 6% increase over the previous year.

A near record of 65 rams was reported harvested for a success rate of – 723, or 68.8% success for residents and 100% for nonresidents. A total of 930 bighorn have been reported harvested in Nevada since legal hunting was initiated in 1952, for an average success of 41.6%. The average age of rams harvested during 1981 was 7.2 years which is comparable to the past 5 year average.

Hunter reports based on 88 returns suggest that 687 days were expended in the field while observing 3,410 sheep for an average of 38.3 sheep per hunter and 5.1 sheep per hunter day. Hunter observations continue to compliment population survey data collected by the Department and show that sheep population levels in Nevada are at relatively high levels.

TRAPPING AND TRANSPLANTING EFFORTS

The reintroduction of desert bighorn sheep into historically occupied ranges continues to be an important management program in Nevada. A total of 20 animals was captured in cooperation with the National Park Service from the vicinity of Lake Mead and transported to the Stillwater Range of Churchill County, Nevada. Details of the capture operation are presented in another section of this publication.

Close monitoring of recent transplants in Nevada indicates resident populations are firmly established in the Virgin Mountain Range of Clark County and the Stonewall Mountain area of Nye County, Nevada.

REPORT ON THE 1981 BLACK MOUNTAIN DESERT BIGHORN SHEEP TRAPPING OPERATION

Robert P. McQuivey
Nevada Department of Wildlife
Reno, Nevada

Abstract. A total of 20 desert bighorn sheep *(Ovis* canadensis *nelsoni)* were captured for transplant purposes along the shoreline of Lake Mead using the drop net trap. The project utilized fermented apple pulp in combination with alfalfa as the primary bait. Transporting the animals included a 12 minute boat ride in addition to 400 miles of transport in a three ton truck. All of the animals were free-released in good condition into the Stillwater Mountain Range of Churchill County, Nevada.

Trapping of desert bighorn sheep was initiated on the Black Mountain Range of Clark County, Nevada during the summer months of 1981 as a means of providing stock for reintroduction into the Stillwater Mountain Range of Churchill County, Nevada. The capture operation was conducted under cooperative agreement with the National Park Service (Lake Mead National Recreation Area) whereas the release was on public domain administered by the Carson City District of the Bureau of Land Management. Costs for the operation were partially covered by a $4,000 gift contribution from the Fallon Chapter of Nevada Bighorn Unlimited, a private sportsmen's group. The entire project was also filmed by the American Broadcasting Company for viewing on the American Sportsman, a national television program.

BACKGROUND

The Stillwater Mountain Range was first identified by the Nevada Department of Wildlife as a potential reintroduction site for California bighorn sheep *(Ovis* canadensis *califor*niana) in 1974 (Tsukamoto 1974). The area ranged between fifth and eighth on a statewide priority list due to the absence of a completed habitat management plan (Tsukamoto 1977). The management plan was subsequently completed during November of 1978 by the Carson City District of the Bureau of Land Management (Bardwell 1978).

Although the Stillwater Range was originally identified for the release of California bighorn, a review of the historical distribution patterns (Hall 1946) suggested that the area was on the division line between the California and desert races of sheep. As a result of that fact, and because stock of the California subspecies were difficult to obtain, the Stillwater Range was reassigned to the list of potential release sites for desert bighorn. By January of 1981 the area became the number one priority for the reintroduction of desert bighorn in Nevada (Tsukamoto 1981).

The Black Mountain Range was one of several potential capture sites identified for the 1981 trapping season which generally runs between June and September. The area was selected for trapping removal because of the relative abundance of sheep in the area (500 estimated), healthy condition of the herd, and because of the known concentration of animals along the edge of Lake Mead during summer. A cooperative agreement with the National Park Service for the removal of 20 animals was secured during March of 1981.

METHODS

Preparation for trapping was initiated during November of 1980 when approximately 900 gallons of fermented apple pulp were obtained from the Larson orchard of Camino, California. The pulp was stored in 6 surplus military ammunition tanks at the Overton Wildlife Management Area in southern Nevada. The open air containers were stacked above ground and completely covered on all sides and on top with straw bales for protection and insulation.

Prebaiting began at 3 locations in the Black Mountains during late May of 1981. The baiting stations were selected on the basis of known sheep concentrations in relation to proximity of access roads and in consideration of a realistic site where the 70 x 70 ft. trap could be erected. Small piles of pulp covered with alalfa to reduce drying were scattered at bait stations approximately every third day.

Although limited use of bait was noted during June, concentrated use with apparent addiction did not occur until mid-July, after which time bighorn consumed all of the alalfa and mash provided. A total of 5 bales of alfalfa and 650 gallons of apple mash were used during prebaiting and trapping activities.

The supplemental feeding and/or addiction of bighorn to alcohol resulted in an abnormal concentration of sheep at the trap site. Groups of animals not only stayed for longer periods of time in vicinity of the station but also appeared to have been drawn into the area from adjacent canyons. In excess of 50 animals could be observed throughout most of the day at the trap site for several days prior to actual trapping.

The drop net trap was erected on July 29, one day prior to the target trapping date. Some 20-30 animals waited patiently in caves and among the cliffs until construction was completed, after which they immediately walked under the net and began eating. By late afternoon, in excess of 40 bighorn were standing under the net.

The Department's three-ton truck was prepared for transporting the captured animals which included covering the top with a plywood roof, covering the side rack slats with netting, installing a half 50-gallon drum for water, and covering the wood floor with alfalfa. The truck was then left near the Echo Bay Resort boat dock where the anticipated exchange would occur.

Three transport boats which included two 20-ft. Boston Whalers (Law Enforcement Division) and one 31-ft. Bertram (Fisheries Division) were brought into the cove the night prior to T-Day. No special preparations were needed for the boats since we did not plan to cage the animals but rather decided to blindfold and hog-tie instead. Most of the trapping crew also arrived by boat the night prior to trapping.

RESULTS

The drop net trap which was used previously in Nevada to capture desert (McQuivey and Pulliam 1980) was armed with dynamite caps by 7:00 a.m. on July 30,1982. Some delays were experienced in order to accommodate the ABC Television crew and as a result, one person had to stand under the net near the bait in order to keep the bighorn away. This situation occurred even though some 35 people were within 75 yards of the trap.

Within several minutes, the trap was sprung which resulted in the capture of all 21 bighorn. The composition included one 3-year-old ram, 2 yearling rams, 13 ewes of which 2 were of yearling age, and 5 lambs. The 3-year-old ram was released back into the Black Mountain herd, whereas all others (20) were blindfolded, hog-tied, marked with aluminum strap ear tags, and hand carried to the transport boats. Five animals also were fitted with radio telemetry collars.

Eleven of the animals were placed on the deck of the Bertram with the remaining 9 being transported in one of the Boston Whalers. The ride from Cathedral Cove where the animals were captured to Echo Bay, a distance of about 5 miles, was accomplished in approximately 12 minutes. Most of the bindings and blindfolds held securely and all animals arrived at the boat dock in excellent condition.

The sheep were then untied, unblindfolded, and released into the transport truck in preparation for the long drive north. The capture operation from the time the net was dropped until all animals were safely inside the truck took less than 45 minutes. The drive from Las Vegas to the release site, however, took approximately ten hours and was accomplished at night in order to avoid the summer heat. All of the animals were released in good condition directly into the wild on the Stillwater Mountain Range.

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STATUS OF CALIFORNIA BIGHORN IN THE SOUTH WARNER WILDERNESS OF CALIFORNIA

Ernest P. Camilleri
Modoc National Forest
Cedarville, CA

Douglas Thayer
California Department of Fish and Game
Alturas. CA

Abstract. Fourteen California bighorn were reintroduced into the South Warner Wilderness of northeastern California. Four bighorn were released on February 21, 1980 from Lava Beds National Monument, and 10 additional bighorn were released on March 28, 1980 from the Inyo National Forest. Three rams and 3 ewes received radio transmitters. Ewes have developed home ranges within 3 miles of the release site and in preferred habitat. Consistent use patterns over a 25 month monitoring period indicate lambing, rutting and ram summer range areas. Group interaction insures breeding and education of young sheep. Rams from penned environment did not leave ewes in summer. A total of 3 deaths are compared with 3 births.

INTRODUCTION

In 1970 the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Bureau of Land Management and the California Department of Fish and Game agreed to raise California bighorn (Ovis canadensis *californiana)* within Lava Beds National Monument. Their ultimate goal was to use surplus animals for reintroductions into historic habitat of northeastern California.

The first and only attempt towards achieving this goal occurred on February 21, 1980. Four bighorn, consisting of an adult and lamb ram, and an adult and yearling ewe, were released onto the eastern slopes of the South Warner Wilderness near the mouth of Raider Creek. Due to difficulty encountered during the capture effort, the Lava Beds herd was not used as a source for additional animals.

The need for additional animals was met by a team of California Fish and Game personnel led by Richard Weaver, and personnel of the U.S. Forest Service. On March 28, 5 weeks later, 10 bighorn from the Inyo National Forest were released at the same location near Raider Creek. They were comprised of 2 adult rams, 3 adult ewes, 1 yearling ewe, 2 lamb ewes and 2 lamb rams.

The purpose of this paper is to discuss the status of the reintroduction by presenting data on range use, movements, mortality, natality and differences noticed between bighorn originating from British Columbia and southern California.

STUDY AREA

The South Warner Wilderness, located in Modoc County, California, was formed in post-Miocene geologic time through uplift and faulting. The resulting formation runs northerly and is characterized by a gradually sloped western exposure and a steep, broken, cliffy east exposure. Vegetation varies dramatically in direct response to elevation. Bighorn habitat, and subsequently, the remainder of this report is restricted to the eastern exposure.

The study area covers approximately 25 thousand acres. Portions of this area are under permit to graze domestic livestock. A continuous block of approximately 5,220 acres associated with Raider and Hornback Canyons is not excluded from livestock use. This area contains an adequate amount of winter transition and summer range for bighorn.

The winter range lies between 5,000 and 6,600 feet. It is steep and rough with numerous patches of vegetation and cave shelters scattered throughout. The drainages run easterly and coupled with broken topography afford many south facing slopes. Water is available year round. Dominant forage species include cheatgrass (Bromus tectorum), bluebrunch wheatgrass (Agropyron spicatum), big sagebrush (Artemesia tridentata), bitterbrush (Purshia tridentata), and storksbill (Erodium cicutarium).

A transition range lies between 6,600 and 7,400 feet consisting of mid-elevation bench. Preferred forage areas are within 200 meters of the steep winter range. Benches, isolated by steep slopes, occur in every canyon. This habitat arrangement leaves areas unavailable to cattle within permitted livestock allotments. Dominant forage species include Idaho fescue (Festuca *idahoensis*), Sandberg bluegrass (Poa secunda), western needlegrass (Stipa occidentalis), low sagebrush (*Artemisia arbuscula*), and curlleaf mountain mahogany (*Cercocarpus ledifolius*).

The summer range lies between 7,400 and 9,000 feet with small portions extending to 9,800 ft. Topography is rough, containing many cliffs and peaks. Water is abundant in the form of snow, runoff, springs, seeps and lakes. This area receives the majority of recreation use and livestock grazing. Dominant forage species include Kentucky bluegrass (Poa pratensis), Timothy (Phelum spp.), red top (Agrostis alba), bitter cherry (*Prunus emarginatus*), snowberry (Symphoricarpos *rotundifolius*), oceanspray (Holodiscus microphyllus), mountain brome (Bromus marginatus), woolly mule-ears (Wyethia *mollis*), and Groundsel (Senecio spp).

METHODS

Captured bighorn were transported in a horse trailer and released into the open. Prior to each release 3 sheep were equipped with colored telemetry collars that emitted signals at separate frequencies. Signals were monitored using a Telonics multi-frequency receiver from a vehicle, on foot and in the air. Collared sheep were numbered to permit individual identification. Ewes were numbered 2, 3, 4 and rams were numbered 8, 9 and 0. Numbers 2, 3, 8 and 4, 9, 0 were Lava Beds and Inyo sheep respectively.

Observations from a vehicle were restricted to the first 4 hours of daylight. This technique, when using a window mounted spotting scope, proved satisfactory in obtaining visual contact while minimizing the expenditure of time. Aerial tracking was accomplished using a fixed-wing aircraft with an antenna mounted under each wing. Monitoring each antenna individually permitted rapid location of signals. Aerial observations were invaluable in locating sheep during the first 6 months when use patterns were developing and being discovered.

To evaluate bighorn movement, locations of collared sheep were plotted and numbered consecutively on a map. Distances between successive observations were measured and evaluated by month. To permit comparisons between sheep, locations of all collared sheep were determined on the same day.

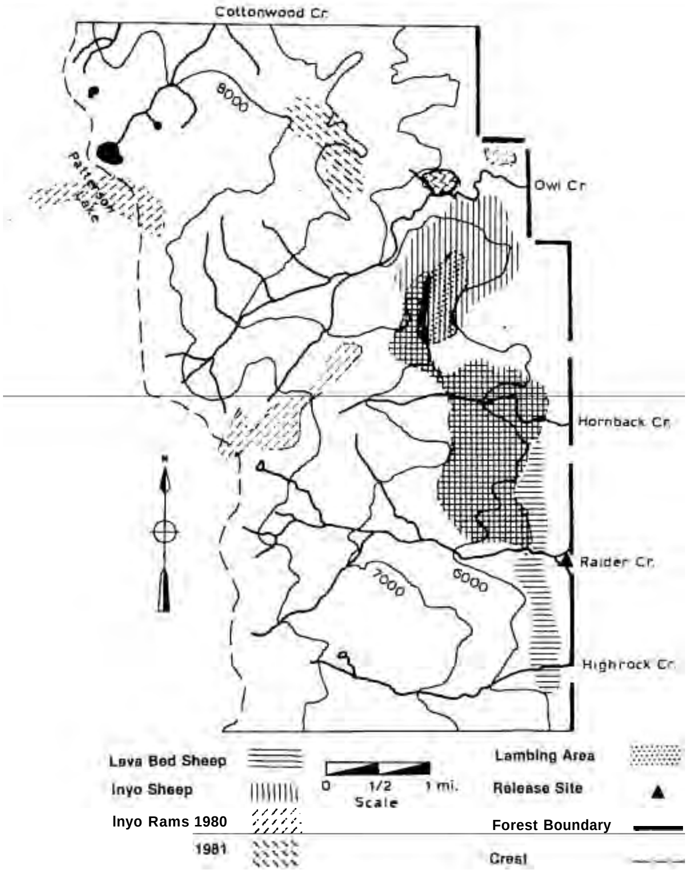

Figure 1. Bighorn range use for the 25 month period following their release into the South Warner Wilderness of northeastern California.

RESULTS AND DISCUSSION

Data were collected on 108 occasions during the 25 month period following the release. Monitoring frequency varied from 1 to 9 attempts per month. Figure 1 displays and identifies differences noted in range use. Lava Beds sheep utilized 1580 acres compared to 2100 and 2800 acres for Inyo ewes and rams respectively. No difference in range use was observed between Lava Beds rams and ewes. They used the same area all year, switching from north exposures in summer to south exposures in winter. At Lava Beds National Monument the Lava Beds rams were confined to a pen and unable to leave ewes in summer. They learned to remain all year on the same range with ewes. According to Geist (1971) rams usually are taught to leave the ewe home range in summer by older rams.

Separate summer ranges were identified for Inyo rams. In 1980, collared sheep numbers 9 and 0 traveled together and remained above 8,000 ft. for most of the summer. The following summer 3 rams traveled with both two-year-old rams, and were not observed above 8,000 ft. The last observation of these rams above 8,000 ft. was on September 17, 1980, the opening day of deer season. They were surrounded by 9 deer hunters and were observed running from one hunter to another, changing direction only to run into another hunter. After shooting ceased they stopped running and waited until dark. The following morning they were relocated 3 miles east below 7,200 ft. within 2 miles of the release site. According to Geist (1974), desertion of ranges from disturbance are not common in wild populations, but occur frequently in transplanted herds. The summer range used in 1981 is remote and not subject to significant disturbance.

During the first 5 days following their release the Lava Beds sheep stayed together, moved little, and remained within .5 miles of the release site. During the second week yearling ewe number 2 moved little and was left alone. Adult ewe number 3 and adult ram number 8 traveled north approximately .3 miles. Over the following three weeks number 8 was always observed alone and numbers 2 and 3 together within 1 mile of the release site.

The Inyo sheep separated following their release. Numbers 9 and 0 remained together and traveled independently of other sheep. All 4 ewes and 2 lambs traveled 1.8 miles northwest before stopping. The 2 remaining lambs joined the Lava Beds ewes and stayed near the release site.

Number 2 displayed the least movement of all collared ewes. Over an eight month period she moved 11.8 miles between 37 successive observations for an average distance between observations of .31 miles. Over the same period numbers 3 and 4 averaged .39 and .67 mi. between observations, respectively.

Number 8 displayed the least movement of all collared rams. Over a 12 month period he moved 24.4 miles between 55 successive observations for an average distance between observations of .44 miles. Over the same period numbers 9 and 0 averaged .72 and .75 miles between observations, respectively.

Numbers 9 and 0 traveled more during their first summer than their second. Number 8 traveled slightly more during his second summer than his first. All rams moved least during March and November. As expected, in lambing season ewes moved very little from May through June.

Except for the possibility of early deaths to new born lambs never observed, mortality consisted of 2 ewes. Both deaths occurred during the first fall and winter following the release. Number 2 died on approximately October 8, 1980, from a fractured skull sustained in a fall from a 20 ft. high cliff. Number 4 died on approximately January 14, 1981, from a neck fracture sustained in a fall from a 15 ft. high cliff. In both cases there was no disturbance by scavengers or predators. Number 2 appeared to have willfully jumped off the cliff, while number 4 had accidentally fallen when a rock ledge gave way. Both animals appeared in excellent condition based on muscular developmnent and fat content.

Natality consisted of 2 lambs in 1980 and 1 in 1981. All lambing occurred in the same canyon between 6,000 and 7,000 ft. during May (Fig. 1). This canyon is characterized by steep topography, limited human accessibility, and an abundance of cave shelters and grassy knolls.

The 3 lambs were produced by 3 Inyo ewes. The 2 ewes that raised lambs in 1980 did not raise lambs in 1981. In 1981, a 3-year-old ewe produced her first lamb. According to Van Dyke (1978) and Kornet (1978) peak lambing occurs in late April and early May in the Steens and Hart Mountains respectively. The lack of lambs in 1981 from 2 Inyo ewes may have been a result of their adjustment of a new climate. All 3 lambs produced have survived and are in the current population.

In 1981, rams and ewes remained together and exhibited breeding behavior from mid-October through November. Number 3 was the only ewe observed to be closely followed by rams in December. Rams from Lava Beds and Inyo peacefully intermixed during this period. Larger rams appeared to tolerate the pursuit of ewes by younger rams. The major portion of the rut occurred on two mid-elevation benches between Raider and Owl Creeks. According to Geist (1971) most populations prevent inbreeding by selecting for heterosis. It would appear that our population is not selecting for heterosis. This should not be construed as a disadvantage because any Inyo ewe that is bred by Lava Beds rams insures the presence of genes from 2 different gene pools and affords the best mix available for the selection of heterosis in the future.

In addition to differences between Lava Beds and Inyo sheep already described, obvious morphological differences were noticed. The Lava Beds sheep are much darker in hair color than Inyo sheep. Inyo rams have wider flaring horns than Lava Beds rams. These differences are so apparent that the origin of individuals is easily determined in the field.

A total of 15 bighorn sheep have been observed within preferred habitat of the South Warner Wilderness. They are comprised of (a) adults: 6 rams, *6* ewes (b) yearlings: 1 ram, 1 ewe (c) lambs: 1 ewe.

It is too early to predict the outcome of the reintroduction. Everthing to date, except the production rate, points to success. The 1982 lamb crop should indicate in which direction it will go.

ACKNOWLEDGMENTS

The authors wish to express thanks to Leo Pyshora of the California Department of Fish and Game for his aerial survey information and Rick Hanson for his ground survey information.

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ATTENDANCE ROSTER, DESERT BIGHORN COUNCIL 1982-83

Barrett, Jim W. (AG&F)
P.O. Box 134
Payson, AZ 85541

Bates, Jim
(Utah Div. Wildl.)
159 No. 1 E.
Price, UT 84501

Belknap, Don (AG&F)
1057 E. Watson Dr.
Tempe, AZ 85283

Blaisdell, James A.(Retired NPS)
5425 Indian Beach Lane
Friday Harbor, WA 98250

Bleich, Vern (CDFG)
P.O. Box 1741
Hemet, CA 92343

Brigham, William R. (BLM)
P.O. Box 1806
Carson City, NV 89702

Bunch, Thomas D. (UT State Univ.)
Utah State Univ.
Logan, UT 84322

Ernest P. Camilleri (USFS)
P.O. Box 72
Cedarville, CA 96104

Steven W. Carothers
(Museum of No. Ariz.)Rt. A, Box 878
Flagstaff, AZ 86001

Carpenter, Lewis E. (SCBS)
815 W. Gettysburg
Fresno, CA 93705

Carpenter, Marguerite
815 W. Gettysburg
Fresno, CA 93705

Carrier, W. Dean (USFS)
630 Sansome St.
San Francisco, CA 94111

Cooperrider, Allen (BLM)
P.O. Box 558
La Porte, CO 80535

Cunningham, Stan (Ariz. St. U.)
213 E. LaJolla
Tempe, AZ 85282

Dee, Michael (DBRI)
524 Irving Ave.
Glendale. CA 91201

DeForge, James R. (DBRI)
218 E. J St.
Ontario, CA 91764

deVos, James D. (AG&F)
3519 Monica Ave.
Phoenix, AZ

Dickinson, Tony
(Diamond A Cattle Co.)Box 208
Tinnie, NM 88351

Dodd, Norris (AG&F)
1210 E. Southern, #3
Phoenix, AZ 85040

Douglas, Charles L. (NPS)
1444 Rawhide Rd.
Boulder City. NV 89005

Fuller, Arthur F. (AG&F)
1025 Hillside Dr.
Kingman, AZ 86401

Garlinger, Bruce H.
(HSU student)
P.O. Box 4251 B
Arcata, CA 95521

Getty, Bud (CA St. Parks)
3638 H St. #13
Sacramento, CA 95816

Glaze, R.L., DVM
Star Rte., Box 645B
Kerrville, TX 78028

Glinski, Pat (AG&F)
6255 E. Halifax
Mesa, AZ 85025

Graham, Richard L.
P.O. Box 1329
Temecula. CA 92390

Guymon, Jim (UDWR)
90 So. 200 W.
Parowan, UT 84761

Haderlie, Milton (USFWS)
2932 W. 20 Place
Yuma, AZ 85364

Hansen, Pat
P.O. Box 596
Kenwood, CA 95452

Harrison, Homer
(Sptsmn. Councl. Central CA)
1700 Los Robles
Bakersfield, CA 93306

Henry, Steve (NMG&F)
Villagra Bldg.
State Capitol
Santa Fe. NM 87501

Holl, Steve (USFS)
Star Rt. 100
Fontana, CA 92335

Holmes, Ken (BLM)
1705 North Valley
Las Cruces, NM 88005

Hull, William B. (Utah st. U)
1379 E. 1000 N.
Logan, UT 84321

Jacot, Francis H. (NPS)
133 Gough St., No. 2F
San Francisco, CA 94109

Jenner, Charles (DBRI)
11381 Loch Lomond Rd.
Los Alamitos, CA 90720

Jessup, David A., DVM (CDF&G)
1701 Nimbus Rd.
Rancho Cordova, CA 95670

Jorgensen, Mark (Cal. St. Parks)
P.O. Box 1661
Borrego Springs. CA 92004

Kelly, Warren E. (USFS)
317 S. Glenvista
Elko, NV 89801

Kenny, Charles (USFS)
301 W. Congress
Tucson, AZ 85704

Kilpatric, Jack (TX P&W)
Box 1228
Marfa, TX 79843

King. Michael (Utah St. U.)
619 N. 500 E.
Logan, UT 84321

Kovach. Steven D. (U.S. Navy)
P.O. Box 1701
San Bruno, CA 94066

Kroner. Robert L.
(Wilderness Consult.)
1075 W. Macada Rd.
Bethlehem, PA 18017

LaRue, Fred V.
(Living Desert Reserve)
P.O. Box 1775
Palm Desert, CA

Lee, Tom E.
(Alexander Lindsay Jr. Museum)
3071 Walnut Blvd.
Walnut Creek, CA 94596

Lindenmeyer, Theresa (CDF&G)
4454 New Jersey St.
San Diego, CA 92116

Lutz, Loren, DDS (SCDBS)
401 N. Garfield
Alhambra, CA 91801

McClintock, Ralph W.
3232 Shari Way
Sparks, NV 89431

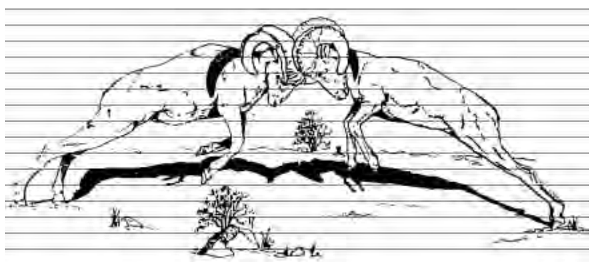
McClung, Dick (DBRI)
P.O. Box 960
Rancho Mirage, CA 92270

McCutcheon, Hank
6508 S. Allison Ct.
Littleton, CO 80123

McKinnie, Harold (CDF&G)
1452 N. Ash St.
Escondido, CA 92027

McQuivey, Robert (NDW)
4411 Pineaire St.
Las Vegas. NV 89117

Miller, Gary
(Ecol. Consult.)
Box 1037
Quartzsite, AZ 85346



Mohr, Russell
1701 Nimbus Rd.
Rancho Cordova, CA 95624

Monson, Gale (Ret. FWS)
8831 N. Riviera Dr.
Tucson. AZ 85704

Morgart. John
Ariz. Coop. Wildl. Unit
Univ. Ariz.
Tucson, AZ 85721

Morrison. Bruce L. (NMG&F)
413 N. Virginia
Roswell, NM 88201

Munoz, Richard (USFWS)
P.O. Box 756
Las Cruces, NM 88001

Olding. Ron (AG&F)
10651 N. Oldfather Rd.
Tucson. AZ 85741

Olech, Lillian A. (BLM)
1996 Cottonwood Circle, A-3
El Centro, CA

Peek, George F.
P.O. Box 7309
San Diego, CA 92107

Poglayen, Inge
Rt. 9, Box 900
Tucson, AZ 85743

Pulliam, Dave (BLM)
601 Greenhurst Rd.
Las Vegas, NV 89128

Remington, Richard (AG&F)
3005 Pacific Ave.
Yuma, AZ 85364

Russi, Terry L. (BLM)
765 N. Sunrise Ave.
Banning, CA 92220

Sanchez. Peter G. (NPS)
P.O. Box 276
Death Valley, CA 92328

Sandoval. Andrew V. (NMG&F)
1480 N. Main
Las Cruces, NM 88001

Seegmiller, Rick
Ariz. Coop. Wildl. Res. Unit
Univ. Arizona
Tucson, AZ 85721

Scott, Joan E. (DBRI)
1141 N. Park Ave.
Pomona, CA 91768

Segreto, Steve (BHRI)
1445 N. Placentia, #61
Fullerton, CA 92631

Juan Spillett
Box 278
Rockland, Id 83271

Stephens, Jon
The Hunting Co.
2123 Briargreen
Houston, TX 77077

Tadlock, Paul (Wildl. Sculp.)
1410 Shannon Circle
New Braunfels, TX 78130

Temple, Larry J. (NMG&F)
1480 N. Main, Suite 142
Las Cruces, NM 88001

Turner, Jack C.
Div. of Live Sciences
Sam Houston State Univ.
Huntsville, TX 77341

Valdez, Raul
New Mexico State Univ.
Las Cruces. NM 88003

Jim Walters (NPS)
Rt. 1, Box 2004 Chester
Carlsbad, NM 88220

Watt, Larry (AG&F)
1516 E. Glencove
Mesa, AZ 85203

Weaver, Richard A.(CDF&G)
P.O. Box 1383
Loomis, CA 95650

Webb, Paul (AGFD)
3201 W. Wescott
Phoenix, AZ 85027

Wehausen, John D.
P.O. Box 1143
Bishop. CA 93514

Welsh, George W. (AGFD)
1954 Golden Ave.
Kingman, AZ 86401

West, Robert L. (TX P&W)
3407 S. Chadbourne
San Angelo, TX 76902

Wiedeman, Bud
676 No. Laurel Ave.
Los Angeles, CA 90048

Wilson, Lanny O. (BLM)
Rt. 3, Box 181
Cottonwood. ID 83522

Witham, James H.
Colorado State Univ.
Ft. Collins, CO 80523

Wood, Marvin (SCBS)
19 N. Byron Dr.
Lemoore, CA 93245

Workman, Gar W.
Dept. Fisheries & Wildl.
Utah State Univ. UMC 52
Logan, UT 84322

Yoder. Robert G. (USFWS)
1500 N. Decatur Blvd.
Las Vegas, NV 89108

Zeller, Bruce (USFWS)
Box 14, Route 89011
Las Vegas, NV 89124

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