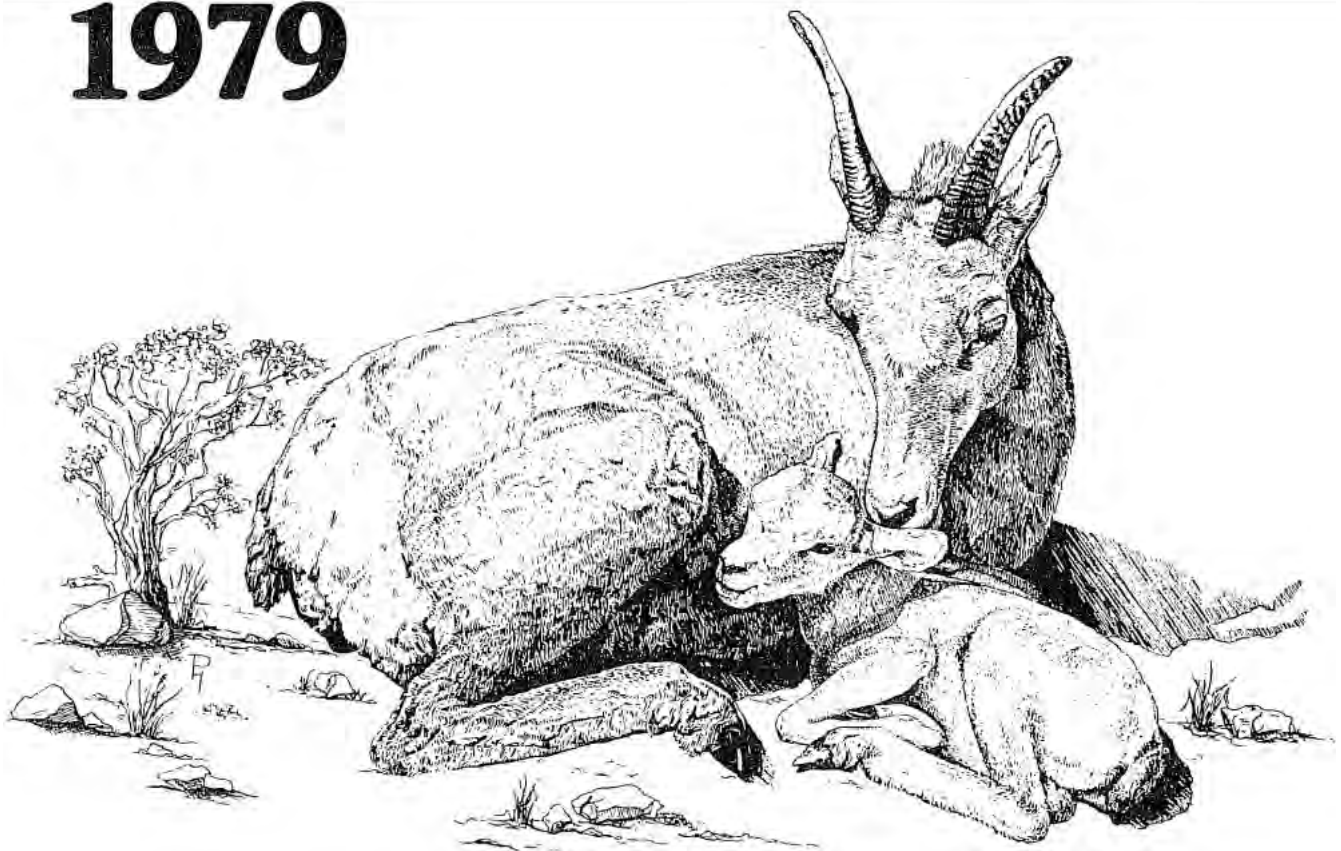


Desert Bighorn Council Transactions 1979



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DESERT BIGHORN COUNCIL 1979 TRANSACTIONS

**A COMPILATION OF PAPERS PRESENTED AT THE
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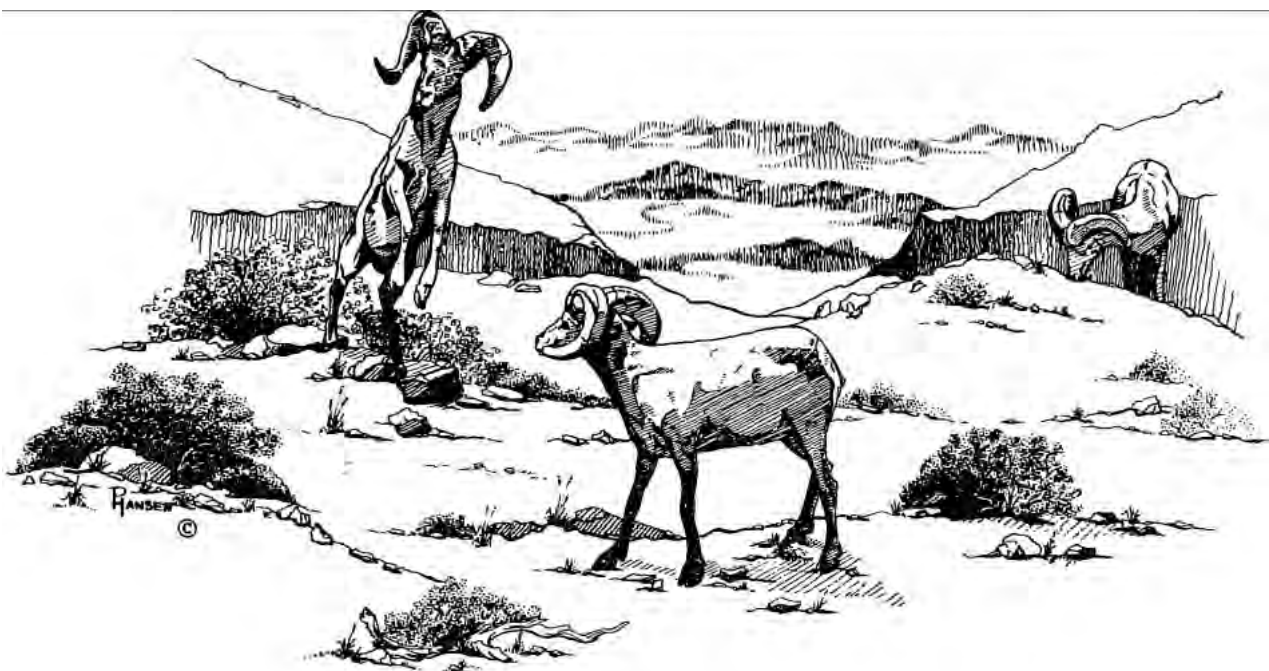


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Editor's Note

Readers of this year's **Transactions** will note that major papers precede Progress Reports, a reverse order from that in prior **Transactions**. Several considerations necessitate this change. Some persons outside the DBC have been unaware that our published papers (but not Progress Reports) undergo peer review. Peer review has been used for a number of years, but has not been reflected in the limited number of names listed under the Editorial Committee. Major contributors, but not necessarily all participants, to the editorial process have been listed.

In academic institutions and some agencies, publications are regarded as fundamental evidence of a professional's productivity. In such instances, only papers published in reputable, refereed journals are given credence. Some persons have presented excellent papers at the annual meeting, but have declined to publish their results in the **Transactions** because their Department Chairman or supervisor considered the **Transactions** to be a non-refereed journal. In reality, our review process is equivalent to that of a number of well known journals having larger audiences.

The inclusion of Progress Reports is unusual in scientific journals, but is not unique to the **DBC Transactions**. The archaeological journal, **American Antiquity**, contains a section on Current Research, which summarizes projects by regions of the country. Owing to the long term nature of bighorn studies, timely dissemination of new information by means of Progress Reports often can aid other workers and save them substantial time. Earlier procedures of placing non-reviewed Progress Reports in the front of the **Transactions** also may have helped promote misconceptions. I have therefore clearly separated reviewed papers from non-reviewed Progress Reports. I also have taken the liberty of judging whether a manuscript is a paper or a progress report, although some authors may not concur with my choices.

If the review process is working, it should lead to rejection of manuscripts that contain no significant new information. High printing costs necessitate continued efforts to reduce words and non-critical illustrations. Despite these constraints, I want the members to be pleased with the content and aesthetic qualities of the **Transactions**. It is my hope that our peer review process will continue to elevate the quality of papers appearing in the **Transactions** while being fair and sensitive to all concerns.



THE EVOLUTION, SYSTEMATICS, AND CYTOGENETICS OF OVIS

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Abstract. True sheep [*Ovis*] originated somewhere in south-central Asia during the Pleistocene Epoch approximately 2.5 million years ago and were dispersed throughout most of the mountainous areas in the northern hemisphere, primarily as a result of geographical events such as glaciation. That, in turn, resulted in considerable diversification in *Ovis* and in the fact that today wild sheep still have a distribution unequalled by any living bovid [Geist 1971].

True sheep are included in the Subfamily Caprinae, which is further divided into four tribes [Saigini, Rupicapriini, Ovibovini, and Capriini]. The Tribe Capriini includes eight genera, three of which *Oioceros*, *Tossunnoria*, and *Sivicapra* are extinct and known only from fossils. The five living genera of caprids are: [1]*Ammotragus* [*Aoudad* or Barbary 'Sheep'], [2]*Pseudois* [Bharal or Blue 'Sheep'], [3]*Hemitragus* [Tahrs], [4]*Capra* [true goats], and [5]*Ovis* [true sheep].

The systematics and distribution of *Ovis* and its near relatives, as well as some of the morphological characteristics used to classify *Capra* and to distinguish sheep from goats, are described. Classification systems for *Ovis* are discussed and, based upon the literature and genetic studies conducted by the authors, a new system is presented wherein the extant wild sheep are divided into four Eurasian species [*O. musimon*, *O. orientalis*, *O. vignei*, and *O. ammon*], with one, two, five, and seven subspecies, respectively, and three North American-type or Amphiberingian wild sheep species [*O. nivicola*, *O. dalli*, and *O. canadensis*], with three, three, and seven subspecies, respectively.

Recent cytogenetic studies indicate the direction of chromosome evolution in Caprids, as well as genetic relationships and factors contributing to speciation. The basic karyotype of the Family Bovidae contains 60 chromosomes [58 acrocentric autosomes or non-sex chromosomes, plus two sex chromosomes]. The Tahrs [*Hemitragus*] have a 48-chromosome karyotype and are considered to be the most chromosomally advanced Caprids. The Bharal [*Pseudois*] has a 54-chromosome karyotype, the Aoudad [*Ammotragus*] a 58-chromosome karyotype, and all of the goats [*Capra*] a 60-chromosome karyotype. The chromosome compliments in the true sheep or *Ovis* karyotypes, however, vary between 52 in the Snow Sheep [*O. nivicola*] to 58 in the Urials [*O. vignei*]. Nevertheless, it appears that all species of *Ovis* are interfertile or when crossed will produce both viable and fertile offspring.

THE EVOLUTION OF OVIS

Fossil records indicate that ruminant animals which include members of the Family Bovidae, first appeared upon the earth

more than 20 million years ago during the Early Miocene Age [Figure 1]. However, it appears that the first true sheep, or members of the genus *Ovis*, did not appear until about 2.5 million years ago during the Early Pleistocene or 'Glacial' Epoch, which also is synonymous with the Late Pliocene [Flint 1971].

The fossil record of *Ovis* is fragmentary, and concrete data relating to its mode of evolution are scanty. Thus, there is considerable debate and much speculation as to the evolution and taxonomic relationships of *Ovis*. Some authorities speculate that true sheep originated from Rupicapriini or goat-antelopes [Thenius and Hofer 1960]; whereas, others believe that *Ovis* originated from Aoudad or Barbary sheep [*Ammotragus*] or an *Ammotragus*-like ancestor [Geist 1971, Bunch et al. 1976].

There also is considerable speculation and confusion as to the relationship of *Ovis* to the following Rupicaprids: 1) Chamois [*Rupicapra rupicapra*], which inhabits the Alps, Apennines and Carpathians to the Caucasus Mountains in Asia Minor, and the Pyrenes and Cantabrian Mountains of Spain; 2) Goralis [*Nemorhaedus goralis*], which inhabit the Himalayan Mountains east through West China and North Korea; 3) Serows [*Capricornis sumatraensis* and *C. crispus*], which are found from Sumatra and the Malayan Peninsula north through Vietnam, Thailand, Burma, Assam, the eastern Himalayas and China, and on the islands of Formosa; and 4) The so-called Rocky Mountain goat [*Oreamnos americanus*], which is found from southern Alaska south through British Columbia and western Alberta to Washington, central Idaho, and western Montana, and which has been successfully introduced into Colorado, South Dakota, and Utah.

Fossil records also indicate that *Ovis* probably originated somewhere in the southern Himalayas or northern China [Korobitsyna et al. 1974] and then dispersed both east and west, as well as north. It further appears that *Ovis* was one of the first animals domesticated by man in the Middle East approximately 10,000 years ago [Walker 1964]. Interestingly, dispersion of wild sheep was primarily eastward, whereas domestic sheep were spread primarily westward.

Generally speaking, modern-day wild sheep have adapted to two types of terrain. This is also reflected in their appearance [Schaller 1977]. The North American type or Amphiberingian wild sheep, which includes the Snow sheep [*O. nivicola*] of Siberia, prefer areas on or near precipitous terrain, cliffs or rocky outcroppings -- similar to habitats preferred by the wild goats [*Capra* spp.] of Eurasia. That adaptation is exemplified by their relatively short legs, broad chests, massive shoulders, and heavily muscled bodies. In contrast, the Eurasian wild sheep usually prefer open, rolling mountains, foothills and plateaus. That preference or adaptation is exemplified by their relatively long legs, lithe builds, light bones, and lighter-muscled bodies. They are adapted or built for speed rather than for saltatorial movements, whereas North American wild sheep are excellent jumpers and climbers. Some authors [i.e., Walther 1961] even claim that Eurasian wild sheep appear to be poor jumpers and avoid rocky areas. Thus, the extant forms of wild sheep basically can be divided into two major groups: 1) The relatively slender, running-type sheep of Eurasia, and 2) The relatively compact and saltatorial-type of North American and Siberia. Thereafter, however, there is considerable dissention among taxonomists as to the classification of *Ovis*, which will be treated in more detail later in this paper.

The origin and diversification of *Ovis* occurred primarily during

the Pleistocene Epoch and were a result of events which took place during that period. The Pleistocene Epoch was characterized by repeated, worldwide climatic oscillations, the appearance of sharply defined or modern temperate zone biotic communities, and the relatively rapid evolution of the larger mammals, including the emergence of man [see Figure 1]. Climatic oscillations during the Pleistocene were not abrupt but resulted from a series of gradual changes, including the elevation of continental land masses and mountain ranges. Intermittent periods of glaciation were perhaps most important to the dispersal of *Ovis*. Also, glaciation probably was the major factor influencing diversification of the genus.

The sequence of glacial episodes between the beginning of the Pleistocene, about 2.5 million years ago, and the beginning of the Holocene or 'Recent' Epoch, about 10,500 years ago. Those major glacial episodes are referred to as the Nebraskan, Kansan, Illinoian, and Wisconsinian. In addition, between those major glacial episodes there were any number of glacial-eustatic cycles or extended cold periods related to major fluctuations in sea levels. Because of the storage of water in icecaps during extended cold periods and also the release of water during intermittent warmer periods, sea levels apparently fluctuated as much as +10 to -90 meters, as compared to present-day levels [Richards 1965].

As can well be imagined, fluctuations in sea levels greatly influenced dispersion of *Ovis*, and perhaps resulted in the isolation of populations, which thereby accelerated evolutionary

processes. For example, the Bering Land Bridge and land masses linking continental-shelf islands, such as England, Ceylon, and Borneo, were exposed during fluctuations in sea levels. The Bering Land Bridge permitted two-way movement of land animals between Asia and western North America. It is believed there were at least two major immigrations of wild sheep from Asia into North America and at least one and perhaps two emigrations of *Ovis* back into Asia from North America. Pluvial conditions in lower or middle latitudes also were synchronous with glacial advances and retreats [Morrison 1965]. Those resulted in lakes, such as Bonneville and Lahontan. Such bodies of water further influenced the distribution of terrestrial animals.

Conditions during the Pleistocene differed markedly from those of today [McIntyre et al. 1976]. For example, whereas about 10 percent of earth's surface presently is covered by glaciers, almost 30 percent was covered during the last glacial maximum some 18,000 years ago [Flint 1971]. In other words, about as much of the earth's surface then was covered by ice as presently is represented by land. Glaciers extended at least as far south as Long Island, New York, and De Moines, Iowa, and mean annual temperatures were 10° to 12° C lower than today. It is estimated, however, that advance or retreat of lowland glaciers averaged less than 100 meters per year [Flint 1971]. Thus, glaciation was a slow, gradual process that involved tens or hundreds of lifespans, but still forced or speeded up biotic movements, adaptations and other evolutionary processes.

Adaptations to cold by mammals include the development of a thick fur coat and an increase in body size. Berman's Rule, for example, states that endothermal animals usually are larger in the colder parts and smaller in the warmer parts of their range. That, or perhaps optimal nutrition, may account for the 'gigantic' size of some Pleistocene mammals as compared to their present-day descendants. A decrease in size in the bighorn sheep [*O. canadensis*] at the end of the Pleistocene actually has been documented from fossil records [Harris and Mudel 1974]. A gradual diminution in size of animals also is claimed to be a sign of domestication [Herre and Rohrs 1973], which may account for most domestic sheep being smaller than their wild relatives.

THE SYSTEMATIC CLASSIFICATION OF *OVIS* AND ITS NEAR RELATIVES

The true sheep, all of which belong to the genus *Ovis*, are even-toed ungulates and therefore, belong to the Order Artiodactyla [Table 1]. They also have a compartmentalized stomach, consisting of a rumen, reticulum, omasum, and abomasum, which are structures especially adapted to breaking down and digesting cellulose by bacterial fermentation. Thus, sheep also belong to the Suborder Ruminantia. Along with cattle, bison, buffalo, musk ox, goats, and true antelopes, the sheep are included in the Family Bovidae, which is divided into a number of subfamilies, including the Subfamily Caprinae. In turn, the Subfamily Caprinae is further divided into four tribes [Saigini, Rupicapriini, Ovibovini, and Capriini].

The Tribe Capriini includes eight genera, three of which are extinct and known only from fossils. The extinct genera are:

- [1] *Oioceros*, "goral-like" animals which lived during the Miocene and lower Pliocene in such diverse locations as China, Kenya, and Yugoslavia (Gentry 1968).
- [2] *Tossunnoria*, "creatures intermediate between goral and goats" [Schaller 1977], which inhabited China during the lower Pliocene.

Subdivisions	Glacial States	Cultural Landmarks	Years
[Epochs]	[Traditional]		B. P.
Holocene Recent	Post Glacial	Bronze Age	5,000
		Bow and arrow	11,000
		Magdalenian cave paintings	16,000
		Upper Paleolithic	35,000
Late Pleistocene	4--WISCONSINAN [WEICHSEL]	Neanderthal Man	75,000
	R/W Interglacial		125,000
Middle Pleistocene	3--ILLINOIAN [RISS]	Saale Glaciation	
		First human hearth	425,000
	M/R Interglacial		545,000
	2--KANSAN [MINDEL]		
	GIM Interglacial	First bifacial tools	700,000
Early Pleistocene	1--NEBRASKAN [GUNZ]		

Figure 1. Provisional time scale of the Quaternary Geologic Period (Adapted from Dixon 1979).

Table 1. The systematic classification of the true sheep or Ovis and their near relatives.

Order Ruminantia

Family Bovidae

Subfamily Caprinae

Tribe Caprini

Extinct Genera:	1. Oioceros [Goral-like]
	2. Tossunnoria [Goral-goat]
	3. Sivicapra [Goat-like]
Living Genera:	1. Ammotragus [Aoudad or Barbary "Sheep"]
	2. Pseudois [Bharal or Blue "Sheep"]
	3. Hemitragus [Tahr]
	4. Capra [True Goats]
	5. Ovis [True Sheep]

- [3] Sivicapra, a probable descendent of *Tossunnoria* that inhabited the Siwaliks during the upper Pliocene [Schaller 1977] and apparently included the first goats [Pilgrim 1939].

The five general of **Caprids** which are represented by living species [Table 2] are, according to Schaller [1977]:

- [1] *Ammotragus*, the Aoudad or so-called Barbary sheep, which is represented by one species [*A. lervia*] and four subspecies that inhabit the mountains of North Africa from Morocco to Egypt, and northern Sudan to Chad and Mali [Figure 2].
- [2] *Pseudois*, the Bharal or blue sheep, which is represented by one species [*P. nayaur*] and perhaps two subspecies that inhabit the highlands of central Asia from northern India, through Nepal to the mountains of western China [Tibet] [Figure 3].
- [3] *Hemitragus*, of which three geographically isolated species are:
- a. The Arabian Tahr [*H. jakari*] found in the mountains of the extreme southeastern portion of the Arabian Peninsula.
- b. The Nilgiri Tahr [*H. hylocrius*] of the mountains of southern India.
- c. The Himalayan Tahr [*H. jemlahicus*] that is found south of the main range of the Himalayas from Bhutan to Kashmir and has been established in the mountains of southern New Zealand [Figure 4].
- [4] Capra or true goats are the closest relatives of Ovis and are so alike in skeletal structure to the true sheep that it is extremely difficult to classify fossil fragments as to genus [Schaller 1977]. All of the true goats have a

60-chromosome karyotype [Nadler 1974] and interbreed freely in captivity [Gray 1954]. Thus, morphological characteristics, particularly shape or configuration of the horns of males, presently are used to classify the goats [Figure 5]. According to Schaller [1977], there are six living species of goats. These are:

- a. The wild goats [*C. aegagrus*] which have scimitar-shaped horns with a sharp anterior keel [see Figure 5] and inhabit mountainous or rocky areas from Greece to Iran and from Iran to Turkmenia to Pakistan [Figure 6]. Though there is considerable debate as to what constitutes a valid subspecies, the wild goats generally are classified into four subspecies:

- [1] *C. a. cretica*, found on Crete and several other islands.
- [2] *C. a. pictus*, found on Erimomilos and several other islands near the Greek mainland.
- [3] *C. a. aegagrus*, found from Turkey to Iran.
- [4] *C. a. blythi*, found from Iran and Turkmenia to Pakistan.

b. The ibexes [*C. ibex*] have scimitar-shaped horns [see Figure 5] like wild goats but with the anterior surface relatively flat and broken by prominent transverse ridges. They are found in the Alps of Switzerland and northern Italy, the mountains of North Africa, Arabia, Palestine, and throughout many of the mountains of central Asia, east through Nepal [Figures 7 and 8]. Although some taxonomists have classified ibexes into

Table 2. The systematic classification of the living **Caprids** or Tribe Caprini [adapted from Schaller 1977].

Common Name	Genus	Species	Number of Subspecies
1. Aoudad or Barbary 'Sheep'	<i>Ammotragus</i>	<i>lervia</i>	4
2. Bharal or Blue 'Sheep'	<i>Pseudois</i>	<i>nayaur</i>	2
3. Tahrs <i>Hemitragus</i>			
Himalayan Tahr		<i>jemlahicus</i>	0
Nilgiri Tahr		<i>hylocrius</i>	0
Arabian Tahr		<i>jakari</i>	0
4. True Goats	<i>Capra</i>		
Wild Goats		<i>aegagrus</i>	4
Ibexes		<i>ibex</i>	5
Markhors		<i>falconeri</i>	4
Spanish 'Ibex'		<i>pyrenaica</i>	4
Tur		<i>cylindricornis</i>	0
Domestic Goats		<i>hircus</i>	
5. True Sheep	<i>Ovis</i>		
North American Bighorns		<i>canadensis</i>	7
Dall and Stone Sheep		<i>dalli</i>	3
Snow Sheep or Asiatic Bighorns		<i>nivicola</i>	3
Argalis		<i>ammon</i>	7
Urals		<i>vignei</i>	5
Asiatic Mouflons		<i>orientalis</i>	2
European Mouflons		<i>musimon</i>	1
Domestic Sheep		<i>aries</i>	[900 + breeds]

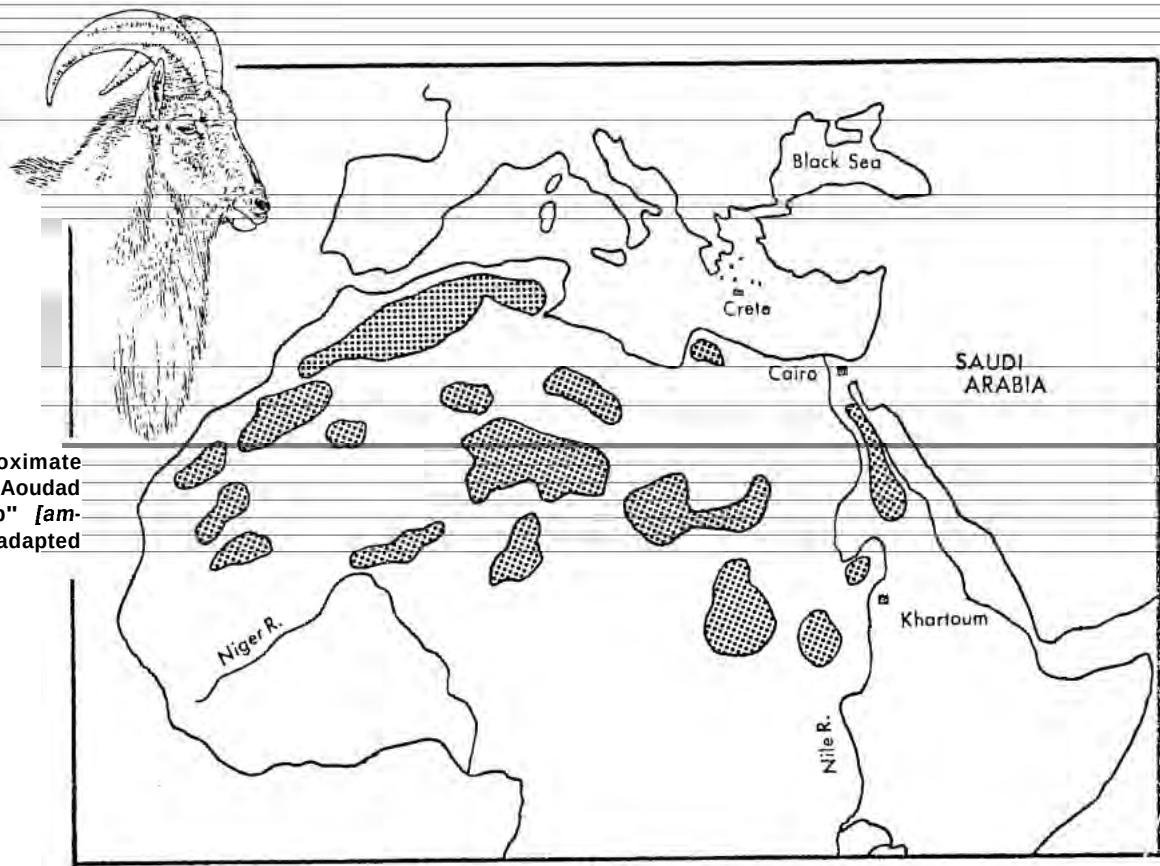


Figure 2. The approximate distribution of the Aoudad or Barbary "Sheep" [*ammotragus lervia*] [adapted from Schaller 1977].

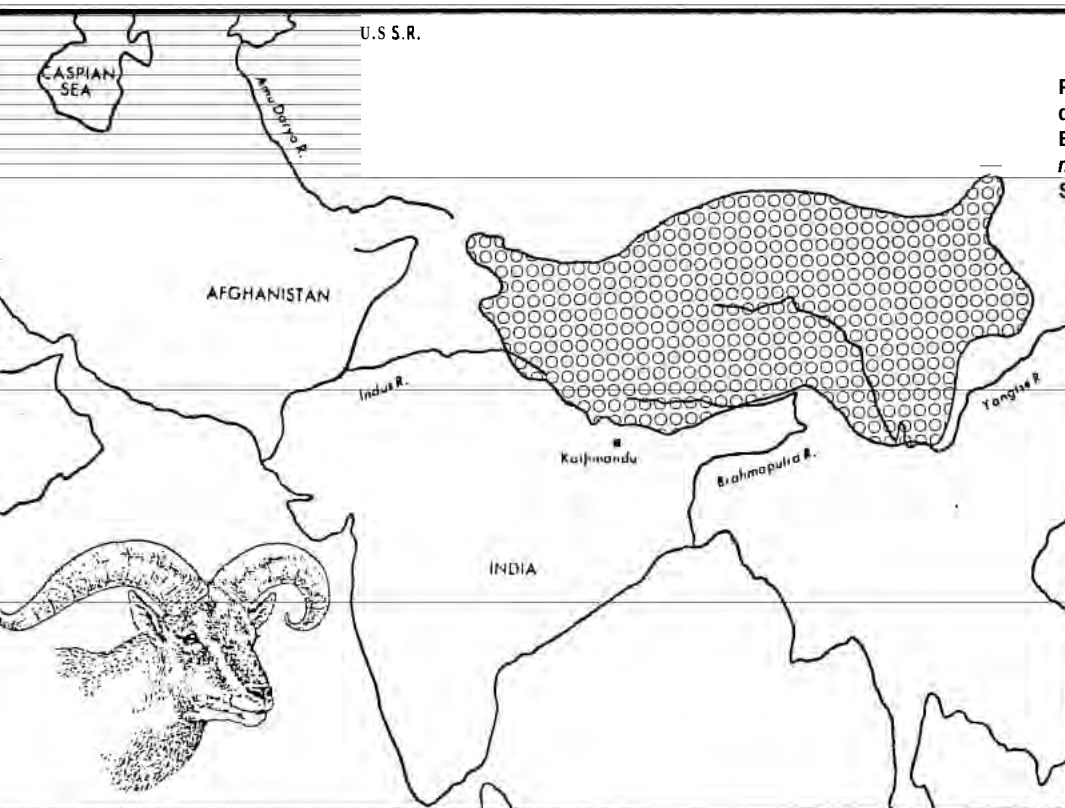


Figure 3. The approximate distribution of the Bharal or Blue "Sheep" (*Pseudois nayaur*) (adapted from Schaller 1977).

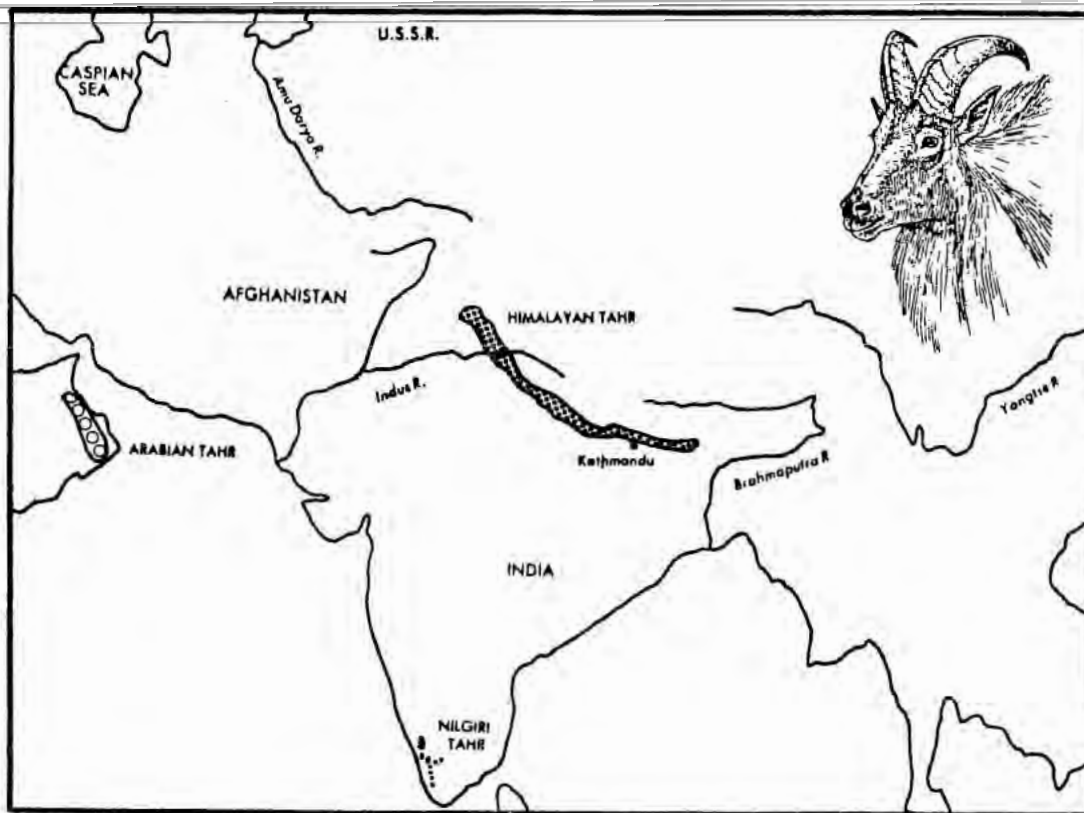


Figure 4. The approximate **distribution** of the Arabian, Himalayan and Nilgiri Tahr [*Hemitragus jayakari*, *H. hylocrius* and *H. jemlahicus*, respectively] (adapted from Schaller 1977).

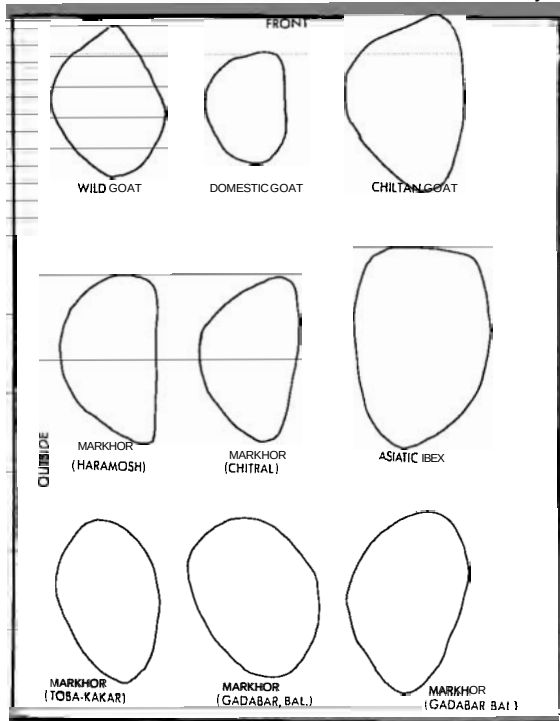


Figure 5. Horn core **cross-sections** of the True Goats (*Capra*), illustrating the shape and relative widths of the frontal clash surfaces of the horns (from Schaller 1977).

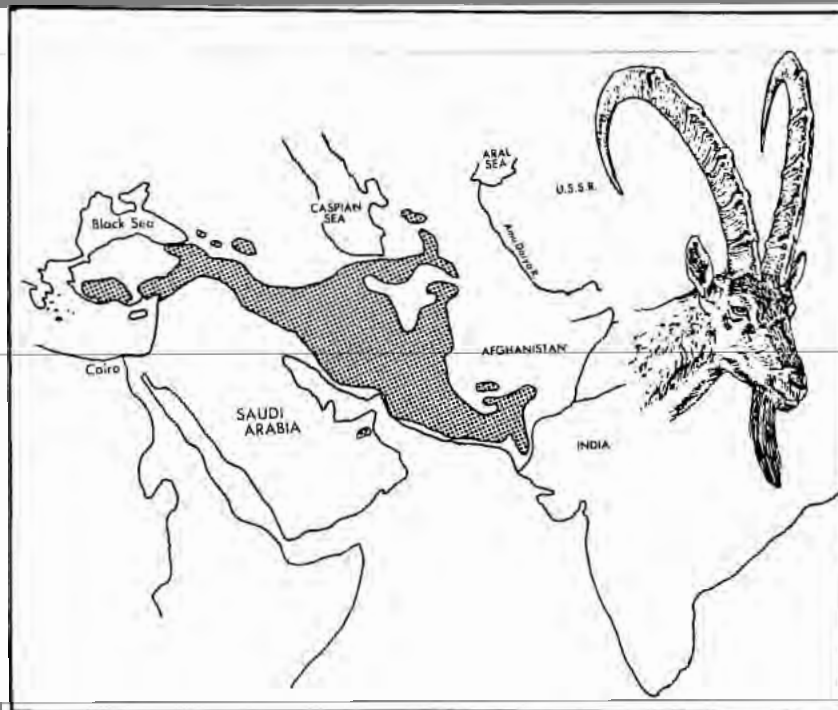


Figure 6. The approximate distribution of the Wild Goat (*Capra aegagrus*) (adapted from Schaller 1977).

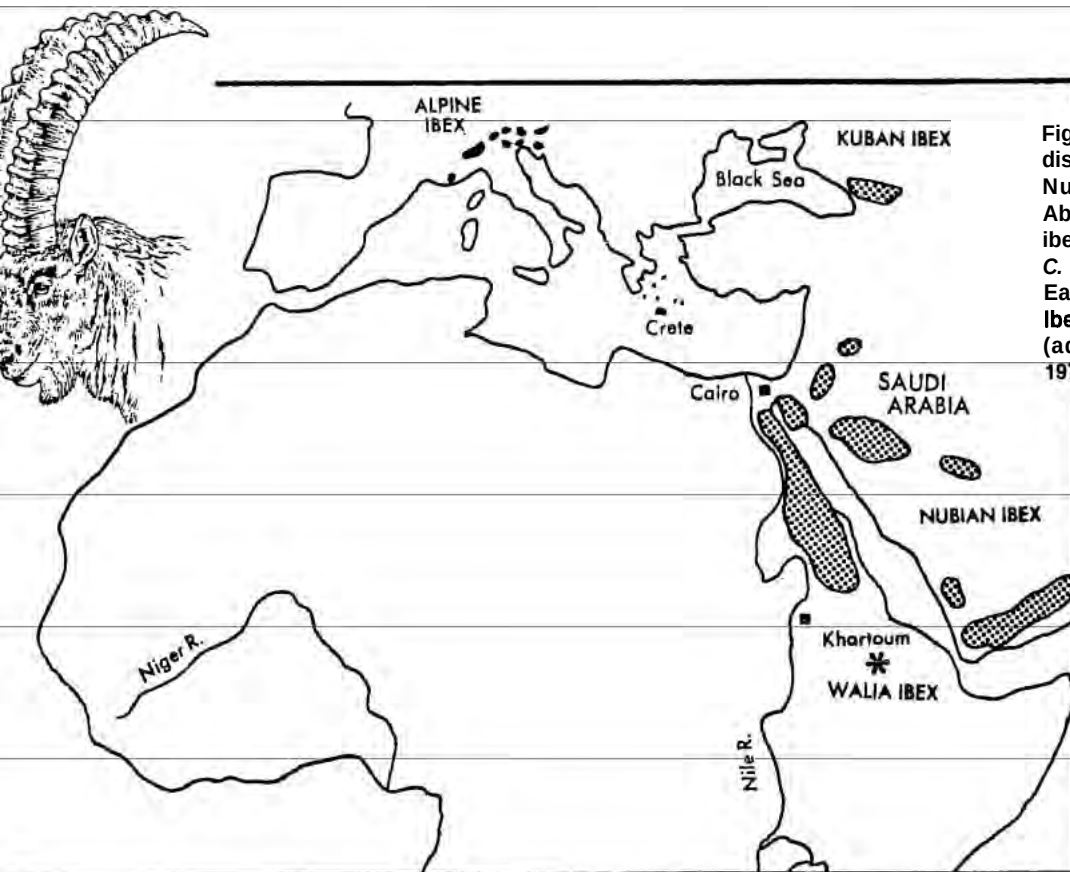


Figure 7. The approximate distribution of the Alpine, Nubian, and Walia or Abessinian Ibexes (*Capra ibex ibex*, *C. i. nubiana*, and *C. i. walis*), as well as the East Caucasian or Kuban Ibex or Tur (*C. i. caucasica*) (adapted from Schaller 1977).

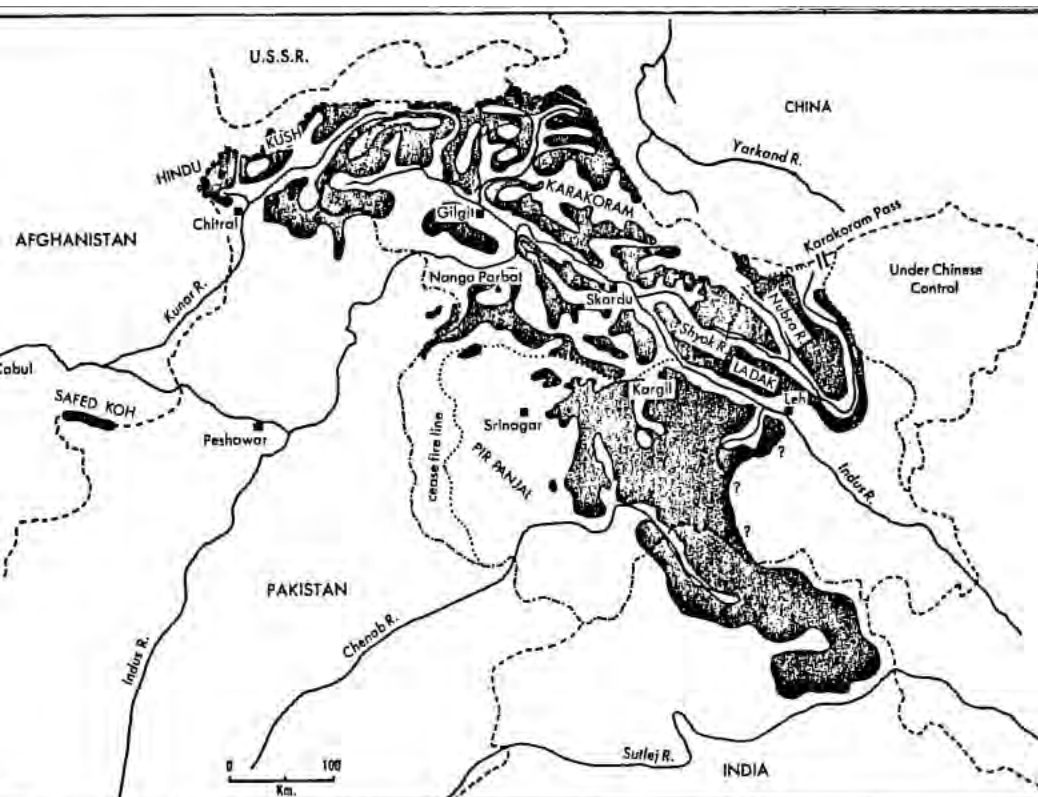


Figure 8. The approximate distribution of the Asiatic or Siberian Ibex (*Capra ibex siberica*) (from Schaller 1977).

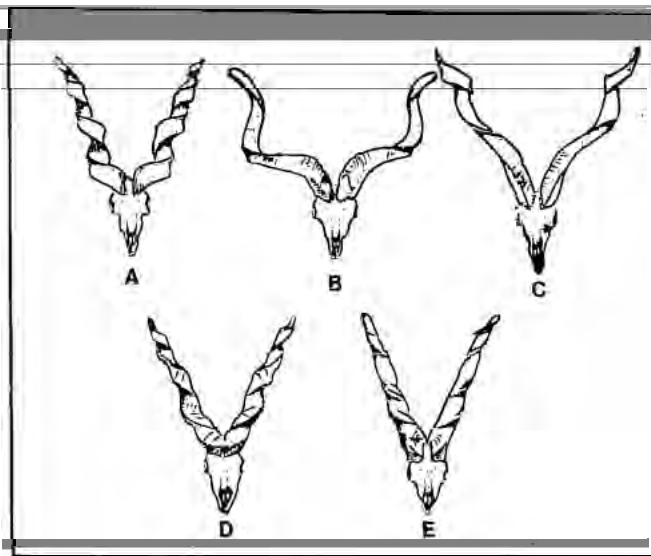


Figure 9. Horn shapes of various subspecies of Markhor (*Capra falconeri*); A C. f. *ognevi* of southern Russia, B and C. C. f. *falconeri* or **Astor** and Kashmir Markhor, respectively, D and E C. f. *megaceros* or Straight-horned Kabul or Sulaiman Markhor of north-central Pakistan (from Schaller 1977).

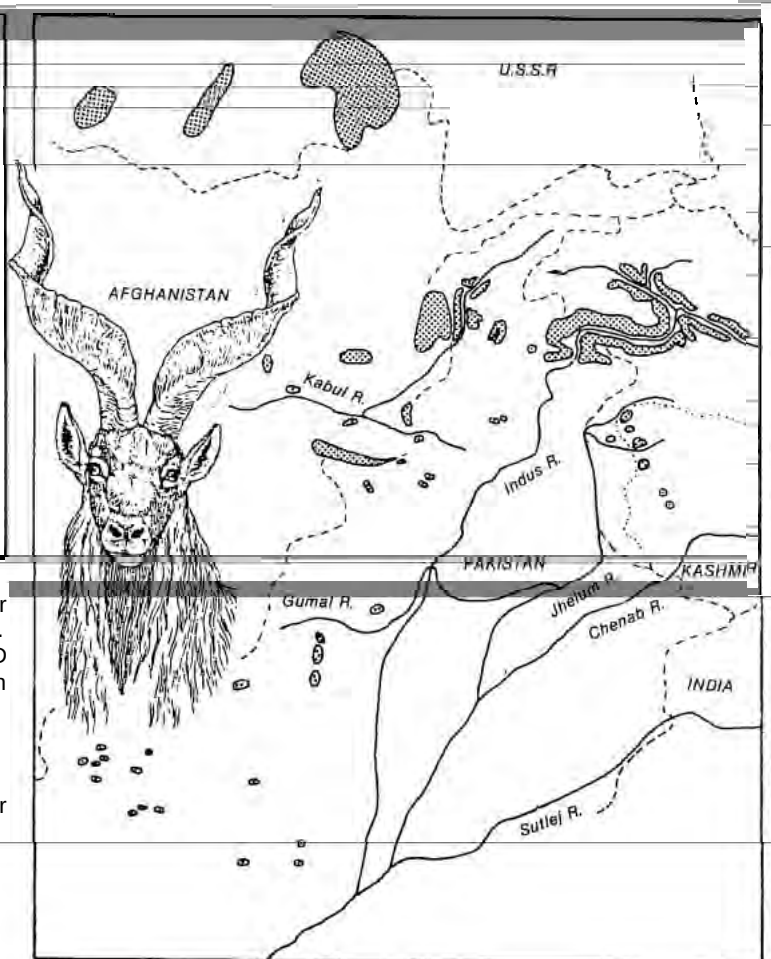


Figure 10. The approximate distribution of the Markhor (*Capra falconeri*) (from Schaller 1977).

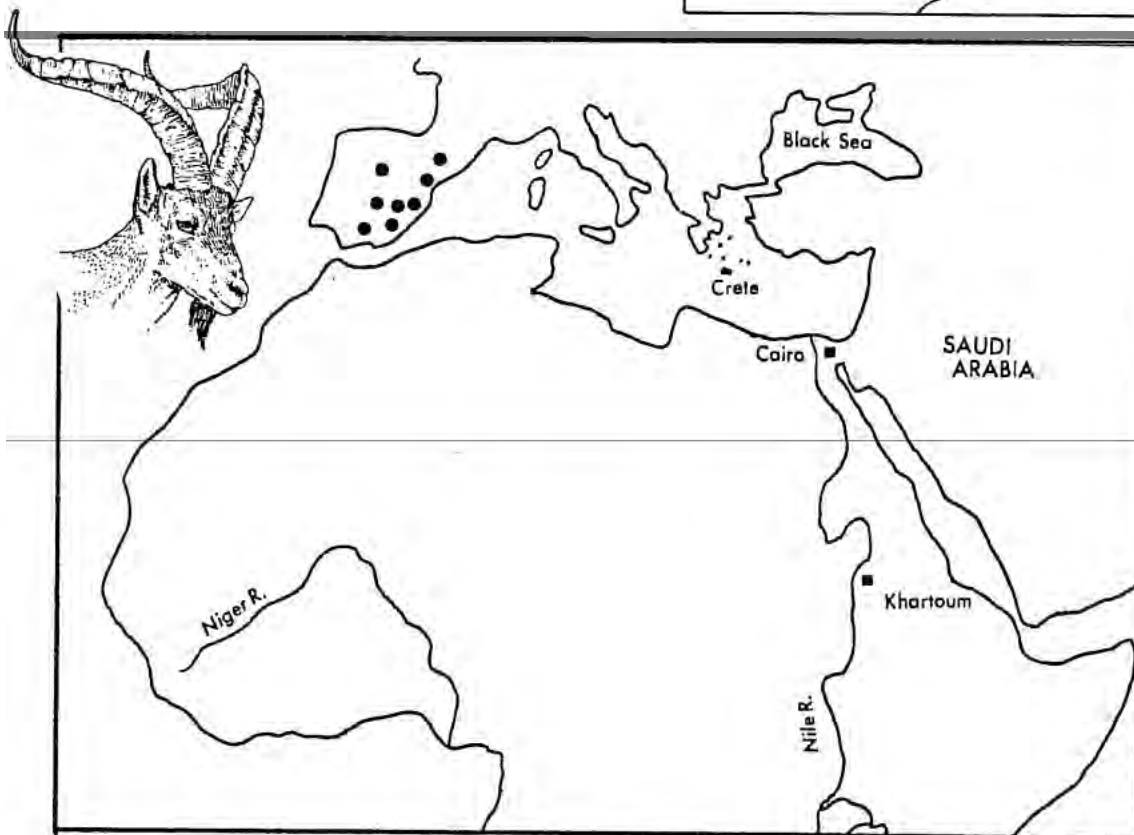


Figure 11. The distribution of the Spanish Wild Goat (*Capra pyrenaica*) (from Schaller 1977).

as many as 13 subspecies [i.e., Lydekker 1913], Schaller [1977] classifies them into only five:

- [1] The Alpine Ibex [C. *i. ibex*] of the Alps and neighboring highlands.
- [2] The Nubian Ibex [C. *i. nubiana*], which is found in the Red Sea Hills and the coastal mountains of North Africa and in Arabia and Palestine.
- [3] The Walia or Abessinian Ibex [C. *i. walia*], which is found only in the mountains of Simian Plateau in Ethiopia.
- [4] The East Caucasian or Kuban Ibex or Tur [C. *i. caucasica*], which inhabits the western Caucasus.
- [5] The Asiatic or Siberian Ibex [C. *i. siberica*], which ranges throughout the mountains of central Asia, from the Tien Shan and Altai Mountains to the Himalayas in Kashmir.

c. The markhors [C. *falconeri*] have posteriorly sharp-keeled horns [see Figure 5], which are twisted into an open or tight spiral [Figure 9]. The markhors are found primarily in Pakistan, with perhaps two subspecies being represented in adjoining areas in northern Afghanistan and southern Russia [Figure 10]. Seven subspecies of markhor often are recognized, but Schaller [1977] suggests that four or even fewer subspecies or distinct types of markhor are valid. These are:

- [1] C. f. heptneri of northern Afghanistan.
- [2] C. f. ognevi of southern Russia.
- [3] The Straight-horned Markhor [C. f. *megaceros*] often referred to as the Kabul or Sulaiman Markhor of north-central Pakistan.
- [4] The Astor or Kashmir Markhor [C. f. *falconeri*], which has horns with an extremely open spiral and with relatively few turns compared to the Straight-horned Markhor [See Figure 9].

Schaller [1977] claims that the Chiltan markhor, [previously classified as C. f. *chialtanensis*] is not a markhor, but only a uniquely-horned wild goat [C. *aegagrus*].

d. The Spanish wild goat or so-called Spanish Ibex [C. *pyrenaica*] has horns with a sharp posterior keel [see Figure 5] and which curve out and up and then back, in-

ward, and up again. This goat species inhabits the Pyrenees and mountainous districts of Spain and Portugal [Figure 11], and reportedly can be classified into four recognizable subspecies on the basis of the amount of black in the pelage [de Beaux 1956].

e. The East Caucasian or Dagestan Tur [C. *cylindricornis*] of the Caucasus [Figure 12] has massive, almost round, horns, that curve out, up, back, inward, and up, somewhat like those of the Spanish goat.

f. The domestic goats [C. *hircus*], of which there are more than 300 breeds, probably originated from the wild goats [C. *aegagrus*], but some authors suggest that the markhors [C. *falconeri*] also contributed to the domestic stock. However, virtually all of the horns of the domestic breeds of goats spiral in the opposite direction than those of the markhors.

- [5] Ovis, or the True Sheep, can be difficult to distinguish from Capra. That is true particularly when the large and characteristic horns of the adult males are absent and when sheep have hair instead of wool. In 1975, we reported to the Desert Bighorn Council [Spillett et al. 1975] some of the difficulties of sheep and goat taxonomy.

Morphologically, sheep differ from goats in that they possess preorbital and inguinal glands, as well as interdigital glands on all four feet; whereas, goats lack these glands or possess interdigital glands on only the front feet. Instead, goats have an odoriferous tail gland, which is lacking in sheep [Geist 1971].

Probably the most reliable characteristic for distinguishing sheep from goats in the field is the fact that goats, when disturbed or while moving, almost invariably erect the tail and sheep usually do not. Goats also have flat and relatively long tails which are bare underneath, as compared to the somewhat round and hairy tails of wild sheep [Schaller 1977]. However, in the case of skeletal remains or fossils, how does one determine whether or not the tail was raised, round, bare underneath, or even if the aforementioned glands were present? That is why most paleontologists and archaeologists lump their data in regards to sheep and/or goat remains, rather than attempt to identify and separate them.

Table 3. Cytogenetic Groupings of Ovis

2n = 52	2n = 54	2n = 56	2n = 58
Snow Sheep [<i>O. nivalis</i>]	Domestic Sheep [<i>O. aries</i>]	Argalis [<i>O. ammon</i>]	Urals [<i>O. vignei</i>]
	North American Bighorns [<i>O. canadensis</i>]		
	North American Thin-horn Sheep [<i>O. dalli</i>]		
	European Mouflons [<i>O. musimon</i>]		
	Asiatic Mouflons [<i>O. orientalis</i>]		

The taxonomy of goats is somewhat confused, but relatively clear-cut as compared to the many classification systems which have been presented for sheep. Some of the so-called "lumper" taxonomists, for example, claim there are only two species of wild sheep [Pfeffer 1967, Heptner et al. 1966]. They claim that all Eurasian wild sheep, with the exception of the Snow Sheep of Siberia, which they consider to be a North-American-type wild sheep, are *O. ammon*. And, all of the North American wild sheep and the Snow Sheep are *O. canadensis*. In contrast, some of the "splitter" taxonomists claim there may be as many as 40 or more species of wild sheep [Ellerman and Morrison-Scott 1951]. More and more taxonomists now are concluding that, at best, there are only three valid species of Eurasian wild sheep: The mouflons [*O. musimon* or *O. orientalis*], the urials [*O. vignei* or *O. orientalis*] and the argalis [*O. ammon*]. Additionally, some feel that European mouflons [*O. musimon*] should be considered subspecific to the Asiatic mouflons [*O. orientalis* and/or *O. vignei*] [Schaller 1977]. But some others [Bunch, N'Guyen, and Lauvergne 1978] contend that European mouflons are not wild sheep, but feral descendents of primitive domestic sheep [*O. aries*].

Schaller [1977] considers European and Asiatic mouflons and urials or red sheep, all to be *O. orientalis*, whereas Bunch et al. [1979] presented genetical evidence that mouflons [*O. musimon* and *O. orientalis*] have a 54-chromosome karyotype, urials [*O. vignei*] a 58-chromosome karyotype, and red sheep actually are hybrids between Asiatic mouflon and urials and may have karyotypes varying from 54- to 58 chromosomes.

Thus, if the European mouflon is considered a valid wild sheep species, we feel there are both genetic and morphological evidences to justify classifying the Eurasian wild sheep into four groups or species, i.e., European Mouflon [*O. musimon*], Asiatic Mouflon [*O. orientalis*], Urals [including the so-called Red Sheep] [*O. vignei*] and the Argalis [*O. ammon*].

Most taxonomists now agree that there are only three species of North American-type wild sheep. These are [1] Snow sheep or Asiatic bighorns [*O. nivicola*] of Siberia, [2] North American thin-horn or Dall and Stone sheep [*O. dalli*] of Alaska and northeastern Canada, and [3] Bighorn sheep [*O. canadensis*] of western North America, from British Columbia to the southern extremity of Baja California in Mexico.

a. There still is considerable debate as to the subspecific status of various forms of wild sheep. Generally, however, only one species of European mouflon is recognized. This is the Corsican or Sardinian Mouflon [*O. m. musimon*], which inhabits the Islands of Corsica and Sardinia. Wild populations of mouflons also have been established in many European countries [i.e., France, Germany and Poland], as well as in the United States, particularly in the Southwest.

b. We recognize two subspecies of Asiatic Mouflon [*O. orientalis*] [Figure 13]. These are:

- [1] The Cyprian Mouflon [*O. o. ophion*] or Cyprus.
- [2] The Armenian Mouflon [*O. o. gmelini*] of central, southern, and eastern Turkey and northern Iraq eastward into the Elburz and westward along the Zagros mountains of Iran, with an extension northward toward the Caucasus.

c. We also classify the Red Sheep along with the urials [*O. vignei*] and recognize five subspecies [Figure 14]; these are:

- [1] The Laristan Urial [*O. v. laristanica*] of southeastern Iran.
- [2] The Transcaspiian Urial [*O. v. arkal*] of northeastern Iran and those parts of Russia south-east of the Caspian Sea.
- [3] The Afghan Urial [*O. v. cycloceros*], which is widely distributed throughout the mountainous parts of Afghanistan, southeastern Iran, southern Turkmenia, and Pakistan.
- [4] The Punjab Urial [*O. v. blanfordi*], which is found only in the Salt and Kala Chitta Mountains between the Indus and Jhelum Rivers of Pakistan.
- [5] The Ladak Urial [*O. v. vignei*], which also is known as the Shapo and inhabits major mountain valleys, such as the Kumar, Indus, Gilgit, and Shyok of northern Pakistan and India, as well as, perhaps, the southwestern corner of the Pamirs, the lower Wakhan Corridor, and the north bank of the Amu Darya River [Flint et al. 1965].

Apparently the range of the Ladak Urial overlaps the ranges of two argalis: the Marco Polo Argali [*O. a. poli*] in the Turkestan area, and the Tibetan Argali [*O. a. hodgsoni*] in the Zashar Range of Ladak. The ranges of the other urials do not overlap those of the argalis.

d. Relatively little is known about the argalis [*O. ammon*], which are confined to central Asia [Figure 15]. Schaller [1977], however, recognizes seven subspecies of argalis. These are:

- [1] The Karatau or Bukhara Argali [*O. a. nigrimon*], which is the smallest and least specialized of the Argalis [Clark 1964], and which inhabits the eastern bank of the Syr Darya in Russia.
- [2] The Nura Tau Argali [*O. a. severtzovi*] of the desert ranges on the Kyzyl Kum, between the Amu Darya and Syr Darya in Russia. Both the Karatau and the Nura Tau Argalis occur solely in Russia; [Clark 1964] claims the Karatau is the most westernly occurring of the Argalis, but Schaller [1977] claims it is the Nuratau Argali.
- [3] The famous Marco Polo Sheep or argali [*O. a. poli*] has its center of distribution in the Pamirs, which consist of vast valleys flanked by high ranges, most of which are located in Russia, but also include the Great and Little Pamirs in the Wakhan Corridor of Afghanistan and the Tagdumbash Pamir in China, which has two valleys extending to the Pakistan border at the Kilit and Khunjerab passes.
- [4] Karelina's Argali [*O. a. karelina*] which inhabits the Tien Shan Mountains, that run through the center of Sinkiang, and are located to the east of the Pamirs or the range of the Marco Polo; this argali apparently is closely related to the Marco Polo, but has heavier and more tightly curled horns.
- [5] The precise range of the Tibetan Argali [*O. a. hodgsoni*] is obscure, but Schaller [1977] claims its range starts some 300 km east of

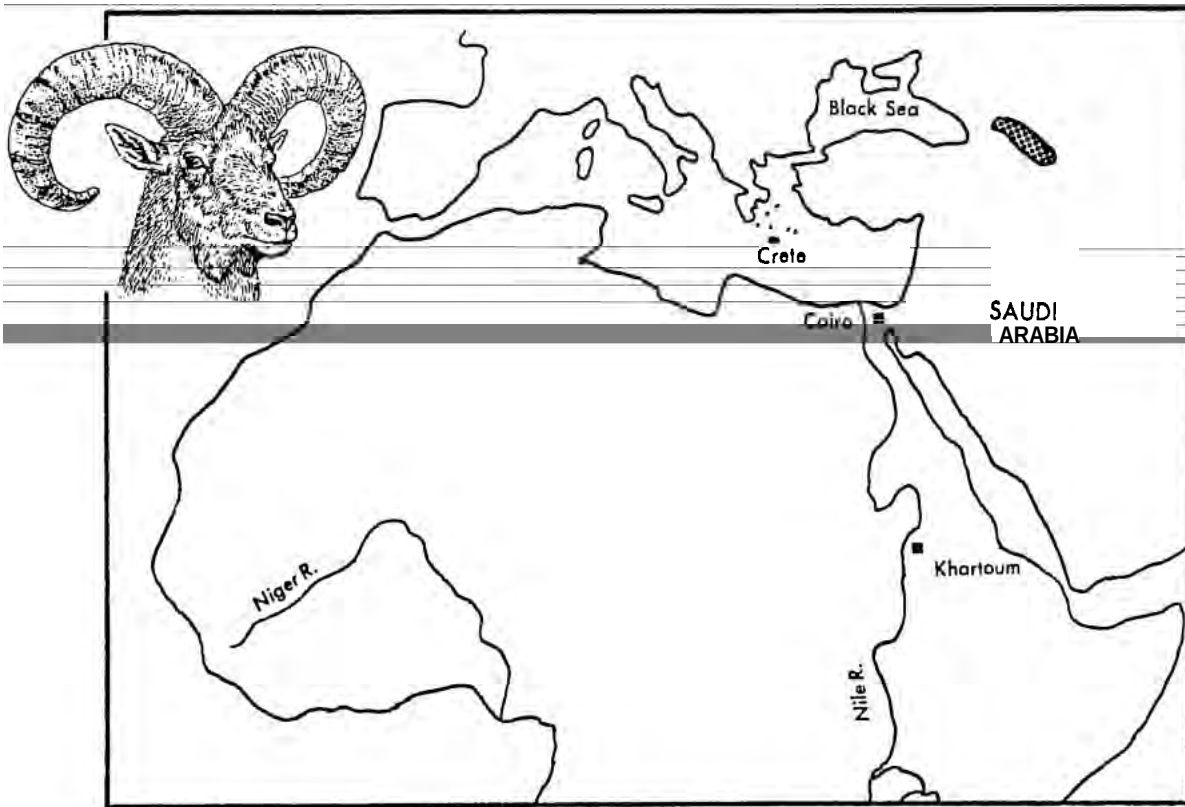


Figure 12. The approximate distribution of the East Caucasian or Dagestan Tur (*Capra cylindricornis*) of the Caucasus in Russia (from Schaller 1977).

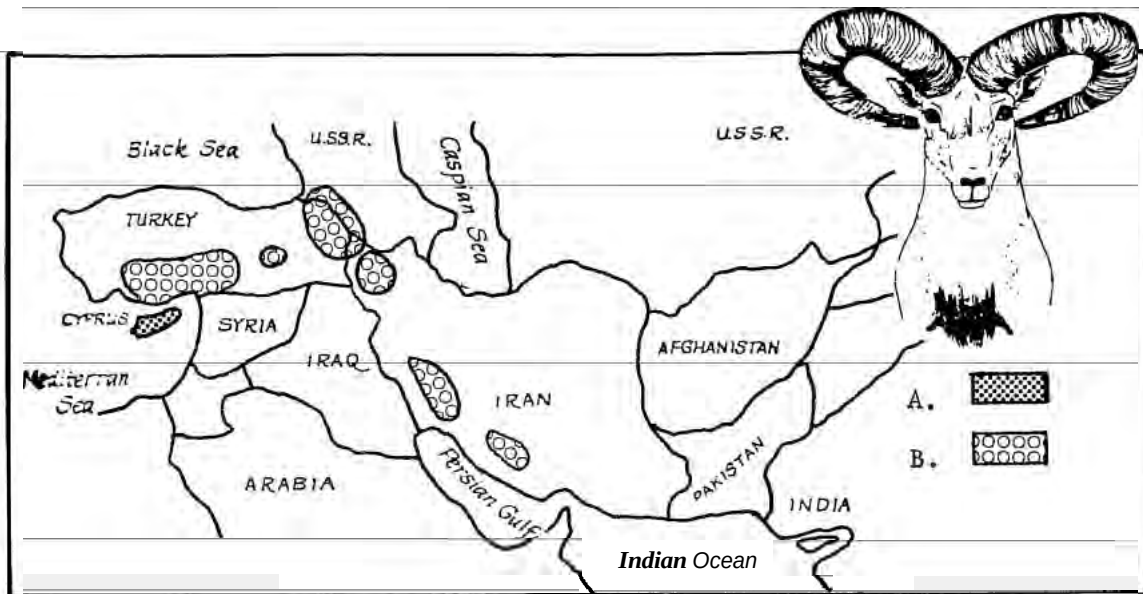


Figure 13. The approximate distribution of the Asiatic (Cyprian and Armenian) Mouflons (*Ovis orientalis ophion* and *O. o. gmelini*) (adapted from Clark 1964).

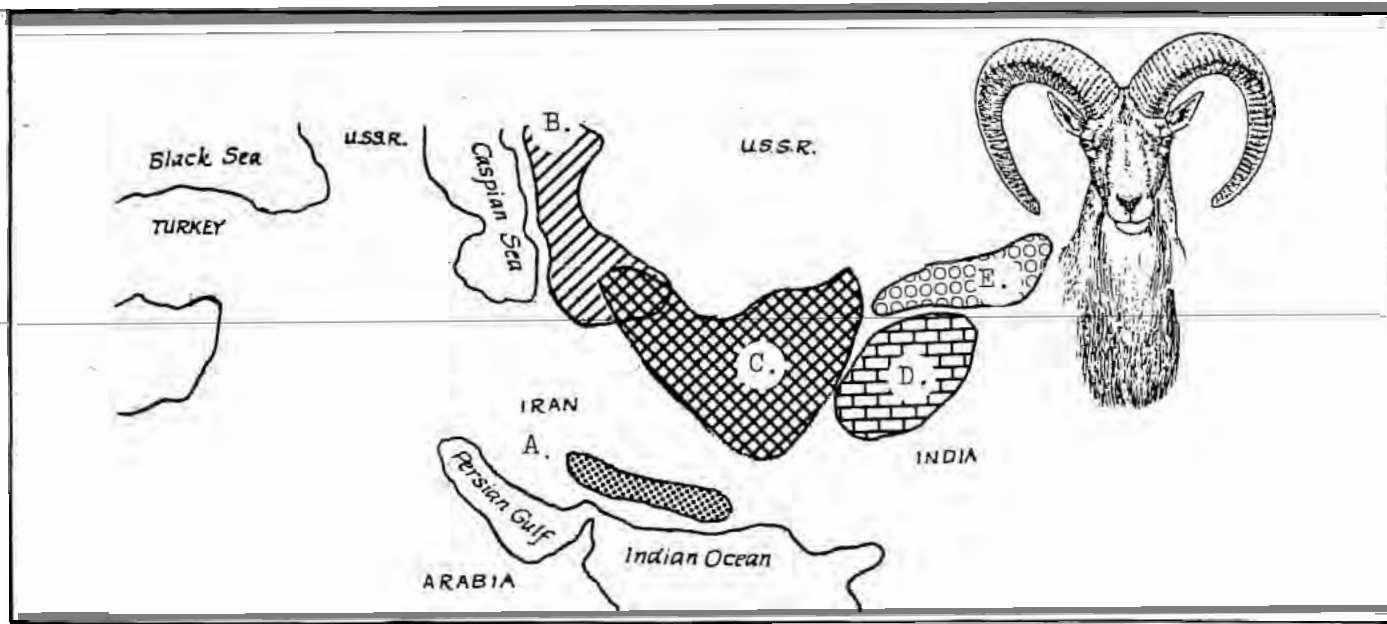


Figure 14. The approximate distribution of the Laristan, Transcaspiian, Afghan, **Punjab** and Ladak Urials (a. *Ovis vignei laristanica*, b. *O. v. arkal*, c. *O. v. cycloceros*, d. *O. v. blanfordi* and e. *O. v. vignei*) (adapted from Clark 1964). The Laristan and Transcaspiian Urials actually are hybrids between the Asiatic **Mouflons** (*O. orientalis*) and the Urials (*O. vignei*) and often are called Red Sheep (adapted from Clark 1964).

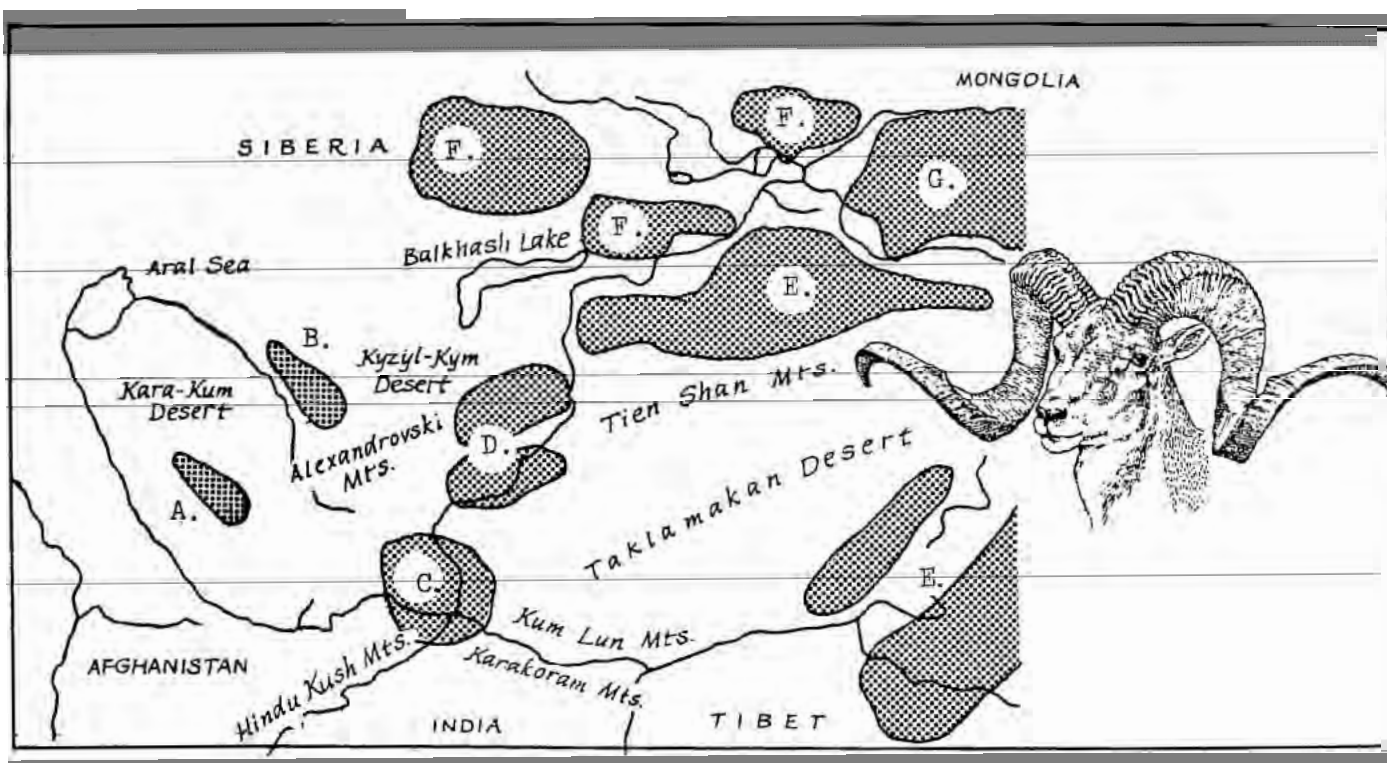


Figure 15. The approximate distribution of the Karatau, Nura Tau, Marco Polo, Karelin, Tibetan, Siberian or Altai, and Mongolian Argalis (a. *Ovis ammon nigrimontana*, b. *O. a. severtzovi*, c. *O. a. poli*, d. *O. a. karelini*, e. *O. a. hodgsoni*, f. *O. a. ammon*, and g. *O. a. darwini*, respectively) (adapted from Clark 1964).

that of the Marco Polo, and Clark [1964] claims its range extends "through southern Tibet, across the high Tibetan Plateau, eastward through Bhutan and Sikkim, and northward along the Chinese border to the southern Gobi -- in all, a distance of approximately 2,000 miles."

[6] The Siberian or Altai Argali [*O. a. ammon*], which is the largest of all *Ovis* and stands more than 50 inches at the shoulder and weighs in excess of 500 pounds; it inhabits the Altai Mountains, where southern Siberia, Sinkiang, and Mongolia come together, as well as adjoining ranges, to just south of Lake Baikal. It and the Mongolian Argali [*O. a. darwini*] are the most northerly occurring of the argalis.

[7] The Mongolian Argali [*O. a. darwini*] which is widely dispersed across the Gobi Desert Plateau of Mongolia and in China, where it occupies the Khiagan and other ranges [Schaller 1977]; this large sheep may stand more than 45 inches at the shoulder and weigh well in excess of 300 pounds and appears to be closely related to both the Tibetan and Siberian argalis [*O. a. hodgsoni* and *O. a. ammon*].

Whereas Eurasian wild sheep prefer habitats that are gently to steeply rolling, but not unusually precipitous, Snow Sheep or Asiatic Bighorn [*O. nivicola*] and American wild sheep [*O. dalli* and *O. canadensis*] occupy open, rugged terrain in the vicinity of cliffs, habitats similar to those of the Asiatic ibexes. Both Eurasian and American-type sheep, however, are adapted to altitudinal and climatic extremes. Their altitudinal range extends from about 100 m below sea level in the case of the Desert Bighorn in Death Valley to 6,000 m in the case of some of the Argalis. In fact, the Marco Polo Argali rarely go below 3,000 m. Wild Sheep also tolerate temperatures which may exceed 50°C in Death Valley to well below -50°C in Alaska and Siberia.

e. Although the Snow Sheep or Asiatic bighorns [*O. nivicola*] inhabit the whole eastern half of Siberia [Figure 16], an area almost twice as large as that inhabited by the Argalis [*O. ammon*], they apparently have been studied little or all of the information pertaining to them is sequestered in Russian literature. Further although Clark [1964] lists five subspecies of Snow Sheep, Schaller [1977], Geist [1971] and Heptner et al. [1966] list only three. These are:

- [1] *O. n. alleni*, which inhabits southeastern Siberia.
- [2] *O. n. lydekkeri*, which has an extensive distribution in north-central Siberia, primarily above the Arctic Circle.
- [3] *O. n. nivicola*, which inhabits the extreme eastern part of Siberia.

f. The North American wild sheep usually are classified into two species [*O. dalli* and *O. canadensis*]. Three subspecies of thin-horn or Dall and Stone Sheep [*O. dalli*] generally are recognized [Figure 17]. These are:

- [1] The Dall or White Sheep [*O. d. dalli*] of Alaska and the Yukon and Mackenzie Territories of Canada.
- [2] The Peninsula Dall or White Sheep [*O. d. kenaiensis*] of the relatively small Kenai Penin-

sula on the south-central coast of Alaska, which is usually somewhat smaller than the Dall sheep.

- [3] The Stone or Black Sheep [*O. d. stonei*] of the southern Yukon and northern part of British Columbia.

g. Although Clark [1964] lists 10 subspecies of North American bighorns [*O. canadensis*], taxonomists today generally agree there are only seven [Figure 18] -- or eight if you include the extinct Badlands or Audubon Bighorn [*O. c. auduboni*], which formerly inhabited parts of eastern Montana and Wyoming and western portions of North and South Dakota and Nebraska [Clark 1964]. The extant American bighorn subspecies are:

- [1] The Rocky Mountain Bighorn [*O. c. canadensis*], which is the largest, most abundant and northern in range, sporadically inhabiting the Rocky Mountains from British Columbia and Alberta, Canada, south through Montana, Idaho and Wyoming, into Colorado and northeastern Utah, and also is the only bighorn subspecies which may not be considered as a Desert Sheep.
- [2] The California Bighorn [*O. c. californiana*], sometimes called the Lava-Bed or Rimrock bighorn, which formerly ranged from British Columbia to south-central California and western Nevada, but presently is restricted to isolated populations, some of which are relatively recent reintroductions.
- [3] Nelson's Bighorn [*O. c. nelsoni*], which according to Clark [1964], is the most numerous of the Desert Bighorns and inhabits the mountain ranges of Death Valley and the Mojave Desert, including almost the whole lower third of California and southern Nevada, and also inhabits southeastern Utah and possibly northern Arizona;
- [4] The Arizona or Mexican Bighorn [*O. c. mexicana*] which inhabits much of Arizona, parts of western New Mexico, and parts of Chihuahua and Sonora in Mexico [Clark 1964].
- [5] The Texas Bighorn [*O. c. texiana*], which may persist in remnant populations in the Sierra Diablo region of West Texas and adjoining parts of Mexico.
- [6] The Lower Californian Bighorn [*O. c. cremnobates*], which inhabits southern California and the upper half of Baja California in Mexico.
- [7] The Baja or Weem's Bighorn [*O. c. weemsi*], which appears to be one of the larger, if not the largest, of the Desert Bighorns, as well as the southernmost wild sheep in North America, and inhabits the lower portion of the Baja California Peninsula.

h. The domestic sheep [*O. aries*], of which there are more than 900 breeds, probably originated from mouflons [*O. musimon* and/or *O. orientalis*], although some authors [i.e., Zeuner 1963] claim they originated from urials [*O. vignei*], and some others think argalis [*O. ammon*] may have been involved.

Thus, we have briefly reviewed the taxonomy of *Ovis* and its near relatives, as well as briefly considered the present 'distribution of the wild sheep as presented in Clark's [1964] classical Great Arc of the Wild Sheep [Figure 19].



Figure 16. The approximate distribution of the Snow Sheep or Asiatic Bighorns (a. *Ovis nivicola alleni*, b. *O. n. lydekkeri*, and c. *O. no. nivicola*) (adapted from Clark 1964).

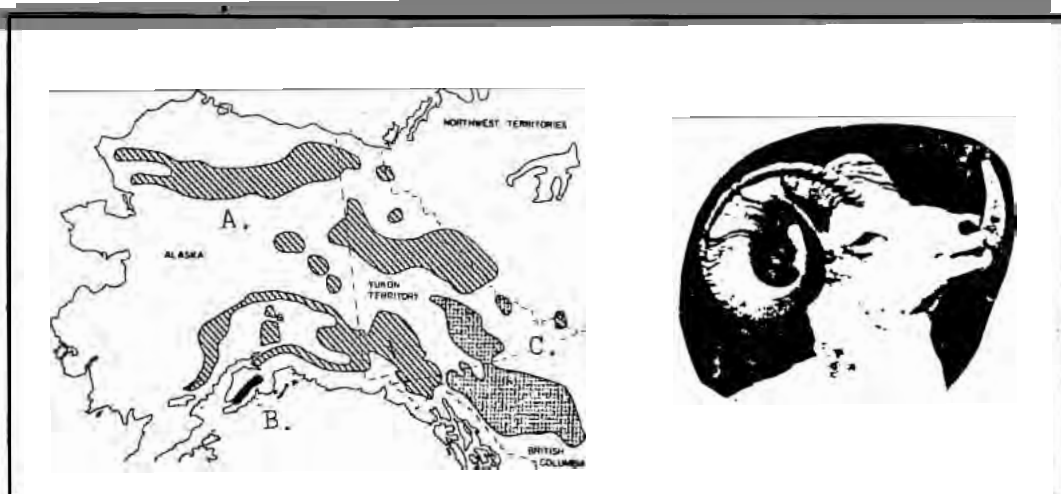


Figure 17. The approximate distribution of the North American **Thin-horn** or **Dall** and Stone sheep (a. *Ovis dalli dalli*, b. *O. d. kenaiensis*, and c. *O. d. stonei*) (from Nichols 1978).

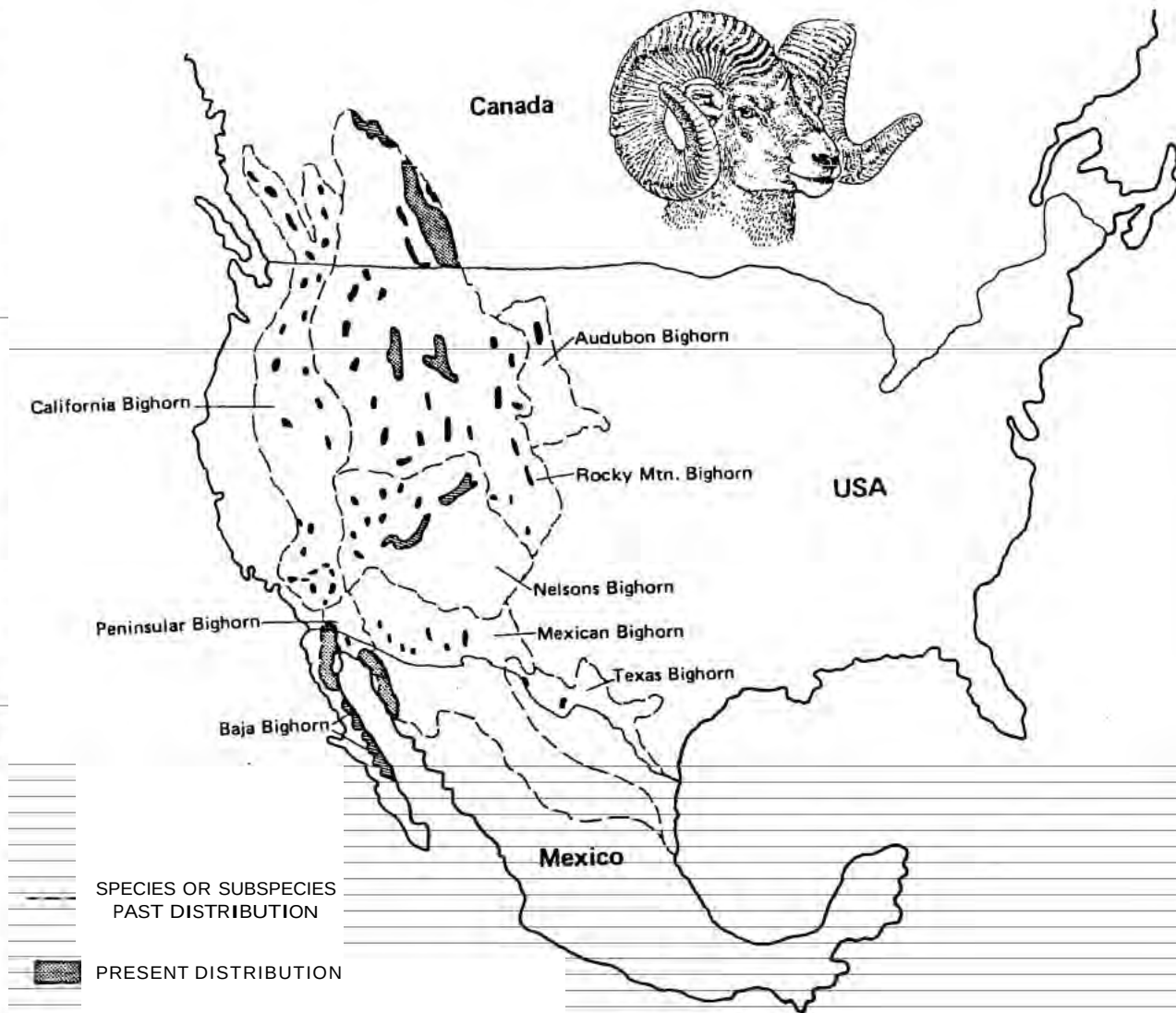


Figure 18. The approximate past and present distribution of the North American Bighorn Sheep (*Ovis canadensis*): a. Rocky Mountain (*O. c. canadensis*), b. California (*O. c. californiana*), c. Audubon's - extinct (*O. c. auduboni*), d. Nelson's (*O. c. nelsoni*), e. Arizona or Mexican (*O. c. mexicana*), f. Texas (*O. c. texiana*), g. Lower California or Peninsular (*O. c. cremnobates*), and h. **Weem's** or **Baja** (*O. c. weemsi*). Not every small present population is shown and those within the ranges of the Audubon's and Texas Bighorns are re-introductions of other subspecies (from Wilson 1979).

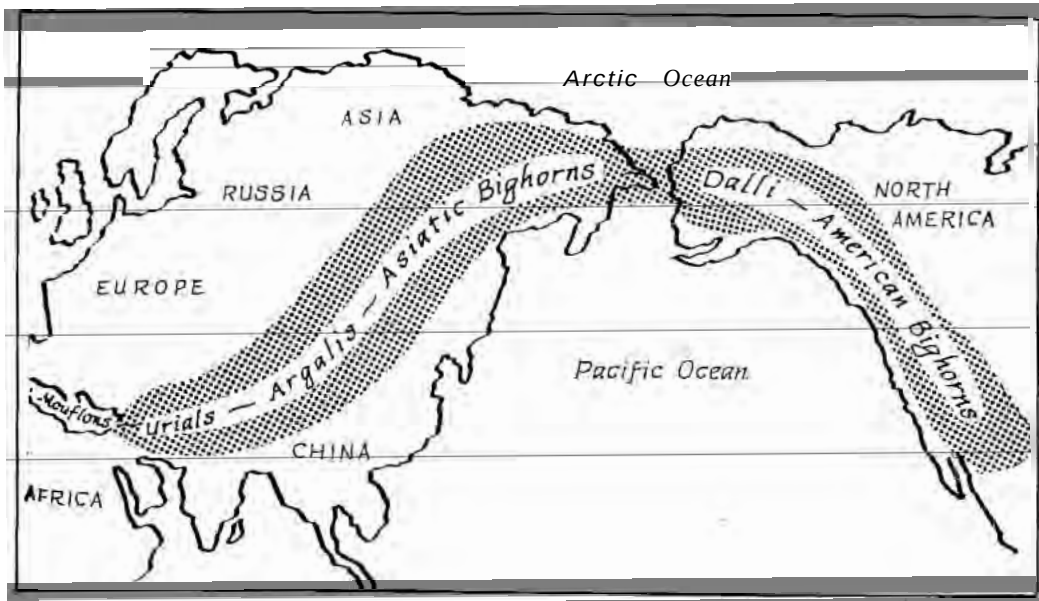


Figure 19. Clark's (1964) classical "Great Arc of the Wild Sheep."

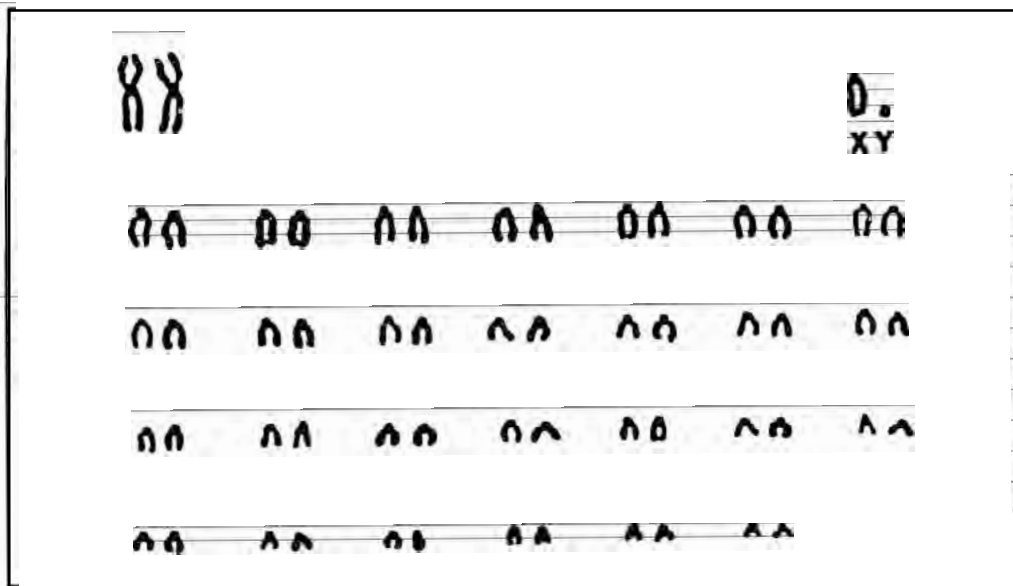


Figure 20. An Auodad or Barbary "Sheep" (*Ammotragus levia*) karyotype, containing 27 pairs of acrocentric autosomes plus 1 pair of metacentric chromosomes and a large acrocentric X and small bi-armed Y sex chromosomes.

THE CYTOGENETICS OF OVIS

Although ancestral prototypes of caprids or true sheep [*Ovis*] and true goats [*Capra*] have long been extinct, cytogenetic studies have provided some indications as to the direction of chromosome evolution in more recent forms of Caprids, and of the factors contributing to speciation. As previously mentioned the Tribe Caprini, which is within the Family Bovidae is comprised of five living genera.

Chromosome evolution within Bovidae has involved reductions in chromosome numbers, which occur as specific chromosomes become fused at the region of the centromere. Such repackaging of genetic material is called a Robertsonian translocation. A Robertsonian translocation usually occurs by the fusing of non-homologous acrocentric chromosomes [centromere almost terminal], which results in the formation of a metacentric chromosome [centromere submedial to medial]. Thus, two acrocentric chromosomes fuse to form a single chromosome and thereby, reduce the total chromosome number by one.

The basic 60-chromosome karyotype of Bovidae contains 58 acrocentric autosomes or non-sex chromosomes plus 2 sex chromosomes, which are designated XX in the female and as an XY combination in the male. All goats or Capra have this basic 60-chromosome karyotype, which contains 29 pair of acrocentric autosomes plus either 2 large acrocentric X's or a large acrocentric X and a small bi-armed Y. Aoudads or Barbary Sheep [*Ammotragus*] have a 58-chromosome karyotype, that contains 27 pairs of acrocentric autosomes or 4 acrocentric autosomes less than [Capra], plus 1 pair of metacentric

chromosomes that are absent in *Capra*, a pair of large acrocentric X's in the female or a large acrocentric and a small bi-armed Y in the male [Figure 20] [Bunch et al. 1977]. The fundamental number [FN=58], which refers to the number of arms of autosomes, remains unchanged. Thus, it appears that the karyotype of the Aoudad evolved away from the *Capra*-type by a simple Robertsonian translocation.

The chromosome evolution of *Ovis* has been more complex and involves several Robertsonian translocations [Table 3]. The Urial [*O. vignei*], considered as *O. orientalis* by Schaller [1977], have a 58-chromosome karyotype and are considered the most primitive *Ovis* genotype in terms of both chromosome number and, to some extent, behavior. The urial karyotype appears to be indistinguishable from that of the aoudad. Geist [1971] suggested that the aoudad could be the living representative of a sheep-goat ancestor, a theory that is compatible with the observable direction of chromosome evolution in *Ovis*. The aoudad-like ancestor, however, would have had to maintain a 60-chromosome karyotype.

Chromosome numbers among *Ovis* have been reduced to: 56 in the Argali [*O. ammon*], 54 in the European Mouflon [*O. musimon*] of the Mediterranean region and the Asiatic Mouflon [*O. orientalis*] of the Near East, as well as in the North American wild sheep [*O. dalli* and *O. canadensis*], and 52 in the Snow Sheep [*O. nivicola*] of Siberia [Schmitt and Ulbrich 1968, Wurster and Benirschke 1968, Nadler 1978, Nadler et al. 1971, 1973a, 1973b, Korobitsyna et al. 1974, Nadler and Lay 1975, Bunch et al. 1976, Nadler and Bunch 1978] [Figure 21]. The universal chromosome number of domestic sheep is 54, and

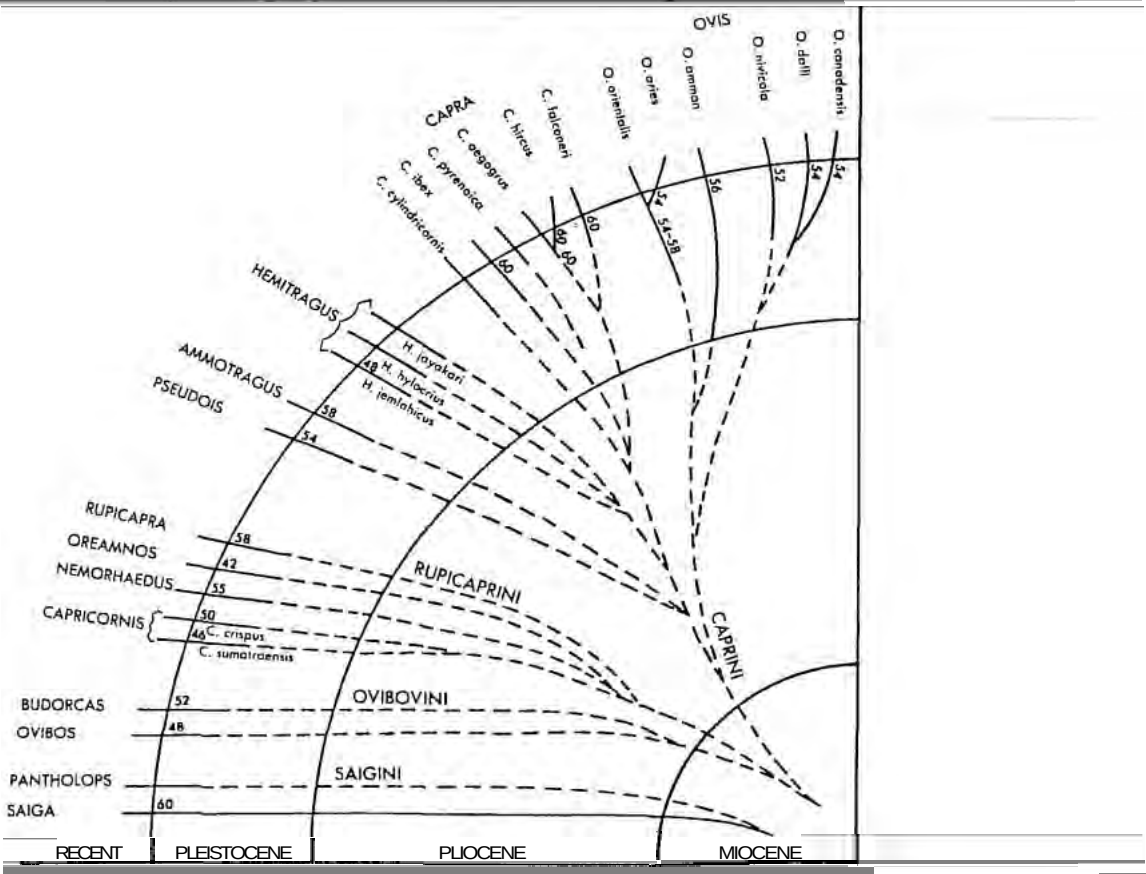


Figure 21. Evolution of the Subfamily Caprinae, with the **2n** chromosome numbers listed for species (from Schaller **1977**).

the karyotype of the domestic sheep [*O. aries*] is indistinguishable from the 54-chromosome karyotypes of wild sheep [Bunch 1978].

Probably the most **interesting** chromosomal divergence within Caprinae occurred **between** the true sheep [*Ovis*] and the Bharal or Blue Sheep [*Pseudois nayaur*]. Both genotypes have 54 chromosomes; however, the acrocentric components **comprising** the bi-armed chromosomes are similar in only the **lower half** [longest arm segment] of the chromosome [Bunch et al. 1978]. That phenomenon may have contributed to early speciation between *Ovis* and *Pseudois*.

The most advanced Caprinae karyotype is found in the Tahr [*Hemitragus*], which has a 48-chromosome karyotype. The evolution of the tahr karyotype involved six Robertsonian translocations. Two of the six translocations are identical to those in wild sheep, and one matches a translocation seen in the Aoudad [Ammotragus]. Similarities in chromosome arm components are identical only to the longer arms of the bi-armed chromosomes of the Bharal [*Pseudois*]. The establishment of the 4128 [numerical ranking based on the Capra karyotype] **bi-armed** chromosome within the Tahr [*Hemitragus*] **chromosome** complement may have produced a permanent genetic barrier between *Ovis*, with a 419 translocation, and the Bharal [*Pseudois*], with a 4113 translocation.

The previously described translocations are significant because they may establish genetic barriers that restrict **and/or** limit gene flow and provide for interpretations of evolutionary pathways. Two alternative theories, the Monophyletic and the Polyphyletic, have been presented to account for chromosomal evolutionary patterns [Nadler et al. 1973a]. The Monophyletic Theory postulates that the evolutionary **pathway** was via acrocentric translocations, which resulted in **a sequential** reduction of chromosome numbers. The Polyphyletic Theory, in contrast, implies that identical translocations occurred among independent ancestral groups, which resulted in a process of convergent evolution.

Both theories are credible, and both methods of chromosome evolution may have operated at various times in the Tribe Caprini. A monophyletic origin is strongly indicated in *Ovis*, since their pathway of chromosome evolution appears to be sequential, and the pattern of specific fusions has not been altered, as appears to have been the case in the Bharal, [*Pseudois*] and Tahr [*Hemitragus*]. **Only** a few breeds of domestic sheep do not have the typical 54-chromosome karyotype pattern. And, the significance of the reduction in chromosome numbers by variant translocations in these breeds is undetermined. The karyotype of the Aoudad [Ammotragus] may be representative of the earlier prototype of *Ovis*, or it may have arisen by convergent evolution. The karyotype of the Tahr [*Hemitragus*], for the most part, appears to have developed independently from the other genotypes, with the exception of the 115 bi-armed chromosome common to the Aoudad [Ammotragus] and *Ovis*. The 115 translocation may have become established in an earlier ancestral type, which then gave rise to Ammotragus, Hemitragus, and *Ovis*, and therefore, had a monophyletic origin. Conversely, the 115 translocations may have arisen independently in each genotype.

As we gain further information on mechanisms and contributive factors that foster spontaneous translocations, the route of chromosome evolution in *Ovis* and related genera may be defined more definitively.

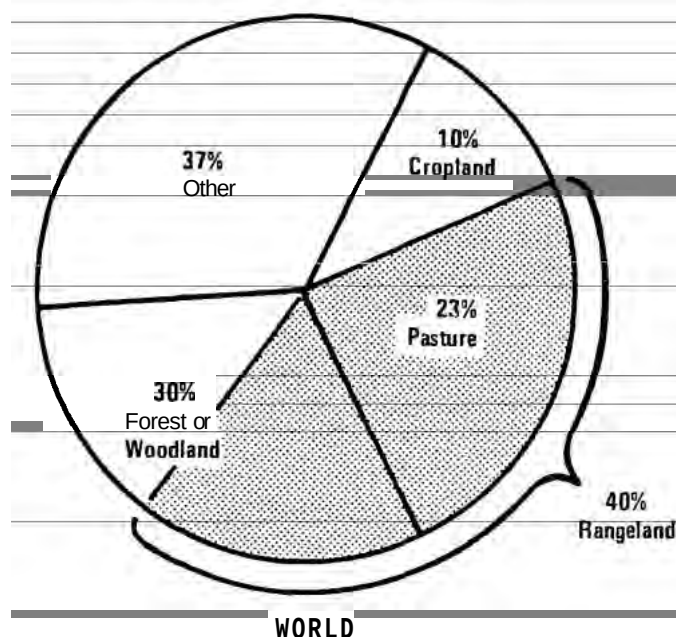
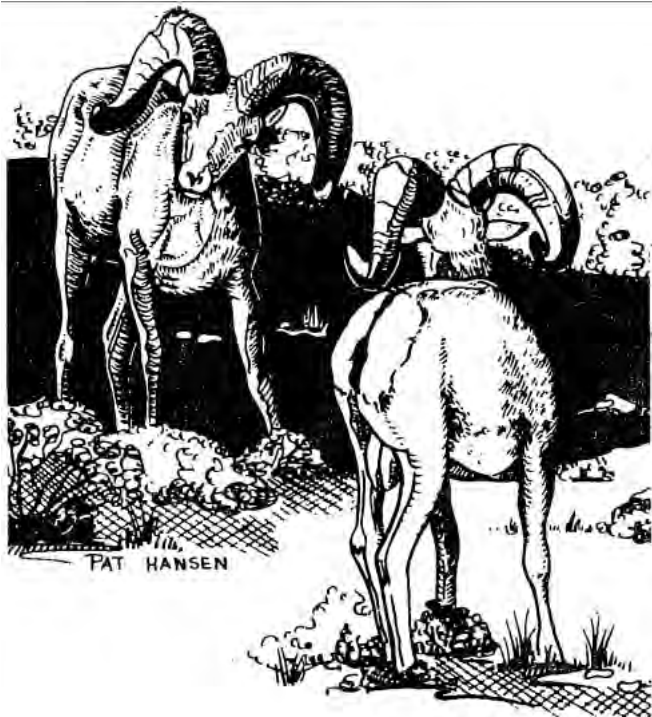


Figure 22. The classification of the Earth's land surface into major types, including rangeland.

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DESERT BIGHORN MOVEMENTS IN A SOUTHWESTERN ARIZONA MOUNTAIN COMPLEX

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Abstract. Twenty-two desert bighorn sheep were radio collared in the Plomosa and New Water Mountains of southwestern Arizona. Herd movements were generalized from 1300 relocations obtained on collared animals. Relatively distinct areas of ewe concentrations occurred in the Plomosa, the West New Water and the East New Water Mountains. Ram movements between breeding and non-breeding areas were extensive and complex. Interchange of sheep was documented between the Plomosa, New Water, Sheep Tank, Kofa and Tank Mountains, and the Bear and Livingston Hills. The desert bighorn herds existing in this widespread mountain complex are interconnected and should be managed as a single unit.

INTRODUCTION

Historically, the distribution of desert bighorn sheep in Arizona was more extensive than at present (Russo 1956; Buechner 1960). Ancestral movements of individuals between mountain ranges were governed by the combined effects of ecological and sociological barriers. Recently, bighorn movements have been further restricted by some man-induced alterations of habitat. An analysis of generalized movements of sheep between mountain ranges in any area yields not only the paths of interchange, which are presently sustaining specific herds, but also contributes insight into historical movement patterns.

A five-year research program funded by Southern California Edison and Arizona Public Service utility companies was initiated in October 1977 in the Plomosa and New Water Mountains of southwestern Arizona. The primary objective of this study is to assess the effect that construction of the 500 kV Palo Verde to Devers transmission line corridor will have upon the local desert bighorn (*Ovis canadensis mexicana*) herd. A segment of this research has been to document the generalized movement patterns of sheep within the study area.

STUDY AREA AND METHODS

The western borders of the Plomosa and New Water Mountains are located 12 km east of Quartzsite, Yuma Co., Arizona. Interstate Highway 10, the major vehicular artery between Phoenix and Los Angeles, bisects the two ranges and parallels the northern border of the East New Water Mountains, approximately 30 km east of Quartzsite.

The varied topography within the study area is a result of the complex geological history of the Plomosa and New Water Mountains. Low hills and extensive ridgelines and peaks are

the dominant geomorphological types, with interspersed buttes and mesas being less common. In general, these ranges are a series of sub-parallel north to south trending mountain blocks, which reach a maximum elevation of 600 m above the desert floor.

Vegetation is typical of Sonoran Desert plant communities. Lower elevations are dominated by creosotebush-white bursage-big galleta-cactus (*Larrea divaricata*-*Ambrosia dumosa*-*Hilaria rigida*-*Opuntia* spp.) associations, which grade into mixed palo verde-cactus (*Cercidium* spp. -*Cereus gigantea*-*Opuntia* spp.) associations on the higher slopes. Other widely dispersed and common perennials are brittlebush (*Encelia farinosa*), ocotillo (*Fouquieria splendens*), white ratany (*Krameria grayi*) and wolfberry (*Lycium* spp.).

Although all bighorn were captured in the primary study area of the Plomosa and New Water Mountains, the movements of some extended outside the area in a south and southeast direction. This produced a series of secondary study areas, which included the Kofa, Sheep Tank and Tank Mountains, and the Bear and Livingston Hills. Specific areas within these ranges exhibit considerable variation in elevation, topography and vegetation.

Twenty-two desert bighorn (15 in November 1977 and 7 in November 1978) were captured by Arizona Game and Fish Department personnel and instrumented with radio collars (Telonics-Mesa, Arizona). The helicopter/M-99 technique (Wilson et al. 1973) employed by the Department enhanced the opportunity for selectively capturing sheep of different age classes and sex from widely dispersed locations.

An intensive aerial relocation program was initiated on December 1, 1977. Most fixed-wing flights have been spaced at 5-day intervals with occasional variations (4-7 days) resulting from inclement weather and unavailability of aircraft. Field observations of radio collared sheep were used as supplemental data. More than 1300 relocations were plotted during the first 15 months of the study (Table 1).

Ewe home ranges were analyzed to determine areas of overlap. Areas with a high degree of home range sympatry were used as indicators of ewe concentration. Ram home ranges were larger than those of ewes and, for varying reasons, often were incompletely defined. As a result, ram data were expressed as generalized movements of individuals to and from breeding (mid-June to December) and non-breeding (January to mid-June) areas.

RESULTS

Twelve ewe home ranges are generalized in Figure 1. Eight of these were estimated from relocations ($x = 103$) obtained over a period of 16 months, while four partial ranges were defined from 4 months of observation ($x = 23$ relocations). These data support the concept that each home range was a composite of seasonal or behavioral home areas, although this type of analysis is not included in this paper.

The pattern of overlapping home ranges indicated that three relatively distinct areas of ewe concentration existed in the study area. Ewes within each of the three areas of concentration are referred to as ewe associations, and occurred in: (1) the Plomosa Mountains north of Interstate 10, (2) the West New Water Mountains-Livingston Hills, and (3) the East New Water Mountains. Zones of greatest home range sympatry corresponded with either perennial water sources, or areas of spring ewe/lamb concentration, or both.

Although radio-collared ewes were completely loyal to specific

Table 1. General information on individual radio collared bighorn.

ID	SEX	AGE	DATE OF CAPTURE	RELOCATIONS AS OF 15 MARCH 1979
1A	F	4-5	11/77	110
2A	F	6-7	11/77	102
3A	F	3-4	11/77	110
4A	F	2-3	11/77	106
00A	F	2-3	11/77	103
11A	F	2-3	11/77	99
12A	F	9-10	11/77	100
16A	F	6-7	11/77	99
8/9C	M	3-4	11/77 & 78	109
14A	M	3-4	11/77	87
58	F	9	11/78	22
6B	F	7	11/78	26
9B	F	7	11/78	25
188	F	9	11/78	22
13A	M	6-7	11/77 & 78	46
7B	M	7	11/78	26
178	M	2	11/78	22
5A	M	6-7	11/77	14'
6A	M	3-4	11/77	11'
7A	M	9-10	11/77	54'
9A	M	7-8	11/77	7*
6C	M	4	11/78	13'

*verified radio failure

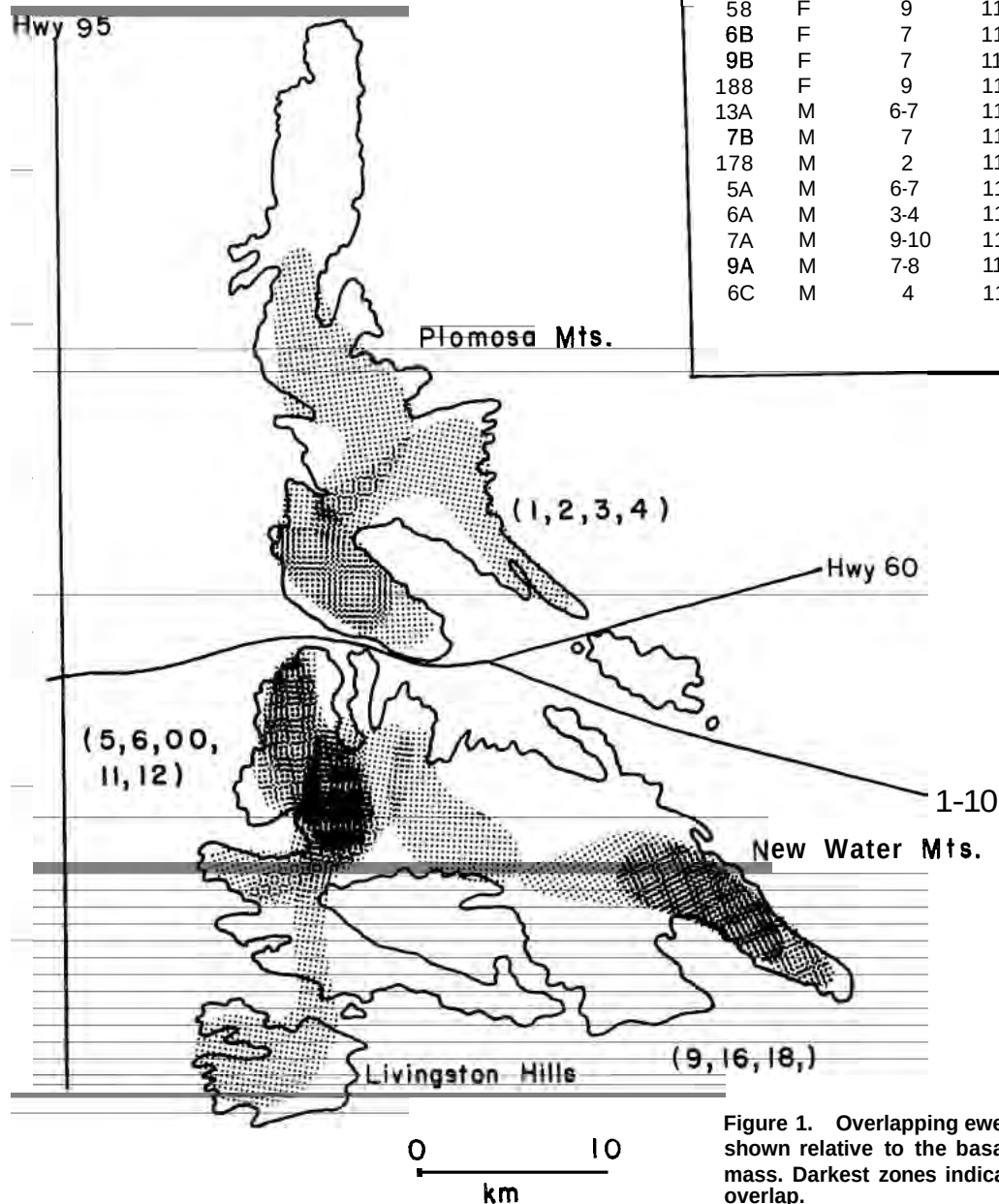


Figure 1. Overlapping ewe home ranges (shaded areas) are shown relative to the basal contour line of each mountain mass. Darkest zones indicate areas of greatest home range overlap.

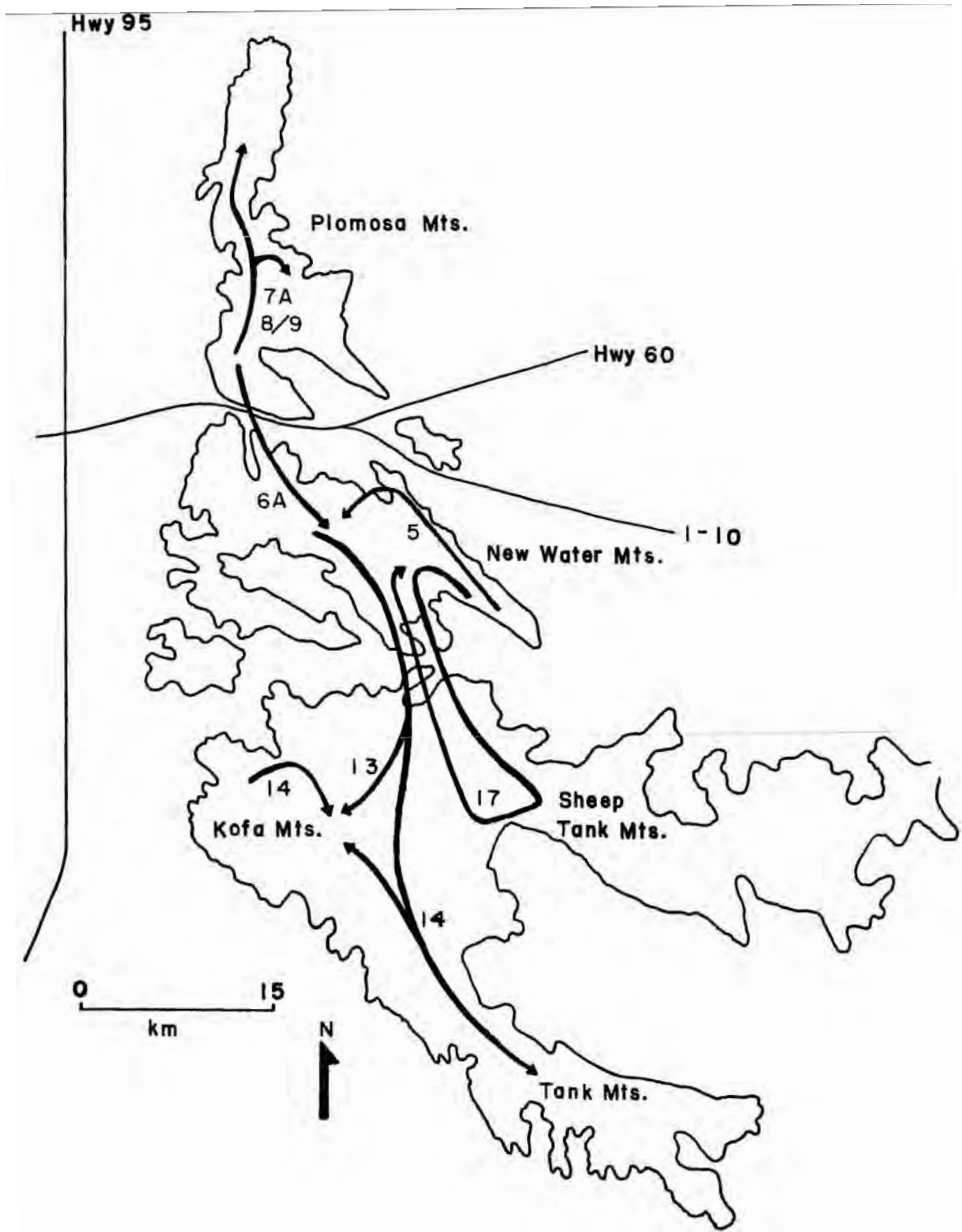


Figure 2. Movements of specific radio collared rams from breeding to non-breeding areas are depicted by arrows. The basal contour line of each mountain mass is shown.

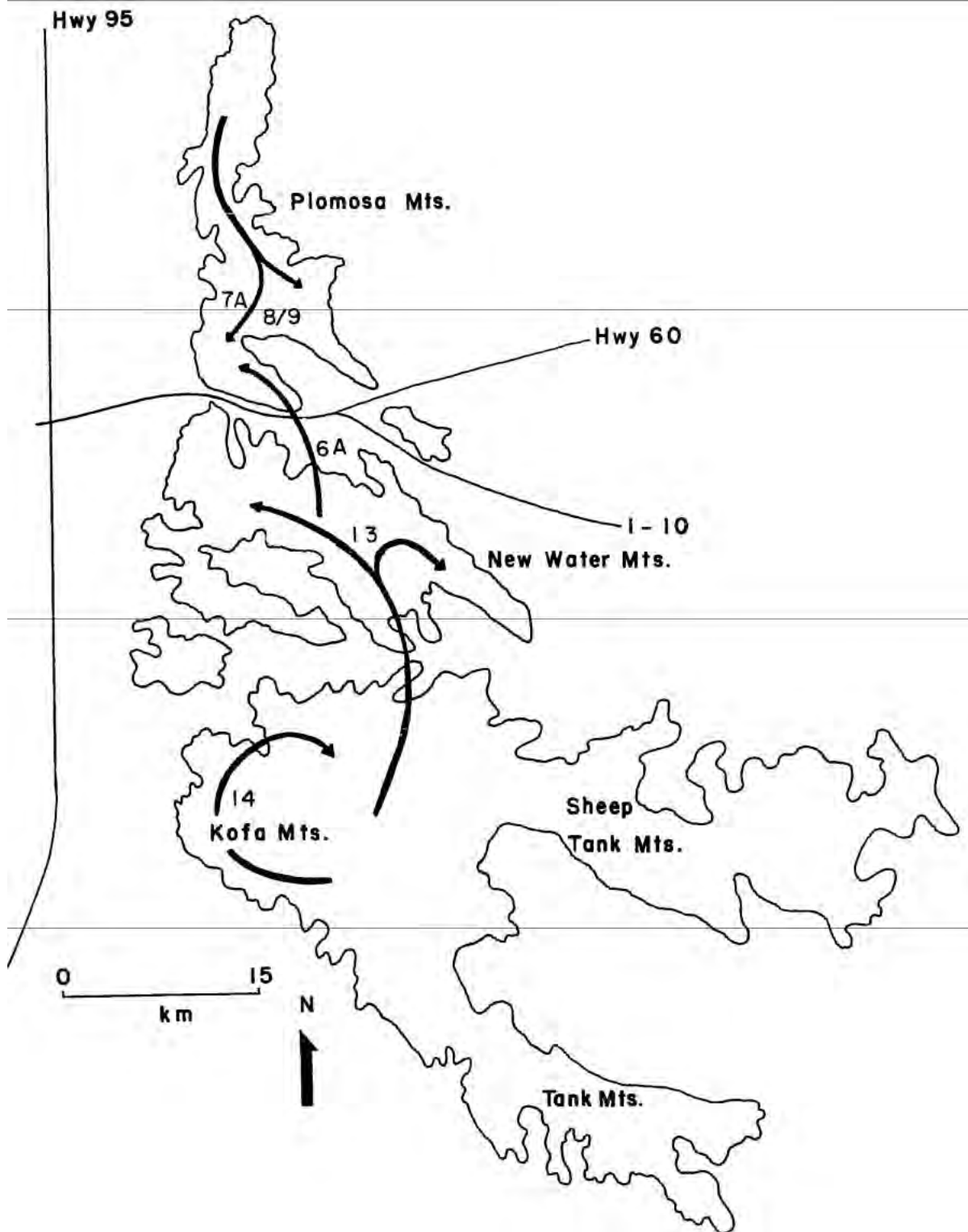


Figure 3. Movements of specific radio collared rams from non-breeding to breeding areas are depicted by arrows. The basal contour line of each mountain mass is shown.

ewe associations, limited evidence from unmarked animals indicates interchange of animals between areas may occur. Sightings of ewes crossing Interstate Highway 10 by jumping the boundary fences and by utilizing culverts below the highway are included in Arizona Game and Fish Department records (R. Remington A.G.& F. pers. comm.). In addition, a female lamb of 1978, having a distinctive broken horn was sighted in both the Plomosa and West New Water Mountains, which necessitated the crossing of Interstate Highway 10.

Movements of radio-collared rams between breeding and non-breeding areas are shown in Figures 2 and 3. Three of the 10 rams captured in the primary study area traveled south into the Kofa Game Range. Despite sampling deficiencies, ram movements overlapped from the northern end of the Plomosa Mountains to the southwest corner of the Kofa Mountains (70 km straightline) with extensions into the New Water (31 km), the Sheep Tank (31 km), and Tank Mountains (42 km). The greatest straightline distance traveled by an individual was 56 km (#14A).

Ram movements across Interstate Highway 10 were demonstrated by 6A (twice) and by a very old unmarked ram with distinctive horn characteristics. The latter was observed in a non-breeding Plomosa bachelor herd (winter 1977) (Arizona Game and Fish Department 1977) and then in the West New Water Mountains during the subsequent breeding season.

DISCUSSION

It is possible that relatively distinct ewe associations existed in the Plomosa and New Water Mountains prior to recent man-induced perturbations. These ewe associations possibly were created as maternal bands and developed a dependence upon one of the few permanent water sources within the study area. The lack of long-range movements and the home range loyalty displayed by most ewes would promote attachment to specific perennial watering sites, if these sites were limited and widely dispersed. The separation of East and West New Water ewe associations in an area of continuous and relatively undisturbed bighorn habitat exemplifies this situation.

The separation of Plomosa and West New Water ewe associations was not explained completely by ecological barriers. Waters historically used by bighorn in the Plomosa Mountains consisted of a series of dispersed, semi-permanent tinajas. The nearest dependable perennial water was a spring in the West New Water Mountains, 12 km south through continuous bighorn habitat. In all likelihood, the Plomosa ewe associations that developed with ephemeral tinajas would have been disrupted during periods of extreme drought. Under these conditions, interchange of ewes between ranges would be promoted.

The construction of Interstate Highway 10 through Plomosa Pass effectively separated the Plomosa and West New Water Mountains. As a continuous linear obstruction, this highway has not totally eliminated ewe movements between these ranges. However, it appears that it has intensified the separation of Plomosa and West New Water ewe associations. This is further indicated by ewe home range boundaries (see Figure 1) which abut, but do not cross, the Interstate Highway.

Increased isolation of ewe associations should be self-perpetuating, because of the nature of yearling home range development. Yearling ewes generally adopt the home range of their maternal band, but may switch to different bands -- if they are encountered (Geist 1971:98). Yearling desert bighorn

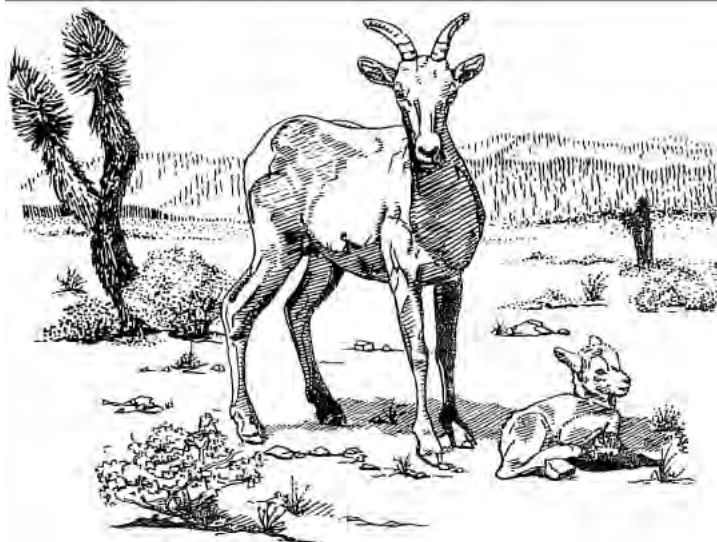
ewes have excellent opportunities to associate with different ewes when bands are concentrated during periods of water stress. Regarding the three ewe associations in the study area, potentially beneficial effects of yearling mixing would be negated. Although a yearling ewe could develop a separate home range from that of its maternal band, the adopted home range would still be that of a band which was linked to the same ewe association in which it was born.

The presence of isolated ewe associations within the study areas increases the probability of inbreeding. However, this may be compensated for by the complex and widespread movement of rams during the breeding season. Each ewe association was serviced by rams representing at least two different groups. Movement data established the following implications for potential reproductive interchange: (1) Plomosa ewes were bred by Plomosa and New Water (non-breeding area) rams, (2) West New Water ewes were bred by Plomosa and Kofa rams, (3) East New Water ewes were bred by New Water and Kofa rams, and (4) West Kofa ewes were bred by Kofa rams. Unverified but probable interchange within the primary study area may take place between West New Water ewes and New Water rams, and East New Water ewes and Plomosa rams.

The desert bighorn herds in the Plomosa-New Water-Kofa Mountain complex are interconnected and should be regarded as a single unit. Management policies and decisions should be directed toward the identification and preservation of the traditional routes of ram movement, an essential factor that contributes to the stability of this widespread desert bighorn population.

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DESERT BIGHORN CHRONIC SINUSITIS IN ARIZONA

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Abstract. Desert Bighorn Chronic Sinusitis (DBCS) is a disease that is prevalent throughout most of the desert bighorn range in Arizona. Based on 69 skull examinations, 45 percent of the ewes and 22 percent of the rams were infected with DBCS. In most cases, the extent of skeletal necrosis was believed to have contributed to the demise of the sheep. Seven percent of the rams harvested during the 1978 hunt had sinusitis. The significance of DBCS in populations of desert bighorn is discussed.

Desert Bighorn Chronic Sinusitis (DBCS) is believed to be a bot-fly (*Estrus ovis*) induced bacterial infection that often leads to a pyogenic osteomyelitis within the frontal and cornual sinuses. Although symptoms of DBCS (osteonecrosis of the skull) were reported during the early 1960's, it was not until 1977-78 that DBCS was described as a disease with the potential of becoming a major mortality factor in the desert bighorn (Bunch et al., 1978a, b and c; Paul and Bunch, 1978). In a captive population of Nelson's bighorn (*Ovis canadensis nelsoni*) maintained at Zion National Park, Springdale, Utah, DBCS resulted, either directly or indirectly, in the death of 45 percent of the sheep that were one year or older. This high incidence, however, was partially attributed to captive conditions where the sheep were confined to an 80 acre enclosure.

Since 1962, sporadic reports have been made on a disease similar to DBCS in the desert bighorn of Arizona (*O. c. mexicana*) (Bunch et al., 1978c). This survey was initiated to determine whether desert bighorn of Arizona are infected with DBCS, and if so, to assess the incidence and geographical distribution of the disease.

Twenty ewe and 49 ram skulls which came from areas that represent nearly the entire range of desert bighorn sheep in Arizona were examined (Figure 1). Forty-five percent of the ewe skulls displayed varying degrees of DBCS and the skeletal anomalies were similar to those observed in the sheep at Zion National Park (Table 1). Twenty-two percent of the ram skulls were suspect for DBCS and, if added to the confirmed number, the frequency of infection would be 30 percent in the rams (Table 1). The total incidence for both ewes and rams is 28 percent, or 34 percent if the four ram skulls suspect for DBCS are included. These statistics, however, are conservative since DBCS is not always detectable upon examining the skull externally. At Zion National Park, only about 50 percent of the sheep with DBCS evidenced skeletal lesions of the skull.

Necrosis of the skulls included spongy, porous bone, as well as extensive osteolysis of the frontal bone, horn core, and horn sheath. The necrosis in ewe skulls covered a wider area of the skull, but without the large lesions or cavities as observed in rams skulls.

During the 1978 Arizona desert bighorn hunt, 2 of 27 rams, or 7 percent, were confirmed as having DBCS (see Figure 1, area 2 and 4). Additional rams, however, may have had sinusitis since a water-like exudate was observed draining from the cornual sinuses of several sheep as the horn plate was removed from the skull for mounting purposes.

Desert Bighorn Chronic Sinusitis is capable of inducing mortality within young as well as older sheep. The youngest animal whose death (abscessation of the brain) was attributed to DBCS was a 4 year old ram. Most of the sheep with DBCS, however, were 6-8 years of age at time of death. Recently, a ram approximately 13 years of age was captured near Quartzsite, Arizona, with symptoms of DBCS. The ram had a horn broken off approximately 4 inches above the base and the head region smelled putrid. The ram died during treatment and post-mortem examination revealed the presence of DBCS in both horn cores.

The impact of DBCS on populations of desert bighorn can be measured to some degree from skull examinations, particularly where the extent of skeletal damage can be related to causes leading to the demise of the sheep. Skull examinations, however, cannot provide a clinical picture from time of initial infection to death. Daily behavioral observations are usually impossible to obtain unless diseased animals are maintained under captive conditions.

Prior investigations on the sheep at Zion National Park have provided some insights which may parallel the effects of DBCS in a free living population of wild sheep. These include: (1) Gross emaciation of body during severe, chronic infections; (2) Sheep with advanced DBCS will often segregate away from other sheep; (3) Lactating ewes may be incapable of raising their lambs; (4) Blindness often accompanies DBCS; and (5) Brain abscesses may occur without general emaciation of body.

Desert Bighorn Chronic Sinusitis is an additive mortality factor in populations of desert bighorn. Ewes that die between 6-8 years, particularly at the rate observed from the skull examinations in this study, would greatly reduce the production rate of the population. Reduced productivity could eventually lead to general population declines and in some cases, extirpation.



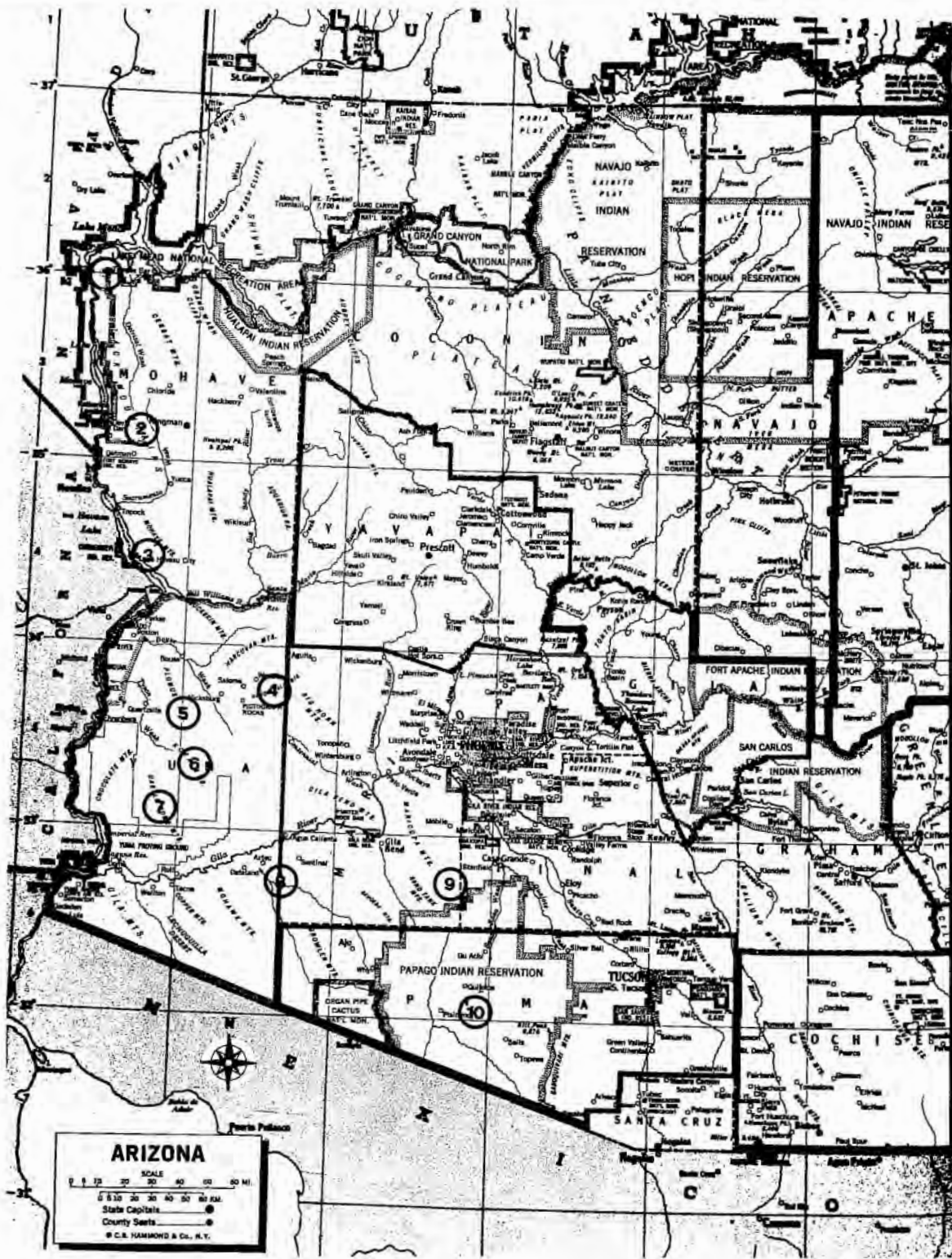


Figure 1. Distribution map identifying areas where desert bighorn skulls (*Ovis canadensis mexicana*) were confirmed as having Desert Bighorn Chronic Sinusitis (DBCS).

Table 1. Incidence of osteonecrosis in desert bighorn skulls (*Ovis canadensis mexicana*) collected in Arizona.

Sinusitis				
No. of Skulls	Sex	Location	+	-
Date of Collection				
1	Ewe	Lake Mead'	+	1974
1	Ram	Lake Mead'	+	Unknown
1	Ewe	Lake Havasu City'	+	1974
1	Ram	Agua Dulce Mt.		
2	Ram	New Water Mt. ^a	+	- 1976
1	Ram	Trigo Mt.		-
1	Ewe	North Plomosa Mt.		-
2	Ewe	Kofa Mt. ^a		-(2)
9	Ram	Kofa Mt. ^a	+(3)	-(5)a 1956,'68,'78
1	Ram	Yuma County	+	Unknown
5	Ram	Castle Dome Mt. ⁷	+(1)	-(4)b 1977
1	Ewe	Aguila Mt. ^a	+	Unknown
1	Ram	Aguila Mt. ^a		-
1	Ram	Crater Mt.		
1	Ram	Tinajas Altas Mt.		
1	Ram	Santa Catalina Mt.		
1	Ram	Cabeza Prieta Mt.		-
1	Ewe	Table Top Mt?	+	1965
2	Ram	South Mt. ¹⁰	+	- Unknown
1	Ram	Unknown		
2	Ewe	Ragged Top Mt.		-(2)
1	Ewe	Bill Williams River. Planet Ranch		
1	Ram	Heart Tank. Sierra Pinta Mt.		
10	Ewe	Unknown	+(5)	-(5) Unknown
20	Ram	Unknown	+(3)	-(17)c Unknown

aTwo skulls suspect for sinusitis with horn sheaths unattachable.
bOne skull suspect for sinusitis with broken right horn.
cOne skull suspect for sinusitis with broken left horn.
to ¹⁰ See figure 1 for geographical location.

There still exist many unknowns about DBCS. For example, we still do not know how long the disease persists, and whether it is always terminal. We do not have any information on the susceptibility of lambs. We have not definitively established the domestic sheep bot fly as the principle agent involved in DBCS. Consequently, we have only partially unraveled the biology of a disease that poses a serious threat to the continued survival of our desert bighorn.

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SKELETAL LESIONS ASSOCIATED WITH DESERT BIGHORN CHRONIC SINUSITIS

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Abstract. Skeletal lesions associated with desert bighorn chronic sinusitis are discussed. Pictorial illustrations provide a broad spectrum of bone anomalies that can be used to identify skulls affected by this disease.

Desert bighorn chronic sinusitis (DBCS) usually is associated with a pyogenic osteomyelitis that causes extensive destruction within the frontal and cornual sinuses. It is hypothesized that the infection is initiated primarily from bacterial invasion associated with necrotic bot fly larvae that die following entrapment within the trabeculae of the frontal and cornual sinuses; however, mechanical damage of the horn, as well as hemolytic agents, may be contributive. Desert bighorn sinusitis generally appears to be terminal. Infected bighorn can be successfully treated only under rare conditions and with difficulty.

Factors favoring the occurrence of DBCS are believed to include: the configuration of the sinuses in desert bighorn (The cornual sinus has hundreds of cavities and chambers.) (Figure 1), the incidence and frequency of infestation with bot fly larvae (*Estrus ovis*) (Figure 2), and the abnormal migration of the larvae into the cornual sinuses.

The incidence of DBCS may vary from 0 to more than 45 percent in different desert bighorn populations. The incidence of DBCS in the transplanted population at Zion National Park, Springdale, Utah, slightly exceeds 45 percent (as of February 1978). Native desert bighorn populations in southeastern Utah also are infected with DBCS; this condition was identified in 2 of 10 skulls examined from San Juan County. A ewe captured during a recent translocation by the Utah Division of Wildlife Resources had an advanced form of DBCS. She had a ruptured eye and a large lesion draining the frontal bone. Only 1 of 42 skulls examined from New Mexico had evidence of DBCS; however, some of the skulls could not be adequately evaluated because the horn sheaths were glued to the horn cores. In Arizona, the disease appears to be extensive, affecting nearly all populations of desert bighorn surveyed. Forty-five and 22 percent, respectively, of the 20 ewe and 49 ram skulls examined from Arizona had been infected with DBCS. Also, two of the 27 rams harvested during the 1978 Arizona desert bighorn hunt were infected. DBCS was described in Nevada desert bighorn as early as 1965; however, no recent surveys have been conducted on the incidence of the disease in that state. Recent reports indicate that some southern California populations of desert bighorn also are infected with DBCS. In infected populations, the incidence of DBCS in ewes is believed to be equivalent to or to exceed the occurrence in rams.

Skeletal lesions associated with DBCS are extremely variable. The **foci** of Infection usually **is** in the cornual sinus area. Here, the supuration may be creamy to granular in texture, with a layer of connective tissue of varying thicknesses **encap-**sulating the abscess (Figure 3). The accumulation of **large** amounts of infective agents tends to disperse them into the **various** **sinal** cavities, and **this** often results in fistulas **being** formed in the horn core, sheath and frontal bone (Figure 4). These fistulas oftentimes have a **ourulent** drainage, with an **oil-like** or even a **mucoid** to slimy exudate oozing **out onto** the external **surfaces** (Figure 5). Fistulas in the horn complex often **drain** exteriorly from the horn core and then along the inner Surface of the horn sheath, causing a **chaffing-away** or blistering of the sheath (Figure 6). The **blistering** and chaffing eventually may penetrate the horn sheath and produce an exteriorly draining fistula (Figure 7). These necrotic areas become structurally weakened and the breaking away of the horn may result (Figure 8). A DBCS Infection commonly induces growth of the sheath into the horn core (Figure 9), eventually dissecting the body of the core. **Necrosis** of the osseous **and** **sort** tissue at the **terminal** portion of the horn then results (Figure 10), and this **portion** of the horn readily breaks away (Figure 11) or simply drops off (Figure 12). The **osseous** **composition** of the trabeculae of the **remainina** **portion** of the horn may proliferate, with the tissue **becoming** **grossly** thickened (Figure 13). The proliferation of the osseous matrix of the horn **core** also has been observed in intact horns that have fistulas through the exterior wall of the horn core and sheath (Figure 14). Abscesses resulting from a DBCS infection may cause the associated region of the horn core and sheath to expand, resulting in **differences** in the circumference and length of an animal's two horns. The bone that lies adjacent to the **suppuration** may become **lytic**, instead of **proliferative**, as well as extremely porous (Figure 15). Continued osteolysis causes extensive destruction of the cornual and frontal sinuses, and **sometimes** of the orbital bones. The proliferative tissues may be indicative of a lower level, more chronic form of the disease. In contrast, **osteolysis**, with its massive bone **destruction**, may be a **symptom** of a more severe and more **pyrogenic** DBCS infection.

The larger osseous lesions of the frontal bone often are **associated** with **regenerative** new bone, which forms irregular, flat **and/or** spiked osteophytes (Figure 16). In rams, the entire trabeculation of the horn core is often destroyed, producing a **large** channel from the base to the tip of the horn core (Figure 17). The extensive channelization may be attributable to the **rupturing** of abscesses **during** head clashes with other rams or to the rapid **spreading** of the disease. Occasionally, channels are observed in the cornual sinus of infected ewes (Figure 18).

When an abscess overlays the brain case, the disease penetrates the brain encasement, resulting in abscessation of the brain, a subsequent lack of motor coordination, and eventually death. **Sheep** having abscessation of the brain usually show signs of thinning of the brain case (cranium), **fistulization** of the brain case, **and/or** the formation of osseous tubercles within the brain **case** (Figures 19 and 20). An abscess in the basal **region** of the brain case often **will** result in fistulas of the frontal bone that are anterior or posterior to the brain itself (Figures 21 and 22).

The **suppuration** often penetrates the orbit, resulting in abscessation of the eyeball and eventual blindness (Figures 23 and 24). Emaciation is **predictably** associated with eye **in-**fections. Sheep having advanced forms of DBCS have been observed to lose up to nearly half their body weight prior to

death. The suppuration also may be observed along the infraorbital foramen, and secondary infections resulting from drainages may **infect** the tooth arcade.

Thanks **is** given to Paul Webb, Big Game Supervisor, Arizona Game and Fish Department, Walter Snyder, Big Game Supervisor, New Mexico Game and Fish Department, Larry Wilson (Supervisor, Southeastern Region) and Jim Bates (Big Game Biologist, Southeastern Region), Utah Division of Wildlife Resources. Robert C. Heyder, Superintendent, Zion National Park, **Springdale**, Utah, E. Linwood Smith, Ecological Consultant, **Tucson**, Arizona, James H. Witham, Biologist, desert bighorn studies, Quartzsite, Arizona, and others who **assisted** in providing skeletal materials upon which this study was based.

Research was supported by The International Sheep and Goat Institute, Utah State University, **Logan**, and the Foundation for North American Wild Sheep.

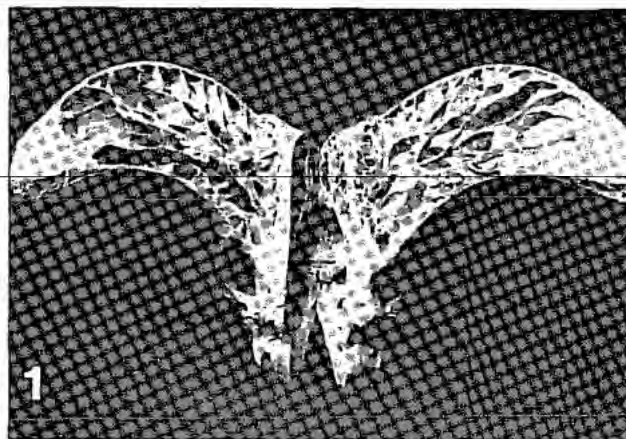


Figure 1 The cornual (**horn** core) and frontal **sinuses** are continuous, with a complex **architecture** consisting of hundreds of interconnecting chambers of **varying** sizes.



Figure 2 Third **instar** bot fly **larvae** (*Estrus ovis*) are 24.30 mm in length. Arrows point to fragments of larvae. The oral hooks are well developed, strongly recurved, and internally **con-**nected to the cephalopharyngeal skeleton. The ventral surface bears 11 rows of **spines**. The posterior spiracles are **con-**spicuous, black, and nearly contiguous, enclosing the **spiracular** button. Mature larvae are **normal** **yellowish-white** prior to emerging from their host.

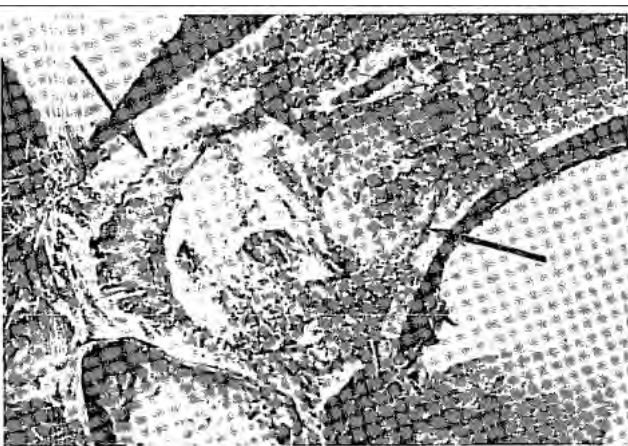


Figure 3. Foci of infection often occur within the lower portion of the horn core. The supuration may have a creamy to granular inner core encapsulated by a gelatinous matrix (arrow). Sometimes, however, an oil-like mucoid or even slimy exudate may result (see Figure 24).

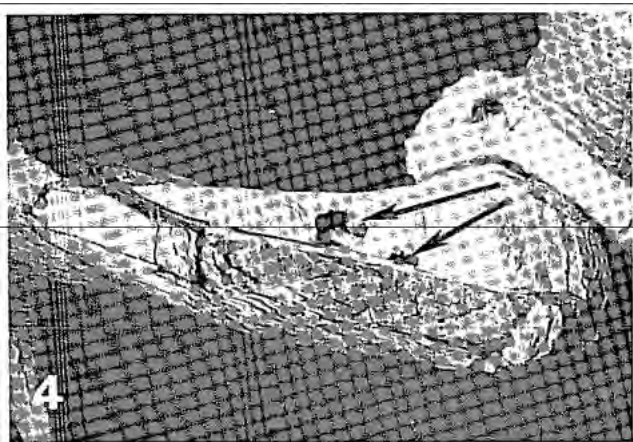


Figure 4. Fistulas (arrows) often penetrate to the exterior and drain centers of infection.



Figure 5. A purulent exudate drained from the fistula (arrow) in the frontal bone of this sheep.

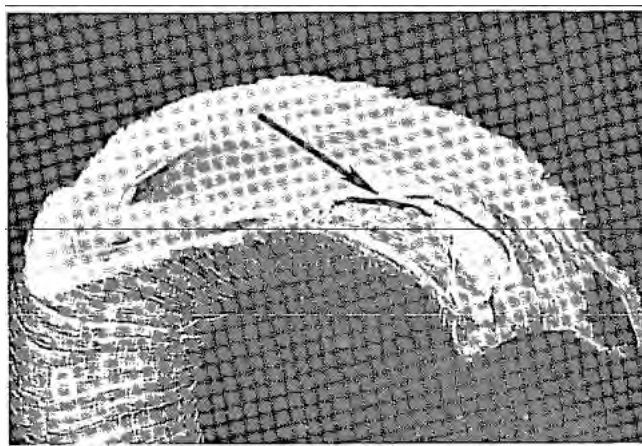


Figure 6. Horn core fistulas often drain between the inner surface of the horn core and sheath, causing a blistering effect on the inner surface of the horn sheath.

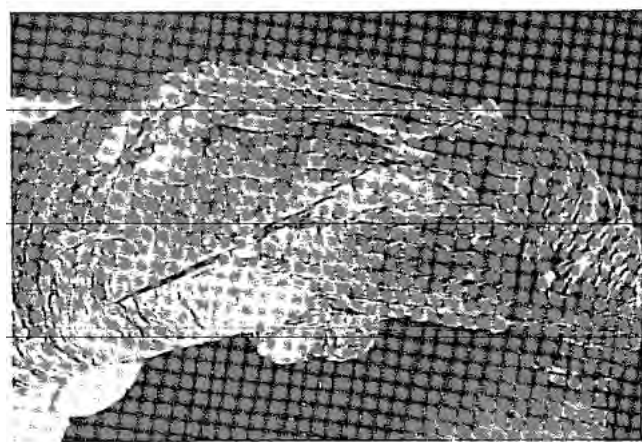


Figure 7. This case illustrates that the blistering of the inner surface of the horn sheath eventually may erode through the sheath and result in external blistering and chaffing away of the sheath. Fistulas in the sheath often occur in areas where the purulent exudate is unable to drain along the sheath's inner surface to its base.

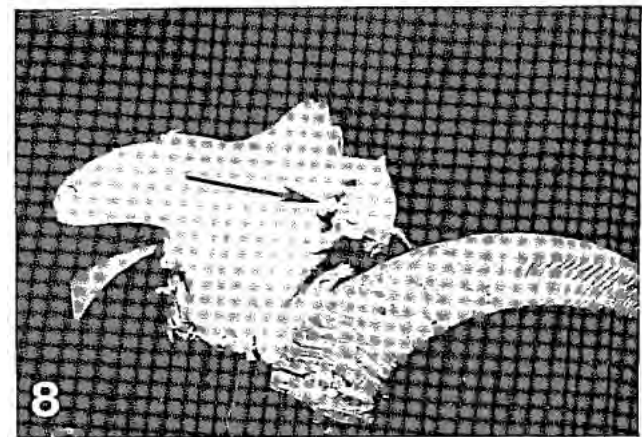


Figure 8. Necrosis of the horn core (arrow) may result in the breaking away of the sheath.

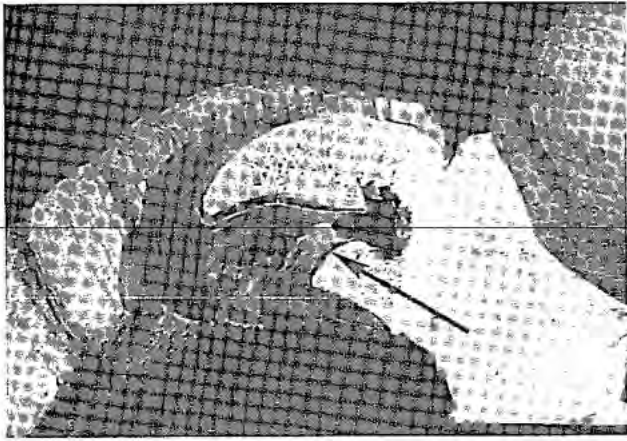


Figure 9. Desert bighorn chronic sinusitis often stimulates an inward growth of the sheath (arrow), leading to the dissection of the horn core.

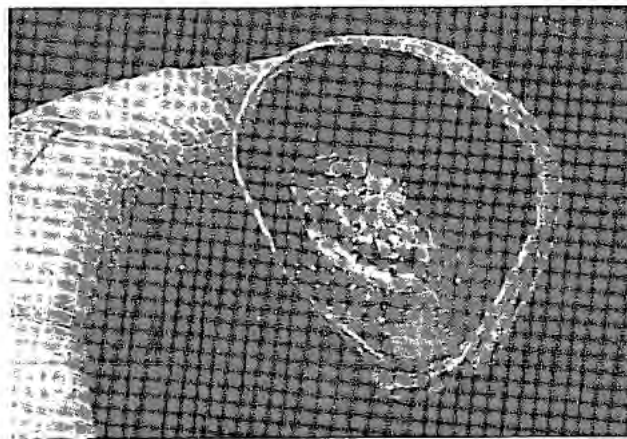


Figure 10. This sheath has completely dissected the horn core, resulting in necrosis and osteolysis at the terminal region of the core (see Figure 22).

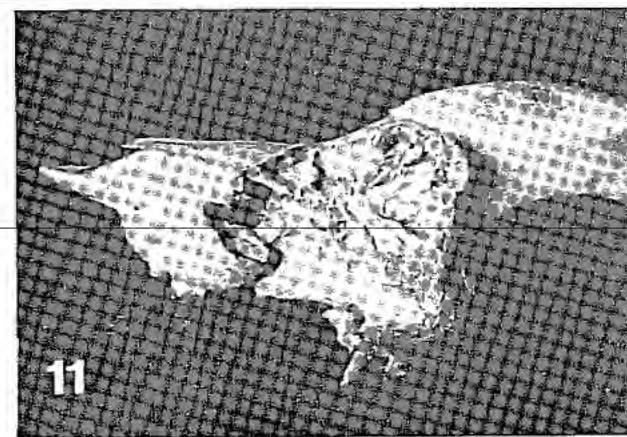


Figure 11. Desert bighorn chronic sinusitis characteristically weakens the bony matrix structure of the frontal and cornual sinuses. Head clashes then can produce massive fractures.

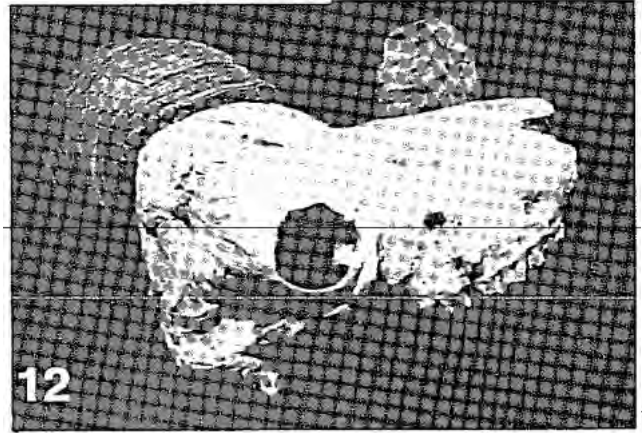


Figure 12. Sluffing out of the sheath and horn core often follows extensive osteonecrosis at the horn base.

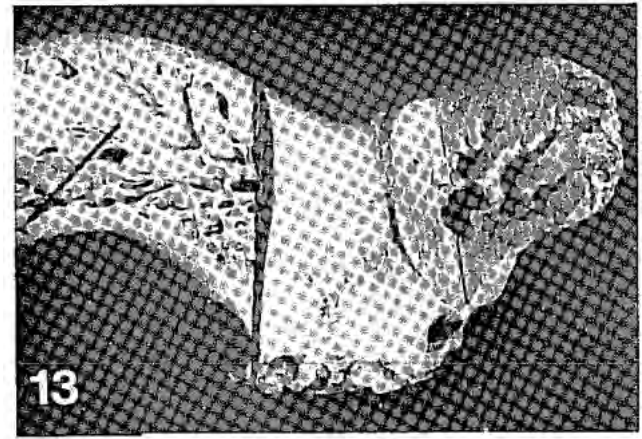


Figure 13. The bony matrix (trabeculae) adjacent to an area of suppuration may become proliferative, causing a thickening of the trabeculae (right horn). This left horn core has a fistula on the lower, terminal end (arrow).

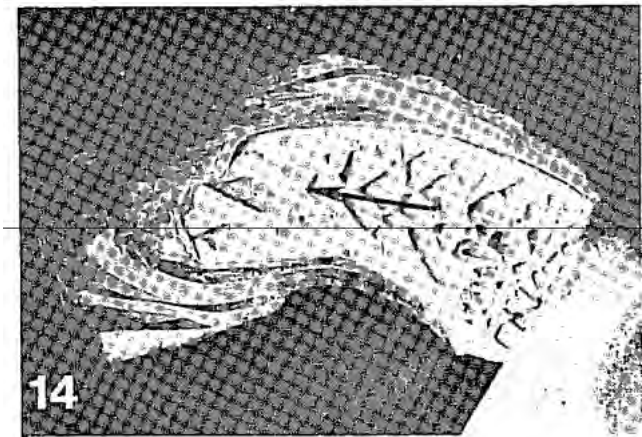


Figure 14. The osseous matrix of the trabeculae often proliferates (arrow) in regions where fistulas are draining from the horn core. The upper surface at the bend of this horn has chafed away extensively.

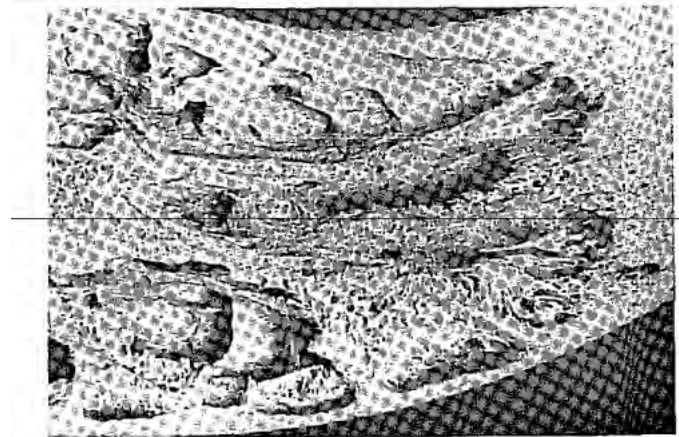


Figure 15. Osteolysis of the horn core matrix resulted in this extensive paresty. Further necrosis could cause complete channelization of the inner structure (see Figure 17).

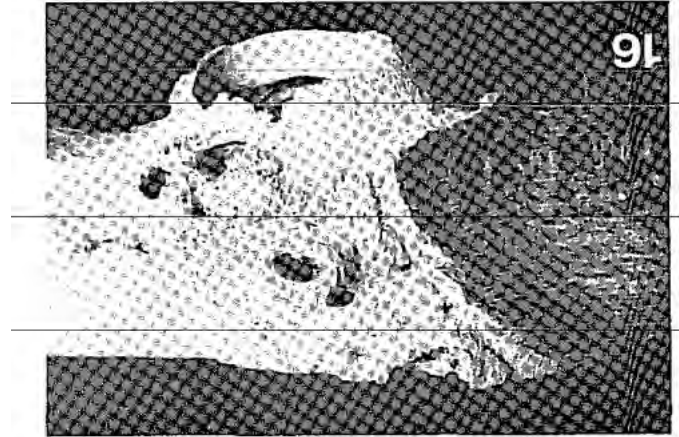


Figure 16. Regenerative bone in the form of irregular, flat and/or spiked osteophytes is often associated with fistulas of the frontal bone.



Figure 17. This extensive channelization of the inner matrix of the horn core was caused by drainage of the purulent exudate between the sheath and horn core. Arrows indicate additional sites of external eroding of the horn core.

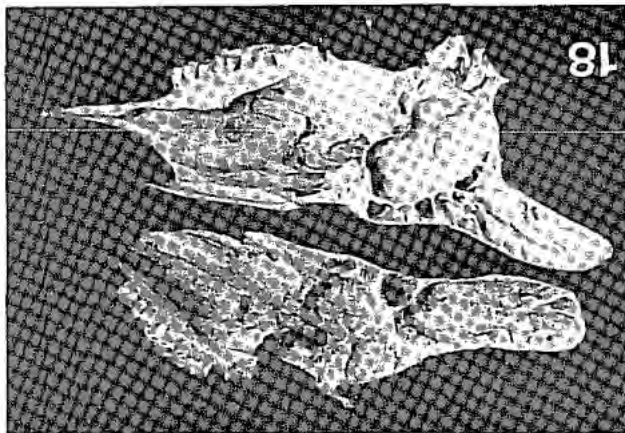


Figure 18. The upper skull illustrates osteolysis of the trabeculae within the horn core of a ewe. The lower skull represents a normal matrix within a cornal sinus.

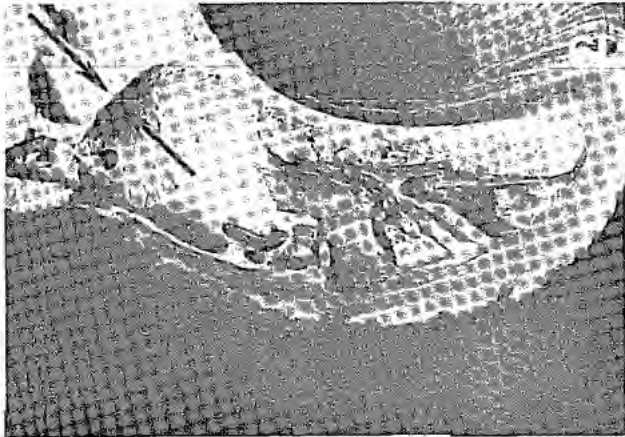


Figure 19. Supuration adjacent to the brain case has caused this thinning of the bone overlaying the brain (arrows). Note the extensive chamber at the base of the horn core, complete destruction of trabeculae and abnormal inward growth of the horn sheath.



Figure 20. A thinning of the dorsal bone of the brain case in this skull resulted in a fistula (arrow) leading to the brain. Death probably was caused by abscessation of the cerebral hemispheres.

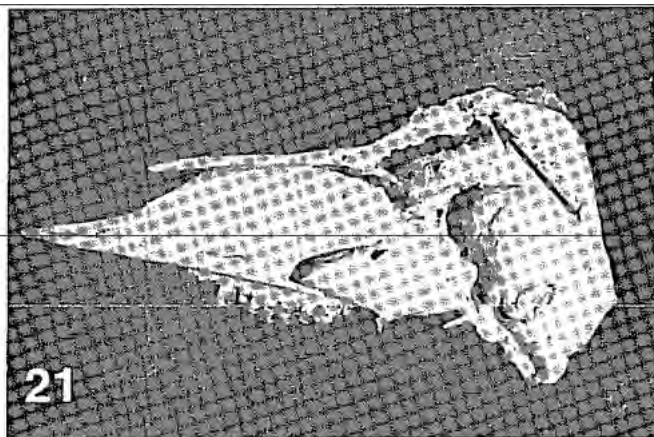


Figure 21. This sheep had a fistula in the frontal bone (arrow) and massive destruction of the bony matrix within the frontal sinus.

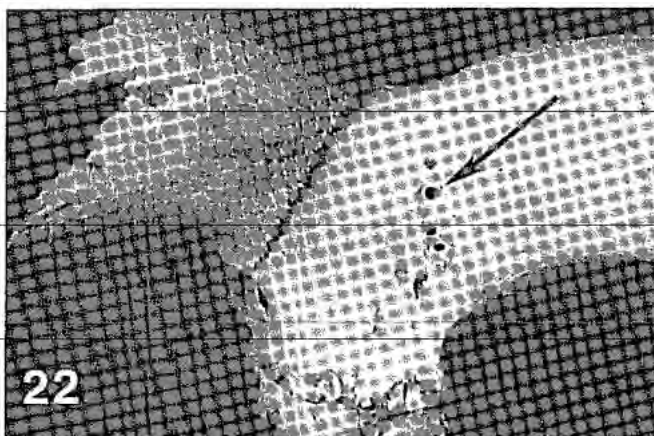


Figure 22. Six fistulas (4 large and 2 small) are evident at the back of this skull. The left horn core has been completely dissected by inward protrusion of the horn sheath (see Figure 10).

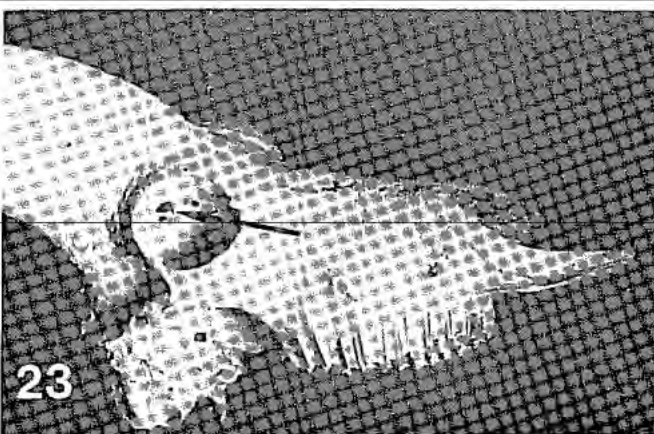


Figure 23. A fistula extended into the orbit of this sheep.

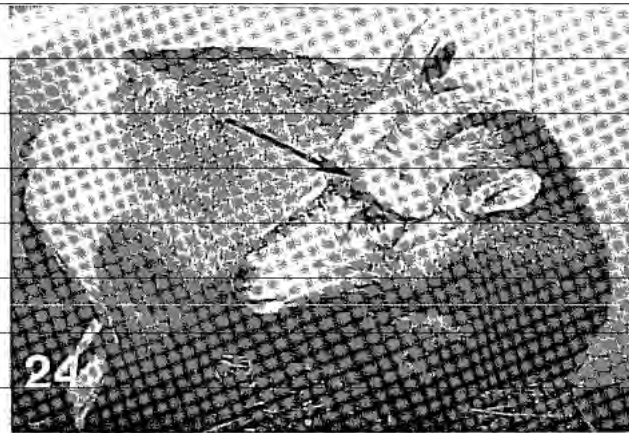


Figure 24. The left eyeball of this ewe is enucleated from supperation that entered the orbit through a fistula (see Figure 23). Above the eye is a large bulbous chamber (arrow) filled with a liquified substance. The purulent exudate is draining exteriorly along the nasal bone.



SUMMER ACTIVITY RHYTHMS OF PENINSULAR BIGHORN SHEEP IN ANZA— BORREGO DESERT STATE PARK, SAN DIEGO COUNTY, CALIFORNIA

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Abstract: Peninsular bighorn sheep (*Ovis canadensis cremnobates* Elliot) were observed in the In-Ko-Pah and Jacumba Mountains of the Anza-Borrego Desert State Park, San Diego County, California, between 14 September 1974, and 11 September 1976. From an analysis of over 2100 h of observations, it is concluded that waterholes are focal points both for maintenance activities (moving, feeding, drinking, standing, and lying) and for interactions, especially during the summer months. Management recommendations to promote the sheep's undisturbed use of waterhole areas during the critical summer months are made, based upon this conclusion.

INTRODUCTION

The need for protection and management of bighorn sheep, *Ovis canadensis*, has become increasingly evident since the turn of the century. One race, the Audubon's or badlands bighorn (*O. c. auduboni*), has been extinct for 63 years. Entire populations of other races have been destroyed or virtually decimated by human encroachment, hunting, diseases, parasitic infections, and other factors (Buechner 1960). The same trend of decrease in number has occurred in the population of peninsular bighorn sheep (*O. c. cremnobates* Elliot) that occurs in the Anza-Borrego Desert State Park, San Diego County, California and was the subject of the present study. Recent status reports (Jorgensen and Turner 1972, 1973, 1974; Russi 1976a; Turner and Jorgensen 1975; unpub. data, Anza-Borrego Desert State Park files 1977, 1978) have indicated a decrease both in population size (number of sheep observed during summer counts) and in the lamb: ewe ratio within the observed bands. Despite this decrease, the Anza-Borrego population of peninsular bighorn remains one of the largest existing groups of this race, numbering approximately 375-400 animals (Russi, per. comm.).

Welch (1969) indicated that effective management of bighorn sheep has often been severely limited by a lack of knowledge about their behavior. This is especially true for races such as the peninsular bighorn, for which little behavioral data are available (see Jorgensen 1974; Merritt 1974). It is therefore the purpose of the present and previous studies (Olech 1978) to (1)

assess the importance of waterholes to peninsular bighorn sheep during the summer months; (2) investigate the types of activities and resource utilization occurring around waterholes, concentrating on such factors as interacting, moving, feeding, drinking, standing, and lying; and (3) provide recommendations concerning management of the waterhole areas in the Park.

ACKNOWLEDGEMENTS

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MATERIALS AND METHODS

The population of peninsular bighorn sheep found in the Anza-Borrego Desert State Park is concentrated into two distinct groups. The southern group, numbering approximately 100 animals (Russi, pers. comm.), is restricted to the In-Ko-Pah and Jacumba Mountains near the Mexican-American border. This group was studied between 14 September 1974, and 11 September 1976. The northern group, which is concentrated in the Pinyon Ridge and San Ysidro and Santa Rosa Mountains, was not observed due to a legal closure of much of the area in which they occur during the summer.

Vegetation type and density appear to influence the distribution of sheep at elevations of 2480 m or more, while availability of water affects distribution at lower elevations (Russi 1976b). During the warm, arid period from May through September, sheep collect within 0.6 to 1.2 km of the few persistent waterholes. From October through April the animals are widely scattered (Russi 1976b). Thus, success in locating sheep was greatest during the summer months. Summer observations are especially important for desert races as those months (after the lambing season and during the period when water is in especially short supply) are critical to desert bighorn survival.

During most of the year, mature rams form groups only with other rams. Adult ewes, lambs, and immature sheep of both sexes also form social groups. During the rut, groups composed of mature rams and ewes occur (Geist 1971). Because the bighorn observed in the present study did not remain in one restricted area for any length of time, several observation sites were necessary to obtain data that included all possible combinations of sex and age classes. Three primary sites near heavily utilized water sources were selected for intensive study. Four secondary areas also were used for observation. Study sites included the area within a 0.3 km radius of each waterhole observed. Data collection was restricted to daylight hours (dawn to dark).

Upon making contact with a band of sheep, the location and general activities of the sheep members, along with any identifying information (scars, horn chips, pelage color, etc.) for each individual, were recorded using a tape recorder. Location and activity information were recorded continuously throughout an observation period using a verbal shorthand based on Geist (1971). Recorded observations were transcribed later.

Data were reduced separately for ram, mixed, and maternal bands in order to assess possible differences in activity rhythms and resource usage. For the purpose of the present

report, activities were divided into one of six classifications: interacting (the type of interaction-agonistic, courtship, etc. was also noted), moving, feeding, drinking, standing, and lying. The type of activity performed at 15 min. intervals by each observed animal was noted. The percent frequency of each activity shown in Figures 1, 2, and 3 was calculated by dividing the total number of observations of sheep performing each of the six classes of behaviors at a given time by the total number of observations at that same time.

RESULTS

Peninsular bighorn sheep exhibit a polyphasic activity rhythm which differs for each type of band observed.

Ram Bands: Figure 1 indicated summer activity patterns for peninsular bighorn ram bands near waterholes. The average number of observations represented by each data bar is 66 ($R = 14-136$). Members of ram bands became active around 0600 h, and this period of activity continued until 0845 h. Most interactions, which were primarily agonistic encounters, occurred during this period. There was also a general movement towards water during this time period, in which the animals browsed or appeared to scan the surrounding ridges en route. The second and highest activity period occurred between 0900 and 1130 h, during which rams approached water directly, drank, and moved away from water. Low levels of interaction and feeding also occurred during this period. A minor activity period between 1200 and 1400 h included maintenance activities but very few interactions. A minor period of interaction occurred between 1530 and 1615 h, after which the rams moved out of the study area. A minor feeding period occurred later in the day, from 1945 to 2000 h. A maximum of 23% of the individuals observed at a given time were active in ram bands.

Mixed Bands: The summer activity rhythms of mixed bands of peninsular bighorn sheep are illustrated in Figure 2. Data bars represent an average of 46 observations ($R = 12-133$) for each 15 min interval. Mixed bands became active in the study area at 0915 h. This activity period lasted until 1330 h and included high level of interacting (i.e., courtship) as well as maintenance activities (moving, drinking, and standing). This period of high activity reached a peak of 80% activity at 1145 h. A peak of drinking, during which animals also moved into and out of water, occurred between 1430 and 1445 h. A third activity peak, which involved courtship and mating interactions, occurred around 1945 h.

Maternal Bands: Figure 3 shows the summer activity rhythms for peninsular bighorn sheep maternal bands near waterholes. The average number of observations represented by each data bar is 38 ($R = 4-73$). Maternal band members became active in the study area around 0915 h. Activity continued until 1545 h. The primary behaviors which occurred were moving to and from water, during which animals browsed en route, and drinking. Interactions were relatively rare, and are detailed below. A maximum of 48% activity was reached at 1400 h.

The different drinking periods (from 1045-1100 h, 1115-1130 h, 1200-1215 h, 1345-1400 h, and 1500-1515 h) in Figure 3 were actually made up of several groups which alternated in their use of water. Different maternal bands constantly approached or left water, but no two groups used the waterhole simultaneously. The approach to water appeared to be controlled by each band's lead ewe; the lead ewe prevented other band members from approaching or watering by threatening with Low Stretch or by a Rush Charge (for a description of these behaviors, see Geist 1971; Olech 1978). When being prevented from approaching water, other band members browsed, bedded down, or paced back and forth. Lambs

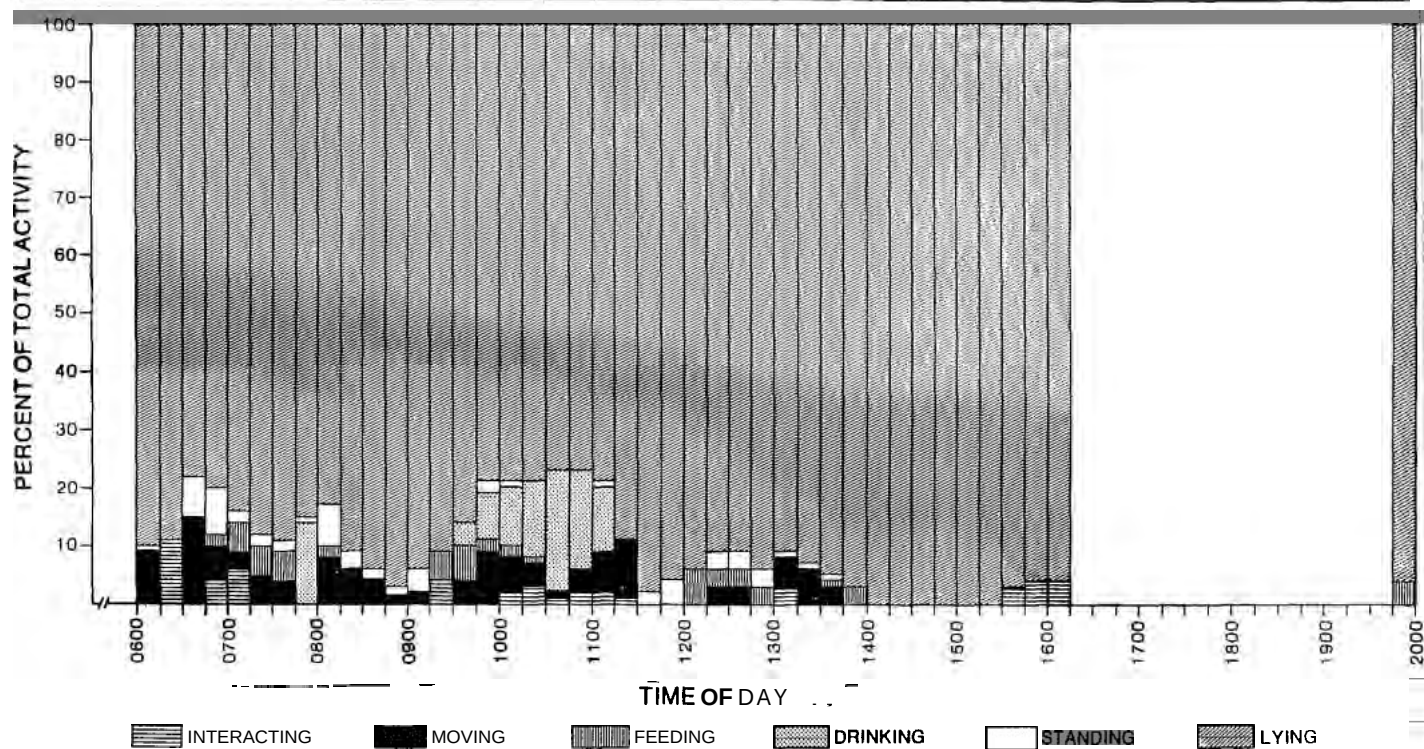


Figure 1. Summer activity patterns for peninsular bighorn sheep ram bands near waterholes.

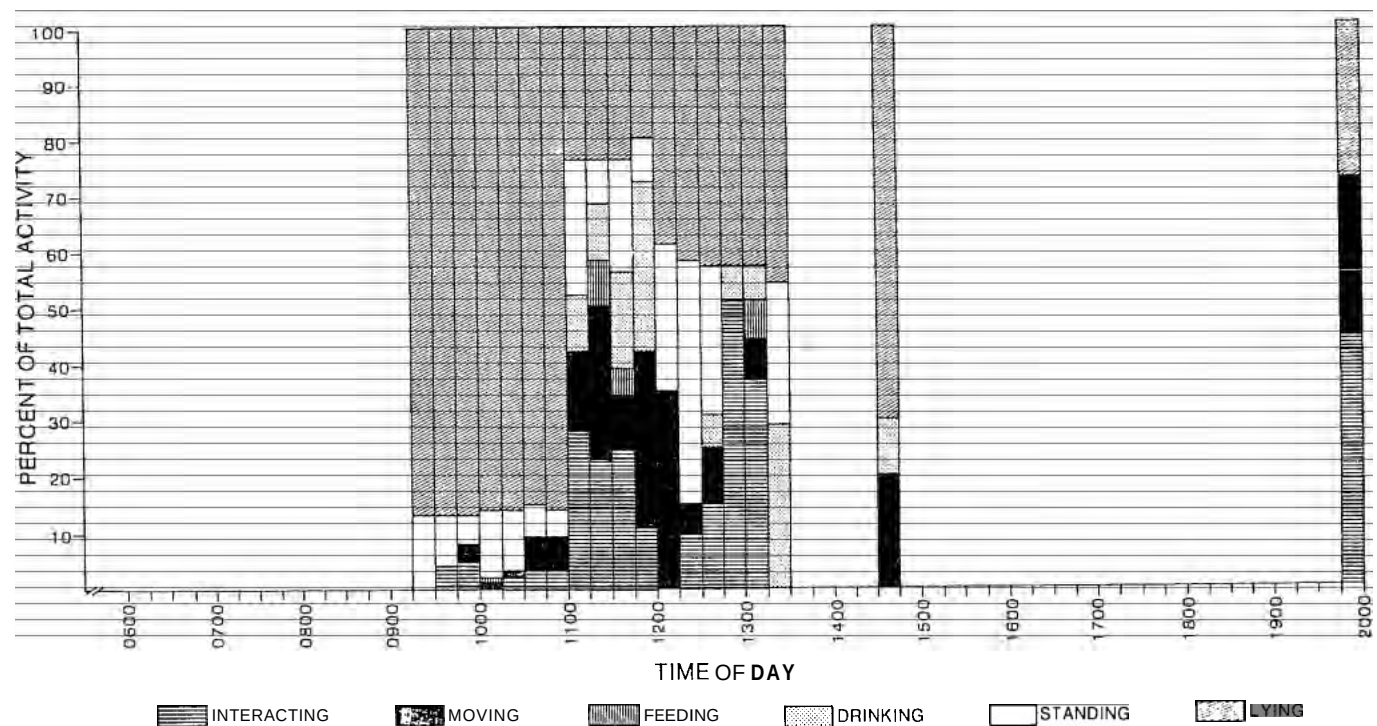


Figure 2. Summer activity patterns for peninsular bighorn sheep mixed bands near waterholes.

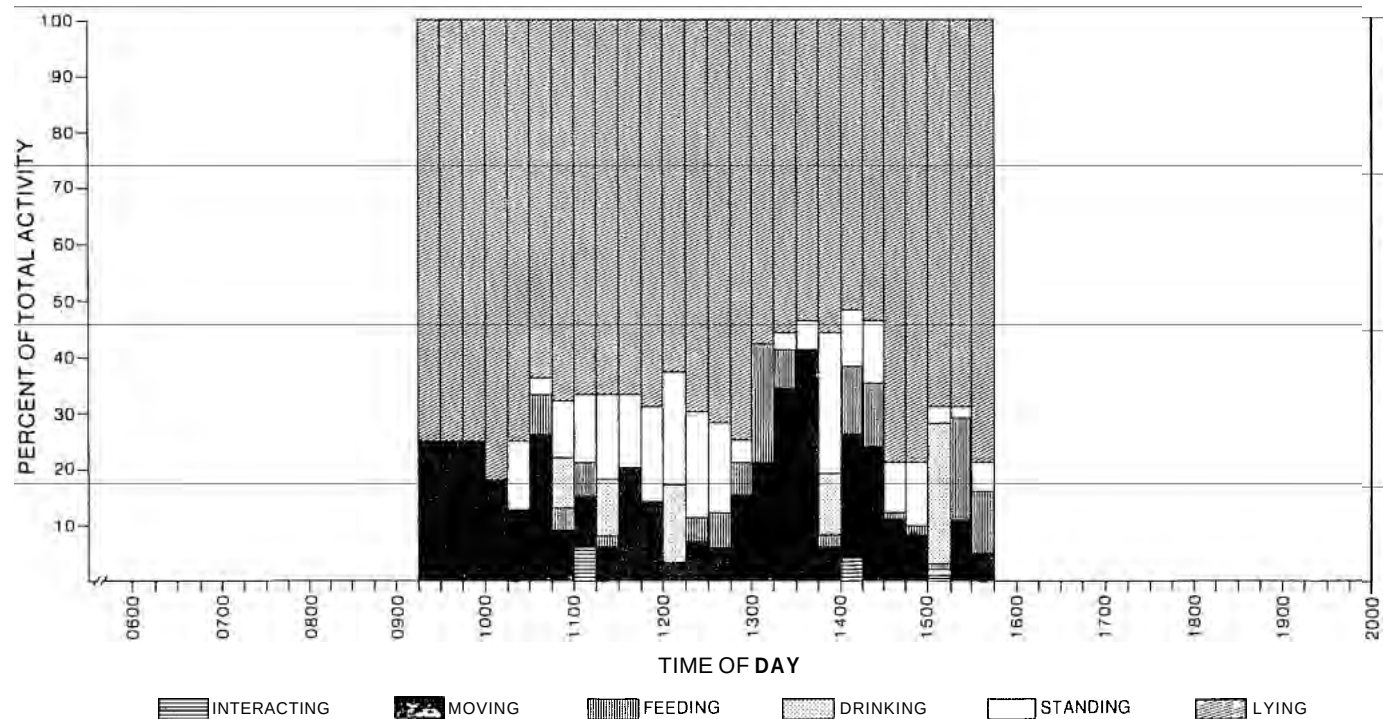


Figure 3. Summer activity patterns for peninsular bighorn sheep maternal bands near waterholes.

generally broke away from the group and ran toward the waterhole. When this occurred, other band members also moved quickly toward water, but waited when they were blocked by the lead ewe. Thus, the lead ewe appeared to control her band's entry to water. This was the primary type of interactions between members of maternal bands. (This type of alternate water usage by different bands and leadership by one band member was not observed in either ram or mixed bands, and is discussed in more detail in Olech 1978).

DISCUSSION

The results of the present study establish the importance of waterholes to peninsular bighorn sheep during the summer months. The few waterholes which persist throughout the summer are not only focal points for drinking; they are also a primary site for social interactions and maintenance activities (moving, feeding, drinking, standing, and lying).

Members of ram bands utilize waterholes and adjacent areas throughout the day. Dominance interactions, which occur in the pre-rut period, take place in areas immediately adjacent to waterholes. These interactions are important in determining which rams will mate (Geist 1971). Rams also utilize these areas for feeding and resting throughout the day.

Waterhole areas also were observed to be primary sites for courtship and mating in mixed bands, as well as providing resting areas.

Maternal bands utilized watering areas chiefly for drinking. Dominance-asserting interactions also occurred in these locations. These contribute to group cohesion (i.e., to all animal's ranking in a band being defined) and ultimately to a predictable social environment, which is the purpose of social adaptations in bighorn sheep (Geist 1971).

In light of the observation made during the present study that waterholes provide a focal point for social interactions and maintenance behaviors during summer months, several recommendations for management of waterhole areas can be made. Their implementation is especially critical because of the ever-decreasing recruitment observed in recent years (Jorgensen and Turner 1972, 1973, 1974; Russi 1976a; Turner and Jorgensen 1975; unpub. data, Anza-Borrego Desert State Park files 1977, 1978).

1. Implement closure of bighorn sheep habitat in the In-Ko-Pah and Jacumba Mountains to pedestrian and vehicular traffic, especially from May through September. It is essential that the dominance-determining and courtship interactions which occur around waterhole areas proceed without interruption if the sheep's population size and structure are to be improved. A few water sources persist throughout the summer in this area. Sheep should be allowed free access and uninterrupted drinking at these water sources, especially during the hottest periods of the year. This is especially true for young lambs and lactating ewes.

2. Major access roads on Bureau of Land Management property above the Carrizo Gorge area should be closed, especially from May through September. Motorcycle activity on B.L.M. land disrupts normal activity patterns of sheep in the Carrizo Gorge area. Although these waterholes were normally centers for social activities, feeding, and resting, sheep never were observed to use waterholes when motorcycles were heard above these water sources, despite the high temperatures. The disruption of social interactions, and the obstruction of normal patterns of feeding and drinking, could lead to a decrease in lamb production and survival.

3. Implement regular maintenance of waterholes in the Carrizo Gorge area by State Park personnel. The soil in this area is

prone to erosion. When sheep slide into waterholes, they knock soil and rocks into the waterholes, which then become mudholes, useless as drinking sources. It is important to maintain these water sources for high summer use. Waterhole maintenance projects should be carried out either before the peak waterhole use period (May through September) or before sheep begin their daily use of the areas for minimizing disturbance to the sheep.

4. Continued research on seasonal home ranges, lambing grounds, range fidelity, and rutting areas and their location should be conducted. In order to increase the effectiveness of management of peninsular bighorn sheep, more specific information is needed in these areas. In addition, there should be continuous monitoring by a State Park employee of the relationship between human encroachment and bighorn sheep use of habitat, so that management decisions can be based on factual evidence.

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A COMPARISON OF THREE BIGHORN AREAS ON THE HUMBOLDT NATIONAL FOREST

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Abstract. This report compares range conditions, productivity and species composition on three bighorn areas of the Humboldt National Forest.

The Humboldt National Forest is located in the north central and northeastern part of Nevada. The forest covers 25 million acres in nine widely scattered parcels.

We are privileged to have three subspecies of bighorn (*Ovis canadensis*) on the forest. They are the Desert Bighorn (*O. c. nelsoni*), found in the Grant Range, the California Bighorn (*O. c. californiana*), found in the Santa Rosa Mountains and Rocky Mountain Bighorn (*O. c. canadensis*), found on Mount Moriah. The desert population is an old established herd that has been here historically. Both the California and Rocky Mountain subspecies are reintroductions into historic ranges.

The vegetative information I will present in this paper has been taken from Humboldt National Forest Range Environment Analysis (REA) surveys. An REA survey for a grazing allotment is accomplished this way. The first step is the preparation or updating of a vegetative type map. Areas are typed into eleven vegetative classifications: grassland, wet meadows, dry meadow, perennial forb, sagebrush, browse-shrub, coniferous timber, heavy timber, barren, pinyon-juniper, and broadleaf trees.

In the second step the suitable and non-suitable grazing areas are mapped. Suitability is determined by many factors including steepness of slope, soil stability, water location, class of livestock, intensity of anticipated grazing, distributional habits of the livestock and other multiple use considerations. Only the suitable range is used in determining livestock numbers.

The third step is the field analysis. Transects are established within each range type. The transects consist of thirty or more circular plots on a line. In uniform vegetation such as bunch grass, fewer plots may be used. The plot size may vary from .06 square feet to 96 square feet depending upon vegetation density and diversity. All vegetation inside the circular plot is identified and the portions of the plant that are available for consumption are clipped and weighed. Animal use is recorded and soil condition and trend is determined.

The combination of range suitability, forage production, range condition and trend, past utilization studies and other variables are then analyzed to determine a tentative carrying capacity for livestock and wildlife. Follow-up trend and actual use studies are then used to adjust the tentative capacity up or down.

I now had the means to find out how much forage was produced. The next step was to determine the daily or annual forage requirement of an adult bighorn. I searched all of my bighorn literature and could not find a single reference to this.

Stomach analysis studies gave the plant composition eaten but not the amount of a bighorn's daily or annual need. Not finding anything in the literature, I established a figure that would be as realistic and credible as I could make it. Using the forage requirements for domestic sheep and goats and for deer, I estimated that a mature bighorn would require about 1,460 pounds of forage per year, or four pounds of forage per day.

The Santa Rosa Mountains are located north of the town of Winnemucca, near the Oregon-Nevada state line. As reported to you last year in Kingman, the Nevada Fish and Game Department released twelve California Bighorn into Eightmile Canyon on March 23, 1978. Two mortalities have occurred, five lambs were born and the latest estimate is that fifteen bighorns have come through the winter in good condition.

The Santa Rosa Mountains are historic range for bighorn. The last recorded sighting was made in the 1930's. The best estimate we can make is that the bighorn disappeared because of a combination of factors including poaching, disease and competition for food, water and space with domestic livestock, particularly domestic sheep. During the last decades of the nineteenth century, and until about 1910, large bands of nomadic sheep and cattle grazed this area. After the National Forest was established, livestock numbers were reduced and eventually domestic sheep were removed from the range. The length of the grazing seasons were also reduced.

Forest Service records show that from 1964 to 1973, one hundred twenty-five cows used the range each year. The grazing season extended from May 21 to August 20, with 375 animal units per month (AUM's) of use. A season long grazing system was in effect. The area has been in non-use from 1974 to the present.

Depending on elevations, the annual precipitation varies from 8 to 24 inches, falling mainly as snow. However, severe thunder storms do occur during summer. Growing seasons generally are short and below freezing temperatures may occur every month of the year. The soil - landscape relationship of the Eightmile Canyon, consists of extensive volcanic horizontal flow rock exposures or steep rocky cliffs and crags. Approximately 60% of the area has a soil cover that is the result of somewhat mature or old developed residual surfaces. Soils have a gravel clay loam surface to clay subsoil and a very gravelly clay loam sub-stratum. The soils have moderate to slow permeability, but have a fair moisture holding capacity to even out the plant - moisture relationship during the hot arid summer.

The Eightmile Canyon cattle and horse allotment covered a land area of more than 15,000 acres. About 40% of the area was classed as unsuitable. The suitable range produced sufficient forage for 125 cows for a three month season. However, livestock distribution was difficult to maintain and this resulted in an over-used condition in the riparian areas.

This range is typically a sagebrush-grass vegetative type. REA data for this area were gathered in 1966. Studies showed that forage production varied from a low of 385 pounds per acre to a high of over 1500 pounds per acre. Plant composition averaged 35.5 percent grasses, 12.5 percent forbs and 50 percent shrubs. The most common grasses were *Poa secunda*, *Sitanion hystrix*, *Bromus mollis*, *Bromus tectorum* and *Festuca idahoensis*. The most common forbs were *Lupinus* sp., *Senecio integerrimus*, *Astragalus* sp., *Senecio serra* and *Agastache urticifolia*. Most common shrubs were *Artemisia tridentata*, *Chrysothamnus viscidiflorus*, *Chrysothamnus*

nauseosus, and *Symphoricarpos* sp. *Poa secunda*, *Lupinus* sp. and *Artemisia tridentata* were the most numerous plants.

In fall, 1978, data from two line intercept transects were taken to determine ground cover densities. The results were 25.5 percent grass, 11.5 percent forbs, 23 percent shrubs, 85 percent litter and 31.5 percent bare ground. With the area closed to livestock grazing, we expect the plant cover to move toward a perennial grass range. Without the cattle use in the riparian areas, the willow and wild rose will close their canopies and access to the stream will become difficult for the bighorn. The Eightmile Canyon area is well watered with springs and small running streams. Adequate water will always be readily available even though access to Eightmile Creek is restricted.

The primary limiting factors will be the small size of the winter range, the segmented nature of the bighorn habitat in the Santa Rosa Mountains and the number of livestock fences that could prohibit easy movement from one area to another. There are approximately six square miles of winter range here; however, we doubt very much that forage will be a problem. Over 1.5 million pounds of forage will be produced here annually.

We have little idea of the crowding that bighorn can stand. What population density per square mile can we expect from a free roaming bighorn herd? McQuivey found seven bighorn per square mile in the River Mountains of Southern Nevada. But can there be fifty to one-hundred bighorn per square mile? We hope so.

In a recent memo to the Forest Supervisor, I recommended that the Eightmile Canyon area be designated a zoological area with bighorn having primary management priority.

Let's look at another bighorn area. Mount Moriah lies due east of the town of Ely near the Nevada-Utah state line. This area was historic bighorn range populated with the Rocky Mountain subspecies. These bighorn disappeared at about the same time and most likely from the same causes as the Santa Rosa herd.

On January 25, 1975 a group of sixteen Rocky Mountain bighorn were reintroduced into the Smith Creek drainage of Mount Moriah. Twenty-three animals have been observed during a single survey and the present population could be about forty animals.

This area has an average annual precipitation of eight inches at the lower elevations to twenty-five inches at the highest elevations. It falls mainly as snow; however, severe summer storms do occur.

The soil-landscape of the Smith Creek area has extensive areas of rock surface exposures of limestone origin, with steep rock cliffs and crags. Roughly one-third of the area has a soil cover ranging from shallow soil, rock-controlled slopes, to deep soils of colluvial toe slopes. Soils have a light colored, very gravelly-loamy profile with well drained, rapidly permeable characteristics.

Elevations change from 5,500 feet at the forest boundary to over 12,000 feet in a distance of seven miles.

The area presently occupied by bighorn is part of the Rye Grass C&H Allotment. This allotment was heavily grazed prior to 1910 by wild horses, domestic sheep and cattle. The Forest Service assumed administration of this area in 1910. Livestock reductions began almost immediately. Reductions in AUMs and changes in season of use and class of livestock have occurred over the years. During the early 1930's, there were 7025 domestic sheep and 840 cows using the allotment for three

months each summer. In 1966, the permit was converted to cows exclusively and presently there are 350 cows using 1,073 AUMs from June 16 to September 30. The grazing system is a four pasture rest rotation. Only light cow use occurs on the east side of the Moriah range. Almost no use occurs on the lower portion of Smith Creek; Hampton Creek and Hendrys Creek are grazed biannually by twenty cows.

REA surveys were conducted in 1958. At that time, there was an average annual production of 700 pounds of forage per acre. Plant composition was 65% grasses, 15% forbs and 20% shrubs. The most common grasses are *Agropyron spicatum*, *Poa iongliligula*, *Poa secunda*, *Oryzopsis hymenoides*, *Sitanion hystrix* and *Bromus tectorum*. The most common forbs are *Penstemon*, *Aster*, *Phlox*, *Lygodesmia* and *Selaginella*. The most common shrubs are *Artemisia tridentata*, *Artemisia arbuscula*, *Chrysothamnus viscidiflorus* and *Tetradymia spinosa*. The entire east side and parts of the west side of the Mount Moriah range are excellent bighorn habitat. Forage is more than adequate. As an example, the eastern portion of the mountain range encompasses about 64,000 acres. Let's assume this area will average fifty pounds of forage per acre. An annual production of 3,200,000 pounds of forage is possible. The twenty head of cows using the east side of the mountain during a 105 day season will consume 42,000 pounds of forage per grazing season.

The Mount Moriah bighorn habitat is extensive and continuous. The winter range extends along the east face of the mountain range and into the canyon bottoms and side slopes.

Limiting factors are not evident at this time. The summer range is extensive and the winter range covers fifteen to twenty square miles. Bighorn appear to be using more of the range each year. Three bighorn rams were observed at the 10,000 foot level in an area called "The Table." and a ewe was seen about ten miles southwest of the release site.

There is more than enough forage produced each year and a large amount of forage is left to be carried over to the next grazing season.

Water is well distributed on the summer range and snow is usually present at low elevations in winter.

Escape cover is well interspersed among the feeding areas. There is one area that needs to be monitored. It is a small burn on the south slope of Smith Creek in the transition range between summer and winter ranges. This is the only concentration area that has been identified to date.

The third bighorn area is the Troy area of the Grant Range. This is a desert bighorn population and probably has been on this mountain as long as there has been desert bighorn anywhere in the southwest. The Troy area lies about 75 miles southwest of the town of Ely. Elevations change from 5,500 feet at the forest boundary to over 11,000 feet at Troy Peak, a four mile distance. Precipitation averages five inches at the lower elevations to over sixteen inches at higher elevations. Drought conditions occur 45% of the time. Most precipitation falls as snow; however, severe rain storms do occur in summer. Soils are similar to the Mount Moriah area but are of volcanic origin.

REA surveys for this area were conducted in 1976. Survey results showed that the lower elevations produced thirteen pounds of forage per acre and the higher elevations produced 180 pounds of forage per acre. The plant composition is 19.4% grasses, 6.4% forbs and 74.2% shrubs. The most common grasses are *Agropyron spicatum*, *Poa secunda*, *Stipa comata*, *Hilaria jamesii* and *Sitanion hystrix*. The most common forbs

are Penstemon, *Erigeron*, *Lithospermum*, *Eriogonum* and *Astragalus*. The most common shrubs are *Artemisia arbuscula*, *Atriplex confertifolia*, *Sarcobatus vermiculatus*, and *Chrysolhammus viscidiflorus*.

From 1951 to 1974, eighty-five cows grazed this area each year. During this same period the grazing season varied from three months to five months. In 1975, 1977 and 1978, the allotment was in non-use. Grazing will resume this year; the proposed system will be to graze two successive years and rest the area two successive years. The grazing season would be from June 16 to September 15, with 255 AUMs of use.

This grazing allotment encompasses 18,040 acres, with 17% or 3,067 acres identified as suitable range. The suitable range is found in the canyon bottoms and in the higher areas at the head of Grant and Irwin Canyons. The suitable range is capable of producing 552,000 pounds of forage per year. Eighty-five cows during the ninety day season would require 153,000 pounds of forage. The unsuitable range is 14,973 acres. Let's split this into 4,000 acres of winter range and 10,973 acres of intermediate and summer range. The winter range at the lower elevations produces thirteen pounds per acre for a total of 52,000 pounds. The 10,973 acres of intermediate and summer range will produce between 13 and 180 pounds per acre. We have conservatively estimated this area will produce an average of 30 pounds of forage per acre, or 329,190 pounds. Now let's assume there are seventy-five bighorn on the area, year-long. These animals will spend four months on the winter range and eight months on the summer range and will need 36,000 pounds of forage in winter and 73,500 pounds of forage in summer. There is sufficient forage on the summer range; however, on the winter range the production and the needs are too nearly the same. 52,000 pounds produced, 36,000 pounds needed. Like the Eightmile Canyon area, the Troy winter range is limited in size and is one of the limiting factors on this herd. Revegetation projects would be of little value because of the low precipitation and the drought conditions that occur 45% of the time.

The wildlife manager will always have problems achieving desired distribution of wild or domestic animal populations within the habitat. Domestic livestock can be manipulated by salting and herding. There is no easy way to achieve proper distribution of wild ungulates. Even though forage may be produced rather uniformly throughout a winter range, there will be areas that are still unused when spring comes. On the Troy winter range there is an annual production "maybe" of 52,000 pounds of forage, but if there are seventy-five bighorn here, there will always be a demand for 36,000 pounds of forage. If drought occurs 45% of the time, I would say that these bighorn are undernourished 45% of the time. This situation can be compounded when deer are added to the winter range or livestock trespass occurs from the adjacent BLM lands.

The Eightmile Canyon and the Mount Moriah bighorn ranges have a good diversity of forage. Even during drought years more forage will be produced than the bighorn can consume. The Troy winter range will always be a poor forage producer. This desert bighorn herd will increase during good forage years and decrease during poor forage years.

So you won't think I have completely ignored the livestock-bighorn interactions on the Troy Canyon-Troy Peak area, let me say this, then you can draw your own conclusions.

If all of the livestock were removed — we would still have a situation where more than 50% of the forage produced occurs on 17% of the allotment.

We would still have a situation where the majority of the forage produced is unavailable for four months of the year.

We would still have a limited winter range that only produces thirteen pounds of forage per acre and a total forage production of 52,000 pounds.

There would still be a forage demand on the winter range that is nearly as high as the forage production.



BIGHORN SHEEP IN THE PUSCH RIDGE WILDERNESS AREA, ARIZONA

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Abstract. This report summarizes data collected on desert bighorn sheep (*Ovis canadensis*) from the Pusch Ridge Wilderness Area, Santa Catalina Mountains, Arizona. The sheep population has not been studied extensively but data from the Arizona Game and Fish Department and U.S. Forest Service indicate certain trends.

Sheep distribution in the Santa Catalina Mountains has declined since 1936 due to roads, trails, and human activity. The population is now restricted to the northwest and southwest portion of the range. From annual aerial surveys and ground counts the population is estimated at 70 to 100 individuals and apparently is stable and healthy.

Between 1962 and 1978, 72 permits were issued for hunting sheep in the Santa Catalina Mountains and 22 mature rams were shot. Body measurements and examinations of 12 harvested rams indicate that these sheep are heavier than other desert bighorn rams in Arizona. The mean field-dressed weight is 149 pounds (68 kg).

Long term effects of man on this sheep population are unclear. Tucson lies at the base of the Santa Catalina Mountains and photographers, hikers, birdwatchers, hunters and other recreationists frequently use the Pusch Ridge Wilderness Area. This summary reveals that more knowledge is required in order to understand herd dynamics and evaluate the impact of man for management and planning purposes. Research providing data on sheep distribution, density, movements, response of bighorns to fire, habitat utilization and the impact man has on the population are warranted.

INTRODUCTION

Bighorn sheep are an important resource of the Pusch Ridge Wilderness Area (PRWA), Santa Catalina Mountains, Arizona. This report summarizes desert bighorn sheep (*Ovis canadensis*) data collected by the Arizona Game and Fish Department (AGFD) and the U.S. Forest Service (USFS) in PRWA between 1925 and 1978. In addition, future research needs for management and planning are identified.

Information from 12 trips (30 man-days) by the authors into PRWA (Alamo, Pina, Deadhorse, Catchment, Slash, Romero, and Montrose Canyons and Buster Spring, Table Mountain and Pusch Peak; see Fig. 1) between 10 May 1978 and 11 January 1979 are included.

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PUSCH RIDGE WILDERNESS AREA (PRWA)

The PRWA was established on 24 February 1978 through the Endangered American Wilderness Act and contains 56,430 acres (22,837 ha) (Anon. 1978b). This new wilderness forms the southwest portion of the Santa Catalina Mountains located in the Coronado National Forest, Arizona. The Santa Catalina Mountains are roughly triangular in shape with an east-west base of about 20 miles (32 km) and the apex roughly 20 miles (32 km) north of the base. Elevations range from over 9,000 feet (2,745 m) at Mt. Lemmon to 2800 feet (854 m) at the southwestern base of the range (Whittaker and Niering 1965).

The Catalina Mountains are unique among Arizona and New Mexico ranges because they possess a full sequence of plant communities from limited subalpine fir (*Abies lasiocarpa*) forests to highly developed Sonoran Desert. Vegetation patterns of other ranges in southeastern Arizona are similar (Blumer 1909, Martin and Fletcher 1943, Nichol 1952, Wallmo 1955, Lowe 1961) to the Catalinas but differ because the forest types are reduced or absent and/or Sonoran Desert Communities are limited or absent (Whittaker and Niering 1964). Vegetation of the Santa Catalina Mountains brings together mountain coniferous forests, Mexican oak (*Quercus oblongifolia*) and pine (*Pinus* spp.) oak communities of southern affinities, desert grasslands with affinities to the east, and Sonoran desert with affinities to the west and south (Whittaker and Niering 1965).

The PRWA consists of steep, highly erosive areas with large, deep canyons which support a variety of riparian vegetation. Hogbacks rise from the desert floor to higher elevations forming vertical rock faces and spectacular geologic formations. Vegetation varies from desert grassland at the lower elevations to ponderosa pine (*Pinus ponderosa*) and mixed conifers at higher elevations. Whittaker and Niering (1964, 1965) provide a physical and vegetation analysis of the Santa Catalina Mountains.

BIGHORN SHEEP IN PRWA

Approximately 1,296 square miles (3,357 km²) (or 18 percent) of the total sheep habitat in Arizona sustains "high populations" of sheep. Included in this acreage are the Santa Catalina Mountains north of Tucson (Fig. 1) which encompass the PRWA. The AGFD classified the bighorn sheep in the PRWA as a "high sustaining population" (Anon. 1978a).

Numbers: Accurate and/or precise censuses of desert bighorn sheep in PRWA have not been made. However, reports as early as 1893 discuss the occurrence of bighorn sheep in the Santa Catalina Mountains: "Mountain sheep. (*Ovis cervina* Desm.) - Not uncommon on the bare rocky spurs of the Santa Catalina Mountains, where they were seen during 1894. Several were killed in the fall of 1893 by an Indian hunter, and the meat sold to settlers at the foot of the mountains..!" (Allen 1895). Later published reports mention the presence of bighorns in the Santa Catalina Mountains (Mearns 1907; Dice and Blossom 1937; Cowan 1940) but do not provide accounts of numbers and distribution. Crude population estimates by the USFS (Krausman and Shaw 1979) range from 220 sheep in 1926 to 35 individuals in 1954. The data indicate that most sheep populations in Arizona have experienced a decrease in numbers.

The AGFD has conducted annual aerial surveys of bighorn in PRWA since 1962 (Stair 1962, 1963, 1964, 1966-1974, 1975-1977,

Hernbrode 1964, 1968. Cocking 1978). In 1973, a high of 34 individuals were observed from the air. The mean number of sheep seen during aerial surveys between 1971 and 1978 was 17 individuals (Krausman and Shaw 1979). The total population number has not been determined. Conservative estimates by the AGFD placed the population at 50-70 individuals in 1975 and 1976 (Stair 1975/1977) and between 70-100 individuals in 1977 and 1978 (Cocking 1978). Considerable attention has been directed towards the sheep population near Tucson and views have been expressed indicating that the conservative estimates by the AGFD are "vastly underestimating bighorn numbers and the areas where the animals can be found" (Quimby 1977). Until systematic census techniques and analysis can provide empirical data on the sheep in PRWA, estimates of the population numbers for management purposes will continue to be questionable.

Distribution: Data on sheep distribution in PRWA are incomplete. Studies have not been conducted concerning sheep distribution throughout the year, and the locations of many sightings have not been accurately recorded. In order to obtain an idea of sheep distribution in PRWA, 899 reported locations of bighorn sightings between 1936 and 1978 were tabulated. We used data from AGFD aerial surveys, random observations and ground counts, USFS records, and accounts from hikers and hunters reported to the USFS or AGFD (Table 1). Limitations of these data are obvious. Locations are often too generalized to provide an accurate documentation of distribution. For example, in many cases location was simply recorded as "Pusch Ridge" with no additional details. Furthermore, some of the observations may be duplicates; the location provided with observations may be erroneous, and systematic measurements of any biological data or observations were not taken over the years. However, these records show that more than 95 percent of the sheep have been observed in the southwest and northwest portions of the Santa Catalina Mountains. Reports by hunters (314 observations) indicate that more than 95 percent of their sightings were also in the southwest and northwest portion of the Santa Catalina Mountains. Regardless of data limitations, it is clear that the distribution of sheep in the Santa Catalina Range has been reduced. Forest Service sheep censuses in 1936 and 1941 reported sheep as far east as West Spring and West to Pusch Ridge (Fig. 1). Most sightings were in the southwest and northwest portions of the Catalinas, but the surveys indicated a wider distribution than in 1978. Areas where sheep had been reported in the early surveys but not recently contain hiking trails, jeep trails, and the Mt. Lemmon highway, all being factors which probably reduced sheep distribution (Fig. 1). Research is needed to document distribution and movement throughout the year.

Food Habits: Data on bighorn food in PRWA are limited but there is no reason to believe that their foods differ substantially from sheep in similar habitats. Welles (Russo 1956) mentioned the use of catclaw acacia (*Acacia greggii*), agave (*Agave utahensis*, A. *Schottii*), saguaro (*Carnegiea gigantea*), brittle-bush (*Encelia farinosa*), heron-bill (*Erodium cicutarium*), *Euphorbia* spp., ocotillo (*Fouquieria splendens*), iron tree (*Oleaya tesota*), *Opuntia acanthocarpa*, oak (*Quercus* spp.), *Selaginella repincola* and jojoba (*Simmondsia chinensis*) by sheep in the Santa Catalina Mountains. Stair (1964) reported on the contents of two ram stomachs collected in PRWA. Additional food items included silk-tassel (*Garrya wrightii*), *Opuntia* spp., barrel cactus (*Ferocactus* spp.), Arizona rosewood (*Vauquelinia californica*), mistletoe (*Phoradendron boleanum*), pig-weed (*Amaranthus* spp.), cotton-top (*Trichachne californica*), *Panicum* spp., and blue-stem (*Andropogon* spp). Hernbrode (1968) suggested that Arizona rosewood is an important food for bighorn in PRWA. Between May and December 1978, fendlera (*Fendlera rupicola*), sagebrush (*Artemisia ludoviciana*), wild-buckwheat (*Eriogonum wrightii*), Arizona rosewood, red-berry buckthorn (*Rhamnus crocea*), Agave *shottii*, palo verde (*Cercidium microphyllum*), mesquite (*Prosopis juliflora*), jojoba, *Opuntia* spp., and brittle-bush showed signs of use by ungulates (which could include cattle, deer and sheep). Most of these are plants used by bighorn sheep in southwestern Arizona (Russo 1951) and are also recorded as food items in bighorn food studies conducted in ranges with similar vegetation (Halloran and Kennedy 1949, Halloran and Crandell 1953, Russo 1956).

Habitat: Desert bighorn sheep habitat is typically characterized by broken, cliffy terrain in rugged mountains and buttes (McCann 1953; Russo 1956). Several studies indicated that sheep avoid timbered areas (McCann 1953) or are nervous when in timber (Devan 1958). However, Barmore (1962) reported heavy use of the juniper-pine community in combination with rough canyons. This is possibly the case with bighorn sheep in PRWA. Sheep may be utilizing wooded areas where detection would be more difficult. Even in the desert-scrub communities where sheep are most commonly reported in PRWA, dense cover is available along canyon floors and around boulders and caves (Table 1).

Table 1. Distribution of desert bighorn sheep in PRWA, Arizona, determined from 899 sightings by the AGFD, USFS, hikers and hunters between 1936 and 1978.

Location	Percent of observations
Pusch Ridge	35
Alamo Canyon	23
Pusch Ridge-Pima Canyon-Kimball Mt. Complex	11
Deadhorse Canyon	8
Pima Canyon	7
Buster Spring	5
Montrose Canyon	3
Table Mountain	2
Romero Canyon	2
Coxcombs	1
Cargodera Canyon	1
Sabino Canyon	1
Catchment Canyon	1

This report does not include a habitat evaluation of PRWA, but dominant plants were recorded in the areas examined. In Catchment Canyon, oak, Arizona rosewood, side-oats grama (*Boutelous curtipendula*), hopbush (*Dononaea viscosa*) and Agave *shottii* are abundant. Alamo Canyon is an open area with grasses and *Opuntia* spp. mixed with bear-grass (*Nolina* spp.), sotol (*Dasyllirion wheeleri*), ocotillo, turpentine-brush (*Aplopappus laricifolius*), saguaro and *Selaginella rupincola* at lower elevations. At elevations above 4,000 feet (1,200 m) more trees are apparent including alligator juniper (*Juniperus deppeana*), Mexican pinyon-pine (*Pinus cembroides*), nut pine (*P. edulis*) and oaks. Canyons on the north side of PRWA (Catchment, Slash, Deadhorse, and Alamo; see Fig. 1) have dense cover along washes and steep slopes and cliffs. Ben-

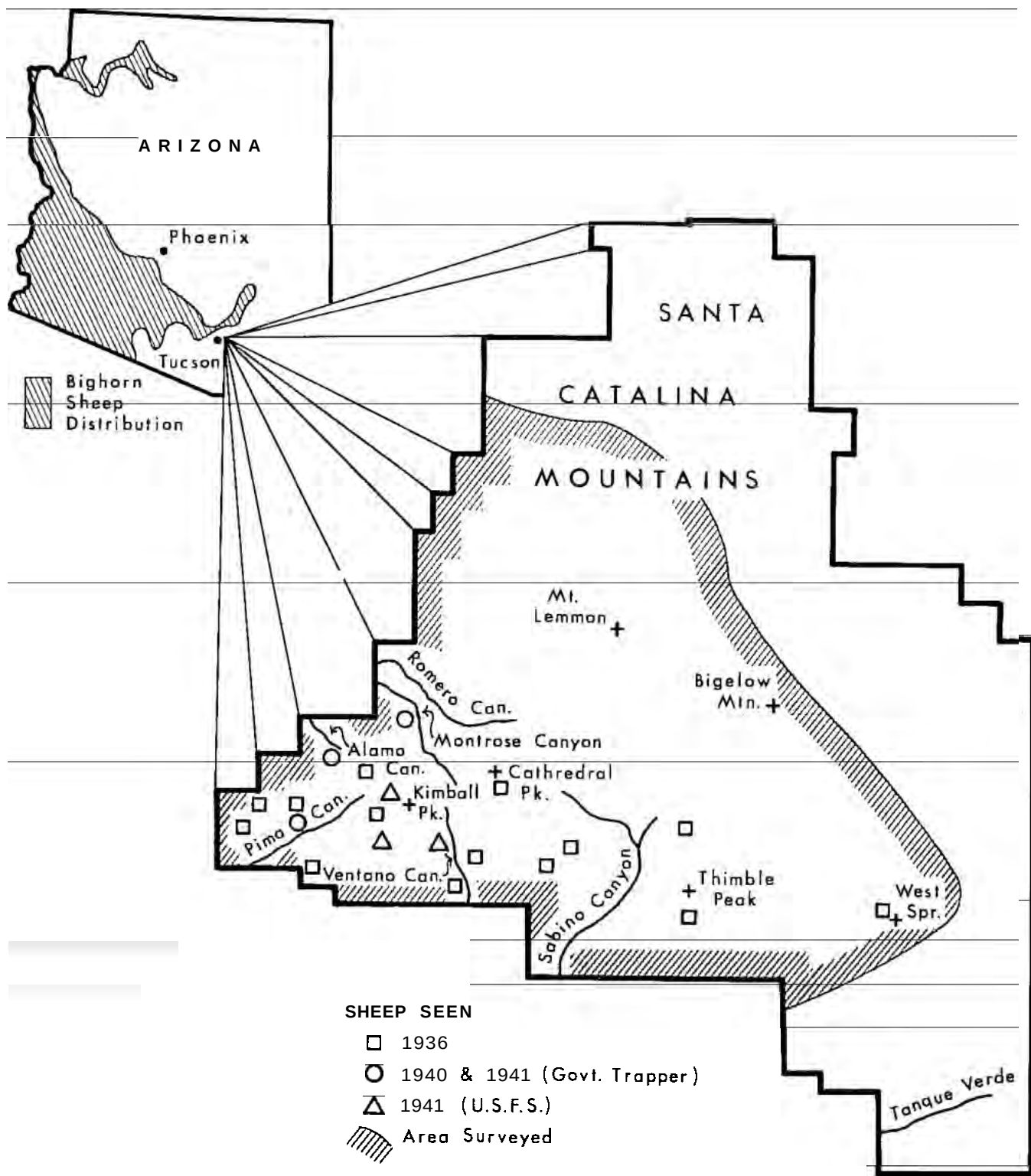


Figure 1. Desert bighorn sheep distribution in Arizona and the historic range of desert bighorn sheep in the Santa Catalina Mountains.

ches with grassy cover (*Bouteloua* spp., *Andropogon* spp.) and scattered pines, juniper and oaks are distributed throughout the higher elevations.

The south slopes of Pusch Ridge are covered with grasses and a pine-juniper stand occurs at the top of Table Mountain interspersed with manzanita (*Arctostaphylos* spp.). Data on habitat utilized by bighorns in PRWA are lacking and more research is warranted.

Reproduction and Lambing Grounds: Lambing areas are an important habitat component for bighorn sheep. Since the lamb is most susceptible to various mortality causing factors in the species, it is important for adequate lambing areas to be available. Hansen and Deming (n.d.) discuss the importance of water, food, escape cover, and shelter as requirements which they found necessary for lambing areas in the southwest.

Data on lambing areas in PRWA are not available and breeding seasons and lambing times have not been reported. Hernbrode (1966) reported one lamb on Buster Mountain, PRWA which was only a few days old on 28 June 1966. Desert bighorns on southern ranges appear capable of breeding throughout the year and lambing can occur at any time. However, reports from Arizona (Russo 1956) and California (Welles and Welles 1961) suggest mating peaks from August and September with most lambing occurring in January and February. Similar observations have been reported for southern Nevada (McQuivey 1978).

It is important to obtain information on lambing area and peak rutting and lambing times in PRWA for a better understanding of herd dynamics and management. Of added interest is the effect of man on lambing areas. Although lambing areas are often located in the most difficult and rugged terrain within an area, they are often exposed to flat canyon floors or alluvial fans (Hansen and Deming n.d.). Areas in PRWA that appear to meet these requirements include Alamo and Deadhorse Canyons, and the south side of Bighorn and Pusch Peaks (Fig. 1).

Body Size: Welles and Welles (1961) stated they had "no reason to believe that the Death Valley bighorn are significantly larger than those measured and weighed in Arizona or smaller than those in Nevada." Desert bighorn sheep in Arizona are larger (Russo 1956) than Nevada bighorns (Aldous et al. 1958), but the sheep in PRWA are even larger (mean field dressed weight = 149 lbs. (68 kg)) than those reported by Russo (1956) Table 2). Bighorns collected in PRWA are slightly shorter in length than those reported by Russo (1956) but tailer and much heavier. Although our sample size is small, these data indicate that PRWA bighorns are heavier and stockier than other desert bighorn sheep in Arizona. The average age of harvested males was 6 years, with a range from 3 to 11 years (Krausman and Shaw 1979).

The average horn measurements from 19 sheep that were shot in the Santa Catalina Mountains are as follows: average out-

side curl (right and left horn) 32.2 inches (82 cm); average basal circumference (right and left horn) 15.7 inches (40 cm); average maximum spread 21.8 inches (55 cm). Mean measurements are larger than Arizona averages reported by Russo (1956): average outside curl (right horn) 28.9 inches, (left horn) 29.2 inches; average basal circumference (right horn) 13.2 inches, (left horn) 13.4 inches.

Fire History: The Santa Catalina Mountains have been influenced by fire. A fire history has been maintained, but the records between 1906 and 1958 were destroyed. Only partial information between 1959 and 1978 is available (Anon. n.d.).

Between 1959 and 1976, 252 man caused fires and 550 lightning fires were reported in the Santa Catalina Mountains. A total of 3,287 acres (1,330 ha) burned between 1959 and 1978. Eighty percent of the fires were 0.25 acres (0.1 ha) or less and 17 percent were 9 acres (3.6 ha) or less. Slightly over 2 percent of the fires burned between 10-99 acres (4-40 ha) and less than 1 percent burned between 300-999 acres (121-404 ha) (Anon. n.d.). Less than 3 percent of the fires reported occurred in areas bighorn sheep occupy (Table 1). Two were larger burns. The Alamo Canyon fire in 1975 burned 360 acres (146 ha) and in 1978, 300 acres (121 ha) were burned along the northwest end of Pusch Ridge. Since 1973 approximately 7 smaller fires (10.99 acres (4-40 ha)) were reported in bighorn sheep habitat (Anon. n.d.).

The role of fire has not been studied as intensively in desert ecosystems as in other ecosystems and its effect on bighorn sheep is not clear. However, it is likely that fire benefits bighorn sheep habitat as it benefits the habitat of other wildlife species. The U.S. Forest Service is proposing to allow fires to burn in PRWA. Preliminary studies have indicated that fire does not adversely affect desert scrub in PRWA (Loe, pers. comm. 1979). Research efforts should continue in order to document the effect fire has in bighorn sheep habitat.

Mortality and Limiting Factors: Data on decimating factors affecting bighorn sheep in PRWA are lacking. The skeleton of a ewe was found in 1974 and a medium-size ram was found near Pusch Peak in 1977 (Stair 1966-1974, 1975-1977) but the causes of death were not reported. All the rams harvested between 1962 and 1978 were reported in good health, and disease and parasites did not appear to be detrimental to the sheep (Stair 1975, 1977, Cocking 1976).

Many researchers consider competition to be an important factor influencing bighorn sheep populations. Competition with livestock has been suggested as a limiting factor (Carson 1941, Buechner 1960, Wilson 1968) but in order to analyze competition and its effects, information on diets, population sizes, distribution of competing species, vegetative cover, and forage production need to be obtained (Buechner 1960). These data are not available for PRWA. In spite of restrictions on grazing, cattle were observed in Alamo and Catchment Canyons between May and December 1978. In December, 12 head of cattle were at 4,000 feet (1,220 m) in Catchment Canyon.

Table 2. Comparative mean weights and measurements of desert bighorn sheep in PRWA with other bighorn in Arizona and Nevada. Measurements are in pounds or inches. Sample sizes are in parentheses.

Field Dressed Weight	Total Length	Tail Length	Height at Front Shoulder	Heart Girth	Hind Foot	Source
105(25)	57.5(23)	3.3(23)	36.3(33)	39.5(33)	14.6(33)	Aldous et al. 1958 (Nevada)
120(7)	61.7(7)	4.6(7)	36.1(7)	40.7(7)	15.6(7)	Russo 1956 (Arizona)
149(9)	57.0(7)	4.5(10)	39.5(9)	41.5(9)	16.1(9)	This study (PRWA)

If grazing continues, attempts should be made to document the affect of livestock on desert vegetation used by bighorns.

Water is a possible limiting factor. The dependency of bighorn sheep on free water is apparent. Simmons (1961) and Irvine (1969) demonstrated that seasonal shifts and movements occur in relation to the availability of free water and Halloran and Deming (1958) maintain that bighorns need water every 5 miles (8 km) in arid areas. The amount of water required varies. Turner (1973) demonstrated that metabolic water formed by oxidation is not sufficient to meet the needs of bighorns and the sheep need free water above that received from forage (such as *Opuntia* spp., saguaros and other succulents) during hot summer months. Koplin (1960) noted that rams drank from 1.5 to 2.5 gallons (5.7-9.5 l) of water during each trip to waterholes and ewes drank as much as 2 gallons (7.6 l). Hailey (1966) found bighorns consume an average of 0.82 gallons (3.1 l) of water per day in southwest Texas while other researchers (Weiles and Weiles 1961) reported sheep to use an average of 1.5 gallons (5.7 l) a day in Death Valley.

Between May and December 1978 free water was available for sheep from artificial sources (the AGFD catchment at the base of Catchment Canyon, the tank on Table Mountain, and the trough at Buster Spring) and in potholes and wash bottoms throughout PRWA. Of the natural water holes observed, many were surrounded by brush which often hinders use by sheep.

During dry years water may be limiting to bighorn sheep in PRWA. Welles and Welles (1961) found water to be limiting to the sheep population in Death Valley and other researchers have indicated that lack of water is detrimental to sheep populations (Allen 1939, Halloran and Deming 1956, Simmons 1969). Additional documentation of free water locations and sheep use is needed in PRWA.

RECREATIONAL ACTIVITIES AND BIGHORN SHEEP

Much of the literature dealing with interactions between bighorn sheep and humans suggests that major increases in human activities will have negative impacts on sheep populations. However, knowledge concerning these interactions is not complete.

Several authors have suggested that recreational activities can be detrimental to sheep populations (Van Den Akker 1960, Nelson 1966, Welsh 1970, Dunaway 1971, DeForge 1972). Effects ranging from seasonal reduction in summer range (Weaver et al. 1972) to permanent displacement and subsequent increases in stresses have been described. Other authors have suggested that certain low levels of human activities might be tolerated (Light and Weaver 1973, Light 1973). However, the exact conditions under which sheep will not tolerate humans are not well understood. Examples are numerous of sheep tolerating considerable human activity (Nelson 1966, Smith (1954), Geist (1971) and Welles (1961) all cite examples where sheep tolerate people sometimes to the point of nearly becoming tame. One of the few herds in which systematic observations of human/sheep interactions have been made is the Mt. Baxter herd in California (Wehausen 1976, Elder 1977, Hicks 1977). These authors found that sheep tolerated considerable interaction with humans with no permanent displacement. Although these sheep were disturbed by backpackers, there appeared to be no negative effects on reproductive success. Lambs and ewes were less tolerant of people than rams, and human approach from above was far more disruptive than from below. However, this was not a hunted herd and it is not known what effects hunting may have on sheep behavior and tolerance for humans.

It seems clear from the literature that human activities can be very detrimental to bighorn sheep. However, some types and levels of recreational activities may be entirely compatible with sheep well-being. Understanding the tolerance limits of a specific herd would require an understanding of specific habitat requirements for the herd as well as recreational use patterns in their habitat.

RECREATIONAL USE OF PUSCH RIDGE

Hiking and Backpacking: Few data are available concerning recreational uses of the Pusch Ridge area. Recreational developments are limited to a number of trails typically following drainages into the mountain range. Of the several trails in the area, limited use data are available only for Plma Canyon which receives more use than the other trails. Comprehensive studies of recreational uses of this trail have not been made. However, a trail counter was placed in the canyon by Forest Service personnel in April, May and June, 1978; 4885 people went past the counter and rough estimates of use for Plma Canyon were developed. Annual use of this trail was estimated at approximately 25,000 people, with 15,000 to 20,000 of the visits occurring between October and June (D. McAllister, pers. comm. 1978).

Studies have not been made of the extent to which recreationists travel on this trail or the duration of their visits. Plma Canyon is the primary access route to Table Mountain. There is no developed trail to this peak but hikers occasionally traverse the steep and rugged terrain to Table Mountain. A hiker's registry is located at the summit and provides some insight into the use of this area, although there is no basis for estimating what percentage of hikers visit Table Mountain without signing the registry. Approximately 85 percent of use appears to occur from November to April. Of 90 parties involving 160 people that signed the registry from 1974-1978, only three volunteered that they had seen sheep. (The registry does not specifically request any information, and many hikers may not have been looking for sheep.)

Sport Hunting: Between 1962 and 1978, 72 permits were issued for sheep in PRWA and 22 sheep were harvested. Hunter success ranged from 0 percent to 100 percent with a mean of 30.5 percent. The most man-days of hunting (62) were in 1972. Since then man-days of hunting have decreased to 10 in 1978, the year with the highest success and fewest days hunted.

The influence of hunting on sheep populations has received little attention in the literature. Long term effects of hunting were studied on the Desert Game Range in Nevada (Hansen 1967). Data are incomplete but Hansen (1967) documented two trends which occurred after hunting began in 1954. The average age of adult males decreased from 89 years in 1955 to 6.6 years in 1963 and the ram:ewe ratio changed. The pristine population had a sex ratio of 100 adult rams:100 ewes. After regulated hunts began the ratio dropped to approximately 23:100 in 1962, 1963 and 1964. Less than 3 percent of the total population was harvested during the hunts. Numbers decreased from about 3,000 in the early 1950's to about 1,200 in the early 1960's. The effect of hunting on the overall reduction was not determined.

Long-term effects of hunting bighorn populations are not known. Until basic biological data are gathered and complete information on populations are obtained and correlated with harvest data, the influence of hunting cannot be determined.

Even without better data on actual recreational uses of the

Pusch Ridge area, several observations can be made. The population of Pima county is growing at an annual rate of over two percent. In recent years participation in outdoor recreation activities has increased at an even greater rate. The demand for outdoor recreation on Pusch Ridge will continue to grow. Furthermore, a major recreational development is planned for the land immediately west of the ridge. Acquisition of land for a state park (Catalina State Park) is already in progress and when this facility is developed, it will attract thousands of persons to desert areas immediately west of sheep habitat. Potential impacts of increased human use in this area on the sheep herd are great. A better understanding of population dynamics and habitat requirements of the Pusch Ridge sheep herd is essential if development plans for Catalina Park are to avoid the potential for serious detrimental impacts on the sheep.

RESEARCH NEEDS

The bighorn sheep of Pusch Ridge are a unique and valuable resource. The existence of this herd was undoubtedly a significant consideration in designation of the area as wilderness and the social values of these sheep extend beyond those few individuals who have an opportunity to view or hunt them. Hunters, as well as non-hunting wildlife enthusiasts, are concerned with the well-being of this herd and this concern is evidenced by the attention the sheep are given by the news media.

This summary of current knowledge regarding bighorn sheep of PRWA suggests the need for more information. The future well-being of this population will require management and planning based on a sound understanding of basic biological parameters of the herd and of human intrusions into its habitat. Future research efforts should focus on the following objectives:

1. Obtain accurate population data and a systematic procedure for monitoring population numbers, health, and productivity via aerial flights, telemetry and ground work.
2. Determine distribution and seasonal movements of the bighorn sheep throughout the year.
3. Identify breeding periods, lambing seasons and lambing areas.
4. Determine basic habitat requirements of the bighorn sheep.
5. Evaluate the response of desert bighorn sheep to the effects of fire on its habitat.
6. Obtain accurate information concerning recreational uses of the Pusch Ridge area.
7. Monitor impacts of human activities on the bighorn sheep.

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THE BARBARY SHEEP: SOME CONCEPTUAL IMPLICATIONS OF COMPETITION WITH DESERT BIGHORN

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Abstract. Barbary sheep (*Ammotragus lervia*) have become successfully established in Texas, New Mexico and California, thereby causing concern over their potential threat to desert bighorn sheep (*Ovis canadensis mexicana*, O. c. *nelsoni*). This paper discusses some theoretical aspects of ecological justifications frequently used for introducing Barbary sheep into the United States. The outcome of potential sympatric existence between Barbary sheep and desert bighorn is hypothesized, using fundamental concepts of interspecific competition theory applied to Barbary sheep and bighorn biology. It is concluded the introduction of Barbary sheep cannot be justified ecologically and that sympatric existence of both species would promote competitive interaction leading to a decline in desert bighorn numbers.

INTRODUCTION

Of the eighteen free-ranging exotic ungulates in the United States today, a few were introduced by negligence or by accident but the majority were released by well meaning people interested in wildlife. Fortunately for North American wildlife species, most of these releases were failures, or have limited their success to relatively restricted areas. Unfortunately, however, three of these exotics have done so well they now present a management problem to wildlife agencies and land managers alike. The European boar (*Sus scrofa*) thrives primarily in the eastern third of the nation and California whereas the other two successful exotics, the feral burro and the Barbary sheep, both occur in deserts of the Southwest. Ironically, both also occupy areas of vital significance to a threatened North American subspecies, the desert bighorn sheep.

The rationales used to introduce any exotic usually follow the same basic patterns and can be divided into two main schools of thought. The first, under the pseudo-ecological auspices of environmental balances, generally espouses the "vacant niche" theory. The second group are somewhat more materialistic but still subscribe to being ecologically oriented; they talk in terms of "land use", "maximum productivity" or "economic and ecological diversity" and follow the banner that a greater variety of huntable game for recreational purposes is in integral part of the process of good game management.

Modern wildlife researchers are becoming increasingly disillusioned with these justifications and hardcore sentiment against the release of exotics is rising steadily in the United States.

To date Barbary sheep do not occupy ranges sympatric with the desert bighorn. However, since their release about 20 years ago, dispersal has been documented to well over 100 miles (Berrett 1967, Simpson et al. 1978). They presently occur in historic desert bighorn habitat in Trans-Pecos Texas and southeast New Mexico and they are rapidly nearing currently occupied desert bighorn ranges. In fact, Barbary sheep have already radiated into the San Andres Mountains in New Mexico, which is a historic bighorn range that is presently occupied by the only natural population of *Ovis canadensis mexicana* left in the state (Sandoval, personal communication). Presently one only can speculate on the outcome of the sympatric existence between Barbary sheep and desert bighorn. The objectives of this paper are (1) to review the ecological justification for introducing the Barbary sheep, and (2) to hypothesize the outcome of Barbary sheep/desert bighorn sympatric existence based on the fundamental concepts in interspecific competition theory.

The impact of the burro on endemic wildlife and flora of the southwest has been documented extensively (Hanley and Brady 1977, Normont and Douglas 1977, Seegmiller 1977, Morgart and Ohmart 1976). Emotionalism over this animal has erupted into torrid public meetings, Environmental Impact Statements, and Acts of Congress. Solutions have become so confused in the process that wildlife and land managers have been hamstrung by public opinion and legislation while the burro problem continues to compound itself. The Barbary sheep poses as great, if not a greater, threat to native flora and fauna than the burro, but is as yet not the subject of strong public controversy or governmental regulation. Awareness of its competitive potentials and incisive action by regulatory agencies now, could avoid the tedious emotional and legislative problems which hamper solution of the burro issue. It is with a view to developing this foresight of the Barbary sheep threat to desert bighorn management that we present this paper.

DISCUSSION

The Vacant Niche Theory: From an ecological point of view, the major justification that has been used for introducing Barbary sheep onto North American rangelands is to fill an ecological niche supposedly left vacant by the extinction of some large herbivore during the Pleistocene. The fact that 48 genera of megafauna became extinct in North America during the Late Pleistocene has been established (see Martin and Wright 1967, Martin 1970). The reasons given for the extinctions range from climatic changes (Guilday 1967), to an "overkill" by early hominid hunters (Martin 1967, 1970, 1973).

If one accepts the palynological evidence that little change in North American flora has occurred since the Pleistocene (Martin 1963), then certain large herbivore niches may have in fact been left vacant by megafaunal extinctions. No definitive evidence exists, however, to prove this fact to be true or false. ~~Nonetheless, an exotic species, which evolved on another continent under different environmental conditions, is not likely to~~ have developed the same genetic makeup or behavioral programming as any extinct North American species. Therefore, exotics such as the Barbary sheep, cannot be assumed to have the genetic specificity to fill an ecological niche without imposing unnatural competitive effects on endemic species, even though they may be "replacing" a taxonomically closely related extinct species. For one thing, there is no evidence that a close relative to the Barbary sheep became extinct in the Pleistocene. For another, it is not known which habitats con

stituted the niches of the extinct forms and what adaptive behaviors allowed niche occupancy and co-existence in the past. To assume that the Barbary sheep is presently, or is capable in the future of, filling precisely the same community function as some ancient Artiodactyl is over-simplifying a very complex ecological phenomenon.

Competition Theory: As a Barbary sheep population becomes established — i.e., becomes a viable population — in an ecosystem, energy flow is diverted from ecological niches that have been occupied by one or more endemic species for thousands of years. Therefore, if available energy constitutes a limiting factor to any of the interacting species, either a competitive or an amensalistic interaction must result.

In theory, the process of competition or amensalism between two ecologically similar species meeting for the first time consists of three stages: (1) niche overlap and/or behavioral intolerance; (2) shortage of limiting resource(s); and (3) reduced population fitness. Niche overlap between two species infers an overlap in one or more of their "niche dimensions." These niche dimensions may be measured empirically by three basic parameters: (a) spatial utilization of the environment; (b) patterns of temporal activity; and (c) items used for food (Pianka 1974). For Barbary sheep and desert bighorn, these niche dimensions may be represented by seasonal diets and use of habitats. Although they do not occur sympatrically as yet, Barrett (1967) and Simpson et al. (1978) reported that Barbary sheep and desert bighorn in similar habitats select similar terrain features (precipitous) and forages (either predominantly browse or grasses). This suggests potential for niche overlap if they were to occupy the same area. However, niche overlap does not in itself demonstrate competition or amensalism. Exploitation competition or amensalism would occur if the two species shared one or more resources such as food and/or water that were physically in short supply (Birch 1957, Pianka 1974). Competitive interaction would reduce the amount of the limiting resources to both species, whereas amensalistic interaction would result in a reduction to only one species while the other remained unaffected. Neither interaction would involve any type of behavioral responses between the interacting species.

Interference competition or amensalism arises from direct encounters or from indirect exploitation of a resource (Birch 1957, Pianka 1974). The resource need not be necessarily in physical short supply, but behaviorally is made in short supply to one or both species through interference in its use.

The "competitive exclusion principle" states that two species cannot co-exist on the same limiting resource(s) (Hardin 1960). Therefore amensalism or competition results in a reduced fitness in the populations of one or both species, respectively, through increased mortality, increased dispersal, decreased natality and/or decreased recruitment. The survivor is that species able to maintain a viable population under competitive interaction, while the other is excluded from the zone of overlap. The means by which a species can win a competitive interaction include having a superior efficiency at exploiting resources, inhibiting resource use by the losing species, and/or increasing in number at a faster rate.

The ability of two ecologically similar large herbivores to exploit food resources and obtain nutritional needs may depend largely on their digestive strategies. Both being ruminants, Barbary sheep and desert bighorn are each capable of digesting relatively coarse plant tissues that are high in

cellulose. In general, smaller ruminants have a higher metabolic rate and a more rapid rumen turnover rate, and thus require a higher quality diet (Bell 1971). Therefore, on an equal diet at submaintenance levels a larger ruminant will displace a smaller one, presuming both species rely on the same food supply (Bell 1971). The Barbary sheep has a larger body size (max.: ♀ 140 lbs, ♂ 320 lbs; [Ogren 1965]) than the desert bighorn (max.: ♀ 125 lbs, ♂ 200 lbs; [Russo 1956]). This suggests that the former may be able to survive on lower quality forage resulting from exploitative competition and a deteriorated range condition.

To date, no data are available on the comparative water requirements of Barbary sheep and desert bighorn. Data dealing with the ability of Barbary sheep and desert bighorn to tolerate one another's presence is also lacking since they are only approaching sympatry in one area. Hence, the potential for interference competition cannot be predicted for either of these two situations.

Perhaps the most important measure for predicting the outcome of competitive interaction is the ability of each species' population to increase in number. Rate of increase is mainly a function of both reproductive potential and mortality. Desert bighorn have a relatively long life span (16-17 years) and a low reproductive potential, the latter being characterized by one lamb per birth and one birth per year (Russo 1956, Hansen 1967). In contrast, Barbary sheep commonly produce twins, and occasionally triplets (Ogren 1965), and two births per ewe within a seven month period have been recorded (Blunt 1963). Detailed information on ecological longevity and mortality of Barbary sheep was not found, but Zoological Gardens have recorded animals living longer than 20 years. The species' ability to increase in numbers has been documented in Palo Duro Canyon, Texas (Simpson et al. 1978). Since the release of 44 Barbary sheep in 1957 and 1958, the Palo Duro population had grown to an estimated 1,200-1,500 individuals by 1977. Using Kelker's (1947) formula, this indicates an annual rate of increase of about 1.75 or 75 percent.

Presumably Barbary sheep would dominate any competitive interaction with desert bighorn. Consequently, in order to co-exist, the bighorn population must have the phenotypic plasticity to partition its niche beyond the overlap with Barbary sheep, yet maintain population viability. The probability of desert bighorn having this degree of adaptive plasticity is low. Species evolving in a particular environment over a long period of time develop specializations toward survival in that environment. Concomitant with this specialization occurs a loss in the species' ability to readily adapt to change. Exotics that succeed in a new environment, on the other hand, show a considerable genetic variability and are able to adapt more easily to differing conditions. Bighorn, therefore, may exist in reduced numbers and distribution after competition has stabilized, but this remains the more unlikely outcome to competition.

For total extinction of desert bighorn to occur, Barbary sheep would have to occupy precisely the same niche, or nearly so, throughout the desert bighorn range such that the bighorn population became too reduced to be a viable population. The chances of complete niche overlap throughout the range are unlikely.

SUMMARY

In light of this brief discussion we have no alternative but to conclude there is no valid ecological justification for the introduction of Barbary sheep into North America. The assumption

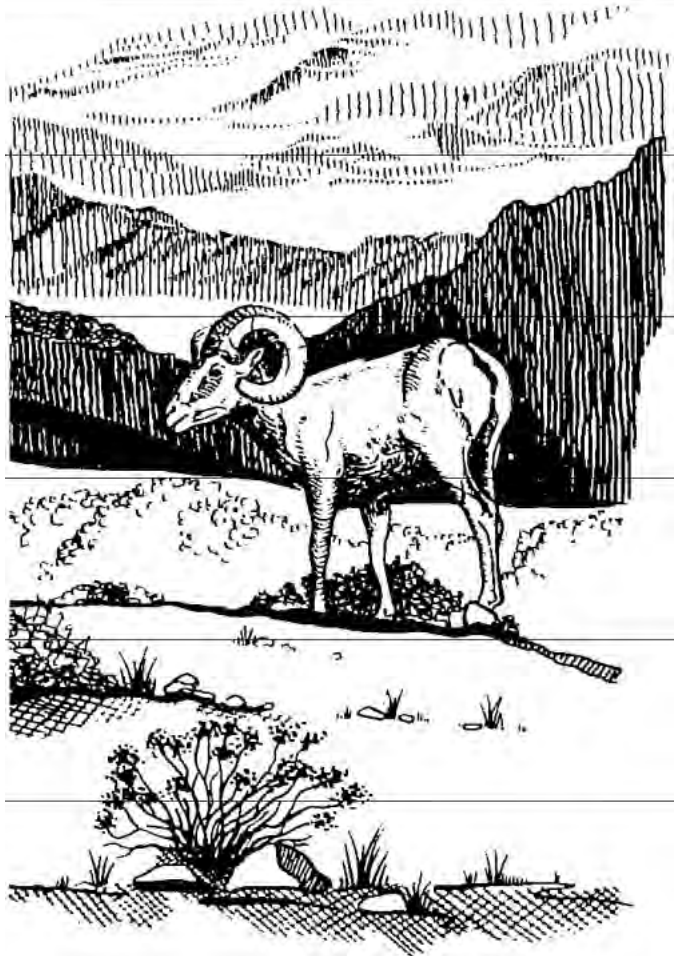
tion that Barbary sheep precisely fill the niche left vacant by the extinction of some large herbivore during the Late-Pleistocene is entirely speculative and without supportive evidence. The complexities of the adaptive morphology and behaviors necessary for both survival and interspecific co-existence preclude the likelihood of an exotic species entering a "balanced" ecosystem without causing competition and alteration of structure and function.

We hypothesize that sympatric existence between Barbary sheep and desert bighorn would lead to competitive interaction. The digestive strategies and reproductive potentials of each species suggest that Barbary sheep almost certainly would emerge as the successful competitor from this interaction. Thus, the desert bighorn population would have to change its mode of resource utilization, or exclude itself from the zone of overlap. As the adaptations necessary for these latter are probably beyond the species' genetic capabilities, it is unlikely that Barbary sheep and desert bighorn interactions would stabilize until the desert bighorn became extinct in sympatric areas.

Sound management of natural resources by wildlife and land management agencies is a difficult endeavor that is complicated by addition of new considerations — i.e., exotic introductions. At this point, the large number and widespread distribution of Barbary sheep has made management and control of its population expensive and nearly impossible. Immediate action is necessary by all concerned to insure that Barbary sheep do not penetrate further into historic desert bighorn habitats.

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BIGHORN USE OF ARTIFICIAL WATER SOURCES IN THE BUCKSKIN MOUNTAINS, ARIZONA

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Abstract. Three artificial water holes were installed in the Buckskin Mountains, Arizona, in the fall of 1977 and spring of 1978. Time-lapse photography equipment was used to monitor bighorn use of these waterholes for a total of 61 days between April and October of 1978. Ninety-five sheep were photographed at water between June and October. Bighorn 'preferred' to visit water in the early morning during the summer, whereas late afternoon and evening visits were preferred in the fall. Animals drank for an average of 3.3 minutes and loitered around the waterhole an average of 11 minutes.

INTRODUCTION

Arizona supports one of the largest harvestable populations of Mexican desert bighorn (*Ovis canadensis mexicana*) in the United States. However, habitat modification by man has jeopardized the future of this population. Some of the initial results of an investigation to determine ways to compensate for habitat losses are presented herein.

The Buckskin Mountains of western Arizona (Figure 1) are composed of a series of dissected mesas rising more than 1,200 feet above the desert floor. Historically, these mountains have supported bighorn sheep and the Arizona Game and Fish Department estimates that 60 animals presently inhabit the range. However, the population has been steadily declining during recent years because of habitat degradation.

The Buckskin Mountains have only two known dependable natural water sources — the Colorado River and Goat Springs (Moon and Bristow, 1972; Rinker, 1974; Arizona Game and Fish, 1976). The completion of State Highway 95 between Parker and Lake Havasu City in 1972 reduced the value of the river as a dependable water source (Ferrier, 1974). This highway is located between the mountains and the river, and has allowed recreational and housing development along the river. Heavy traffic also has resulted in a number of road kills.

Goat Springs, an important ewe and lamb water source, is only one-half mile from the new highway. As a result of easy access, more and more people visit this spring each year to observe bighorn. Consequently, bighorn use of the spring has been adversely affected.

Mining, feral burro use, and a water resource development project also have caused habitat degradation. The water project's most adverse impact will be the destruction of sheep habitat in the diversion area (Ferrier, 1974). Several habitat or population assessments (Moon and Bristow, 1972; U.S. Department

of the Interior, 1978) identified prime bighorn habitat and high sheep densities in this area.

Artificial watering facilities might partially compensate for habitat losses by making portions of a previously dry range available to bighorn. This has been accomplished elsewhere in the Southwest (McQuivey, 1978). If properly located, water facilities might provide water in an essentially dry range, and also hold animals away from the highway.

In order to assess the practicability of placing water in the Buckskin Mountains, a study was initiated in late 1976 to provide information on: (1) acceptance and use of new water sources by bighorn; (2) effective artificial water facility placement; and (3) manipulation of range use through water placement. Such information would aid both in the planning of efficient watering facilities and the development of future bighorn management plans.

METHODS

Biologists from the Arizona Game and Fish Department, Bureau of Land Management, and Bureau of Reclamation surveyed the Buckskins during the winter of 1976 to locate potential sites for water development. Criteria for site selection included: (1) historic bighorn use; (2) habitat quality, as evaluated by the BLM (USDI, 1978); (3) relationship to other developments, and (4) feasibility of constructing a watering device at the site.

Two locations initially were selected for testing (see Figure 1). Site I was located along the water project tunnel alignment in an area considered to be marginal to poor bighorn habitat. Site II was located in bighorn habitat midway up the river side of the Mesa and near the proposed pumping plant site. A water source in this area hopefully would minimize road kills by deterring bighorn from crossing Highway 95. Site III, which was selected during the early summer of 1978, was located in a winter use area approximately 2.5 airline miles south of Site II.

Temporary, portable watering devices were installed at Sites I and II during August, 1977. These devices consisted of a water trough and a 300-gallon storage tank. Water was hauled to the facilities on an "as-needed" basis.

Time-lapse photography systems were installed at Sites I and II in April and at Site III in June of 1978. These systems were similar to those described by Helvie (1972) and Constantino (1973 and 1974). A Super 8 movie camera and intervalometer, programmed to expose one frame of movie film per minute during daylight hours, were used.

Rain gauges and thermographs also were placed at the three sites.

RESULTS

Only data for Site II will be presented, as no sheep were photographed at Site I during the 46-day monitoring period and, although Site III was used by bighorn on 76 occasions, use occurred only during the fall. We believe the data were biased by the time lag involved in bighorn finding and using water in a dry, winter range and such a bias precludes an accurate analysis of use patterns.

Time-lapse photography was used to monitor bighorn use of Site II for a total of 61 days between April and October of 1978. Bighorn use began in June and continued through October. 95 bighorn sheep were photographed during this period (Table 1).

Extent of Use: Bighorn use of Site II, as measured by the average number of animals photographed per day, varied each month (see Table 1). The mean number of bighorn using the

site per day ranged from 0.8 in June to 3.6 in July. Water use was greatest during the mid-summer months.

Table 1. Water use by bighorn at Site II between April and October 1978. R = Males, E = Females. L = Lambs.

Month	Total Bighorn Observed	No. Days Monitored	$\bar{x}$ No. Bighorn /Day	$\bar{x}$ Time Near Water (Minutes)	$\bar{x}$ Drinking Time (Minutes)
Jun	10	12	0.8 E	15.6	4.5
			R	15.0	4.0
			L	9.9	5.0
Jul	47	13	3.6 E	9.4	2.9
			R	13.3	3.3
			L	6.8	3.4
Aug*	18	6	3.0 E	12.8	3.5
			R	16.1	3.3
Sep	11	9	1.2 E	7.8	3.3
			R	8.8	3.2
Oct	9	6	1.5 E	8.0	3.4
			R	9.0	1.8
Totals or Means	95	61	1.5	11.6	3.4

*Lambs then sufficiently mature to be classified by sex.

Time Spent in the Vicinity of Water: Bighorn experienced little stress when using the artificial watering facilities. Typically, they approached water with little hesitation, coming directly and rapidly to the water trough. After drinking or waiting for their turn at the trough, they loitered in the area an average of 11.6 minutes (see Table 1). Golden and Ohmart (1976) observed a 1 to 10-minute loitering period and Constantino (1973) a 21-minute period. Bighorn spent more time loitering around water during the summer months. Rams spent the most time and lambs the least.

Drinking Duration: Mean time spent drinking by bighorn ranged between 4.5 minutes in June and 2.7 minutes in October, and the overall mean for the 5-month period was 3.4 minutes (see Table 1). These periods are similar to the 3 minutes, 1 second to 3 minute 35 second times recorded by Weaver (unpublished manuscript) and 2.5 minutes reported by Golden and Ohmart (1976) and shorter than the 5.3 minutes reported by Welles and Welles (1961).

With the exception of October, when rams drank only half as long as ewes, there was little difference between mean monthly drinking times for different sexes or age groups. Lambs drank slightly longer than did adults during June and July when data were recorded for them.

An inverse relationship between the mean number of animals per day using Site II and the time spent drinking is apparent. As more animals used the site, they spent less time drinking.

Time of Day: The time of day when bighorn used Site II varied seasonally (figure 2). Similar to what Graves (1961), Welles and Welles (1961), and Hansen (1964a) found, bighorn at Site II also preferred to water during the morning and evening hours.

Fifty-four and 75 percent, respectively, of the bighorn visits to Site II during June and July occurred between dawn and 8 a.m. Equal numbers of rams and ewes (4 of each) also were photographed at Site II between 8 a.m. and 6 p.m. during June and July.

A bi-modal distribution in watering times during August indicated a transition in preference from early morning to afternoon visits. However, 44 percent of the bighorn visits to Site II still occurred between daylight and 8 a.m.; 29 percent of the total visits occurred after 6 p.m.

A slight preference for mid-afternoon visits to Site II was demonstrated by bighorn during September, with 36 percent of their total visits to the site occurring between 2 and 4 p.m. The October data, however, indicate a preference for evening visits. Fifty-five percent of the bighorn visits to Site II then occurred between 4 p.m. and 6 p.m.

DISCUSSION

The use of artificial water sources is influenced by such factors as the availability of natural water, range conditions, and temperature. The availability of natural water and range conditions were unusually favorable in the Buckskin Mountains during 1978. These factors undoubtedly effected waterhole use.

The Buckskin Mountains were exceptionally wet during the first 4 months of 1978. Parker, Arizona, on the south edge of the Buckskin Mountains, received 6.44 inches of precipitation or +4.82 inches more than normal during this period (U.S. Department of Commerce. 1978). As a result, the vegetation was abundant and lush on this area. Ephemeral tinajas and seeps also provided water late into the spring. Such conditions generally postpone the use of free water by bighorn (Kopin 1960).

Ambient temperature and precipitation are important factors determining bighorn use of water holes (Graves, 1961; Welles and Welles, 1961; Turner, 1970; Seegmiller. 1977). Thus, our data were used to ascertain the influence of these weather parameters on waterhole use by bighorn.

There was a direct correlation between rainfall and waterhole use (Figure 3). Bighorn began to use the artificial water facilities 36 days after the last measurable precipitation. Use then continued throughout the summer and fall months, until heavy rains occurred the latter part of October. However, monthly variations in the mean number of sheep coming to water, drinking times, and time of day when bighorn used water, could not be related directly to rainfall.

The proportion of each day in excess of 100°F corresponded well with the mean number of bighorn coming to water, the time of day when water activity occurred, and inversely with the time spent drinking (Figure 4).

The relationship between ambient temperature and waterhole use by bighorn is quite simple. As summer temperatures increase (reflected in the percentage of the day with temperatures exceeding 100°F), bighorn increase their use of water and limit their activities, as well as make their excursions to water during the cooler hours of the day (Welles and Welles, 1971; Blong and Pollard, 1968; Wilson, 1971). Daily or more frequent waterings also explain the inverse relationship between temperature and time spent drinking. Turner (1970) demonstrated a relationship between the amount of water consumed and the length of time absent from water. It follows that more frequent visits to water would result in less water consumed during each visit, and hence, less time spent drinking per visit. The shift to afternoon water visits and decreased drinking times during the fall months were the result of a decline in daily ambient temperatures. The resulting relief from water stress lowered water demands. In turn, this allowed mid-day activity and fewer visits to water.

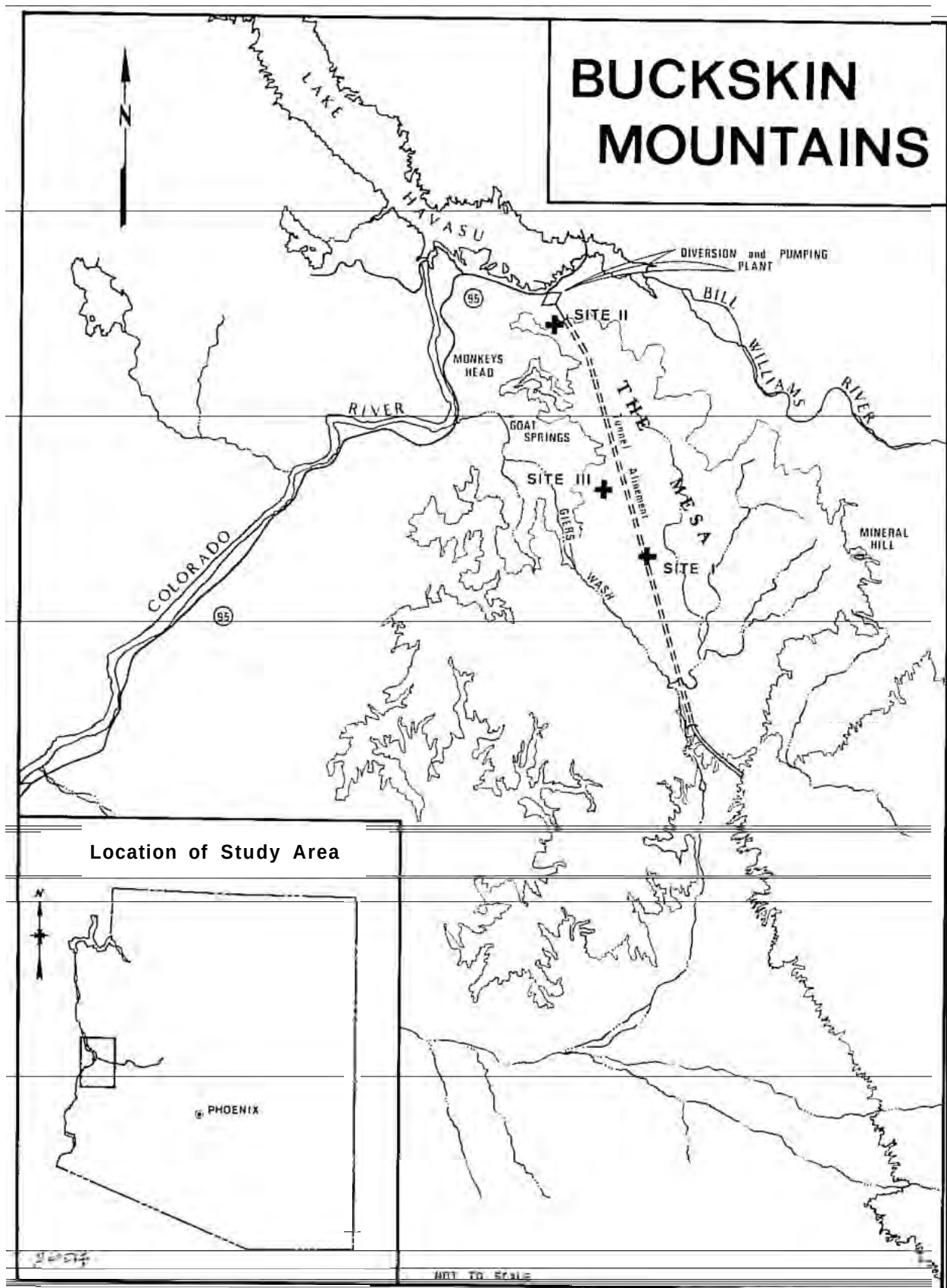


Figure 1. Map of the Buckskin Mountains in west-central Arizona and location of three artificial watering facilities.

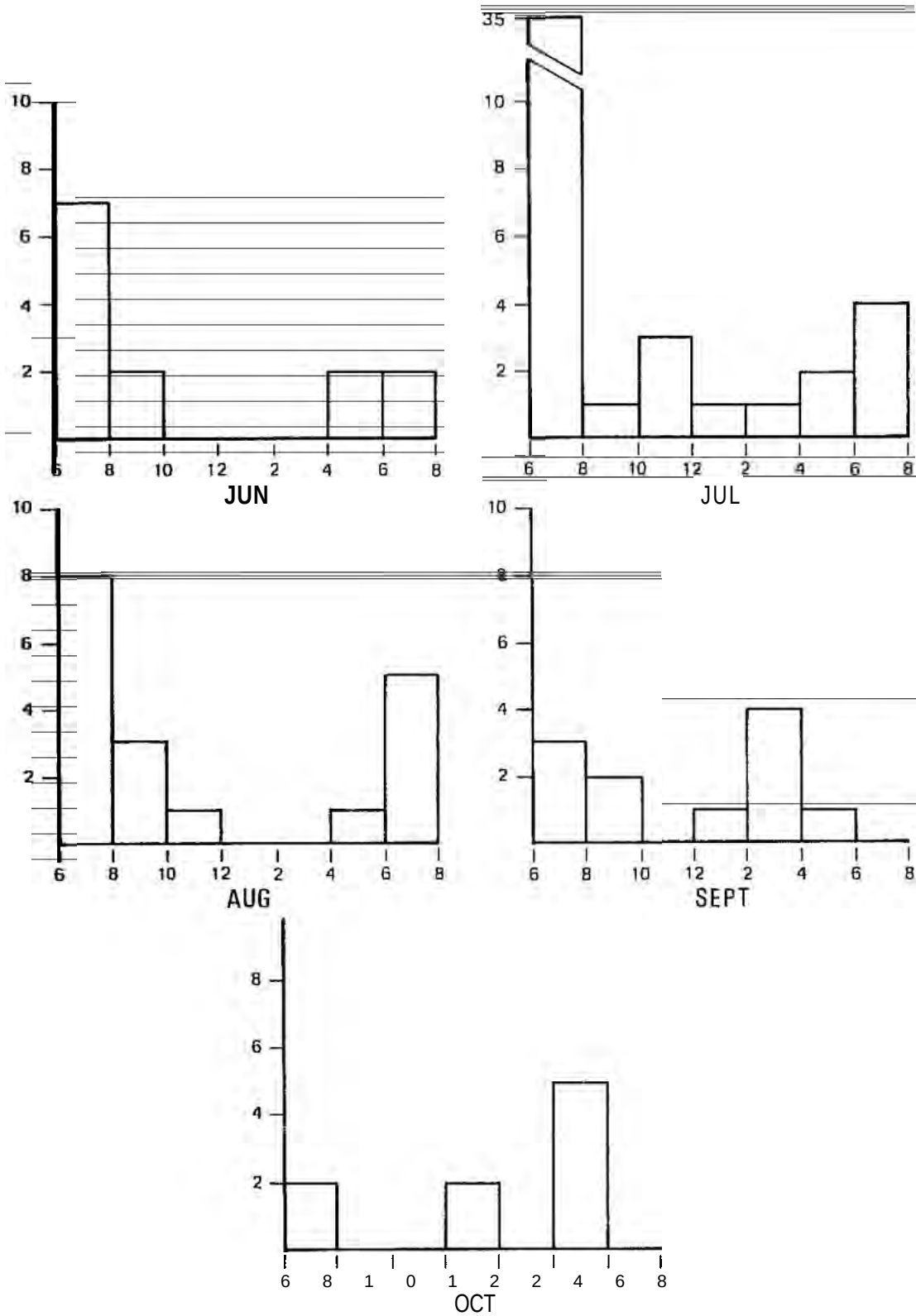


Figure 2. Monthly frequency distribution in percent of bighorn visits to water during 2-hour daylight time periods between June and October 1978.

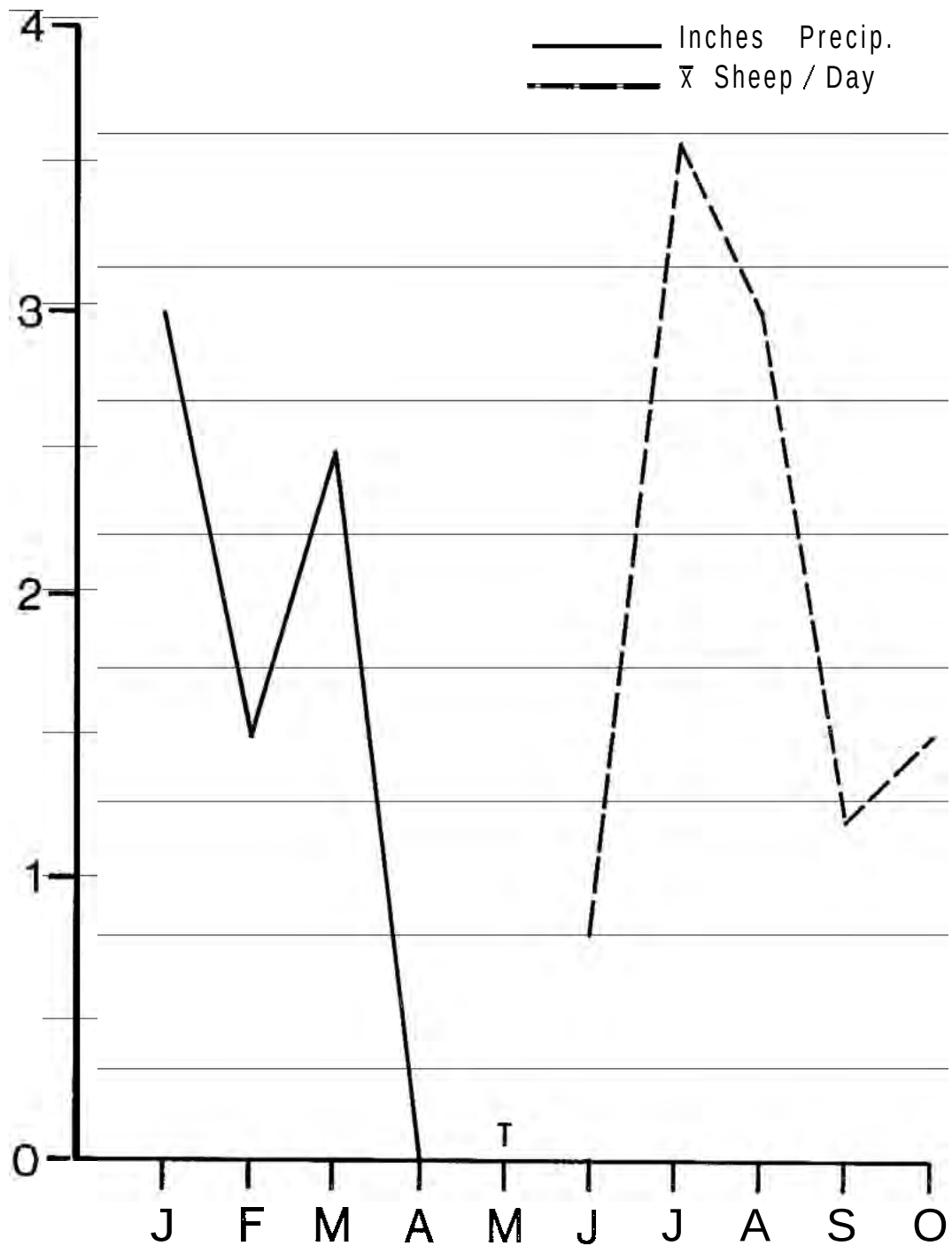


Figure 3. Monthly precipitation and bighorn use of water in the Buckskin Mountains, Arizona.

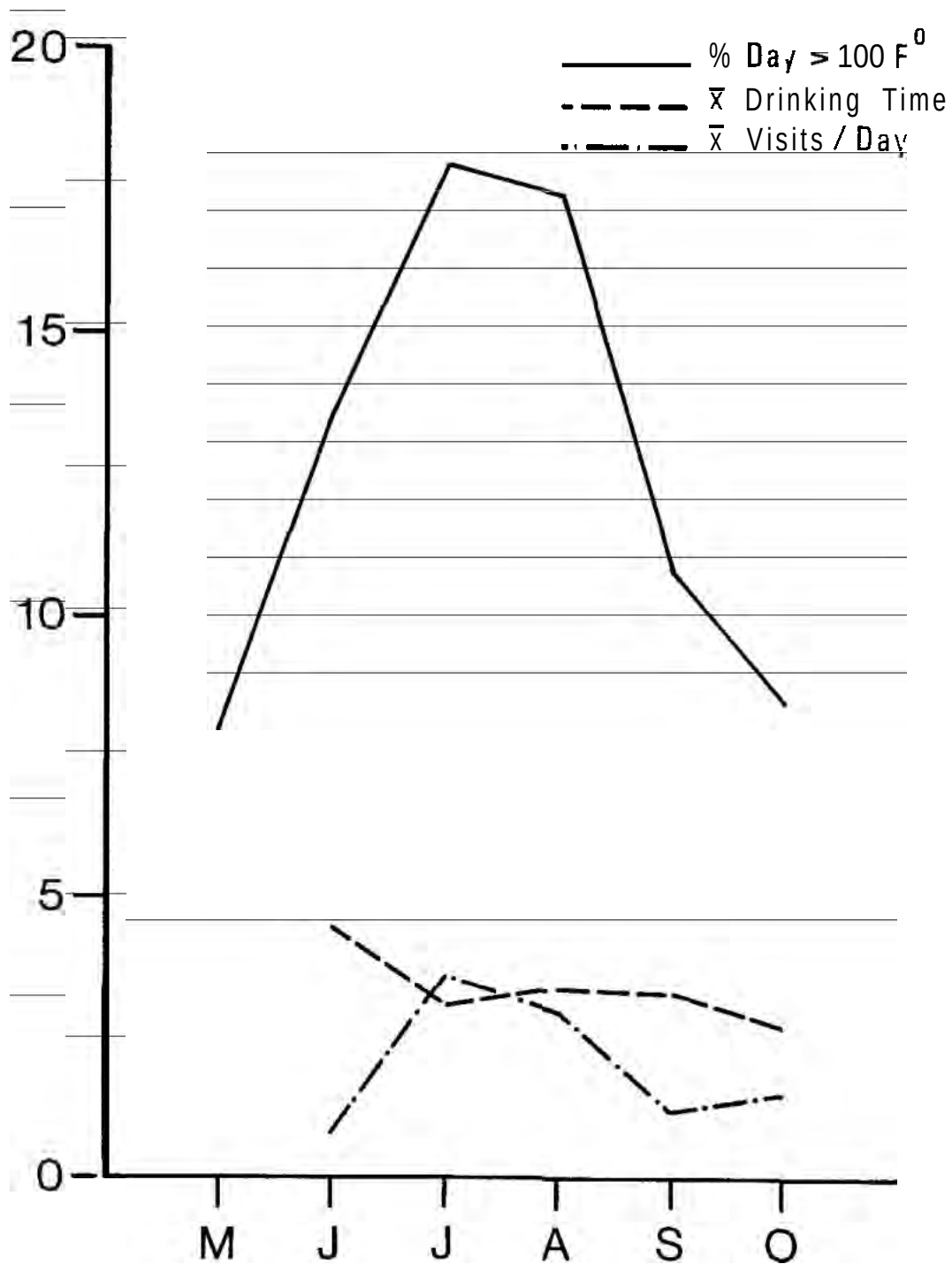


Figure 4. Mean percent of month over 100°F, mean time spent drinking by bighorn, and mean number of visits per day by bighorn to watering facilities between May and October 1978.

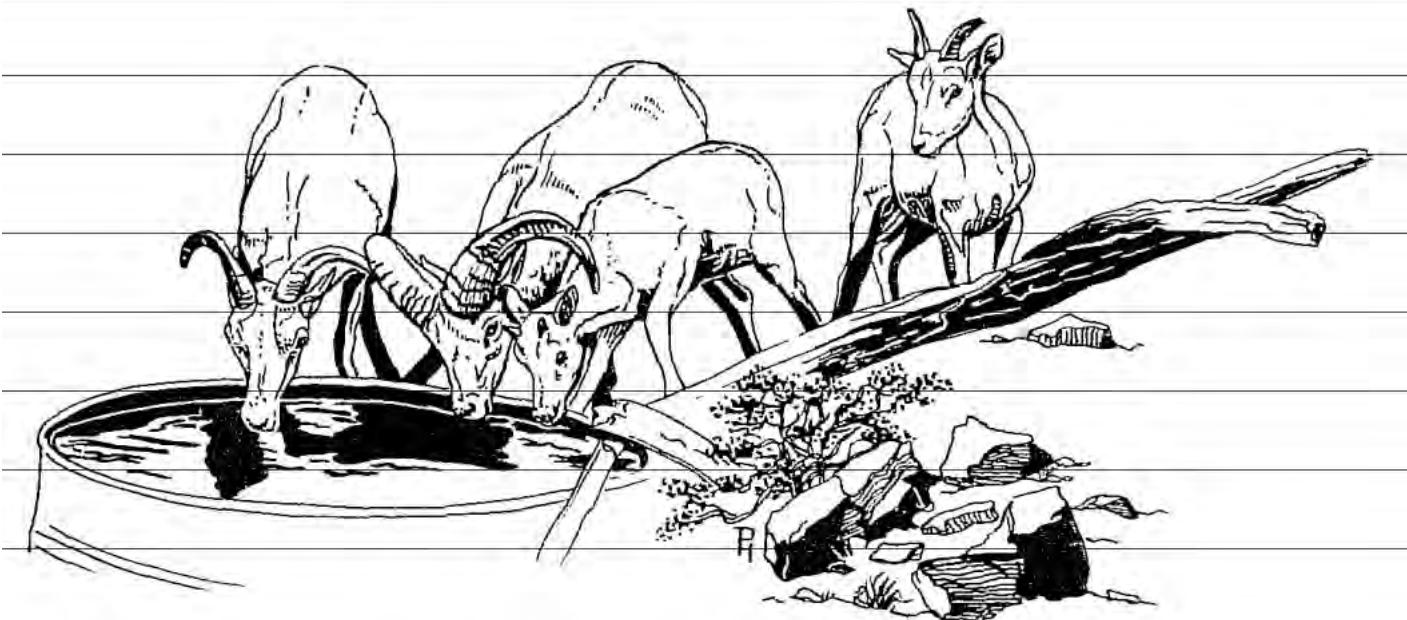
Manipulation of bighorn range use through proper water placement appears possible. No bighorn have been observed nor reported on or near State Highway 95 since they began to use Site II. Thus, it appears the bighorn have accepted this new water source and abandoned their traditional Colorado River source.

Recommendations: The monitoring program should be continued at least another 2 years. Continuation would provide additional data for Site II and also help determine whether or not habitat use can be manipulated by artificial water placement.

Use of two sites in close proximity (Sites I and II) undoubtedly influences the use of each. In order to determine interrelationship between these sites, individuals should be marked. Possible marking techniques include colored plastic collars similar to those used by Leslie (1977) or dyes (Hansen, 1964b; Simmons and Phillips, 1966). Water consumption rates also should be determined.

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AN ECOLOGICAL SURVEY OF THE WHITE MOUNTAIN PEAK BIGHORN

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Abstract. Desert bighorn (*Ovis canadensis nelsoni*) in the White Mountains of California used talus slopes for 42 percent of all summer activities. Although 69 percent of all escape activities occurred on talus slopes, when distribution and abundance of habitat types are considered, cliffs and chutes seemed to be preferred escape cover. In contrast to other recent surveys, bighorn were found using canyons and basins on the eastern side of the mountain range. Observations and records reveal that these bighorn will not tolerate humans approaching directly or being above them.

INTRODUCTION

The University of California, Berkeley, presented a proposal to the Inyo National Forest early in 1977 for increased activity and use of facilities at the White Mountain Scientific Area for continued high altitude - deep space research (K Ayres per. comm.; B. Williams per. comm.). The lack of data from which to predict the impacts of such increased activity on desert bighorn (*Ovis canadensis nelsoni*) populations demonstrated the need for a study of the White Mountain Peak bighorn.

Only two previous studies had been conducted on the White Mountain bighorn sheep herds: an aerial survey by the California Department Fish and Game in the fall of 1969 and summer of 1970 (Weaver and Mensch 1970), and a study to determine forage competition between bighorn and summering cattle and feral horses (Jorgensen 1975).

Field studies were conducted on the White Mountain Peak bighorn between June 30 and August 15, 1977. Results were submitted as a senior thesis to the Wildlife Management Department at Humboldt State University. Data in this paper concern summer habitat utilization, specific areas used, and bighorn-human interactions.

I wish to thank Jerry Stefferud of the Inyo National Forest for suggesting this study, and to acknowledge the assistance provided by biologists of the Bishop office of the Inyo National Forest and the California Department of Fish and Game. Also, special thanks are given to John Wehausen for his help during and after the field work, and to my brother Dan for his company and physical help during the field work. Lastly, I wish to thank my faculty advisor, Dr. Stan Harris, for his help and encouragement throughout the study, and for reviewing this manuscript.

STUDY AREA

The White Mountain Range is located on the eastern edge of Mono County, California. The 14.5-square-mile (37.6 km²) study area ranged between 10,000 and 14,242 feet (3,048 to 4,341 m) in elevation, and included the northern portion of the White Mountain Scientific Area (Figure 1).

Vegetation on the study area consists primarily of perennial grasses and reflecting the low and extreme elevations of the area. Grasses two to four inches (5.1 to 10.2 cm) high occurred up to 13,950 feet (4,252 m). Forbs varied from low thick mats 0.5 inches high (1.3 cm) to succulents averaging four to five inches high (10.2 to 12.7 cm), and occurred up to 14,000 feet (4,267 m).

MATERIALS AND METHODS

Bighorn observations were made with 8x40 binoculars and a 20-50x spotting scope. Backpackers encountered in the study also were interviewed, and pertinent historical records, on file with the U.S. Forest Service in Bishop, California, were consulted.

Data were plotted on 15 minute USGS topographic maps for later analysis.

Seven habitat types were defined. These were:

- 1) Cliffs and Chutes - narrow corridors between rock outcroppings or cliffs and usually contain loose rock fragments of varying sizes.
- 2) Talus slopes - usually are steep and unstable, and consist of rock and rock fragments between 10 and 36 inches (25 and 91 cm) in diameter.
- 3) Fell Fields - generally unstable slope with rock fragments less than 10 inches (25 cm) in diameter.
- 4) Rocky Grass - areas containing grasses and forbs, but where more than 50 percent of the surface area is covered by rocks.
- 5) Grass - areas having grasses and forbs on more than 50 percent of the surface area covered by vegetation.
- 6) Grass-Sagebrush Association - areas below 12,200 feet (3,719 m) in elevation, having grasses, forbs, and more than 25 percent sagebrush (*Artemisia rothrockii*) in their crown cover.
- 7) Timber - generally small isolated patches of limber pine (*Pinus flexilis*) and bristlecone pine (*P. aristata*) below 11,000 feet (3,353 m) in elevation.

Habitat types were classified by ocular estimation. Determinations of habitat utilization were derived both from direct and indirect observations of bighorn.

Quality of escape cover corresponding to the defined habitat types are as follows: Cliffs and chutes provide excellent escape cover. Talus slopes provide good escape cover. Fell fields are considered as fair escape cover. All other habitat types provide poor escape cover. Determinations of escape cover utilization were derived from direct observations of bighorn and interviews, with a later inspection of the area for confirmation of the habitat type used.

Direct observations of bighorn, interviews, and historical records were used to evaluate interactions between bighorn and humans.

RESULTS

Most of the study area was comprised of talus slopes (Figure 2). Due to small sample sizes, no effort was made to classify habitat utilization by age and sex classes (Table 1).

In order to determine if bighorn closely associated with good or excellent escape cover, three activities (bedding, feeding, and natural movements, as determined from tracks) were selected for analysis. A chi square (Siegal 1956) test showed that a significant amount of time was spent either in, or in

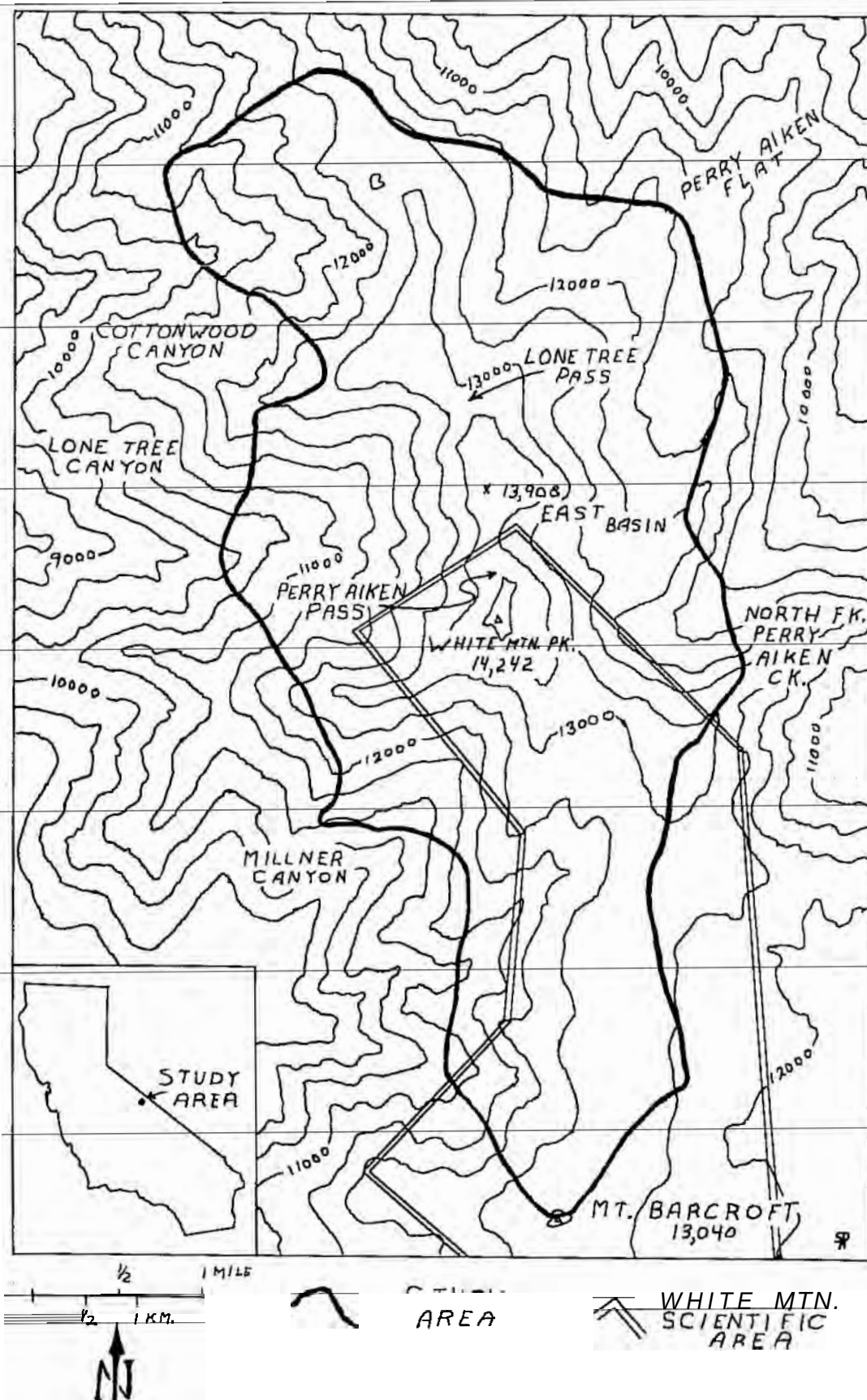


Figure 1. Topographic map of the 1977 White Mountain Peak bighorn study area with 500-foot contour intervals.

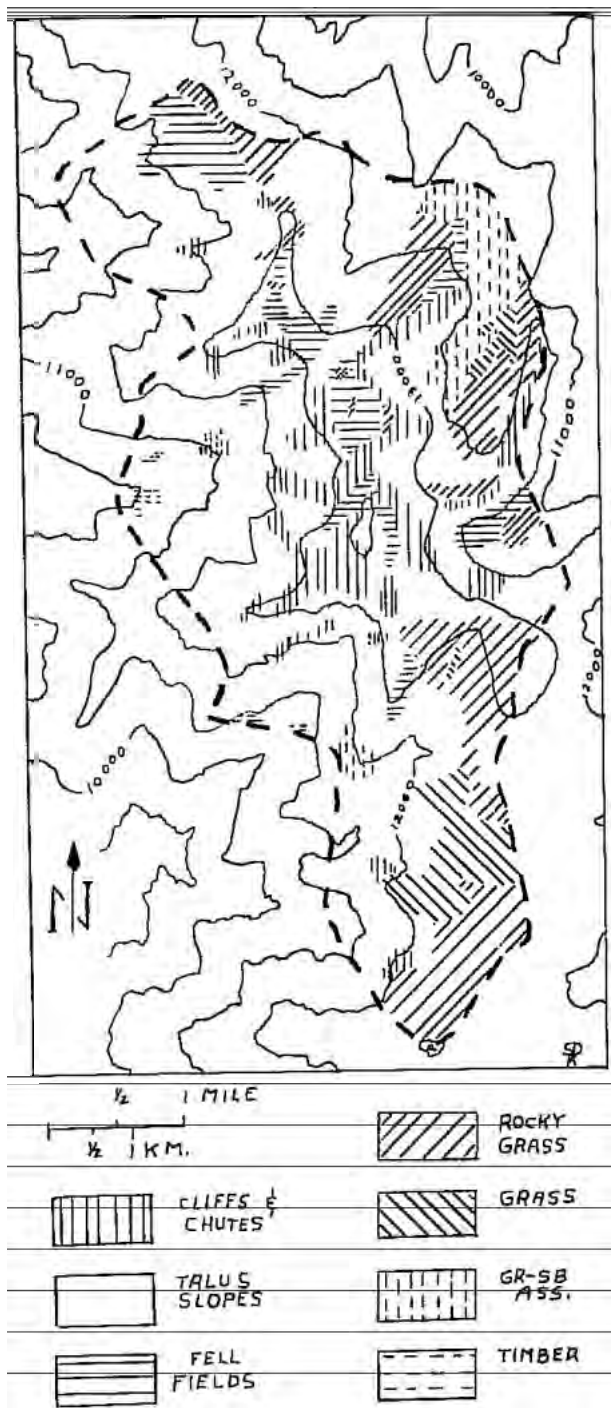


Figure 2. Distribution of habitat types found in the 1977 White Mountain Peak bighorn study area. Contour intervals are 1,000 feet. GR-SB ASS. = Grass-Sagebrush Association

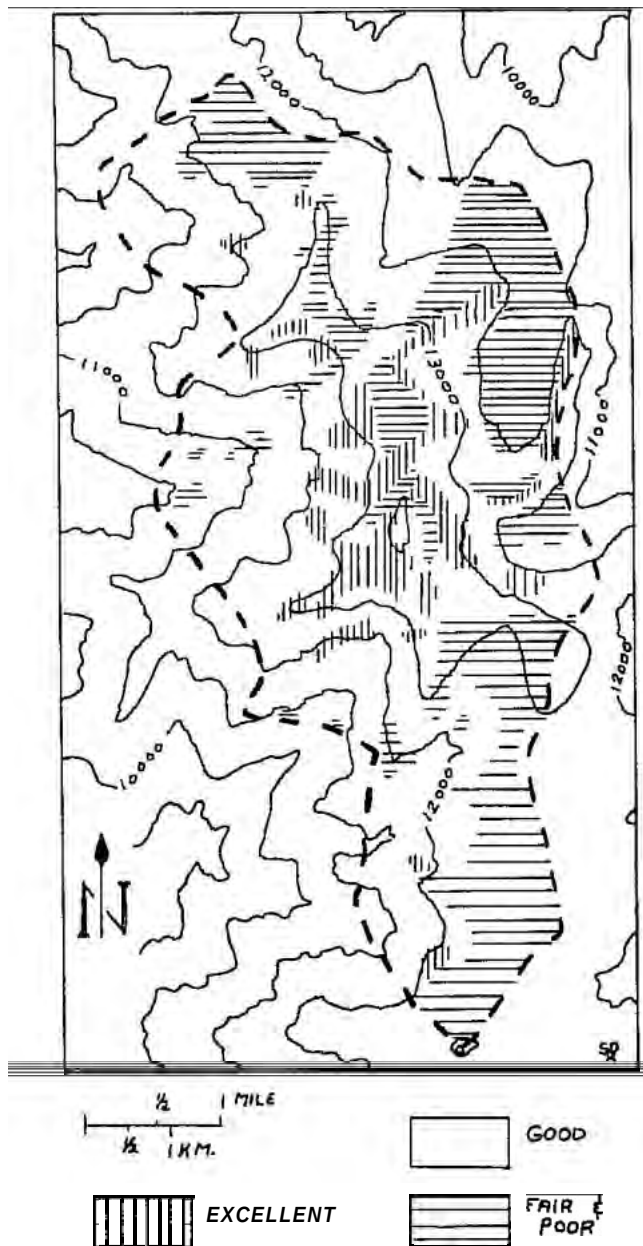


Figure 3. Distribution of escape cover within the 1977 White Mountain Peak bighorn study area, with 1,000-foot contour intervals.

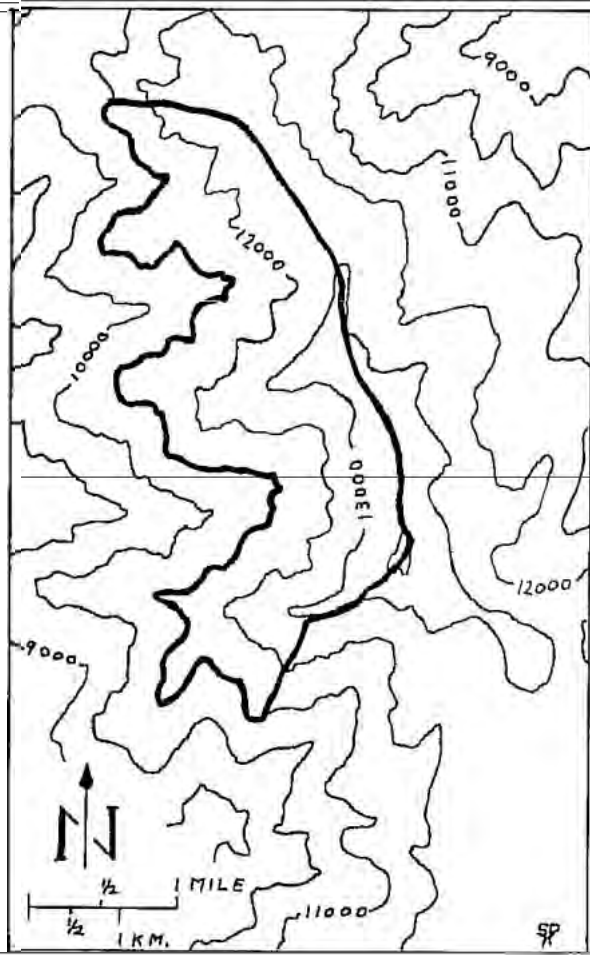


Figure 4. Extent of desert bighorn summer range for the White Mountain Peak area in 1970 (from Weaver and Mensch 1970). Contour intervals are 1,000 feet.

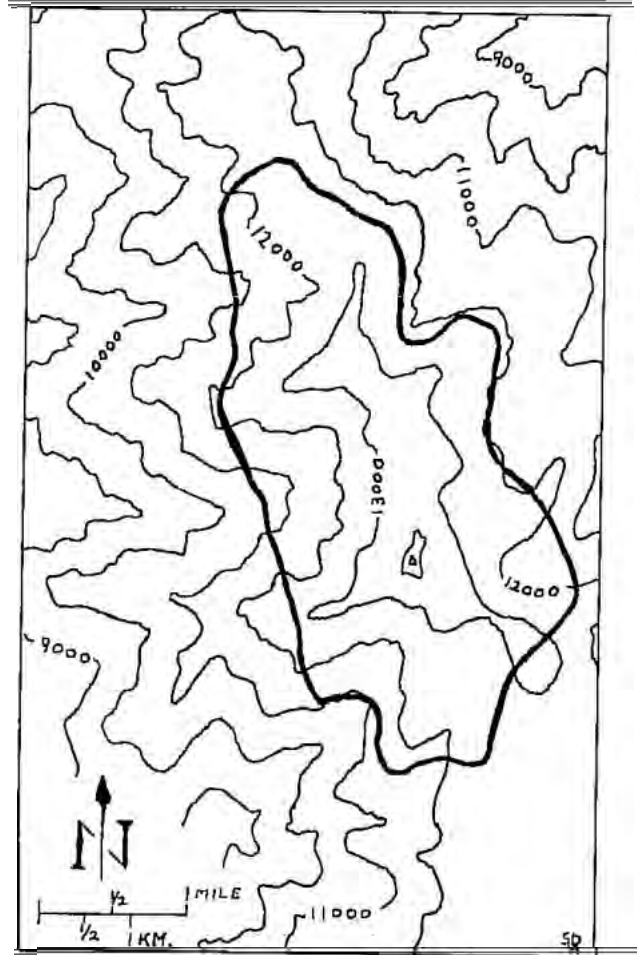


Figure 5. Extent of desert bighorn summer range in 1977 within the White Mountain Peak study area. Contour intervals are 1,000 feet.

Table 1. Percentage of activities recorded for White Mountain Peak bighorn during the summer of 1977. Numbers are a percent of the corresponding sample size (n).

Habitat Type		Cliffs and Chutes	Talus Slopes	Fell Fields	Rocky Grass	Grass	Grass. Sagebrush Association
Escape Cover Type		Excellent	Good	Fair	Poor	Poor	Poor
Activity	n						
Overall	180	4	42	28	21	0	5
Movements							
Tracks	43	7	39	33	21	0	0
Trails	6	0	17	83	0	0	0
Escape	18	15	69	0	15	0	0
Bedding	95	0	44	36	20	0	0
Feeding	18	0	0	0	44	0	56

close proximity (35 m or less) to good escape cover ($\chi^2 = 7.86$, $df = 2$, $p = < .05$).

Excellent escape cover is not widely distributed in the study area (Figure 3). One observation on a group of four demonstrated that they would go a short distance (40 to 45 m) out of their way to reach a cliff and chute area, although they already were on a steep talus slope.

The summer distribution of bighorn, found by the California Department of Fish and Game during an aerial survey, is shown in Figure 4. Weaver and Mensch (1970:3) stated, "There was no evidence of bighorn use on the eastern slopes of the mountain...". Jorgensen (1975:8) also noted that bighorn had abandoned the east slopes of the mountain range, and had all but abandoned the crest of the mountain range. Jorgensen (1975), however, surveyed all of the drainages on the east slope of the mountain range -- except those due east of the present study area.

Figure 5 shows the summer range of the White Mountain Peak bighorn as determined during this study. Significant amounts of bighorn sign were found continually both in the Lone Tree and Perry Aiken Passes (see Figure 1). Six bighorn trails also were adjacent to these passes, indicating significant amounts of use on the crest and east slopes of this mountain range.

Bighorn-human interactions were examined from two viewpoints: (1) that of a passive observer, and (2) that of an active observer. A passive observer does not look directly at the bighorn, but rather ignores them. Reactions to a passive observer are illustrated by two examples. Joan Haynes observed a group of bighorn half way between Mt. Barcroft and White Mountain Peak, during the summer of 1964. As long as the observers remained inside the jeep, the bighorn watched the vehicle and its occupants. As soon as one person stepped from the vehicle, the bighorn left the area (J. Wehausen pers. comm.). The distance between the observers and the bighorn is unknown. Observations as a passive observer resulted in an encounter with a fixed flock of 10 sheep at a distance of approximately 80 yards (73 m) on a horizontal plane. The lambs in the group continued to play and feed, but the older members intently watched me. After five minutes the group fled to steep talus slopes, apparently in response to my presence.

When an observer either appeared above or tried to gain elevation over a group of bighorn, they fled immediately. This happened even when the observer was as much as 400 yards (366 m) distant from the sheep on a horizontal plane



Whenever an active observer directly approached bighorn, 300 to 350 yards (294 to 320 m) seemed to be the critical flight distance. Beyond 350 yards, the animals stood and watched the observer, but obviously were nervous and concerned. However, when an active observer approached closer than 300 yards, bighorn immediately left the area. No cases of mass panic, as described by Geist (1971), were observed.

DISCUSSION AND CONCLUSIONS

The wide distribution of talus slopes in the White Mountain Peak area greatly influenced habitat selection by bighorn. This is evident from locations of tracks, beds, and escape cover utilization (see Table 1).

Fell fields probably are selected for trailing because they are easy to cross. This conclusion may be subject to observational bias, because: (1) trails are easily seen on fell fields, and (2) trails do not form well in other habitat types.

While both rocky grass and grass-sagebrush association areas received approximately equal use for feeding (see Table 1), grass areas did not receive any recorded usage. However, due to the close proximity to good escape cover and the presence of scowl type scats, grass areas probably are utilized to some extent during the early summer.

Generally, activities of the White Mountain Peak bighorn tended to be related to the proximity of adequate escape cover, such as moderate to steep talus slopes. Although talus slopes were used most as escape cover, cliffs and chutes, where present, seemed to be preferred.

The White Mountain Peak bighorn apparently have extended their range since the studies by Weaver and Mensch (1970) and Jorgensen (1975). Since Jorgensen (1975) did not survey the canyons east of the study area, he may have overlooked some east slope utilization. Utilization of canyons and basins on the east slope of the mountain range depends largely on the Lone Tree and Perry Aiken passes, which are about the only points used by bighorn in east-west movements from Lone Tree Canyon to the eastern slopes. Due to the gentle topography of Cottonwood Canyon, there are not critical crossing points there.

White Mountain Peak bighorn apparently are curious of humans who ignore them. The majority of the bighorn, however, are very "spooky," and will not tolerate humans directly approaching or being above them. A rapid increase in human activity, as proposed by the University of California, Berkeley, probably would cause the White Mountain Peak bighorn to abandon valuable summer range, especially the upper parts of Millner Canyon, North Fork Perry Aiken Creek Canyon, and White Mountain Peak, as well as all of East Basin.

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ROCKY MOUNTAIN BIGHORN IN DESERT HABITAT

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A group of Rocky Mountain bighorn (*Ovis canadensis canadensis*) live in the lower San Francisco River in southwestern New Mexico. This population is the result of a successful transplant of Canadian stock. The climate and vegetation of the area presently used by sheep is compared to the San Andres National Wildlife Refuge in south central New Mexico which was historically, and is presently, used by desert bighorn (*Ovis canadensis mexicana*). The San Francisco River area fits the general description of desert bighorn range and is similar to the San Andres desert sheep range.

INTRODUCTION

It is known from records of early explorers that bighorn sheep were historically found along the San Francisco River in southwest New Mexico and southeast Arizona. A soldier in Coronado's expedition about 1540 mentioned seeing bighorn sheep in an area which was probably near the confluence of the Gila and San Francisco Rivers in Arizona (Hammond 1940). James Pattie, who trapped along the San Francisco River, wrote of seeing bighorn in the canyon about 1825 (Bailey 1931). The last written report of bighorn anywhere in this area is of three that were shot near the confluence of the Mogollon Creek and the Gila River (Buechner 1960). The historic distribution of desert bighorn is given by Monson (1971) and Manville (1971). Both of these distribution maps show the San Francisco River area occupied by desert sheep. Buechner (1960) does not include the lower San Francisco River as inhabited by bighorn, but does include the upper Gila River and Mogollon Mountains only a few miles east of the San Francisco River. These areas were probably occupied originally by the subspecies mexicana rather than canadensis.

The present population of bighorn sheep along the San Francisco River is from a transplant made in 1964 of three rams and thirteen ewes released on Sheridan Ridge, which is part of the western foothills of the Mogollon Mountains. These sheep came from the Sandia Mountains near Albuquerque, a population that was started with Rocky Mountain bighorn from Canada in the 1940's. Also in 1964, a transplant of eight ewes and two rams from Banff, Alberta, were released in an area near Turkey Creek and the Gila River. In 1960, Buechner suggested the Turkey Creek area and the south facing slopes of the Mogollon Mountains as the best areas for bighorn sheep.

Within a year, most or all of the Sheridan Ridge transplant had moved west about 6 miles to settle in the San Francisco River canyon. There is still a small group of sheep in the Turkey Creek area and a small group on Whitewater Creek on the western edge of the Mogollon Mountains. The sheep along the San Francisco River number at least 100 individuals. This population has been hunted four times since 1970 with 17 rams being taken.

Factors which have no doubt contributed to the success of the sheep along the San Francisco River canyon are the excellent forage available in the area, the escape terrain provided by the steep river canyon and side canyons, the perennial water source provided by the river and the fairly intensive predator control practiced by the livestock operations in the area.

The purpose of this paper is to compare the San Francisco River area to desert sheep range and especially the San Andres National Wildlife Refuge. I would like to express my appreciation to the New Mexico Department of Game and Fish for funding two year study on the San Francisco River sheep population and particularly Byron Donaldson, Andrew Sandoval and Dr. Robert Lange, and to Dr. Raul Valdez for reviewing this paper and for help and advice during my graduate study.

METHODS

A literature search was made to compare the climate and vegetation of the San Francisco River area to other sheep ranges.

RESULTS AND DISCUSSION

The San Francisco River is on the western edge of the Chihuahuan desert as described by Jaeger (1957). The San Andres National Wildlife Refuge in south central New Mexico and the Big Hatchet Mountains in extreme southwest New Mexico which were historically, and are presently, occupied by desert bighorn are also on the edge of the Chihuahuan desert.

The vegetation of the San Francisco River area is characterized by a southern woodland association of pinyon (*Pinus spp.*) juniper (*Juniperus spp.*). This area is also in the lower and upper Sonoran life zones as described by Bailey (1913). Indicator plants of both zones are commonly found together over much of the area.

According to Buechner (1960), vegetation of the Turkey Creek area and the south facing slopes of the Mogollon Mountains, which are similar to the San Francisco River area, have much in common with the Big Hatchet Mountains.

The climate and vegetation of the lower San Francisco River area are more similar to the desert sheep range of the San Andres Wildlife Refuge than to the Sandia Mountains or the Sangre de Cristo Mountains in northern New Mexico, both of which are presently inhabited by Rocky Mountain bighorn.

When comparing the San Francisco River area to the San Andres Wildlife Refuge, many similarities are noted. The San Andres Refuge ranges in elevation from 4200 to about 8200 ft. compared to 4300 to about 7400 ft. in the San Francisco River area. The San Andres Refuge receives an annual average precipitation of 12-13 inches while the San Francisco River area receives 13-14 inches annually. Both areas receive the majority of the annual precipitation during the summer months, that is, July, August and September. Light to moderate snows are common during winter in both areas, although snow rarely remains on the ground for more than a few days except on north facing slopes. Summer daytime temperatures above 90°F are common in both areas. Compared to northern mountain ranges in New Mexico, winters in the San Andres Refuge and along the lower San Francisco River are relatively mild, although daytime temperatures below 32°F are common.

Major plant species common to both the San Andres Refuge and the San Francisco River area include common plants of the lower Sonoran life zone such as mesquite (*Prosopis spp.*), black gramma (*Bouteloua eriopoda*), acacias (*Acacia spp.*),

beargrass (*Nolina* spp.) and prickly pear (*Opuntia* spp.). Indicator plants of the upper Sonoran zone common to both areas include juniper (*Juniperus* spp.), pinyon pine (*Pinus edulis*), blue grama (*Bouteloua curtipendula*). Desert plants common to both areas are yuccas (*Yucca* spp.), sotol (*Dasylirion* spp.) and ocotillo (*Fouquieria splendens*).

The following statement by Monson (1971) is particularly relevant. "We look upon desert bighorn as an ecological entity, affected by environmental forces and distinguished from other bighorn on a basis of habitat rather than differences in size of bones. They belong chiefly to the warmer desert regions of southwestern North America where there is no snow or the snow cover is thin and ephemeral, and the annual precipitation is 5-15 inches." Hence, the lower San Francisco River area is desert bighorn habitat.

It will be most informative to follow the history of this herd to see if it does become recognizably different from Rocky Mountain bighorn and assumes desert bighorn appearance and habits.

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DECLINE OF BIGHORN SHEEP (*Ovis canadensis*), THE GENETIC IMPLICATIONS

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Abstract. Although bighorn sheep (*Ovis canadensis*) were numerous at the beginning of the nineteenth century, they have since declined sharply to fewer than 25,000 today. Several factors have contributed to this decline.

We know that herds of bighorn sheep have become more geographically isolated through time. With this isolation less genetic flow from other populations probably has resulted in an increased homozygous condition due to inbreeding. Has this inbreeding resulted in genetic deficiencies and have these deficiencies led to a loss of endocrine immune surveillance which is detrimental to survival? It is these questions and more which we propose to answer.

This research effort will supply data and direction leading to the improved management of bighorn throughout North American and, ultimately, enhance the survival of the species.

INTRODUCTION

The bighorn (*Ovis canadensis*) is a species which has decreased greatly in numbers through time. Their past history indicates that they were numerous during the ice age (Pleistocene) period. As glaciated ice fields receded and the bighorn spread into North America, they increased in number due in part to a lack of competition from an ecological equivalent (Geist, 1971). The bighorn in North America once numbered between 1,500,000 to 2,000,000 sheep at the beginning of the nineteenth century. Today bighorn number less than 25,000 in all of North America (Buechner, 1960). With such a decline, one should look for causative problems or changes within the bighorn's lifestyle or environment.

The bighorn survived and spread to most major mountain ranges in the Northern hemisphere, thus implying that sheep were successful dispersers and colonizers (Geist, 1971). In contrast today, bighorn are not dispersing and colonizing as they did so successfully in the past (Geist, 1971). Furthermore, their pioneering habits have been suppressed because of their high degree of specialization and the surrounding competition and stresses which they face today (DeForge, 1976).

The movements of bighorn sheep for food and water requirements are restricted by the introduction of fences, roads, livestock, and building developments (Oldemeyer, et al., 1971; Wilson, 1968; DeForge, 1972). Thus, the bighorn today tends to use the same range year after year. Home ranges are inherited by young sheep from their parents, thus producing a high

degree of loyalty (Geist 1971). This loyalty, or loss of **exploration**, is due to their very nature or way of life, and competition resulting from the above-stated circumstances (fences, roads, etc.).

Scientists researching the bighorn have investigated habitat needs, bighorn behavior, diseases, etc., and although the answers to some problems have been found, most research has produced more questions than answers. In California, as well as other states, poor lamb survival has been of **major concern**. High lamb mortality during years of both good forage production and water availability has been witnessed (Weaver, 1974; Sudmeier, 1978). Also, **sharp population declines** in the last five years in such areas as the San Jacinto Mountains has been reported (Lutz, 1978). Furthermore, the apparent **extinction** of sheep from such mountain ranges as the Whipples, Shadow, Quail, and Granite Mountains in San Bernardino County has occurred within the last **twenty-five years** or less (Weaver, 1969; Sudmeier, 1978). In the "Status of the Bighorn Sheep in California," Weaver (1974) states: "Sheep have declined in number in many areas during the past quarter century. However, there are thrifty herds remaining in some areas."

Why are some herds thriving while other herds apparently under **similar** conditions are doing so poorly? Is there a genetic reason for this difference?

As bighorn sheep herds become more geographically isolated through time, less genetic flow from other populations (gene pools) may have resulted in an **increased homozygous condition**. It is possible that genetic and **endocrine-immune deficiencies** which do not favor survival have resulted from this inbreeding.

It is this question that we propose to study. If the results do show genetic deficiencies, then a program of relocation and introduction of "new blood" into **thrifless** herds will be proposed in an effort to genetically revitalize the herds and produce a more healthy bighorn species in North America.

INBREEDING

The reasons for suspecting inbreeding and genetic weakening in bighorn sheep are the following:

1. Studies in other **species** have shown the genetic effects of close inbreeding and the **definite** stress-related failure of these species to **survive** a normal lifetime and to produce viable **offspring** (Stiehm and Fulginiti, 1973; Plechner, 1978a). The **aging** process in these animals has definitely **begun** much earlier in life due to loss of endocrine-immune **surveillance** leading to self-immune (auto-antibody-immune complex) diseases (Good and Fisher, 1974). (Note: The early production of auto-antibodies is associated with **aging** in people and final death.)

2. Field studies (DeForge and Jenner, 1977) have shown that often 90 percent of the ewes conceive and have a lamb, yet often **80 percent** or higher lamb mortality results within the first 10 months (Welles and Welles, 1961; DeForge, 1976, 1978). Standard post-mortem studies have not revealed the reason for these **early** deaths. However, an antibody deficiency in the lambs, specifically **IgA** and others, could cause this problem. This specific antibody deficiency would be a genetic **trait** that eventually could become widespread and detrimental to the sheep (Note: There is excellent evidence in allied species that these tendencies are **familial** (Stiehm and Fulginiti, 1973; Plechner, 1978b, 1978c)). It is easy to understand how such a **condition** could be readily transferred to an entire herd of sheep through one dominant ram, with the result that after

80-100 years of close inbreeding many individuals would exhibit this and other genetic weaknesses.

3. This situation of antibody deficiency (**agammaglobulinemia**) is occurring in a captive herd of bighorn sheep at the Brookfield Zoo in Chicago (DeMartini, 1978). The resident veterinarian has found that virtually no antibodies are being passed from the ewes to her **lambs**. Consequently, most of the lambs are dying by the time they reach six weeks of age from a chronic respiratory disease.

4. The value of **wild dogs**, hyenas, and other predators in Africa has been recognized as an important means of keeping the animal herds intermixed and **dispersed** so that natural inbreeding is less likely to occur. Because of man's encroachment and associated activities such as the building of highways and railways, herds of wild sheep are quite limited and certainly isolated from other wild sheep herds. Now that we are **seeing** a very serious decline in our sheep herds, a few dominant rams servicing their own bands of ewes may be **responsible** for reproduction in a large segment of the now diminished herd. Thus, it seems likely that a true state of **unmonitored inbreeding** has occurred for many years. Consequently, we must examine this immune factor, plus all those other factors necessary for survival of our **wild** sheep, if we are to reverse the bighorn's decline.

OBJECTIVES

1. Evaluate the effects of **inbreeding** on bighorn sheep in the state of California.
2. Determine taxonomic identity of all bighorn sheep herds within California.
3. Investigate the occurrence of disease and parasites **afflicting** bighorn populations within California's bighorn herds.
4. Establish a complete genotypic and phenotypic **profile** on these bighorn sheep.
5. Create guidelines for the successful relocation and introduction of new blood into **thrifless** herds throughout California.
6. Establish guidelines using our **basic** protocol, which can be applied to all species of **wildlife**, to assist in their continued survival.

METHODS

Our research team will be working in conjunction with the University of California, where James R. DeForge will be in a doctoral program. Veterinarians, personnel from the Department of Fish and Game, and other professional and lay people will be assisting in the collection and analysis of the data.

Significant numbers of bighorn sheep from all recognized herds in California along with other states and Mexico will be sampled to determine a base profile and standard with which to work and compare. These sheep will be immobilized and sampled by methods that have been tested, proven, and routinely used by members of this research team in past bighorn projects.

The sampling will include the following:

1. Phenotype
 - a) General appearance — 35 mm slides will be taken of each sheep sampled, including a **lateral** full body view, a frontal view, and a caudal view.

b) All pertinent physical measurements will be taken at the time.

c) Age, sex, and overall clinical condition will be determined.

2. External parasites

3. Fecal samples

a) Physical characteristics

b) Parasites

c) Bacteria

d) Virus

4. Blood Samples

a) Immune panel

1. B lymphocytes

2. T lymphocytes

3. Immunoglobulins - IgA, IgG, IgM

4. Colostrum - immunoglobulins

b) Blood chemistry

c) Blood serology

d) Electrophoresis - determination of genetic distances and levels and heterozygosity for serum proteins of bighorn herds (Nei, 1972; Adest, 1977).

e) Haptoglobin - newer method to assist and reinforce the already established methods for taxonomic identity.

f) Hematology

(Note: When possible ewe and lamb bloods will be analyzed for immune transference.)

5. Histopathology

Any sheep found in a terminal or near terminal state will be evaluated and treated therapeutically. If an animal is found dead, a complete histopathological evaluation will be performed to add further data to the standard bighorn profile.

6. Immunopathology

All tissues collected will also be microscopically examined for further data regarding immune precipitates, vasculitis, circulating antigen-antibody compounds, autoimmunity, and other immune complex disorders, which often accompany inbreeding and genetic disorders.

7. Effects of stress

The relationship of environmental stress and bighorn sheep behavior patterns will be researched in a new manner, by means of testing certain stress-related hormones, such as epinephrine, cortisol, ACTH, estrogen, T₃ and T₄. These findings will be correlated with the environmental observations of DeForge. If possible, offspring will be tested for resting cortisol levels and ACTH-stimulated cortisol levels to insure a healthy adrenal cortex, which is of tantamount importance to stress-related diseases and is necessary for normal endocrine immune surveillance and survival,

8. Translocation (pending State approval)

Upon determining which herds have the ability to survive and propagate for the future, specific animals will be taken and translocated to those herds that have shown the greatest decline and have the greatest possibility of extinction; then secondly, sheep will be taken for the repopulation of historic bighorn range no longer inhabited or utilized by bighorn sheep today.

In addition, a 16 mm movie film documentation will be made of this research. This will supply a visual account of both bighorn range conditions as well as field procedures. William D. Phifer will direct this effort.

CONCLUSIONS

This project will provide a genetic profile on bighorn sheep herds, and develop a standard profile which may be used as a basis to test, determine, and develop healthy bighorn sheep. This standard genetic bighorn profile will correlate such findings as phenotype, taxonomy, habitat, and environmental stress. These results may then be used to locate and capture healthy sheep as determined by this standard bighorn profile. These animals will then be translocated into the herds showing the greatest decline and greatest chance of extinction. After these established sheep herds have been stabilized, we would then repopulate historic bighorn ranges that are no longer inhabited.

With this data, we will be able to prescribe the genetic repopulation of sheep within the same subspecies status. We will establish norms for each subspecies and determine the true taxonomic identity of our bighorn populations.

The suggested methods for all segments of this bighorn sheep project, including various clinical, blood and immunological tests, are all established, proven procedures currently in great acceptance. Our program is merely the overall organization and application of these procedures in a specific wildlife research program.

This protocol may be used as a base standard for most species of wildlife in the United States and may be easily applied to these species with minimal change.

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BIGHORN SHEEP SKULL IDENTIFICATION AND CERTIFICATION IN NEVADA

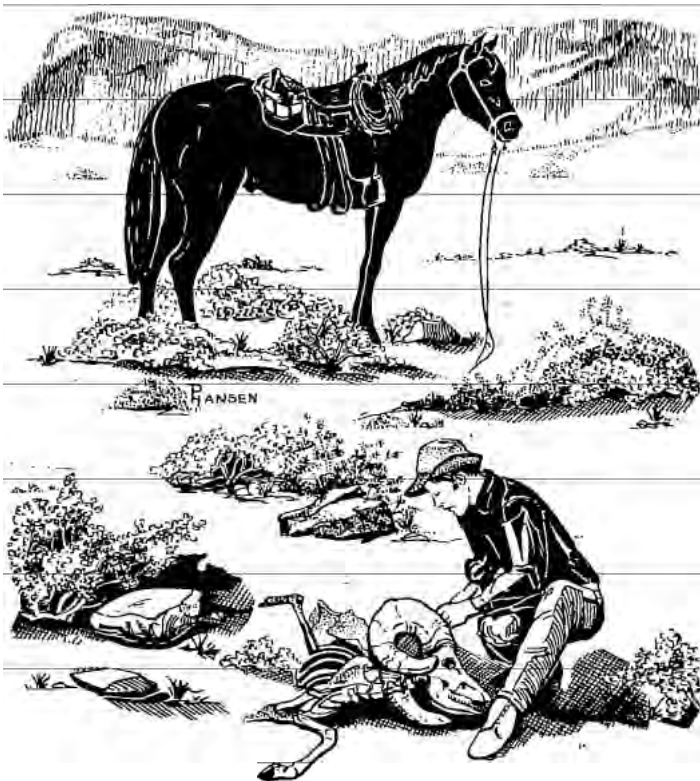
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Abstract. Since 1972, bighorn sheep legally harvested in Nevada were identified by using a lead wire seal which indicated that the animal had been legally harvested and inspected by a representative of the Department. The lead wire sealing procedure did not provide positive identification of the bighorn trophy. A new procedure initiated in 1978 replaced the lead wire seal with a unique identification number that is branded onto the horn. The branded number coupled with close up photography of the horn section including the brand number provides positive identification of legally harvested bighorns from Nevada.

INTRODUCTION

During the early 1970's, national interest was aroused with reports of increased activity involving illegal possession of bighorn sheep and the promotion of "trophy poaching" (Tsukamoto 1974). Welsh (1971) reported that poaching accounted for 41% of the one hundred and forty-one observations of bighorn sheep deaths analyzed from Arizona and Nevada. Poaching accounted for the largest number of deaths despite the fact that it was also the most difficult category to uncover due to the clandestine nature of the activity. During the meeting of the 17th annual conference of the Desert Bighorn Council held in Tucson, Arizona, on April 6, 1972, a resolution was passed concerning the permanent identification of heads/horns of legally taken bighorn sheep. The resolution in part stated, "Now, therefore, in order to provide the greatest possible protection to desert bighorn sheep, be it resolved by the Desert Bighorn Council that all States having resident mountain sheep populations be encouraged to establish a system for the identification of all legally acquired bighorn sheep heads/horns, such as an official seal, to be permanently attached to heads/horns." The Northern Wild Sheep Council passed a similar resolution in February, 1976, and a committee was adopted to work on a system for marking, registering and circulating data (Thorne and Hickey 1977).

In 1972, the Nevada Department of Fish and Game recommended to the state of Nevada Board of Fish and Game Commissioners to adopt such a regulation. As a result of Commission action the following regulations were promulgated: "Commencing with the 1972 sheep season, any person killing a bighorn sheep shall have their tag validated and the skull sealed by personally presenting the skull and hide to a representative of the Department of Fish and Game within five (5) days after the bighorn sheep is killed. It is unlawful for any person to have in his control or possession such bighorn sheep skull without the Department seal permanently attached to the horn. Any bighorn sheep trophies legally taken prior



to the 1972 season are exempt from the above sealing requirement."

PROCEDURES

The formulation of a sealing procedure that would be an effective means of permanent and nonduplicatable identification of all legally taken bighorn sheep was no easy task. Nevada's initial attempt was to validate the tag with a signature and date by an authorized Department representative. The skulls were then sealed by drilling a 1/16 inch diameter hole through the outer curl of the horn catching only a small section of the inner ridge of the outer circumference of the horn. A lead wire seal was positioned near the 3rd quarter of the horn so as to be concealed when mounted in life form. The lead seals contained the Inscription NEV-FG on one side and NEV and year on the opposite side (See Figure 1).

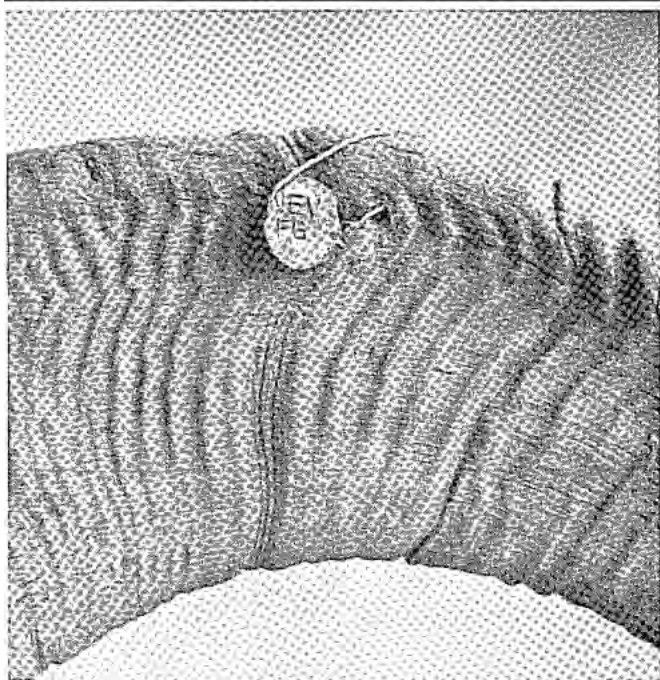


Figure 1. Nevada Department of Fish and Game Bighorn Sheep Seal used on all legally harvested animals during the 1972-1977 hunting seasons.

All states that presently hunt desert bighorn have instituted the lead wire seal procedure for identifying legally harvested sheep. Several states hunting other subspecies of sheep seal the horns. In Montana, for example, skulls are sealed using a lead wire seal attaching a plasticized numbered tag, measuring approximately 1 1/2 inches square.

The lead wire seal was a first attempt at identifying legally harvested bighorn in Nevada. After evaluating the sealing of 267 legally harvested bighorn, several deficiencies were noted in the technique, as follows:

1. The lead wire seal and seal press can be purchased by anyone; therefore, illegal imitations of seals could be easily duplicated.
2. In most cases the sealing procedures did not address whether the horn could be positively identified in the future.

Although attempts were made to take measurements at various locations on the horn, horn shrinkage rendered these measurements useless as a means of positive identification.

General photos taken at various angles were taken as an aid to identification, but were not detailed enough to provide positive identification.

3. Lead wire seals were often damaged and the inscriptions rendered unreadable. On occasion the hole was drilled into the horn core creating some difficulty for taxidermists. Seals were frequently lost when the wire broke from handling and/or corrosion.

4. Hunters sometimes complained about the necessity of drilling a hole into the horn of their trophy. Were it not for the regulation, most hunters would not voluntarily give permission for this procedure.

The development of new procedures was guided by the following criteria:

1. Procedures be simple to accomplish.
2. Require no specialized and/or costly equipment.
3. Do not damage or otherwise detract from the trophy value of the horn.
4. Provide permanent, nonduplicatable identification.

Beginning in 1978, all legally harvested bighorns were branded with a four to five digit number followed by a NV alpha abbreviation of the State, as per example: 7801NV.

78. designated year of sealing

01 - animal number

NV - State abbreviation

The unique brand number is located on the back side of the right horn between the third and fourth year annuli, as shown in Figure 2.

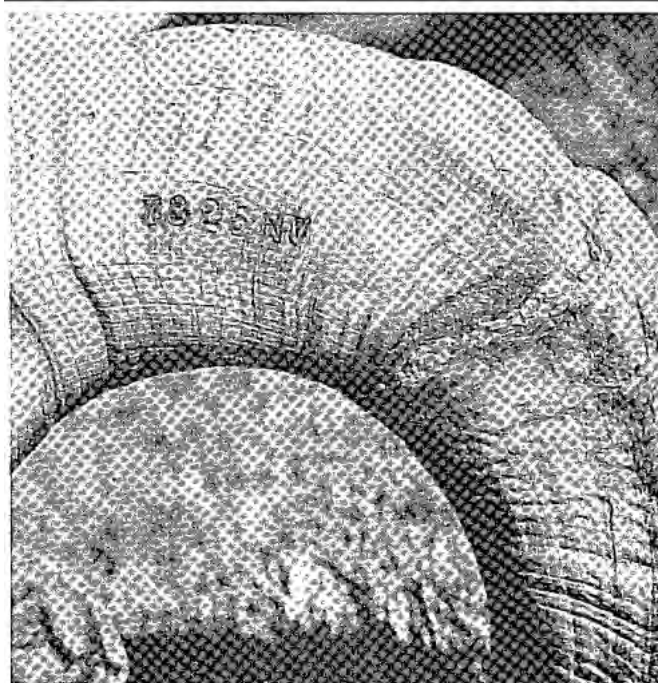


Figure 2. Nevada Department of Fish and Game Bighorn Sheep branded serial number for positive identification and certification of legally harvested bighorns in Nevada.

Metal stamping dies with ¼ inch characters are used as the iron to brand the serial number onto the horn. Dies are available from McMaster-Carr Supply Company, Los Angeles, California, for approximately \$25.00 per set. The dies are held with an adjustable vise grip plier and heated using a 14 ounce propane cylinder torch. Branding dies were always pretested on a block of wood to insure that they contained sufficient heat to produce a well defined permanently etched brand. Branding multiple numbers simultaneously was not successful because of the uneven heat distribution and retention characteristics of the individual dies and the rough surface of the horn. In addition to the branding, the following procedures are followed during the sealing process:

1. Physical measurements of the horn are taken using the official Boone and Crockett scoring system.
2. A photo record is maintained of the hunter and his trophy. A front and side view (left and right) of the horns is taken. Additionally, a close up photo of the branded number showing the details of the horn corrugations and annuli is taken. This photo is used as the basis for positive identification of the horn in the future.
3. A bighorn sheep certificate of possession is issued to all hunters who legally harvest a sheep.

During the 1978 season, 55 legally harvested desert bighorn sheep were branded with the new identification procedure. A permanent file was established at two separate locations in the Department of Fish and Game to assure maintenance of permanent records. The sealing procedures were well accepted by the hunters. Checkout time did not increase with the adoption of the new procedures.

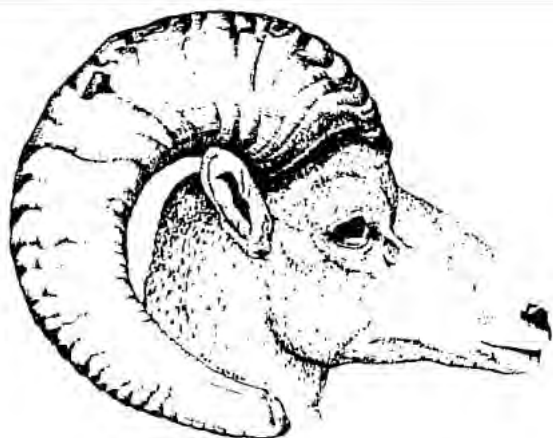
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DESERT BIGHORN RESEARCH AND MANAGEMENT BIASES RELATING TO POPULATION CHARACTERISTICS AND HUMAN INTERPRETATIONS

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Abstract. Some of the reasons for biased desert bighorn population data are reviewed. Specifically, ewe-lamb ratios, ram-ewe ratios, census surveys to determine total numbers, literature reviews and references to other publications or populations are discussed. Recommendations which could help reduce the degree of biases are given.

INTRODUCTION

Desert bighorn sheep are one of the most difficult native North American wild ungulates to study and are subject to high sample biases. The reasons for making this statement are:

1. Desert bighorn are difficult to survey because they blend with their surroundings and their densities (number per unit area) are usually sparse.
2. The terrain they occupy is extremely rugged and difficult to survey regardless of the method used; therefore, all are seldom observed or counted. Thus, one obtains a census estimate, not a true census.
3. Significant numbers of one sex or the other can be missed. Rams three years of age or older usually occupy areas separate from the ewes, lambs and younger rams except during the rut.
4. Desert bighorn are generally widely distributed and rarely congregate in predetermined areas as do bighorn populations on winter ranges in more northern latitudes.
5. Most desert bighorn populations have not been studied to the extent that ideal conditions for surveying a given population are known.
6. When resting or frightened, desert bighorn often seek overhangs or caves where they are difficult to observe.
7. Most desert bighorn populations have been separated in time and space for several decades. Many have evolved unique behavior and habitat use characteristics.
8. They appear to have a more complex social structure than has been previously documented and understood.

The purpose of this paper is to discuss some of the reasons biases occur and to offer suggestions to help reduce the degree of some of the biases in the future.

Lamb-Ewe Ratios: Bighorn counts other than those made on foot to determine lamb-ewe ratios **should not be conducted** one month before, or during the lambing season. Stress caused by harassment from aircraft or other motorized vehicles could result in undue stress to pregnant ewes which could cause abortions or injuries to newborn lambs. Therefore, increased lamb **and/or** ewe mortality would result in higher than normal mortality rates, thus biased data.

Data biases can occur as a result of desert bighorn ewes' secretive behavior during the lambing period. During this period, pregnant ewes seek out rough, precipitous areas as lambing grounds. This has been documented in Arizona, New Mexico, Nevada, California (Monson, 1959) and Utah (Wilson, 1966). During the lambing period, pregnant ewes or ewes having newborn lambs are extremely wary and **will hide** or run at the least disturbance. For these reasons, they are easily missed during counts compared to non-productive older adult ewes and yearling ewes **which** seldom show the same degree of wariness during the lambing season.

For general management purposes, it is recommended that aerial censuses for determining lamb-ewe ratios not be taken from one to two months following the lambing season. Lambs one to two months of age, will often lie prone and not move when alarmed. I have walked within two to three feet of hidden lambs and they did not move. Again, significantly biased samples can be gathered if aerial counts are made during this period.

It is recommended that counts to determine lamb-ewe ratios should be taken from just before sunrise until two hours following sunrise when lambs are between two and three months of age. Nelson's bighorn lambs in southeastern Utah were observed seeking areas to rest and hide from two to three hours following sunrise. On many days, ewes did not return for their lambs until dusk (Wilson, 1968). Therefore, ewes counted without their lambs would give a biased sample. To my knowledge, this behavior trait has been documented **only in** a southeastern Utah population; it is conceivable that bighorn in other populations exhibit the same behavioral trait.

Ewes **will** often leave their lambs with other ewes for long periods during the day as documented by Honess and Frost (1942), Russo (1956), Welles and Welles (1961) and Wilson (1966). I have seen as many as eight lambs with one ewe. If a count were made during one of these periods (usually one to two months following the lambing season and usually two hours following sunrise), **missing** the lambs or the adult ewes would result in a biased sample.

Lambs often will not accompany ewes to waterholes **until** they are weaned (two to four months) (Wilson, 1968). Therefore, lamb-ewe ratios computed from waterhole counts also can be significantly biased if made during this period.

Yearling rams are a constant source of potential data bias when undertaking lamb-ewe counts. Yearling rams can be difficult to differentiate from ewes for anyone who has not observed many bighorn. They can be extremely difficult to differentiate to the trained eye when bighorn are running, particularly if they are **being** observed from a helicopter or airplane. If there is any doubt as to the age **and/or** sex of any animal(s) during a census, they should be shown as unclassified.

Lamb-ewe ratios compiled from waterhole counts can be significantly biased when taken during or following rainy periods **and/or** before lambs are about four months of age. **Following** rainy periods in southern Utah, desert bighorn have

hundreds of small ephemeral tanks available to them and **will** normally move **into** the areas of ephemeral tanks and away from permanent tanks until the ephemeral sources become dry (Wilson, 1968). Lactating ewes go to water almost daily, but on many occasions do not bring their lambs with them (Wilson, 1968). It also is **probable** that ewes which are not **lactating** do not **water** as often as lactating ewes. Lactating ewes are difficult to differentiate unless accompanied by a lamb. In all three cases, a biased lamb-ewe ratio could result.

Ram-Ewe Ratios: As previously discussed, yearling rams can be difficult to differentiate from adult ewes. This is also a constant source of bias when determining ram-ewe ratios.

The rut is probably the best period to obtain ram-ewe data. Generally, the rams are in habitats occupied by ewes, lambs and young rams. During this period the rams are active and less wary, thus easier to observe than at other times of the year (Welles and Welles, 1961; Wilson, 1968). Less area needs to be surveyed during the rut and the **probability** of sampling more of the population is increased. At times other than the rut, older rams (over three years of age) generally occupy areas separate from ewes, lambs and young rams, and significant segments of the ram population can be missed (Wilson, 1968; Geist, 1971).

One must be careful in using waterhole counts for ram-ewe ratios as rams can go up to 5 days without watering (Grove, 1961). ~~At night they may do so.~~ **Bighorn, particularly** rams, are known to be active on moonlit nights (Monson, 1964; Wilson, 1968) and **occasionally** on dark nights (Monson, 1964). Therefore, waterhole counts during the rut and during the dark of the moon would reduce biases when **computing** ram-ewe ratios.

Surveys to Determine Total Numbers: Population estimates other than those which are known to be minimum population estimates should never be used for making harvest recommendations. Harvest levels developed from minimum population estimates will always be conservative, therefore, the possibility of over-hunting should be significantly reduced. Any additional mortality or stress, such as hunting during periods of population declines, can have long-term adverse population implications. Population declines, particularly in their initial stages, are often difficult to identify or predict.

Some of the biases that can result in counting bighorn for the purpose of making population estimates are:

1. The time of year, as previously discussed, and climatic conditions.
2. The familiarity with the habitat and the bighorn experience of the person(s) making the census survey.
3. The method of aerial survey (helicopter or fixed wing) and the experience of the pilot.
4. There are no known methods of determining the number of bighorn missed in a survey.

I learned early in my career the degree to which one can over- or underestimate a bighorn sheep population. On June 24, 1966, I completed a walking survey for bighorn the north side of White Canyon (about 100 square miles) in southeastern Utah. Based on the number of animals observed, I estimated there were 50 bighorn in the area. On June 27, 1966, three days later, I observed 32 ewes and lambs in one herd in the same area. I am positive I did not observe any of these sheep during the previous survey.

Literature Review Prejudice: It is generally standard practice to undertake a comprehensive literature review before undertaking research. In the area of bighorn behavior, this could lead to prejudices. I have often wondered how much my Utah research was biased by initiating "research" with preconceived ideas. How many of the conclusions relating to animal behavior were the result of others influencing my conclusions which could be in error? For example, I read repeatedly that hunting is justifiable as: (1) Hunting reduces excessive rams from a population; (2) Unproductive old rams are removed from the population; (3) Fewer rams in the population would result in reducing excessive ewe harassment during the rut. These three reasons sounded logical and I recommended a bighorn hunt in Utah for these reasons. It never entered my mind to question these reasons because they were cited in the literature on so many different occasions. To my knowledge, there are no data to support these contentions.

Reference Citation Biases: Citations of other publications is a standard procedure used by authors to substantiate some of their findings, give information on a subject for which their data may be lacking, or for comparative reasons. Extreme prejudices can occur in the latter two instances.

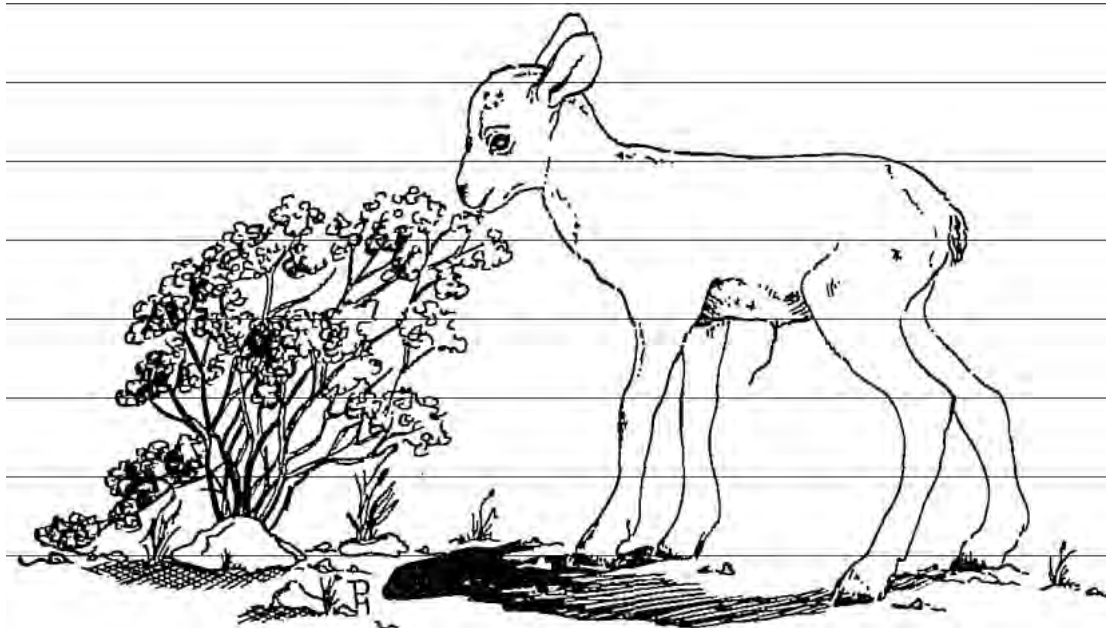
In reviewing the desert bighorn sheep literature, the rut is probably the least understood or described. Most of the rut-related research quoted in the literature has been done by Geist (1971) for Rocky Mountain bighorn in Canada. Neither Welles and Welles (1961) nor Geist's observations or conclusions adequately describe what I observed for Utah desert bighorn or other desert bighorn populations. Therefore, in my opinion, there are significant differences in rut behavior between populations. Not recognizing these differences, yet managing on the basis of rut behavior of other populations, could result in poor management.

One of the greatest prejudices in bighorn research is the citing of references for comparative reasons, particularly those related to learned behavior. Too often the exception rather than the norm (or in some cases, quoting out of context) can result in improper management recommendations or decisions. For example, the caption of a picture in Big Game of

North America, Ecology and Management (Schmidt and Gilbert, 1978, p. 293) states: "Bighorn habituate readily to humans and artificial situations where there is no hunting." The possible ramifications of this statement as it relates to bighorn management are far reaching. To my knowledge, there are four populations in North America of over 250 bighorn populations that exhibit the above stated behavior. These four known bighorn populations are in National Parks. In California, bighorn have not been legally hunted since 1873 and none of the California populations have become habituated to humans (Richard Weaver, 1979, personal communication). Valerius Geist, who wrote the chapter on bighorn for Big Game of North America, Ecology and Management, qualifies the above remark in the text. However, in my opinion, emphasizing the exception rather than the norm could prejudice some future management decisions.

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MOVEMENTS OF DESERT BIGHORN SHEEP IN THE STUBBE SPRING AREA JOSHUA TREE NATIONAL MONUMENT

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Abstract. The Stubbe Spring herd of desert bighorn is the largest group of sheep in Joshua Tree National Monument. Concentration of this herd in the Stubbe Spring area has caused concern since 1965 about possible over-utilization of the summer range surrounding one water source. A telemetric study of movements of bighorn sheep in the Stubbe Spring area was initiated in the summer of 1976 to assist in selecting a guzzler site in the Little San Bernardino Mountains. It is hoped that installation of an additional guzzler will enable the herd to expand its range and its numbers. Signals from radio collars were monitored from aircraft and from the ground. Helicopter surveys of the study area and surrounding bighorn habitat were conducted in 1977 and 1979. Data were processed by computer to derive 95 percent confidence intervals for home range areas. These analyses indicate a site 1½ to 2 miles west to southwest of Stubbe Spring to be the location at which a new guzzler would have the highest probability of use by sheep.

INTRODUCTION

One of the most severe problems facing desert bighorn sheep is the loss of habitat. Most habitat loss can be attributed to human encroachment, or alteration of the environment. In Joshua Tree National Monument, this encroachment has taken the form of mines, roads, campgrounds, hiking trails, and parking lots. In addition, communities surrounding the Monument have increased in size. The tremendous increase in numbers of residents in the Morongo Valley, and the tripling of visitor use in the Monument has resulted in increased demands for water. It is thought that increased pumping of underground water has led to reduction of the water table to the point that many of the historic springs of the Monument have gone dry. An unfortunate shift in the climatic regime also resulted in reducing the average annual precipitation from about 4.5 inches to one inch, as recorded at Monument Headquarters. Long-term weather records indicate that the Monument has been experiencing a drought over the past 10-20 years. The season most affected has been from January through March. Precipitation during these months is vital for filling tanks and charging springs [and guzzlers] for summer use by wildlife [Douglas, 1976].

In the mid-1950's, some springs within Joshua Tree National Monument [JOTR] had already gone dry, and many others were

beginning to produce less water. Former water sources that numbered in the 60's have now decreased to fewer than 10. The severity of this problem is exemplified by the history of Stubbe Spring. In 1948 the spring produced 222 gallons per day, by 1964 the flow was reduced to 96 gallons; in 1967 the flow was only 15 gallons per day. In 1968 the spring was flowing intermittently and was virtually useless to bighorn. A five year spring rehabilitation program led to the construction of a collecting system and guzzler at Stubbe Spring in 1968.

In 1957, Lowell Sumner noted that trails radiate in all directions from Stubbe Spring, and that sheep appear to come from unusually long distances to this water source. Our aerial surveys confirm Sumner's observations, and we postulated that this may indicate why the lamb count at Stubbe Spring has been low for many years. We reasoned that ewes may not bring nursing lambs with them because of the distances involved. It also is known that female bighorn sheep may leave their lambs in a nursery group, under the care of other females, while foraging at a distance from the area, or while visiting a distant waterhole.

Our studies since 1974 confirm earlier reports that a disproportionately large number of sheep were relying on water at Stubbe Spring, in relation to springs in other parts of sheep habitat. Knowledge of the extent of movements of sheep in the Stubbe Spring area was necessary before park managers could place an additional water source [guzzler] in the Little San Bernardino Mountains, and thereby help spread out the distribution of sheep and increase the availability of critical summer range.

Guzzlers generally are installed at sites of drying springs, or at sites of former springs. In JOTR, the majority of springs have been dry for so long that there are no sheep in the population that would remember using springs that are now dry. As a consequence, guzzlers need not be located at spring sites, but they must be placed within sheep use areas where there is a high probability that sheep will find and use them.

Several potential guzzler sites were selected for JOTR in the early 1970's by Weaver, Hansen, and Blaisdell. Selection was based on areas having adequate forage, escape terrain, and historic water sources. Once such site was the Pinyon Well area. We anticipated that the telemetry study would show whether bighorn traversed the nine air miles from Stubbe Spring to the Pinyon Well area. As it turned out, the sheep did not move that far from Stubbe Spring.

METHODS

This study was begun in 1976 as a cooperative effort between the California Department of Fish and Game [CDF&G] and the National Park Service [NPS].

A corral trap having a drop-gate panel was installed at Stubbe Spring in June of 1976. This trap was borrowed from the Nevada Dept. of Fish & Game. The periphery of the trap consisted of heavy nylon mesh netting suspended from external poles. The trap is designed so that there are very few objects trapped sheep can strike while struggling to get free. This trap was used in trapping operations during 1976 and 1977. A similar trap was built by the NPS and used in trapping operations in 1978.

Three trapping sessions, each of two weeks duration, were conducted in July of 1976, 1977, and 1978. The 1976 trapping period was unsuccessful owing to moderate temperatures;

this moderate weather was followed by late summer rains, which precluded further attempts to trap.

Trapped animals were restrained by hand, and blindfolded to minimize excitement. These trapped Individuals were equipped with radio telemetry collars [Telonics, Mesa, AZ] with a lithium chloride battery having a life expectancy of 18-24 months. Radio signals were monitored at least once a week during the first phase of the study, and twice a month thereafter. Most monitoring was done from fixed wing aircraft.

Four rams and five ewes were fitted with telemetry collars in the trapping period of July, 1977. Ages of rams were 8, 8, 9, and 12 years. Unfortunately, the batteries did not function for the expected period and it was necessary to equip more sheep with collars in 1978. Eight days of trapping were done during 23 July to 8 Aug 1978. Three ewes and one yearling ram were captured and equipped with collars. Summer rains dispersed the sheep and prevented the trapping of more individuals.

Locational data were assigned coordinates by superimposing a grid system on a map of the study area. These data were run through a principal components analysis program at the University of Nevada's Computer Center. Data for each sex were analyzed separately, and combined. Ninety-five percent probability ellipses of locational data were constructed as an aid to analysis of seasonal use areas.

Helicopter surveys were conducted in October, 1977 and June, 1979. Each survey required approximately 13 hours of flight time. A part of the Monument having major concentrations of bighorn sheep were surveyed. These include the Stubbs Spring area, the Wonderland of Palms Oasis-Queen Mountain area, the Quail Mountain area, and the Eagle Mountains.

RESULTS AND DISCUSSION

This research project was designed as a short term, highly directed approach to answer two pertinent management questions: What is the extent of movements of bighorn utilizing Stubbs Spring, and where should an additional guzzler be placed to allow use of more potential summer range? Thus, movements and home ranges of Individual sheep were of limited importance, whereas the extent of herd movements was of paramount concern.

Results of the helicopter surveys are given in Tables 1 and 2. Most sheep were seen in the Stubbs Spring area. Of special interest was the survey of 1977 in which 27 ewes and 3 lambs were seen about two miles west of Stubbs Spring. More lambs were seen throughout JOTR in October 1977 flight than were seen during the June flight. More rams were seen during the June flight. Two rams were seen in the 1978 burn on Quail Mountain on the flight of June, 1979. These rams were well within the burn, perhaps attracted by the new vegetational regrowth in the area.

Almost every sheep that watered at Stubbs Spring during the trapping periods was captured and equipped with a collar. Table 3 lists the animals trapped, age, sex, and numbers of relocations. We might have chosen an equal number of rams and ewes, had we been given a choice. Nevertheless, our sample was random, and represents approximately 20 percent of the Stubbs Spring herd. Owing to the highly social nature of desert bighorn sheep, our sample should reflect the distribution of the majority of the herd with respect to Stubbs Spring

TABLE 1. Results of helicopter survey of Joshua Tree National Monument for bighorn sheep 10/3/77-10/5/77 **

Number of individuals Seen				Location
Ewes	Rams	Lambs	Total	
1	1	1	3	Fortynline Palms Oasis
4	1	2	7	Barker Dam
27	8	3	38	Stubbs Spring area
1	1	1	3	Eagle Mountain
33	11	7	51	TOTALS

**Revised from Biannual Report No. 8 CPSU/UNLV

TABLE 2. Results of helicopter survey of Joshua Tree National Monument for bighorn sheep 6/25/79-6/27/79

Numbers of Individuals Seen				Location
Ewes	Rams	Lambs	Total	
7	6	0	13	Wonderland of Rocks/ Queen Mtn.
0	2	0	2	Quail Mountain
12	7	3	22	Stubbs Spring area
7	3	0	10	Eagle Mountain
26	18	3	47	TOTALS

TABLE 3. Summary of desert bighorn sheep equipped with radio-telemetry collars in Joshua Tree National Monument, including sex, age, number of observations, and maximum distance traveled from Stubbs Spring.

Collar #	Sex	Age	#Observations	Max. Distance from Stubbs Spring in miles
1	male	12	12	6.25
3	female	2	15	4
4	male	8	Not Relocated	
5	female	4	23	3
6	female	1	7	1.25
7	female	3	13	3.25
8	male	9	5	2
9	male	8	10	5.25
10	female	5	18	5.75
1A	female	*	13	3
2A	female	*	10	1
3A	male	1	11	2.25
4A	female	1	7	2.25

*Age not determined

Sufficient locational data [five or more relocations] were obtained to allow plotting of home ranges for 12 individuals [Table 3]. One ram [No. 4] was not relocated after being equipped with a collar. One ewe [No. 4a] collared in 1978 died after seven locations were recorded. One ram was found dead in the bottom of a shallow well in the Covington area. This location represents the northernmost point of the composite ram range [Fig. 1].

Composite home ranges for all bighorn sheep equipped with radio collars are shown in Figure 1. The composite range of rams [dotted outline] extends farther to the northwest and southeast of Stubbe Spring than does the range of ewes. Ewes [dashed outline] ranged farther to the west and southwest of Stubbe Spring than did rams. The composite home ranges represent data from 12 animals, four rams and eight ewes; a total of 38 locations was recorded for rams, and 106 for ewes.

Although composite home ranges define the maximum extent of movements by radio collared animals, the distribution of locations within the composite ranges are obscured. Data also were evaluated by dividing the Stubbe Spring area into four

quadrants, with Stubbe Spring being the Intercept. Location records of all animals were tallied for each quadrant. The area southwest of Stubbe Spring contained 47 percent of the location records of collared animals. The southeast and northwest quadrants contained 25 and 24 percent, respectively. Little activity was recorded in the northeast quadrant, which contained only 4 percent of the locations.

Figure 2 shows the distribution of major vegetational communities in the study area [modified from Leary, 1977]. The importance of the rugged, broken terrain to the southwest, northwest, and southeast of Stubbe Spring is reflected in use of ~~by~~ ~~are~~ ~~collared animals~~ ~~these quadrants~~ ~~in~~ ~~several different vegetational communities within a three mile~~ radius of Stubbe Spring [Table 4]. The northeastern quadrant differs most from other sectors in that the terrain is less broken, as is reflected by the Yucca community being dominant in three-and-a-half sections [Table 4]. The shortage of escape terrain in the northeastern quadrant probably limits use by sheep more than does the kind of vegetational community.

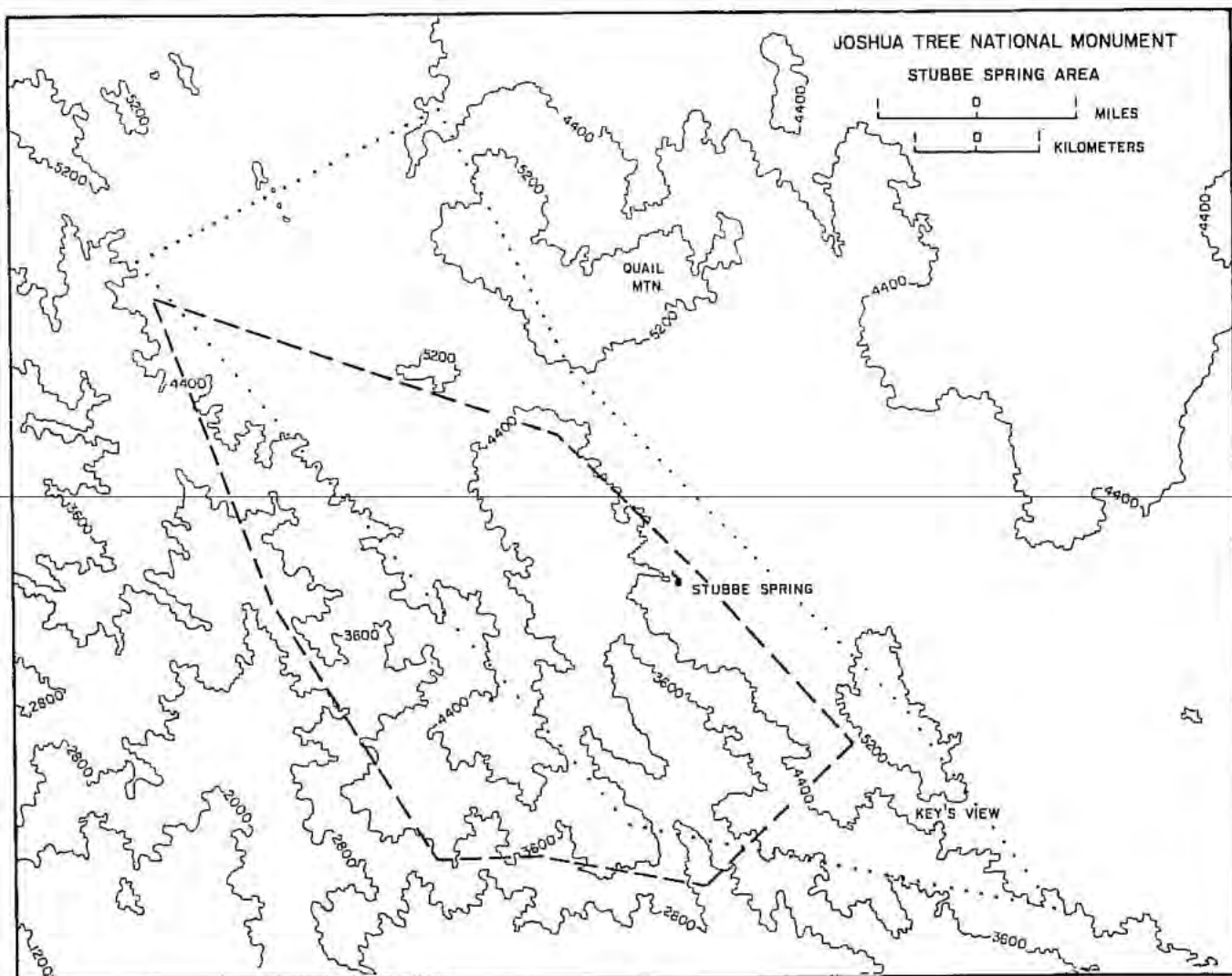


FIGURE 1. Composite home ranges for rams and ewes in the Stubbe Spring area. Maximum movements of rams are outlined with a dotted line; maximum range of ewes is outlined with a dashed line.

Bighorn sheep do not use **all** parts of their home range to the same extent. A Fortran IV Principal components analysis of locational data provides a means of **assessing** the most **important** parts of the **composite** home ranges insofar as bighorn **use** is concerned. **All** locational data are processed as **x,y** coordinates to yield the length and width **axes** of the home range for the confidence interval selected. The **angle of orientation** of the axes is given [in radians] so that the **probability** ellipses can be plotted on a **grid** overlay of the study area. The 95 percent probability ellipse delimits an area the sheep would be expected to **use** 95 percent of the **time**. To the best of our knowledge, this is the first **time** this type of analysis has **been** used for desert bighorn sheep.

TABLE 4. Major vegetational communities represented in each quadrant within a three mile radius of **Stubbe** Spring, Joshua Tree National Monument. Amounts of each community are given by sections of land occupied.

Quad rant	Black- brush Yucca	Desert Wood- land	Ambro- sia	Yucca
NW	4	3	0	0
SW	0	4.5	2.5	0
NE	3	0.5	0	3.5
SE	2.5	2	25	0

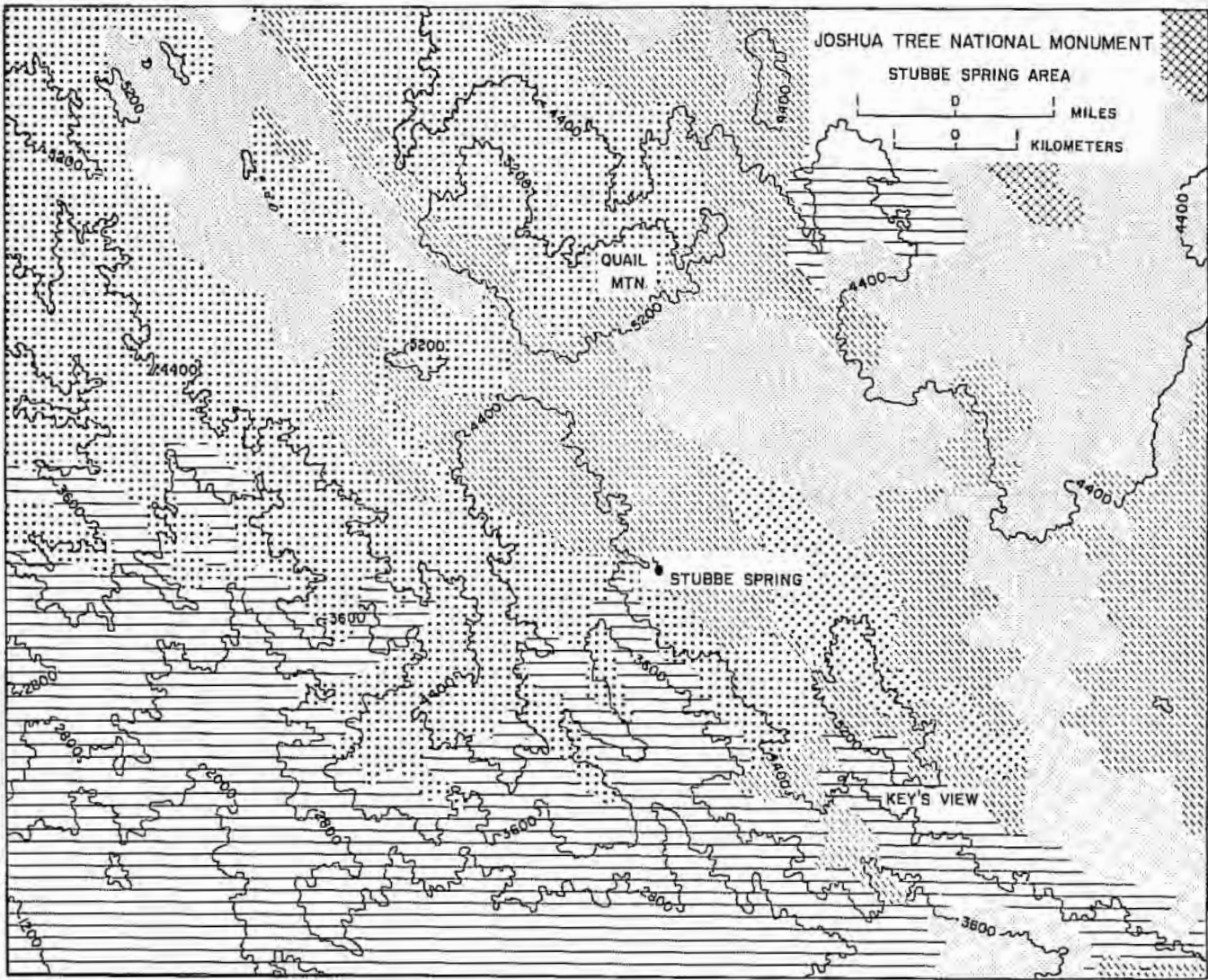


FIGURE 2. Map of **vegetational** communities in the **Stubbe** Spring area, Joshua Tree National Monument. California. Key as **follows**:

- Desert Woodland and **Juniper-Mixed** Shrub..... ☐
- Ambrosia-Mixed** Shrub..... ☐
- Blackbrush-Yucca**..... ☐
- Yucca..... ☐
- Granitic Outcrop Associations..... ☐

Figure 3 shows the 95 percent probability ellipses for movements of collared Individuals for all seasons. Ranges are shown for rams, for ewes, and for both sexes combined. Ewes moved farther west from Stubbe Spring than the rams did, whereas rams moved farther northwest and southeast [compare with maximum movements shown in Fig. 1]. It is important to note that the combined range as well as ranges for rams and ewes fall within a three mile radius of Stubbe Spring, at the 95 percent level.

Figure 4 shows 95 percent probability ellipses for summer movements of rams, ewes, and for both sexes combined. These ellipses delimit critical summer habitat for the Stubbe Spring herd. The importance of water is readily apparent from the highly constricted summer movements around the spring. The combined summer ranges of rams and ewes are well within a 15 mile radius of Stubbe Spring. This seven square miles is the critical summer habitat.

The shaded area of Figure 5 is the area recommended for placement of a new guzzler. The shaded area falls close to the western periphery of the 95 percent probability ellipses for distribution of rams and ewes. This assures the highest level of probability that a guzzler will be found and used. A site 1% miles west to southwest of Stubbe Spring would be in the juniper-mixed shrub vegetation and in good bighorn habitat. This area is one in which a group of 38 sheep, comprised mostly of ewes and lambs, was seen during the helicopter survey in 1977 [Table 1].

A new guzzler about 1% miles from Stubbe Spring should effectively double the usable summer range of the Stubbe Spring herd. The availability of free water and adequate escape terrain are critical components of summer range for desert bighorn. The amount and quality of forage determines how many animals can be supported by the range. Annual pro-

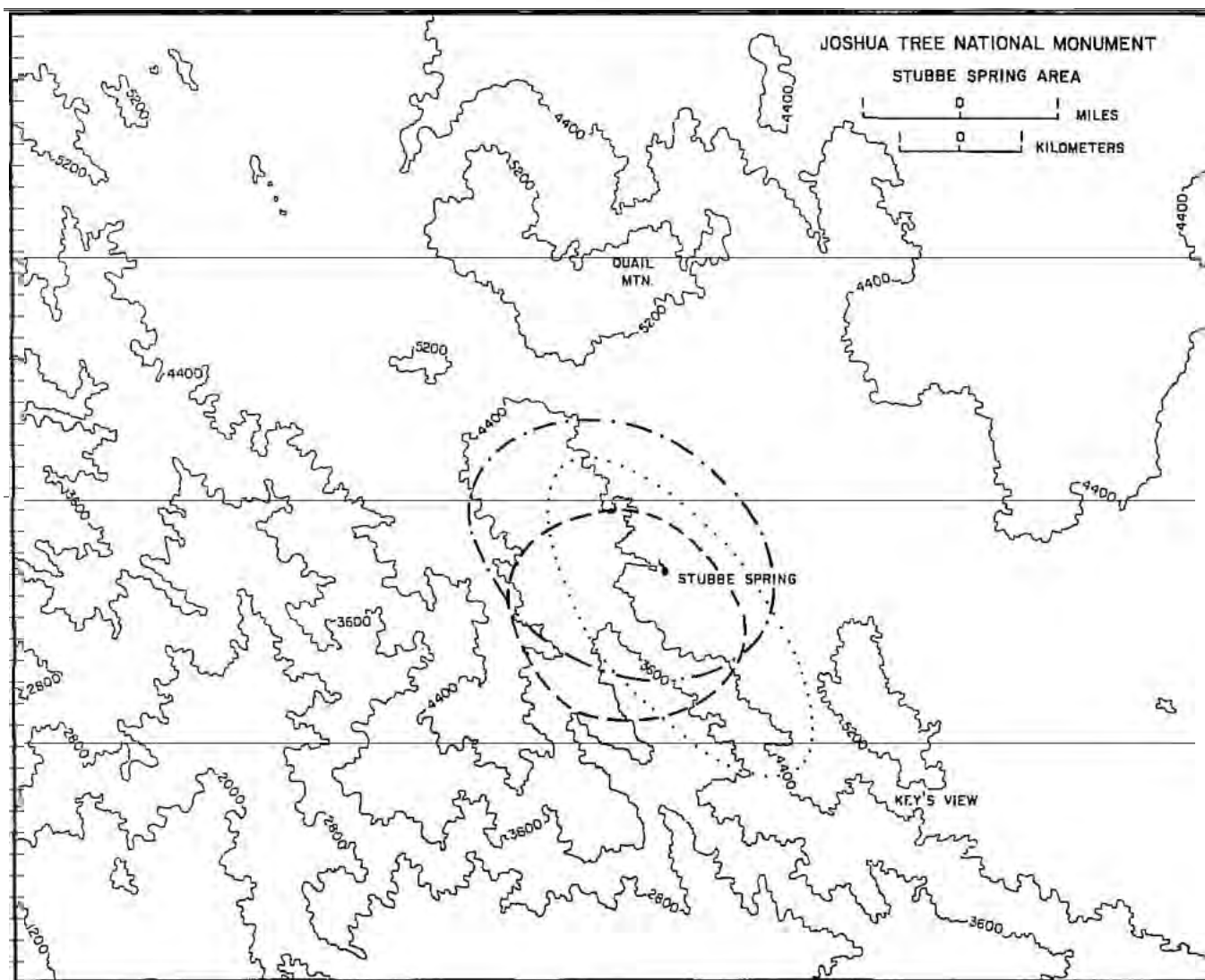


FIGURE 3. Distribution of marked sheep, for all seasons, in the Stubbe Spring area. Ninety-five percent probability ellipses are used to show major use areas. Key as follows:

Rams.
Ewes.
All.

duction of biomass by desert plants is highly variable and depends on the vagaries of climatic regimes. Based on records from time-lapse camera surveys, helicopter surveys, and ground observation, the Stubbe Spring herd is comprised of about 50 individuals. The possibility of 50 sheep overgrazing a summer range of 3 to 7 square miles [1-1.5 mi. radius] is very real as long as the herd relies exclusively on Stubbe Spring. A potential summer density of from 7 to 18 sheep per square mile is higher than most recorded densities of desert bighorn sheep in the Southwest. The bighorn population having the highest known density in the Southwest is the River Mountain herd in Lake Mead National Recreation Area. This population of about 260 animals resides in a habitat of approximately 34 square miles [7 sheep per square mile]. Although the year-round density is high, there are several dependable water sources for sheep during summer months [Leslie and Douglas, 1979].

MANAGEMENT RECOMMENDATIONS

In order to be effective, a guzzler must be placed in an area heavily used by sheep. Experience of sheep managers and biologists in the Southwest has shown that guzzlers must be placed for the convenience of sheep, not for man. Therefore, locating a guzzler adjacent to a road may be convenient for humans, but it may have no relationship to the distribution or needs of sheep.

1. We recommend that the new guzzler in the Stubbe Spring area be placed with aid of helicopter to transport materials and workmen.
2. At least two yearly maintenance checks should be performed, one prior to the rainy season, and one prior to the hot summer months, to assure that the equipment is in working order.

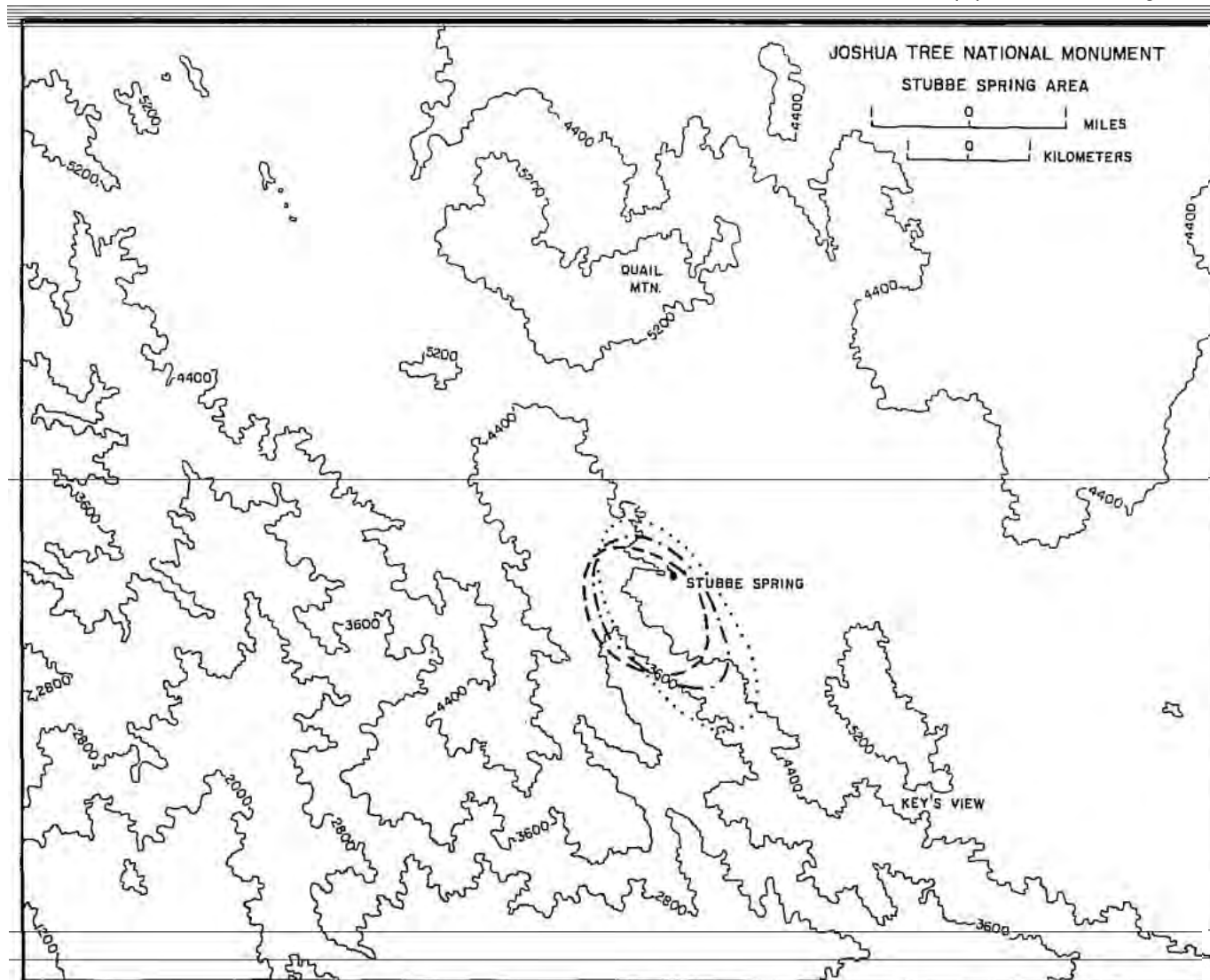


FIGURE 4. Distribution of marked sheep, for summer months only, in the Stubbe Spring area. **Ninety-five** percent probability ellipses are used to show major use areas. Key as follows:

Rams.....
 Ewes-----
 All-. - . - . - .

3. The guzzler should be considered to be a large, effective **tinaja** or pothole, and allowed to be full or empty as weather dictates.

4. It is Important that long-term **monitoring** be **conducted** to record acceptance and use of the new source by bighorn, and the numbers of Individuals using the new source.

5. We recommend that temporary water sources consisting of one or more drums of water piped to a drinker, and regulated by a float valve, be placed by helicopter in the recommended area. Two or more such water sources could be placed in appropriate sites and monitored for use. Placement should be accomplished in the Spring of 1980, prior to hot weather and before sheep are clustered around **Stubbe Spring**. The use of these test sources should be monitored by **timelapse** cameras throughout the Spring and Summer, and checked periodically to determine the amount of water consumed. The tanks should be kept filled as much as **practicable**. The test source receiving the most use would be the obvious site for placement of the new guzzler. These test sources would not present a hazard to the sheep, because even if all of the water were to be consumed, the sheep would continue on to **Stubbe Spring**, as

they are accustomed to doing.

6. Optimum timing would consist of **placing** the test sources in Spring, 1980, monitoring use for two summers, choosing the most heavily used source in late Summer, 1981, then installing the guzzler in early Autumn, 1981. In that way, the **guzzler** would be ready to receive winter precipitation, and could be anticipated to provide water to the herd during the Summer of 1982.

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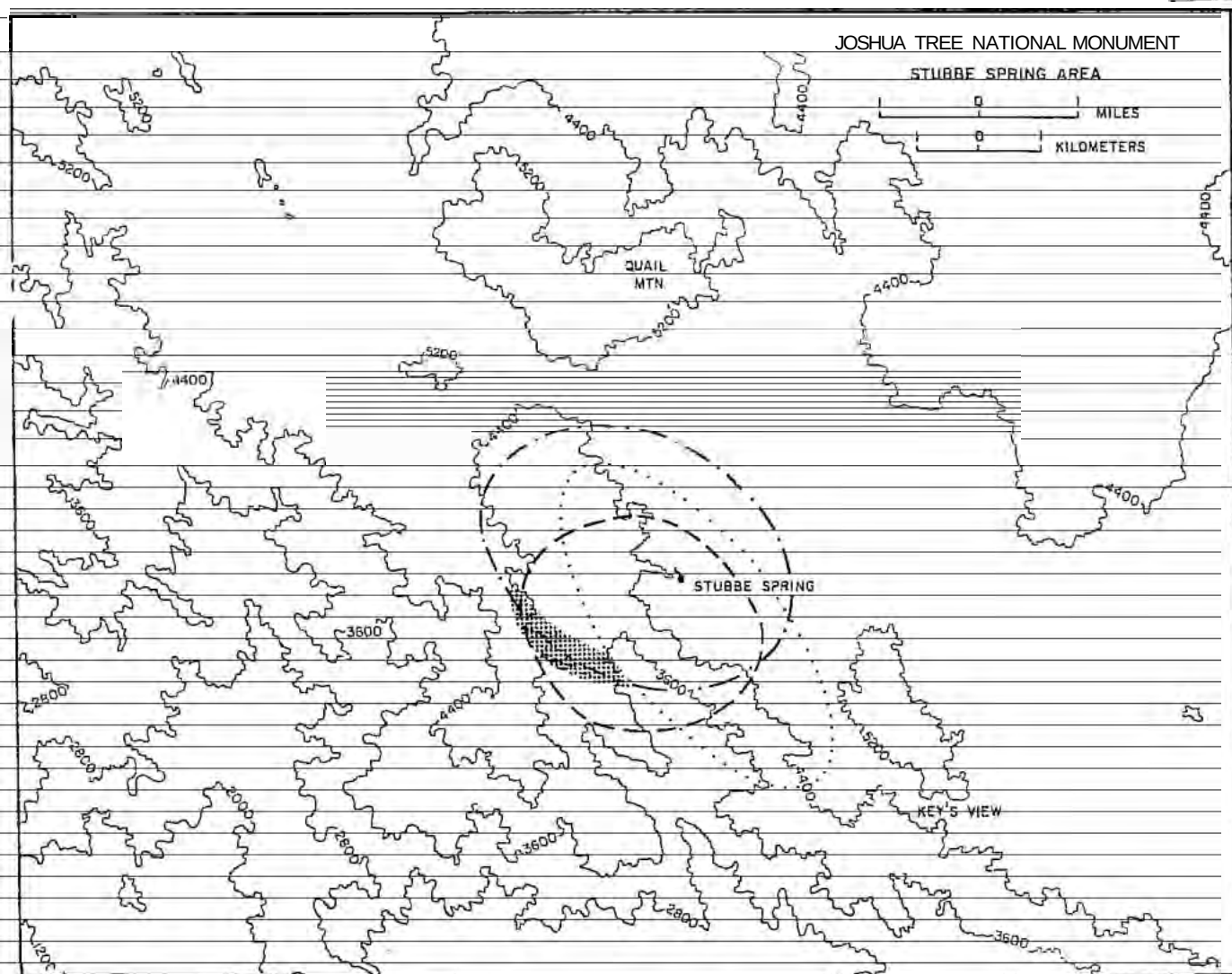


Figure 5. **Generalized** map of the **Stubbe Spring** area, Joshua Tree National Monument. Area recommended for placement

of new **guzzler** is shown by shading. This area is approx. **2 1/2** miles west-southwest of **Stubbe Spring**.

ECTO AND ENDOPARASITES OF THE DESERT BIGHORN (*Ovis canadensis cremnobates*) IN NORTHERN BAJA CALIFORNIA, MEXICO

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INTRODUCTION

The present report is based on preliminary studies which were initiated during the hunting season of October and November 1976 and continued until the hunting season of October, November and December 1978.

A total of 12 male specimens were examined of which five were collected during October and November of the 1976 hunting season and seven collected during October, November, and December of the 1978 hunting season.

The first five soecimens were collected in the area known as Arroyo Grande and Matoni and the other seven from "Picl del Diablo" and the Sierra San Pedro Martin.

These areas are situated between coordinates 31°0' and 31°30' North latitude and 115°0' and 116°40' East Longitude. The specimens collected during the first phase were analyzed micro and macroscopically and the other seven were analyzed only macroscopically.

METHODS

Blood specimens were examined from smeared slides and blood droplets and stained with Wright-Giemsa utilizing the technlque for microfilaria of Knott.

Coccidia were examined by placing in a solution of 25% potassium dichromate. Samples were obtained from the rumen and small and large intestine.

The technique of Faig was used to detect ciliates. Viscera were fixed in AFA, stained with hematoxylin of Delafield or Van Cleave, cleared in methyl sailcylate, and mounted in neutral synthetic resin.

RESULTS

The hematological examination revealed Anapiasma ovis. The fecal examination revealed at least two helminths.

The autopsy revealed the presence of Cyslicercus tenuicoliis in the iungs and mesenteries.

The cestodes Wyominia tetoni and one specimen of Thysanosoma actinioides were isolated from the bile ducts.

The rumen contained large numbers of ciliates, among which were the following genera: Ophryoscolex sp., Entodinium spp., Isotricha spp., and Dasylichra spp.

The ectoparasites Dermacenlor variabilis and Otobius megnini were also found in large numbers.

Of the first five specimens examined, the percentage parasitized with a particular parasite were as follows: 60% with the ticks Dermacenlor variabilis, 60% with the cestodes Wyominia leloni, 40% with the coccidia Eimeria sp., 40% with the cestodes Cysticercus tenuicoliis, 40% with Anapiasma ovis. 20% with the cestodes Thysanosoma actinioides, and 20% with the ticks Otobius megnini.

The specimens collected during the second phase were only examined macroscopically. Their organs were examined by making transverse and longitudinal slits paying special attention to the endoparasites of the liver, gall bladder, iungs, nasal passages and frontal sinuses.

The body and ears were examined lor ectoparasltes.

The results of the gall bladder and lung examinations were negative.

The liver contained the cestode Wyorninia leloni.

The frontal sinuses contained only one specimen of Oestrus.

The ears contained the ectoparasites Dermacenlor variabilis and Otobius megnini.

The following percentages of parasites were found in the specimens examined: 100% with ticks Dermacenlor variabilis and Otobius megnini, 85% with the cestode Wyominia tetoni, and 14% with the dipteran larvae of Oestrus ovis.



STATUS OF DESERT BIGHORN SHEEP IN CANYONLANDS NATIONAL PARK — 1978

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Abstract. Census surveys of desert bighorn sheep in Canyonlands National Park were initiated by the National Park Service in December, 1977 in cooperation with the Utah Division of Wildlife Resources. The population is significantly higher than was estimated by a 1974.75 research project. At the end of 1975, the population was estimated at 80-130. The actual count in December, 1978 was 232. Part of the increase is undoubtedly only apparent and not real, due to the lack of an adequate survey history prior to 1977. However, the indications are that the population is indeed increasing, most probably because domestic livestock grazing on bighorn range within the park ended in 1975.

Clay Dean (1977), after studying desert bighorn sheep (*Ovis canadensis nelsoni*) in Canyonlands during 1974 and 1975, estimated the park population to be 80-130. There were 60-100 bighorn sheep on the island in the Sky District and an additional 20-30 residing in the southern canyons of the Needles District. The Maze District, then as now, had no resident population. Dean concentrated his study on the island in the Sky District and arrived at that district's estimated population from a 1974 aerial census and from ground counts in 1974 and 1975. Twenty-three bighorn sheep were counted in six hours of flying time. Applying correction factors of having observed 30 percent and 25 percent of the herd, he arrived at estimates of 77.92 animals. An absolute minimum of 34 bighorn were observed from the ground during the fall of 1975. The ground count was estimated as representing 40-60 percent of the actual population or 58-93 animals.

The Utah Division of Wildlife Resources began making counts in the park in 1974 in conjunction with Utah's surveys of bighorn south of the park. However, survey time was very limited and did not exceed two hours.

In December, 1977, Canyonlands National Park in cooperation with the Utah Division of Wildlife Resources initiated census surveys of desert bighorn sheep in the park. Flying time in 1977 was six hours split between the island in the Sky District and the Needles District. Whereas all of Dean's six hours flying was over the island in the Sky District, only about four hours were spent flying that District in 1977. Observers were not the same in 1974 and 1977. Bates and Wyiie counted 62 bighorn sheep within the park (Wilson and Bates, 1977). Thirty-nine were observed on the Island in the Sky District and 23 on the Needles District. Bates used a conversion factor of 20 percent based on observation of sheep sign and not seeing any of five marked sheep. He estimated the park population of desert bighorn sheep at 300.

During the December 1978 census, a total of 232 bighorn sheep were counted in the park (Wilson and Bates, 1979). Bates, Wyiie and park personnel counted 162 animals on the island in the Sky District in about 6-8 hours of flying time and counted 70 animals on the Needles District. Survey conditions were very good with 6-8 inches of snow cover and persistent cold weather which helped bunch the sheep. These conditions, which were totally lacking in 1977, enabled observation of a greater percentage of the herd. Because of this and other variables, an estimate of the population is being reserved until one or two more good surveys are conducted. It was noted that the actual count for 1978 on the island in the Sky District closely approached or exceeded the estimated population for 1977 depending on which conversion factor was used.

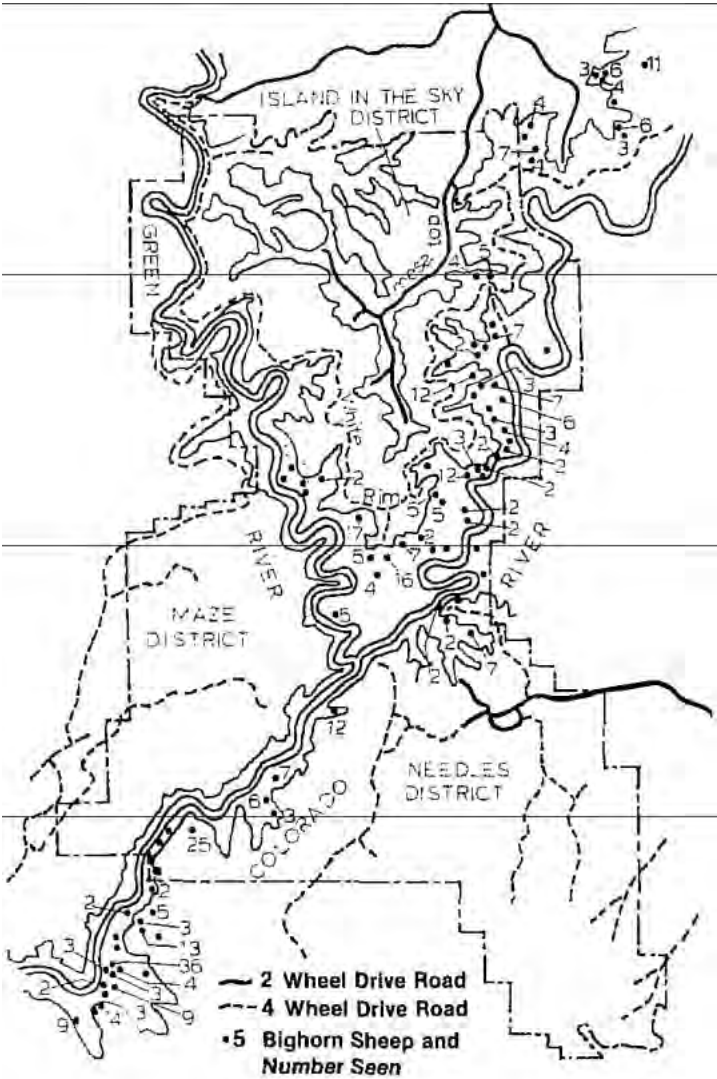


Figure 1. Distribution of bighorn sheep in Canyonlands National Park during December 1978 survey.

While the apparent population increase may not be strongly supported by census data alone, other factors also indicate that the desert bighorn population is increasing within Canyonlands National Park. Sheep sign and tracks covered a more extensive area in 1978 than in 1977, indicating increasing numbers and extended range. Incidental observations by park employees and park visitors support this indication. Fifty

sheep were counted northeast of the park in the Potash vicinity in 1978 compared to a count of one in 1977. This may be due to sheep movement from the park. Sheep range and available forage appear to be heavily used.

Population data and herd composition from 1974 through 1978 are detailed in Tables 1 and 2. Clay Dean's 1974 and 1975 ground counts were conducted from late September to mid-December. Dean's 1974 aerial survey was made at the end of November after Thanksgiving Day. Surveys are conducted by the Utah Division of Wildlife Resources in late November or early December when rams and ewes are together. In all cases, survey aircraft were helicopters.

The National Park Service has funded research to begin in 1979 under the direction of Dr. Gar Workman of Utah State University in cooperation with the Utah Division of Wildlife Resources. The objectives of that research are:

1. To study movements of desert bighorn sheep in the park.
2. To evaluate utilization of forage by desert bighorn sheep.
3. To study the influence of man's activities on desert bighorn sheep.
4. To obtain physiological and disease information from all sheep captured during the study.

Table 1. Canyonlands Desert Bighorn Sheep Aerial Surveys 1974 - 1978.*

Year	Aerial Hours	Rams	Ewes	Lambs	Total	Lambs per 100 Ewes	Rams per 100 Ewes
1974	2	4	6	4	14	67	67
1975	2	7	15	11	33	73	47
1976	2	12	15	7	34	47	80
1977	6	99	101	32	232	32	98

*All surveys by the Utah Division of Wildlife Resources

Table 2. Island in the Sky District Bighorn Sheep Surveys. 1974 - 1978.**

Year	Aerial Hours	Rams	Ewes	Lambs	Total	Lambs per 100 Ewes	Rams per 100 Ewes
1974	6	10	9	4	23	44	111
1974	ground	21	10	2	33	20	210
1975	ground	12	16	6	34	37	75
1977	4	14	16	9	39	56	88
1976	8	69	67	26	162	39	103

**1974-75 surveys were conducted by Clay Dean.

1977-78 surveys were conducted by Utah Division of Wildlife Resources

No district survey data is available for 1976.

Follows (1969) and Dean (1977) both list multiple factors adversely affecting bighorn sheep distribution and population in Canyonlands National Park. Livestock grazing was undoubtedly one of the more critical factors, both from the forage and space competition aspects. The bighorn withdrew to a restricted range inaccessible to livestock and their numbers decreased. In 1975, domestic livestock grazing was terminated on bighorn habitat in the park except for Shafer Canyon where cattle grazing will continue until 1983. Removal of domestic sheep from the prime habitat of the White Rim opened the way for habitat recovery and an expansion of bighorn sheep populations and distribution. The census surveys conducted in Canyonlands indicate that herd recovery and expansion are indeed occurring.

Some areas of the park are still not adequately covered by the census and plans are to increase flying time so that all bighorn habitat areas are surveyed. This will increase the value of the census data.

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STATUS OF THE ZION DESERT BIGHORN REINTRODUCTION PROJECT — 1978

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Abstract. In Zion National Park, Utah, desert bighorns which had been propagated in an 80-acre enclosure were released into the wild. The two separate release efforts were reviewed. The population status was discussed. Mountain lion predation on the bighorns was noted.

INTRODUCTION

In 1973, 12 desert bighorn sheep (*Ovis canadensis nelsoni*) from Nevada were released into an 80-acre holding-propagating enclosure in Zion National Park, Utah. The objective of the project has been to restore the species in areas of the Park and southwestern Utah where it has been extirpated.

The project has been a cooperative effort between the National Park Service, U.S. Department of the Interior, the Utah State Division of Wildlife Resources, and the Nevada State Department of Fish and Game. Special acknowledgment for project support is given to Robert C. Heyder and Neil J. Field of the National Park Service, Floyd Coles and Jim Guymon of the Utah State Division of Wildlife Resources, Dr. Tom Bunch of Utah State University, and the Zion Natural History Association.

DISCUSSION

Review of Project History:

The captive herd increased from 12 animals in 1973 to 22 in 1976. In January 1977, 13 of the bighorns were trapped and transported by helicopter to a remote release site in Parunuweap Canyon eight miles southeast of the propagating enclosure located in Zion Canyon. Four of the released bighorns were radio-collared. Radio-monitoring and observation revealed that about two months after the release herd disintegration occurred, apparently due to the onset of lambing. Mountain lion (Fells *concolor*) and bighorn interactions were noted. Two radio-collared bighorns were killed by mountain lions. Four released ewes returned to the Zion Canyon propagating enclosure within five months after the release.

Within the enclosure, it was discovered that the recurrent bighorn mortality from sinusitis was apparently caused by a bot fly (*Oestrus ovis*). Drs. Tom Bunch and Steve Paul of Utah State University initiated a study of the disease.

Because of the disease problem and the small number of bighorns remaining in the wild from the first release, it was decided by the cooperators to release all of the animals in captivity into the Park after the lambing season of 1978. In the spring of 1978, prior to lambing, there were 13 bighorns present in the propagating enclosure, including the returnees. Most of these were captured, marked and examined for disease. Eight radio-collars (Telonics, 120 South Mesa Drive, Mesa, Arizona) with mortality sensors were installed on

selected bighorns. One ewe was found to have sinusitis and was transported to Utah State University for treatment. After several months of treatment, she was returned to the Zion enclosure. She gave birth to a healthy lamb soon afterward.

Past Year's Events:

During the lambing season of 1978, six lambs were born within the enclosure. In June of 1978, after lambing, the enclosure fence was opened and the bighorns were released.

The bighorns divided into two groups. One group remained in Zion Canyon. This herd utilized the slopes above the enclosure and occasionally visited the enclosure as they established their home ranges.

The other group, led by several ewes of the first release, moved up into Parunuweap Canyon toward the first release site. Two radio-collared ewes of this group were killed by mountain lions within a month after the release. Other types of interactions occurring between the mountain lions and the bighorns could not be definitely determined. One radio-collared ewe remained in Parunuweap Canyon for at least a month after the predation before returning to Zion Canyon. The other ewes returned to Zion Canyon immediately after the predation.

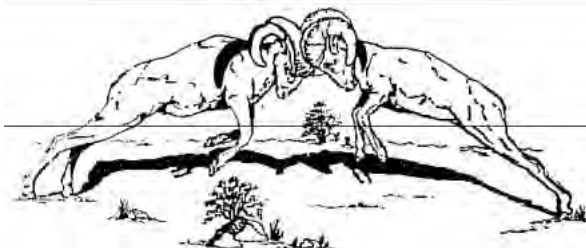
Mountain lion predation is not known to have occurred in Zion Canyon. It appears that the lions do not frequent this area as much because of the high level of human activity present here.

Two bighorns from the first release have been observed this past year. One two-year-old ram was observed with the herd in Zion Canyon. He had been released as a lamb in Parunuweap Canyon and this was the first observation of him since. In addition, during the summer of 1978, a large unmarked yearling ram was observed south of the Park boundary in a farmer's pasture in Springdale, Utah. The ram associated with a small herd of cattle and became quite a local attraction. He was eventually captured, radio-collared and released back into the Park. He later joined the Zion Canyon bighorn herd. This ram had to be one of the cohort born in the wild the first year after the first release.

CONCLUSION

As it stands now, the first release cannot be considered to have been a great success. It would appear that the number of bighorns in the first release was too small to adjust to the stress of coping with a new environment which included mountain lion predation and harassment. Release timing is believed to have contributed to the problem because the bighorns were released just prior to lambing. Herd breakup was noted as the ewes isolated themselves to lamb, while at the same time they were trying to establish new home ranges.

The second release appears to be doing well. The bighorns have maintained a loose herd association and they have home ranges adjacent to the Zion propagating enclosure. Seventeen bighorns have been accounted for at present. It is expected that after the lambing season of 1979 the bighorn population will contain 24 animals.



TEXAS REINTRODUCTION EFFORTS STATUS REPORT 1979

Jack Kilpatrick
Texas Parks and Wildlife Dept

During the past couple of years, the emphasis for reestablishing Desert Bighorn Sheep in Texas has shifted from the Black Gap Area to the Sierra Diablo Mountains near Van Horn and the Chisicote Ranch in the Sierra Vieja Range. The reason for this move was the inability to control mountain lions in an area which borders Mexico and the vast Big Bend National Park. Consequently, all penned sheep, except for two large rams, were moved to pens at the Sierra Diablo Area and Chisicote Ranch. Predation is still a threat in these areas, but is being controlled at this time.

During January, 1979, penned sheep in the Sierra Diablo (three rams, two ewes and two lambs), were released into the wild to supplement the free ranging population of approximately 10 to 15 head released in 1974. The present population in the Chisicote brood-pasture consists of 12 sheep: three rams, four ewes, three yearlings and two new lambs. Sightings of free ranging sheep on Black Gap are becoming fewer and fewer. We estimate that no more than 10 sheep occupy this range.

In summary, the total estimated population of Texas Bighorns is approximately 45-50 head. Immediate goals for our management program are to obtain additional ewes for our brood pasture facility at Sierra Diablo in order to supplement the reintroduction effort there. This mountain range encompasses approximately 200 square miles of bighorn habitat which is probably the best in the State, and we feel that additional releases should be made to insure success of the reintroduction effort there.



BIGHORN SHEEP STATUS REPORT FROM NEW MEXICO

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Abstract. The New Mexico Department of Game and Fish, in cooperation with the Bureau of Land Management, Forest Service, Fish and Wildlife Service, and New Mexico State University, is attempting to reestablish bighorn sheep (*Ovis canadensis*) on historic sheep ranges where conditions are, or can be made, compatible with the sheep. The preliminary survey of historic sheep ranges was recently completed. The objectives were to determine which areas have the highest potential for the reestablishment and perpetuation of bighorn populations, and to evaluate and rank selected areas in order of suitability as bighorn habitat.

Twelve desert bighorn (*Ovis canadensis mexicana*) were transplanted in the Big Hatchet Mountains from the captive population at Red Rock. Forty-one Rocky Mountain bighorn (*O.c. canadensis*) were removed from the Pecos Wilderness and transplanted in the Cabresto Peak area, Manzano Mountains, and Cimarron Canyon.

Scabies mites (*Psoroptes cervinus*) were discovered in desert sheep harvested from the San Andres National Wildlife Refuge. Attempts to provide some type of treatment were initiated. Five percent CO-RAL in dust bags suspended over salt blocks was placed at 38 treatment stations distributed throughout the sheep range. No significant utilization of the stations has been noted.

Transaction papers presented by Montoya (1975, 1976) and Snyder (1977) explain in detail New Mexico's bighorn sheep restoration program. Therefore, this paper presents only project highlights for the past year.

EVALUATION OF HISTORIC BIGHORN SHEEP RANGES

Sixteen historic desert bighorn and six Rocky Mountain bighorn sheep ranges (Figure 1) were evaluated in order of suitability as bighorn habitat. In order to obtain the necessary information for establishing selection criteria and a basis for correlation in the location of bighorn reintroduction areas, a qualitative evaluation of environmental conditions and trends with emphasis on the ecosystem of the bighorn was undertaken. These investigations were designed to provide an adequate description of the habitat with emphasis on topography, plant communities, forage availability, water availability, and land status and use.

Considering water availability, plant communities, competition (forage, spatial, degree of human use) and present range conditions, great differences exist among the areas investigated. Even though the potential transplant sites are characterized by rugged terrain, hot arid climate, similar climatic regions, nor do they reflect similar floral and faunal development.

In order to arrive at an objective conclusion as to the relative suitability of the ranges evaluated as bighorn habitat, the areas were grouped into three general regions (Figure 1). The

delineation is based on climatic conditions, distinct floral and faunal components and possible interspecific competition that might seemingly preclude successful reintroduction of bighorn sheep.

Region I includes the more mesic, higher elevations of north-central and west-central New Mexico. Most of this area con-

sists of forested mountains, alpine meadows, isolated volcanic peaks, and lava flow. Elevation ranges from 5,000 to 13,160 feet (1,524 to 4,011 m). The climate is semiarid to subhumid. Winters are cold; summers are warm; and days are sunny. Precipitation generally increases with elevation. In most of the region, slightly more than half of the annual

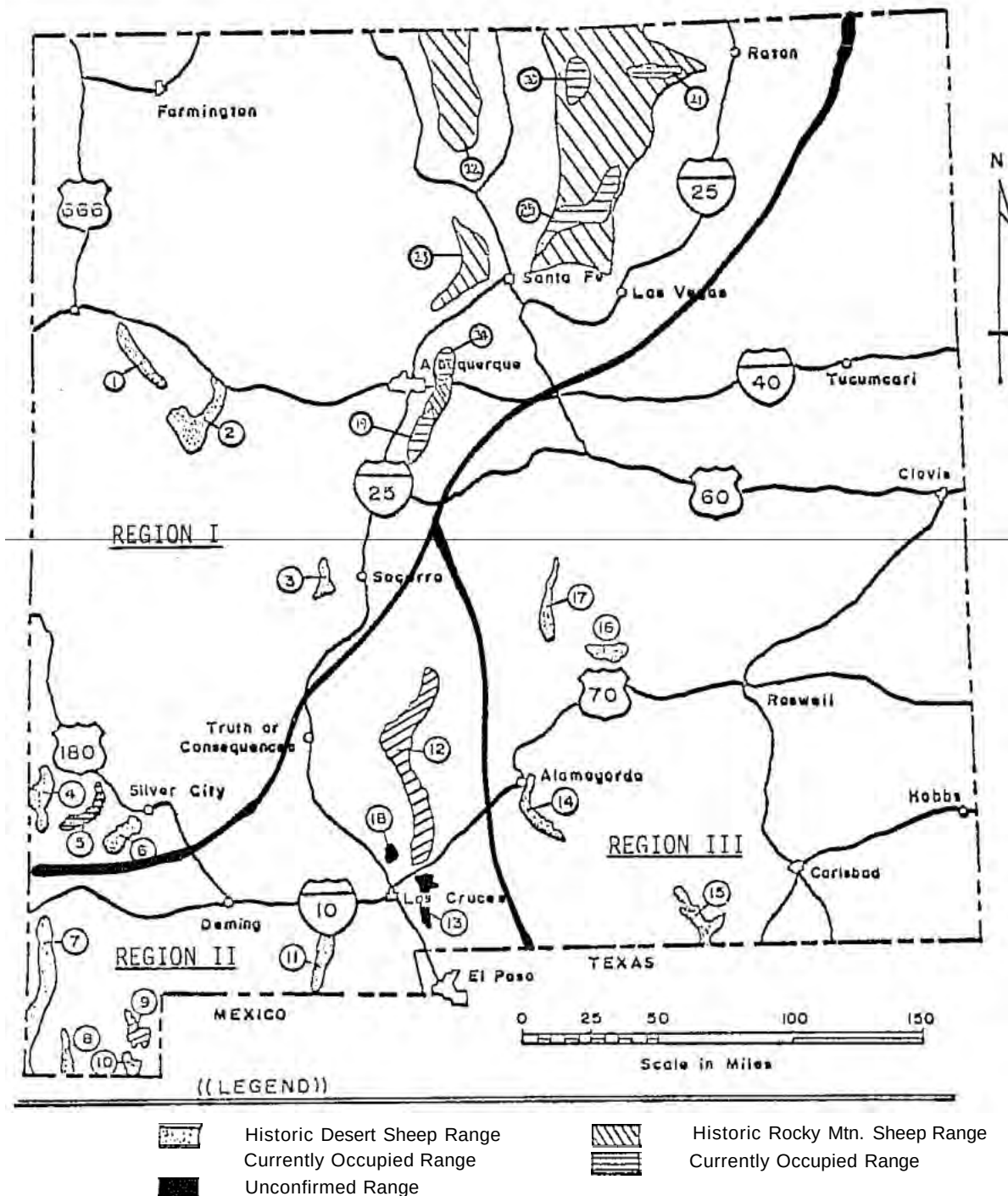


Figure 1. Map of New Mexico showing the past, present, and potential bighorn habitat, grouped into three distinct regions.

precipitation comes in summer, in brief afternoon and evening thundershowers. Snowfall is common, averaging from about 15 to over 200 inches (38 to 508 cm). Daily temperatures vary by 30 to 40 degrees. There is a great diversity of geological formations in this region. The basaltic and andesitic flows, and the Gila conglomerate, all of Quaternary and Tertiary age, cover most of the area.

Region II encompasses the arid, isolated ranges of the south-central and southwest portion of the state, west of the Tularosa Basin, then extending west along the arid south-facing front of the Mogollon Plateau. The mountain ranges, which trend from north to south, are not continuous for long distances. Elevation varies from 4,000 to 5,000 feet (1,219 to 1,524 m) in the basins and valleys to over 9,000 feet (2,743 m) on some of the higher peaks. The potential bighorn habitat is discontinuous and separated by natural barriers, such as flat expanses of desert. The climate is of the arid continental type characterized by low rainfall, warm summers, and mild winters. Annual precipitation averages about 10 inches (25.4 cm). Somewhat over half of the precipitation falls in summer. Snow occurs a few times each winter but usually disappears within a day. Evaporation amounts to about 90 inches (229 cm) per year. The mean annual temperature is about 61 degrees F. (16°C). The geology consists of Tertiary sedimentary fault blocks, separated by grabens of Quaternary age. In the extreme southwestern corner of the state, the mountains consist of Tertiary igneous rock. Numerous volcanic cinder cones of early Tertiary age dot the landscape southwest of Las Cruces.

The third region includes the Sacramento and Guadalupe Mountains on the east side of the Tularosa Basin. The two ranges are discontinuous, being separated by a wide gap south of the community of Pinon. They extend north-south for

over 150 miles (240 km). Elevations range from 4,000 to 9,000 feet (1,219 to 2,713 m). The potential bighorn habitat is situated along a series of west-facing cliffs and in the southeast escarpment and rugged canyons of the Guadalupe Mountains. The climate is semiarid, continental type characterized by low rainfall, warm summers, and mild winters. The deep canyons throughout this region contain more surface water than the desert ranges of southwestern New Mexico. Temperatures, however, appear to be similar to those of the southwestern part of the state. The geology consists of Tertiary sedimentary faulted bedrock and an extensive fossil reef complex of Permian age.

Delineation of this area was also based on political and esthetical parameters. The close proximity of this area to the Texas state line, Carlsbad Caverns National Park and Guadalupe Mountains National Park would dictate that any bighorn sheep releases be a cooperative effort between the New Mexico Department of Game and Fish, Texas Parks and Wildlife Department, and the National Park Service. In addition, the apparent wide distribution of aoudads (*Ammotragus leervia*) would probably preclude the successful reintroduction of bighorn sheep. The Department has recently addressed this situation by allowing an unlimited number of licenses for aoudads of either sex in the Guadalupe Mountains and the Mount Taylor area north of Grants.

Results. A total of 1,173,170 acres (1474.755 ha) were evaluated as potential desert bighorn habitat, and 179,200 acres (72,521 ha) as potential Rocky Mountain bighorn habitat. Twenty-three percent of the total areas evaluated were classified as good to optimum habitat for desert bighorn (Sandoval 1978) (Table 1). Twenty-two percent of the areas evaluated were classified as suitable habitat for Rocky Mountain bighorn (Grunigen 1978) (Table 2).

Table 1. Relative suitability of historic desert bighorn sheep ranges as potential transplant sites in New Mexico

Area	Size (mi ²)	Available habitat ^a	Competition	Land status ^{b/}
Alamo Hueco Mtns.	66	35	LOW	57
Big Hatchet Mtns.	89	27	High (Livestock grazing)	99
Burro Mtns.-Gila Middle Box	90	38	High (Rocky Mtn. bighorn)	68
Caballo Mtns.	82	5	High (human use and livestock grazing)	93
Cooke Range	102	14	Moderate (ibex and livestock grazing)	74
Florida Mtns.	44	41	Occupied (ibex)	87
Fra Cristobal Mtns.	61	32	LOW	0
Guadalupe Mtns.	182	55	Occupied (aoudads and human use)	95
Ladron Mtns.	54	35	Moderate (feral goats)	65
Little Hatchet Mtns.	60	7	High (Livestock grazing and human use)	90
Magdalena Mtns.	146	12	High (human use)	91
Malpais Lava Flow	154	2	Low	35
Peloncillo Mtns.	339	24	Moderate (livestock grazing)	71
Sacramento West Escarp.	101	27	Occupied (aoudads and feral goats)	70
San Mateo Mtns.	29	24	Moderate (human use)	96
West Potrillo Mtns.	134	0	Moderate (ibex)	100

^{a/} Percent of total area classified good to optimum habitat.

^{b/} Percent of total area administered as National Resource or State Lands.

Table 2. Relative suitability of areas evaluated as potential Rocky Mountain bighorn sheep habitat in the Santa Fe National Forest, New Mexico.

Area	Size (mi ²)	Available Habitat ^{a/}
Chama River	81	37
White Rock Canyon	28	32
Ojitos Canyon	53	32
Santa Fe Baldy	32	9
Gascon Point	36	8
San Pedro Parks	50	0

^{a/} Percent of total area classified good to optimum habitat.

Discussion. A modification of the numerical scoring method proposed by Hansen (1971) was utilized for evaluating habitat factors that significantly affect bishorn sheep. The method is based on environmental characteristics as well as degree of human use and consists of a series of components which, in combinations, subjectively determine the suitability of an area as a potential release site.

This system possesses several inherent limitations which should be recognized upon its application. 1). The overall numerical value given to a section of land is not the value of the suitable sheep habitat within that section. it is the average value of the entire section as sheep habitat. 2). The relative importance of the various components may change, depending on habitat characteristics of the areas being evaluated. Consequently, this system does not give an absolute value of a particular range as sheep habitat; it gives an Index of the area's relative suitability as potential habitat.

RESTORATION

Desert Bighorn Sheep. New Mexico's initial release of desert bighorn took place on January 10-11, 1979. Twelve sheep (6 ewes, 2 female iambs, 2 male lambs, and 2 rams) were captured at Red Rock and transoorted to the Big Hatchet Mountains, 80 miles (128 km) southeast (Figure 1, Area 9). This action was prompted by the rapidly declining numbers of bighorn in the Big Hatchets which had reached adelicate balance between survival and extirpation. And secondly, immediate action was also necessary in the management of the captive population at Red Rock. The decline in productivity of the captive herd could possibly be detrimental effects of crowding or disease within the enclosure.

The sheep were hazed into a net with a helicopter. The net was made of nylon and measured 1,500 feet (457 m) long, 7 feet (2.1 m) high, and had a seven-inch (17.8 cm) mesh. The drive net capture technique had been used successfully to capture deer and elk, but never before to trap bighorn in rough, open terrain. The technique proved to be highly successful for desert bighorn. All of the animals were captured without injuries, and no sheep were drugged. The sheep showed little reluctance to go into the net once driven to it. Bands of sheep were easily driven to the net site in the beginning but became progressive. ly more difficult as time wore on: relocation of the net could have solved this problem. Adult rams separated from the ewe. juvenile bands showed the greatest reluctance to be driven to the net and bunched up rather quickly. Before sheep were

removed from the net, they were ear tagged with large plastic tags and metal tags. Four ewes were radio collared, while identification (ID) collars were placed on the remaining adult sheep.

The sheep were released the following morning into a 40-acre (16 ha) temporary holding paddock in Romney Canyon west of Big Hatchet Peak. A two-year-old ram was released outside of the paddock. He was not sighted until two months later, approximately six air miles (9.6 km) southeast. with a three-year-old radio-collared ram from the existing remnant herd. The goal is to imprint the sheeo to the release site. By imprintina the ewe segment to suitable winter range having lambing ground characteristics, it is hoped that the release site will become traditional lambing grounds. Establishing a new population in what appears to be the most suitable part of the available habitat has other advantages. In addition to making better use of the habitat, transplanted bighorn would supplement the existing gene pool and should enhance population quality. Additional sheep in the Big Hatchets should alleviate the remnant herd's apparent inability to overcome the threshold between survival and extinction, thus insuring the existence of this population.

A qualitative evaluation of the preferred habitat of the remnant population suggested that these high-use areas are deficient in botanical composition, namely species diversity, are readily accessible to livestock grazing, and lack adequate cover to provide cover, concealment, and lambing grounds. The objective, therefore, was to imprint the sheep to the most suitable portion of the habitat.

Bighorn will be retained for approximately six to eight months. By this time, the majority of the lambs should have been born, be agile and able to keep up with the adult sheep. When it's decided to free the bighorn, the paddock will be disassembled for possible use in subsequent releases.

Post-release monitoring indicated that the sheep formed two groups, one consisting of three radio-collared ewes, the second made up of the remaining sheep including a three-year-old ram and subadults. Two days after their release, the sheep regrouped. During the first two weeks, the sheep were wary, and would flee at the slightest disturbance. They spent about 90 percent of the time in approximately 20 percent of the available area within the paddock. The only time the sheep were observed to move to the lower end of the oaddock was when they were disturbed as the perimeter of the paddock was being inspected. The water catchment unit located in the canyon bottom at the lower end of the paddock was not utilized until about 15 days after the release.

Four lambs have been born to the transplanted sheep. The first was born around February 5. A four-day-old iamb was found dead with all four feet entangled in the paddock fence along the upper cliffs. A necropsy indicated that starvation was the probable cause of death. The abomasum contained soil, fur, scanty vegetable material, but no milk curd. Food was absent in the rumen, reticulum, omasum, and intestines; while no fat was present in the kidneys, mesentery, heart, and bone marrow.

The population in the Big Hatchets now stands at approximately 28 bighorn. The remnant herd includes five rams, five ewes, one male iamb and two unclassified lambs (Watts 1978).

The Department initiated a control program to remove mountain lions (*Felis concolor*) one month prior to the release. A Department lion hunter on horseback and using dogs spent

approximately 20 man-days per month searching the area for lion sign. An agreement had been reached with military personnel to relocate lions removed from the Big Hatchets in the Organ Mountains within the Fort Bliss Military Range. Bobcat (*Felis rufus*) and coyote (*Canis latrans*) control efforts were implemented immediately after the release. During the first six weeks, 18 coyotes, nine fox, eight bobcats, and one eagle (*Aquila chrysaetos*) were removed. The eagle was live-trapped and released in the Organ Mountains east of Las Cruces. Although no lions have been caught, at least three are suspected to be ranging in the Big Hatchets.

Pending the outcome of this initial release, it might be necessary to transplant additional ewes from Red Rock to achieve maximum reproduction during the critical establishment phase of the population. In order to alleviate intraspecific competition in the propagating enclosures at Red Rock, the majority of the ram segment will be segregated from the ewe-juvenile bands. By minimizing excessive harassment of ewes by socially immature rams, it is hoped that this population can be maintained at its highest qualitative and quantitative level. As rams reach social maturity (four to five years of age), they will probably be released into unoccupied habitat or utilized to supplement existing herds. As of March 8, 1979, the Red Rock population stood at 25 rams, 11 adult ewes, three sub-yearlings, and three lambs. A mountain lion entered the enclosure last summer and killed at least one ewe and possibly four, as three ewes are unaccounted for.

Rocky Mountain Bighorn Sheep. Forty-one Rocky Mountain bighorn sheep were removed between August 29 and September 8, 1978, via helicopter from the Pecos Wilderness northeast of Santa Fe (Figure 1, Area 25). A drop-net trap suspended over bait stations consisting of granulated salt was utilized. The drop-net trap caused two mortalities. The pannier method of helicopter removal caused three mortalities believed to be due to in-flight hypothermia. The M-99, Rompun (xylazine HCL) drug combination caused two mortalities probably due to hyperthermic shock directly related to inadequate immobilization that allowed struggling and temperature increase. The crate method of helicopter removal caused one mortality believed due to a broken neck. Rompun when used alone caused no mortalities.

On September 1, 20 sheep were released in the Sangre de Cristo Mountains northeast of Taos (Figure 1, Area 20). The sheep were transported by vehicle to a staging area and airlifted by helicopter in individual wooden crates to an alpine tundra ridge near Cabresto Peak, southwest of the Latir Lakes. This habitat is very similar to the occupied range in the Pecos Wilderness. This release included 10 mature ewes, three mature rams, four yearling ewes, two ewe lambs, and one ram lamb. Six of these animals were instrumented with radio collars. It is still too early to conclusively evaluate the success of this transplant. Aerial surveys indicated the sheep were remaining in the vicinity of the release site.

On September 7, 16 sheep were released from a gooseneck trailer in Canon Monte Largo of the Manzano Mountains southeast of Albuquerque (Figure 1, Area 19). They included seven mature ewes, one mature ram, one yearling ram, five ram lambs, and two ewe lambs. Five of these animals were radio-collared. This release supplemented 16 sheep transplanted there last year. Lambs from the initial release survived to the yearling category and some reproduction from the supplemental release has occurred. Some erratic wandering has taken place, but the majority of the sheep have remain-

ed within six miles (9.6 km) of the release site. Two sheep, a ewe and a ram, were killed by deer hunters.

Five sheep were released on September 7 in Cimarron Canyon southwest of Raton (Figure 1, Area 21). These animals included one mature ewe, one mature ram, two ewe lambs, and one ram lamb. Two of these animals were instrumented with radio collars. This release supplemented a small number of sheep associated with this area. The Cimarron Canyon herd derived from a 1970 release on Wheeler Peak, approximately 25 miles (40 km) west.

The representative sheep habitats in the Manzano Mountains and Cimarron Canyon are somewhat atypical from those normally associated with Rocky Mountain bighorn. Both areas are lower in elevation and more xeric than the Pecos. The Manzanos have fringes of vegetation typical of the Canadian and Hudsonian Life Zones. Cimarron Canyon lies primarily in the Transition Zone. Approximately 465 Rocky Mountain bighorn are currently found in New Mexico resulting from reintroductions dating back to 1941 (Table 3).

Table 3. Estimated Rocky Mountain bighorn populations in New Mexico.

Area	Year Released	Estimated Numbers	Apparent Trend
Sandia Mtns.	1941	30	Declining
San Francisco River	1964	100	Increasing
Turkey Creek	1965	25	Holding
Pecos Wilderness	1965	200	increasing
Wheeler Peak	1968	30	•
Manzano Mtns.	1977 & 1978	30	•
Cabresto Peak	1978	20	•
Cimarron Cyn.	1970 & 1978	10	•

• Too recent to be evaluated

SCABIES EPIZOOTIC

A bighorn sheep hunt was conducted October 1-9, 1978, in the San Andres National Wildlife Refuge. Six permits were issued and five hunters were successful. The rams ranged in age from 4-13 years. Gross examination of the rams revealed that each had scabies lesions. Up until this time, indications of scabies had not been noted during numerous observations of sheep in the wild, sheep trapped to supplement the Red Rock population, or sheep harvested by hunters. How the mite got into the population is unknown. The area has been closed to grazing since 1951. The mite has probably been present in the population over this period without obviously contributing to a decline in numbers.

The mites were distributed in the ears and over the body. Lesions in the ears were characterized by large flakes of yellow-white raised epidermis and serum-exudate-bearing hairs lifted from the follicles. These lesions were present from the distal 1/4 of the ear to the external auditory meatus where the material became dark yellow, waxy and hard (Lang et al 1979). The pelage on the neck of some sheep appeared rough and was falling out of the skin in tufts. Other sheep had loose hair on the neck, withers, sternum and rump.

An attempt to provide some type of treatment was initiated in October. Five percent Co-Ral in dust bags suspended over

plain and sulfur salt blocks was placed at 38 treatment stations. These stations are located along frequently-used travel routes, bedding grounds, mineral licks, and water sources. By late winter, the dust bags had solidified to some degree. Solidification varied from approximately 20 percent in some bags to 100 percent in others. No significant utilization of the stations has been noted. Nevertheless, determination of use has been difficult due to deterioration of the salt blocks, frozen ground, and frequent snow and rain showers.

Extensive ground surveys have revealed very few sheep occupying the preferred habitats, suggesting large-scale emigration or mortality. Even though emaciated sheep were observed during January and February, no evidence of mortality has been documented. Sheep have been observed with drainage from the ears and with ears folded over. Some showed lateral and dorsal alopecia with signs of pruritis including excessive scratching, biting, head shaking and horning shrubs.

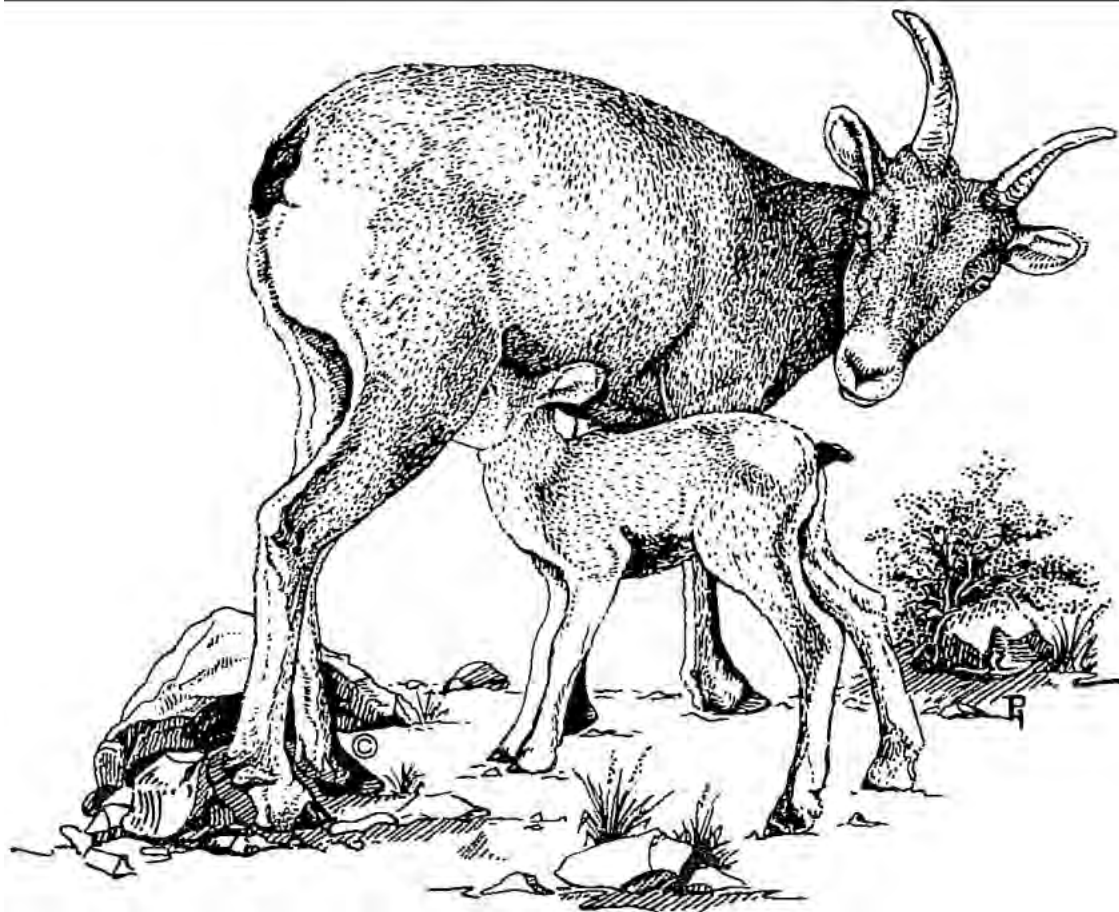
The status of this population is uncertain. An intensive helicopter survey will be conducted this spring to ascertain numbers, composition, and distribution of the population.

CONCLUSION

This summarizes New Mexico's bighorn sheep restoration program and current status. The Department will continue to translocate Rocky Mountain bighorn as surplus stock becomes available from existing populations. Desert bighorn will be reintroduced in historic ranges until all suitable habitat is occupied.

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LAVA BEDS BIGHORN SHEEP PROGRAM — — UPDATE

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Abstract. The 1978 lamb crop at Lava Beds was the highest to date. A total of 9 lambs was born, indicating that all adult ewes reproduced. The herd presently consists of 36 animals: 15 rams, 12 ewes and 9 lambs. Plans are progressing for future re-introduction programs using stock from Lava Beds.

INTRODUCTION

By now the California Bighorn Reintroduction program at Lava Beds National Monument needs no further introduction to this group. Previous transactions papers presented by Research Biologist James A. Blaisdell of the National Park Service have fully explained the plans and operational details of this popular project. Additions reports in past years have further documented project progress and problems. This paper presents some project highlights of 1978.

REPRODUCTION

We are pleased to report that 1978 has been a successful year at Lava Beds in terms of lamb crop and general herd condition. The population reached its highest number to date -- boosted by a 100 % reproduction rate. Seven lambs were born between April 15 and May 28, 1978, while two additional animals were born in late June or early July. No twinning was observed at the onset of winter but lambs appeared to be healthy and surviving. No unusual weather was experienced in 1978.

HERD LOSSES

Accurate surveys are becoming increasingly difficult to obtain as the herd scatters over the 1100 acre enclosure. Snows this past winter have made foot travel over the volcanic terrain hazardous, consequently we have had only few days where reliable counts were obtained. The highest number thus far indicates the Park contains 36 animals with a loss of four ewes. Our most recent count was 35 animals, including 8 of the 9 reported lambs. We remain optimistic; however, that the missing lamb was simply hidden or overlooked and not lost. With the snows gone, Park employees will be making an increased effort to obtain more accurate counts and account for any missing animals.

We cannot say with any certainty what may have happened to the four missing ewes. To date, no remains have been found. We suspect that if these animals are down, they may be members of the original transplant group and mortality may have been a natural event. The possibility of predation does exist.

Predation is, of course, a continuing concern be it natural or man caused. Although we cannot prove that we have lost a single healthy animal to a predator, we do know that coyotes, bobcats, golden and bald eagles are a part of the bighorn environment and move freely in and out of the enclosure. A transient cougar may also be an occasional visitor. Blaisdell, during a herd count last December, reported cougar sign in the

enclosure. In spite of the presence of these animals, none are known to be dependent on the transplant herd as a food source; any predation is likely to be opportunistic.

Counts of rams have been consistent at fifteen animals. Except during the rut, the rams are frequently seen in groups of nine to twelve.

As far as we have been able to determine, we have had no mortality due to disease since 1975.

HERD COMPOSITION

As mentioned earlier, our best population estimate is 36 animals, consisting of 15 rams, 12 ewes and 9 lambs. Because none of the missing ewes have been located, it is impossible to know the age structure of the ewe herd. Future lamb crops may become increasingly difficult to predict.

We did have a pleasant surprise last year regarding ram numbers. Heretofore, Jim Blaisdell, who had logged more field observations than any other Park employee, consistently observed and recorded 13 rams. Suddenly his count jumped to 15 rams. His explanation of the increase was simple: expecting thirteen rams and always counting thirteen animals, he naturally never looked for additional rams!!!!

If precipitation levels continue to be high through March and April, the growth of grasses and forbs should be good and with this we anxiously anticipate another successful lambing season.

MANAGEMENT ACTIVITIES

No major management problems were experienced this year. A prescribed fire was set on the east face of the enclosure and burned several acres of brush and grasses. The task was accomplished in late afternoon under prescription conditions: no suppression action was necessary the next day. This year we plan on burning some brush/grass acreage between guzzlers 2 and 3 when it comes under prescription.

In August the Forest Service guzzler went dry for as yet undetermined reasons. The remaining two guzzlers provided the necessary water for the animals without interruption.

This year we continued to spread granulated salt on the snow pack and soil making it available to the sheep in a more natural manner and thereby reducing the likelihood of disease transmission. The bighorn have had little trouble locating the salt lick and have been observed utilizing it as early as the second week of March.

Several administration matters regarding herd management were suggested at this year's Interagency Bighorn Sheep Committee meeting in December. These are as follows:

1. Raider Canyon, Warner Mountains of Modoc National Forest, was recommended after a field trip, as the most satisfactory location for a first reestablishment attempt using animals from the Lava Beds herd. Assuming continuing reproduction levels and no major losses, target release date could be as early as 1962.

2. California Fish and Game Department suggest a modification of the Memorandum of Understanding between the 5 agencies involved in our approximately 25 breeding ewes are available before attempting a transplant. The modification suggested that when 20 ewes existed in the enclosure, the herd be split and a transplant made. This recommendation was made in light of past disease history and the hope that an earlier release opportunity might avoid a disease outbreak and the loss of the entire transplant stock.

3. There had been a research proposal to take blood from the Lava Beds herd for disease and genetic studies. The Committee felt that herding or corralling the animals for this specific study might be traumatic and suggested that when the herd was ready for transplanting, biosamples could be taken at that time.

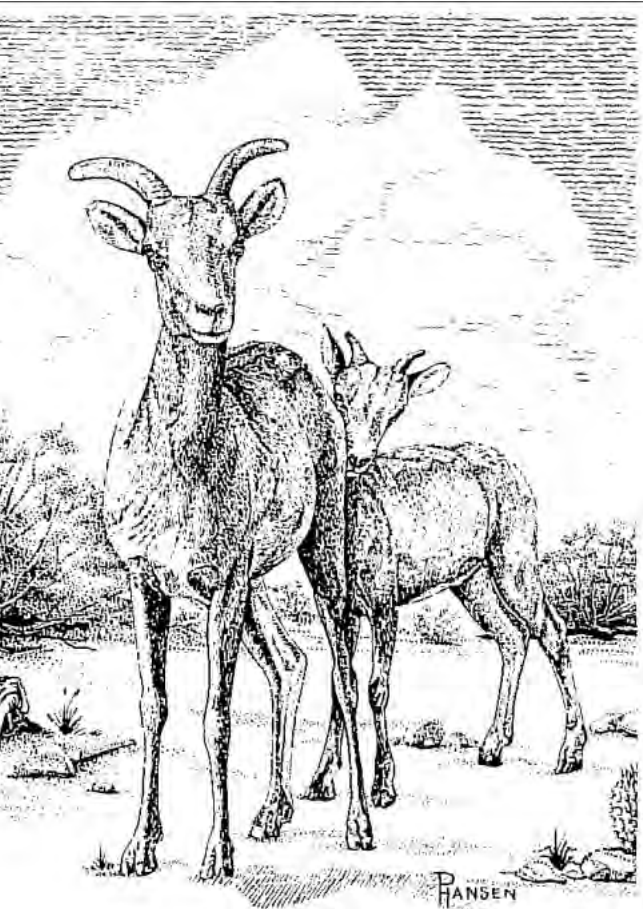
MISCELLANEOUS NOTES

This past fall, a lone mature ram was observed near Park Headquarters, six miles south of the enclosure. For the next several days he was observed by Park staff and visitors, working his way back toward the enclosure. Four days later, when a count was conducted, all 15 rams were accounted for inside the enclosure. The entire perimeter of the fence line was checked; his exact method of escape remains unknown.

With the end of 1978, Jim Blaisdell concluded his bighorn research project at Lava Beds and turned the details over to Park staff. Although he is now at the Seattle office of the National Park Service, his expertise continues to be made available to the Park. Routine field counts and observations are being conducted by Park staff on a weekly basis or as required. Blaisdell's enthusiastic assistance and professional expertise will be missed by all; however, periodic field consultation is expected to keep him involved in the program.

CONCLUSION

The Lava Beds herd has had a highly successful year with 100% reproduction and a year end count of 36 animals. Plans are progressing for future reintroduction programs using stock from Lava Beds. The overall health of the sheep appears to be excellent: 1979 promises to be another good lambing year.



UTAH BIGHORN SHEEP STATUS REPORT

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DISTRIBUTION

Both the desert bighorn (*O.c. nelsoni*) and the Rocky Mountain bighorn (*O.c. canadensis*) are found in Utah today. Both subspecies were quite abundant in Utah as recorded by early white explorers and trappers. Bighorns could be found on nearly every mountain range in Utah with Rocky Mountain bighorns occupying northern portions of the state and desert bighorn occupying southern portions.

Rocky Mountain bighorn sheep were extirpated from their historic range in the Wasatch Mountains about 1927. In 1960, the Utah Division of Wildlife Resources became interested in re-establishing the bighorn. By 1966, 34 Rocky Mountain bighorns from both Wyoming and Canada had been shipped to Utah. These animals have gradually escaped from their holding paddocks. Presently, frequent sightings are made in the Willard Peak and Wellsville Mountain areas.

Sometime between 1944 and 1951 the remnant population of Rocky Mountain bighorn sheep in Dinosaur National Monument had disappeared. The Colorado Fish and Game reintroduced Rocky Mountain bighorns into the Monument in 1952. Since then bighorns have become abundant in the Monument.

Rocky Mountain bighorns have also been sighted in the Uinta Mountains. Occasional sightings of sheep west of the Green River just north of the town of Green River are believed to be individuals that have crossed the Green River on the ice from the Uinta-Urley Indian Reservation where they were established in 1969.

Historically, both Rocky Mountain and desert bighorn inhabited east-central and southern Utah. Occasionally, sheep have been observed in the San Rafael Swell. Sightings have also been made in the Henry Mountains, Little Rockies and La Sal Mountains. The last bighorn in Capitol Reef National Monument was shot in 1946. Bighorns are occasionally seen along the San Juan River and the canyons which drain into it.

Present day desert bighorn distribution in Utah is centered in Grand and San Juan counties along the Green and Colorado rivers from Canyonlands National Park south to the San Juan River. This area has been divided into three hunting units to better distribute hunting pressure. Their range appears to be expanding in a northerly direction along the Colorado River.

MANAGEMENT OBJECTIVES

1. To increase the knowledge of the life history, distribution, behavior, population and habitat requirements of desert bighorn sheep as well as the effects of human intrusion and activity.

2. To maintain the current distribution of desert bighorn sheep by reducing impact on present desert bighorn habitat and populations.
3. To expand the present distribution of desert bighorn sheep into suitable and historic habitats through natural expansion and selected transplants.
4. To provide increased opportunity for consumptive and non-consumptive uses of bighorn by increasing the population.

POPULATION TREND

The sheep appear healthy and their range is expanding. In the 1978 survey, sheep were observed further up the Green and Colorado rivers than in previous years. Some sightings have been reported from the Lockhart Basin area but heavy winter cattle use would preclude winter sheep use. Heavy livestock-sheep competition was also observed in the White Canyon area.

Lambs per 100 ewes was down from 53 in 1977 to 38 in 1978. This reduced reproduction or survival may be attributed to two consecutive years of drier than normal summers.

An accurate population estimate can not be made. Five hundred sixteen animals were classified in December 1978 and it is estimated that 25 percent of the population was observed during the winter census.

HUNTING

Prior to 1876, Utah had no regulations regarding the taking of bighorn sheep. When Utah became a state in 1876 the legislature set a July through December season on big game. Bighorn sheep were protected from hunting in 1899. Studies began in 1966 indicated that Utah did have a limited, huntable population of desert bighorn sheep east of the Colorado River in San Juan County. Ten permits were issued in 1967 for trophy rams. Four hundred and thirty-two applications were received.

In Utah, a trophy ram is defined as a male sheep with horns scoring 144 Boone and Crockett points or which is at least seven years old. A mandatory hunter training and orientation program is required of all successful applicants. Scoring and aging techniques are taught along with the problems and hazards which face the hunter in this rugged area.

Interest in sheep hunting has remained high with an average of 31 applications per permit. A total of 49 rams has been harvested to date with an average hunter success of 41 percent. The number of resident permits issued is determined as 8 percent of the rams observed during the winter aerial survey. This number is further limited to 33 percent of the total trophy rams observed in each hunting unit. In 1978, twenty-three permits were issued and eight sheep were taken in a 30 day season.

In 1978, non-residents were allowed for the first time to participate in this once-in-a-lifetime hunt. Three non-resident permits were issued; one for each hunting unit. The total number of non-resident permits is calculated as 10 percent of the number of resident permits.

All trophy heads taken are checked by an officer within 72 hours of the taking of the animal. The horns are measured, aged, and an aluminum pin is permanently driven into the horn sheath in an inconspicuous area. This pin identifies the head as legally taken and prevents illegal trafficking and unlawful taking of sheep.

SURVEYS

Winter aerial surveys flown in November and December were initiated in 1969 to determine desert bighorn productivity and population trend. The surveys have indicated a steady increase in sheep numbers and lamb-ewe ratios until recent years (Table 1).

In 1975 and 1976, the Utah Division of Wildlife Resources conducted spring aerial surveys flown in May and June to determine the peak lambing season and gain baseline data to evaluate lamb mortality. Counts indicate lambing has not been completed by early June. Flights later in June or July have been avoided because the sheep are more difficult to locate.

Table 1 Trend in indices of desert bighorn sheep in the Southeastern Region of Utah, 1976-1978.

1976			
Hunting Unit	Males/100 Females	Lambs/100 Females	Sheep/Hour
Red Canyon	35	58	20
White Canyon	85	72	40
Canyonlands Park	80	47	—
TOTAL	79	67	35
1977			
Red Canyon	84	48	11
White Canyon	74	55	6
Canyonlands Park	78	52	10
TOTAL	78	53	9
1978			
Cataract-			
Glen Canyon	105	58	36
Red Canyon	43	45	10
White Canyon	71	38	28
Canyonlands Park	98	32	19
TOTAL	79	38	19

RESEARCH

From December 1972 to December 1975 the Division conducted a program of radio collaring and monitoring of desert bighorn sheep to gain knowledge of range and movement. A total of 33 sheep were captured with etorphine and instrumented (Bates et al. 1976).

In monitoring the instrumented bighorns it was found that the amount of movement between relocations was larger during each season of the year for rams than for ewes. However,

analysis indicated that these differences were not statistically different. Movement between relocations varied by season although both rams and ewes displayed similar trends. Relocation distances were shortest during winter and summer, longer during the spring and longest during the fall. Analysis of the data indicated that fall movements of rams significantly exceeded movements during winter and summer ($P < 0.05$) but did not exceed spring movements. For ewes, fall movements exceeded those of all other seasons ($P < 0.10$) and in addition spring movements exceeded movements during the winter ($P < 0.10$).

While relocation differences of rams and ewes did not differ significantly, the areas of their home ranges did ($P < 0.025$). The mean area of the home range for rams was 38.3 square miles, while for ewes the mean area was 15.4 square miles. In support of this observation, it was also noted that rams utilized more drainages than ewes. Home ranges of rams and ewes overlapped extensively and there was no indication that mutually exclusive home ranges of individuals existed.

There was a differential use of various elevations by the desert bighorns monitored in the study. Overall, rams were located at higher elevations than ewes ($P < 0.10$). Seasonal fluctuations in elevation preference were greater for rams than for ewes. The elevational zones in which ewes were found did not vary significantly by season of the year. On the other hand, rams occupied the 6,000 plus elevational zone less often than expected during the winter ($P < 0.05$) and more often than expected during the summer ($P < 0.05$).

Research is currently being planned in Canyonlands National Park to measure the effects of recreation and associated human interference on bighorn sheep.

TRANSPLANTS

The DWR has adopted a program of transplanting desert bighorn sheep into suitable and historic habitat from which the species has been extirpated. Currently two projects have been completed and at least six others are approved or in progress.

In 1975, 1976 and 1977, twenty-three desert bighorns were captured from the Glen Canyon, Red Canyon and White Canyon areas and subsequently released into the Moody Canyons of Escalante drainage. The releases consisted of seventeen ewes and six rams. Seven of these bighorns were instrumented for telemetry work. Reproduction has resulted at the transplant site and indications are that the sheep are doing well (Floyd Coles, DWR game manager, personal communication, March 1, 1978).

An earlier transplant in 1973 involved the capture in Nevada of twelve desert bighorns that have been released into an 80-acre holding paddock at Zion National Park. The purpose of the enclosure was to serve as a holding and propagation pasture until numbers increased to the point where a release into the wild could be effected. In January and February of 1977, 13 bighorns were removed from the paddock and ultimately were released into the wild at another location in Zion National Park (McCutchen 1975 and 1977).

Desert bighorns will be transplanted into habitats that are suitable for their needs and are within their historic range at Beckwith Plateau, San Rafael Desert, and San Rafael Swell in Emery County, Westwater Canyon along the Colorado River in Grand County, and Little Rockies and Orange Cliffs in Garfield County. In December 1978, 19 bighorns were transplanted to the San Rafael Swell and Westwater Canyon areas. These

animals are believed to be doing fine. Transplants will continue as long as the sheep population continues to expand.

THREATS TO DESERT BIGHORN SHEEP IN UTAH

Mineral and Energy Development

Lands inhabited by desert bighorn sheep have deposits of copper, phosphate, potash, placer gold, uranium and vanadium. The area is also underlain by large basins of oil and gas as well as reserves of coal and oil shale. Bighorn populations declined as a result of the uranium boom of the 1950's. Uranium ore prices have again increased to the point that remote areas will again be prospected resulting in disturbance to the sheep by roads and competition for the limited free water sources. Nuclear and coal fired generating plants are being constructed in close proximity to bighorn habitat. Development of energy sources in the area could certainly negatively impact desert bighorn and its habitat

Recreation

Habitats occupied by desert bighorns are highly scenic and contain a tremendous recreational resource. A measure of this potential is the existence of five national parks (Zion, Bryce, Arches, Capitol Reef and Canyonlands), two national monuments (Cedar Breaks and Natural Bridges), the Glen Canyon National Recreation Area and three float boating rivers (Green, Colorado and San Juan) within bighorn historic range. In addition, a wealth of archeological sites, boating, fishing, backpacking, hunting, picnicing and back country camping areas are found in bighorn country. Canyonlands National Park has experienced a 300 percent increase in number of visitors from 1968 to 1977.

Encroachment upon desert bighorn populations is reaching down from the mesa tops and extending up from the canyon bottoms. Along Lake Powell, back country campers using either conventional vehicles or house boats have had considerable impact on documented sheep range. Heavy recreational use has moved the sheep off the Castle Butte and Scorpion Canyon areas. Little sheep sign is noted now in Blue Notch, Hidden Valley and the immediate vicinity.

Livestock competition

The diet of the desert bighorn consists of semi-arid climax plant species (Irvine 1969). Over-grazing by domestic livestock makes these plants less available to bighorns. Without proper nutrition they are unable to combat parasites. Bighorn have been forced to use less desirable areas resulting in reduced numbers (Wilson 1968). Domestic livestock has exposed the bighorn to both scabies and lung worm. Desert bighorns have also been exposed to the bot fly (*Oestrus ovis*). The bighorn is not the natural host for the bot fly thus a condition called sinusitis results which is always fatal. This disease has been identified in desert bighorn sheep in Utah by Dr. Tom Bunch of Utah State University. Skulls found in San Juan County had been infected and a ewe taken in the December 1978 transplant operation was found to be infected and was turned over to Dr. Bunch for treatment. The Zion herd has experienced 45 percent mortality in sheep one year or older as a result of sinusitis (Bunch et al. 1978). Sinusitis may be a serious disease limiting the desert bighorn in Utah.

STATUS OF THE BIG HATCHET DESERT SHEEP POPULATION, NEW MEXICO

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Abstract. A two-year field study (1975-1978) was conducted on the remnant population of desert bighorn sheep (*Ovis canadensis mexicana*) inhabiting the Big Hatchet Mountains of New Mexico. Information on the distribution, population dynamics, habitat characteristics, movements, and food and watering habits of the sheep was compiled in an attempt to determine the present status and future potential of the population. Distribution of the present herd represents a small portion of their former range. Adult mortality approached 50% for the two years, contributing to an overall 40% reduction in population size. Excessive lamb mortality, linked to external movement patterns, precluded any increase. The Big Hatchet sheep were unique in their apparent independence of free water sources. The herd, which presently contains 10 adults and 3 lambs, is headed for eventual extinction if the present rate of decrease persists.

INTRODUCTION

The Big Hatchet Mountains of southwest New Mexico are inhabited by a remnant population of desert bighorn sheep (*Ovis canadensis mexicana*). Numbering 125 to 150 animals in the early 1950's (Gordon 1956), the population subsequently declined following a period of severe drought and overgrazing by deer (*Odocoileus hemionus*), bighorn sheep and livestock (Gross 1960). An estimated 25 sheep remained by 1960 (Gross 1960). Aerial surveys in 1964 and 1969 indicated the population was not increasing.

In 1976 a two-year field study was initiated in attempt to determine the status and factors limiting population growth of the Big Hatchet sheep. The project was funded by the Bureau of Land Management and contracted to the New Mexico Game and Fish Department and New Mexico State University. Information on the distribution, movements, population dynamics and preferred habitat of the sheep was compiled throughout the study. Lenarz (1977) presented some tentative results of the study. This paper is a summary of project results. For their assistance during this study I would like to thank: The Bureau of Land Management for funding the project; The New Mexico Department of Game and Fish, in particular Dr. Wain Evans, Andy Sandoval and Larry Temple; Dr. S.D. Schemnitz for providing advice throughout the study; Drs. R. Valdez and W. Conlev for reviewing this paper and; M.T. Everhart and family for their generous hospitality at the Hatchet Ranch.

METHODS

To facilitate consistent relocation of the small population, radio telemetry was employed. In September 1976, 5 sheep (2 rams, 3 ewes) were darted from a helicopter, using etorphine (M99) as the immobilizer, and instrumented with radio transmitting collars. Over the following year 2 of the transmit-

ters failed and 2 of the collared sheep died; therefore, 4 additional sheep (3 rams, 1 ewe) were collared in September 1977 utilizing the previous methods. All 5 remaining transmitters continued to function for the duration of the study.

Each collared sheep was located from the ground 6 to 10 times each month. Sighting information recorded included location, group size and composition, activity and habitat type.

Vegetational composition of the occupied sheep habitat was determined using the line intercept method (Canfield 1946). Food habits of the sheep were determined by the microhistological technique (Adams 1962). Analysis of fecal samples was completed by the Composition Analysis Laboratory at Colorado State University, Fort Collins.

RESULTS AND DISCUSSION

The desert sheep in the Big Hatchets presently occupy a small portion of their former range reported by Gordon (1956). Distribution of the ewes was restricted to 2 widely separated (5 km) mountains on the southern end of the range, and a cluster of volcanic hills 4 km south of the range. Mature rams frequented these areas with the ewes from June through December. In January the rams moved 2 to 6 km north, along the eastern side of the range, and remained there through the winter and spring. There was little interchange between the ewes and rams during this period; however, a single class 3 ram was distinctive in his habit of moving back and forth between the ewe and ram groups.

The maximum population estimate was recorded in August 1976, shortly after the project's beginning. A total of 22 individual sheep were identified. Of the 7 adult rams, 6 were estimated to be at least 5 years old. Horn length and body size of the 11 ewes indicated most were 4 years or older. This population structure was indicative of an old, declining population (Geist 1971) and suggested that recruitment had been low in the previous 4 to 5 years. When the field study was terminated in June 1978 only 10 adult sheep remained in the population. Over the two-year period, 10 adult and yearling sheep died or disappeared. In one instance, cause of death was determined to be predation by mountain lion (*Felis concolor*). Cause of death could not be determined from the only other carcass located, nor from the missing sheep.

Lamb survival was equally depressed. Of the 11 lambs born, none survived to adulthood. Three lambs were present in the population in December 1978, ranging in ages from 6 to 10 months. One lamb survived to yearling age, then disappeared. The disappearances of 5 of the 7 lambs (all 7 assumed dead) were related to the aberrant movement pattern to be discussed. Three lambs born 6 to 9 months prior to the study survived and all were recruited into the adult segment of the population.

Lambing occurred in the months of January, March, April, May, June, August and September; however 73% of the lambs were born between March and June. During the first year, Lenarz (1978) recorded 2 collared ewes giving birth to 2 lambs each, spaced 9.5 and 10 months apart (versus 12 months). Apparently, estrus in these ewes was triggered by the weaning or loss of their first lamb. This aperiodic estrus was contrary to normal bighorn sheep reproduction (Geist 1971). Unfortunately both ewes died and no other ewes have exhibited this breeding pattern. Ewe to lamb ratios varied from 100:44 in the first year to 100:80 in the second year. However, during the first year several lambs born to collared ewes disappeared within 2 to 11 weeks after birth; therefore, additional lambs may have been born to uncollared ewes and disappeared before being observed.

Early in the first year sheep were observed periodically leaving the mountain range. They travelled south across 4 km of creosote flats to a cluster of volcanic hills (Cairn Hills). Eighteen such moves were recorded over the two-year period. The majority of moves were initiated in the early morning, with groups being led by various adult ewes. The sheep remained in Cairn Hills for 3 to 5 days if undisturbed, but returned to the mountains running if disturbed.

During the second year, sheep were observed utilizing 2 natural mineral licks located in Cairn Hills. All subsequent trips there involved use of these licks. An additional 4 licks, located in the ram winter range, were frequently visited by the rams in winter and spring; however, no ewes or yearlings were observed using a lick except in Cairn Hills. Analysis of the ram-lick soils showed high concentrations of sodium relative to adjacent non-lick soils, and frequency of use at individual licks was directly related to sodium content (Table 1). Sodium levels in the Cairn Hills licks exceeded those found in the ram licks (Table 1). Apparently movements to Cairn Hills were precipitated by a craving for sodium. Preference for sodium in choice of lick sites has been demonstrated in Rocky Mountain goats (Herbert and Cowan 1971), Rocky Mountain elk (Knight and Mudge 1967), moose (Botkin et al. 1973), white-tailed deer (Weeks and Kirkpatrick 1976) and mule deer (Stockstad et al. 1953). Attempts to alter this movement pattern by placing mineral supplements in the occupied range were unsuccessful. Mineral stations showed no use after 11 months.

These movements across flat expanses had a significant effect on lamb survival. Of the 7 lambs which disappeared, 5 did so while at or during movements to and from Cairn Hills. Predation was suspected although no carcasses were found. Of the 7, 6 disappeared between 2 and 11 weeks of age and one disappeared at 5 months.

A peculiar aspect of the Big Hatchet sheep was their apparent independence of free water. In the 320 observations spanning all seasons, sheep were seen drinking on only 2 occasions. Both instances involved drinking rain water collected in rock depressions. There are no natural water sources of free water in the Big Hatchets. Artificial sources in the occupied sheep

observed use or signs of use were recorded at these sources. During the driest portion of the year, April through June, when the need for water should have been greatest, these artificial sources were dry. The sheep did not alter their distribution in response to this lack of water. A possible alternate source of water was prickly pear (*Opuntia* spp.), which occurred in 9 of 10 monthly composite fecal samples, comprising 53% of the diet in June. Other succulent plants also may have been utilized for their stored water content.

Monitoring the population will continue for at least 2 more years in conjunction with a sheep re-introduction evaluation study being conducted by the New Mexico Department of Game and Fish. Concentrated attempts to restrict the sheep to the mountain range with the use of mineral supplements could possible eliminate the major source of lamb mortality. However, a minimum threshold population size may exist, below which the low reproductive rate of desert bighorn (Hansen 1967) cannot compensate for the effects of random mortality. If this is the case, additional sheep may be required before a positive rate of increase is realized.

CONCLUSIONS

The Big Hatchet sheep population was drastically reduced in the late 1950's to approximately 20 to 25 animals, and has apparently fluctuated around this number for the last 20 years. Concurrent with the population reduction they experienced a constriction in distribution. The population declined significantly during this study, due in part to the unexplainable disappearance of 8 adult and yearling sheep. The lack of any increase was attributed to the unusually high lamb mortality, resulting in low recruitment. Lamb mortality was directly related to the abnormal movement pattern, which was probably in response to a craving for supplemental sodium. Their aperiodic estrous, extended breeding period, regular movements across flat country and apparent independence of free water illustrate the uniqueness of this remnant population. The recent decline of the herd may represent a normal fluctuation, or indicate a dangerous trend towards eventual extinction.

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Table 1. Frequency of use and sodium content of natural licks, Big Hatchet Mountains. New Mexico.

MOUNTAIN LICKS			
Lick #	Visits/Lick	Sheep Minutes	PPM Na
4	3	315	1140
3	2	225	761
6	2	115	356
5	1	41	55
7	0	0	160
CAIRN HILLS LICKS			
1	2	487	11852
2	2	869	1693

Mean sodium content, non-lick soils, mountains (n = 7) = 39ppm.
Mean sodium content, non-lick soils. Cairn Hills (n = 2) = 153ppm.

range consisted of 2 umbrella catchment units on the mountain and several earthen stock tanks around the base. No

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ARIZONA BIGHORN SHEEP STATUS REPORT — 1979

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Abstract. A total of 1306 bighorn sheep classified on helicopter and ground surveys included 360 rams, 610 ewes and 279 lambs. Fifty-four hunters harvested 45 rams for a hunter success of 83%. A research program funded by electrical utilities has been initiated to study the effects of powerline construction on bighorn populations. Transplanting efforts include monitoring sheep released at Aravaipa Canyon, construction of a fenced enclosure in the Virgin Mountains and investigating proposed release sites of desert bighorn in the Superstition Mountains and Rocky Mountain bighorn in the Blue River drainage of eastern Arizona. A strategic management plan for bighorn sheep has been written to identify bighorn problems and to develop strategies to solve these problems.

In 1978, 1306 bighorn sheep were counted during helicopter and ~~ground~~ surveys. Classifications included 360 rams, 610 ewes and 279 lambs. Calculated average ratios were 59 rams to 100 ewes to 46 lambs. Twenty-one areas, some including a number of mountain ranges, were surveyed as they are every year. Observations by area were from no sheep as a low to a high of 249.

Enough large rams were classified to justify a conservative statewide total of 58 hunting permits including 6 authorized by the Hualapai Indian Reservation. The permits were distributed over 22 different areas; the number of permits by area varied from 1 to 7.

A total of 1842 first choice applications was submitted for the 52 permits (excluding the Hualapai Indian Reservation) for an average of 35 applications per hunting permit. Residents applying totaled 1341 and non residents, 501.

Four hunters did not use their permits. Two, both nonresidents, would have been cited had they tried to check in and/or hunt since they had illegally submitted more than one hunting application. It is not known why the other 2 hunters failed to participate.

In 1978, 54 hunters harvested 45 rams for a hunter success of 83%. As shown in the following table, this is the third consecutive year of comparatively high hunter success. We believe that an increase in hunting expertise with a concomitant increase in bighorn populations account for a higher hunter success. The fact that Boone and Crockett scores are as high or higher than they have ever been lends credence to this supposition.



**A 10-Year Summary of Arizona Desert Bighorn Sheep Hunting
1969-1978**

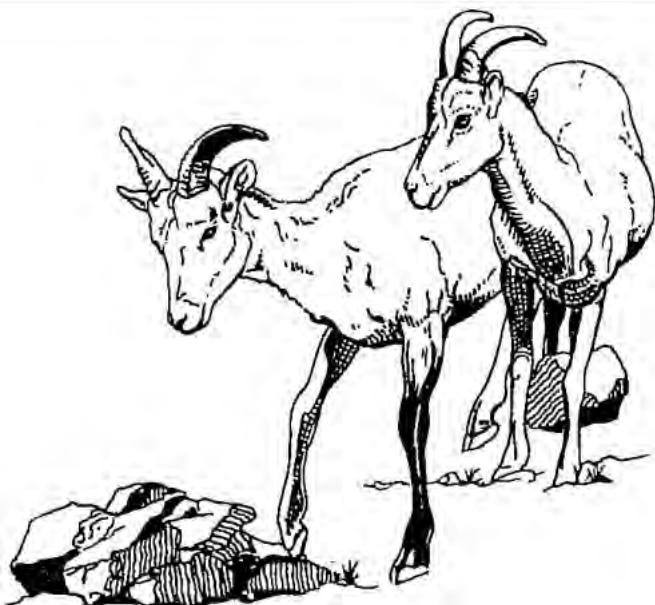
Year	Permits	Hunters	Harvest	% Hunter Success
1969	86	84	42	50
1970	79	76	39	51
1971	85	81	31	38
1973	71	68	38	56
1974	63	62	41	66
1975	60	57	35	61
1976	61	61	46	75
1977	57	57	50	88
1978	58	54	45	83

A group of residents of Tucson that are opposed to hunting bighorn sheep set up a hunter harassment program in the Santa Catalina Mountains in an attempt to scare the sheep from the hunters. Apparently, all of the hunters had some contact with the harassers but the anti-hunters were unsuccessful as all hunters harvested a ram.

Transplanting Program: At the present time, there are 4 transplant areas in various stages of planning and development--Aravaipa Canyon, Virgin Mountains, Blue and San Francisco River drainages and the Superstition Mountains.

The Aravaipa Canyon herd is still viable and appears to be expanding into new territory. Two rams were observed in the southeastern tip of the Winchester Mountains about 50 airline miles southeast of the release site. Thirty-two sheep, seen on spring (1978) helicopter surveys, included 9 rams, 18 ewes and yearlings and 5 lambs.

An enclosure of approximately 600 acres has been constructed by the Bureau of Land Management in Hedricks Canyon located in the north end of the Virgin Mountains. This area is slated to receive about 12 sheep in October or November 1979.



As a result of New Mexico's release of Rocky Mountain bighorn sheep near the New Mexico-Arizona border, a small population exists within Arizona along the San Francisco River drainage. Present plans are to obtain bighorns from Colorado (in trade for desert bighorns from Arizona) and release them in the Blue River drainage some 30 miles north of where the present population occurs. Hopefully, this will be accomplished in the winter of 1979-80.

Bighorn sheep were last seen in the Superstition Mountains about 1955. This mountain range probably holds more potential for desert bighorns than any other area under consideration. However, since it is so close to the metropolitan area of Phoenix, problems involving people visitations are anticipated. Much of the Superstition Mountains is in wilderness status. With an associated network of foot trails, the area is constantly besieged by hikers and backpackers, especially during the fall, winter and spring. In an attempt to counter this unknown people influence, Forest Service and Game Department personnel have been analyzing a small but high quality piece of bighorn sheep habitat just north of the Superstition Mountains isolated by the Salt River. Though this area does not enjoy official wilderness status, it is more of a wilderness than its southern counterpart because of its isolation. If approved, an enclosure will be constructed in this area in 1980 by the U.S. Forest Service with sheep trapping operations to be initiated soon thereafter.

Research: Several private and federally funded research programs are underway or are proposed. One, funded by electrical utilities (the Salt River Project in Arizona and Southern California Edison), is designed to determine the effects of powerline construction on bighorn sheep in the Plomosa, New Water and Dome Rock Mountains. The proposed powerline is to route power to Los Angeles from the Palo Verde Nuclear electrical generating plant near Buckeye, Arizona. This study, a little over a year in progress, has already provided important information on sheep distribution, herd interchange, movement and lamb mortality.

A proposed study of cattle-bighorn relationships has been submitted to the Bureau of Land Management for their consideration for funding. Another proposal that will be funded by the Bureau of Reclamation concerns the movement of bighorns across and around the Central Arizona Project canal in the vicinity of the Harquahala Mountains.

Planning: A bighorn sheep strategic management plan was submitted to the Arizona Game and Fish Commission and approved on 8 December 1978. This plan very simply identified the numbers, distribution and past, present and projected utilization of bighorn within Arizona. A goal and 1985 objectives were also identified. Problems recognized throughout the state as affecting bighorn were included in the plan as follows:

Population limitations	Transplanting needs
Lamb mortality	Enforcement problems
Livestock-bighorn relationship	Disease
Influence of developments	Influence of recreation
Water requirements	Response to fire

Strategies or proposed solutions were presented for each of the problems recognized in the plan. Actions needing cooperation of land management agencies were shown as well as action needed from state and/or federal legislatures. Although the strategic plan is basically a decision making tool for administrators, it also informs the public, the land management agencies and department personnel about what action should be taken for the species now and 5 years hence.

BIGHORN SHEEP POPULATION ESTIMATE FOR THE SOUTH TONTO PLATEAU— GRAND CANYON

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Abstract. A comparison of hiker observations and aerial surveys in 1977 and 1978 was used to estimate the bighorn sheep population on the South Tonto Plateau, Grand Canyon National Park. An averaging of these observations indicate a population of approximately 50 sheep in this area of the national park.

From May 23 to June 3, 1977 and August 10 to September 21, 1978, helicopter surveys for desert bighorn sheep were conducted between Red Canyon and Fossil Canyon on the Tonto Plateau of Grand Canyon National Park. These surveys includ-

ed only the south side of the Tonto Plateau but covered the elevational range from the Colorado River (elev. 2800 ft.) to the canyon rim (elev. 6900 ft.). The surveys included a total of 18 hours of helicopter flying time. The intent of the survey was to generate direct count statistics on numbers, sex and ages, and distribution of sheep within the study area.

The surveys were conducted using the park's contract Bell Jet-Ranger aircraft. This aircraft allowed for two observers plus the pilot. The left rear door of the helicopter was removed to offer an unobstructed view from the rear seat. Both 35mm cameras and ½" black and white video tape were used to record observations.

The pattern for surveying terrain within the canyon drainages consisted of clockwise contour orbits at river level (elevation 2800'), the Tapeats Formation (3600'), the Mauv Formation (4000'), the base of the Redwall formation (4400'), the Supai Formation (5600'), and rim level (6900'). All open areas on the Tonto Plateau and areas above the Redwall Formation were inspected separately to insure total coverage of the survey area.

Flights began at 6:30 a.m. each day and usually lasted until 10 a.m. The survey began in the Red Canyon area and moved westward over the Tonto Plateau. Table 1 presents the results of the 1977 and 1978 helicopter surveys. (USDI 1977a, 1978a).

Of particular note was the presence of an "albino" sheep in the survey area. The most recent observation was a lamb observed in the Ruby Canyon drainage. This lamb was part of a small herd consisting of a young adult ram and two ewes. Two other observations of apparent albinism in sheep were made by hackcountry hikers in 1977.

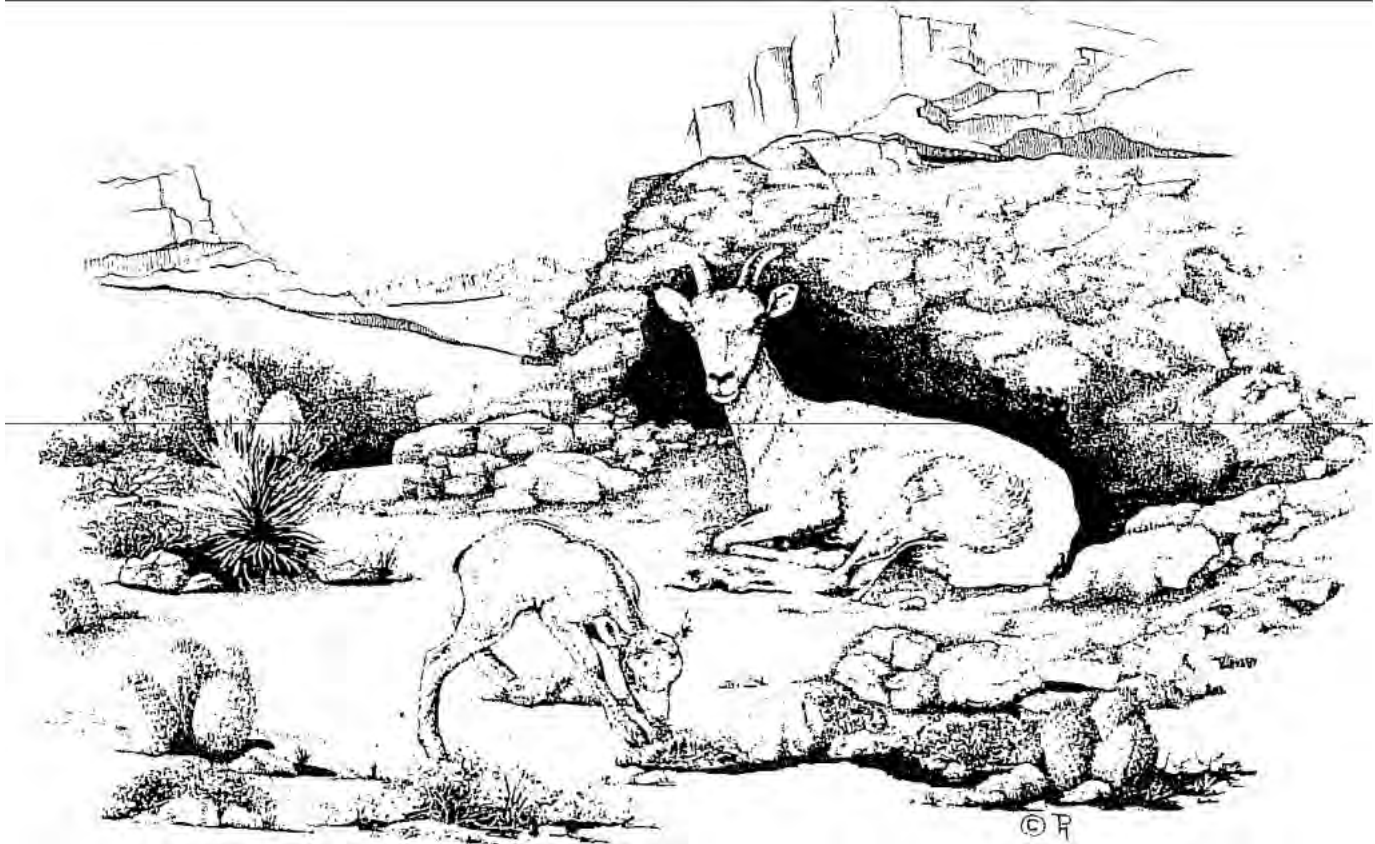


Table I a
1977 Bighorn Sheep Survey — (Park Helicopter)
Grand Canyon National Park

Location	Date (1977)	Ram	Horn Curl	Ewe	Lamb	Undetermined Age or Sex	Total
Pipe Creek	3/23	3					3
	6/1	1					1
	6/2	1		2			3
Horn Creek	5125			1			1
Hermit Creek	611	2					2
Slate Creek	5/23			1			1
	6/1					2	2
Agate Canyon	5123	1	Full	1			2
Sapphire Canyon	5/25	1	314				1
	6/1					2	2
Turquoise Canyon	5123	1		7	1		9
Ruby Canyon	5123			10	4		14
	612	2					2
	613	3	1 Full 2 (314)				3
Bass Canyon	6/3	2	112				2
135 Mile Canyon	7/6	2	1 (1/2) 1 (3/4)				2
Fossil Canyon	716	1	314	5	4		10
						Total Observations	60

Sheep occupied an elevational range from river level to above the Redwall Formation at 5200'. Animals observed above the Redwall Formation were generally seen within proximity of canyon heads. This is most likely due to the availability of water at these locations as opposed to the dry condition encountered at the extremities of ridges. It was noted there was very little water on the Tonto Plateau at the time these surveys were conducted except for moisture available at canyon heads and at occasional seeps. The Colorado River is available to animals that choose to descend the steep inner Canyon. This

trip could involve as much as 5 miles and a 4,000' descent for sheep occupying the deeper canyon drainages.

Observations were recorded by hikers traversing the nine designated trails on the south side of the Tonto Plateau. Observations (USDI 1977b, 1978b) indicate sheep were observed mainly along the Tonto Trail. Analysis of hiker observation forms indicates similar numbers of sheep and a similar dispersal were observed by hikers as were observed during helicopter flights. Table 2 summarizes total numbers of sheep reported by backcountry hikers during 1977 and 1978.

Table 1b.
1978 Bighorn Sheep Survey — (Park Helicopter)
Grand Canyon National Park

Location	Date (1978)	Ram	Horn Curl	Ewe	Lamb	Total
Pipe Creek	811	3	(2-full) (1-3/4)			3
Garden Creek	9121	1	full	5		6
Monument Creek	9121			4		4
Travertine Canyon	10125			1 7	1 2	2 9
Ruby Canyon	9128	1	full	4	1(albino)	6
Turquoise Canyon	9128	1	full	2		3
Cooper Canyon	9114	1		2	1	4
Total Observations						37

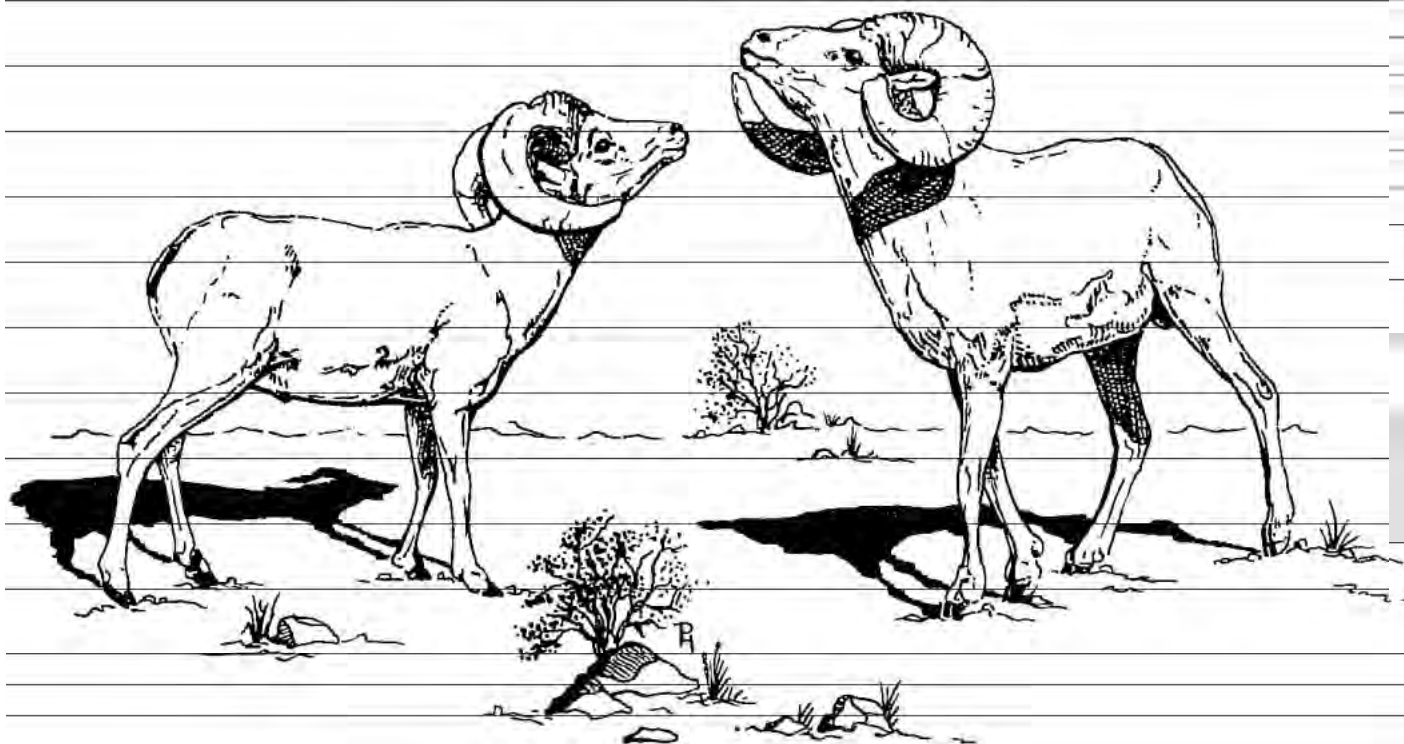


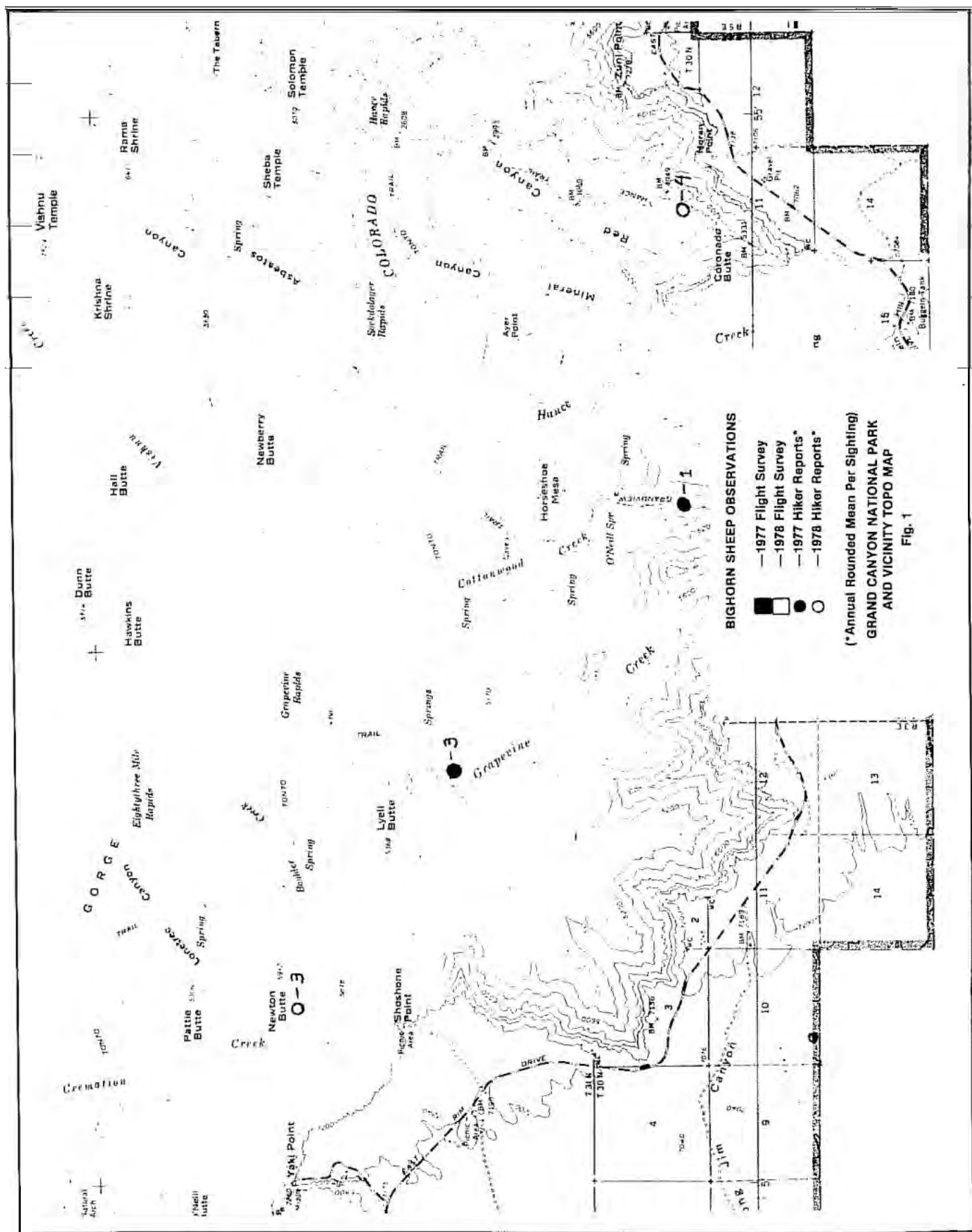
Table 2a.
Summary of Bighorn Sheep Observations as
Reported by Backcountry Hikers — 1977

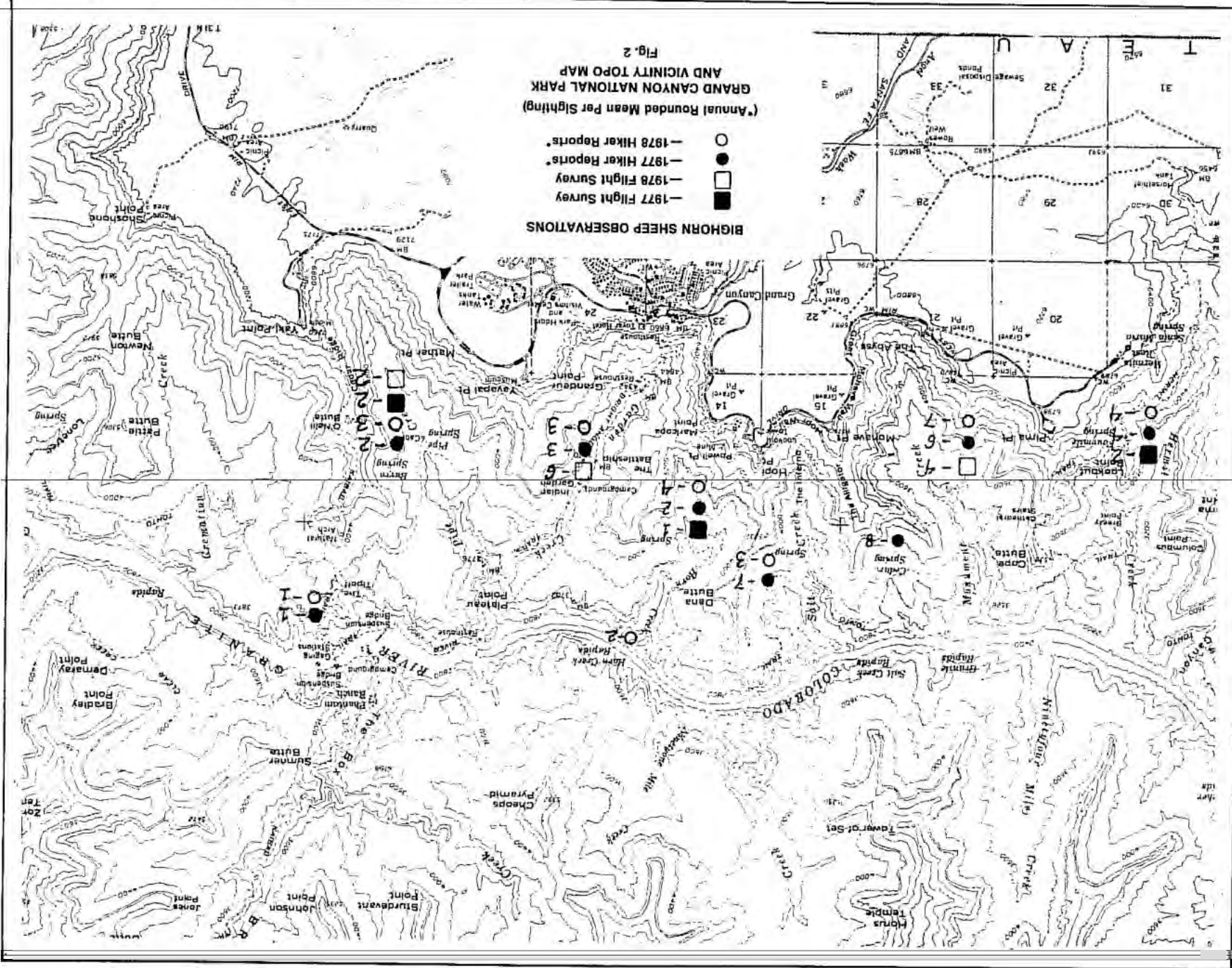
Location	Date (Month)	Ram	Horn Curl	Ewe	Lamb	Undetermined Age & Sex	Total	u
Horseshoe Mesa	1216	1					1	1
Grapevine Canyon	11112			1			3	3
Kaibab Trail	1112					1	1	1
Pipe Creek	6/1	3	2 Full 1 3/4				3	2
	1111	1	Full					
B.A Trail	213	1	114 ("White Coat")				1	
	316			3			3	
	412			3			3	
	5116	1					1	3
	9129			4	1		5	
Horn Creek	4122	1	112				1	
	9127			2	2		4	2
	11111	2	Full				2	
Salt Creek	212			1			1	
	11112	4	1 Full 3 3/4	11			15	
	11/15	5					5	7
	11/15	2		5			7	
Cedar Springs	11/10			6	2		8	9
Monument Creek	7127	1	Full				1	
	6127	2		3	2		7	6
	911			6			6	
	11123	1		8(1 albino)			9	
Hermit Creek	2112					2	2	
	3/77	2	Full				2	
	516			10	5		15	
	6/2	1	Full				1	
	7/2	1	1/2				1	4
	8/28					7	7	
	9/5	1	1/2				1	
	10/29	1					1	
	12/10	1	1/2				1	
	12/10			4	3		7	
	12/31	1		3			4	
Topaz Canyon		4					4	4
Slate Creek	8119			1 (Dead)			1	
	10125	1					1	3
	1114	2	Full	4	2		8	
Sapphire Canyon	611	2					2	
	3177	1	Full				1	2
Copper Canyon	10131	1	3/4			10	11	11
TOTAL 1977 OBSERVATIONS =							158	57

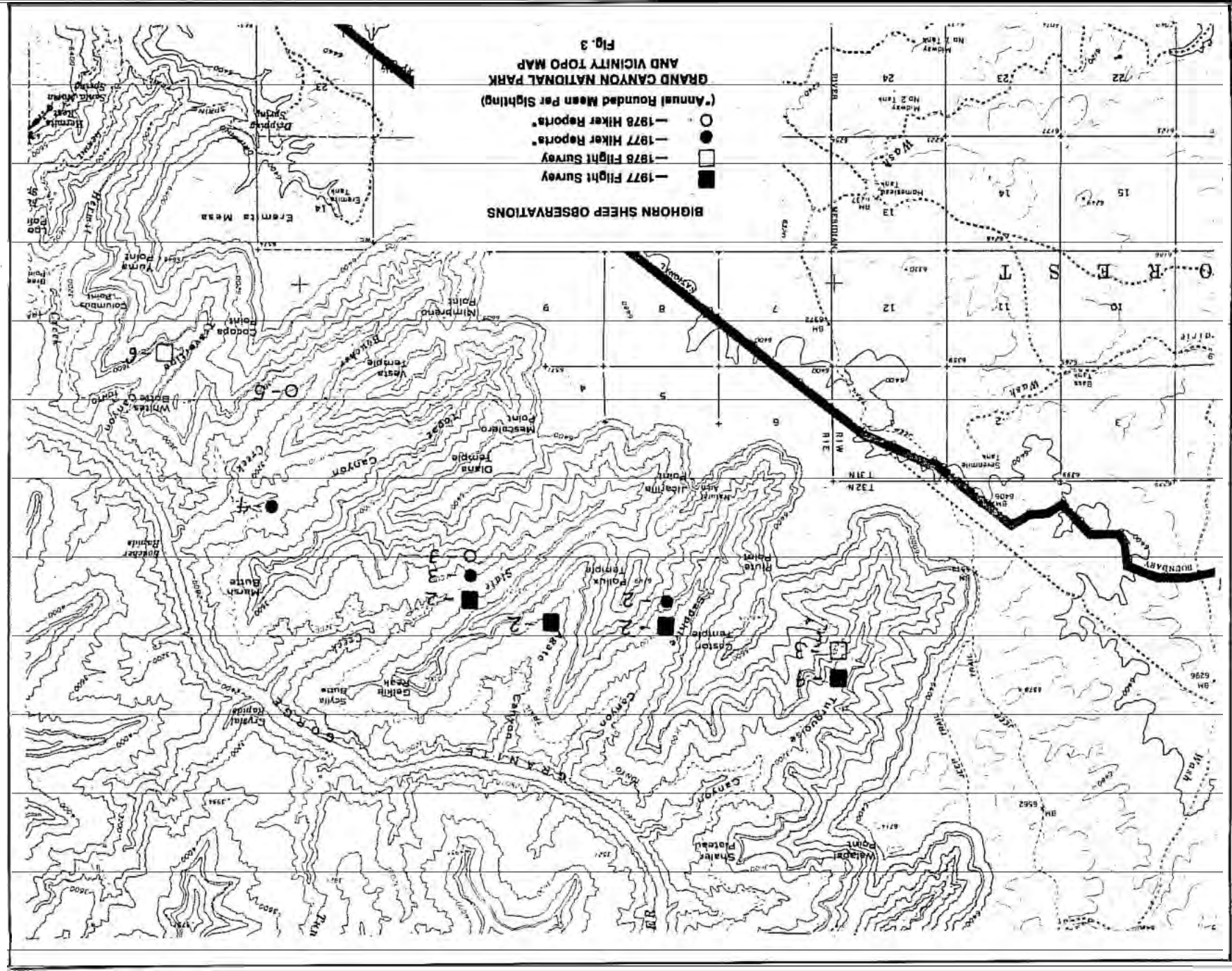
Table 2b.
Summary of Bighorn Sheep Observations as
Reported by Backcountry Hikers — 1978

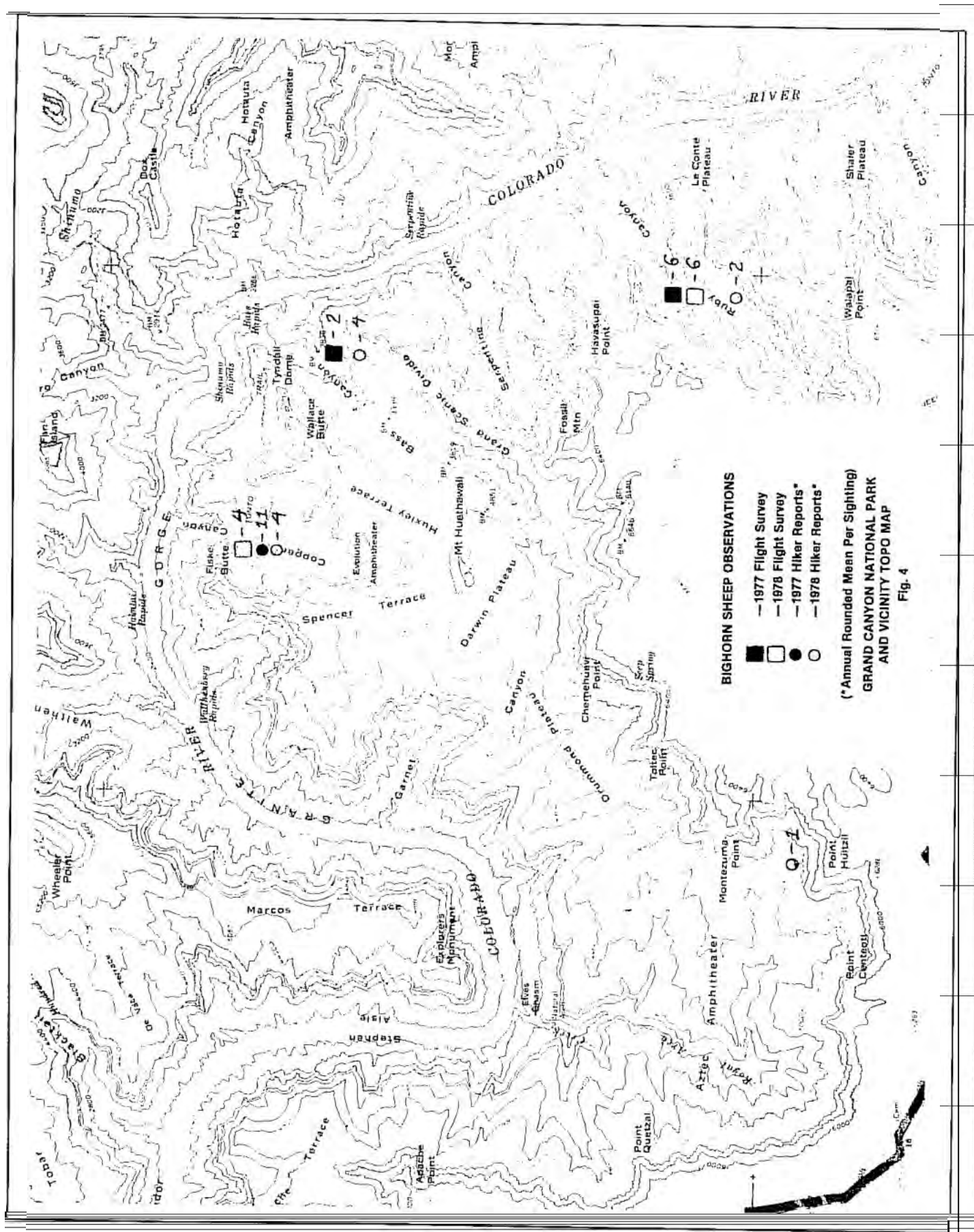
Location	Date (Month)	Ram	Horn Curl	Ewe	Lamb	Undetermined Age & Sex	Total	u
Red Canyon	August	2		2			4	4
Newton Butte	May	3					3	3
Kaibab Trail	March	1	314				1	
	October	1					1	1
	November	1	Full				1	
Pipe Creek	February			2			2	
	February					2	2	
	February	2	Spikes				2	
	March	1					1	
	March	1					1	2
	April	1	Spike				1	
	November	1	314	2			3	
	December	2		3		2	7	
Garden Creek	January					4	4	
	January	2	1/2	1			3	
	February	2	112	2			4	3
	June					2	2	
Horn Creek	January						2	2
	February	1	Full	5			6	
	March	1		1			2	
	September	3	2 Spikes-213				3	
	September	2		7			9	4
	October	1	Full				1	
	October	4		1			5	
	October	2					2	
	November	3		5			8	
	November	1	213				1	
Horn Creek (River Trip)	November 4	1	314	1			2	
	November	1	Full	1			2	2
		1		1			2	
Salt Creek	February					1	1	
	May			9	1		10	
	June	June	1				1	
	July	1						3
	October	2	112 & Full				2	
	November	1	314				1	
Monument Creek	April	1		2			3	
	February			10			10	7
Hermit Creek	January			6			6	
	January			5			5	
	February	3					3	
	April			2			2	4
	April	1	314	3			4	
	May	1					1	
Boucher Canyon	February	5			2		7	
	August	2	314				2	
	October	1	Full	6	2		9	5
	December	3	1 Full 2 112				3	

(continued page 106)









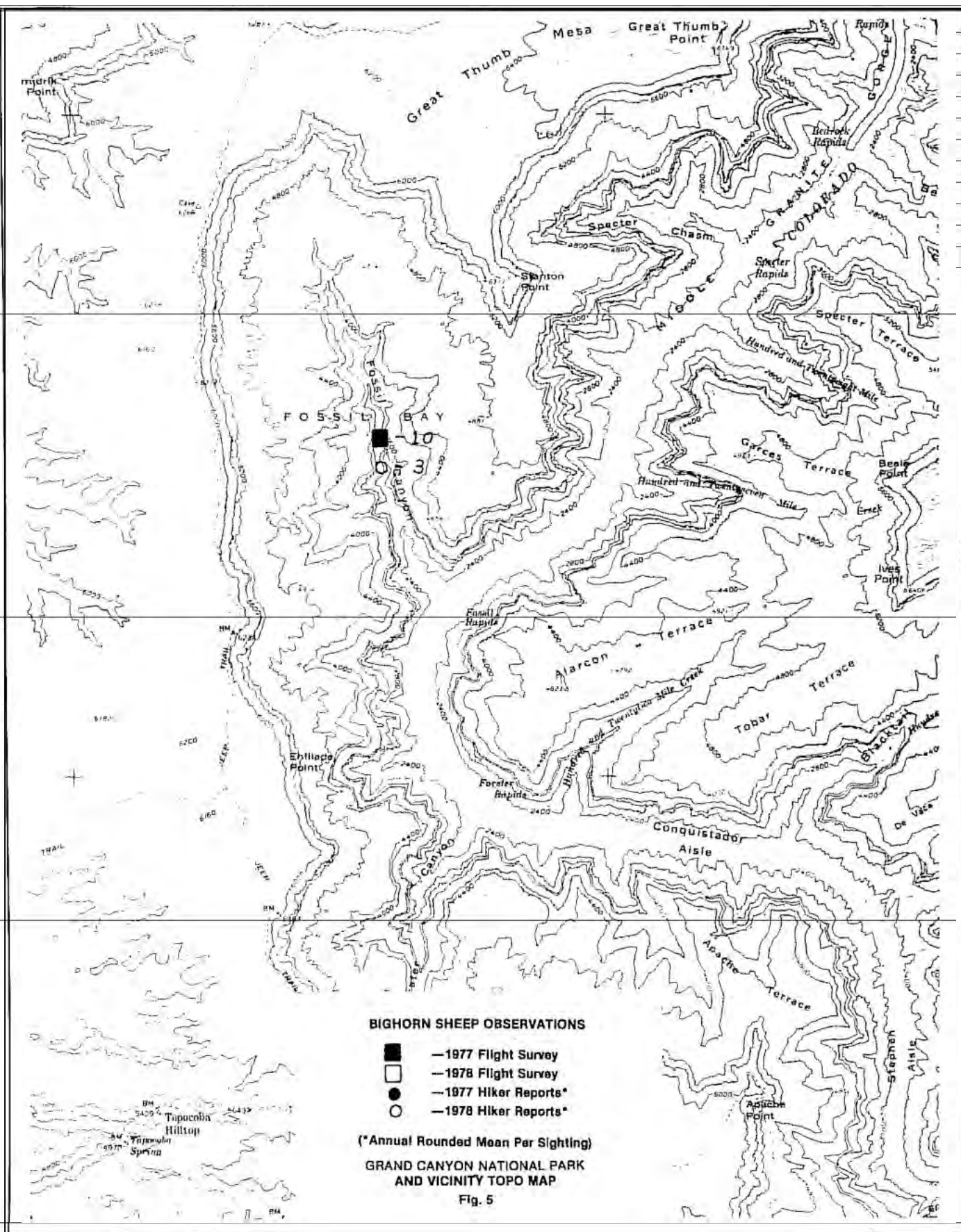


Table 2b. (continued from page 100)
**Summary of Bighorn Sheep Observations as
 Reported by Backcountry Hikers — 1978**

Location	Date (Month)	Ram	Horn Curl	Ewe	Lamb	Undetermined Age & Sex	Total	u
Slate Creek	April	3					3	3
Ruby Canyon	September			2			2	2
Bass Canyon	March	4					4	4
Copper Canyon	September	2	Full	1	1		4	4
Point Hultzil	August	1	1/2				1	1
Fossil Canyon	September	1		1	1		3	3
TOTAL 1978 OBSERVATIONS = 175								55

Obviously the problem of different hikers reporting the same sheep several times makes a population estimate derived from these numbers unreliable. However, there is a similarity between sheep observations obtained from hikers and from the aerial survey.

A simple averaging of hiker observations over the two sample years indicates numbers similar to those obtained from flight surveys. it is reasonable to say that there are approximately 50 sheep between Red Canyon and Fossil Canyon in Grand Canyon National Park.

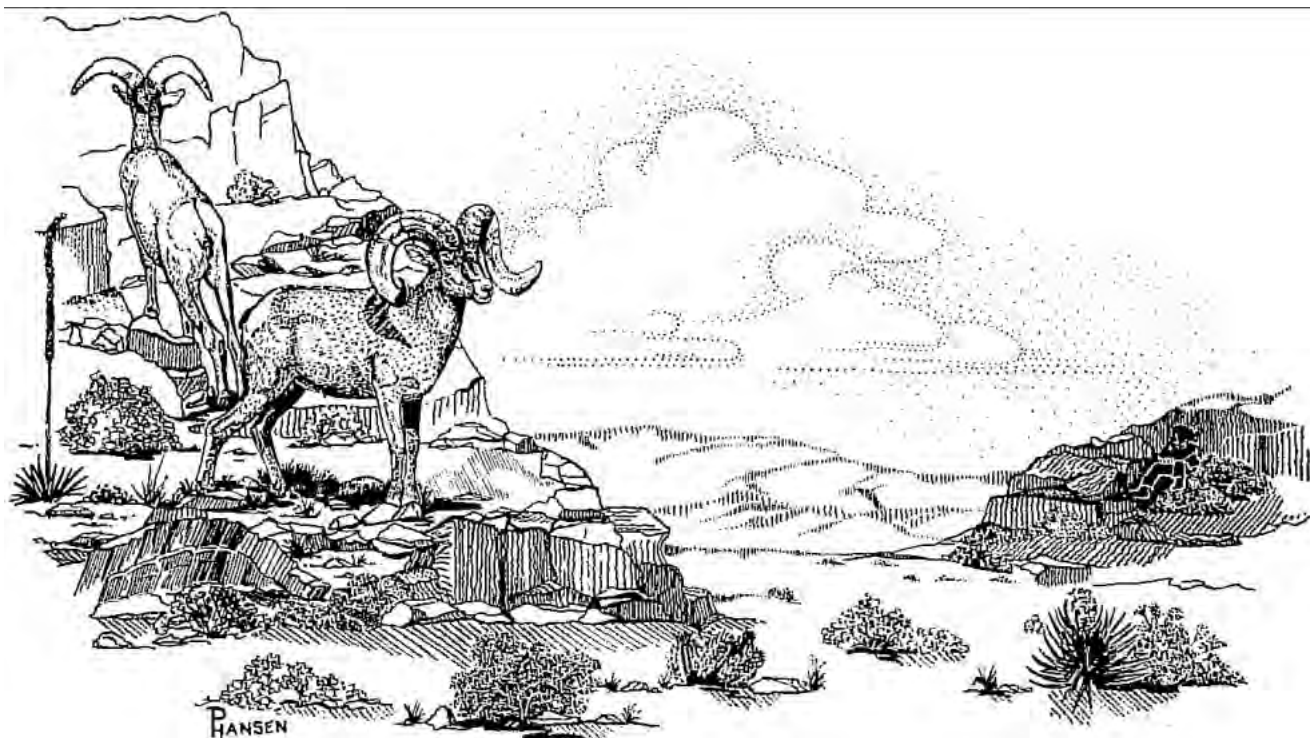
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1977b. Study collection wildlife observation records-bighorn sheep. Grand Canyon National Park, Arizona.

1978a. Bighorn sheep survey notes. Grand Canyon National Park, Arizona.

1978b. Study collection wildlife observation records-bighorn sheep. Grand Canyon National Park, Arizona.



BIGHORN SHEEP STATUS REPORT — NEVADA

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Abstract. Desert bighorn sheep populations generally are at high levels with some individual populations showing decreasing or increasing numbers. Bighorns are hunted annually with hunters enjoying higher than ever success. Major emphasis is being placed on reintroduction of all three subspecies of bighorn on historic ranges of the state. Bighorn water development is a continuing effort to enhance habitat and increase populations of desert bighorn.

Population Information

The statewide bighorn sheep population underwent no major changes relative to total numbers in any of the scattered populations found throughout the state. Some populations ap-

peared to increase slightly while others decreased. The overall trend based on the analysis of herd parameters indicates slightly fewer sheep as a result of lower lamb survival in 1978.

The annual helicopter surveys were completed in two segments during 1968. A February census was conducted in the five major mountain ranges of the Desert National Wildlife Range. Flights totaling 20.8 hours provided a sample of 489 animals that were classified as 172 rams, 275 ewes, 33 yearlings, and 9 new born lambs. The ram:ewe:yearling ratio was 63:100:12.

The preseason survey conducted in late September and early October produced a sample of 1,365 sheep during 82.5 hours of census. There were 748 ewes, 210 lambs, and 407 rams observed for a ram:ewe:lamb ratio of 54:100:128. A total of 17 mountain ranges were censused during this period. Figure 1 shows the comparative ratios of rams and lambs to ewes over the long term. Age composition of rams observed indicate good representation of older age class rams in the population with approximately 28% in the 7 year old or older group.

The ages of rams harvested ranged between 4 and 13 years and averaged 7.2 years. A total of 23 rams or 42% were under 7 years old, while 8 rams or 15% were over 10 years old.

The trophy value of rams harvested were evaluated by using the Boone and Crockett measurement technique. The average B&C score was 156 2/8 points with eight animals over the minimum (green measurement) for entry into the North American Big Game Awards Program.

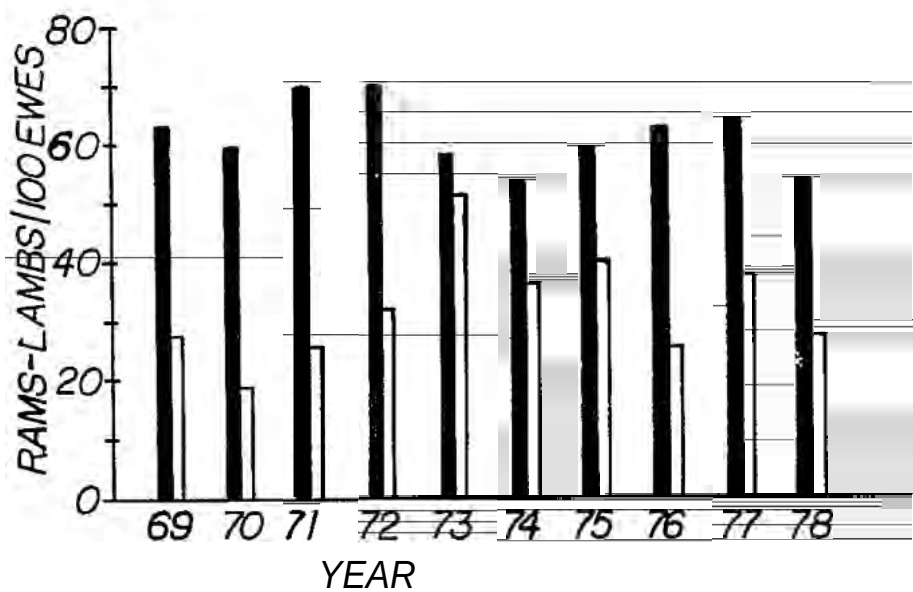


Figure 1. Bighorn Herd Composition Obtained From Aerial Census

Hunting Seasons

Eighty-one desert bighorn sheep permits were available in 16 hunt units of the State. There were 72 residents and 9 nonresident hunters participating during the November-December, 1978 hunting season.

Interest in bighorn hunting remains high judging from the number of applications received for the limited available permits. A total of 582 resident applications were received for the 72 permits. Nonresident interest decreased somewhat from the previous year due to a slight change in application procedure. There were 381 applicants for the 9 available permits.

The 1978 bighorn season resulted in the harvest of 55 rams for an overall success rate of 68%. Resident success was 65% while nonresident success was 89%. Figure 2 shows the long term hunter success since 1952, indicating the relatively high success rates during recent years.

The 80 hunters participating expended a total of 652 hunter days during the 1978 season for an average of 8 days per hunter. Successful hunters spent an average of 7.1 days while the average days expended per sheep harvested was 12.0.

An analysis of hunter report forms indicate that 2086 desert bighorns were observed during the season for an average of 31.6 sheep observed per hunter, and 3.9 sheep observed per hunter day.

Bighorn Sheep Trapping, Transplant and Follow-up.

To date five successful transplants of bighorn sheep have been accomplished in Nevada. Follow-up work shows that the Mount Grant and Stonewall Mountain sites have established breeding herds of desert bighorn. The most recent observations on Stonewall Mountain revealed 18 animals including 4 lambs.

California bighorn have been reintroduced onto two sites in Nevada. In 1968, eight bighorns were released on Hell Creek in the Charles Sheldon National Wildlife Refuge marking the first appearance of this subspecies in Nevada after an absence of over 40 years. In March of 1978, twelve California bighorns from British Columbia were released in the Eight Mile Creek area of the Santa Rosa Range of Humboldt County. Both transplants were successful and have established breeding populations.

The status of the Rocky Mountain bighorn reintroduction was determined through aerial and ground census during March and July, 1978. A total of 23 bighorns were observed during each of the surveys. The maximum observed number indicates a minimum population increase of 44% during the four production seasons following release.

Bighorn sheep trapping was attempted during the summer of 1978 on the sheep range of Clark County. Weather conditions were not favorable for a successful water trapping effort, consequently, no animals were captured for transplant. Close coordination was maintained with the Land Management agencies for inventory of potential reintroduction sites, development of plans and environmental analysis reports for bighorn sheep reintroductions. Several areas have been approved and are now awaiting stock for transplant. Efforts are continuing with even greater emphasis to inventory and describe all potential bighorn habitat in the state for transplants.

Development

Bighorn water development is a continuing effort. A horizontal drill has been purchased for this purpose, however, specific site approval for development on public lands has been very slow in materializing. In addition to drilling, development of natural catchments and guzzlers will be attempted.

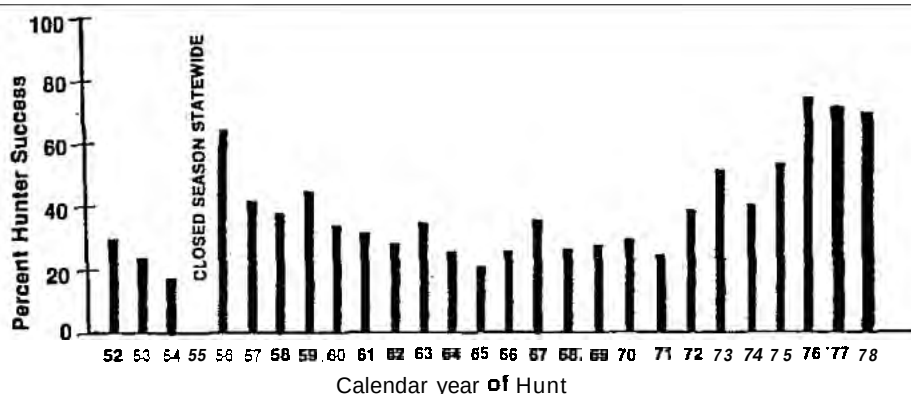


Figure 2. Percent Hunter Success Of All Nevada Sheep Hunts

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DESERT BIGHORN COUNCIL MEETINGS AND OFFICERS 1957-1979 ANNUAL MEETINGS

Year	Location	Chairman	Secretary-Treasurer
1957	Las Vegas, Nevada	M. Clair Aidous	
1958	Yuma, Arizona	Gale Monson and Warren Kelly	
1959	Death Valley, California	M. Clair Aidous	Fred Jones
1960	Las Cruces, New Mexico	Warren Kelly	Fred Jones
1961	Hermosillo, Sonora, Mexico	John Van den Akker	Ralph Welles
1962	Grand Canyon, Arizona	James Blaisdell	Charles Hansen
1963	Las Vegas, Nevada	Al Ray Jones	Charles Hansen
1964	Mexicali, Baja Calif., Mexico	Rudolfo Hernandez Corzo	Charles Hansen
1965	Redlands, California	John D. Goodman	John P. Russo
1966	Silver City, New Mexico	Cecil Kennedy	John P. Russo
1967	Kingman, Arizona	Calud Lard	John P. Russo
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
1974	Moab, Utah	Carl Mahon	Lanny Wilson
1975	Indio, California	Bonhar Blong	Lanny Wilson
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

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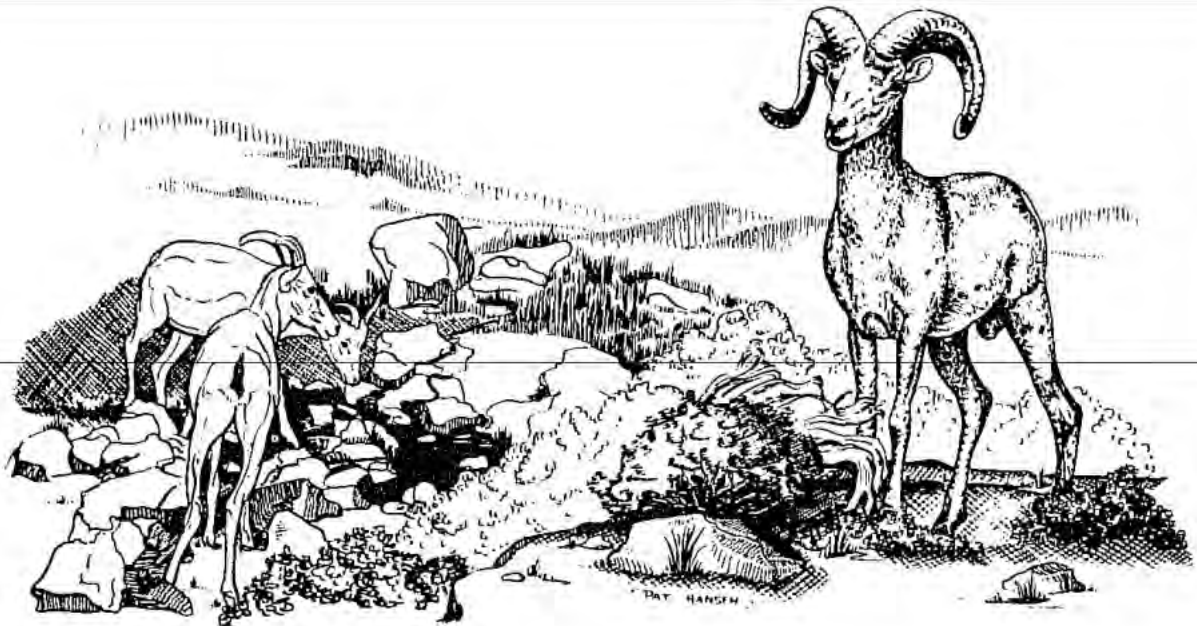
- 1960** Ralph and Florence **Welles**, U.S. National Park Service, Death Valley, California
1962 Oscar V. **Deming**, U.S. Bureau Sport Fisheries and Wildlife, Lakeview, Oregon
1965 John P. Russo, Arizona Game and Fish Department, Phoenix, Arizona
1966 Charles Hansen, U.S. Bureau Sport Fisheries and 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 Bob **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

AWARD OF EXCELLENCE:

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



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