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A MORPHOMETRIC REEVALUATION OF THE PENINSULAR BIGHORN SUBSPECIES

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Abstract: Cowan's *(1940)* taxonomy of North American wild sheep *(Ovis canadensis)* has been used for a half century. However, Ramey's *(1993)* mitochondrial DNA analysis, and his reanalysis of Cowan's original morphometric data failed to find validity in Cowan's desert subspecies divisions. Cowan's desert subspecies were instead found to be a result of small sample sizes and different age distributions among samples. In this study, we reevaluated the Peninsular subspecies (*O. c. cremnobates*) by measuring *198* ram and **145** ewe skulls from the California region and the Sonoran and Chihuahuan Deserts, as well as *28* Rocky Mountain sheep (*O. c. canadensis*) and *13* Dall sheep *(O.dalli)* specimens. We found substantial age effects for adult rams, but not adult ewes. When age effects were removed, univariate, principal components, and discriminant function analyses: *1)* failed to support a separate taxon in the Peninsular Ranges; 2) identified some differences in the Sierra Nevada; and, *3)* revealed considerable difference between northern and southern regions of the Nelson subspecies (*O. c. nelsoni)*. Therefore, we synonymize the Peninsular subspecies with the Nelson subspecies and suggest that the Nelson subspecies be viewed as a polytypic taxon.

Key words: morphometrics, mountain sheep, *Ovis canadensis*, Peninsular bighorn, taxonomy
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INTRODUCTION

The currently accepted taxonomy of North American wild sheep (Shackleton *1985,* Bowyer and Leslie *1992)* was based on comparisons of skull measurements among populations made by Cowan *(1940)*. Cowan described *4* desert subspecies in the southwestern United States: Nelson *(Ovis canadensis nelsoni),* Mexican (*O. c. mexicana*), Peninsular (*O. c. cremnobates),* and Weems (*O. c. weemsi)* bighorn sheep, as well as California bighorn sheep (*O. c. californiana) in* the Sierra Nevada. State and federal conservation programs have relied on Cowan's work as a guide to the differentiation of mountain sheep for *50* years. These taxonomic designations have influenced the choice of source populations for reintroductions and the allocation of monetary resources to conservation programs (Bureau of Land Management *1989).*

A recent reanalysis of Cowan's *(1940)* original data using sophisticated modem analytical methods suggested that some of the subspecies he recognized may not be valid (Ramey *1993).* This analysis showed that differences between putative subspecies in the southwestern deserts apparently resulted from small sample sizes and age-related size differences, as suggested by Cockrum *(1961).* Similar conclusions were reached by Gonzalez *(1976)* concerning

the validity of *O. c. weemsi* in Baja California, and by Bradley and Baker *(1967)* regarding the status of *O. c. mexicana* relative to variation they found within *O. c. nelsoni.* Analysis of mitochondrial DNA (mtDNA) sequence variation by Ramey *(1991, 1993)* cast further doubt on the validity of the subspecies recognized by Cowan *(1940)* in the Southwest. Distribution of the small amount of mtDNA variation in the Southwest was not concordant with Cowan's subspecies boundaries, with the exception of sheep from the Sierra Nevada.

In addition to the lack of genetic support for desert subspecies, some of the boundaries between them have been inconsistent among authors, particularly for the Peninsular subspecies. The original distribution of *O. c. cremnobates* described by Elliot (1903) extended north through Baja California to near the U.S. border. With no evident additional data or analysis, Grinnell *(1933)* extended the boundary north through the Peninsular Ranges of California to San Gorgonio Pass. Cowan *(1940: 565)* shifted the boundary back south to include only "extreme southern California", including both sides of Imperial Valley. However, he noted that the region from the Santa Rosa Mountains to the San Bernardino Mountains appeared to be a zone of intergradation between *O. c. cremnobates* and *O. c. nelsoni.* Jones (1950:31) initially chose the boun-

daries of Grinnell (1933) rather than Cowan (1940), but subsequently switched, referring to the sheep in the Santa Rosa Mountains as *O. c. nelsoni* (Jones et al. 1957:179). Weaver (1957) followed Cowan (1940) in suggesting that the Santa Rosa Mountains might be a zone of intergradation, but Goodman (1962:43) questioned this, stating, "to my knowledge this fact has never been definitely established". Buechner (1960) and Barrett (1965) both extended *O. c. cremnobates* north into the Santa Rosa Mountains and miscited Cowan (1940) as support.

The most consistent shift in the recognized northern boundary of *O. c. cremnobates* resulted from state listing of this subspecies under the California Endangered Species Act. The first listing in 1974 included bighorn sheep in the Santa Rosa Mountains, while those in the San Jacinto Mountains were added in 1980 (California Department of Fish and Game [CDFG] 1974, 1980, At the crossroads, a report on the status of California's endangered and rare fish and wildlife. 147pp.). Following these designations, sheep in these two northern Peninsular Ranges have been referred to consistently as *O. c. cremnobates* (Merritt 1974, Weaver 1975, Berger 1982, Turner and Payson 1982, DeForge 1984). In effect, these recent boundary changes have accepted Grinnell (1933) over Cowan (1940). All of these post-Cowan boundary changes share a common characteristic: they were made without any additional systematic research. A parallel unsupported shift in the boundary between *O. c. nelsoni* and *O. c. mexicana* was effected by Russo (1956) in Arizona.

The purpose of this investigation was to reevaluate taxonomic divisions between Nelson and Peninsular subspecies from a morphometric standpoint using a new data set.

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METHODS

We treated Cowan's (1940) taxonomic divisions as hypotheses to test. Our approach was to examine morphometric differences between Nelson and Peninsular bighorn specimens within the context of variation on 2 geographic scales: 1) the California region; and, 2) the Southwest. Both univariate and multivariate analyses were used.

We first broke the California region into 5 geographic units for univariate analyses: 1) the Peninsular subspecies distribution, including Baja California, as defined by Grinnell (1933), as well as by Cowan (1940); 2) the Mojave Desert from south of the Death Valley region to the Colorado River; 3) the Death Valley region, where Bradley and Baker (1967) indicated sheep to be morphologically different from neighboring Nevada, and which Wehausen (1991) suggested as a potential transition zone; 4) the White Mountains and neighboring west central Nevada; and, 5) the Sierra Nevada, which Cowan (1940) designated as the California subspecies. The San Gabriel Mountains were omitted due to inadequate sample sizes. Preliminary analyses found the Death Valley region to lack distinction from the White Mountains/Nevada region immediately to the north. Consequently, they were lumped for the analyses reported here and will be referred to as "Great Basin". This left 4 California geographic regions. Two represented reputed subspecies (*O. c. californiana* from the Sierra Nevada and *O. c. cremnobates* from the Peninsular Ranges), while the other 2 split the Nelson subspecies into northern and southern regions. This allowed comparisons of differences between reputed subspecies with variation within a subspecies.

Principal components analyses (PCA) were conducted on a larger geographic basis that included: 1) the San Gabriel Mountains of California; 2) southern Baja California; 3) Arizona and Sonora (Sonoran Desert); and, (4) New Mexico, Chihuahua, and Texas (Chihuahuan Desert). We also measured some skulls from the Rocky Mountain region and from Dall sheep to represent yet wider geographic variation.

Skulls from native populations were measured from collections at the Smithsonian National Museum in Washington, D.C., and several locations in California. Sample sizes by region were (ram/ewe): Chihuahuan Desert, 9/4; Sonoran Desert, 34/14; southern Baja California (*O. c. weemsi*), 5/5; Peninsular subspecies (including 1118 from northern Baja California), 43/16 (Cowan's range), 57121 (Grinnell's range); Mojave Desert, 35/46; San Gabriel Mountains, 4/4; Great Basin, 31/26; Sierra Nevada. 23/25; Rocky Mountain region, 10118; and Dall Sheep, 518. While only a subset of these provided complete measurements, our sample size far exceeded what Cowan (1940) used as the basis of his taxonomy for all of North America (Ramey 1993).

We developed a set of measurements that described 4 attributes of skulls: length, width, height, and horns (Table 1). To the extent possible, we used homologous landmarks (Bookstein 1990) such as the intersections of sutures. We included among

TECHNICAL REPORTS

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Table 1. *Skull* and *horn* measurements made for *this* study. Abbreviations are *in* parentheses.

Cranial Length (CRANIAL): Distance from anterior lip of foramen magnum to posterior edge of palate at midline suture.

Palate Length (PALATE): Distance from posterior edge of palate at midline suture to posterior margin of the most intact anterior palatine foramen.

Premaxilla Length (PREMAX): Distance from posterior margin of anterior palatine foramen to tip of premaxillae along midline.

Average Upper Tooth Row (TOOTH): Average length of upper tooth rows measured as the greatest alveolar length of combined upper molars and premolars.

Palate Width (PM2)[a]: Least distance across palate between alveoli of second premolars.

Cheek Width (CHEEK): Greatest distance between malar eminences on the maxillary bones.

Interorbit Width (INTERORB)[a]: Least distance in a straight line taken with calipers resting in notch on inferior orbital rim at lower edge of lachrymal bones.

Intraorbit Width (INTRAORB): Width of largest orbit measured as greatest width of interior lip of orbit.

Zygomatic Width (ZYGO): Greatest distance between external margins of zygomatic arches taken on jugo-squamosal suture.

Post Orbit Width (POSTORB): Minimum width of frontal bone as measured posterior to orbits and anterior to horn cores.

Cranial Height (HEIGHT): Males: Greatest distance from anterior lip of foramen magnum to crest of cranium along midline suture; Females: Greatest distance from anterior lip of foramen magnum to crest of cranium along midline suture even with the anterior edge of horn cores.

Horn Core Length (CORL): Length of horn core measured along the superior edge from the burr to the tip using a steel tape.

Horn Core Basal Circumference (CORC)[a]: Circumference of largest horn core, measured around core near burr at right angle to the axis of the core at that point, using a steel tape.

Horn Core Volume (CORVOL): The estimated volume of ram horn cores when treated as a cone using the previous two measures as basal circumference and height.

Horn Basal Circumference (HORNC)[a]: Circumference of largest horn measured nearest its base using a steel tape.

Horn Length (HORNL)[a]: Measured along the superior horn keel from orbital corner to tip of horn with steel tape.

Horn Volume (HORNVOL): Volume of largest horn estimated from lengths and circumferences. The horn length was divided into four quarters and the circumference of the horn was measured with a steel tape at the base, each quarter, and at a measured length near the end just short of any brooming. The radius of the horn at its base and at each quarter was estimated by treating each circumference as a circle. Horn volume was estimated by calculating and summing the volumes between each circumference calculated as frustrums of conical sections (Hogman et al. 1961). A final conical section was then added from the last circumference to approximate brooming loss using a constant taper for all specimens. An analysis of the ends of unbroomed horns yielded a constant taper across all populations (distance between circumferences accounted for 96% of the variation in circumference differences; $n=19$).

Age (AGE): Growth years determined from annual horn growth rings. For specimens missing horn sheaths, a minimum age was determined from tooth replacement and wear. Specimens with minimum age estimated only from wear were not use in analyses where age was the independent variable.

[a] Measurements from Cowan (1940)

our measurements several variables that Ramey (1993) found to be important in Cowan's (1940) data set. We also generated new variables potentially representing additional variation including some representing horns, horn cores, and the cranial region of the skull that could be measured on incomplete skulls. Horn measurements on rams included the lengths and circumferences necessary to calculate Boone and Crockett scores, but we used these in combination with additional measures to calculate an index of horn volume (Table 1).

We further tested Ramey's (1993) suggestions on the influence of age. For many measurements, age effects were expected at least until 4 years, when tooth replacement is completed (Taber 1971). We investigated age effects for skulls 2 4 years by looking for a significant age covariate for each variable via analysis of covariance (ANCOVA). Because age effects are potentially curvilinear, in addition to AGE, we also tested lnAGE, and 1/AGE. The age covariate that accounted for the most variation in ANCOVA was used, while analysis of variance (ANOVA) was used instead if age effects were not significant, or did not have parallel slopes. The Bonferroni multiple comparisons test was used to compare differences between

the Peninsular and Mojave Desert regions relative to other differences within the California region. We used $P=0.05$ as our cutoff for rejecting the null hypothesis in all statistical analyses.

Multivariate methods of analysis included PCA and discriminant function analysis (DFA). The former assumes nothing a *priori* about potential groupings within the data, instead generating principal components only on the basis of variance in the data. It was used as an exploratory tool (Reyment et al. 1984), both with and without horn variables included, to look at potential size and shape differences and patterns in the Southwest. We used PCA to see if any separation of geographic regions occurred, including Peninsular Ranges versus the Mojave Desert, and what variables were primarily responsible for any such separations. The variation most notable to the eye in series of ram and ewe skulls is horn size and shape. While we included horn variables in PCA, we also excluded them to investigate whether skull variables alone would generate geographic patterns of interest, and because of greater uncertainty regarding environmental (nutritional) influences on horn size. Since an age covariate cannot be used in PCA, we used the results on age effects to eliminate age effects by limiting ages to 1 4 years for ewes, and ≥ 8 years for rams. PCA was performed on a covariance matrix derived from pairwise analyses of $\log_e$ transformed variables. Pairwise analyses allowed the maximum amount of data to be used, including the use of specimens lacking some measurements. Only a limited subset of the specimens having all measurements could be used for plotting principal component scores. $\log_e$ transformed variables were used for PCA so that the first principal component (PC1) might be interpreted as a size component (Reyment et al. 1984, James and McCulloch 1990).

DFA was used as a multivariate test of the distinction between Peninsular and neighboring Mojave Desert specimens. This was performed for all skull measurements and one horn measurement (HORNVOL) for rams only, since there were too few Peninsular ewe specimens containing complete measurements. Ages were again limited to ≥ 8 years. Classification success, posterior probabilities, as well as the results of a jackknife procedure (Afifi and Clark 1990), were used to evaluate the reputed distinction between these two geographic regions.

RESULTS AND DISCUSSION

Univariate Analyses

All but 2 variables (PREMAX and TOOTH) exhibited significant age effects for rams, and 1/AGE consistently explained more variation than the other age covariates. These age effects are contrary to the statement by Cowan (1940:561) that "age variation in the skull during this portion of the animals life [adulthood] is not great." When these age effects were removed, only 1 out of 13 variables showed a significant difference between the Mojave Desert and Peninsular subspecies for Grinnell's boundary, while 3 were significantly different for Cowan's boundary (Table 2). However, these 3 differences occurred only when specimens from the Santa Rosa and San Jacinto Mountains were deleted from the analysis. When specimens from these 2 ranges were added to the Mojave Desert instead, only 1 variable differed significantly. Other California regions differed considerably more from each other. For the 13 variables tested, 8 were significantly different between the northern and southern regions of the Nelson subspecies, and the Sierra Nevada was different from each of these 2 regions for 5-6 variables (Table 2). In contrast, Cowan (1940) found all but 3 of his variables to be significantly larger for *O. c. cremnobates* than *O. c. nelsoni*. Age effects apparently were responsible for most of these differences (Ramey 1993).

Only 2 variables (PM2, CHEEK) had significant age effects in the analyses of ewe skulls, and none of the variables were significantly different between the Mojave Desert and either geographic definition of the Peninsular subspecies. In contrast, the 2 regions within the Nelson subspecies differed significantly for 7 of 13 variables, and the Sierra Nevada differed from each of these for 3-4 variables (Table 2). Cowan (1940) noted that *O. c. nelsoni* females were smaller than *O. c. cremnobares* in every measure he took, but that not all were significantly different. Likewise, we found *O. c. cremnobates* larger for 9 of 13 variables summarized in Table 2 for Cowan's boundaries; however, none was significantly different.

Principal Component Analyses

Morphometric analyses often yield all positive loadings for PC1, and this axis is interpreted as representing overall size variation, whereas subse-

Table 2. Numbers of morphometric variables (13 total) that were significantly different (PS0.05; Bonferroni multiple comparisons test) for bighorn sheep skulls from regions of California. Two definitions of the range of Peninsular sheep were investigated and are presented as Cowan/Grinnell. Variables included: CRANIAL, PALATE, PREMAX, TOOTH, PM2, CHEEK, ZYGO, ZNTERORB, INTRAORB, POSTORB, HEIGHT, CORVOL (rams), HORNVOL (rams), HORNC (ewes), and HORNL (ewes).

Region	Peninsular Ranges		Mojave Desert		Sierra Nevada	
	Rams	Ewes	Rams	Ewes	Rams	Ewes
Mojave Desert	311	010				
Sierra Nevada	8110	314	615	414		
Great Basin	10110	8/9	8/8	7/7	6/6	313

quent components with positive and negative loadings are interpreted as representing variation in shape (Reyment et al. 1984, Marcus 1990). PC1 is often disregarded as representing size variation due to age, sex, and environment, in favor of shape components. Since our analyses eliminated the first 2 of these sources of size variation prior to analysis, we began with less overall size variation. Consequently, our first 2 principal components did not account for most of the variation (our highest was 77.4%). which Reyment (1990) suggested as a criterion for interpretation of PC1 as strictly a size component. Also, not all of our PCA's had solely positive loadings for PC1. However, all positive loadings do not necessarily imply complete absence of shape variation (James and McCulloch 1990), and size variation is not necessarily extraneous relative to taxonomic questions. *Our* results provided an additional reason to treat PC1 as containing useful information.

When horn variables were excluded for rams, PC1 appeared to represent overall variation in skull size, primarily widths, and secondarily lengths and height. This axis largely separated the Sierra Nevada (large skulls) from the adjacent Great Basin region (small skulls; Fig. 1). When horn volume and core length were added to the analysis, horn volume strongly dominated the loadings of PC1, and the Sierra Nevada scored low on this axis along with the Great Basin (Fig. 2). In other words, Great Basin and Sierra Nevada rams both have small horns, but they differ substantially in skull size. If all this size variation were primarily environmentally driven, one would expect a correspondence between skull and horn size. Consequently, we did not disregard the size variation represented by PC1.

When horn variables were added to analyses, both sexes yielded a PC2 that largely represented the skull size variation accounted for by PC1 when horn variables were excluded (thus the separation of the Great Basin from the Sierra Nevada on the PC2 axis in Fig. 2). The subsequent 2 principal components (PC2 and PC3 without horn variables; PC3 and PC4 with horn variables) represented shape variation of the mouth region (feeding apparatus) for both sexes. These components failed to effect geographic separations for either sex, except possibly the San Gabriel Mountains (Fig. 1).

With horn variables included for ewes, PC1 separated the Great Basin and the Sierra Nevada (small homed) from the Mojave Desert and Peninsular Ranges, as it did for rams. Additionally, there was suggestion of a clinal pattern of decreasing horn size from the Mojave Desert and Peninsular Ranges to the Sonoran and Chihuahuan Deserts (Fig. 3).

In general, PCA plots suggested patterns found in univariate analyses -- major overlap between specimens from the Peninsular Ranges and the Mojave Desert, but much less or no overlap of Sierra Nevada and Great Basin specimens with the Mojave Desert and Peninsular Ranges, as well as with each other (Figs. 1-3).

Discriminant Function Analyses

The DFA of ram specimens for the Peninsular and Mojave Desert groups correctly classified 86% and 88% of the specimens for the Grinnell and Cowan definitions, respectively. However, only 46% and 42% of these respective samples were classified with ≥95% probability, suggesting poor classification ability. A jackknife analysis for the Cowan definition verified this yielding a 29% prob-
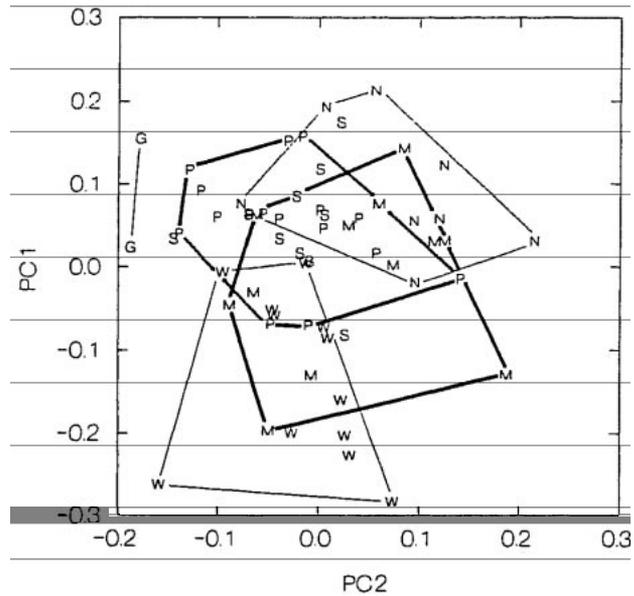
Figure 1. *Principal component scoreplotting for analysis of mountain sheep ram skulls* ***from*** *southwestern United* ***States and*** *Mexico* ***excluding horn*** *variables.* ***G=San Gabriel Mountains;*** ***M=Mojave*** *Desert of California south of 1-15;* ***N=Sierra*** *Nevada;* ***P=Peninsular*** *subspecies* ***populations*** *as defined by* ***Grinnell*** *(1933);* ***S=Sonoran*** *Desert;* ***W*** *=White Mountains, Death Valley region, and neighboring west* ***central*** *Nevada (Great Basin).*
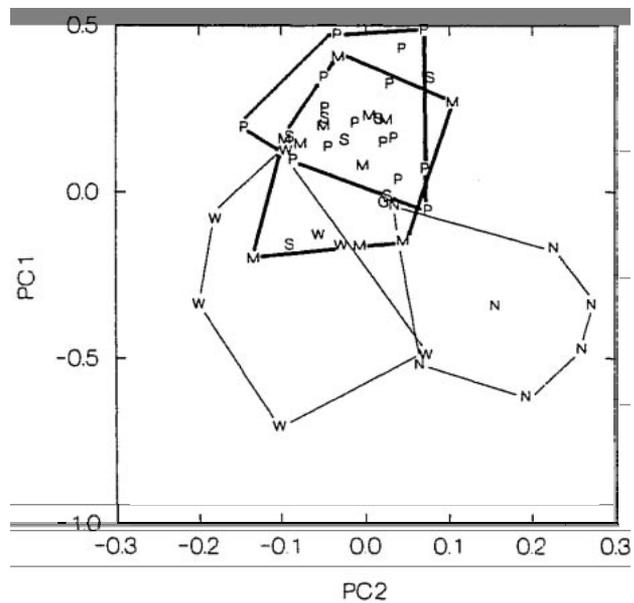
Figure 2. *Principal component score plotting for analysis of mountain sheep ram skulls* ***from*** *southwestern United States and Mexico including horn variables.* ***G=San*** *Gabriel Mountains;* ***M=Mojave*** *Desert of California south of 1-25;* ***N=Sierra*** *Nevada;* ***P=Peninsular*** *subspecies* ***populations*** *as defined by* ***Grinnell (1933);*** ***S=Sonoran*** *Desert;* ***W*** *=White Mountains, Death Valley region, and neighboring west central Nevada (Great Basin).*
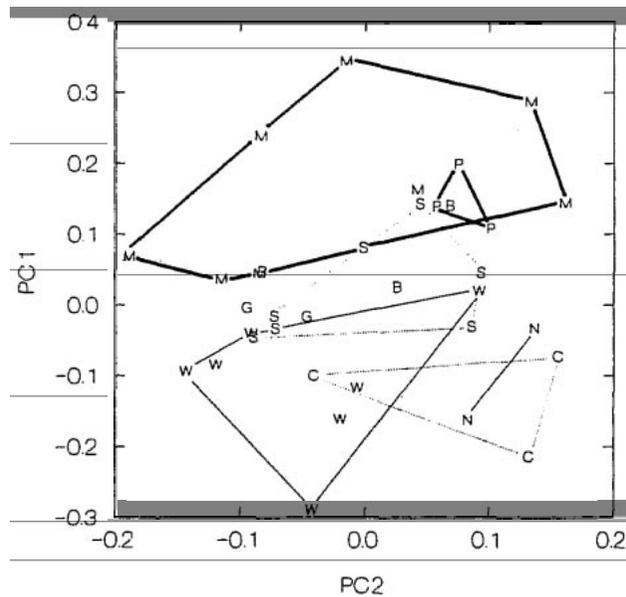
Figure 3. Principal component **score plotting** *for analysis of mountain sheep ewe* **skulls from** *southwestern United* **States and Mexico** *including horn variables.* **B=southern** *Baja California;* **C=Chihuahuan** *Desert;* **G=San** *Gabriel Mountains;* **M=Mojave** *Desert of California south of 1-15;* **N=Sierra** *Nevada;* **P=Peninsular** *subspecies populations as defined by* **Grinnell** *(1933);* **S=Sonoran** *Desert;* W=White *Mountains,* **Death** *Valley region, and neighboring* **west central** *Nevada (Great Basin).*

Figure 4. The relationship **between** *horn core length* **(cm) and an** *index of horn volume* **(l)** *for* **mountain** *sheep ram skulls from southwestern United* **States,** *Mexico, the Rocky Mountains, and* **Dall** *Sheep from Canada and Alaska.* **B=southern Baja** *California;* **C=Chihuahuan** *Desert;* **G=San** *Gabriel Mountains;* **M=Mojave** *Desert of California south of 1-15;* **N=Sierra** *Nevada;* **P=Peninsular** *subspecies* **populations** *as defined by Grinnell (1933);* **S=Sonoran** *Desert;* W=White *Mountains,* **Death** *Valley region, and neighboring west central Nevada* **(Great** *Basin);* **R=Rocky** *Mountains; and* **D=Dall** *Sheep.*
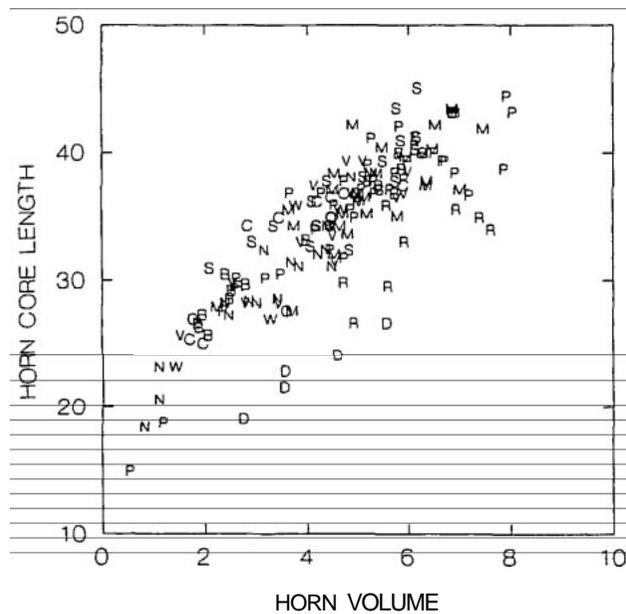
ability of misclassifying Peninsular specimens as Mojave Desert, and a 60% probability of misclassifying Mojave Desert specimens as Peninsular. Overall, this was a 46% probability of misclassification, about equivalent to flipping a coin weighted by the proportions of each group in the sample, which would yield a misclassification rate of 49%. In other words, DFA was unable to differentiate Peninsular and Mojave Desert ram skulls.

The Role of Horns Relative to Evolution and Taxonomy

Cowan (1940) noted that the largest homed ewes in North America were the Peninsular and Weems subspecies, and that *O. c. cremnobates* rams had larger horns than *O. c. nelsoni* rams. *Our* results refuted both of these statements about horns. It was not possible to distinguish sheep on the basis of horn size between Peninsular Ranges and the Mojave Desert when age effects were removed; this was true of both sexes.

However, other regions showed marked differences in horn size. Until variation in horn growth of mountain sheep can be partitioned between genetic and environmental components, some caution should be exercised in the interpretation of differences in horn measurements relative to taxonomy. Wehausen (1991) suggested a possible adaptive reason for larger horns on ewes from the warm deserts. Our results also provided reasons to believe that more than environmental variation underlies horn size variation in rams. First was the lack of correspondence between skull and horn size for rams from the Southwest. Second was the finding that horn core length in rams may be an important shape variable on a larger geographic scale. For the Southwest alone. there was a strong ($r^2=0.843$) curvilinear relationship between horn core length and horn volume (lnHORNVOL), suggesting a coupled growth pattern for horns and cores. However, Rocky Mountain and Dall sheep had shorter cores for equivalent horn volume (Fig. 4), implying different developmental patterns. Therefore, we conclude that horns and their supporting cores should not be ignored in morphometric studies.

Some of the variation in horn size and core length of rams may be adaptive. Taylor (1966) and Geist (1971) discussed the high potential for heat loss through horns. Our finding that horn size of both sexes decreased from the hot deserts of California north to the cold desert regions suggests possible hypotheses regarding selection relative to

heat loss through these appendages. The apparent decreasing size of ewe horns from the Mojave Desert to the hot Sonoran Desert does not support the idea of selection for larger horns in the desert for heat dissipation. However, these findings do not preclude the possibility that heat loss has selected against large horns in the cold deserts, especially alpine habitats, where winter temperatures and wind chills can be severe (Picard et al. 1994). Heat loss from horns should be related to the amount of vascularized core. The correlation of horn volume and core length for southwestern rams means that smaller horns will be associated with reduced potential for heat loss, and might explain the smaller horns in the colder climates of the Sierra Nevada and Great Basin ranges.

The short horn cores of Rocky Mountain and Dall sheep may represent a different evolutionary solution to this problem that does not necessarily compromise horn size. Winter heat loss should be most extreme for Dall sheep. They have particularly short cores relative to horn volume (Fig. 4), and may combine this adaptation with limited horn growth to minimize winter heat loss. Thus, while sexual selection (Trivers 1972) should select for large horns in rams, an opposing selection related to heat loss and winter survival may vary with habitat and be responsible for some of the horn-related variation in North American wild sheep.

CONCLUSZONS

Darwin (1859) noted that there are no clear criteria for designating taxonomic divisions below the species level, and there remains no convention in this regard. However, Avise and Ball (1990:60) suggested that subspecies should be, "actually or potentially interbreeding populations phylogenetically distinguishable from, but reproductively compatible with, other such groups". This study found no evidence that the Peninsular subspecies could be reliably distinguished from the adjacent Mojave Desert, a finding corroborated by genetic results (Ramey 1993). Given Ramey's (1993) reanalysis of Cowan's (1940) original data, there really never has been any support for a Peninsular subspecies. Consequently, we synonymize it with the Nelson subspecies.

In contrast, we found notable differentiation between regions within the Nelson subspecies, as suggested by Bradley and Baker (1967). Similarly, the Sierra Nevada showed substantial differences from other regions investigated, including the adjacent Great Basin. These patterns also are corr-

oborated by Ramey's (1993) findings of a unique mtDNA haplotype for all samples from the Sierra Nevada and a haplotype unique to and well represented in the Great Basin region. While these findings lend support for taxonomic distinction in the Sierra Nevada relative to nearby regions, they do not necessarily provide support for Cowan's (1940) definition of the California subspecies as a whole.

Current subspecies classification of mountain sheep reflects an antiquated typological thinking that lacks an adequate evolutionary basis (Mayr 1982). Cowan (1940) at least acknowledged a shortcoming in this approach by designating intergradation zones. To use our findings of apparent uniqueness in the Great Basin to propose the separation of *O. c. nelsoni* into 2 subspecies would be to further perpetuate a typological approach. Instead, we consider *O. c. nelsoni* to be a polytypic taxon possessing some regional genetic and morphological differentiation. If a taxonomic label is a prerequisite for adequate conservation attention, we believe that the more appropriate choice would be the designation of geographic races that reflect some of this variation. As a taxonomic term, geographic race lacks any connotation of incipient speciation or possession of characters that clearly distinguish it from other races (Mayr 1969).

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USE OF SPRINGS BY DESERT BIGHORN SHEEP BEFORE AND AFTER REMOVAL OF FERAL BURROS

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Abstract: Use of springs by desert bighorn sheep was examined before and after removal of a sympatric population of feral burros in Death Valley National Monument. Following burro removal, use by ewes increased significantly at 1 spring located near escape terrain, but use by rams and ewes did not increase at another spring that was not located adjacent to escape terrain.

INTRODUCTZON

Before their removal in 1985-86, the potential adverse impacts of feral burros (Equus *asinus*) on desert bighorn sheep (*Ovis canadensis nelsoni*) in Death Valley National Monument (DEVA) had been recognized for >50 years (Dixon and Sumner 1939). One concern was that feral burros could usurp and degrade water sources during the hot, dry period of late summer (Weaver 1959). Decreased use of springs by bighorn was observed when the springs were used by feral burros (Sumner 1959, Weaver 1959, 1973, Jones 1980, Dunn and Douglas 1982). However, use of these springs by bighorn was not studied after burros were removed. In this study, I compared use of water sources by a population of 50 desert bighorn (Dunn 1985) in the Tin Mountain area of northern DEVA before and after removal of a sympatric population of 150 feral burros (DEVA files).

STUDY *AREA*

The Tin Mountain study area, located in northwestern DEVA, encompassed approximately 120 km^2 of the Cottonwood Mountains. Elevations ranged from 1,253 m to 2.729 m. A 1,000 m escarpment dominated the west side of the study area, whereas the east side contained rolling terrain at the south end and 2 rugged escarpments ≤ 800 m at the north end.

Ten water sources were located in the study area but 4 of these sources were ephemeral, 1 was surrounded by a fence and unavailable to bighorn or burros, and 1 was in dense vegetation which bighorn generally avoid (Risenhoover and Bailey 1985). Thus, only 4 perennial springs were regularly used by bighorn or burros during summer (Fig. 1). Quartz Spring, located in a small canyon at the base of the western escarpment, was covered with rocks and piped to a drinker that was surrounded by a burro-proof exclosure; therefore, water was available only to bighorn. Yashiro Spring and Bighorn Spring were located at the south end of 2 escarpments that extended from Tin Mountain; both springs were used by bighorn and burros. Burro Spring, located in rolling terrain in the southern part of the study area, was heavily used by burros but the only evidence of use by bighorn was an observation of 2 rams near the spring in August 1981 (Dunn 1984).

METHODS

Time-lapse cameras were used to monitor Quartz, Yashiro, and Bighorn springs before (1981 and 1985) and after (1986, 1987, and 1989) removal of feral burros. Burro Spring was monitored only after removal. Monitoring occurred during late July and early August when water requirements were likely to be highest. The field of vision for cameras at each spring included the spring and a 15-20 m radius area around it. The time-lapse camera system consisted of a movie camera (Minolta, Inc., Torrance, CA), an intervalometer, and a photoelectric cell. The intervalometer allowed 1 frame of film to be exposed per minute and the photoelectric cell turned the system on at dawn and off at dusk. Films were analyzed with a Kodak
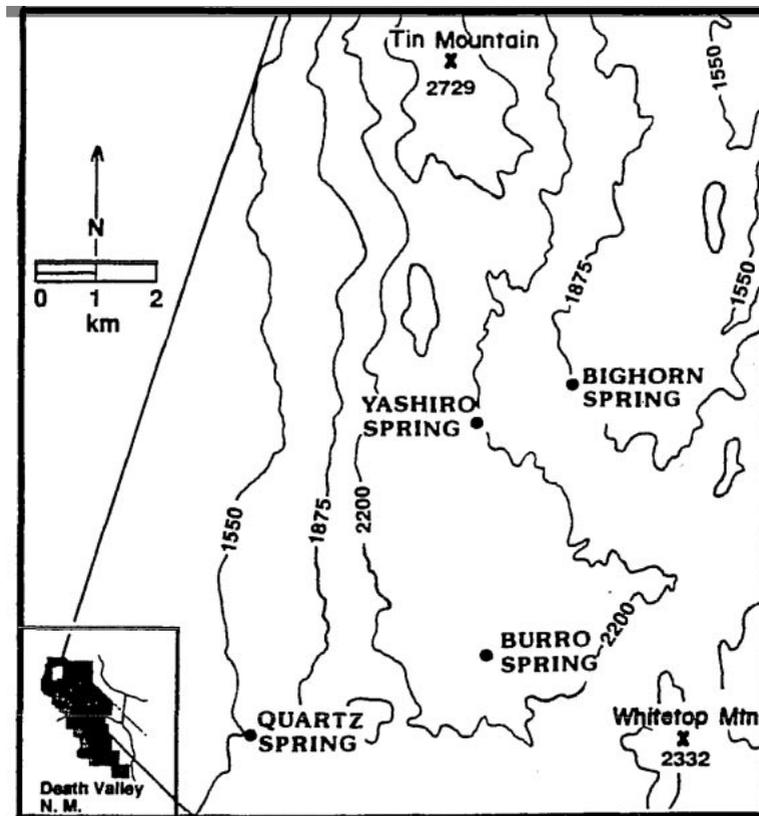
Figure 1. Locations of 4 springs monitored for use by desert bighorn and feral burros in the Tin Mountain study area of Death Valley National Monument, California.

Ektagraphic MFS-8 Analyzing Projector (Eastman Kodak Co., Rochester, NY). Data recorded from each frame in which an animal was observed included time of day, sex and age of bighorn, and total number of bighorn and burros present. Use of springs by bighorn ewes and rams was calculated as the number of individuals per day visiting each spring (only days completely monitored were used) and the duration (minutes within the field of vision) of visits by individuals. Burros repeatedly entered and left the field of vision making identification of individuals impossible. Therefore, I quantified use of springs by burros by 2 methods: 1) the number of minutes burros were present was divided by the total minutes monitored; and, 2) the mean number of burros observed per minute was calculated whenever burros were present at a spring.

Precipitation and temperature records were obtained from the **Wildrose** Ranger Station (DEVA files) to determine the weather conditions during the

study. Data were pooled across years into pre- and post-removal monitoring periods. **Mann-Whitney** tests were used to determine significant ($P \leq 0.1$) differences before and after burro removal in the number of ewes and rams visiting each spring per day, the duration of visits by ewes and rams, and weather conditions.

RESULTS

Quartz Spring was visited almost every day by ewes and rams during the study (Fig. 2). After burro removal, the number of **ewes/day** and **rams/day** did not change (ewes: $P=0.41$; rams: $P=0.96$), nor did the duration of visits by rams ($P=0.66$). However, visits by ewes were significantly shorter ($P=0.02$; Fig. 3). Ewes rarely visited Yashiro Spring, but rams visited this spring 75% of the days monitored (Fig. 2). The number of **ewes/day** and **rams/day** did not change after
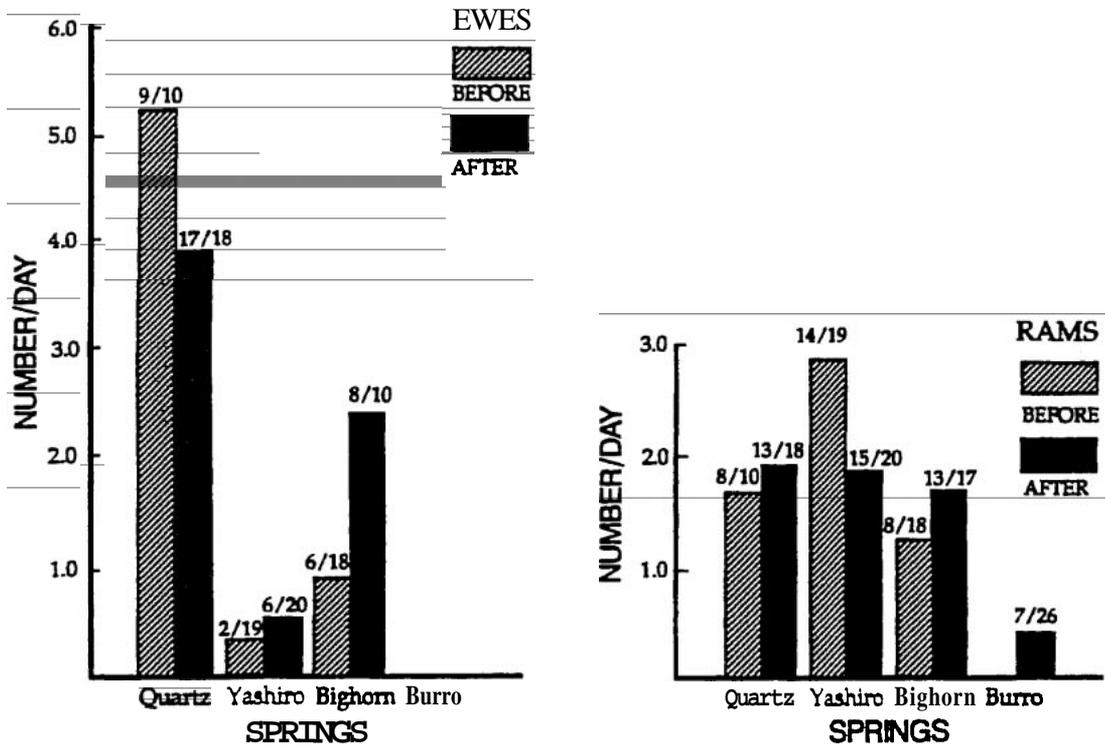
Figure 2. *The number of desert bighorn per day using springs before and after removal of a* sympatric *population of 150 feral burros in the Tin Mountain study area of Death Valley National Monument, California. The number of days* visited/days *monitored is shown at the top of each bar.*

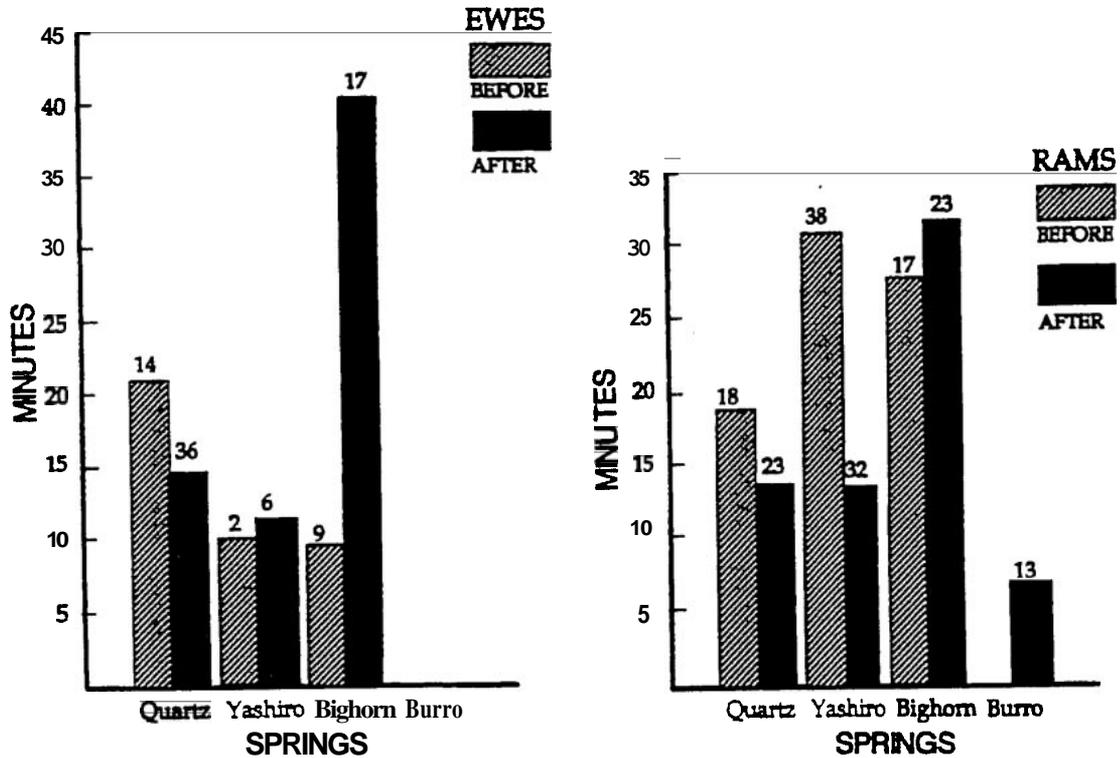Figure 3. *Mean* duration *of visits by individual desert bighorn to springs before and after removal of a* sympatric *population of 150 feral burros in the Tin Mountain study area of Death Valley National Monument, California. The number of visits is shown at the top of each bar.*

burro removal (ewes: $P=0.17$; rams: $P=0.28$), nor did the duration of visits by ewes ($P=0.96$). However, visits by rams were significantly shorter ($P=0.001$; Fig. 3). Before removal, half of the visits by rams were >30 minutes; after removal, only 1 of 32 visits was >30 minutes. Before burro removal, ewes and rams visited Bighorn Spring 33% and 44% of the days monitored, respectively (Fig. 2). After removal, ewes and rams visited during 80% and 77% of the days monitored, respectively. The number of ewes/day and duration of their visits increased significantly after removal (ewes/day: $P=0.04$; duration: $P=0.002$; Fig. 3), but the number of ramslday and duration of their visits did not change (rams/day: $P=0.13$; duration: $P=0.38$). Ewes were not observed at Burro Spring following burro removal, and use of this spring by rams was the least of any spring (Figs. **2** & 3). Before removal, burros were present at Yashiro Spring 64% of the minutes monitored and at Bighorn Spring 85% of the minutes monitored. A mean of 3.2 burros/min were observed at Yashiro Spring and 3.6 burros/min at Bighorn Springs. Summer temperatures were the same before and after burro removal ($P=0.4$), but summer precipitation was significantly higher ($P=0.07$) after burro removal.

DISCUSSION

Comparing resource use by 2 sympatric species with resource use by 1 species in the absence of the other species is a recognized method for determining resource partitioning (Colwell and Futuyma 1971, Sale 1974). and the results of this study suggest that resource partitioning may have occurred between bighorn sheep and burros. Before burro removal, 81% of the total spring use by ewes was at Quartz Spring, the only spring not available to burros. By itself, this is insufficient evidence of resource partitioning because factors other than the absence of burros could have played a role in the high amount of use. For example, high use could have been due to the availability of escape terrain (McQuivey 1978), an important habitat component for ewe-lamb groups (Berger 1991). However, Bighorn Spring also was near abundant escape terrain and use of this spring by ewes increased significantly following burro removal. The increased use of Bighorn Spring by ewes could have resulted from growth of the bighorn population. No population counts were made during the study, but population growth should be reflected in an increase in the total number of bighorn/day for all

springs. Instead, the number of bighorn/day was the same before and after burro removal (12.5 bighorn/day). Use of Bighorn Spring could also have been partitioned temporally (Carothers and Jaksic 1984) with the ewes visiting the spring at night because burros were present 85% of each day. However, I consider it more likely that spatial partitioning occurred with burros displacing ewes from the spring.

The high number of visits >30 minutes by rams to Yashiro Spring before burro removal may have indicated that rams were inhibited by burros from approaching the spring. Burros were present during all of these visits, and on 8/19 visits lasting >30 minutes rams did not even approach the spring to drink. However, rams drank during every visit to this spring after burros were removed.

Differential use of springs by ewes both before and after burro removal indicates that the presence of burros was not the only factor that governed spring use by ewes. A relationship between spring use by ewes and proximity to escape terrain also was apparent. Ewes mostly used Quartz and Bighorn Springs which were adjacent to abundant escape terrain. In contrast, ewes rarely used Yashiro Spring which was near a small escarpment that provided minimal escape terrain, and ewes were not observed at Burro Spring which was >1.5 km from escape terrain.

This is the only study that has examined spring use by desert bighorn before and after removal of sympatric feral burros. Although resource partitioning is suggested by this study, more research is needed to determine changes in demographics, distribution, and use of forage and water by bighorn populations in areas where potential competitors are removed.

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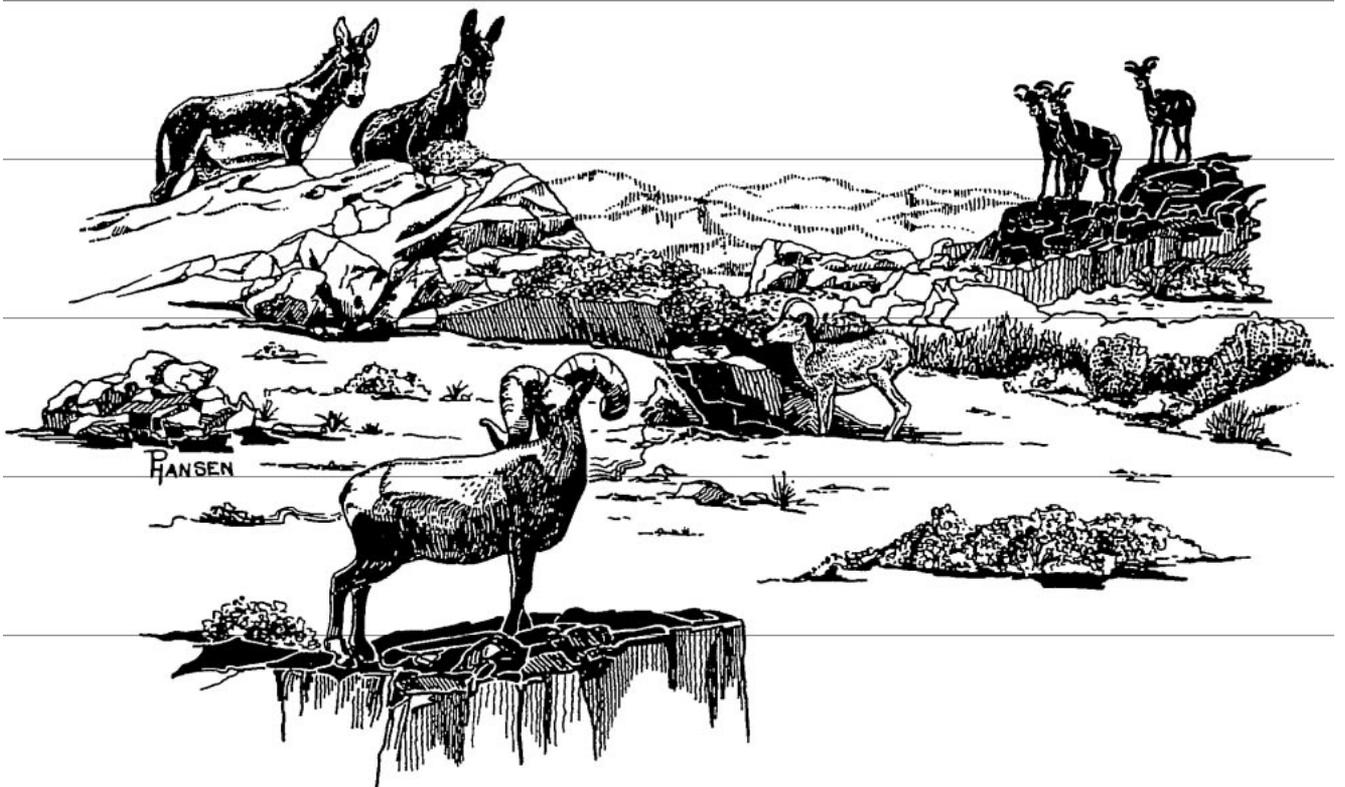
CONSERVING MOUNTAIN SHEEP HABITAT NEAR AN URBAN ENVIRONMENT

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Abstract: We documented the attitudes and beliefs regarding mountain sheep management options of homeowners adjacent to the Pusch Ridge Wilderness (PRW) near Tucson, Arizona. Homeowners within 1.6 km of the PRW primarily enjoyed passive recreational use of the wilderness (i.e. viewing the wilderness), and were aware that mountain sheep lived in the area. They supported management options including: 1) the elimination of dogs within PRW; 2) planned burns to improve mountain sheep habitat; and, 3) closing all or parts of PRW to protect the long term viability (>100 years) of the sheep population.

Key words: Arizona, human dimensions, mountain sheep, recreation, public attitudes.

INTRODUCTION

Mountain sheep management takes place in the arenas of biology, politics, interagency conflicts and cooperation, public opinion, and the public policy development process. A human dimensions approach to mountain sheep management involves the application of social science techniques to improve communication and educate the community about management issues. This approach is especially applicable for management of mountain sheep adjacent to metropolitan areas because any management scenario will likely affect the people living nearby.

Approximately 10-25 mountain sheep (*Ovis canadensis mexicana*) inhabit the Pusch Ridge Wilderness (PRW), adjacent to Tucson, Arizona (R. Olding, Arizona Game and Fish Department [AGFD], pers. commun.). The PRW boundary is near the Tucson metropolitan area, and land immediately adjacent to the boundary is being converted to housing (Fig. 1). The most heavily used mountain sheep habitat is now within 0.6 km of human development (Gionfriddo and Krausman 1986).

Almost all mountain sheep conservation options for PRW involve control and management of humans. Mountain sheep are important to local residents, and Bugarsky (1986) reported that most people in Tucson believed that the sheep herd should be preserved. To protect the sheep from human encroachment the United States Forest Service (USFS), in cooperation with AGFD, designated a Mountain Sheep Management Area consisting of the interior portion of PRW. To further minimize disturbances, the presence of dogs (on leash only) has been restricted to the lower portion of recreational trails along the perimeter of the closed interior area.

Previous studies in the PRW have concentrated on mountain sheep ecology and habitat (Gionfriddo and Krausman 1986. Krausman and Leopold 1986, Etchberger et al. 1989, Mazaika et al. 1992), and recreational use (Purdy and Shaw 1981, Harris 1992). However, to be effective in conserving mountain sheep and managing humans, resource agencies must utilize existing biological knowledge and carefully enlist the public as willing players in conservation plans. Public support can only be gained if managers understand peoples' attitudes and beliefs about mountain sheep and their management. Our specific objectives in this study were to quantify and document: 1) recreational use of PRW by nearby residents, 2) mountain sheep sightings by nearby residents, and, 3) attitudes of residents about possible management options.

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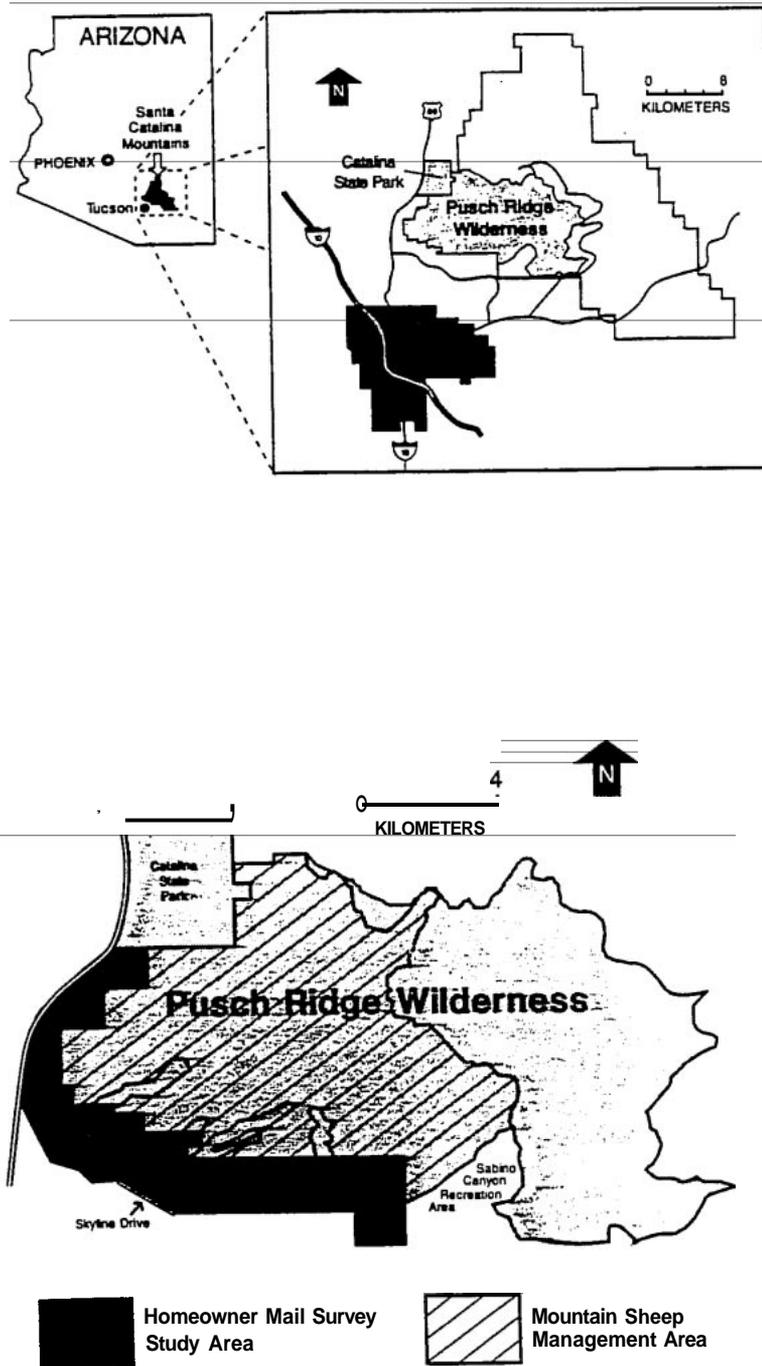
Figure 1. The location of the Pusch Ridge Wilderness in Coronado National Forest, Arizona, and adjacent homeowners.

METHODS

Our objective was to survey selected homeowners living within 1.6 km of the PRW boundary (Fig. 1). A list of 3,362 possible homeowners was generated from the January 1990 mailing list of homeowners from the Pima County Tax Assessor's Office. A random sample of 250 addresses was then selected from the list with a statistical software program (SAS Institute, Inc. 1987). The design of the survey questionnaire followed that of Dillman (1978). and we mailed questionnaires on September 10, 1990. We then conducted follow-up mailings on September 17, October 1, and November 5, 1990. Following the statistical methods in Babbie (1989) we were 95% certain the percentage estimates from the adjacent homeowners survey had a confidence interval of ±5%.

RESULTS

We received 184 completed surveys (80% response rate) from households consisting of 457 individuals (363 adults, 94 juveniles). Respondents had lived in their homes for an average of 8.1 yr (median=5, range=3 mo to 31 yr). Most residents owned their homes (94%), which consisted primarily of single family detached dwellings (80%) or apartments, town-houses, and condominiums. Most respondents (74%) indicated that proximity to the PRW wilderness increased the monetary value of their residence.

The most common activity related to the PRW was viewing the wilderness area, and 55% of the adults and 52% of juveniles reported that they enjoyed viewing the PRW area ≥361 days during the previous year. On average, local residents enjoyed viewing the wilderness 265 days/yr. The next most frequent activity was hiking trails within PRW, and 56% of the individuals ≥18 years old had done so within the last 12 months. Hiking was most likely limited to the designated recreational trails (Harris 1992), and 33% of respondents hiked on these trails 1-12 timeslyr.

Wildlife viewing was reported by 51% of the adults and 53% of the juveniles. The majority of homeowners (87%) were aware of mountain sheep in PRW. but only 12% had seen sheep. Two homeowners reported sighting mountain sheep on their property.

The majority (60%) did not own dogs. However, 26% of the dog owners walked their dogs in PRW, and 79% of the homeowners observed free-roaming dogs in their neighborhood (33% observed

dogs ≥11 timeslyr). The majority (75%) favored increased restrictions on dogs in PRW, and most (88%) also favored more stringent regulations prohibiting free-roaming dogs in their neighborhoods.

The majority (>66%) of the homeowners were willing to give up their activities within PRW for the long term survival of the sheep population. Most (66%) supported closing all or part of the PRW to reduce stress on sheep during lambing and nursing from January through June (Turner and Hansen 1980). Survey respondents also strongly favored (70%) closing portions of the PRW to people if human activities were causing the sheep to abandon previously used areas. In addition, 80% of the adjacent homeowners supported closing areas if the sheep could not gain access to water during critical periods. A majority (57%) were also in favor of planned burnings (11% opposed burnings and 32% were undecided).

DISCUSSION

Our study applied a human dimensions approach to a wildlife management situation based on the premise that managing humans is an important aspect of managing mountain sheep. This social science perspective can provide natural resource managers with important insights regarding the activities and opinions of key constituency groups. Our study clearly indicated that local residents placed a high value on the PRW by choosing to live next to it, by hiking recreational trails, and particularly, by enjoying the views. Furthermore, these people indicated a willingness to support a variety of management activities on behalf of the mountain sheep even when those management options would impact their own activities.

Because of the problems free-roaming dogs may cause (MacArthur et al. 1982), we investigated aspects of dog ownership within the neighborhood surrounding mountain sheep habitat. The current leash law requires dogs be either leashed or confined by a fence on both public and private property (Pima County Leash Law, section 6.04.03). Our survey showed that local residents were very aware of the presence of dogs in and near PRW, and most supported more stringent regulations to reduce the presence of free-roaming dogs in their neighborhoods and in the wilderness.

Controlled burning is a controversial management option that the USFS has used to improve sheep habitat. The public may choose not to support burnings because of the potential threat of damaged

property and altered views of burned areas. Our survey documented general support for planned burnings, and showed that homeowners wanted to insure the long term survival of the sheep herd in spite of short term inconveniences.

The population of sheep in PRW has declined from >200 individuals (Krausman et al. 1979), and if this decline continues, managers may elect to close part or all of PRW to human use. Water is relatively abundant in PRW, and people congregate near the streams and pools along many of the hiking trails. Support for the closure of areas near water was another strong indication of how willing homeowners were to protect the sheep population, even at the expense of their own use of the wilderness.

The natural resource managers (USFS and AGFD) should include the public in the development and implementation of management plans for sheep in PRW. In a highly urbanized setting such as Tucson, the success of any management plan and the long term viability of the sheep herd will be strongly influenced by the cooperation of the public. Our survey results show that the public will likely support a wide range of management options.

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LIMITS IN THE RESOLUTION OF LORAN-C FOR AERIAL TELEMETRY STUDIES

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Abstract: We investigated accuracy of Loran-C for determining geographic position in **2** aerial telemetry studies of mountain sheep in the eastern **Mojave** Desert of California. Before evaluating accuracy of Loran-C, we identified and corrected significant biases in the recorded positions. After these corrections, Loran-C determined positions with **95**% probability within circular areas of **1.2** or 1.5 km² in one study area, and within **0.8** km² in another study area. This low level of resolution suggests that Loran-C has limited utility for aerial telemetry studies. If Loran-C is to be used, we recommend that bias and accuracy first be ascertained within the study area, and that study design incorporate those resolution limits.

INTRODUCTION

Loran-C is an electronic navigation system that estimates geographic position by measuring time-differences of electronic pulses from a network of land-based transmitters (U. S. Coast Guard 1980). Loran-C is often used in aerial telemetry studies because it reduces flight time and requires little knowledge of study area topography, thus potentially reducing error in mapping positions. To analyze Loran-C derived locational data from aerial telemetry of mountain sheep (*Ovis canadensis*) in the eastern Mojave Desert, we required a measure of the error associated with the telemetry positions.

The ability of Loran-C to determine geographic position (accuracy) during aerial telemetry studies is influenced by numerous factors including: the position of the aircraft relative to transmitting stations, latitude/longitude solution, elevation above target (i.e. radio-collared animal), and pilot/observer ability. Here, we describe the bias and accuracy of locations determined by Loran-C in **2** areas of the eastern **Mojave** Desert of California relative to the true position of the aircraft. We test the hypotheses that bias associated with Loran-C varies with individual Loran-C receiver or study area, and that such biases can be mitigated by general correction factors.

This project would not have been possible without the diligent flying of R.W. Anthes and T.W. Evans of the California Department of Fish and

Game (CDFG) Division of Air Services. We are indebted to G.P. Mulcahy and A.M. Pauli for their assistance in data collection. We also thank M.M. Ananda, D.W. Ebert, T.L. Hurst and S.G. Torres for their comments and assistance. This research was supported by the CDFG Bighorn Sheep Management Program.

STUDY AREA

We conducted this research in **2** separate areas of the eastern **Mojave** Desert. The northern study area was a string of mountain ranges directly north of Mountain Pass, San Bernardino County, California. This area encompassed the Clark Mountain Range, Kingston Range, and Mesquite Mountains in California, and the southern part of the Spring Range in Clark County, Nevada. The southern study area was approximately 45 km southwest of Mountain Pass and included Old Dad Mountain and the Kelso Mountains in San Bernardino County, California. Elevations varied from **805** m to **2,417** m in the northern study area, and from **507** m to **1,452** m in the southern study area.

METHODS

A Cessna **185** fixed-wing aircraft equipped with a R-40 Loran-C (Arnav Systems Inc., Graham, WA) was used in both the northern and southern study areas. A second Cessna 185 with an Apollo

II Loran-C (model 612B; II Morrow Inc., Salem, OR) also was used in the northern study area. Therefore, we collected 3 data sets: 2 from the northern area and 1 from the southern area. Data were collected in the southern study area between November 30, 1990 and February 14, 1991 and in the northern study area between September 19, 1991 and January 26, 1993.

We selected mountain peaks and road intersections as reference points ($n=9$ or 10/data set). Geographic coordinates determined by Loran-C were recorded as the aircraft passed directly over these reference points. The directions from which the aircraft approached reference points during repeated passes were randomized. Six positions were compiled for each reference point per data set in the northern study area and 16 positions for each reference point in the southern study area. The geographic coordinates of reference points used for comparisons were determined from 7.5 minute topographic maps.

We recorded latitude and longitude generated by Loran-C to the nearest 0.10 minute. This limited our resolution to the area of a 6x6 second box. In the northern study area, this represented an area approximately 185 m (N-S) by 151 m (E-W), or a linear accuracy ≤ 100 m. We assumed that minor errors in determining reference point coordinates caused by map error or difficulty in determining when the aircraft was directly over the target were within this level of resolution.

Geographic coordinates determined from topographic maps were referenced to the 1927 North American Datum (NAD), and those determined by Loran-C receivers were referenced to datums considered equivalent to the 1983 NAD for conversion purposes. Various measures of latitude and longitude were converted to the 1983 Universal Transverse Mercator Grid (UTM) using the U.S. Army Topographic Engineering Center program CORPSCON V3.01 (beta).

For statistical analyses, we considered the data to be bivariate (Batschelet 1981). Analyses were conducted by combining data within each data set; corresponding reference points were superimposed to form the origin of each combined distribution. These combined distributions were tested for bivariate normality with a goodness of fit test based on the Cramer-Von Mises statistic (Ackerman et al. 1989). We rejected bivariate normality for 2 of the 3 distributions at the 5% level and used nonparametric statistics for further analyses.

To identify potential biases in the distributions, we used Hodges bivariate sign test (Batschelet 1981) to determine whether the center of error distributions deviated significantly from their origins. Because of the large sample size, we used critical values presented by Mardia (1972) for the southern study area.

Comparisons between the two data sets from the northern study area, and between the first data set from the northern study area and the data set from the southern study area, were conducted to test hypotheses of systematic biases based on study area or Loran-C receiver. We used Mardia's two sample test (Batschelet 1981) to determine whether centers of the distributions deviated significantly from each other. Since we had large sample sizes, we used a Chi-square test as the final comparison after conversion to circular distributions (Batschelet 1981).

Accuracy of Loran-C was evaluated after adjusting the distributions for significant bias. The adjustment was made by shifting the distribution data toward the origin by an amount equal to the mean vector (mean northing and easting) of the distribution. After this correction, we evaluated the distribution of points around the origin of each data set. The distances these points fell from the origin were tested for normality using the Kolmogorov-Smirnov goodness of fit test (Zar 1984). We failed to reject the null hypothesis of normality for all 3 data sets at the 5% level. Since these corrected distributions were normally distributed and generally circular around their origin, the mean distance the points fell from their origin was a measure of the accuracy of Loran-C. These distances were used to generate a mean error and standard deviation for each data set from which 68% and 95% error radii were derived. Interpretation of these error radii were based on the Empirical Rule for mound-shaped distributions (McClave and Dietrich 1988).

RESULTS

We rejected the null hypothesis that the centers of the distributions determined by Loran-C were the same as their origins for all 3 data sets (northern data sets $n=54$, $K=1$, P<0.001 and $n=54$, $K=0$, $P<0.001$, southern data set $n=144$, $K=24$, P<0.01). These significant deviations from the reference points suggested bias in the original distributions determined by Loran-C. We rejected the null hypothesis that the 2 distributions from the northern study area, derived using different Loran-C receivers, were from the same population and concluded that these distributions deviated signifi-

Table 1. The accuracy of Loran-C after adjusting for bias and assuming a circular distribution. The northern study area encompassed the Kingston Range, Mesquite Mountains, and Clark Mountain Range in California, as well as the southern part of the Spring Range in Nevada. The southern study area encompassed Old Dad Mountain and the Kelso Mountains in California. The two data sets in the northern area were collected using different aircraft and Loran-C units.

Study Areas	Error (m)		Error Radius (m)	
	Mean	SD	68%	95%
Northern (Data Set 1)	328	179	507	685
Northern (Data Set 2)	308	155	463	618
Southern	248	132	380	511

cantly from each other ($X^2=53.14$, 6 df, $P\leq0.001$). Furthermore, the distributions derived from the same Loran-C receiver for the northern and southern study areas also deviated significantly from each other ($X^2=32.39$, 7 df, $P\leq0.001$). Thus, we found significant and separate biases in each of the 3 distributions determined by Loran-C. Bias in the northern study area was 265 m north and 435 m east for the first data set, and 228 m south and 484 m east for the second data set, while bias for the southern study area was 99 m north and 163 m east. Since no general pattern to Loran-C bias was determined based on study area or Loran-C receiver, the correction factors generated from these biases can be simply viewed as after the fact calibrating of the Loran-C receiver to a particular study area.

After correcting for bias, the accuracy of Loran-C varied between data sets; Loran-C was more accurate in the southern than in the northern study area (Table 1). In the northern study area. our method determined a position with 95% probability within circular areas of approximately 1.2 km² and 1.5 km² for the 2 data sets. In the southern study area this value was approximately 0.8 km².

DISCUSSION

Previous reports suggested that the ability of Loran-C to determine geographic position was comparable to directly mapping positions onto topographic maps. The accuracy of aerial telemetry for mountain sheep using the direct mapping technique is generally reported to be 100 m (Krausman et al. 1984, Miller 1986). However, Miller (1986) discussed an experiment by Witham et al. (1982) in which the resolution of the direct mapping technique was more limited. In Rhode Island and Cal-

ifornia, ground based Loran-C receivers determined positions within 200 m (Patric et al. 1988, Rhoades et al. 1990). A similar result was reported for the estimated accuracy of a helicopter-based receiver during moose surveys in southeastern New Brunswick (Boer et al. 1989).

Our results question the utility of Loran-C for those aerial telemetry studies in which highly accurate locational data are desired. After correcting for bias, our method produced linear errors 5.1 to 6.9 times greater than those commonly reported for the direct mapping technique. When viewed as area, this error translates to an increase of 26.1 to 46.9 times that associated with direct mapping.

For mountain sheep in our study areas, accuracy of aerial telemetry using Loran-C was adequate for delineating population distribution and long-distance movements. However, Loran-C could distort results if high resolution telemetry data were incorrectly assumed in analyses. For instance, geographic information systems (GIS) can be used with aerial telemetry data to analyze habitat selection (Bleich et al. 1992, Bleich 1993, Ebert 1993). but large telemetry errors could result in significant misclassification of habitat use if habitat attribute polygons are small compared to the error associated with the telemetry data. Thus, questions that can be addressed with Loran-C data must be framed in a context that considers the resolution of that technology.

In California, aerial telemetry using Loran-C has been used to track radio-collared mountain sheep in numerous ranges over an extensive geographic area. Our results imply that if correction factors are to be applied, Loran-C bias must be determined for each Loran-C receiver used in each range. Furthermore, our results suggest that there is considerable variability in Loran-C accuracy, especially when

viewed with earlier Loran-C accuracy studies. Investigators using Loran-C should determine accuracy on a study area specific basis. Research objectives should then be evaluated in light of those resolution limits.

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HELICOPTER SURVEY OF PENINSULAR BIGHORN SHEEP IN NORTHERN BAJA CALIFORNIA

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Abstract: We conducted a helicopter survey of Peninsular bighorn sheep (*Ovis canadensis* cremnobates) in northern Baja California, Mexico, in April 1992. The northern Baja bighorn ranges were flown from the international border south to Bahia San Luis Gonzaga. A total of 116 groups ($n=603$ adults and lambs) were seen in 68 hr resulting in an observation rate of 8.9 bighorn/hr. The overall ram:ewe:lamb:yearling ratios were 32:100:45:22. Using observation proportions of 40-60%, we estimate that 780-1,170 adult bighorn sheep were present in the areas surveyed.

INTRODUCTION

Peninsular bighorn sheep range from the San Jacinto and Santa Rosa Mountains in California (Weaver 1975) south to the Santa Rosalia area of Baja California, Mexico, although the southern extent of their range is not clearly defined (Clark 1964). Alvarez (1976) estimated the desert bighorn population in Baja at 4,500-7,800 using data collected by field technicians accompanying hunter groups in 1974. Monson (1980) estimated that the area north of Bahia San Luis Gonzaga supported 1,500 to 3,000 desert bighorn. However, no systematic surveys were conducted to derive these population estimates.

Peninsular bighorn sheep have been legally harvested in Mexico since 1974. However, concern over the illegal take and reported decline of Peninsular bighorn caused all hunting of these sheep to be stopped by Mexican Presidential decree in December 1990 until accurate population estimates could be obtained and evaluated (1992 Federal Register, Vol. 57, 90:19837-19843). In cooperation with the Mexican government, National Wildlife Council of Mexico, and the Secretary of Urban Development and Ecology (SEDUE), the Bighorn Institute conducted a spring helicopter survey of bighorn sheep in the northern two-thirds of the bighorn range in Baja California. This survey was designed: 1) to determine a population estimate for Peninsular bighorn in Baja California; 2) to obtain baseline data regarding distribution, sex and age classification, and lambing areas; and, 3) to characterize the extent and condition of bighorn habitat.

We thank the Foundation for North American Wild Sheep for their generous support in funding this project. Also, we applaud the Mexican government, in particular M. Pastrana of the National Wildlife Council of Mexico, for his leadership and efforts to improve the management of Baja's desert bighorn, and M. Valencia for his diligence and help in getting this project underway.

STUDY AREA

The Baja California peninsula extends approximately 1,300 km south of the United States border and ranges in width from 45-230 km. The total land area is approximately 144,000 km². Our study area was bounded by the United States border on the north, by the southern end of the Sierra Santa Isabel at approximately 30°N, the Sierra Juarez and Sierra San Pedro Martir ranges on the west, and the Sea of Cortez on the east (Fig. 1). Mountain ranges surveyed include the Sierra Cucapa, Sierra Juarez, Sierra Las Tinajas, Sierra Pinta, Arroyo Grande area, Sierra San Felipe, Sierra San Pedro Martir, Sierra Santa Rosa, and Sierra Santa Isabel.

The topography in this region is diverse, ranging from wide valleys and arroyos to extremely rugged terrain of precipitous peaks and steep slopes.

METHODS

The survey was conducted during April 13-21, 1992, beginning in the Sierra Cucapa and terminating south of Sierra Santa Isabel near Bahia San Luis Gonzaga. A Hughes 500-D helicopter was used and 3 observers accompanied the pilot on all flights. The doors were removed from the helicopter to maximize visibility, and observers were rotated as needed at 1.5 to 2.0 hr intervals to reduce fatigue. Mountain ranges, with elevations ranging from sea level to >2,460 m, were flown at 100-150 m contour intervals at speeds averaging 60-80 km/hr. Ranges were flown individually from north to south focusing on areas where habitat appeared potentially desirable for bighorn. Consequently, only the eastern slopes of the Sierra San Pedro Martir and Sierra Juarez were flown. Survey intensity was increased as dictated by habitat quality and bighorn sign. Data collected included group size, sex and age classification, location, and elevation. Sightings of feral animals were noted as was information regarding general habitat quality.

A long-range navigation (Loran-C) instrument was used to record bighorn locations. Using a modified version of the technique developed by Geist (1971), bighorn were classified as Class II-IV rams, ewes, lambs, yearling males, and yearling females. Approximate ages for lambs were assigned based on pelage color, body size, and horn size. Rams were classified according to their horn and body size, and ages were assigned to ram classes as follows: Class II, 2-4 years; Class III, 5-7 years; Class IV, ≥8 years. The helicopter remained in the area of sightings long enough for 2-3 observers to verify the identity and classification of each bighorn group, and care was taken to avoid excessive hovering over animals.

Figure 1. Mountain ranges flown during the April 1992 Peninsular bighorn sheep survey of northern Baja California, Mexico.

RESULTS

Approximately 3,095 km² were surveyed in a total of 68 hr of helicopter time yielding a survey intensity of roughly 1.3 min/km² (Table 1). A total of 603 Peninsular bighorn were observed in 116 groups resulting in ram:ewe:lamb:yearling ratios of 32:100:45:22. Based on observation proportions of 40-60%, we estimate that approximately 780-1,170 adult bighorn sheep and 225-337 lambs were present in the area between the international border and latitude 30°N.

Bighorn sightings included 97 adult rams (38 Class II, 26 Class III, and 33 Class IV), 303 adult ewes (≥ 2 yrs.), 135 lambs, 33 yearling males, and 35 yearling females. Group size ranged from 1-26 sheep with a mean of 5.2 bighorn per group. Fifty-five (47%) of the 116 sightings included rams of Class II or greater (16 lone rams, 12 ram-only bands, 27 ram-ewe groups). The lambs observed during this April s w e y varied from < 1 week to approximately 3 months of age.

Of the 8 main mountain ranges flown, the Sierra Santa Rosa appeared to have the most bighorn per area surveyed. Lamb:ewe ratios in each range varied from 36-58 lambs:100 ewes, when Sierra Cucapa and Sierra Juarez were excluded (due to the low number of bighorn seen in those ranges). The ram:ewe ratios ranged from 19-64 rams:100 ewes, again excluding the Sierra Cucapa due to the low number of sheep seen there. The Sierra San Pedro Martir had both the highest ram:ewe ratio (64:100) and lamb:ewe ratio (58:100).

Vegetation appeared lush and abundant in most ranges with the exception of the arid region of Sierra San Felipe. With the exception of the northern end of the Sierra San Felipe, most ranges contained significant amounts of water, especially the Sierra Las Tinajas, Sierra San Pedro Martir, and Sierra Santa Isabel. Numerous tinajas were sighted and several had an estimated capacity of over 45,000 liters. Bighorn were seen at elevations ranging from 215-1,385 m, with a mean elevation of 720 m.

Burros (*Equus asinus*) were the most common feral animal seen during the s w e y as > 200 were observed in bighorn habitat. The Sierra Juarez and Sierra Las Tinajas appeared to have large numbers of burros, while fewer burros were seen in the Arroyo Grande area. Cattle (*Bos taurus*) were common in Sierra San Pedro Martir, Arroyo Grande, and Sierra Santa Isabel. Extensive damage from livestock grazing was noted in Sierra Santa Isabel. Sierra San Pedro Martir, and Sierra Las

Tinajas. Feral goats (Capra hircus) were observed running with bighorn in the Sierra Cucapa. The few deer (Odocoileus *hemionus*) observed were primarily in the Sierra San Pedro Martir. Numerous coyotes (*Canis latrans*) were seen throughout the study area, and 1 mountain lion (Felis concolor) was observed in the Sierra San Pedro Martir.

DISCUSSION

Our population estimate of 780-1,170 adult bighorn sheep is considerably lower than the 1976 estimate of 1,500-3,000 given by the Mexican government for this same area (Monson 1980). Relatively little is known regarding bighorn numbers and distribution in Baja California; however, it appears that either: 1) this population has declined; 2) previous population estimates were too high; or, 3) we underestimated the total population.

The Santa Rosa and San Jacinto Mountains in California have been surveyed annually since 1983 using experienced observers and the same technique as in the Baja survey. Bighorn observability, based on the proportion of marked animals observed, has varied from 46-67% in these surveys. McQuivey (1978) also found that 40-52% of bighorn in the River Mountains of Nevada were seen in aerial surveys using pilots and observers familiar with bighorn census techniques. In light of these findings, we conclude that the number of bighorn in Baja California was accurately estimated by assuming 40-60% observability.

S w e y results revealed that the overall ram:ewe ratio was 32:100 (Table 1). This low ratio may have been a function of the time of year, the areas sweyed, or it may indicate an actual decrease in the number of rams in the population. Remington and Welsh (1989) reported that herds seen during spring helicopter s w e y s consist predominately of either ewe/lamb/yearling or ram-only associations, and 53% (61/116) and 24% (281116) of our sightings were ewe/lamb/yearling or ram-only associations, respectively. The relatively high lamb:ewe ratio of 45:100 was not unexpected since this was a spring survey. In an analysis of helicopter surveys conducted by the Bighorn Institute in the Santa Rosa Mountains in California, the major difference between spring and fall surveys was that 45% fewer lambs were seen in the fall, although lamb recruitment has typically been poor in this range (DeForge 1984). Most Peninsular bighorn lamb mortalities in the United States have been reported to occur during summer (DeForge and Scott 1982): consequently, a high spring lamb:ewe

Table 1. Summary of Peninsular bighorn sheep observed during 68 hr of helicopter time surveying mountain ranges north of Bahia San Luis Gonzaga in northern Baja California, Mexico in April 1992.

Mountain range	Area surveyed (km²)	Rams	Ewes	Lambs	Yearlings Male	Yearlings Female	Total	No. groups seen	Rams /100 Ewes	Lambs /100 Ewes
Sierra Cucapa	92	1	1	0	0	0	2	1	100	0
Sierra Las Pintas	206	4	11	5	2	3	25	7	36	45
Sierra Juarez	602	1	2	0	0	1	4	2	50	0
Sierra Las Tinajas	252	7	36	19	3	2	67	11	19	53
Arroyo Grande[a]	740	20	85	31	4	13	153	36	24	36
Sierra San Pedro Martir	630	21	33	19	8	2	83	14	64	58
Sierra Santa Rosa	78	18	65	25	13	8	129	21	28	38
Sierra Santa Isabel	495	25	70	36	3	6	140	24	36	51
Totals	3,095	97	303	135	33	35	603	116	32	45

[a]Including Sierra San Felipe

ratio does not necessarily translate to high lamb survival. Therefore, we believe that an estimate based on adult bighorn numbers is more accurate and informative than one which includes lambs observed in the spring.

Our results suggest that bighorn numbers have decreased in the northern two-thirds of Baja's bighorn habitat (Alvarez 1976, Monson 1980). According to the U.S. Fish and Wildlife Service's proposed rule, new data demonstrating a stable or increasing bighorn population in Mexico could cause the withdrawal of the proposal to list the Peninsular ranges populations as endangered (1992 Federal Register, Vol. 57, 90:19837-19843). We find no support for such an action.

There are several potential problems threatening bighorn sheep in Baja California. There has been a long history of bighorn poaching in Baja, and Buechner (1960) wrote of the need to enforce game laws more strongly. Mario Luis Cossio Gabusio, Director General de la Fauna Silvestre, Mexico, stated in 1975 that poaching was the worst problem facing bighorn in Baja. He also acknowledged meat hunting by natives as a problem, and stated that 9/19 bighorn sheep killed during the hunting season had small caliber bullets in their carcasses from previous encounters with humans (Cossio 1975).

Another potential concern is disease exposure from feral animals such as cattle, goats, and burros. We observed all of these animals in bighorn habitat during the survey. Serologic results from 15 bighorn sampled in the Arroyo Grande region in 1988 indicated exposure to several pathogens (parainfluenza-3, contagious ecthyma, bluetongue, and bovine respiratory syncytial virus) that can be carried by livestock (DeForge et al. 1989, Progress report: life history studies of desert bighorn sheep [O. c. *cremnobates*] in Baja California, Mexico. 15pp. Unpublished report submitted to the National Wildlife Council of Mexico). Feral animals may also impact bighorn sheep populations through direct or indirect competition for limited resources such as forage and water.

Predation and human encroachment may also affect bighorn in northern Baja California. Although we observed predators such as mountain lions and coyotes during our survey, the impact of predation on bighorn sheep in this region is unknown. During the survey, the ground crew also encountered numerous motorized off-road vehicles in the basin between bighorn habitat in the Pichado del Diablo and the foothills of the Sierra San Felipe mountain ranges. Araujo (1976) commented on the need to control this type of recreation in bighorn habitat.

We believe that the current management program in Baja California has inadequate information for addressing potential impacts on bighorn such as poaching, human disturbance, and resource competition and potential disease exposure from livestock. This survey provided some of the essential demographic information needed to develop more effective management programs. A systematic survey of the remaining bighorn ranges south of Bahia San Luis Gonzaga still needs to be conducted to provide

baseline population information throughout the Peninsular ranges.

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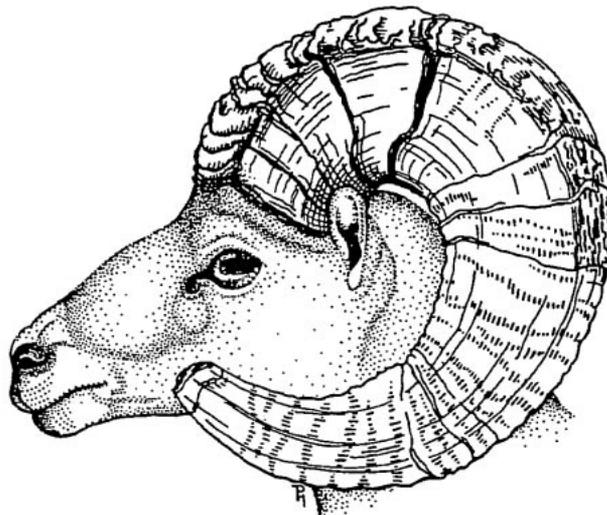
HELICOPTER SURVEY OF DESERT BIGHORN SHEEP IN SONORA, MEXICO

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Abstract: Twenty-five (25) mountain ranges in Sonora, Mexico, were surveyed for desert bighorn sheep from November 29 to December 3, 1992. A total of 155 groups were seen in 20.7 hr of helicopter time, resulting in 528 individual classifications. Observation rates were 9.9 sheep/hr in the northern ranges, and 37.3 sheep/hr in the ranges west and south of Caborca. Ram:ewe:lamb:yearling ratios were 37:100:18:36, and the population estimate ranged from 880-1,760 using observation proportions of 30-60%. Sonora, Mexico appears to have an adequate population to support transplant and hunting programs. These programs could provide the revenue to fund a modem bighorn sheep management program and greatly aid wildlife conservation efforts in Mexico.

INTRODUCTION

The number of desert bighorn sheep (*Ovis canadensis*) in Sonora, Mexico, has been the subject of several investigations over the last 20 years. Mendoza (1976) stated that "very little has been published with respect to this desert species in Mexico", and he "conservatively" estimated that there were 935 sheep in Sonora. Monson (1980) also provided an estimate of approximately 900 sheep in Sonora, relying heavily on Mendoza's earlier work. Surveys in 1989 and 1992 by biologists from the Secretaria de Desarrollo Urbano y Ecologia resulted in population estimates of 200-500 sheep in west central Sonora, near Caborca (unpublished report prepared for the Centro Ecologico de Sonora by C. Castillo, 1992). These estimates were consistent with the work done by Mendoza, but they were limited in scope and precision.

Surveying bighorn sheep from helicopters has been shown to be an effective means for obtaining population data (Remington and Welsh 1989). In 1992, a helicopter survey was conducted to: 1) determine the distribution of bighorn sheep in Sonora; 2) provide population estimates for individual mountain ranges and Sonora as a whole; and. 3) collect classification data needed for population analysis and proper management of this species.

METHODS

The study area consisted of 25 discrete mountain ranges in Sonora, Mexico (Fig. 1). Surveys were flown November 29 through December 3, 1992 using a turbine-powered Bell 206BIII Jet Ranger. This helicopter was equipped with a fuel range extender for surveying remote areas and a Global Positioning System for determining locations. Each survey was flown with three observers and the pilot (who made an excellent fourth observer), and the doors were removed to increase visibility. Most ranges were flown in their entirety, concentrating on the more rugged areas. Surveys were typically flown at 80 km/hr, contouring the area to be surveyed. When animals were spotted, the helicopter would be maneuvered close to the group to facilitate classifications. Numerous sheep (especially rams) were observed during ferrying flights over areas not surveyed. Since the survey was partly intended to yield density estimates (and since flight time was limited) these ram bands were neither classified nor included in the survey totals.

RESULTS

Survey results are presented in Table 1. The mean survey area for each mountain range was 52.8 km². and survey rates averaged 67.8 km²/hr (range=25-114 km²/hr), or 0.9 min/km². Observation rates and group sizes varied considerably. In ranges north of Caborca mean group size was 2.6, and the mean observation rate was 9.9 animals/hr. In ranges south of Caborca mean group size was 3.6, and the mean observation rate was 37.3 sheep/hr. Classifications of sheep across all 25 ranges resulted in ram:ewe:lamb:yearling ratios of
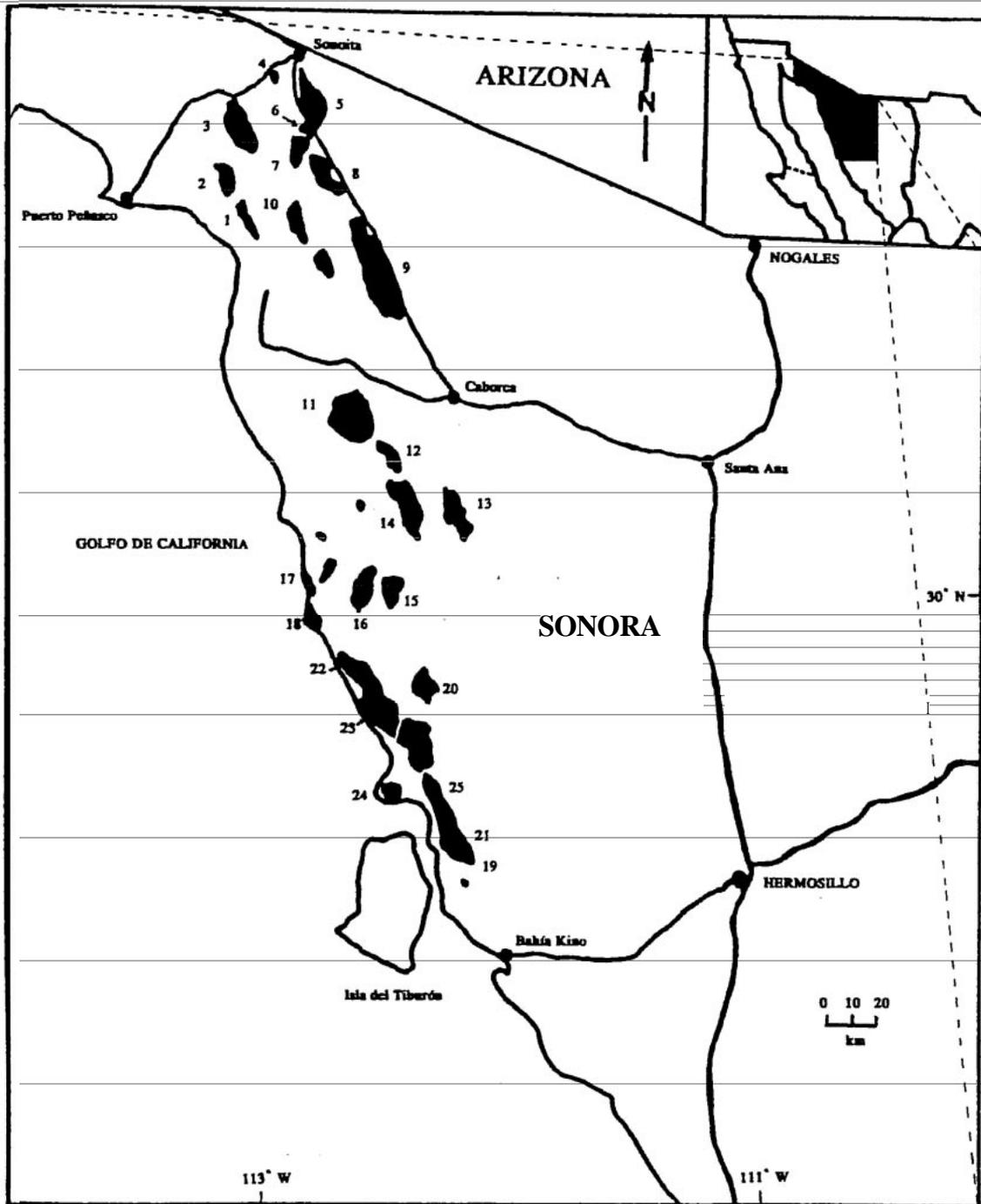
Figure 1. Location of mountain ranges flown during December 1992 helicopter survey of desert bighorn sheep in Sonora, Mexico. Refer to Table 1 for the names of mountain ranges.

Table 1. Results of December 1992 helicopter survey of desert bighorn sheep in Sonora, Mexico.

Mountain Range	Hours	Area (km²)	Classifications[a]	No. Sheep	No. Groups
1) Sierra Prieta	0.3	20	0–0–0–0–0–0–0–0	0	0
2) Sierra Pinta	1.7	60	1–0–1–0–3–1–0–0	6	2
3) Sierra San Francisco	1.9	175	1–6–2–0–11–3–2–1	26	8
4) Sierra Cipriano	0.9	55	0–1–0–0–2–0–0–0	3	2
5) Sierra Cubabi	1.3	85	0–0–1–0–6–0–0–1	8	4
6) Cerro la Silla	0.8	20	1–1–1–1–8–2–0–0	14	6
7) Sierra San Antonio	0.6	35	0–0–0–0–3–1–0–0	4	3
8) Sierra A	0.2	5	0–0–0–0–0–0–0–0	0	0
9) Sierra el Cozon	0.2	20	0–0–0–0–0–0–0–0	0	0
10) Sierra B	1.0	85	0–0–1–0–17–7–1–1	27	9
11) Sierra el Alamo	1.0	70	1–5–2–0–9–1–5–2	25	6
12) N. Sierra el Viejo	0.4	25	1–0–0–0–1–0–0–1	3	1
13) Cerro la Verruga	0.7	50	0–1–0–0–7–2–2–3	15	3
14) S. Sierra el Viejo	2.5	120	2–14–13–3–61–8–14–8	123	36
15) Sierra Picu	1.0	70	0–0–1–0–4–0–1–2	8	4
16) Sierra Aguirre	0.7	100	1–2–3–0–15–2–2–4	29	7
17) Sierra Julio	0.4	15	0–0–1–0–8–3–2–1	15	5
18) Cerro Santa Maria	0.2	15	0–0–0–0–6–1–1–2	10	1
19) Sierra Gobernadora	0.3	20	0–0–0–0–0–0–0–0	0	0
20) Sierra C	0.4	20	0–0–2–1–6–1–1–1	12	5
21) Pico Johnson	1.5	110	3–2–2–4–36–2–9–8	66	16
22) Sierra Cirio	1.6	60	4–4–4–2–40–7–9–7	77	18
23) Sierra la Tordilla	0.4	40	0–0–0–0–22–3–3–2	30	8
24) Sierra Punta Tecopa	0.4	30	1–1–4–0–9–3–1–0	19	8
25) Sierra la Tinaja	0.3	30	0–0–0–0–4–1–1–1	7	3
Totals	20.7	1335	16-37-38-11-278-49-54-45	528	155

[a]*Class I rams, Class II rams, Class III rams, Class IV rams, adult ewes, lambs, male yearlings, female yearlings.*

37:100:18:36. A total of 528 sheep were classified, resulting in a population estimate of 880-1,760 using observation proportions of 30-60%.

DISCUSSION

For a variety of reasons, population estimates based on direct observations of animals tend to underestimate animal numbers. Many animals are not seen during surveys (Miller et al. 1989), and recent bighorn survey work in Arizona indicates that a relatively small proportion (25-45%) of the population is seen during helicopter surveys. Observation proportions of 30-60% in the Sonoran

survey would generate estimates ranging from 880 to 1,760 sheep. However, many potentially significant sheep areas in Sonora were not flown (Tiburon Island and Pinacate, among others), and ram bands seen during ferry flights in outlying areas were not included in survey totals. Therefore, the total population of bighorn sheep in Sonora may exceed 2,000 animals.

A useful method for comparing sheep densities between 2 areas is animals or catch per unit effort (CPUE=sheephr). In 1990 and 1991 the CPUE in the Region 4 and Region 5 management areas in Arizona was 7.1 and 7.2 sheep/hr and 5.8 and 6.5 sheephr, respectively. In contrast, in ranges south of Caborca in Sonora the CPUE was 37.3 sheep/hr. The only area in Arizona that approximates these high observation rates is Unit 15, near Lake Mead, where the CPUE was 17.0 and 18.4 sheep/hr in 1990 and 1991, respectively. This indicates that some areas of Sonora have very high sheep densities which could provide source stock for relocations.

The 37:100 overall ram:ewe ratio in Sonora contrasts with an average ratio of 58:100 in Arizona over the past 5 years. The relatively low numbers of rams observed in some areas of Sonora may be the result of over-harvest (perhaps due to illegal hunting), but it is more likely a result of survey design. Since relatively little was known of the sheep distribution in Sonora, areas to be surveyed were chosen based on observer experience and intuition. A number of ranges appeared to contain only ewes and very young lambs, suggesting that survey areas were disproportionally focused on lambing grounds. The ram segment of these populations may have been at lower elevations in less rugged areas as suggested by a number of ram bands observed in "gentler" terrain while ferrying between the mountainous areas.

Mendoza (1976) reported that after years of travels in the sheep range of Sonora he saw only 5 watering holes, and our observations were similar. Many of these ranges were exceedingly xeric and were geologically and topographically ill-suited for holding water for any length of time. Although managers in the United States have been developing

water sources for 50 years, Sonora's sheep population seems to be doing well without such a program. Some of the ranges in Sonora might be an excellent place to determine whether additional water sources serve to increase sheep numbers and distribute sheep throughout a mountain range.

The bighorn sheep population in Sonora appears capable of supporting a hunting program. As many as 30 permits could be issued, and the resulting revenue could be used to support bighorn sheep management and wildlife conservation work throughout Sonora. Conservation, or the wise use of natural resources, should be practiced with this species. However, if a hunting program is to be encouraged, it is strongly recommended that a mandatory check-in of all harvested animals be required. An identification "plugging" system similar to that used in the United States should also be implemented. This type of approach would also provide essential biological data for management and would help restrict illegal harvest. Several areas in Sonora also have very dense sheep populations. These areas could serve as sources for transplants into unoccupied historic habitat.

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COMMENTS AND STATUS REPORTS

BRINGING BIGHORN INTO THE CLASSROOM

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Abstract: Recent surveys have determined that public opinion about wildlife and wildlife-orientated activities is rapidly changing. To ensure a properly educated, decision-making public, we as wildlife professionals should become actively involved in teaching the public, particularly children, about wildlife. I found that desert bighorn (*Ovis canadensis*) can serve as an excellent focus for teaching wildlife concepts, and that children actively enjoy being involved in the research process. In this report I outline a project for teachers and describe the types of children's activities that I found worked best.

Most of the biological information about bighorn sheep (*Ovis canadensis*) found in scientific publications does not reach the people who pay for research and management--the general public. Instead, the public often obtains their information from less reliable sources. This problem was illustrated in 1992 when a popular Arizona outdoor magazine with a circulation rate of >450,000 per month erroneously described desert bighorn in Arizona as an endangered species.

In an effort to solve information gaps, biologists write popular articles, slide show scripts, or give talks to interested groups. Although these activities have value, they are normally directed towards adults who have entrenched attitudes and are slow to accept new ideas (Kellert and Berry 1980). Children, on the other hand, have more open minds. A knowledge and appreciation of native wildlife can be developed if reliable information about wildlife is integrated into their existing educational curricula.

Future wildlife management policies will be driven, in part, by public opinion and attitudes, and these attitudes are formed early in life. Kellert (1976) formulated the following list of basic attitudes toward animals: 1) naturalistic - primary interest and affection for wildlife and the outdoors; 2) humanistic - primary interest and affection for individual animals, principally pets and large attractive wild animals with anthropomorphic features; 3) moralistic - primary concern for right and wrong treatment of animals with strong opposi-tion to animal exploitation and cruelty; 4) utilitarian - primary concern for the practical and material value of animals; 5) dominionistic - primary satisfactions derived from mastery and control over animals, typically in sporting situations; and, 6) negativistic - primary orientation on avoidance of animals due to indifference, dislike, or fear. He found the most common attitudes were humanistic, moralistic, utilitarian, and negativistic (Kellert and Berry 1980), and children have an even higher sentimental affection for loveable kinds of animals (humanistic) than adults (Westervelt and Llewellyn 1985).

Westervelt and Llewellyn (1985) pointed out that creative teaching approaches can stimulate people to identify with the natural world. However, objective information emphasizing sound ecological principles should be introduced without challenging strongly held humanistic perceptions. LeCount and Baldwin (1986) also noted that it is a mistake to assume that information we give people will stay with them. The most effective programs encourage learners to generate and ask questions and stimulate thinking and imagination. The more involved a person becomes, the longer he or she will retain the information. Children under 12 years relate to the world in very egocentric and anthropomorphic ways (Piaget 1929, Sharefkin and Ruchlis 1974). and for them to accept and understand ecological concepts teaching approaches should be related to what they feel, see, or more importantly, directly experience (Westervelt and Llewellyn 1985).

The Education Branch at Arizona Game and Fish Department (AGFD) conducts Natural History Trips to bring classroom teachers into the field to interact with field biologists. This type of "hands on" activity with adult teachers is very important, because of all the variables in improving science education, changing the attitudes and practices of teachers is by far the most difficult (McCormick 1989). One specific advantage of working with teachers is that they will in turn teach 30-120 students a year, hopefully for several years. By giving teachers a personal experience with a particular species, their personal interest and commitment grows, and their credibility with students is enhanced.

In 1987 AGFD began conducting Bighorn Sheep Natural History Weekends in the Black Mountains along the Colorado River in northwestern Arizona. The goals of this program are: 1) to allow teachers to observe and classify bighorns; 2) to have teachers estimate demographic parameters based on survey data they collect; 3) to provide information on bighorn management and research; and, 4) to provide activities for children related to bighorn and desert ecology. Teachers receive training on bighorn classification and natural history and then observe bighorn from boats over a two day period. They also spend considerable time discussing a specific bighorn research project that they can use in the classroom (Cunningham et al. 1993). This project focuses on how realignment of U.S. Highway 93 could be done in such a way to minimize negative impacts on the 100-150 bighorn in the area.

To increase their involvement in the research project, teachers receive Universal Transverse Mercator (UTM) coordinates for up to 6 animals, topographic maps, a color poster of a radio-collared ewe, and a series of 4 videos on bighorn sheep. Video quality ranges from professionally produced videos on bighorn to a 60 minute video I made with a home video camera. We also provide a video showing teachers how to use UTM coordinates and topographic maps.

Children can easily understand the issues in this project, namely the need to resolve a dangerous situation for humans and the possible consequences for local wildlife. In a recent survey of over 200 business and education personnel, the highest ranked response to "What should our schools do better to prepare our children for the future?" was "emphasize thinking skills" (Staley 1987). Problem solving requires an awareness of real problems and issues, a willingness to search for solutions, and the knowledge of how to proceed. Isolated approaches to problem solving rarely engage students in real issues and problems. Problem oriented activities should be challenging but not impossible to solve. They should also include various points of view (economical, cultural, social, ecological, ethical, and political [LeCount and Baldwin 1986]). By using data collected on an animal (bighorn sheep) that students have developed empathy for, the issues and problems surrounding this animal and others become more meaningful to the interests and lives of students.

Involvement in the bighorn research project is part of a larger thematic unit that includes simulations, inquiry activities, and active experimentation along with movies, slide programs, and lectures that are more normally found in classrooms. The National Science Resource Center (NSRC) reports that most successful science programs are based on a series of modular units. Each module includes the materials and apparatus needed to investigate a topic, as well as the lesson plans for 6 to 8 weeks of student activities. Modular units should: 1) integrate science with other basics; 2) establish a materials support system; 3) provide direct support for teachers; and, 4) assess performance (Harvard Education Letter 1990). The central idea of our unit is to: 1) increase students' awareness and appreciation of general desert ecology using bighorn as a focus species; 2) involve the students in the research process; and, 3) highlight the impacts of human activities on an animal and its habitat.

In the introduction we use 2 types of activities: 1) those that provide prerequisite knowledge, skills and experience; and, 2) those that introduce the main topic. Several topics are used in the learning or cognitive stage such as: 1) history of bighorn and early humans; 2) animal behavior; 3) natural history; 4) concepts of niche and community; and. 5) careers and technology. Finally, at the conclusion of the program we ask students to make some personal decisions based on what they have learned.

Many of the activities we use are copied or modified from the Project WILD guide (Western Regional Environmental Education Council 1992). A Project WILD Activity Guide contains 113 activities for kindergarten to 12th grade designed to help children understand various wildlife concepts. The guide offers a set of activities that have been tested to insure they meet their stated cognitive and affective objectives.

In several of the lessons students must work in groups, and the lessons are structured so that each person's success is linked with every other individ-

ual in the group (positive interdependence). Research has shown that working cooperatively with positive interdependence improves academic achievement, ethnic relations, social skills, higher thinking skills, and linguistic minority learning (Johnson et al. 1990). Cooperative settings have real value in Arizona schools where English as a Second Language (ESL) students are often in the majority. Many teachers place all of the materials they receive in a central location to create a learning center. Learning centers allow teachers to design their own supplemental science curricula that more closely match the developmental levels of their students. These learning centers encourage self-direction among students, and more time is allowed for teachers to meet the individual needs of other students (Orlich et al. 1982).

A large number of the classes participating in the project construct life size papier mâché models of bighorn, create desert murals for their class, develop "rap" songs concerning their ewe, and develop simulations which involve ecological concepts. Although these types of activities might be considered "play," it would be erroneous to underrate their importance in the learning process, particularly for preschool and primary grades (K-3). This type of teacher-directed learning not only encourages child-initiated learning, but also promotes the development of science process skills (observing, comparing, classifying, communicating), as well as an understanding of the science content (Smith 1988). Through the playful exploration of meaningful materials from their local environment, children begin to build important conceptual understandings. This is especially important for the younger students, as children must not only begin to have conceptual understandings, but need to develop positive attitudes toward, and an excitement for, mathematics and science (Henniger 1987).

In conclusion, Rachel Carson summarized it best: "I sincerely believe that for the child, and for the parent seeking to guide him, it is not half so important to know as to feel. If facts are the seeds that later produce wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow. The years of early childhood are the time to prepare the soil. It is more important to pave the way for the child to want to know than to put him on a diet of facts he is not ready to assimilate" (Carson 1956).

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AN ANALYSIS OF HUNTER HARVEST OF MOUNTAIN SHEEP IN CALIFORNIA, 1987-1992

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INTRODUCTION

The California Legislature has authorized 6 Nelson bighorn sheep (*Ovis canadensis nelsoni*) hunting seasons since 1987 (California Department of Fish and Game [CDFG] 1992. Report to the legislature regarding bighorn sheep management. The Resources Agency, Sacramento, California). As part of the CDFG commitment toward effectively managing mountain sheep, a brief analysis of harvest data was conducted to determine if these data reflect the size, age structure, and associated availability of rams within the respective populations. Further, this analysis will help identify whether harvest data can be useful as an additional management tool for indexing the status of ram populations and interpreting demographic changes over time. This is a contribution from the CDFG Bighorn Sheep Management Program.

METHODS AND RESULTS

The annual harvest data from the Marble Mountains (Zone 1) and Kelso Peak/Old Dad Mountains (Zone 2) from 1987-1992 were used for these analyses. Based on mark/recapture population estimates derived from ground and aerial surveys, the annual harvest level typically varies between 2-5% of the estimated number of mature rams in each mountain range (CDFG 1993. Draft environmental document regarding bighorn sheep hunting. The Resources Agency, Sacramento, California.). This harvest level is unlikely to result in dramatic differences in the demographics of the respective populations, and proportional differences in the size and age structure are more likely to be influenced by recruitment. This low harvest level and long season (2 months) should allow for the hunters to be selective.

We used 2-way analysis of variance (ANOVA) to test for differences in "green" scores of harvested rams between hunt areas (Zones 1 and 2) and years.

This analysis showed a significant ($P<0.05$) difference in scores between mountain ranges. There were no significant ($P<0.05$) year effects, area by year interactions, or decreasing score patterns detected for the annual harvest. There were higher mean scores and smaller variances in scores (by year) for rams harvested in the Marble Mountains (Fig. 1). Given this difference in variance, the results obtained through our 2-way ANOVA must be interpreted with caution. Differences between mountain ranges were further tested by an unpaired r-test using a Satterthwaite and Cochran (SAS Institute, Inc. 1988) correction for unequal variances. This analysis also indicated that rams from the Marble Mountains had a significantly ($P<0.05$) higher mean score ($\bar{x}=165$, $n=16$, SD=7.2) than rams from Old Dad Mountain ($\bar{x}=159$, $n=30$, SD=6.8).

A 2-way ANOVA was also used to test for differences in ages of harvested rams between hunt areas and years. This analysis did not show any statistically significant differences in ages between mountain ranges. There were no year, area by year interactions, or decreasing patterns detected for ages of animals harvested. However, the diagnostic plot of ram ages by mountain range for each year showed a pattern of higher mean ages and smaller variance for rams in the Marble Mountains (Fig. 2). This pattern is similar to that observed for the score data. Differences in ages between mountain ranges were further tested by an unpaired t-test using a Satterthwaite and Cochran (SAS Institute, Inc. 1988) correction for unequal variances. This analysis did not detect a statistically significant ($P<0.05$) difference' in ages of harvested animals between mountain ranges. Rams from the Marble Mountains had a mean age of 9.2 years ($n=16$, SD=2.2), while the rams from Old Dad Mountain had a mean age of 8.5 ($n=30$, SD=1.6). It is worth noting that the lack of statistical significance was singularly determined by a relatively young (4 years) animal harvested in the Marble Mountains.
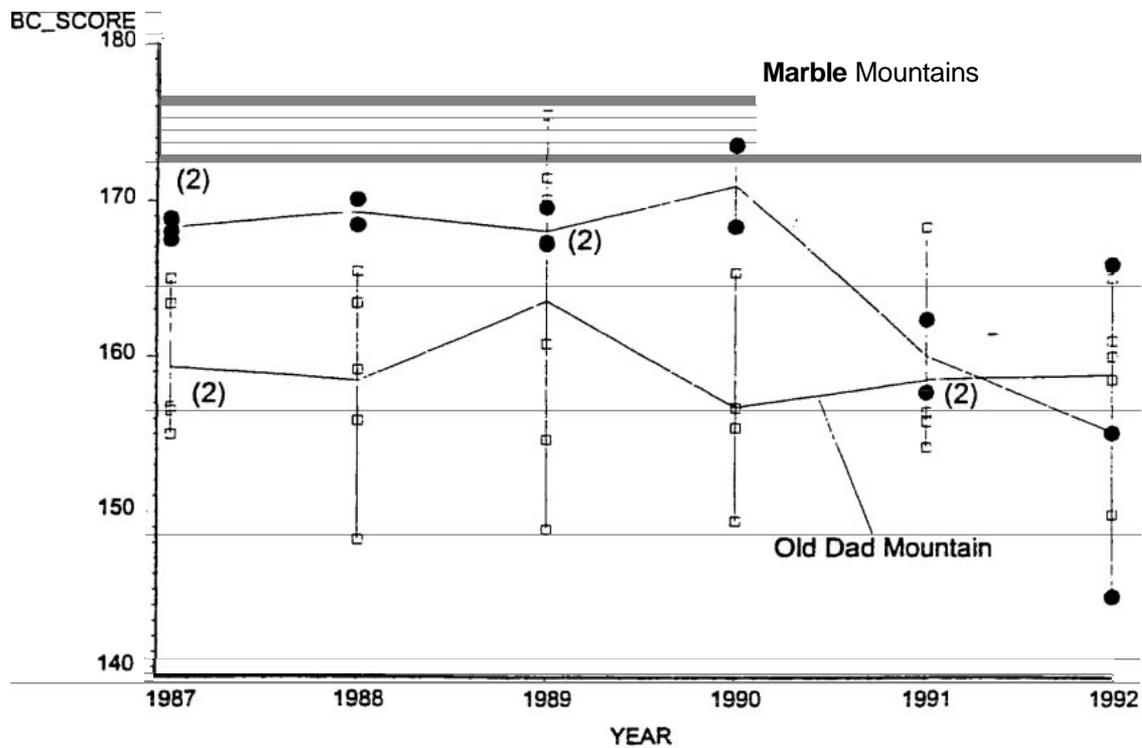
Figure 1. Boone and Crockett "green" scores of harvested rams from 1987-1992, San Bernardino County, California. Lines connect yearly averages.
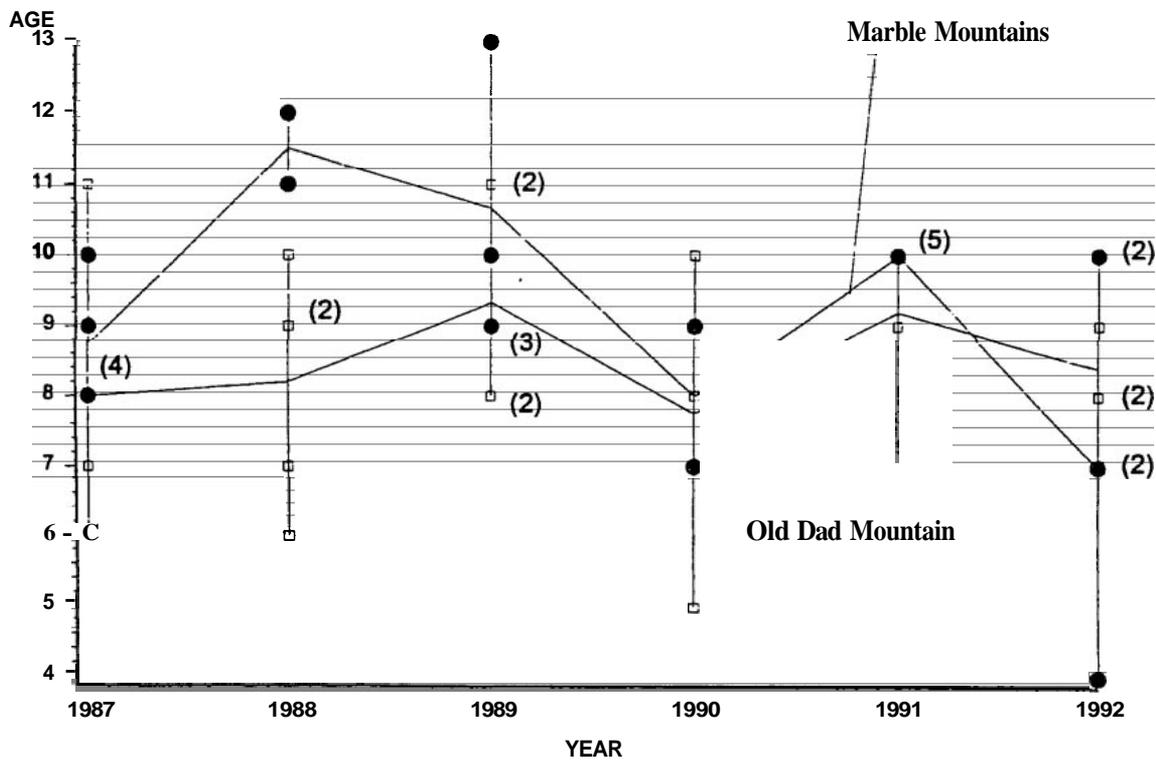

Figure 2. Estimated ages of harvested rams from 1987-1992, San Bernardino County, California. Lines connect yearly averages.
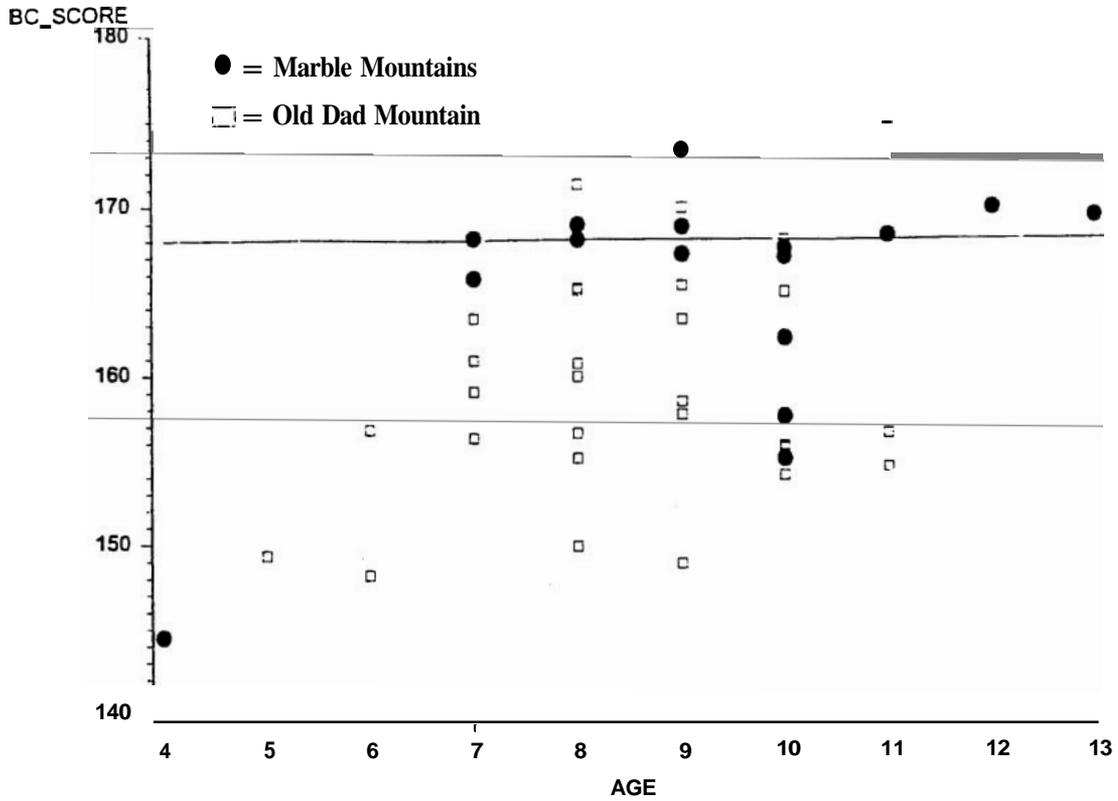
Figure 3. Scatterplot of estimated ram ages by score, 1987-1992, San Bernardino County, California.

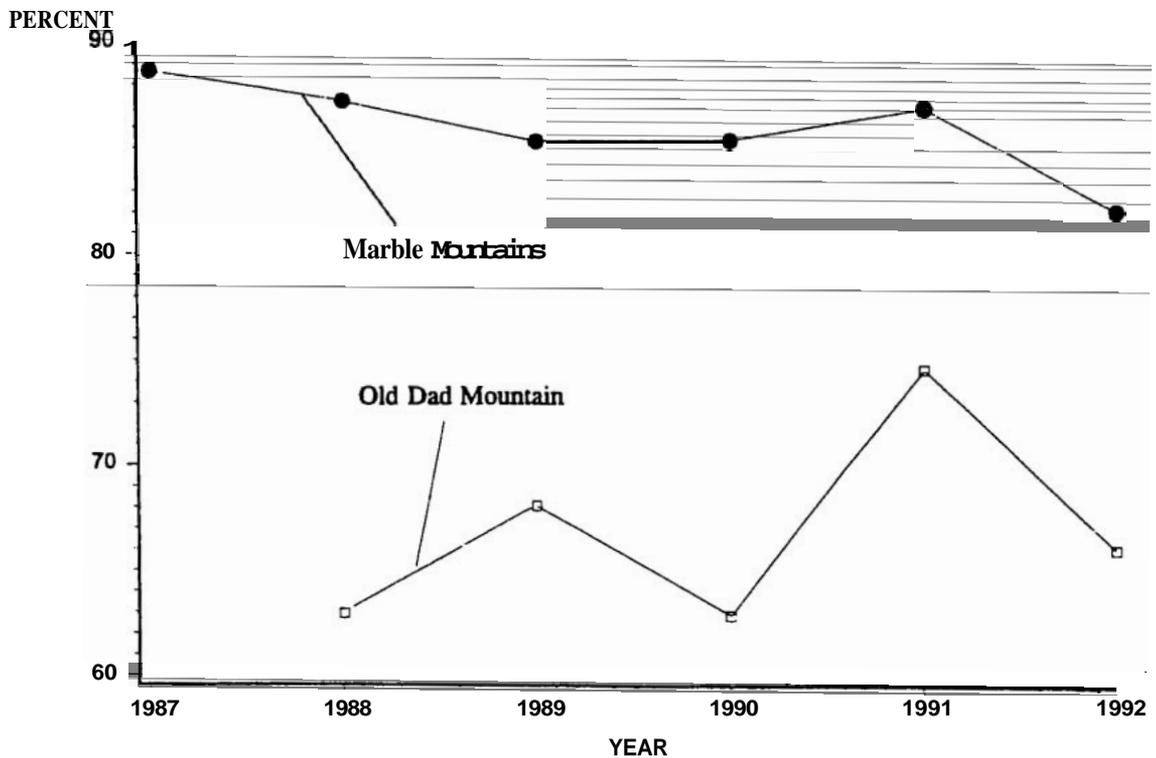*Figure 4. Percentage of rams ≥ Class II observed during annual helicopter surveys, 1987-1992.*

The relationship between age and "green" scores was examined by preparing a bivariate scatterplot between ages and scores (Fig. 3). The Pearson product-moment correlation coefficient ($r=0.39$) indicated a statistically significant linear association ($P<0.05$, $n=46$). Younger rams had higher scores in the Marble Mountains compared to rams from the Old Dad Mountains. Given that score is a component of age and growth patterns, rams harvested in the Marble Mountains had a higher rate of horn growth than those in the Old Dad Mountains (Fig. 3). As is common with most biological growth functions, the relationship appears slightly curvilinear. This relationship can be linearized by a simple natural log (ln) transformation (Neter et al. 1985).

DISCUSSION

Although these analyses should be carefully interpreted, several interesting issues related to the sampling and estimation methods of the age and score data should be noted: 1) Field aging of rams is more variable than "green" scores. The coefficients of variation for scores were approximately 4% (by mountain range), the coefficients of variation for estimated ages were 18-23%. This may reflect a sampling bias due to sportsmen targeting larger, rather than older, rams. 2) Estimated ages represent truncated data in the sense that ages are often difficult to measure on older animals, and therefore represent a minimum. Also, the variance in estimating age most likely increases with increasing age, a condition called heteroscedasticity. Therefore, researchers must be careful in using field estimates of age for refined population models. 3) Horn growth rates may vary between populations. Any differences in growth rates should be considered when comparing the "green" scores between populations.

From the CDFG's aerial survey data (1987-1992), the proportion of larger rams was higher in the Marble Mountains than in the Old Dad Mountains (Fig. 4). Therefore, the harvest of higher scoring animals in the Marble Mountains may simply be a function of the availability of higher scoring animals and a more rapid growth rate. However, Wehausen (1992) noted that field surveys in the Marble Mountains since 1984 have documented low percentages (availability) of Class I and II rams, and this was attributed to poor recruitment.

Therefore, the resulting harvest of larger animals may functionally represent the lack of a diverse size and age structure. This was indicated by the low variance in scores for harvested rams in the Marble Mountains (Fig. 1). Conversely, the Old Dad Mountain Management Unit supported a population with higher recruitment values during 1987-1992.

Although these analyses demonstrate some of the potential advantages of analyzing harvest data, they must be carefully interpreted. These relationships could be clarified by examining catch (numbers of animals) or "green" score per unit effort for each mountain range (or management unit). Catch per unit effort (CPUE) is frequently used in fisheries for assessing stock abundance from harvest data (Ricker 1975). These types of CPUE models might provide better insight into the availability of harvestable rams, and the effort associated with several harvest parameters. The advantage of incorporating effort when evaluating harvest success, score, or age, is that the index "corrects" or emphasizes harvest parameters as a function of effort. As an example, our analysis of age differences between populations (Fig. 2) could have de-emphasized the 4-year-old ram that was harvested with little effort. These types of adjustments made by CPUE indices would allow the true differences between populations of mountain sheep to be represented, and would therefore be useful as another management tool to index population changes over time.

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RESTORING BIGHORN SHEEP IN NEVADA

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INTRODUCTION

The Nevada Department of Wildlife (NDOW) is charged with the preservation, protection, management and restoration of wildlife belonging to the people of the State of Nevada. It is the policy of the NDOW that big game transplant and reestablishment programs will be used to develop new populations or to bolster existing populations (NDOW *1984*). This paper presents results of the bighorn sheep (*Ovis canadensis*) restoration effort from *1968-1992* and outlines the program success and costs.

HISTORICAL DISTRIBUTION

Nevada's physiography is described as the "Great Basin" (La Rivers *1962*). Across Nevada there are a series of broad, flat valleys with no exterior drainages. Separating the valleys are "block fault" north-south trending mountain ranges that rise 1,200-1,500 m above the valley floors. Many of these ranges harbored bighorn sheep before settlement and the introduction of domestic livestock. The historical presence of bighorn sheep is frequently confirmed by the discovery of skeletal remains, usually skulls and horn sheaths.

Early explorers reported seeing bighorn sheep in Nevada, and they used bighorn for food whenever the opportunity presented itself (Jackson and Spence *1970*). The settlement of Nevada, beginning about *1860*, brought many changes that affected bighorn sheep and other wildlife. Hunting (including poaching), disease, human encroachment, and habitat destruction were responsible for the decline, and in some cases extirpation, of bighorn in Nevada (Tsukamoto *1975*). Rocky Mountain bighorn (*O. c. canadensis*) were last observed in the Ruby Mountains in *1921*, and on Wheeler Peak in eastern Nevada in *1929* (Hall *1946*). California bighorn (*O. c. californiana*) disappeared around *1930*. Nelson desert bighorn (*O. c. nelsoni*) managed to escape many of these adverse impacts by living in the most inhospitable areas of the state. However, in *1974* it was estimated that only *2,200* desert big-

horn were found in *28* mountain ranges of southern Nevada (Tsukamoto *1975*).

BIGHORN TRANSPLANT PROGRAM

Bighorn have been transplanted to *48* locations in Nevada, and >100 animals/yr were transplanted in 6 of the last *25* years (*166* in *1986* alone). Most releases were made to restore extirpated populations; however, augmentations were made to existing populations of desert sheep in the Toiyabe, Monte Cristo and Silver Peak mountain ranges. A total of *792* desert bighorn have been moved to *24* sites since *1968*, resulting in an estimated *1,890* sheep in *1992* (Table *1*). This population estimate, and those that follow, were derived from results of fall helicopter surveys using observation proportions ranging from *33-60%* (McQuivey *1978*). The average size of release groups was *14*, and all of the source stock for desert bighorn transplants came from Nevada.

The first California bighorn transplant occurred in *1967* when the U.S. Fish and Wildlife Service relocated *8* California bighorn sheep from the Hart Mountain National Wildlife Refuge in Oregon to the Hell Creek Enclosure on the Charles Sheldon National Wildlife Range (Table 2). Subsequent transplant stock of California bighorn have also been obtained from sources outside of Nevada, especially British Columbia, Canada. Most of these relocations involved small numbers of sheep, but this has not adversely affected transplant success. Twenty-five transplants at *17* sites have resulted in an estimated *956* California bighorn in Nevada.

Transplant stock of Rocky Mountain bighorn have been received from Alberta, Canada, and the states of Wyoming and Colorado. Demand for this subspecies in Nevada is low because of limited release sites, and *210* sheep have been released in *7* areas (Table *3*). Each release site received an average of *30* animals, and the population is currently estimated at *290* bighorn.

Many of the early techniques used to capture bighorn for transplants, such as snares and steel leg-hold traps were crude and inefficient (typically

Table 1. Summary of desert bighorn (Ovis canadensis nelsoni) transplants in Nevada.

Location (Source)	No. of Releases	Animals Released	1992 Population Estimate	Year First Hunted	Year Of First Release
Wassuk Mts. (Lone Mt.)	5	40	56	1992	1968
Stonewall (River Mts.)	3	34	171	1984	1975
Virgin Mts. (River Mts.)	3	42	144	1990	1979
Stillwater Range (River, Black Mts.)	7	100	143	1986	1981
Hot Creek Range (River Mts.)	2	24	30	----	1982
Jefferson (River Mts.)	2	26	101	1982	1982
Toiyabe Range (River, Black Mts.)	2	21	94	1990	1982
Gold Butte (River, Black Mts.)	3	41	89	1990	1983
Pilot Mt. (River, Black Mts.)	3	25	168	1991	1983
Pancake Range (River Mts.)	1	26	115	1990	1984
East Range (River Mts.)	1	30	84	1990	1984
Tobin Range (River, Black Mts.)	2	52	18	—	1984
South Pahroc (Black Mts.)	2	36	15	—	1985
Excelsior Mts. (Lone Mt., River Mts.)	3	19	60	1992	1986
Clan Alpine (River, Black Mts.)	2	41	44	1992	1986
Desatoya (Black Mts.)	1	30	61	1990	1986
Egan (Black Mts.)	1	19	60	—	1986
North Hiko (Black Mts.)	2	24	55	1992	1986
South Hiko (Black Mts.)	1	22	35	1992	1987
Last Chance (River Mts.)	2	49	95	----	1988
Gabbs Valley Range (Lone Mt. River. Black Mts.)	3	36	167	1992	1988
East Pahranagat (Sheep Range)	2	16	30	—	1990
Spector (River. Muddy Mts.)	2	19	35	—	1990
Bare Mts. (Black Mts.)	1	20	20	—	1991
Totals	56	792	1,890	16	

≤3 animals/day), and selectivity of animals was nonexistent. In the 1960's corral traps were built around water holes where bighorns congregated during the hot summer months. These traps were large and cumbersome, and required considerable effort to erect. Chemical immobilization techniques surfaced in the 1970's, but this technique was limited because of high mortality risks and expense. The development of the drop net and the use of apple pulp for bait was a major breakthrough in successfully trapping bighorn sheep. Use of drop net and net gun techniques have accounted for 89%

Table 2. Summary of California bighorn (Ovis canadensis californiana) transplants in Nevada. B.C. = British Columbia, ID=Idaho, OR=Oregon, NV= Nevada

Location (Source)	No. Of Releases	Animals Released	1992 Population Estimate	Year First Hunted	Year Of First Release
Hell Creek (Hart Mt., OR)	1	8	40	1984	1967
Eight Mile (Penticton, B.C.)	1	12	115	1985	1978
Granite (ID, NV, OR)	3	24	115	1988	1980
Jackson Range (OR, BC)	2	28	140	1990	1984
Jarbidge (B.C., ID)	2	24	15		1981
Pine Forest (B.C.)	2	38	200	1992	1985
Snowstorms (ID)	3	27	75	1992	1985
McGee Mts. (OR)	1	15	40	—	1987
Andorno Canyon (OR)	1	5	15	—	1987
Sawtooth Mt. (B.C.)	1	20	35	—	1989
Calico Range (B.C.)	1	18	25	—	1989
Hayes Peak (B.C.)	1	15	25	—	1989
Virginia Range (B.C., ID)	2	27	32	—	1990
Montana Mts. (OR)	1	15	23	—	1991
Catnip Rim (OR)	1	14	21	—	1991
Sheep Creek Range (ID)	1	20	25	—	1991
Black Rock Range (NV)	1	11	15	—	1992
Totals	25	321	956	6	

of all sheep captures in Nevada (Table 4). The net-gun technique is the most recent one developed and requires specialized equipment and training. Experiences in California have shown that net-gun capture generally causes fewer stress-mediated shifts in physiological and biochemical parameters, resulting in less morbidity and mortality (Jessup et al. 1988).

PROGRAM SUCCESS

The sheep transplant program is responsible for 70% of the sheep populations in Nevada in 1992. With few exceptions, our transplants of bighorn sheep have been successful based on increased numbers of sheep and persistence of populations over the short term. Berger (1990) stated that population size is a marker of persistence trajec-tories, and that populations of ≤ 50 animals would not persist because this number was below a minimum viable population size for bighorn sheep. Although most of our 48 transplants involved < 50 animals (mean=27.5/site), the vast majority of reintroduced populations have persisted and increased in size. There are currently 24 transplant sites with bighorn populations estimated at ≥ 50 individuals, and the total number of sheep resulting from transplant operations is estimated at 3,036 (1,323 originally released). The NDOW will consider hunting a newly established population of bighorn when the estimated population size exceeds 50 animals. The number of bighorn hunting tags issued is based on analyses of population estimates in relation to age class structure, sex composition of the herd, and expected hunter success. The objective of the bighorn sheep harvest program is to take

Table 3. Summary of Rocky Mountain bighorn (Ovis canadensis canadensis) transplants in Nevada. WY = Wyoming, CO = Colorado

Location (Source)	No. Of Releases	Animals Released	1992 Population Estimate	Year First Hunted	Year Of First Release
Mt. Moriah (WY)	3	46	50	1985	1975
Wheeler Mt. (CO)	2	20	15	1985	1979
Grafton (CO)	2	22	25	——	1986
Pilot Peak (CO)	1	20	40	——	1987
Badlands (CO)	1	26	50	——	1989
Ruby Mts. (Alberta, Canada)	2	45	75	——	1989
East Humboldt (Alberta, Canada)	1	31	35	——	1992
Totals	12	210	290	2	

Table 4. Number of bighorn captures by various techniques in Nevada from 1969 to 1992.

Bighorn Subspecies	Drive Net	Corral Trap	Drop Net	Darting	Net Gun	Drive Trap	Total
California	37	0	44	12	215	13	321
Desert	16	43	599	0	134	0	792
Rocky Mountain	0	0	210	0	0	0	210
Totals	53	43	643	12	349	13	1,113
Percentage	5%	4%	58%	1%	31%	1%	

no more than **8%** of the ram population, or one-third of the rams **7** years old or older (McQuivey **1978**). As of **1992, 16** desert bighorn transplant populations have been opened to limited hunting. This represents **66%** of the transplanted populations. The average time from initial stocking to the first hunting season was approximately **8** years, and the shortest time was 4 years (Table **1**). Six of **17** (35%) of the reintroduced California bighorn herds have been opened to hunting, and the average time from initial stocking to the first hunting season was **8.6** years (Table **2**). Only 2 of 7 Rocky Mountain bighorn transplant populations have been hunted, and neither has sustained a huntable population over time. It is too early to determine the status of the transplanted Rocky Mountain bighorn herds based on the monitoring data collected thus far (Table 3).

As a result of the transplant program, the current distribution of bighorn in Nevada is far more representative of the likely historical distribution than was observed in **1967**. The network of population linkages (Bleich et al. **1990)** has improved the viability of bighorn in Nevada, and further efforts will be made to identify and fill gaps in distribution. The program also has been successful in meeting the aesthetic objective of providing increased wildlife viewing opportunities. The general 'public has thoroughly enjoyed seeing bighorn return to their former ranges; however, not all people are happy with the program. Domestic sheep ranchers have openly opposed the widespread reintroduction of bighorn because they believe that the presence of bighorn sheep imposes restrictive regulations on their grazing use of public lands. Resolution of conflicts involving overgrazing, disease interactions between bighorn and domestic livestock, and urban

Table 5. Cost of bighorn sheep (Ovis canadensis) transplant operations in Nevada from 1983 to 1991.

Year	Cost	No. Of Bighorn Released	Cost/Bighorn	No. Of Release Sites	Cost/Site
1983	$42,885.00	93	$461.13	8	$5,361.00
1984	$80,080.00	137	$584.53	7	$11,440.00
1985	$73,425.00	58	$1,265.95	4	$18,356.00
1986	$120,760.00	175	$690.06	12	$10,063.00
1987	$159,332.00	131	$1,216.27	9	$17,704.00
1988	$187,323.00	77	$2,432.77	5	$37,465.00
1989	$141,879.00	150	$945.86	12	$11,823.00
1990	$180,245.00	112	$1,609.33	6	$30,041.00
1991	$238,595.00	105	$2,272.33	7	$34,085.00
Totals	$1,224,524.00	1,038	$1,179.70	70	$17,493.20

encroachment are priority activities of the NDOW. The key to the success of the bighorn restoration effort has been the high degree of public support, investment, and involvement.

The financial cost of conducting a restoration program has been of concern to the NDOW as well as the public. Hunters have generously raised funds to help defray the cost of these programs. Hundreds of volunteers have assisted in capture operations, post-release monitoring efforts, and the financing and construction of habitat improvements. The cost of the trapping and transplant program from 1983 through 1991 has steadily risen (Table 5). Most of this increase can be attributed to greater manpower needs, poor climatic conditions requiring extended days of trapping, and special equipment needs while trapping along the shores of Lake Mead.

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STATUS OF BIGHORN SHEEP IN ARIZONA, 1992

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POPULATIONS

Estimates of Arizona's desert bighorn sheep (*Ovis canadensis mexicana* and O. c. *nelsoni*) indicated a population of approximately 5,550 animals. The 1992 desert bighorn sheep helicopter surveys produced 2,301 observations in 200.2 hr (11.5 sheep/hr), and showed that the sheep population has recovered from the drought years of 1989 and 1990. Survey results yielded ratios of 62 rams, 25 lambs, and 19 yearlings:100 ewes.

The Rocky Mountain bighorn sheep (*O. c. canadensis*) population, estimated at nearly 400 animals, has continued to expand both in numbers and range. The 24.3 hr of winter surveys resulted in a record observation of 302 animals. These survey results produced ratios of 50 rams, 56 lambs, and 28 yearlings:100 ewes.

Since 1980, a mean of 74 sheep have been transplanted annually, with a mean of fewer than 2 mortalities. In 1992, using net-guns fired from helicopters, 24 bighorn sheep were successfully captured in the Kofa National Wildlife Refuge and released into the Superstition Mountains. In 1993, 110 bighorn sheep are expected to be captured using both drop-nets and net-guns and transplanted to four release sites. This transplant effort will include a desert bighorn for Rocky Mountain bighorn trade with Colorado.

RESEARCH

The Arizona Game and Fish Department (AGFD) is currently involved in several bighorn sheep management study projects. These include: 1) survey methodology and efficiency tests (multiple survey tests during the past 10 years have produced observation rates which vary from 20-60%); 2) movement and mortality studies with Rocky Mountain sheep; 3) development of a bighorn sheep management plan for Sonora, Mexico (in cooperation with the Centro Ecologico de Sonora); and, 4) development of a tri-state bighorn sheep complex between Arizona, Nevada, and Utah, in cooperation with the Bureau of Land Management, the Natural Resource or Game and Fish Department in each of the states, the Arizona Desert Bighorn Sheep Society (ADBSS), and the Foundation for North American Wild Sheep (FNAWS).

HARVEST

Bighorn sheep permits remain the most sought after hunting permits in Arizona. There was a record total of 4,407 applicants (3,366 resident and 1,041 non-resident applicants) for the 80 regular season permits. This application rate represents over 55 hunters applying for each permit, with individual unit odds varying from as low as 20:1 to 184:i. Recent draw odds have fluctuated between 5:1 and 318:1, depending on the unit's accessibility and harvest history.

As a result of this year's survey, permits for the 1993 season were increased from 80 to a record 97. Two additional permits will again be issued to raise funds for bighorn sheep management programs. Aravaipa Canyon will be opened after 3 years with no permits and the Catalina Mountains will have no permits offered for the first time in many years. This shows the dynamic nature of bighorn sheep populations and their susceptibility to adverse conditions. The Peloncillo Mountains, site of recent transplant efforts, was to be opened to hunting this year. Due to the poaching of 2 Class IV rams this unit will have to remain closed for at least several more years.

During the 1992 hunting season, all 83 hunters participated (1 additional hunter was allowed into the field due to an irregularity in the drawing process), harvesting 74 rams for an 89% success rate. The 1992 season produced 22 animals (28% of the harvest) qualifying for the Arizona Trophy Book (minimum score of 162 Boone and Crockett points). Of these rams, 10 (14%) scored >170 points. During the last 5 years, these trophy harvest percentages have been 38% and 19%, respectively.

For the 10th consecutive year, the AGFD and the ADBSS entered into an agreement whereby the ADBSS auctioned 1 permit (at the FNAWS convention) and raffled another to raise funds for bighorn sheep management projects. In 1992, these permits

produced over $400,000, including a record auction bid of $303,000. To date, these permits have produced over $1,500,000. Arizona's bighorn

sheep management program is dependent upon the funds derived from these permits.

STATUS OF BIGHORN SHEEP IN CALIFORNIA, 1992

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POPULATIONS

Three subspecies of bighorn sheep (Cowan 1940) occur within California. California bighorn (*Ovis canadensis californiana*; $n = 325$) are restricted to the Sierra Nevada of eastern California; Peninsular bighorn (*O. c. cremnobates*; $n = 570$) occur in the western Sonoran Desert of Riverside, Imperial, and San Diego counties; and Nelson bighorn (*O. c. nelsoni*; $n = 3,900$) occur in the eastern Sonoran Desert, the Mojave Desert, the Transverse Ranges, and the Great Basin Desert of Mono and Inyo counties. California and Peninsular bighorn remain classified as threatened by the California Fish and Game Commission. All populations of Nelson bighorn, with the exception of those found in areas open to hunting, are fully protected by state law.

Two native populations and 3 reintroduced populations of California bighorn currently exist in the Sierra Nevada Mountains. These populations include from north to south: 1) Lee Vining Canyon, Mono County (reintroduced); 2) Wheeler Ridge, Inyo County (reintroduced); 3) Mount Baxter, Inyo County (native); 4) Mount Williamson, Inyo County (native); and, 5) Mount Langley, Inyo County (reintroduced). Currently, 7 natural populations of Peninsular bighorn sheep are recognized in California. These populations include from north to south: 1) San Jacinto Mountains, Riverside County; 2) Santa Rosa Mountains, Riverside and San Diego counties; 3) San Ysidro Mountains. San Diego County; 4) Pinyon Ridge, San Diego County; 5) Vallecito Mountains. San Diego County; 6) Jacumba/Inkopah Mountains, San Diego and Imperial counties; and, 7) Pinto/Inkopah drainage, south of Interstate 8, San Diego and Imperial counties. The California Department of Fish and Game (CDFG)

is currently funding research on all of these populations in an effort to clarify distribution, population status, and health.

As part of the CDFG's commitment to restoring bighorn sheep populations in historic mountain ranges, 2 translocation projects were conducted in 1992. During October 1992, 5 rams (1-3 years old) were relocated from the Kelso Peak/Old Dad Mountain Management Unit to the Avawatz Mountains in cooperation with the U.S. Army. During November 1992, 30 ewes and 14 rams were translocated to the Bristol Mountains (15 females, 6 males), the Bullion Mountains (15 females, 4 males), and Sheephole Mountains (4 males). The translocations to the Bristol and Bullion Mountains established new populations, and the relocations to the Sheephole and Avawatz Mountains augmented existing small populations. The translocation of bighorn sheep to the Bristol Mountains occurred in cooperation with the Bureau of Land Management (BLM). The translocation to the Bullion Mountains, in the Twentynine Palms Marine Corps Air Combat Gunnery Range, was a cooperative effort with the Department of the Navy.

In light of ongoing genetic research (e.g. Ramey 1993). it is imperative that all translocations of bighorn sheep be documented for future reference. On April 23, 1993, a yearling ram was captured by hand in a farmyard 5 km ESE of Hinkley, San Bernardiio County, California. The animal seemed in good condition and showed no clinical evidence of disease. Ectoparasites and blood were collected and submitted for laboratory analyses, and all serological tests for pathogen exposure were negative. The animal was marked with metal ear tags and released in the Ord Mountains, approximately 32 km SE of the capture site, a mountain range that

receives only occasional bighorn use. Interstate Highway 15, a potential barrier to movement and genetic interchange in the eastern Mojave Desert (Schwartz et al. 1986), separates the capture site from the Ord Mountains. Although the source population from which this ram emigrated could not be determined, the Eagle Crags are the closest mountain range north of Interstate Highway 15 that has a resident bighorn sheep population. Bighorn sheep were translocated to the Eagle Crags, located approximately 45 km N of the capture site, from Old Dad Peak and the Marble Mountains in 1983 and 1987 (Bleich et al. 1990). The selection of Ord Mountain rather than the Eagle Crags as a release site for this yearling ram was based on logistical constraints and the immediate need to **minimize** animal handling and transport.

RESEARCH

The CDFG continues to collaborate with several organizations in support of its Bighorn Sheep Program. Detailed demographic studies continued in 9 Mojave Desert and Sierra Nevada populations through a contract with the University of California, **Los** Angeles, White Mountain Research Station. The emphasis of this work has been to evaluate the demographic consequences of disease processes, bighorn removal (from hunting and reintroduction projects), predation, and habitat. Recent research (Wehausen 19920) focuses on elucidating the potential factors influencing population size and density, adult survivorship, and recruitment among several populations. Potential differences in the quality of forages occurring on ranges used by male and female bighorn sheep were explored by Bleich et al. (1992*a*). Although differences existed in some individual forage species, no distinct patterns emerged from the analysis. The role of precipitation and temperature in winter range diet quality of bighorn sheep in the Sierra Nevada was reported by **Wehausen** (1992*b*). This research emphasized the importance of the timing, rather than total amount, of precipitation in influencing forage growth and digestibility.

A detailed demographic investigation of bighorn sheep inhabiting the Kingston, Clark, and Mesquite Mountains is also continuing in cooperation with the University of Nevada, **Las** Vegas. During the **CDFG's** November 1992 translocation project in the Mojave Desert, pregnancy rates were assessed using both ·ultrasound and pregnancy-specific protein B (blood samples). Pregnancy was detected in 18/27 (67%) ewes by ultrasound and in 26/31

(84%) ewes by analysis of pregnancy-specific protein B. Pregnancy rates have important demographic consequences, particularly with regard to the interpretation of recruitment data for population modeling.

Personnel from the CDFG, the University of Alaska, University of Rhode Island, and the University of Capetown, South Africa used Geographic Information System technology to evaluate the reliability of the habitat model developed by **Hansen** (1980). Tested in the Sheephole Mountains, San Bernardino County,' the model appears to have value in evaluating sites that are being considered for the reintroduction of desert bighorn sheep (Bleich et al. 1992*b*). More robust tests of the model are planned in 6 additional mountain ranges for which telemetry data are available.

Five years of intensive research into the evolutionary significance of sexual segregation in bighorn sheep were completed (Bleich 1993). Results strongly support the hypothesis that, among **polygynous** ungulates, males enhance their body size and condition by taking greater risks while foraging than do females, with resultant increases in reproductive success. Females, on the other hand, appear to **minimize** risk to themselves and offspring while surviving on poorer quality, but adequate, forage. The differential use of habitats by males and females during sexual segregation has important implications for habitat protection and enhancement, as well as for aerial survey methodologies. This research was a collaborative effort involving funding from the CDFG, Boone and Crockett Club, Foundation for North American Wild Sheep (FNAWS), National Rifle Association, Safari Club International (SCI), and Society for the Conservation of Bighorn Sheep (SCBS).

In 1992, 25 Nelson bighorn sheep were **radio**-collared and monitored in the Chocolate Mountains, Imperial County. The Chocolate Mountains study will allow the CDFG: 1) to develop a detailed demographic description of this population; 2) to evaluate their potential as source stock for translocation; and, 3) to assess the potential of this range to support limited sport hunting. This research is a collaborative effort between the CDFG and the University of Rhode Island, and includes additional funding from the Imperial County Fish and Game Commission, SCI (Sacramento, San Francisco Bay Area, and San **Diego** Chapters), and FNAWS (East Coast Chapter). Additionally, volunteer support from local sportsmen and conservationists has greatly augmented the field monitoring efforts. The CDFG Bighorn Sheep Program will continue a **co**-

operative study with the Arizona Game and Fish Department in the Chocolate Mountains to reevaluate existing population survey methods and to test new techniques. Survey method bias, consistency, and precision will be modeled, and operational costs and the use of marked animals will be evaluated.

The CDFG has prepared recommendations for a monitoring program of the local bighorn population in the Eagle Mountains, Riverside County. This monitoring effort is in response to a landfill project, approved in 1992 by the Riverside County Board of Supervisors, that may impact the distribution of Nelson bighorn sheep by altering existing water sources. The monitoring program will be conducted for 5 years in cooperation with the University of Nevada, Las Vegas, and is funded by the Mine Reclamation Corporation.

A cooperative effort continued in 1992 between the CDFG and the U.S. Army to assess factors potentially limiting the bighorn sheep population in the Avawatz Mountains, San Bernardino County. The 5 radio-collared animals translocated to this range in October 1992 augmented the existing small population and will serve as sentinel animals for locating unmarked animals. Fixed-wing telemetry data are being gathered in an effort to delineate the distribution of bighorn sheep in the Avawatz Mountains. This population remains of great interest because it appears that numbers remain at a low level, relative to the apparent carrying capacity of the range, and few obvious limiting factors are present. Additionally, a boundary extension proposed by the Fort Irwin Military Base may incorporate the entire Avawatz Mountains.

The annual San Gabriel Mountains Nelson bighorn sheep survey was conducted for the 17th time in March 1992 in cooperation with the United States Forest Service (USFS), SCBS, and local conservationists. A population estimate of 600-700 animals was derived by a combination of aerial (helicopter) and ground observations of bighorn sheep.

In 1992, the CDFG Bighorn Sheep Management Program funded a detailed morphometric reexamination of the current subspecies classification of desert bighorn sheep in California. The results of this analysis are presented elsewhere in the 1993 Transactions and may have important conservation implications with regard to subspecies recognition and regional selection of reintroduction stock to restore or augment bighorn sheep populations in the Peninsular Ranges.

Recent CDFG funded disease investigations have

shown that bighorn sheep in the Peninsular Ranges. relative to other statewide bighorn populations, have higher exposure to known disease agents (Clark et al. 1993, Elliott et al. 1994). This finding has resulted in the CDFG funding a comprehensive investigation ($250,000 over 3 years) to study the distribution, demography, and disease ecology of Peninsular bighorn sheep. The University of California, Davis (UCD) is the primary collaborator, along with the California Department of Parks and Recreation (CDPR), and the San Diego Zoological Society. Other recently completed research conducted collaboratively with UCD and other cooperators includes the summarization and publication of several years of research on psoroptic scabies (Boyce 1992, Mazet et al. 1992, Boyce et al. 1992), and investigations of Babesia and *Anaplasma* infections in bighorn sheep (Thomford et al. 1993, Goff et al. 1993*a*, Goff et al. 1993*b*, Jessup et al. 1993).

Additionally, the CDFG is cooperatively funding the monitoring and assessment of the peninsular bighorn sheep population in the San Jacinto Mountains. Key participants include the Bighorn Institute, BLM, and USFS. The CDFG is also continuing to investigate the potential for transmission of infectious diseases between bighorn sheep, cattle. and deer in the San Bernardino Mountains in San Bernardino and Riverside counties. This study is being expanded to include detailed monitoring of distribution and range-use, recruitment, and adult survival. In December 1992, 6 additional animals were captured and fitted with radio collars, and more sheep will be captured and marked in 1993. Distributional information for this population is critical given the proposed development of a large housing tract on the southeastern end of the San Bernardino Mountains.

In summary, 133 Nelson bighorn sheep in 11 populations were captured and radio-collared for ongoing CDFG research and relocation projects. Additionally, 52 bighorn sheep in the Peninsular Ranges were captured, sampled, and radio-collared for CDFG-funded health and demography studies.

HABITAT IMPROVEMENTS

The CDFG, in cooperation with volunteers from the Volunteer Desert Water and Wildlife Survey (VDWWS), constructed 2 artificial catchments to benefit bighorn sheep in San Bernardino County. In addition, 150 maintenance inspections were made on bighorn sheep catchments and springs. Members of the VDWWS contributed 8,019 hours of

labor and 254,549 vehicle kilometers to the CDFG while accomplishing these tasks. All development and maintenance work occurred cooperatively with BLM. A historical account of bighorn sheep water development activities in Inyo County, California, was presented by Bleich (1992).

HARVEST (1987-1992)

Since bighorn sheep hunting was authorized by the California Legislature in 1987, 6 hunting seasons have been held (Table 1). To date, a total of 50 adult rams in the 3 hunt zones (Marble Mountains, Old Dad Peak/Kelso Mountains, and Clark/Kingston Mountains) have been harvested for an overall success rate of 94.3%. Animals shot during annual hunts have ranged from 4 to ≥ 13 years of age, and 14 (28%) have qualified for the Boone and Crockett Records Book based on their "green" scores. Hunters in 1992193 did not experience any disruptions from protesters.

For the fourth consecutive year, the CDFG prepared an environmental document that detailed the anticipated environmental effects of hunting bighorn sheep. This document, through the State Resources Secretary, is intended to comply with the mandates of the California Environmental Quality Act. In this document the CDFG proposes to issue 11 tags for the 1993 hunting season as follows: 3 at the Marble Mountains (Zone 1), 4 at Old Dad Peak/Kelso Mountains (Zone 2). 3 at the Clark-Kingston Mountain Ranges (Zone 3), and 1 fund-raising tag that is valid in any hunt zone. State law limits the number of tags issued to ≤15% of the mature rams (≥2 years) estimated in each hunt zone during annual CDFG surveys. For hunting purposes, legal rams are those possessing ≥ ¾ curl. The special fund-raising tag sold for $100,000 at the February 1993 convention of FNAWS, an increase of $39,000 (45%) over the price paid for the 1992 auction tag (Table 1). An analysis of hunter harvest is presented elsewhere in the 1993 Desert Bighorn Council Transactions.

PROBLEMS/OPPORTUNITIES

In the May 8, 1992 Federal Register (Vol 57, 90:19837-19843) the United States Fish and Wildlife Service (USFWS) published the Proposed Rule to list the Peninsular Ranges population of desert bighorn sheep as endangered. The CDFG has several reservations regarding the procedural aspects of this listing, the inferences that have been drawn from available data, and the management

implications. The CDFG also continues to review and respond to legislation (California Desert Protection Act, S. 21) that would designate lands in the California Desert as wilderness, would establish the Death Valley and Joshua Tree National Parks, and would create the East Mojave National Park. In February 1992 the CDFG provided comments on this bill and also H.R. 2929. Although H.R. 2929 would conditionally allow hunting in the East Mojave National Park, these 2 legislative proposals are essentially identical.

The CDFG has several concerns regarding S. 21. This bill does not make specific provisions for access to wilderness areas for law enforcement, the maintenance of wildlife habitat, or other wildlife management purposes. Therefore, the proposed establishment of wilderness areas may negatively impact desert bighorn sheep, mule deer, and upland game management activities (i.e. translocations and habitat improvements). Public access on existing roads will also be severely limited. The continuance of the CDFG's harvest and translocation programs may also be jeopardized by not permitting the removal of bighorn sheep from the Old Dad Peak/Kelso Mountains Management Unit since this Management Unit is located within the proposed East Mojave National Park boundaries. The proposed expansion of Death Valley National Monument will restrict ongoing management activities for the continued maintenance and improvement of habitat for bighorn sheep in the Last Chance Range and the Dry Mountain area. Further, any future opportunities to harvest desert bighorn sheep from these populations will be eliminated. H.R. 518 was submitted to Congress in 1993. This revision is similar to S. 21 and does not address any of the CDFG's concerns. Although this legislation provides for the protection of utility rights-of-way and the continuance of low military overflights, it is unfortunate that the needs of wildlife and their management under existing CDFG programs are not clearly addressed.

The Sierra Nevada Bighorn Sheep Interagency Advisory Group (SNBSIAG) held its annual meeting at Lee Vining (Mono County) in October, 1992. Participating agencies included the CDFG, National Park Service (NPS), BLM. and the USFS. The Lee Vining herd is currently being monitored during the summer by Yosemite National Park staff. Current estimates indicate that this population increased to approximately 70 animals and has expanded into the Bloody Canyon area. This expansion risks contact with domestic sheep and the SNBSIAG is discussing available options. CDFG

Table 1. Summary of Nelson bighorn sheep tag allocations, harvest, applications, and revenue from 1987-1993 in California.

Year	Allocated	# Harvested	# Applicants	Revenue	Tag Fees	Total
1987	9	9	4,066	$70,000.00	$21,930.00	$91,930.00
1988	9	7	3,385	$59,000.00	$18,525.00	$77,525.00
1989	9	9	3,185	$40,000.00	$17,525.00	$57,525.00
1990	6	6	2,591	$37,000.00	$13,955.00	$50,955.00
1991	8	7	2,834	$42,000.00	$15,570.00	$57,570.00
1992	12	12	3,798	$61,000.00	$22,464.50	$83,464.50
1993	11		4,318	$100,000.00	$25,082.00	$125,082.00
Totals	64			$409,000.00	$135,051.50	$544,051.50

will monitor this population during the winter of 1993194. Updated demographic information for other bighorn sheep populations in the Sierra Nevada is also needed, and the CDFG will attempt to place radio collars on ewes in the Mount Baxter herd whenever possible.

The CDFG Bighorn Sheep Program currently is participating in regional habitat management planning for the 4 southeastern California metapopulations of Nelson bighorn sheep. This planning process is being coordinated by BLM, and other cooperators include NPS, and USFWS. The primary objective of this cooperative effort is to ensure the health of bighorn sheep metapopulations by coordinating and planning regional habitat management. The CDFG also recently entered (November 1992) into a Memorandum of Understanding that establishes an interagency task force to develop a habitat management and population recovery program for bighorn sheep in the Peninsular Ranges. In addition to the CDFG, agency cooperators include BLM, USFS, USFWS, and CDPR. A primary objective of this interagency group will be to identify, stabilize, and protect bighorn sheep populations in the Peninsular Ranges.

This status report is a contribution from the CDFG Bighorn Sheep Management Program.

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STATUS OF BIGHORN SHEEP IN COLORADO, 1992

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POPULATZONS

Historical data, bone fragments, skulls, and Indian petroglyphs and pictographs indicate that bighorn sheep occurred in the arid areas of western Colorado, but contemporary populations were not known in the mid-1970's when the idea of introducing desert bighorn sheep evolved. The transloca-

tion of desert sheep into Colorado began in 1979 and continues to the present time.

Three areas were selected for release of desert bighorn. One was in west-central Colorado and 2 were located in the southwestern part of the State. The first site to receive sheep was near Grand Junction, Mesa County, adjacent to the Colorado National Monument. This location is recognized as Sheep Management Unit 56 (S-56). The initial transplant occurred in 1979 when 11 sheep (*Ovis canadensis mexicana*) were brought from the Kofa National Wildlife Refuge in Arizona. A second transplant occurred in 1981 when 18 sheep (*O. c. nelsoni*) from the River Mountains of Nevada were released. The last release occurred in 1982 when an additional 9 sheep (*O. c. nelsoni*) from the Lake Mead area of Arizona were relocated. The current population of desert bighorn in this unit is estimated to be 100-110 animals, and most of the occupied area is within a Bureau of Land Management Wilderness Study Area. If wilderness classification is authorized, additional protection for sheep habitats would be provided. However, manipulation of vegetation and other habitat improvement techniques would be precluded. The potential expansion of the Colorado National Monument threatens to engulf about 40% of the area currently used by sheep. The expansion, if authorized, would include areas where approximately 80% of the sheep were harvested. Increased use of this area by recreationists, especially mountain bikers, has the potential to displace sheep from formerly used areas.

The second location in Colorado to receive desert bighorns was the east side of the Uncompahgre Plateau in southwestern Colorado. This location is recognized as Sheep Management Unit 62 (S-62). The animals were all delivered from the Lake Mead area beginning in 1983, with the final transplant in 1985. Ten sheep (*O. c. nelsoni*) from the Arizona side of Lake Mead were released in Dominguez Canyon in 1983, with an additional 10 in 1984. Nevada provided 21 sheep (*O. c. nelsoni*) during the summer of 1985, which were released in Big Dominguez Canyon, approximately 9.6 km north of Dominguez. The Dominguez/Big Dominguez population is estimated to be 100-125 sheep. Approximately 64 km to the south of Dominguez Canyon lies Roubideau Canyon, where 18 desert bighorn sheep (*O. c. nelson0* from the Black Mountains of Arizona were released in 1991. Twenty-one sheep (*O. c. nelsoni*) from the Arizona side of Lake Mead were released at the Roubideau

Canyon site during the summer of 1993. The population estimate in S-62 north of Escalante Creek and the Middle Fork of Escalante Creek is 100-125 animals. The Roubideau Canyon sheep are not included in this estimate and are regarded as a discrete population, even though 2 sheep released in Roubideau Canyon found their way to Dominguez Canyon, approximately 64 km to the north. Contagious ecthyma was discovered in this population during the spring of 1993 and may have been acquired from sympatric domestic sheep.

Desert sheep were also released in the Dolores River Canyon. The Middle Dolores Canyon is recognized as Sheep Management Unit 63 (S-63) and the Upper Dolores Canyon is recognized as Sheep Management Unit 64 (S-64). A total of 56 desert sheep were released in the upper unit, S-64, during 1986-87. All of the animals were *O. c. nelsoni*. In 1986, 35 animals were received from the Lake Mead area of Nevada. In 1987.21 sheep were delivered from the Lake Mead area of Arizona. The current population in S-64 is estimated at a minimum of 125 animals. Nineteen sheep (*O. c. nelsoni*) from the Muddy Mountains, Nevada, were released into the middle Dolores area, S-63, in 1990. The Colorado Division of Wildlife is anticipating additional releases in this area in the future. Research was conducted in this area to generate data for evaluation of a desert bighorn habitat suitability model (McCarty 1993).

HARVEST

Hunter harvest has occurred in unit S-56 since 1988. Two ram licenses have been issued each year, except 1990, when 4 licenses were issued. Hunter success has been 100% for all years and the average age of rams killed was 6 yr. Unit S-62 was opened to hunting, north of Escalante Creek and the Middle Fork of Escalante Creek, for the first time in 1992, when 1 permit was offered. A single ram was harvested. Two licenses are available for the 1993 season. Unit S-64 will be open to hunting for the first time during the 1993 sheep season and 2 ram licenses are available.

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STATUS OF BIGHORN SHEEP IN NEVADA, 1992

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*POPULA*TZONS

Nevada's desert bighorn sheep (*Ovis canadensis* nelsoni) occupy mountain ranges in the southern two-thirds of the state. Helicopter surveys are conducted on approximately one-half of the occupied mountain ranges annually, and 2,027 bighorn were classified during the September-October 1992 census. There were 583 rams, 1,053 ewes, and 391 lambs observed yielding a ram:ewe:lamb ratio of 55:100:37. This ram:ewe ratio approximates the long term average, while the lamb:ewe ratio is much higher than average. This is the second consecutive year of above average lamb survival and the third highest lamb:ewe ratio recorded since 1969. Table 1 shows the current status of desert bighorn populations in Nevada. Reintroduced populations now represent 36% of the total, attesting to the success of the program. Although desert bighorn populations have increased since the 5-year drought ended in 1991, some of the historically abundant populations in areas such as the Sheep Range, McCullough Range, and Highland Range of Clark County are far below former levels. Fall helicopter surveys indicated that the Sheep Range population declined 81% from 1988 (n=1,133) to 1992 (*n*=217), and the McCullough and Highland Ranges populations also have declined by 51% and 84%, respectively, during the past 11 years (1982-1992).

Significant population increases have been noted in recent northern Nevada transplant sites, as well as in the Mormon Mountains, Muddy Mountains, and Black Mountains in southern Nevada. A severe die-off (61%) due to pneumonia in the Mormon Mountains in 1980 has been offset by a slow but steady recovery, and the estimated size of the population in 1992 is 409 (*n*=462 in 1980). The Mount Jefferson herd increased to 106 in 1992 (*n*=26 in 1982). while the Pancake Range herd increased to 115 (n=26 in 1984).

RESEARCH

Nevada is cooperating with the Idaho Fish and Game Department and the University of Idaho on disease interactions between domestic and wild sheep, and Drs. A. Ward and D. Hunter have sampled several bighorn populations, including some herds in direct contact with domestic sheep. No trapping and transplant efforts with desert bighorn were conducted in 1992 because of poor trapping conditions, personnel changes, and higher work priorities.

HABITAT IMPROVEMENTS

Desert bighorn water developments were constructed in the East Pahranagat Range of Lincoln County, the Last Chance Range in Nye County, and the Clan Alpine Range in Churchill County. Water developments were constructed using volunteer labor in cooperation with the Bureau of Land Management (BLM), Carson City and Las Vegas Districts. Three Slickrock water catchments were built in the Last Chance Range, 2 in the Mormon Mountains, and 2 in the Pahranagat Range. The Nevada Department of Wildlife (NDOW) added a hypalon apron to 1 project in the Bare Mountains and 1 in the South Spring Range. These projects were coordinated by NDOW and BLM, and the Fraternity of the Desert Bighorn (FDB) provided valuable technical advice and labor. An 11,350 liter capacity guzzler was constructed on the Clan Alpine Range using funding and volunteer labor from the Fallon Chapter of Nevada Bighorns Unlimited (NBU). This guzzler was named "Little Angel" by a bidder who paid $700 for the privilege at the fund-raiser. There are over 100 water developments for bighorn sheep in Nevada, and volunteers from NBU and the FDB also provide hundreds of man hours in scheduled maintenance activities.

HARVEST

Desert bighorn sheep were hunted on 33 of 46 mountain ranges in 1992. Eleven of the 29 management units currently hunted originally were stocked with transplanted sheep and 2 received augmentations. Thirty of 113 available permits were for hunts in transplanted or augmented herds.

Table 1. Status of desert bighorn populations in Nevada in 1992.

Population Status	<25	25-50	51-100	101-200	>200	Total
Native	4	3	5	4	6	22
Supplement[a]	0	1	5	1	0	7
Reintroduced[b]	2	3	5	5	0	15
Total	6	7	15	10	6	44

[a] Native populations that have been supplemented.
[b] One failed reintroduction is not included.

Table 2. Summary of desert bighorn sheep harvested in Nevada, 1979-1992.

Year	No. Permits	No. Harvested	% Success
1979	81	59	72.8
1980	86	66	76.7
1981	90	65	72.2
1982	90	58	64.4
1983	111	94	84.7
1984	121	86	71.1
1985	128	110	85.9
1986	131	107	81.6
1987	135	112	83.0
1988	138	114	82.6
1989	135	111	82.2
1990	136	91	66.9
1991	126	85	67.5
1992	115	92	80.0

Two auction tags were also made available in 1992 in Reno, Nevada. The tag vendors were Foundation for North American Wild Sheep and NBU (Reno Chapter), and they generated successful bids of $65,000 and $63,000, respectively. NDOW received 3,232 applications for the 113 regular permits available in 1992. The odds of receiving a permit for resident hunters was 1 in 22, while nonresident odds ran 1 in 96. Hunter success dropped to approximately 67% in 1990 and 1991, and increased in 1992 to about **80%** (Table 2).

PROBLEMS/OPPORTUNITIES

The desert bighorn management program will continue to focus on restoring and improving

bighorn habitat, primarily through water developments. NDOW believes this may be the most cost-effective way to increase bighorn populations. No transplants were conducted in 1992, but it is anticipated that 1993 will be a very active year. The transplant plan for 1994 and 1995 contains proposals for 2 bighorn reintroductions and 13 augmentations, and is currently before the Nevada Board of Wildlife Commission for approval. This plan will require the availability of 300 animals for stocking. In addition, there are several requests from other states for desert bighorn stock from Nevada.

STATUS OF BIGHORN SHEEP IN NEW MEXICO, 1992

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POPULATIONS

In 1992, 278 desert bighorn sheep (*Ovis canadensis mexicana*) were estimated to be in New Mexico based on fall surveys. All 6 populations contain ≤ 100 sheep (Table 1). Population trends between 1987-92 (presented in previous Desert Bighorn Council Transactions status reports) indicate that all populations are stable to increasing, except the declining Alamo Hueco herd.

In October 1992, 23 bighorn (16 ewes, 7 rams) were captured with the helicopter net-gun method at the New Mexico Department of Game and Fish (NMGF) Red Rock Wildlife Area and subsequently released into the Ladron Mountains in central New Mexico. All bighorn were radiocollared. The transplant was a cooperative project involving the NMGF, the Bureau of Land Management (BLM). and the U.S. Fish and Wildlife Service (USFWS) (Fisher 1993). Post-release monitoring from October 1992 to May 1993 documented minimal movement of bighorn outside the mountain range, the birth of 6 lambs, and the death of 5 adults. One ewe died from a fall, 1 ewe was killed by a mountain lion, 1 ewe died of unknown causes, and 2 rams were shot illegally during a deer hunt in November (Knadle and Thompson 1993). Two hunters plead guilty to killing the rams, which cost them $8,000 in fines, loss of hunting privileges for 3 years, and 200 hours of community service.

To date, 118 desert bighorn have been transplanted in New Mexico, 92 from the Red Rock Wildlife Area and 26 from Arizona. Due to the success of Red Rock as a propagating facility (Fisher 1991), NMGF has not obtained desert bighorn from outside the state since Arizona bighorn were transplanted into the Peloncillo Mountains in 1980.

RESEARCH

Eleven desert bighorn ranges in New Mexico were evaluated for suitability as transplant sites using a Geographic Information System (Dunn 1991). This evaluation will help direct the bighorn transplant program for the next 5-10 years, although sociopolitical factors will continue to impact the availability of release sites (see Problems and Opportunities section).

It has become increasingly difficult to assess and manage the San Andres bighorn population because: 1) they have not been physically examined since 1989 (Clark and Jessup 1992); 2) intensive ground monitoring ceased in 1991; and, 3) functional radio collars decreased from 9 in 1992 to 4 in 1993. Four ewe mortalities were documented in 1992 (1 accidental fall, 3 causes of death unknown), and 1 of these ewes was infested with scabies mites (Logan et al. 1993). The NMGF has proposed to USFWS to sample and radiocollar bighorn in the San Andres National Wildlife Refuge in fall, 1993. Objectives are to: 1) continue monitoring the effect of psoroptic scabies on population dynamics; and, 2) radiocollar enough bighorn to be prepared for a removal/treatment operation as recommended by Clark and Jessup (1992). if both agencies agree on this management strategy. It is essential that radio collars be placed on a significant proportion of the population prior to any removal effort because of the small numbers of animals ($n \leq 25$) relative to the occupied area (250 km^2).

Table 1. Size of desert bighorn herds in New Mexico, 1992.

	Estimated Population Size				
Status	<25	25-50	51-100	101-200	>200
Native	0	1	0	0	0
Supplement	0	0	1	0	0
Reintroduced	2	1	0	0	0
Captive	0	0	1	0	0

HABITAT IMPROVEMENTS

The BLM (Socorro Resource Area) installed 2 water catchment units in the Ladron Mountains at a cost of $5,000. Foundation for North American Wild Sheep (FNAWS) members provided assistance and helicopter time was donated by Aerowest, Albuquerque. The BLM (Mimbres Resource Area) also removed 6 km of net-wire fence in the Peloncillo Mountains and built 1.6 km of 4-strand fence to control livestock. Expenses totaled $13,800 (partly funded through the Sikes Act), and maintenance of existing water units cost $4,000.

HARVEST

Desert bighorn were last hunted in 1978 when the San Andres hunt was closed due to the discovery of scabies mites on harvested rams (Sandoval 1980). In 1980, the subspecies (*Ovis canadensis mexicana*) was listed as endangered by the state of New Mexico. In 1988, the listing was restricted to non-captive animals of the New Mexico genetic stock. This action de-listed the transplanted Peloncillo bighorn because they originated from stock transplanted from Arizona and New Mexico (NMGF 1988). Peloncillo bighorn may be hunted as early as 1995 if population size and ram quality continue to increase.

Desert bighorn research, management, and restoration have benefitted from funds raised by the auction of 1 Rocky Mountain bighorn (*O. c. canadensis*) permit at the FNAWS convention. The auction raised $183,000 during 1990-1992, and the 1992 auction permit sold for $67,000. The 1992 permit resulted in the harvest of the New Mexico state record Rocky Mountain bighorn (188% Boone and Crockett points) in the Pecos Wilderness.

PROBLEMS/OPPORTUNITIES

Strong public opposition, fueled by the Wise Use Movement, forced NMGF to withdraw its proposal to the BLM to transplant desert bighorn into the Caballo Mountains in Fall 1992. Based on the high ranking the Caballo Mountains received in Dunn's (1991) analysis, NMGF proposed a transplant to the BLM in 1991 and recommended that public access be restricted by closing 8 roads (ranchers and miners would be permitted access). Hard rock mining, the dominant land use in the Caballos, had previously resulted in a myriad of roads within potential bighorn habitat.

Because bighorn transplants were not stipulated in the BLM Resource Management Plan, public input was required to comply with the National Environmental Policy Act. In June 1992, public meetings were held in Truth or Consequences and Las Cruces, which drew 125 and 350 people, respectively. Public comment was overwhelmingly negative, and no supportive statements were made at the Truth or Consequences meeting. Public sentiment was further inflamed by derogatory editorials (Ballinger 1992). Full-page cartoons in local newspapers depicted a bighorn surrounded by a cyclone fence, implying that bighorn would preclude all human activities (Pearson 1992). NMGF also received a petition with >1,000 signatures opposing the transplant, and a Caballo rancher threatened to put domestic sheep on his private land if bighorn sheep were transplanted.

The dominant theme of the protest was that mining, ranching, and recreation would be restricted, thereby: 1) threatening economic livelihoods; 2) violating "custom and culture" of the Sierra County Land Use Plan; and, 3) inviting government intrusion. Many people stated that they were against

road closures, not bighorn; however, because of the way the proposal was presented, they would not support the proposal even if roads were left open (Meeting Minutes, NMGF Files). The issues also became confused because the bighorn protest was used as a platform for venting anger and frustration over other economic threats (e.g., changes in mining and grazing regulations).

The bighorn protest coincided with the growth of the national Wise Use Movement, a loose coalition of >400 organizations representing miners, ranchers, farmers, loggers, and recreationists (primarily off-road vehicle users). Mining and logging interests, as well as the religious right, provide financial backing, and grass-roots participation is strong in thousands of rural western communities. This 1990's "Sagebrush Rebellion" combines slogans of personal liberty, dominion theology, county supremacy, and maximum use of public lands for maximum profit (The Wise Use Agenda 1989, O'Callaghan 1992).

The Wise Use Movement is a potent force in New Mexico environmental politics because one of its most important tenets--the land use plan--has been modeled after ordinances adopted in Catron County, New Mexico in 1990. Under the Catron County Model, a county defines its custom and culture, i.e., its historical way of life, via a land use plan. Federal agencies contend that these plans should not direct federal policy decisions and thus violate federal supremacy. This issue is currently being addressed in court (Ashton 1993).

In the interim, the future of transplants to the Caballos and other areas is uncertain. The protest taught us some hard lessons. NMGF now knows that proposals should not proceed without knowing community sentiment. For example, restrictive clauses such as road closures should be evaluated in light of first hand knowledge of community ideology. On the positive side, the protest did induce the formation of a New Mexico State Chapter of FNAWS, whose support will help counteract public opposition.

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STATUS OF BIGHORN SHEEP IN TEXAS, 1992

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POPULATIONS

Six populations of free-ranging desert bighorn sheep occur in the Trans-Pecos region of Texas in the Sierra Diablo, Baylor, Beach, Van Horn, Sierra Vieja and Elephant Mountains. Each population derives from reintroduced stock since native desert sheep in Texas were extirpated in the early 1960's. The Sierra Diablo, Sierra Vieja, Beach and Elephant Mountain herds are a direct result of the brood pen operation in Texas. The Baylor and Van Horn Mountain herds resulted from releases of wild-trapped sheep from the Mormon Mountains, Nevada. Helicopter surveys were completed in all mountain ranges supporting free-ranging sheep during late September and early October, 1992. Free-ranging population estimates were calculated using the observers' knowledge of the mountain range and estimated observation success during the survey. The total free-ranging population estimate for the state is 304 bighorn sheep.

The largest herd is located in the Sierra Diablo Mountains in Hudspeth and Culberson Counties. Nine yearling rams and 1 ewe were released from the Sierra Diablo brood pen facility into this range in May, 1992. Seventy-one sheep were seen in the fall survey (ram:ewe:lamb:yearling ratio of 136:100:24:24), and this herd was estimated to number at least 181 animals and to have remained stable since 1991. During the fall survey 11 sheep were seen in the Van Horn herd (14:100:43:0), 24 sheep were seen in the Beach Mountain herd (111:100:100:0), and 17 sheep were seen in the Baylor herd (100:100:100:40). The Beach Mountain herd increased to an estimated 28 animals in 1992, while the Van Horn and Baylor herds remained stable at 25 and 17, respectively. Thirty-seven sheep were seen in the fall survey (60:100:20:5) in the herd located on the Elephant Mountain Wildlife Management Area in Brewster County. This herd increased to an estimated 45 animals in 1992, and several sightings of desert sheep were reported outside of the Wildlife Management Area. In addition, approximately 8 animals range in the Sierra Vieja in Presidio and Jeff Davis Counties.

Three captive herds are currently held in Texas. The largest is located in the brood pen facility at Sierra Diablo Wildlife Management Area north of Van Horn. As of April 1, 1993, this brood pen facility contained 9 mature rams, 31 breeding ewes, 9 yearling ewes, and 18 lambs born this year. Since 1984 the Sierra Diablo brood pen facility has produced 225 lambs, with 165 surviving through weaning age for an overall success of 73.3%. Seventy-seven rams and 35 ewes have been released from this facility with 10 ewes and 8 rams awaiting release in the spring of 1993.

Ten ewes and 2 yearling rams were removed from the Sierra Diablo brood pens in November, 1992, and placed in an 8 acre holding pen on the Beach Mountain Ranch in Culberson County. As of April 1, 1993, 10 lambs have been born in this enclosure, and all of these animals will be released in the late spring of 1993 to supplement the Beach Mountain herd. This will be the second and final release scheduled for these mountains. The third captive herd is in a brood pasture on the Chilicote Ranch in the Sierra Vieja. This herd consists of 5 rams, 9 ewes, and 6 yearlings. As of April 1, 1993, 1 lamb had been born in the enclosure.

Further stocking of the Sierra Diablo and reintroduction of sheep at Black Gap Wildlife Management Area are high priorities at this time. Actual stocking priorities will be evaluated when the source of sheep available for release is determined.

RESEARCH

The development of a feed ration specifically designed for the sheep held in the brood pens on Sierra Diablo is underway. Veterinary management and historical breeding records are also being compiled and evaluated to assist in the management of this facility. Texas A&M University is beginning embryo transfer research on captive bighorn sheep and 2 rams are currently being used to perfect semen collection procedures.

A long range plan for desert sheep management is being written to assist in making stocking priority and other management decisions. Evaluations of historic and potential sheep habitat are being con-

ducted utilizing a habitat suitability index that numerically classifies topography, vegetation, water, predators, exotics and existing land use. This is supplemented by a written evaluation indicating conditions not reflected in the numeric scale.

Currently there are no active research projects being conducted on free-ranging bighorn sheep in Texas. However, research to estimate the carrying capacity of habitats for desert sheep in Texas is being considered to improve the habitat suitability index included in the long range plan. This research will focus on the evaluation of forage availability and food habits of sheep in the mountain ranges surrounding Van Horn.

HABITAT IMPROVEMENTS

Prior to **1993,** Texas **Parks** and Wildlife and the Texas Bighorn Society have cooperated in the construction of **10** water sources for bighorn. Two additional guzzlers were constructed in **1993** in the

Victoria Canyon area of the Sierra Diablo Wildlife Management Area by the Texas Bighorn Society. A long range plan for development of water catchments has been completed.

HARVEST

One permit to hunt desert sheep was issued for **1992.** The hunt was successful on the first day and the Boone and Crockett "green" score of the harvested ram was **161⅞.** Since the first hunt in **1988,** the issuance of **6** permits has resulted in the harvest of 4 rams. Each permit issued has been for the Sierra Diablo herd with all of the harvested rams coming from Victoria Canyon. Boone and Crockett green scores of the harvested rams ranged from **153%** to **166%.** One of the rams harvested was from a public drawing permit, with the balance being from private landowner permits. Two private landowner permits have been issued for **1993** in the Sierra Diablo.
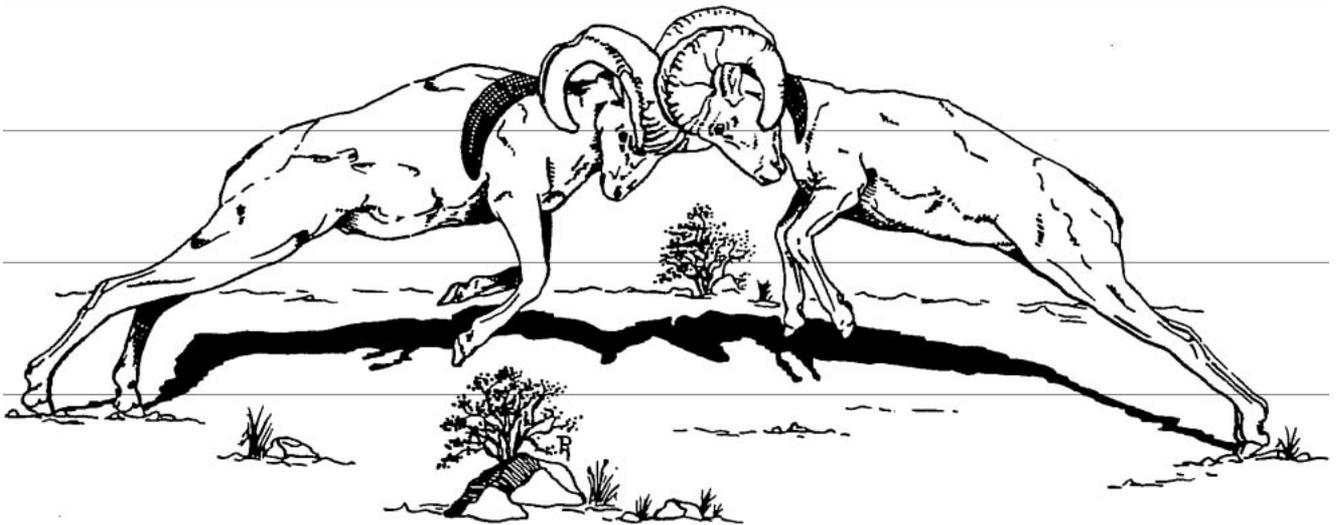
PROGRAM 37th ANNUAL MEETING
DESERT BIGHORN COUNCIL
MESQUITE, NEVADA, APRIL 7-8, 1993

WEDNESDAY, APRIL 7, 1993

8:30 CONVENE

8:40 KEYNOTE ADDRESS
William Molini, Director, Nevada Department of Wildlife

9:00 INTRODUCTION OF SESSIONS
Kathy Longshore, Program Chairman

STATUS REPORTS: Chair - *Rick Brigham*, Bureau of Land Management, Reno, NV

9:10 ARIZONA
Ray Lee, Arizona Game and Fish Department

9:30 CALIFORNIA
Steve Torres, California Department of Fish and Game

9:50 COLORADO
Tom Lytle, Colorado Division of Wildlife

10:40 NEVADA
Pat Cummings, Nevada Department of Wildlife

11:00 NEW MEXICO
Amy *Fisher,* New Mexico Department of Game and Fish

11:20 TEXAS
Gary *Calkins,* Texas Parks and Wildlife Department

11:40 UTAH
Jim Karpowitz, Utah Division of Wildlife Resources

TECHNICAL REPORTS: Chair - Steve Torres, California Department of Fish and Game, Sacramento, CA

1:30 A MORPHOMETRIC REEVALUATION OF THE PENINSULAR SUBSPECIES OF BIGHORN SHEEP IN CALIFORNIA
John D. Wehausen, University of California, White Mountain Research Station. Bishop, CA; *Rob* R. *Ramey 11,* Cornell University, Ithaca, NY

2:00 MITOCHONDRIAL DNA VARIATION, POPULATION STRUCTURE AND EVOLUTION OF MOUNTAIN SHEEP IN THE SOUTHWESTERN UNITED STATES AND MEXICO: IMPLICATIONS FOR CONSERVATION PROGRAMS
Rob R. Ramey 11, Cornell University, Ithaca, NY (Paper to be presented by *John Wehausen*)

PANEL DISCUSSION: Panel Moderator - *John Wehausen*, University of California, White Mountain Research Station, Bishop, CA;

3:00 PROPOSED LISTING OF PENINSULAR BIGHORN SHEEP UNDER THE FEDERAL ENDANGERED SPECIES ACT
Don Armentrout, Bureau of Land Management;
Walter Boyce, University of California, Davis;

Amy Fisher, New Mexico Department of Game and Fish;
Mark Jorgenson, Anza-Borrego Desert State Park;
Steve Torres, California Department of Fish and Game;
Roy Woodward, California Department of Fish and Game

THURSDAY, APRIL 8, 1993

TECHNICAL REPORTS: Chair - **Amy** *S. Fisher,* New Mexico Department of Game and Fish, Santa Fe, NM

8:30   THE DISTRIBUTION AND HOST ASSOCIATIONS OF *DERMACENTOR HUNTERI* (ACARI: IXODIDAE)
          Paul R. Crosbie, University of California, Davis, CA
9:00   ANZA BORREGO BIGHORN SHEEP POPULATION HEALTH STUDY
          Walter Boyce, University of California, Davis, CA; *David Jessup,* California Department of Fish and Game, Rancho Cordova, CA
9:30   FORAGE MEASUREMENTS: DO THEY TELL US ANYTHING ABOUT DESERT BIGHORN SHEEP?
          James A. *Bailey* and *Craig McCarty,* Colorado State University, Fort Collins, CO.

TECHNICAL REPORTS: Chair - *Don Ebert,* Department of Biological Sciences, University of Nevada, Las Vegas, NV

10:30   RESOLUTION OF LORAN-C FOR AERIAL TELEMETRY STUDIES
          Jef R. Jaeger, University of Nevada, Las Vegas, NV; *John D. Wehausen,* University of California White Mountain Research Station, Bishop, CA; *Vernon C. Bleich,* California Department of Fish and Game. Bishop, CA; *Charles L. Douglas,* University of Nevada, Las Vegas, NV
11:00   AN EVALUATION OF DESERT BIGHORN SHEEP IN SONORA, MEXICO.
          Raymond M. Lee, Arizona Game and Fish Department, Phoenix, AZ
11:30   SUMMARY OF PARTIAL HELICOPTER SURVEY AND BIGHORN CENSUS OF NORTHERN BAJA CALIFORNIA, MEXICO
          James R. DeForge, Bighorn Institute, Palm Desert, CA; *Stacey D. Ostermann,* Bighorn Institute, Palm Desert, CA; *Dale Toweill,* Advisor-Bighorn Institute (Idaho Department of Fish and Game); *Peter Cyrog,* Bighorn Institute. Palm Desert, CA

TECHNICAL REPORTS: Chair - *James A. Bailey,* Colorado State University, Fort Collins, CO

1:30   RESIDENTIAL HOMEOWNERS' SUPPORT OF MOUNTAIN SHEEP MANAGEMENT
          Lisa K. Harris and *William W. Shaw,* University of Arizona, Tucson, AZ
2:00   RESTORING BIGHORN SHEEP (*Ovis canadensis* spp.) IN NEVADA
          George K. *Tsukamoto,* Nevada Department of Wildlife, Reno, NV
2:30   BRINGING BIGHORN INTO THE CLASSROOM
          Stan C. Cunningham, Arizona Game and Fish Department, Phoenix, AZ

3:30   BUSINESS MEETING
5:00   ADJOURN
6:00   BANQUET AT THE PAVILION - hosted by Fraternity of the Desert Bighorn

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