DISTRIBUTION, MOVEMENTS, AND MORTALITY OF ROCKY MOUNTAIN BIGHORN SHEEP IN ARIZONA

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Abstract: Seventeen Rocky Mountain bighorn sheep were radio collared in two adjacent subpopulations in southeastern Arizona and monitored for 26 months to document distribution, degree of interchange, survey observation rate, and mortality. Marked sheep were located outside of their subpopulation only 4.2 percent of the time. However, sheep moved freely between two hunt units prompting a change in the hunt unit boundary. Five sheep also moved across the Arizona-New Mexico state line. Average annual mortality rate during the study was 5.5 percent. Blood samples revealed no vitamin or mineral deficiency but some exposure to epizootic hemorrhagic disease (6 of 7), blue tongue (4 of 7), and contagious ecthyma (2 of 5). Average observation rates of marked bighorns were 29 percent for rams and 81 percent for ewes for 2 years of October helicopter surveys. It appears that rams are not seen in the same proportion as they occur in the population.

Key Words: observation rate, *Ovis c. canadensis*, mining, mortality, Rocky Mountain bighorn sheep, telemetry.

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INTRODUCTION

In 1826, explorer James Ohio Pattie reported "multitudes" of bighorn sheep on the cliffs of the San Francisco River near it's confluence with the Gila River (Davis 1973). Like many other sheep populations in the Southwest, sheep along the San Francisco and Gila Rivers were extirpated around the turn of the century, probably as a result of the introduction of domestic livestock and unregulated market hunting.

In 1964, the New Mexico Department of Game and Fish released 10 (2M:8F) Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) from Banff National Park, Canada, into Turkey Creek, 27 km northeast of Glenwood, New Mexico. Six months later, 16 (3M:13F) additional sheep were released along Sheridan Ridge, about 11 km southeast of Glenwood, New Mexico. These sheep came from the Sandia Mountains in New Mexico, which had been stocked with sheep from Banff in 1939 and 1940 (Ogren 1957). Two additional rams from the Sandias were released at Frisco Hot Springs in July 1965. By 1967, the sheep released along Sheridan Ridge had moved into the side drainages of the San Francisco River, not far from the Arizona-New Mexico border (Larsen 1971).

The first postextirpation Rocky Mountain bighorn were reported in Arizona in 1971 on the upper Blue River and the San Francisco River near the Arizona-New Mexico border (Apache County News 1971).

In May 1979, the Arizona Game and Fish Department (AGFD) transplanted eight (2M:6F) Rocky Mountain bighorn sheep from Rocky Mountain National Park in Colorado to Bush Creek along the upper Blue River of eastern Arizona (Figure 1). Twelve (5M:7F) additional sheep from Colorado were released near Bush Creek the following March. Lambs were observed in the first year and the population expanded in both size and distribution over the next several years.

By the mid-1980s, sheep were seen along the length of the San Francisco River from the New Mexico border to the town of Clifton (Figure 1). Small numbers of sheep also began appearing along Eagle Creek, which joins the Gila River 4 km west of it's confluence with the San Francisco (Figure 1). The number of sheep observed along Eagle Creek steadily increased, allowing the issuance of one permit tag in 1984. No more than 65 sheep were observed during surveys prior to 1990; however, during the October 1994 survey, 136 sheep were observed along approximately 25 km of the creek (AGFD files). During this period, fewer sheep were being observed along the San Francisco River (from 113 in 1988 to 56 in 1994).

Presently, the Eagle Creek and San Francisco River drainages represent two distinct areas of sheep occurrence. Corridors of interchange between these two areas include along the Gila River, which connects them, or through the Phelps-Dodge Mine, which lies directly between the two drainages (Figure 1). It is not uncommon for sheep to be observed using the cliffs and talus slopes created by the mining activity. The Phelps-Dodge Mine is the world's largest copper mine.

The Eagle Creek and San Francisco River subpopulations are in different AGFD administrative regions and, except for 15 percent of the Eagle Creek drainage that is part of the San Francisco River area, are hunted separately.

Objectives of this study were to: 1) document the amount and frequency of interchange between the two subpopulations, 2) determine the frequency of interchange across the Arizona-New Mexico border, 3) determine mortality rates and causes, 4) sample sheep for vitamin and mineral deficiencies and exposure to common livestock diseases, and 5) estimate survey observation rates of sheep in this river canyon habitat type.

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STUDY AREA

The study area was located in Graham and Greenlee counties in southeastern Arizona along the Arizona-New Mexico border. The area lies within the Basin and Range Physiographic Province in the transition zone between the Sonoran and Chihuahuan biotic communities, resulting in a diverse association of flora and fauna (Bureau of Land Management 1994). Rainfall is highly variable. Average annual rainfall varies from 17.8 cm to 40.6 cm, with most falling in the late summer months (Bureau of Land Management 1991).

The study area encompassed the Gila, Blue, and San Francisco rivers and Eagle Creek. These drainages are perennial and subject to periodic "scouring" during high rainfall events. The cliffs along these drainages are comprised of sedimentary, basalt, or volcanic tuft material and provide ideal escape cover for bighorn sheep (Bureau of Land Management 1993). Many cliffs along the Gila River rose over 300 m above the river. Elevation ranged from 1025 m at the confluence of the San Francisco and Gila rivers to 2374 m above the upper Blue River.

METHODS

Eight sheep (2M:6F) along Eagle Creek and nine sheep (3M:6F) along the San Francisco River, from the town of Clifton to the New Mexico border, were captured and radio-collared October 26-27, 1992, in 7.5 hours of helicopter time. Each animal was marked in the right ear with a numbered, red duflex tag. Ages ranged from 1 to 6 years. Biweekly telemetry flights from November 1992 to January 1995 yielded 620 telemetry locations.

Latitude/longitude coordinates determined from telemetry locations were recorded using a Global Positioning System (GPS) and then entered into a Geographic Information System (GIS). Distribution and home range for all marked sheep were analyzed with GIS. Each collared sheep yielded a sample of that individual's range. We also calculated occurrence of sheep outside the subpopulation it was captured in and movements into New Mexico.

Population surveys were conducted by helicopter each October. The entire study area was flown in 4 or 5 days each year. The rate of helicopter coverage averaged approximately 21 km^2 per hour.

Telemetry flights were conducted prior to or immediately following annual helicopter surveys in October to determine which radio-collared sheep were in the area surveyed and thus available to be sighted.

Mortality rates were determined using MICROMORT, a software package which calculates cause-specific and seasonal mortality rates based on radio-days gathered from telemetered animals (Heisey 1985, Heisey and Fuller 1985).

Blood samples were taken from each animal. Sera for serological studies was drawn and heparinized for vitamin and mineral analysis. Clots were sent to Montana for DNA analysis. Serum samples were tested for exposure to blue tongue (BT), epizootic hemorrhagic disease (EHD), contagious ecthyma (CE), infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD), bovine respiratory syncytial virus (BRSV), and brucellosis.

RESULTS

Sheep captured in one subpopulation (Eagle Creek or San Francisco River) generally stayed in that area. Of the 321 locations of the eight Eagle Creek sheep, only four (1.3 percent) locations (from two of the sheep) were in the San Francisco River drainage. Of the nine sheep radio-collared along the San Francisco, six were located at least once in Eagle Creek, but only 22 of 299 (7.4 percent) locations of San Francisco sheep occurred in Eagle Creek. Overall, marked sheep (n=17) were located outside their subpopulation of capture only 4.2 percent of the time.

Some sheep captured in Eagle Creek moved between the two portions of that drainage that were in different hunt areas. All eight sheep captured in Eagle Creek moved back and forth across the boundary between Game Management Units 27 and 28, which are hunted as separate populations. All eight sheep were captured in the Unit 28 portion of Eagle Creek, but 14 percent of the locations were in the Unit 27 portion.

Six marked sheep were located within the perimeter of the mine. Forty-five locations (7.3 percent) occurred within the mine perimeter, with half of these locations being of a single 6-year-old ewe.

Five of nine sheep captured along the San Francisco River were located across the state line in New Mexico. Three ewes (#12, #15, and #17) captured on the San Francisco River were located at least once near Glenwood, New Mexico, approximately 32 river km into New Mexico between November 14 and April 20. The other two sheep making interstate movements were never located further than 6.4 km from the Arizona-New Mexico border. The longest distance between two locations recorded during the study was 52.8 km for a 5-year-old ram.

The limited number of radio-collared individuals precluded a detailed analysis of sex-specific, cause-specific, and seasonal mortality rates. The average annual mortality rate for all marked sheep was 5.5 percent during the study. Only two mortalities, a 5-year-old ewe from Eagle Creek (cause of death unknown) and a 3-year-old ram from the San Francisco River (killed by a mountain lion - *Felis concolor*), were recorded in 12,876 radio days.

Eight blood samples were taken at capture and tested for vitamin and mineral deficiencies and disease titers. Vitamin levels were very good. Serum copper (Cu) and whole blood selenium (Se) showed considerable individual variation but were all within the levels reported for domestic animals (Table 1). Positive exposure to BT (4 of 7 samples), EHD (6 of 7), and CE (at least 2 of 5) was detected (Table 2). Serum neutralization tests for IBR, BVD, and BRSV, as well as the Brucella plate test, were all negative.

Estimates of animals seen during annual October helicopter surveys ranged from 73 percent to 90 percent for ewes and 25 percent to 33 percent for rams (Table 3). During the 1993 surveys, average size of ewe groups was 5.7, while ram groups averaged 2.2 (AGFD files). Observation rates for all sheep were 73 percent and 64 percent in 1993 and 1994, respectively.

DISCUSSION

Early observations of Rocky Mountain bighorn sheep in Arizona indicate that the sheep now in the Eagle Creek and the San Francisco River areas are descendants of sheep transplanted into both New Mexico and Arizona. Five of nine sheep that were radio-collared in the upper reaches of the San Francisco moved freely across the Arizona-New Mexico border. Once in Arizona, whether by transplant or immigration, the sheep population increased. The high lamb production and low natural mortality undoubtedly enabled Rocky Mountain bighorns to expand in both abundance and distribution.

In the mid-1980s, sheep undoubtedly from the San Francisco River population became established in the Eagle Creek drainage. As the Eagle Creek population continued to increase in abundance, the population along the San Francisco appeared to decrease.

The number of lambs in October has always been consistently high in the Eagle Creek subpopulation, averaging 53 lambs:100 ewes from 1989 through 1994. The relatively high reproduction and low mortality suggests that much of the recent increase in the Eagle Creek subpopulation is due to a positive recruitment:mortality ratio rather than to immigration. Trends in survey data show that this subpopulation continues to increase and sheep are now being found in areas they did not previously use, such as along the Gila River.

The small amount of sheep movement from the San Francisco River to Eagle Creek does not exclude the possibility that this rate is lower now than during past immigration. The movement rate of sheep from Eagle Creek to the San Francisco River was only 1.3 percent during this study.

A small portion of Eagle Creek was in both Game Management Units 27 and 28, which were hunted separately. Telemetry locations from this study showed sheep in Eagle Creek freely moved across this boundary, resulting in the possibility that a hunter with a tag for sheep surveyed along the San Fran-

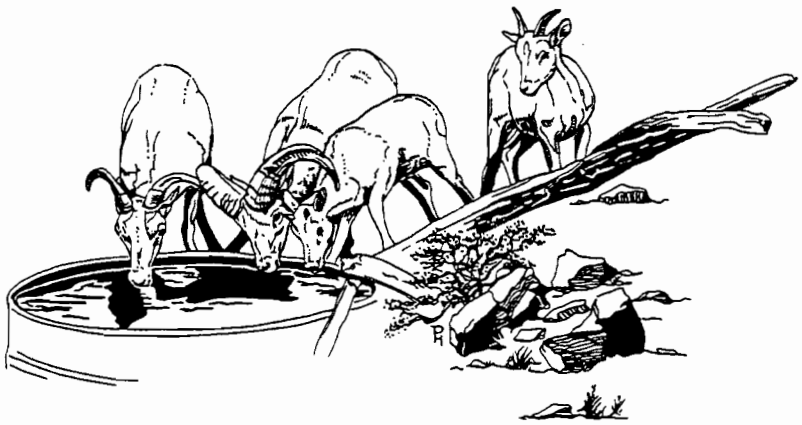
cisco would harvest a ram out of the Eagle Creek population by hunting that small portion that is in Game Management Unit 27. The boundary between the two hunt areas was redefined to better divide the subpopulations. The new boundary includes only 1.2 percent of the Eagle Creek telemetry locations, as opposed to 14 percent with the old boundary.

One ewe was located consistently on the Phelps-Dodge mine property. Six of 17 instrumented sheep were located at least once within the perimeter of the mine. The main mining operations are located on uplands which separate Eagle Creek and the San Francisco River. As a result, it is unclear whether the mine represents a barrier to movement among the subpopulations. Sheep from both subpopulations occasionally frequented the mine, but rarely moved through to the other drainage. These two areas of high sheep use are canyon-rimmed, riparian corridors and as such there may not be a high degree of natural interchange, even in the absence of the mine, because of a strong affinity to one drainage or the other.

Three sheep from the San Francisco River population were also located near the confluence of the Gila and Eagle Creek; some in the company of Eagle Creek sheep. Movements such as these may be inhibited by the presence of the town of Clifton, which the San Francisco River flows through (Figure 1). The small degree of interchange, along with this interaction around the mine and Gila River, should be enough to maintain the exchange of genetic material between sheep in this metapopulation.

No abnormally high mineral levels were detected in the blood samples analyzed. However, none of the animals sampled spent a considerable amount of time in the mine after they were radio-collared, indicating their normal core use area did not include the mine.

Rams appear to be observed in a lower proportion than their occurrence in the population. These observation rates of rams are consistent with information collected in populations of desert bighorn sheep (*O. c. mexicana*) (AGFD Files). The observation rate of ewes is higher than estimates obtained in other habitat types commonly used by bighorn sheep in Arizona (AGFD Files). Habitat segregation and group size doubtless accounts for much of the difference in observation rates. The concentration of ewes and lambs along the river results in a higher proportion of animals seen than in populations associated with more extensive and homogenous terrain. Rams frequently occupy the gentler uplands adjacent to these river systems, while ewes and their lambs show a higher fidelity to the cliffs directly above the stream bed. Also, rams generally occur in smaller groups or singly and ungulate group size has been shown to influence sightability (Samuel et al. 1987).



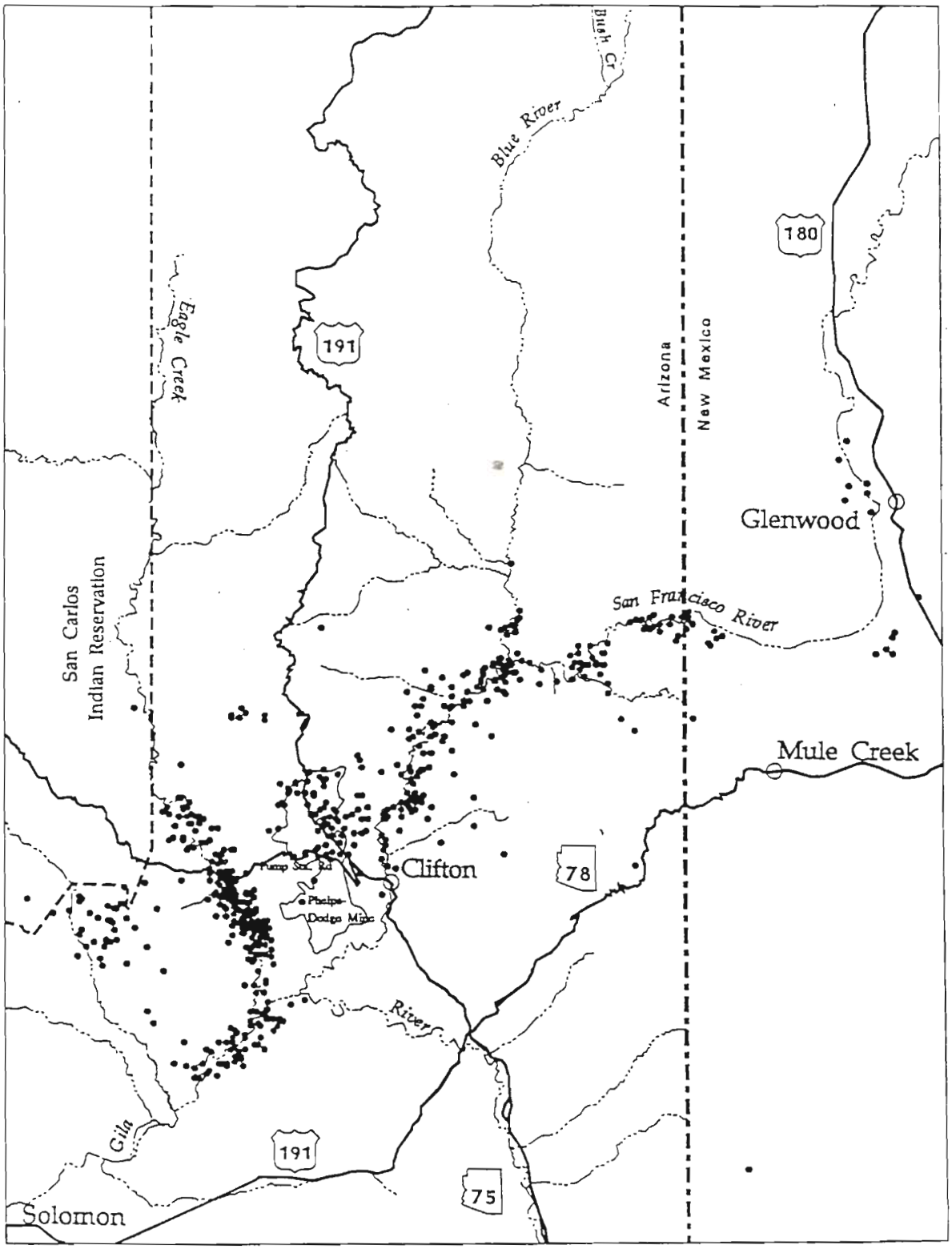


Figure 1. *Distribution of Rocky Mountain bighorn sheep along the San Francisco, Blue, and Gila Rivers and Eagle Creek, southeastern Arizona.*

Table 1. *Blood/serum mineral and vitamin values for 17 Rocky Mountain bighorn sheep captured in south eastern Arizona, 1992.*

Animal ID	Serum Vit. A (ug/ml)	Serum Vit. E (ug/ml)	Serum Cu (ppm)	Whole blood Se (ppm)
1	0.93	11.5	0.57	0.23
2	0.60	10.0	1.65	0.18
3	1.24	16.2	0.84	0.15
4	0.87	13.2	0.75	0.15
8	1.07	13.7	0.72	IS[a]
10	0.56	7.3	1.11	0.28
12	IS[a]	IS[a]	0.81	IS[a]
18	1.07	11.2	0.72	0.24

[a]Insufficient Sample

Table 2. *Occurrence of blue tongue (BT), epizootic hemorrhagic disease (EHD), and contagious ecthyma (CE) in Rocky Mountain bighorn sheep captured in southeastern Arizona, 1992.*

Animal ID	BT (AGID)	EHD (AGID)	CE (CF)
1	POS	POS	NS[a]
2	NEG	POS	POS 1:5[b]
3	NEG	NEG	NEG
4	NEG	POS	POS 1:5
8	POS	POS	NEG
10	POS	POS	AC[a]
18	POS	POS	NEG

[a]NS = Non specific, AC = anticomplementary (Exposure could not be determined).
[b]Complement Fixation (CF) titers of 1:5 are considered suspicious of previous exposure.

Table 3. *Observation rates of Rocky Mountain bighorn sheep during helicopter surveys, Eagle Creek and San Francisco River drainages, October 1993-94.*

Year	Number available to be observed			Number actually observed			Percent observed		
	F	M	ALL	F	M	ALL	F	M	ALL
1993	11	4	15	10	1	11	90	25	73
1994	11	3	14	8	1	9	73	33	64

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