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BIGHORN SHEEP RESPONSE TO EPHEMERAL HABITAT FRAGMENTATION BY CATTLE

J. A. Bissonette and Melanie J. Steinkamp

ABSTRACT.—We studied seasonal cattle grazing as an agent of ephemeral habitat fragmentation on a newly reintroduced population of California bighorn sheep (Ovis canadensis california) in Big Cottonwood Canyon, Idaho, 1988–99. We evaluated the hypothesis that bighorn sheep avoid cattle. We documented sheep response to the proximity to cattle by direct observation. The core areas used by bighorn and distances to escape terrain generally decreased as cattle moved closer to sheep. Likewise, sheep moved from cattle as cattle approached them. Severity of response we observed is in marked contrast with that reported for established bighorn populations, suggesting that newly reintroduced bighorn sheep are more highly sensitive to the presence of cattle.

Key words: bighorn sheep, cattle, disturbance, Idaho, Ovis canadensis.

Prior to the 20th century, California bighorn sheep were abundant in montane regions of the western United States (Van Dyke et al. 1986). However, since 1840 population numbers of bighorn sheep and their area of distribution have decreased (Cowan 1940, Buechner 1960). Disease, excessive hunting, activities associated with mining, human disturbance, and pressure from livestock for resources and space reportedly contributed to the extirpation of the subspecies from most of its range (Smith 1954, Geist 1971, Graham 1971, Demarchi and Mitchell 1973, Demarchi 1975, Trefethan 1975, Van Dyke 1978, Smith et al. 1988).

California bighorn sheep were once abundant in parts of southwestern Idaho; the last observations were recorded during the 1920s (Hanna 1978). The Idaho Department of Fish and Game (IFG) initiated reintroduction programs of returning California bighorn to parts of their historic range in 1963. Thirty-eight sheep from the Chilcotin River herd in British Columbia were transplanted into the drainages of the East Fork of the Owyhee River between 1963 and 1966 and have provided a base for subsequent reintroductions. In 1967, 12 additional bighorn were reintroduced into the nearby Little Jack’s Creek drainage. Both populations were allowed to expand until 1980 (Towell 1985). From 1980 to 1989, >100 sheep were relocated to 5 different regions in southern Idaho.

Livestock pressures have been heavy on rangelands in the western United States that historically supported populations of bighorn sheep (Mackie 1978). Seventy percent of the public land area in the 11 westernmost states is grazed at least seasonally. Within Idaho rangeland conditions varied. In 1986 surveys from the Owyhee range in Idaho reported 57% of the range in poor condition, 35% fair, and only 5% in good condition (Bureau of Land Management, Owyhee rangeland program summary, Burley District, ID, files, 16 pp., 1986); while in 1982, 30% of the range was in poor condition, 57% fair, and 18% in good condition (Bureau of Land Management, Twin Falls, land use decisions summary and rangeland program summary, Burley District, ID, files, 26 pp., 1982). Peiper (1988) reported that improvement in range condition has been slow since 1973.

Bighorn sheep are more sensitive to land uses associated with development than most native ungulates (Andryk and Irby 1986). Additionally, bighorn sheep are comparatively less abundant, react adversely to disturbance, and occupy habitats sensitive to change (Van Dyke et al. 1986). Livestock activities on these sites can negatively affect sheep through resource exploitation (i.e., forage, space, cover, water) or behaviorally (Geist 1971). On shared ranges social intolerance may impose greater limitations on distribution and habitat use of bighorn.
than competition for forage; however, biologists disagree whether livestock impact bighorn sheep spatial boundaries, limiting distribution. Wilson (1975) and Van Dyke et al. (1986) reported that bighorn show aversions to cattle and avoid them when unaccustomed to their presence on the range (Drewek 1970, Kornet 1978), while others did not detect reactions between sheep and cattle (King 1985, King and Workman 1985). Analyses that test the avoidance of livestock by bighorn sheep are limited.

Habitat fragmentation theory has application to seasonal livestock grazing. Habitat fragmentation may be permanent (e.g., subdivision construction) or ephemeral, as in seasonal livestock grazing. Effects of permanent fragmentation on habitat use have received increasing attention in recent years; however, less is understood about effects of seasonal fragmentation. We postulated that areas used by bighorn sheep are fragmented during spring and summer by cattle on grazing allotments. An area may appear large but, due to fragmentation, have a much smaller useable area. If bighorn sheep avoid livestock, the area available to them is reduced temporarily as livestock graze seasonally in sheep habitat, resulting in sheep exclusion from areas of potential use. A population may be influenced as sheep are restricted to smaller patches of habitat and effects of density dependence are felt. In our study we wanted to determine whether avoidance occurs, assess its effect on habitat use by sheep, and consider how avoidance, if it occurs, might influence future decisions for reintroductions.

STUDY AREA

We conducted the study in Big Cottonwood Canyon 16 km northwest of Oakley (Cassia Co.), Idaho. The canyon is approximately 18 km long, with Cottonwood Creek flowing to the northeast through the canyon bottom. Elevation of the canyon floor increases gradually from 1400 to 2100 m. Average elevation gain from the canyon floor to the mesa top is 365 m. Canyon walls are steep and characterized by a combination of cliffs, boulder slopes, grass, and shrub slopes. Woody vegetation includes four-wing salt brush (Atriplex canescens), spiny hopsage (Grayia spinosa), low sage (Artemisia arbuscula), horse brush (Tetradymia canescens), rabbit brush (Chrysothamnus nauseosus), blue-bunch wheatgrass (Agropyron spicatum), and juniper (Juniperus occidentalis).

Big Cottonwood Canyon lies within the Sawtooth National Forest and contains a cattle grazing allotment that is leased from late May until early October. This grazing allotment consists of 5 pastures managed on a reverse-rotation basis and supports 400 cows with calves. Mesas south of the canyon contain another allotment of 3 pastures; this allotment is managed on a deferred-rotational system with 100 cows with calves. Permit dates for the Big Hollow allotment are late May to late October.

METHODS

Thirty-seven California bighorn sheep (19 with radio-collars, 18 with pattern-coded collars) were released into Big Cottonwood Canyon by the Idaho Department of Fish and Game during December 1986, December 1987, and November 1988. Collars marked with different designs in permanent ink allowed us to distinguish between non-transmittered individuals. The population at the beginning of our 1st summer field season (1988) was 23, 13 from the 1st reintroduction in 1986 and 10 from the 2nd in 1987. Fourteen additional sheep were released in November 1988.

We recorded daily locations of bighorn sheep by visual observation from May to September 1988 and June to September 1989. Telemetry was used only to aid in locating radio-collared bighorn sheep. We conducted weekly visual surveys to locate any uncollared sheep not close to collared individuals. Sheep were viewed from ≥500 m using a spotting scope to reduce chance of detection and disturbance. If we were detected and sheep movement followed, we disregarded subsequent observations of those individuals for the remainder of the day. Every effort was made to identify individuals within groups. We determined individuals by collar design or by telemetry frequency. Locations were recorded in Universal Transverse Mercator (UTM) coordinates. For each location we recorded group size and composition.

We defined escape terrain as broken habitat on which mountain sheep may safely outmaneuver or outdistance predators (Gionfriddo and Krausman 1985). Specifically, escape terrain may be characterized by a ruggedness index as defined by Beasom et al. (1983), and terrain class and number of cliff faces >120%
following Krausman and Leopold (1986). For every location we measured distance to escape terrain using a range finder once sheep left the area. We determined slope with a clinometer. We located cattle by hiking a systematic route on foot 3–4 times/wk. With the exception of group composition, data recorded for each cattle location were identical to sheep locations. We recorded cattle and sheep locations simultaneously allowing sheep movements to be analyzed in response to cattle movement for that specific time. Data not taken during identical time periods were not used in paired analyses.

Even though a controlled test was not possible, we wanted to observe the response of sheep when livestock were in proximity to sheep. On 14 August 1989, 5 cows were moved directly into an area of continuous sheep use and held continuously for 40 h. Cattle were kept within approximately a 0.8-km² area by 2 cowboys. Sheep response was observed and recorded. Cattle were watered every 5 h by removing them from the group one at a time and taking them to a trough in the bordering pasture. After 40 h all cattle were removed. We located sheep daily for the next 10 d.

We combined individual bighorn sheep locations for each group for analysis with Program Home Range (Samuel et al. 1985); thus, each location represented a group of bighorn sheep, not an individual. We used 95% harmonic mean measures of activity to estimate home ranges and core areas. We defined core areas as the maximum area where the observed utilization distribution as determined from the harmonic mean values was greater than a uniform utilization distribution (Samuel et al. 1985). Kolmogorov’s test was used to determine if observed use was significantly (P ≤ 0.05) greater than expected. All comparisons were considered significant at the 0.05 level. All data points were plotted at a scale of 1:12,000.

We recognize that harmonic mean measures have been criticized. Naef-Daenzer (1993) tested the spatial resolution of the conventional harmonic mean measure and a bivariate normal kernel estimator with a new kernel estimator he developed. The harmonic mean estimator generalized the distributions of 2 parallel gradients and estimated density at higher than zero for areas containing no sample points. Worton (1989, 1995) and Boulanger and White (1990) have outlined some undesirable properties of harmonic mean measures that were eliminated from kernel estimators using appropriate smoothing techniques. Specifically, with the harmonic measure, estimates of zero area can occur, and isopleths may include areas with no sample points (Worton 1995). We had no estimates of home range or core areas that approached or even came close to zero. Additionally, the isopleths we generated were based on tightly grouped locations of sheep, thus avoiding the problem of areas with no sample points. Finally, we did not employ interstudy comparisons, thus avoiding the onerous problem of comparing between methods, thereby reducing the effect of inherent bias.

We plotted mean monthly home ranges and core areas of sheep and cattle and then overlaid them to determine changes in size and location between consecutive months. We measured avoidance by quantifying changes in size and location of bighorn sheep range and core areas as cattle moved through bighorn sheep habitat. Changes in location were determined from harmonic means. We compared data collected during the 1st and 2nd field seasons to determine whether range and core areas were related to seasonal changes.

We calculated daily distances between bighorn sheep and cattle using UTM location coordinates. We defined consecutive locations as locations taken 1 d apart. Only cattle and bighorn sheep paired locations recorded at the same time were analyzed. Simple linear regressions were used to test for associations between 3 variables: distance (m) between cattle and bighorn, distance sheep moved in response, and distance from location of sheep to escape terrain. First, we tested sheep response to proximity of cattle; then we tested to determine whether distance between sheep and escape terrain was related to proximity of cattle.

**RESULTS**

**Response of Bighorn Sheep to Cattle**

Sheep range size did not change significantly in size or location (P < 0.05) from June to July in 1988 or 1989. Cattle were in adjacent pastures but because of topography were usually not visible to sheep or the observers. During August 1988, when cattle were moved to an allotment adjacent to areas receiving high sheep use, home range position shifted and range size decreased (Table 1). In September sheep expanded their range, coincident with
**TABLE 1. Spatial responses of bighorn sheep in Little Cottonwood Canyon, Idaho, to the proximity of cattle.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Range size (km²)</th>
<th>Core area Mean distance (m)</th>
<th>Core area Size</th>
<th>Core area % use</th>
<th>Core area % area²</th>
<th>Mean distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/88</td>
<td>13.4</td>
<td>4.3</td>
<td>61.4</td>
<td>32.1</td>
<td>0.5</td>
<td>4019</td>
</tr>
<tr>
<td>7/88</td>
<td>13.7</td>
<td>4.7</td>
<td>53.9</td>
<td>27.3</td>
<td>0.3</td>
<td>4045</td>
</tr>
<tr>
<td>8/88</td>
<td>5.0</td>
<td>1.5</td>
<td>59.0</td>
<td>42.9</td>
<td>0.5</td>
<td>2251</td>
</tr>
<tr>
<td>6/89</td>
<td>13.4</td>
<td>4.7</td>
<td>57.5</td>
<td>40.0</td>
<td>0.3</td>
<td>4820</td>
</tr>
<tr>
<td>7/89</td>
<td>13.5</td>
<td>1.5</td>
<td>67.0</td>
<td>40.0</td>
<td>0.3</td>
<td>5148</td>
</tr>
<tr>
<td>8/89</td>
<td>7.2</td>
<td>0.3</td>
<td>55.6</td>
<td>40.0</td>
<td>0.3</td>
<td>3246</td>
</tr>
</tbody>
</table>

1. Percent of total home range area that core area encompasses
2. Mean distance between cattle and bighorn
3. Mean distance of sheep to escape terrain
4. Sheep density
5. Mean daily distance sheep moved during the month
6. Cattle placed in allotments close to sheep
7. Field experiment data

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the movement of cattle during late August into a pasture adjacent to a high use sheep area. Sheep tended to concentrate into smaller core areas in 1988 and 1989 as proximity to cattle decreased.

No significant change (<3%) in core area of bighorn sheep occurred between July and August 1989 prior to moving cattle close to bighorn. When cattle were moved purposefully to within 800 m, bighorn sheep responded by immediately vacating the area and creating a new distinct core area. Distances moved by bighorn sheep directly after movement of cattle into the sheep core area were 355% greater than daily sheep movements during early August (3000 vs. 845 m, respectively). Sheep remained together and stayed within 35 m of escape terrain for the following 9 d. This was the longest time period during the study that sheep remained within 35 m of escape terrain. Distances between cattle and bighorn sheep remained >4000 m for the following 5 d.

**Response of Bighorn Sheep Relative to Escape Terrain**

As mean daily distance between cattle and sheep decreased, the mean distance between sheep and escape terrain tended to decrease. Core-area size appeared to be directly related adjusted $r^2 = 0.81$ to distance to escape terrain (Fig. 1); the closer to escape terrain, the tighter sheep grouped together. A correlation matrix, generated from these spatial data, adds further corroboration for the association (Table 2). The mean daily distance that bighorn moved during the month was positively correlated with increasing distance of sheep to escape terrain.

**DISCUSSION**

Hicks and Elder (1979) suggested that bighorn sheep were more likely to move greater distances when cattle were close, but were less likely to relocate when cattle were distant. Our data show increased movement by bighorn sheep as cattle moved closer. When we moved cattle to within 800 m, bighorn left the area. Sheep response to cattle was much more extreme than at any other time or when compared to their behavior when confronted by humans at other times during the field season. We were unable to differentiate between the effect that cattle had and the potential effect of the personnel involved. We do not doubt that personnel moving the cattle had an effect. Furthermore, the presence of both cattle and personnel close to sheep may well have augmented bighorn response nonlinearly. However, at other times when we accidentally alerted sheep during the study ($n = 10$), bighorn responded by relocating much shorter distances (between 872 and 1190 m). Additionally, their response was typically short-lived and they left the proximity of escape cover by the next day or sooner.

Although both the proximity of cattle and personnel influenced bighorn response, the important point is that extreme proximity evoked a highly charged response. Even without our intentional movement of cattle toward sheep, their increasing affinity for escape cover as cattle moved closer suggests strongly that livestock were perceived as a threat.

Escape terrain is an important component of good sheep habitat (McQuivey 1978, Leslie and Douglas 1979, Weyhausen 1980, Krausman and Leopold 1986). We would have predicted
that tighter grouping should result as sheep moved farther from escape cover. However, our data show the direct opposite result, suggesting that when sheep move farther from escape terrain, they do so under less threatening situations. Selective pressures under these conditions appear not to result in tighter groups.

The response of bighorn sheep to cattle we observed is in contrast with bighorn sheep in national parks. In some parks sheep approached humans closely and were photographed from car windows (Van Dyke et al. 1986). Smith (1954) reported sheep eating from his hand, whereas others reported that sheep unaccustomed to people or cattle fled at the sight of humans or vehicles > 1600 m (Van Dyke et al. 1985). It appears that newly reintroduced sheep are more sensitive to disturbance, perhaps resulting from recent transplant activities, and react differently than do established, undisturbed populations. Sheep reintroduced into Big Cottonwood Canyon were net-gunned from helicopters, blindfolded, and flown to a base. They then had blood drawn, were given inoculations, weighed, measured, placed into the back of a covered pickup with several conspecifics, and then transported approximately 160 km and kept overnight in the vehicles. All were released the following morning into an area foreign to them. As a result of exposure to such activities, any disturbance may more likely be viewed as a threat. In the Big Cottonwood Canyon population, alert-alarm behavior appears to be reinforced yearly with each new group of reintroduced animals. Age may also play a part; 55% of individuals released were < 2 years of age. Heightened sensitivity and subsequent frequent reinforcement of alert behaviors appear to characterize the population and may be a general phenomenon for newly reintroduced populations placed into new areas. Sensitivity of these populations to disturbance may diminish over time as populations become established.

Avoidance has implications for reintroductions of bighorn sheep. The total area of potential habitat may not be used by sheep if livestock are present. If cattle allotments remain in use, it would appear wise to consider the possibility of ephemeral fragmentation by cattle when goals for desired bighorn population sizes are developed. Goals should be consistent with total useable habitat. Control of disturbance for recently reintroduced populations of bighorn sheep is certainly appropriate.

### Table 2. Correlation matrix for home range, core area, and mean distance variables for bighorn sheep in Big Cottonwood Canyon, Idaho, 1988–89.

<table>
<thead>
<tr>
<th></th>
<th>Core area</th>
<th>Mean distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range size</td>
<td>Size</td>
<td>% use</td>
</tr>
<tr>
<td>Range size</td>
<td>1.0</td>
<td>0.694</td>
</tr>
<tr>
<td>Size</td>
<td>1.0</td>
<td>-0.380</td>
</tr>
<tr>
<td>% use</td>
<td>1.0</td>
<td>0.035</td>
</tr>
<tr>
<td>% area</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>c-s</td>
<td>1.0</td>
<td>0.520</td>
</tr>
<tr>
<td>e-t</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Percent of total home range area that core area encompasses

Mean distance between cattle and bighorn

Mean distance of sheep to escape terrain
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LITERATURE CITED


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