Validation Of A Helicopter Sightability Model For Bighorn Sheep

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Abstract: We surveyed the bighorn sheep population at Leslie Gulch, Oregon (W117^o 16', N43^o 20') to obtain an estimate of population size and to begin validation of the Idaho sightability model developed by Bodie et al. (1995) and subsequently employed by the Idaho Department of Fish and Game, 1996-2000. There were approximately 150 bighorn sheep including 33 radiocollared ewes in the surveyed herd. This herd had not been surveyed using the techniques described by Bodie et al. (1995). The survey area was partitioned into sampling units prior to the survey, and each unit was stratified as having a "high-" or "low-" probability of bighorn sheep occurrence in an effort to partition sample variability (Bodie et al 1995). We surveyed all sampling units in strata with high-probability of bighorn sheep occurrence, and 10 of 38 units in strata with "low" probability of occurrence. We relocated radiocollared bighorns from a fixed-wing aircraft before and after the helicopter survey. Radio-equipped bighorn sheep located before the survey moved 1.2 $\pm$ 0.85 km prior to being observed from the helicopter. However, probability of locating radio-equipped bighorns was 66%, consistent with the Idaho model (Bodie et al. 1995) despite differences in bighorn sheep habitat components and arrangement. The Idaho model, developed in canyon-and-range habitats, appears robust relative to the steep hills and rocky faces of the Leslie Gulch study area. Distance traveled by many of the radio-equipped bighorn ewes prior to being located by helicopter-based observers is of continuing concern, because bighorns may avoid being included in helicopter surveys.

Key words: Aerial survey, bighorn sheep, helicopter, Idaho, *Ovis canadensis*, population estimates, sightability, visibility bias.

The Idaho sightability model (Bodie et al. 1995) was developed to estimate the number of California bighorn sheep in the canyonlands of southwestern Idaho. This sightability model assigns a statistical probability of observation to bighorn sheep based on activity and habitat. Model assumptions are: (1) the population is demographically closed during the survey, (2) no animals are counted more than once, (3) survey techniques and weather conditions are the same as those used to develop the model, and (4) bighorn sheep behavior is the same as the behavior of bighorns used to develop the model (Bodie et al. 1995). Concerns about the validity of model assumptions (particularly assumption 4) have increased in recent years, at least in part due to declines in bighorn sheep population estimates despite a lack of other data to indicate reasons for a general population decline. Some biologists suspect that bighorn sheep are learning to avoid being counted during helicopter surveys.

Bodie et al. (1995) pointed out that the Idaho sightability model was not validated by surveying bighorn populations of known size in comparable habitats. We used the Idaho model to estimate bighorn sheep numbers in the Lower Owyhee River population wherein approximately

25% of the sheep were radiocollared. This bighorn sheep population had a long history of being exposed to helicopters. Recent helicopter activities included net-gun captures and annual counts. In January, 15 ewes were captured in the Santa Rosa Mountains of Nevada then collared and released at Leslie Gulch. In addition, 18 ewes in the resident Leslie Gulch population were captured and collared. All were captured with helicopter net-gun procedures following Oregon Department of Fish and Wildlife (ODFW) animal handling and welfare protocols. Helicopter counts had been conducted at Leslie Gulch annually since 1981; the most recent count before the July survey was in March. The annual helicopter counts were part of a general big game survey and did not follow the Idaho sightability technique methods.

STUDY AREA

The 2,518 ha Leslie Gulch study area, in Malheur County, Oregon (Fig. 1), extended north from Mahogany Mountain to Sheephead Basin, and east from Owyhee Reservoir to Grassy Ridge. It constituted the entire range of Oregon's Lower Owyhee River herd of bighorn sheep (see map *in* Toweill and Geist 1999). This herd of California bighorn sheep was re-established in previously occupied habitat via transplants beginning in 1965. The Lower Owyhee River bighorn sheep population was believed demographically closed and relatively stable.

The area is within the Shrub-Steppe Province and Desert Shrub Zone (Frenkel 1976). Vegetation was similar to vegetation in southwestern Idaho. Dominant vegetation included bluebunch wheatgrass (*Pseudoroegneria spicata*), sagebrush (*Artemisia tridentata wyomingensis* and *A. t. tridentata*) and western juniper (*Juniperus occidentalis*).

Elevation ranged from 814 m at Owyhee Reservoir to 1,710 m near Mahogany Mountain. Topography consisted of steep hills with rocky outcrops, different from the rocky canyons and wide plateaus where the Idaho model was developed (Bodie et al. 1995). The patchy rough terrain in Oregon contrasts with continuous canyons in Idaho. Both areas had abundant caves and crevices.

Geology of the Leslie Gulch area is dissected late Miocene tuffs overlain by 2 layers of consolidated volcanic rhyolitic ash deposited during eruptions of the Mahogany Mountain and 3 Fingers calderas about 15.5 million years ago (Baldwin 1964). Much of the volcanic material fell as fine ash intermingled with rock fragments, forming layers as much as 1,000 feet thick. The present steep slopes, cliffs and honeycombed rock towers have resulted from subsequent erosion and chemical weathering. Less-resistant ash has weathered away leaving numerous caves, rock overhangs and crevices that provide excellent shelter for bighorn sheep attempting to hide from aerial disturbance.

The climate of the study area includes hot summers and cold winters in an arid regime (Lahey 1976). Mean maximum temperature in July was 32 ^{o}C; maximum summer temperatures averaged 40 ^{o}C (Lahey 1976). Extreme summer temperatures may reach 49 ^{o}C within canyonlands near Owyhee reservoir. Winter temperatures typically range from -18 to 4 ^{o}C. Precipitation during summer (July-August) averages about 2.5 cm; winter precipitation (December-February) averages 10 cm (Lahey 1976). Total annual precipitation rarely exceeds 20-25 cm.

METHODS

We divided the study area into 54 counting blocks of 40.0 $\pm$ 21.4 ha each. Boundaries followed draws, flats, roads, or the reservoir edge, places bighorn sheep were less likely to cross undetected. We pre-assigned each block to either high-probability or low-probability of bighorn occurrence, based on habitat and knowledge of prior distribution, following the approach used by Bodie et al. (1995). Most of the radiocollared sheep were known to have been in high-probability counting blocks within 7 days prior to the survey (Walt VanDyke, unpublished data). We surveyed all 16 high-probability blocks and 10 of 38 (26%) low-probability blocks. We used a table of random numbers to select low-probability blocks for sampling. We digitized block boundaries using ArcView (ESRI, Redlands, California) and compared the resulting map with the location of each bighorn sheep seen during the survey.

We located all radiocollared bighorn sheep on July 3, before the helicopter survey on July 5 and 6. We used a scanning receiver (Telonics, Mesa, Arizona) in a Cessna 182 airplane fitted with external antennas and flown approximately 300 m Above Ground Level (AGL). We determined sheep locations by signal strength and recorded locations on the aircraft GPS unit. We also used the same technique to record sheep locations on July 6, after the helicopter survey. We used a paired t-test to compare distances moved by radiocollared bighorns before and after the helicopter survey. In addition, strategically placed volunteers collected sheep behavior data before and during the helicopter survey. We selected observer locations and travel routes to minimize the potential for them to disturb bighorn sheep. Volunteers recorded bighorn sheep responses to the (apparent) helicopter disturbance and mapped bighorn sheep movements.

We used a Bell 206 Jet Ranger helicopter, flown with doors off for increased visibility. Flights began at about 0700 hrs MDT on July 5 and 6, 2001. Two experienced observers (primary observer in the left front; secondary observer in the right rear seat) counted and classified bighorn sheep. Data recorded during each flight included: date, temperature, percent cloud cover, wind (speed and direction), precipitation, and names of the primary and secondary observers. Data we collected for each group of bighorn sheep included: time of initial sighting, total number of ewes (classed as adult or yearling), lambs, and rams (classified by horn length into 4 categories), activity (moving or not), habitat, relative helicopter position, and GPS location. Habitat categories were riparian, cliff, talus, terraces, dissected cliff, flats or open slopes, and caves. Helicopter position was recorded as above, below or level with observed sheep. We recorded data for sheep seen outside designated counting blocks when it appeared that we chased them from a designated counting block.

Van Dyke was the primary observer on all flights because he was most familiar with the study area; secondary observers (all experienced in classifying bighorn sheep from a helicopter) varied by flight. We documented the initial location of each bighorn sheep by recording the GPS coordinates from helicopter navigation instruments. We analyzed location data in ArcView.

In an effort to evaluate observer performance, a third experienced observer equipped with a scanning receiver accompanied all flights. We used the scanning receiver to identify radiocollared animals near the helicopter whether observed or not. We used a hand-held GPS receiver (Garmin 12 XL, Garmin International Inc., Olathe, Kansas) to record the locations of any bighorn sheep missed by the survey crew. The third observer did not communicate his observations with other crewmembers during survey flights.

To minimize the risk of bighorn sheep moving between blocks before being counted, we began the survey in each block at its highest point (e.g., ridgelines). Subsequent passes were at progressively lower elevations. Although a modification of the procedure described by Bodie et al. (1995), we adopted this protocol because data (Bodie et al. 1995, table 1) revealed that bighorn sheep were more visible to observers when the helicopter was above (visibility 0.62) or at the same elevation as bighorn sheep (visibility 0.86). Beginning at elevations below sheep would have resulted in reduced visibility (0.44) and increased likelihood of animals crossing delineated boundaries undetected. No visibility factors in the model were altered by this search pattern change. Survey flights were flown as parallel transects in a systematic pattern at approximately 40 km/h, 50 m above ground level on 100 m contours. When sheep were observed, the helicopter was maneuvered until all sheep were counted and classified to sex, age, and horn class.

RESULTS

We confirmed that bighorn ewes move about considerably during helicopter surveys. We located all 33 radiocollared bighorn ewes before the helicopter flight: 24 (73%) were in designated counting blocks, 4 (12%) were in the survey area but not in a designated counting block, and 5 (15%) were outside the survey area. We failed to predict where the radiocollared ewes would be before the helicopter flight even though we had recent records of their locations. Radiocollared ewes were present in 31% (5/16) of the designated high-probability counting blocks prior to the survey. Surprisingly, radiocollared ewes were equally likely (30%) to occur in low-probability counting blocks (3/10). During the helicopter survey, collared ewes were only seen in high-probability blocks but uncollared sheep were counted in both high- and low-probability counting blocks.

We counted 91 bighorn sheep during the survey (Table 1), including 19 of 29 radio-equipped ewes present in the survey area, as determined by the third observer with a scanning receiver. Fourteen of the 19 (74%) radioed ewes were in counted blocks, but only 1 of the 14 animals was in the same block it occupied prior to the helicopter flights. None of the 9 radiocollared bighorns that were outside of designated counting blocks before the survey was observed during the survey, and of the 10 bighorn ewes present in

Table 1. Number of bighorn sheep counted from the helicopter in selected blocks, Leslie Gulch Oregon, July 2001.

Stratum	Units sampled	Number of each class counted					
		Total	Ewes	Rams	Lambs	Slegal*	Legal
High	16	79	35	32	12	21	11
Low	10	12	3	6	3	6	0
Total	26	91	38	38	15	25	11

* Slegal = sublegal (in Idaho) rams with horns of less than 3/4 curl

counting blocks but not detected during the survey, 4 (44%) had moved outside the study area when relocated immediately after the completion of the survey.

Linear distance moved might be related to a bighorn sheep's ability to avoid the helicopter. Bighorn sheep found in the survey area before the helicopter survey but for which radio signals were not heard during the survey (n = 4) moved an average of 3.0 $\pm$ 3.14 km between the first location (3 July) and last location (6 July). Bighorn sheep found in the area before the survey and also seen from the helicopter (n = 19), moved less than half the distance (1.41 $\pm$ 0.95 km) of the 4 ewes that were originally within the survey area but not observed from the helicopter.

Radio-equipped bighorn sheep (n = 19) moved an average of 1.2 $\pm$ 0.85 km between fixed-wing and helicopter survey locations, and an average of 1.3 $\pm$ 0.95 km after being counted from the helicopter. There was no difference between distances moved by bighorn sheep before and after being counted from the helicopter (paired t = -0.048, n = 19, P = 0.962). Directions traveled during these movements varied. Some radio-equipped bighorn sheep returned toward their original locations after the helicopter passed, while others continued to move away from their original location. One ewe traveled 2.7 km before being observed from the helicopter and 2.9 km afterward, but was last found only 0.3 km from her original location. Another ewe traveled 0.5 km before being observed from the helicopter, 2.9 km afterward, and was finally located 3.5 km from her original location.

The primary observers missed 15 bighorns that were seen by the third observer. All undetected animals were moving when first observed but were away from typical escape terrain. Ten of these sheep were first observed in open shrub/grass habitat and 5 (one group) were in talus near the bottom of a small canyon. Most (9) were lower than the helicopter; 5 were higher, and 1 was about level with the helicopter. All missed sheep would have been readily detectable if observers had looked in their direction.

We saw a slight but significantly greater proportion of radiocollared ewes (66%) than the detection probability (57%; SE 0.03) estimated for bighorn ewes by Bodie et al. (1995). Using the Idaho model, we estimated the population of bighorn sheep in the Leslie Gulch survey area at 172 ± 68 animals (Table 2). Recent helicopter surveys (Van Dyke, file data) had produced population estimates of 175 (1999), 150 (2000) and 160 (March 2001).

Initiation of helicopter flights resulted in a general melee of bighorn sheep movements, as indicated by movement of radiocollared animals between and away from designated counting blocks and supported by observations of ground-based observers (n = 20 observer days). Not only did bighorn sheep flee as the

Table 2. Total number of sheep estimated to have been present in Leslie Gulch, Oregon in July 2001. Helicopter counts were adjusted for sightability and sampling.

Number of Units			Variance				Bound
Stratum	Popn*	Sample	Estimate	Sampling	Sightability	Model	90%
High	16	16	112	0	308	12	29
Low	38	10	60	1308	72	2	61
Total	54	26	172	1308	380	14	68

* Popn is number of counting units in the study area

helicopter approached; observers reported that both rams (n = 5) and a ewe hid under rimrock or in caves to escape the approaching helicopter. Volunteers reported that some bighorns that were observed feeding or resting prior to the helicopter survey, fled while the helicopter was still "a mile away." Bighorns probably traveled far greater distances than the straight-line measurements we made between locations determined aerially. Ground observers noted that sheep ran about in an unorganized pattern sometimes crossing the same draw several times.

The sightability model also estimated population parameters. Early July lamb survival was 49 lambs/100 ewes. Many rams were present, in fact there were about the same number of rams as ewes (100.7/100). There were 81 rams with less than ¾ curl and 20 rams greater than ¾ curl per 100 ewes.

DISCUSSION:

Bighorn sheep movements during surveys create sampling problems. Bighorns that run from the helicopter may travel long distances (Bleich et al. 1990) making their detection difficult. To offset the impact of such emigration, Bodie et al. (1995) suggested eliminating sampling units and expanding the survey area so that such out-migration was minimized. However, this approach masks an unstated assumption (5): that animals moving away from the helicopter will remain in the survey area. Almost all (13 of 14) radiocollared bighorn ewes changed counting blocks before being observed from the helicopter, some left the survey area. Bighorn movements out of survey blocks during sightability surveys will result in conservative population estimates.

Bighorn sheep behavior at Leslie Gulch was similar to behavior of bighorns used to develop the model (assumption 4). Bighorn sheep managers faced with lower counts in the last few years are concerned that bighorns may have learned to avoid aerial surveys. However, the sheep used to develop the sightability model were subjected to far more helicopter activity in a shorter period than is experienced by sheep during management surveys. Bodie et al. (1995) developed their model using radiocollared sheep that had been drive-trapped and net-gunned before the first survey flight. Then, these already experienced sheep virtually became grizzled veterans of helicopter surveys by the end of the study having experienced 14 sightability and 6 survey flights, yet the estimated population in the Little Jacks Creek study area did not differ through all these flights (Bodie et al. 1995, table 2). Further, if significant learning occurs, two closely spaced counts might be expected to yield different estimates with the second count being lower. The June 1994 helicopter survey of bighorn sheep in the Owyhee River area was so low and unexpected that a different crew was used to repeat the survey in the same month. The second survey counted 11 fewer sheep (336) than the first survey (347) but estimated the population to be slightly higher (532 as compared with 486).

The bighorns at Leslie Gulch were also experienced with helicopters. Our survey followed several exposures of those sheep to helicopters earlier in the same year and annual surveys before that, yet we estimated about the same number of sheep (172) as estimated during the March count (160) and sightability of radiocollared ewes (66%) was about the same as reported by Bodie (57%). If sheep learn to avoid surveys after being exposed to helicopters, this learning had probably already occurred before our survey. All these sheep surveys were of experienced bighorns. What is lacking and will be rare by definition is sightability estimates for naïve sheep.

Data collected during this survey failed to satisfy a previously stated assumption and identified a new assumption that was also violated. Assumption (1) that the population is demographically closed during the survey was violated as almost all (13 of 14) radiocollared ewes within survey blocks moved out of those blocks before they were observed, presumably due to being disturbed by the helicopter. At least 4 of these radiocollared ewes moved completely out of the survey area. The new assumption that (5) bighorn sheep disturbed by helicopters remain available for observation is also unsupported.

Volunteers on the ground thought we violated assumption (2) by double counting some sheep. They saw the helicopter fly over the same bighorns more than once and assumed a double count was made. Careful checking of the data sheets showed that no similar groups were counted twice. If the same group was flown over more than once, the observers must have recognized that they were the same animals and did not double count or they misclassified one of the groups. The possibility remains that some individual sheep may have been double counted if they changed groups. Double counting would result in an over-estimate of true population. No radiocollared ewes were counted more than once.

We attempted to increase survey efficiency by stratifying sampling blocks based on the probability that sheep would be counted in each block. Our stratification was unsuccessful because we were unable to predict in which blocks sheep would be counted. Our sampling blocks may have been too small. Larger blocks would make it less likely that sheep could change blocks. Bodie et al. (1995) used larger blocks (mean = 24.3 km^2) when they attempted to stratify their study area but they recommended that such efforts be abandoned due to inability to predict where sheep would be counted. We concur, but suggest that stratification may increase survey efficiency in some habitats where survey methodology encourages animals to select escape habitat, which can be easily identified. There may also be an advantage to moving quickly to a sampling block to reduce time available for sheep to leave the area.

CONCLUSIONS

This survey is one attempt to validate the Idaho sightability model for bighorn sheep (Bodie et al. 1995). We found that at least one model assumption was violated, and identified a fifth assumption, previously unstated, which also appeared to be violated. The significance of violating these two model assumptions may be minimal, resulting in a slight under-estimate of true population size in easily surveyed, clearly bounded habitats. However, large blocks of homogenous habitat might provide many escape opportunities and allow more bighorn sheep to remain undetected. We saw no evidence that sheep become more proficient at escaping helicopter surveys with experience. The Idaho model was developed with experienced sheep.

We suggest that helicopter surveys be conducted in such a way to minimize the potential for sheep to escape from the survey area. Specifically, helicopter search patterns should begin at the highest elevations within a survey area, and then follow parallel transects to lower elevations. Where possible, search blocks should be selected with borders that are less likely for sheep to cross undetected. Observers should not focus exclusively on those habitats most likely to provide bighorn sheep security habitat or visible sheep in more open terrain may be missed.

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STATUS REPORTS

Kirby Smith - Moderator