Poor Population Performance of California Bighorn Sheep on Hart Mountain National Antelope Refuge

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Abstract: In 1995 the end of winter population of California bighorn sheep on Hart Mountain National Antelope Refuge (HMNAR) was estimated at 600 individuals. By 2003 this population was estimated at 300 individuals and lamb recruitment during the period was adequate to maintain the population. For a 4 year period beginning in January, 2004 we radio marked and monitored 49 adult bighorn (12 rams and 37 ewes) to determine cause of adult mortality, measure lamb production and recruitment, monitor herd health, and measure sex and age specific survival. Two rams died due to capture related injuries and 3 collars failed, therefore survival analysis was based on 44 individuals. Nineteen bighorn died during the study resulting in annual survival estimates of 0.832 and 0.897 for adult males and adult females, respectively. Cougar predation or probable cougar predation accounted for 63.2% of all mortalities. Exposure to disease and blood chemistry values did not differ from historic values measured at HMNAR.

KEY WORDS: California bighorn sheep, cause of mortality, Oregon, survival

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California bighorn sheep (*Ovis canadensis californiana*) were extirpated in Oregon by 1912. In 1954 California bighorn were successfully reintroduced to Oregon when 22 sheep were trans-located from Williams Lake, British Columbia, Canada, to Hart Mountain National Antelope Refuge (HMNAR). By 1992 the herd was estimated to be 600 individuals. With this increase, HMNAR has served as the primary source herd for California bighorn in Oregon and from 1969–2003 673 bighorn were moved from HMNAR to start new herds in Oregon, Nevada and Idaho.

By 1996 the herd had started to decline and in 2004 the population was estimated to be 300 individuals (Oregon Department of Fish and Wildlife, unpublished data). During the period of decline lamb ratios were high enough ($\bar{x}$ = 39.8 lambs:100 adult females, range 21-61) that the population should have increased or remained stable. With adequate lamb ratios, we hypothesized that the decline was due either to an increase in adult mortality, or to emigration. Our objectives were to:

1. Measure age and sex specific adult survival.
2. Determine causes of adult mortality.
3. Measure lamb recruitment.
4. Monitor herd health.

STUDY AREA

The study area encompassed 185.2 km^2 which is the entire bighorn range on HMNAR and included the west escarpment of Hart Mountain and Poker Jim Ridge (Figure 1). Elevations ranged from 1,385 m in the Warner Valley to 2,467 m on Warner Peak. Extensive cliffs and steep talus slopes provided escape terrain throughout the range. Vegetation was shrub-steppe typical

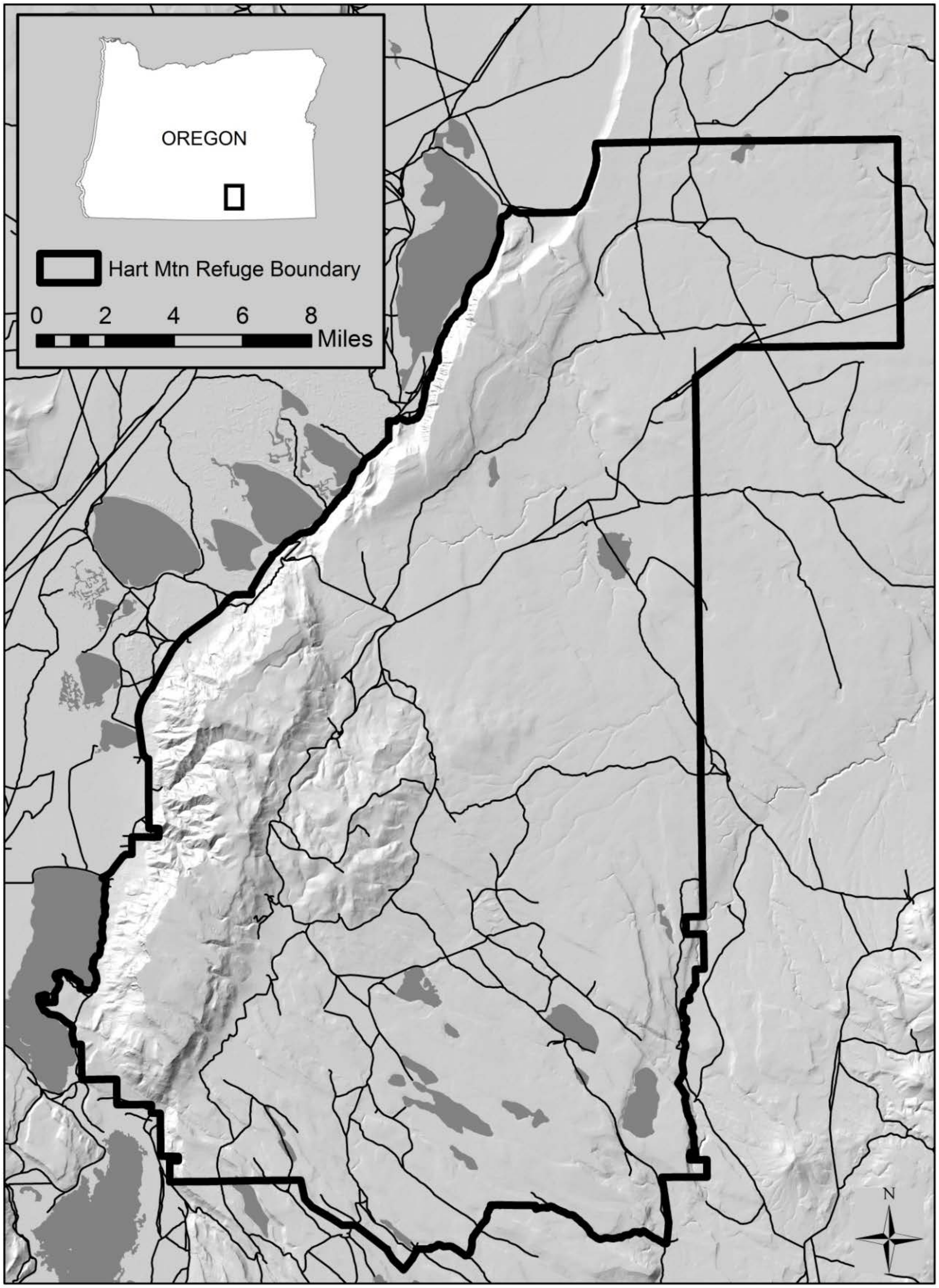

Figure 1. Hart Mountain National Antelope Refuge, Oregon, December 2004.

of the northern Great Basin including low sagebrush (*Artemisia arbuscula*) on Hart Mountain and Poker Jim Ridge, mountain big sagebrush (*A. tridentata vaseyana*) above 1,700 m, and Wyoming big sagebrush (*A. t. wyomingensis*) below 1,700 m. Isolated aspen (*Populus tremuloides*), mountain mahogany (*Cercocarpus ledifolius*) and ponderosa pine (*Pinus ponderosa*) stands occur on Hart Mountain. Western Juniper (*Juniperus occidentalis*) were encroaching on the west slope of Hart Mountain and east slope of Poker Jim Ridge (Miller et al., 2007). The Hart Mountain National Antelope Refuge Coordinated Management Plan (USFWS 1993) provides detailed habitat descriptions.

METHODS

Bighorn were captured using a net gun fired from a MD 500D helicopter. Following capture, individuals were manually restrained, processed at the capture location and released, or transported to an operations base for processing and released. Captures were distributed throughout the sheep range and rams were captured from all age classes. Captured sheep were fitted with a VHF radio collar (Advanced Telemetry Systems®) with a 6 hour mortality switch. Two large All-Flex ear tags were placed at the 3 and 9 o'clock positions on each collar for individual animal identification. Signal checks were done at least once per week and more often as time allowed.

When a mortality signal was heard the collar and carcass were located as soon as possible to determine cause of death. Upon location of the carcass a visual inspection of the remains was recorded and pictures were taken. Mortalities occurring within 14 days of capture were attributed to capture related injuries and these individuals were excluded from analyses. Cause of death was determined based on evidence at the location. Characteristics of the carcass and kill site used to attribute cause of death to cougar or probable cougar included cougar tracks or scat at site, evidence of caching, presence of claw marks in the hide, hemorrhage in throat area, signs of entrails or rumen content being removed from the subsequent feeding site, and evidence of ribs being removed from one side of the carcass.

Biological samples including blood, feces, and pharyngeal swabs were taken from each bighorn to monitor herd health. Analysis of samples was consistent with the testing protocol suggested by the Western Wildlife Health Committee (WWHC, Foster 2005). In addition to WWHC suggested bacterial and viral analysis from serum, blood chemistry values were compared to normal values (Whittaker et al. 2001) as an index of overall herd health. Fecal samples were analyzed for the presence of common bighorn parasites using flotation and the Baermann technique (Forrester and Lankester 1997) to estimate larval levels of *Protostrongylus*. Pharyngeal swabs were analyzed for presence of *Pasturella* and *Mannhaemia* bacteria.

Herd composition surveys were conducted annually in March and July from 2004 through 2008. The sheep range was flown using a Bell Helicopter (B-3 or L-3) and all bighorns were classified as ewes, lambs or rams. Rams were further classified by horn characteristics to Class I through IV (Geist 1971). All marked individuals were identified and noted during surveys. Detection rates calculated as the ratio of marked animals observed during surveys relative to the known number of marked animals alive in the study area. We used the Kaplan–Meier product limit estimator (Kaplan and Meier 1958, White and Garrott 1990) to estimate survival probabilities ($S_{(t)}$). Annual mortality rates were calculated as 1-$S_{(t)}$. We used logistic regression to determine if sex, age class, or capture location predicted adult survival where the binary response variable was alive or dead (White and Garrott 1990).

RESULTS

Between January 2004 and December 2006, 49 bighorn sheep (12 rams and 37 ewes) were radio-collared (Table 1). Two rams died due to capture and 3 radio collars failed; thus analyses were based on 44 individuals. Comparison of blood chemistry, parasitology, and bacteriology with historic and normal values showed no indication of herd health issues which could result in a population decline for the HMNAR bighorn population (Table 2, Table 3). PI3 values were within the reference range for active or recent infections, but no indication of disease was noted during the study.

Table1. Bighorn sheep marked on Hart Mountain National Antelope Refuge, Oregon. January 2004 – December 2007.

	Males		Females	
Capture Date	N	Age Range (Yr)	N	Age Range (Yr)
Jan. ‘04	12	1–7	28	1–8
Nov.’04			5	2–4+
Dec ‘05			4	Adult

Table 2. Blood chemistry, complete blood counts and trace mineral values from California bighorn caught at Hart Mountain National Antelope Refuge, Oregon, December 2004.

Parameter (units)	n	$\bar{x}$	Median	Range	Normal Range[a]
Thyroxine (nmol/L)	40	93	89	72-140	NR
Triiodothyronine (nmol/L)	40	2.3	2.2	1.3 - 3.4	NR
Selinium (ng/ml)	40	73	70	31 - 124	NR
Vitamin E (ug/ml)	41	2.01	1.98	0.51 - 4.81	NR
Sodium (Meq/L)	38	154	154	149 -162	146 – 164
Potassium (Meq/L)	38	4.9	4.8	3.6 - 7.1	4.0 – 7.2
Chloride (Meq/L	38	105	105	100 - 111	88 – 105
Glucose (MG/DL)	38	134	131	88 - 174	89 – 199
BUN (MG/DL)	38	9	9	5 - 19	7 – 28
Creatinine (MG/DL)	38	2	2	1.6 - 2.5	1.5 – 2.8
Uric Acid (MG/DL)	38	0.4	0.3	0.2 - 1.8	0.1 – 0.6
T. Protein (G/DL)	38	6.7	6.5	5.7 - 8.7	5.8 – 8.3
Albumin (G/DL)	38	3.6	3.7	2.6 - 4.2	3.0 – 4.9
T. Bilirubin (MG/DL)	38	0.1	0.1	0.1 - .02	0 – 0.4
GGTP (U/L)	37	64	59	35 - 112	23 – 123
Alk. Phos. (U/L)	38	206	181	83 - 388	82 – 1,050
ALT (U/L)	38	32	34	11 - 50	23 – 60
AST (U/L)	38	230	214	164 - 484	117 – 545
LDH (U/L)	37	651	656	557 - 798	535 – 1,160
Calcium (MG/DL)	38	10.3	10.3	9.6 - 11.1	8.9 – 12.4
I. Phos.(MG/DL)	37	6.6	6.7	4.7 - 8.5	4.0 – 9.6
Cholesterol (MG/DL)	38	58	56	47 - 77	42 – 71
RBC (M/uL)	36	11.6	11.6	8.5 - 13.5	NR
WBC (K/ul)	36	39	37	22 - 60	NR
HGB (G/DL)	36	18.3	18.4	14 - 21.5	NR
HCT %	36	52	53	42 - 62	NR
MCV fl	36	41	41	38 - 45	NR
Platlet (K/uL)	36	748	706	322 - 1,000	NR
SEG %	36	39	33	6 - 69	NR
Lymph %	36	61	65	25 - 94	NR

[a] Normal chemistry values from Whittaker et al. 2001; NR = Not reported.

Table 3. Serum Titer analysis for selected bacteria or virus from 41 California bighorn on Hart Mt. National Antelope Refuge, Oregon, 2004.

Disease Organisim	# Positive	% positive
Leptospira brat.	9	21
Leptospira can.	0	0
Leptospira gripp.	2	4
Leptospira hardj.	2	4
Leptospira icter.	0	0
Leptospira pom.	0	0
Blue Tongue	5	12
BRSV	0	0
BVD	0	0
EHD	5	12
IBR	0	0
PI-3	20	49

Leptospira spp positive at 1:100 (n=11) or 1:200 (n=2)

PI-3 positive range = 1:8 to 1:256

No marked individuals left the HMNAR bighorn sheep range. We were unable to determine the fate of one animal. All available habitat surrounding HMNAR was stocked with bighorn sheep prior to this study and none of these herds exhibited unexpected population growth prior to or during the study period. There are no data to indicate the population decline on Hart resulted from bighorn moving out of the known herd range.

Nineteen bighorns died. Cougar predation or probable cougar predation accounted for 63.2% of the mortalities (Table 4). Two young rams died of injuries likely sustained as a result of head butting during the rut. Individuals dying of undetermined causes were not located quickly enough to confirm cause of death. Mortalities occurred throughout the year with no indication cougar predation was more prevalent in any particular season (Table 5).

Annual adult survival, averaged 0.832 and 0.897 for adult males and adult females, respectively (Table 6). Annual survival varied more for males (0.636 – 1.00) than for females (0.880 – 0.930), and male survival was slightly less than females in all years except 2005. Neither age class or capture location adequately predicted survival ($P > 0.05$) and gender influenced survival only during 2004 ($\chi^2 = 5.35$, $P = 0.0207$).

Table 4. Mortality cause for radio-collared bighorn sheep on Hart Mt. National Antelope Refuge, Oregon, 2004–2007.

Cause of Death	N	%
Capture Myopathy	2	10.5
Predation [a]	12	63.2
Injury	2	10.5
Hunting	1	5.3
Unknown	2	10.5
Total	19	

[a] All due to cougar or probable cougar predation

Table 5. Season of cougar caused mortality for radio marked bighorn sheep on Hart Mountain National Antelope Refuge, Oregon.

Year	Season	# Cougar Mortality
2004	Winter	2
	Spring	
	Summer	1
	Fall	3
2005	Winter	
	Spring	1
	Summer	2
	Fall	
2006	Winter	2
	Spring	1
	Summer	
	Fall	1
2007	Winter	1
	Spring	2
	Summer	
	Fall	1
Combined	Winter	5
	Spring	4
	Summer	3
	Fall	5

Seven classification surveys were conducted between 2004 and 2007 (Table 7). Three included only one observer, while

Table 6. Annual survival probabilities for radio-collared bighorn sheep on Hart Mountain National Antelope Refuge, Oregon, 2004 – 2007.

	Male			Female		
Year	L 95%	Rate	U 95%	L 95%	Rate	U 95%
2004	0.352	0.636	0.921	0.767	0.887	1.000
2005	.	1.000	.	0.778	0.893	1.000
2006	0.598	0.857	1.000	0.836	0.930	1.000
2007	0.535	0.833	1.000	0.753	0.880	1.000
Mean Survival		0.832			0.897	
Mean Mortality (1-St)		0.168			0.103	

Table 7. Detection rates of radio marked bighorn sheep on Hart Mountain National Antelope Refuge, Oregon.

Survey Date	# Observers	Marked Bighorns Observed	Marked Bighorns Available	Detection Rate (%)
3/25/04	1	22	36	61.11
7/27/04	2	31	36	86.11
3/30/05	1	21	38	55.26
7/15/05	2	28	34	82.35
7/16/06	2	24	31	77.42
3/19/07	1	21	28	75.00
7/10/07	2	18	26	69.23

Mean detection rate 1 observer = 64%
Mean detection rate 2 observers = 79%

4 included two observers. Detection rate of marked bighorns observed during surveys ranged from 55%–86%. Not surprisingly surveys using 2 observers ($\bar{x}$ = 79% of available marks detected) resulted in a higher proportion of marked bighorns seen than a single observer ($\bar{x}$ = 64% of available marks detected). The overall average detection rate for marked animals was 73%.

Population modeling has been used to estimate bighorn herd size in Oregon since 1985. The HMNAR bighorn population is tracked using POP II® (Fossil Creek Software, Fort Collins, Colorado, USA) as the modeling platform using classification surveys and harvest data collected annually as inputs. Survival parameters used in the model have been estimated from other Oregon bighorn sheep studies (ODFW unpublished data). Prior to this project, the HMNAR model used annual natural mortality estimates of 7% for adult ewes and 9% for adult rams. A revised population model was developed using average annual mortality estimates (1- $S_{(t)}$) based on radio-collared animals in this study (10.3% for adult ewes, 16.8% for adult rams). All variables in the two models other than natural mortality were the same. Population estimates from the revised model suggests the population is declining and is consistent with data from classification surveys (Table 8).

DISCUSSION

From 1988 to 1996, between 5–11% of the modeled bighorn population and 7 – 23% of the bighorns counted during surveys were removed for relocation to other areas. Most of the animals removed were females and this likely had a regulatory affect on the population. Since 1996, only16 adult ewes

Table 8. Population models using historic natural mortality versus 2004-2007 values measured for bighorn sheep on Hart Mountain National Antelope Refuge, Oregon, 1990 – 2006.

		Historic Mortality Model[a]		Observed Mortality Model[b]		
Year	Bighorns Observed	Population Size	Density (bighorn/km^2)[c]	Population Size	Density (bighorn/km^2)[c]	Lambs/ 100 Ewes
1990	209	448	2.4			45
1991	282	450	2.4			26
1992	395	469	2.5			37
1993	224	449	2.4			34
1994	304	459	2.5			38
1995	165	367	2.0			28
1996	189	355	1.9			29
1997	166	328	1.8			21
1998	236	391	2.1	360	1.9	53
1999	256	420	2.3	346	1.9	55
2000	136	485	2.6	377	2.0	61
2001	187	494	2.7	324	1.7	45
2002	206	531	2.9	317	1.7	35
2003	174	604	3.3	322	1.7	47
2004	192	644	3.5	295	1.6	45
2005		672	3.6	283	1.5	40
2006	141	718	3.9	276	1.5	38

[a] 7% for adult ewes and 9% for adult rams

[b] 10.3% for adult ewes and 16.8% for adult rams

[c] Hart sheep range = 185.2 km^2

have been removed. The lower female removal rate after 1996, and its associated regulatory affect, allowed a substantial population increase in the modeled population (Table 8). However, observed counts were not consistent with modeled results when using the pre-study mortality estimates (Table 8). Population estimates from the revised model using mortality estimates measured in this study agree with the declining trend in number of bighorns observed during aerial surveys. In 1990-1991, Payer (1992) investigated the distribution and survival of 20 Class III and IV bighorn rams on HMNAR. During his study he had 4 mortalities, all due to hunter harvest. Based on Payer (1992), the observed population decline beginning in 1996, and our research, it appears cougar predation on HMNAR bighorns has been sufficient enough to affect population growth.

From 1996 through the start of our research only 16 bighorn were captured for relocation and sampled for herd health monitoring. This capture occurred in 2001. Because the herd was not sampled between 1996 and 2001 we have no evidence of a disease event or other health issue affecting population growth. Because the observed population decline was chronic rather than acute, it is reasonable to assume that a pasturellosis pneumonia event did not occur on HMNAR. This assumption is supported by a lack of reports for coughing bighorn on HMNAR from resident refuge staff or refuge visitors, and there has been no observed decline in lamb recruitment as typically follows an acute respiratory disease outbreak in bighorn sheep.

We recognize that pathological evidence is quickly lost from an aging carcass and therefore the absence of disease caused mortality may be a result of the time it took to locate carcasses after first hearing a mortality signal. However, evidence at carcasses indicative of cougar predation, coupled with no indication of illness in live sheep observed while monitoring radio marked individuals leads us to believe that disease was not a substantial mortality factor.

Historic data suggest habitats on HMNAR can sustain a population of approximately 400 bighorns, or a density of 2.15 bighorn/km^2 (5.6 bighorn/mi^2). Trend in number of bighorns observed during annual classification surveys and modeled population estimates indicate the population is well below this desired population size. We suggest that controlling cougars on bighorn sheep ranges would likely benefit bighorn sheep populations on HMNAR.

Our data suggest that we did not mark enough rams. Future investigations should mark sex and age classes at the ratio they occur in the population. This is a reasonable suggestion for rams due to the ability to determine relative age prior to capture. Adult ewes are difficult to age prior to capture and it may not be possible to select specific age classes without capturing and rel1easing unwanted individuals.

Although we did not find a difference in mortality based on ram age, circumstantially it appears that older age class rams were more susceptible to cougar predation than other segments of the population. Because older rams are solitary or occur in very small groups, and for most of the year were bedded down for a majority of the day, cougars may be able to select for this group. Future projects should select adequate sample sizes of older age class rams to investigate this observation further.

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