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EFFECTS OF CAPTURE ON BIOLOGICAL PARAMETERS IN FREE-RANGING BIGHORN SHEEP (*OVIS CANADENSIS*): EVALUATION OF NORMAL, STRESSED AND MORTALITY OUTCOMES AND DOCUMENTATION OF POSTCAPTURE SURVIVAL

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ABSTRACT: Blood samples and physiological data were collected from 634 bighorn sheep (*Ovis canadensis*) captured by four different methods between 1980 and 1986 in the western United States. These parameters were evaluated for selected physiological, biochemical and hematological values. Postcapture biological parameters were compared among bighorn sheep according to four different outcomes; normal, stressed or compromised, capture myopathy (CM) mortality, and accidental mortality. Significant differences ($P < 0.05$) were noted between outcome groups relative to certain parameters: temperature, respiration, creatinine phosphokinase (CPK), lactic dehydrogenase (LDH), serum glutamic oxaloacetic transaminase (SGOT), blood urea nitrogen (BUN), glucose, white blood cell count (WBC) and plasma pH. Such differences between groups may help in evaluating the clinical status of bighorn sheep at capture, enabling one to predict those animals that might develop CM at a later date, indicate candidates for preventive medical treatment prior to release, and/or which should be followed closely to determine long-term survival. Evaluation of follow-up data ($n = 77$) related to outcome status and long-term survival of bighorn sheep indicated that <4% (3 of 77) were dead within 1 mo of capture (one of these had been classified as normal and two as stressed or compromised at capture); <3% (3 of 77) were dead >1 mo, and <6 mo after capture two were classified in the stressed outcome and one as diseased. Eighty-eight percent (68 of 77) were alive from 1 mo to 5 yr after capture (53 were classified as normal, 12 as stressed or compromised and 3 as diseased), and 2% (1 of 77) had chronic CM but was still alive (this animal had been classified as normal). Of 77 sheep in the follow-up group, <3% (2 of 77) were not observed following capture (one was classified as normal and one as stressed and diseased). Of the fatalities, <3% (2 of 40) had been captured by the net-gun and <4% (1 of 27) by drive-net. Those two unobserved in the follow-up group also had been caught with the net-gun, 5% (2 of 40). The single surviving CM case had been captured by the net-gun. Although the net-gun appears to be one of the safest methods of capturing individual bighorn sheep, based on evaluation of capture data and biological parameters, it may not be associated with the best long-term survival in some bighorn sheep. This further emphasizes the need for close monitoring of animals at capture and following their release.

Key words: Free-ranging bighorn sheep, *Ovis canadensis*, capture outcome, stress, mortality, physiological response, biochemical changes, hematological parameters, survival.

INTRODUCTION

Stress is defined as the cumulative response of an animal resulting from interactions with its environment (Selye, 1973; Fowler, 1978; Moberg, 1985). Homeostasis is maintained by physiological regulation, enabling wild animals to survive through many stressful episodes. Capture of these animals, with restraint and handling, produces some of the most stressful episodes in their lives. The stress concept is controversial and difficult to define precisely (Fowler, 1978; Elliot and Eisdorfer, 1982), but it is important to understand it fully and apply this knowledge in the field in order to keep stress from capture to an absolute minimum. Understanding the effects of capture on bighorn sheep (Kock et al., 1987a, b) has enabled the selection of the least stressful and most appropriate method to capture individual or groups of bighorn sheep. Equally important is (1) the clinical evaluation of bighorn sheep following capture and during handling, (2) the determination of the outcome status (Kock et al., 1987b) prior to release; and (3) the prognosis for long-term survival. The ability to predict an animal's postcapture status is difficult, but it can be enhanced by clinical evaluation, monitoring of biological parameters and an understanding of the effects of stress on these parameters.

This paper further evaluates data collected from 634 bighorn sheep captured in the western United States, between 1980 and 1986, by comparing biological values between normal, stressed or compromised bighorn sheep and mortality outcomes. Follow-up data ($n = 77$) for bighorn sheep, from 1 mo to 5 yr postcapture was evaluated also, both in relationship to capture method and to original outcome status (normal or stressed) in order to better document long-term survival of bighorn sheep following capture and release.

MATERIALS AND METHODS

The animals sampled were captured by four different methods: drop-net ($n = 158$), drive-net ($n = 247$), chemical immobilization ($n = 90$) and net-gun ($n = 137$). These methods have been described (Jessup et al., 1984; Kock et al., 1987b) as well as methods of handling the sheep (Kock et al., 1987a). Individual bighorn sheep, regardless of capture method, were placed into an outcome category. Outcomes, determined by clinical impressions, personal experience, and by case record evaluation, were categorized into one of five outcomes. Those bighorn sheep that experienced minimal stress and excitement prior to, during, and after capture were placed in Outcome 1 (normal; $n = 474$). All were released in apparently good health. Bighorn sheep experiencing one or more of the following were placed in Outcome 2 (capture stress or compromised classification): body temperature >42.2 C, prolonged pursuit by the helicopter, open-mouthed breathing, excessive struggling, clinical evidence of shock and any other evidence of capture stress problems ($n = 95$). All of these sheep were released following appropriate therapy. Outcome 3 (disease classification) represented those bighorn sheep that showed clinical evidence of infections, such as sinusitis, contagious ecthyma and other infections ($n = 40$). Ten of these animals were placed also in the stressed outcome group. There were two mortality outcome classifications: Outcome 4 or capture myopathy (CM) mortality represented those bighorn sheep that died from peracute, acute or chronic capture myopathy ($n = 12$); Outcome 5 (accidental mortality) represented deaths from causes other than CM, such as a broken neck ($n = 11$).

Bighorn sheep in the follow-up group ($n = 77$) were animals that had been marked or radio-collared prior to release and had been monitored actively since capture. They were all from California and were placed into five different categories: bighorn sheep seen more than once following capture, and in apparently good health; CM signs seen but animal survived in the free-living environment; animals found dead after release (1 to <30 days postcapture) and suspected to be due to CM such as evidence of walking on hocks; animals that died >1 mo but <6 mo after capture where the cause of death was not determined but may have been due to CM, predation, nutritional factors, etc.; and bighorn sheep that were collared but that were never seen following release and their fate was unknown.

Blood sampling, processing techniques and variables (biological parameters and their abbreviations) selected for analyses have been described (Kock et al., 1987a). The data from 634 bighorn sheep were entered onto a microcomputer spreadsheet (SuperCalc 4, 1985, Computer Associates International, San Jose, California 95131, USA). The data were organized by outcome classification and each file included codes for outcome, species, season, capture method, state, with county and mountain range, age, and sex. A sample of 80 bighorn sheep were randomly selected from 474 animals classified into the normal outcome. This was performed to balance the sample sizes for statistical analyses. The spreadsheet files were modified into subfiles for specific analyses.

Statistical analyses were performed on four outcome classifications, Outcomes 1, 2, 4, and 5. With the latter two outcome groups a few key data were missing and some of these were estimated using well known regression procedures (Afifi and Elashoff, 1966). Fourteen values were estimated, four temperatures, one cortisol, three AP, five glucose and one PCV. Outcome 3 was not analyzed statistically because we were not concerned specifically with disease status.

TABLE 1. Statistical summary of physiological parameters in bighorn sheep by outcome classification; western United States, 1980–1986.

	Outcome classification							
	n	Normal bighorn	n	Stressed bighorn	n	Capture myopathy mortality	n	Accidental mortality
Temperature (C)	52	40.5[a]	71	42.3[b]	8	41.9[b]	7	41.2[ab]
		1.5[c]		1.4		1.8		0.9
Pulse (bpm)	42	127	61	130	5	147	4	118
		32		33		37		37
Respiration (bpm)	42	57	64	69	5	86	5	62
		22		38		31		45

[a,b] Means with different superscripts are different from each other at $P \leq 0.05$ (Tukey HSD); means without superscripts are not significantly different from each other.

[c] Standard deviation.

The data was initially evaluated using a statistical graphics program (StatGraphics, 1985, Statistical Graphics Corporation, Rockville, Maryland 20280, USA). Summary statistics were generated for the parameters of interest for outcome and on follow-up data categories, including cross-tabulation of the latter data with outcome, and capture method.

The biological effects related to outcome were further analyzed by evaluating physiological, biochemical and hematological parameters. These analyses utilized one-way analysis of variance (ANOVA, BMDP P1V, BMDP Statistical Software, Los Angeles, California 90025, USA) and Tukey's HSD on factor level means (Daniel, 1983). Significant results were graphically represented by means plots derived from ANOVA and 95% Tukey HSD intervals for factor means (StatGraphics). Statistical significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

A summary of biological parameters related to outcome are presented (Tables 1–3). Of special interest are highly significant differences ($P < 0.05$) between outcome classifications relative to temperature, CPK, SGOT, LDH, BUN, glucose, WBC and plasma pH. Testing the differences between the means in each pair of groups resulted in a number of significant differences. The majority of significant differences were associated with the normal and stressed outcome groupings. This was partly due to the disparity in sample sizes when testing differences between means with the Tukey HSD, between these two groups ($n = 80$ and $n = 95$) and the mortality outcome groups ($n = 12$ and $n = 11$).

Physiologic, biochemical and hematologic data are presented (Tables 1–3; Figs. 1, 2). In particular, temperatures of bighorn sheep in the normal outcome classification were significantly lower than bighorn sheep in the stressed and CM mortality outcomes. It should be noted that one of the original classification criteria for a stressed or compromised animal was a temperature >42.2 C. Therefore, the significant result for this particular outcome reflects this. Respiration was not significantly different between outcome groupings based on the random sample ($n = 80$) taken from the normal outcome group. Analysis based on the total number of bighorn sheep in the normal outcome ($n = 474$) revealed a significant overall difference with ANOVA ($P < 0.05$), with a significant difference between respiratory rates in normal and stressed bighorn sheep (54 and 69 bpm, respectively). Due to the biological importance of this physiological parameter, the latter result is considered important.

CPK (log CPK) levels in normal sheep were significantly lower than bighorn sheep in the stressed or CM mortality outcomes. There were no significant differences be-

TABLE 2. Statistical summary of biochemical parameters in bighorn sheep by outcome classification; western United States, 1980–1986.

	Outcome classification							
	n	Normal bighorn	*n*	Stressed bighorn	*n*	Capture myopathy mortality	*n*	Accidental mortality
Cortisol (μg/dl)	64	4.1	54	4.8	8	5.1	9	4.1
		2.4[e]		2.7		1.8		2.5
CPK (I.U./liter)[a]	77	542[c]	81	1,342[d]	12	2,487[d]	8	1,747[cd]
		657		2,219		3,723		2,279
		313[b]		790		1,161		878
SGOT (I.U./liter)	79	148[c]	91	208[d]	12	186[cd]	10	297[d]
		66		109		93		235
LDH (I.U./liter)	73	546[c]	81	723[d]	12	703[cd]	9	884[cd]
		180		270		420		1,020
AP (I.U./liter)	48	289	65	412	9	167	8	365
		218		396		100		274
Potassium (meq/liter)	73	5.7	85	6.5	12	6.8	8	6.3
		1.7		2.3		2.8		1.9
Sodium (meq/liter)	74	150	86	150	12	147	8	148.5
		7.7		8.6		5.2		9
Chloride (meq/liter)	63	102	74	101	12	102	7	100
		8		8		10		9
Creatinine (mg%)	41	1.9	59	2	7	2.2	6	1.8
		0.4		0.4		0.4		0.3
BUN (mg%)	77	16.0[c]	91	18.4[d]	12	17.6[cd]	10	19.2[cd]
		5.9		5.9		7.1		5.6
Selenium (ppm)	61	0.26	79	0.21	11	0.26	8	0.18
		0.3		0.14		0.20		0.07
Glucose (mg%)	69	128[c]	73	164[d]	9	154[cd]	7	142[cd]
		42		72		47		50
Total protein (g%)	77	7.00	90	7.29	12	7.15	10	6.83
		1.00		0.97		0.72		0.95

[a] Statistical results reported on log CPK.
[b] Geometric mean.
[c,d] Means with different superscripts are different from each other at $P \leq 0.05$ (Tukey HSD); means without superscripts are not significantly different.
[e] Standard deviation.

tween the latter two outcomes and the accidental mortality outcome. LDH and SGOT follow a similar pattern in that normal outcome sheep had significantly lower values compared to stressed bighorn sheep. Bighorn sheep classified into the accidental mortality outcome had significantly higher values for SGOT than normal animals, but they were not significantly different from stressed or CM mortality animals. Although potassium levels were not statistically significant, the apparent difference from the raw data between normal bighorn sheep and the stressed group was biologically important. BUN levels in normal bighorn sheep were significantly lower than those sheep classified in the stressed or compromised outcome, but not significantly different from the other outcomes. The overall significance of creatinine levels was almost statistically significant ($P < 0.06$), with bighorn sheep in the stressed outcome appearing to have higher values than those in the normal outcome group.

TABLE 3. Summary statistics of hematological parameters in bighorn sheep by outcome classifications; western United States, 1980–1986.

	Outcome classification							
	n	Normal bighorn	*n*	Stressed bighorn	*n*	Capture myopathy mortality	*n*	Accidental mortality
PCV (%)	58	48.0	74	48.3	10	47.2	8	45.4
		7.2[c]		7.3		7.7		3.5
Hb (g%)	58	16.8	74	17.2	11	17.2	8	16.1
		2.5		2.2		2.8		1.4
RBC ($\times 10^6$/ml)	58	12.2	74	12.4	11	12.0	8	11.0
		2.0		2.0		2.0		1.6
WBC ($\times 10^3$/ml)	58	7.1[a]	74	5.9[b]	11	5.2[ab]	8	4.0[ab]
		3.0		3.0		2.5		1.2
Plasma pH	19	7.2[a]	27	7.3[a]	5	7.0[b]	NC	NC
		0.1		0.2		0.1	NC	NC
Plasma P_{CO_2}	16	12.1	3	16.2		NC[d]	NC	NC
		8.5		12.0		NC	NC	NC

[a,b] Means with different superscripts are different from each other at $P \leq 0.05$; means without superscripts are not significantly different.

[c] Standard deviation.

[d] Data not collected.

Whole blood selenium values in the raw data appeared to be lower in the stress and mortality outcomes than in normal sheep, but these differences were not significant. Glucose values for normal bighorn sheep were significantly lower compared to those animals classified in the stressed or compromised outcome.

WBC values in those sheep classified in the stressed or mortality outcomes appeared to be lower than normal sheep based on evaluation of the raw data, but the only statistically significant difference was between the normal and stressed outcome classifications. Bighorn sheep in the CM mortality outcome group had significantly lower plasma pH levels compared to the normal and stressed a outcome groups.

Follow-up data was obtained from 77 bighorn sheep captured in California. Tables 4 and 5 present cross-tabulation of follow-up categories with capture method and original outcome classification. The majority (88%; 68 of 77) of bighorn sheep were alive at 1 mo to 5 yr postcapture. Of these animals 16% (12 of 77) were classified at capture into the stressed or compromised outcome group.

Three of 77 (<4%) bighorn sheep were dead within 1 mo of capture, <3% (2 of 77) were originally classified in the stressed or compromised outcome and <2% (1 of 77) were considered normal at capture. Evaluation of the raw data on these sheep revealed significant abnormalities in biological parameters following capture. Of particular interest were the two bighorn sheep classified in the stressed group. One animal had a temperature at capture of 42.5 C, LDH of 674 I.U./liter (normal 574 I.U./liter), and potassium at 6.7 meq/liter (normal 5.7 meq/liter). The other animal had a CPK of 1,117 I.U./liter (normal 313 I.U./liter), a SGOT of 181 I.U./liter (normal 148 I.U./liter), a LDH of 711 I.U./liter, a glucose of 38 mg% (normal 50–150 mg%) and a plasma pH of 7.2 (normal 7.3). The bighorn sheep in the follow-up mortality category (<30 days) that was classified originally as normal had a temperature at capture of 41.6 C, cortisol at 6.3 μg/dl (normal 4.0–5.0 μg/dl), SGOT of 211

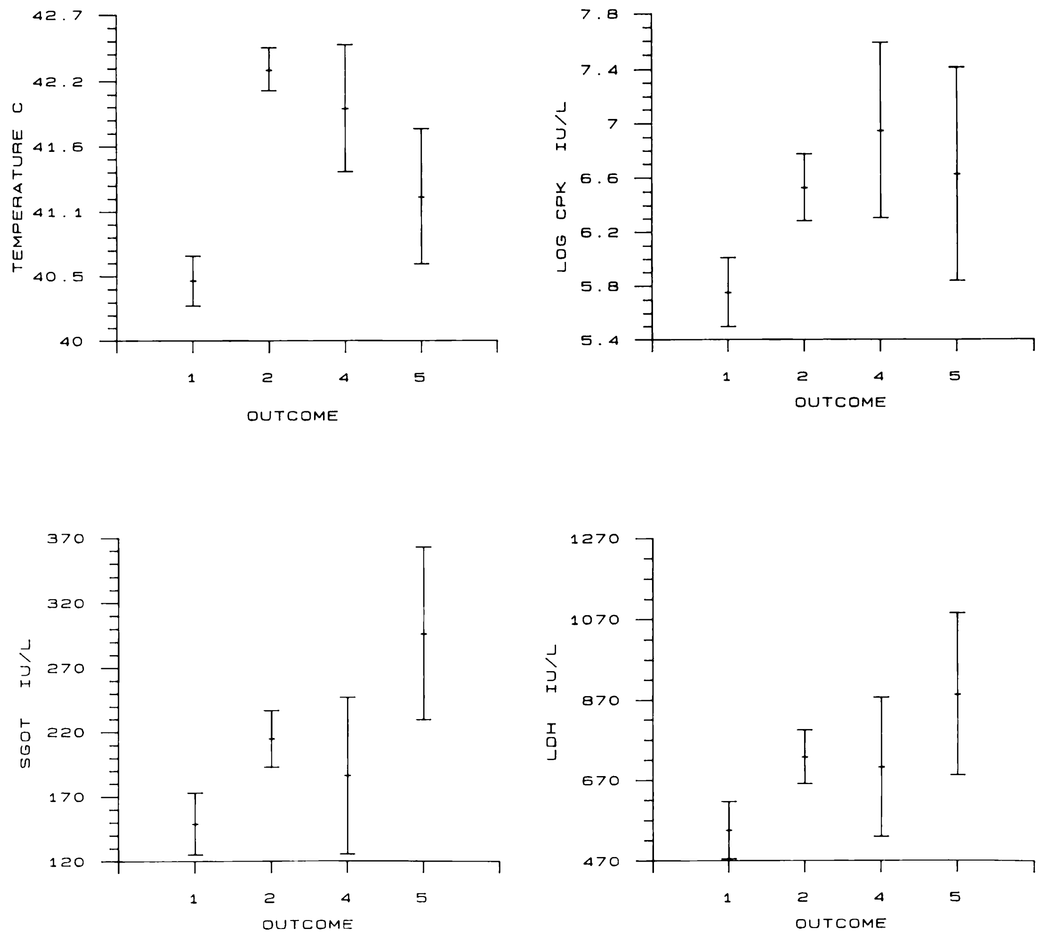

FIGURE 1. Plots of means derived from ANOVA and 95% Tukey HSD intervals for factor means, for significant ($P < 0.05$) physiological and biochemical parameters compared among different outcome classifications in bighorn sheep captured in the western United States between 1980 and 1986.

I.U./liter, LDH of 619 I.U./liter and glucose of 146 mg%.

Three percent (2) of 77 bighorn were not observed following capture and their fate was unknown. One was classified as stressed and diseased at capture and one as normal. The former had a temperature at capture of 42.7 C, SGOT of 180 I.U./liter, potassium of 6.8 meq/liter and a WBC of 7.6 ($\times 10^3$/ml) (normal 7.0) and the bighorn sheep classified as normal had a CPK of 1,276 I.U./liter, SGOT of 241 I.U./liter, LDH of 801 I.U./liter, potassium of 6.3 meq/liter and glucose of 29 mg%, indicating that this animal was incorrectly classified at capture based on clinical signs. One bighorn sheep that died between 1 and 6 mo after capture and was originally classified as stressed, had abnormal biological parameters including a body temperature of 42.7 C, respiration of 132 (normal 40–65 bpm), CPK of 790 I.U./liter, SGOT of 203 I.U./liter, and LDH of 680 I.U./liter. The one bighorn sheep that developed chronic CM following capture but is still alive was classified into the normal outcome group and did not have any abnormal biological parameters at capture.

The majority of the bighorn sheep in

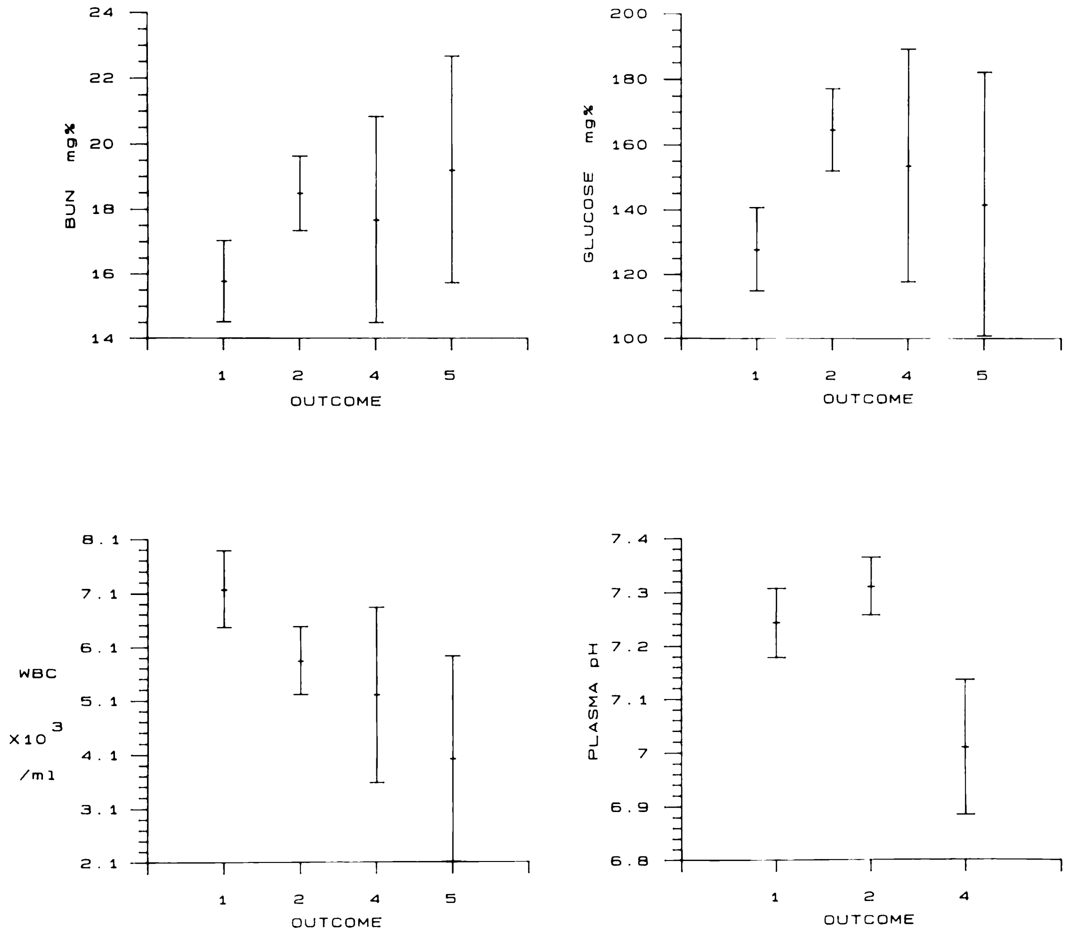

FIGURE 2. Plots of means for significant ($P < 0.05$) biochemical and hematological parameters compared among different outcome classifications in bighorn sheep captured in the western United States between 1980 and 1986.

the follow-up group were captured by the net-gun (52%, 40 of 77) and the drive-net (35%, 27 of 77). This reflects the success of the net-gun in capturing bighorn sheep in California (Jessup et al., 1987; Kock et al., 1987b) and marking or radio-collaring these animals. The net-gun had the highest number of bighorn sheep in both the mortality (5%, 2 of 40) and not observed following capture (5%, 2 of 40) categories. The age and sex distribution in these categories was two ewes (all >2 yr), and two rams (0–2 yr).

There are few studies that specifically evaluate the effects of exertional stress and excitement by classifying animals into different categories at capture and examining biological parameters (Franzmann and Thorne, 1970; Franzmann, 1971, 1972; Franzmann et al., 1975; Seal and Hoskinson, 1978; Kock et al., 1987a). This study attempted to classify the animals at capture and then evaluate the accuracy of these classifications based on biological parameters and ultimately verify this against follow-up field observations. The outcome classifications were based on clinical signs, including body temperature, and not on other physiologic or blood parameters.

Many biological parameters are useful in evaluating exertional stress in man (Savignano et al., 1967; Rose et al., 1970;

TABLE 4. Cross-tabulation of survival status with outcome classifications (determined at capture), in 77 bighorn sheep captured by four different methods in California, 1980–1986.

Survival status (1 mo to 5 yr postcapture)	Outcome classification (at capture)		
	Normal	Stressed	Diseased
Alive	53 (70%)[a]	12 (16%)	3 (4.5%)
Alive (but with chronic CM)	1 (<2%)	NA	NA
Dead (<1 mo after capture)[c]	1 (<2%)	2 (<3%)	NA
Dead (>1 mo to <6 mo after capture)[d]	NA[e]	2 (<3%)	1 (<2%)
Not observed following capture	1 (<2%)	1 (<2%)[b]	NA

[a] Percentage of total number of follow-up cases (n = 77).
[b] This animal was also classified as diseased at capture.
[c] Cause of death probably due to CM.
[d] Cause of death not determined.
[e] Not available.

Bartsch et al., 1977), domestic animals (Cardinet et al., 1967; Gericke and Belonje, 1975; Bartsch et al., 1977; Benjamin, 1978) and wild animals (Franzmann and Thorne, 1970; Seal et al., 1972; Franzmann et al., 1975; Harthoorn, 1975, 1982; Haigh et al., 1977; Wesson et al., 1977a, b; Seal and Hoskinson, 1978; Spraker, 1982; Kock et al., 1987a). These include the physiological measures of temperature, pulse and respiration; biochemical and hematological measures of cortisol, CPK, SGOT, LDH, potassium, glucose, BUN, plasma pH and P_{CO_2}, and WBC. Comparison of these parameters in this study revealed significant differences (Tables 1–3; Figs. 1, 2) between normal bighorn sheep and stressed or compromised animals. This was further supported with results for CM mortality cases.

Of particular interest related to the evaluation of stress was the lack of significance with cortisol between different outcome classifications. The value of blood cortisol as an indicator of stress has been controversial, although some investigators feel that it has the potential of being the best single indicator of "stress" in a variety of different wildlife species (Franzmann et al., 1975; Bubenik, 1982; Jessup et al., 1982; Spraker, 1982; Van Heedren et al., 1985). Our results were varied using this variable to predict final outcome; this has been reported also by Seal and Hoskinson (1978). Turner (1984) reported on the diurnal periodicity of plasma cortisol in bighorn sheep and demonstrated a mean 24-hr plasma cortisol in free-ranging desert bighorn of 4.92 μg/dl. This compares reasonably well with the data from our study of 4.23 μg/

TABLE 5. Cross-tabulation of survival status with original method of capture in 77 bighorn sheep captured in California, 1980–1986.

Survival status (1 mo to 5 yr postcapture)	Capture method			
	Drop-net (n = 5)	Drive-net (n = 27)	Darting (n = 5)	Net-gun (n = 40)
Alive	5 (100%)[a]	24 (94%)	5 (100%)	34 (85%)
Alive (but with chronic CM)	NO[b]	NO	NO	1 (2.5%)
Dead (<1 mo after capture)	NO	1 (3.8%)	NO	2 (5%)
Dead (>1 mo to <6 mo after capture)	NO	2 (7.7%)	NO	1 (2.5%)
Not observed following capture	NO	NO	NO	2 (5%)

[a] Percentage of numbers in each capture method.
[b] None observed.

TABLE 6. Suggested values of selected physiological, biochemical and hematological parameters for possible prognostic use in the field, to provide an assessment of the stress status of recently caught bighorn sheep.

	Field parameters	
	Normal range	Values indicative of stress
Temperature (C)	39.1–41.2	>41.9
(F)	102.4–106.0	>107.5
Respiration (bpm)	40–64	>75
Glucose (mg%)	92–150	<50 or >150
Plasma pH	7.15–7.35	<7.15
	Prognostic parameters	
Cortisol (μg/dl)	2.5–5.0	>5.0
CPK (I.U./liter)	175–670	>700
SGOT (I.U./liter)	100–170	>180
LDH (I.U./liter)	450–600	>650
Potassium (meq/liter)	4.5–6.0	>6.0
WBC ($\times 10^3$/ml)	6.0–8.8	<6.0

dl (range 0.14–14.08 μg/dl) reported previously (Clark et al., 1987; Kock et al., 1987a).

Cortisol has been evaluated in other species. Van Heedren et al. (1985) reported a maximum cortisol response in a stressed free-living white rhinoceros (*Ceratotherium simum*) of 12.25 μg/dl and Seal and Hoskinson (1978) reported a mean cortisol level of 6.1 μg/dl in stressed pronghorn antelope (*Antilocapra americana*). Bubenik (1982) reported cortisol levels of 1.64 μg/dl in calm white-tailed deer (*Odocoileus virginianus*) compared to a value of 3.65 μg/dl in highly excited animals. Mohr and Jessup (unpubl. data) found cortisol levels for captive bighorn sheep (2.94 μg/dl) differed from values for free-ranging bighorn sheep (4.24 μg/dl) (Kock et al., 1987a). In this study, the highest individual values for stressed or compromised bighorn, CM mortality bighorn, and accidental mortalities, were 12.27 μg/dl, 8.51 μg/dl, and 9.84 μg/dl, respectively. The mean cortisol levels in this study do not differ significantly between outcome groups. However, within capture method groupings previously reported (Kock et al., 1987a) cortisol levels do indicate that bighorn sheep captured by either drive-net or chemical immobilization were more stressed than those captured by drop-net (4.47 μg/dl and 4.9 μg/dl vs. 3.82 μg/dl, respectively). Comparison of cortisol levels with other biological parameters indicative of stress revealed that bighorn sheep with cortisol levels >5 μg/dl had markedly elevated CPK levels (1,253 I.U./liter, n = 163) compared to CPK levels for those sheep with cortisol levels <5 μg/dl (590 I.U./liter, n = 313). This suggests that cortisol levels >5 μg/dl for free-ranging bighorn sheep may be considered pathologic.

The results from our study suggest that the two outcome classifications (normal and stressed) were accurate based on the effects on biological parameters. Therefore, values from these data could be prospectively useful in determining the true outcome status of recently captured bighorn sheep. The evaluation of field parameters (Table 6) such as temperature, respiration, glucose utilizing glucose blood clinistix (Visidex 11, Ames Division, Miles Lab., Inc., Elkhart, Indiana 46515, USA), and plasma pH at the time of capture could augment clinical signs and impressions. This could aid in determining whether or not an individual should be treated for stress (Gericke and Belonje, 1975; Kock et al., 1987b) and marked or radio-collared to better document long-term survival. Based on these field parameters, animals not requiring treatment could be processed more quickly and those needing treatment can be rapidly identified. Laboratory derived biological parameters could be evaluated in 24 to 48 hr (Table 6) to provide a prognosis for long-term survival. Evaluation should be based on the collation of field results and several prognostic parameters; not on single abnormal values in the data collected.

The selection of the appropriate capture method in bighorn sheep (Kock et al., 1987a, b) will aid in maintaining minimum mortality rates. Success of a particular capture episode should not be based solely on the numbers caught, immediate mortality and morbidity rates, and the numbers successfully released, but also on the number of bighorn sheep that survive after capture. This data often is difficult to obtain and requires telemetry monitoring and visual sighting and identification of collared animals. The results from this study of biological parameters within outcome classifications and correlation with follow-up data suggests that some bighorn sheep develop clinical problems or succumb from the effects of capture stress and capture myopathy after release. Documentation of the exact cause of death following capture and release is difficult due to predation, high ambient temperature fluctuations and chance occurrences. The net-gun which has great potential as a capture method in bighorn sheep management (Jessup et al., 1988; Kock et al., 1987a, b) appears to have the potential to cause some postcapture CM morbidity or mortality.

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