# EFFECTS OF CAPTURE ON BIOLOGICAL PARAMETERS IN FREE-RANGING BIGHORN SHEEP (OVIS CANADENSIS): EVALUATION OF DROP-NET, DRIVE-NET, CHEMICAL IMMOBILIZATION AND THE NET-GUN

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# EFFECTS OF CAPTURE ON BIOLOGICAL PARAMETERS IN FREE-RANGING BIGHORN SHEEP (*OVIS CANADENSIS*): EVALUATION OF DROP-NET, DRIVE-NET, CHEMICAL IMMOBILIZATION AND THE NET-GUN

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ABSTRACT: Blood samples and physiological data were collected from 634 bighorn sheep captured between 1980 and 1986 in the western United States. Bighorn sheep were evaluated for physiological parameters (temperature, pulse and respiration), selected biochemical parameters (cortisol, creatine phosphokinase (CPK), serum glutamic oxaloacetic transaminase (SGOT), lactic dehydrogenase (LDH), alkaline phosphotase (AP), potassium, sodium, chloride, creatinine, blood urea nitrogen (BUN), selenium, glucose, total protein, plasma pH and plasma $P_{CO_2}$), and selected hematological parameters (packed cell volume (PCV), hemoglobin (HB), red blood cell count (RBC), and white blood cell count (WBC)). These parameters were compared among bighorn sheep captured by four different methods: drop-net ($n$ = 158), drive-net ($n$ = 249), chemical immobilization ($n$ = 90) and the net-gun ($n$ = 137). Biological parameters affected by stress, including temperature, respiration, cortisol, CPK, SGOT, potassium, glucose and WBC revealed significant differences among capture methods ($P < 0.05$). Some blood parameter differences, including temperature, respiration, cortisol, glucose and WBC could be explained partially by the distribution of age and sex within capture method groups. Drop-net and net-gun methods of capture appeared to produce the least amount of alteration to biological parameters related to capture stress or compromise and capture mortality. Drive-net was similar to the former methods while chemical immobilization caused the greatest changes in the above physiological, biochemical and hematological parameters.

*Key words:* Free-ranging bighorn sheep, *Ovis canadensis*, capture methods, physiological responses, biochemical changes, hematological parameters.

## INTRODUCTION

Understanding the results from different wildlife capture methods has improved by evaluating the morbidity and mortality rates and other criteria (Harthoorn, 1975, 1982a, b; De Vos and Remington, 1981; Barrett et al., 1982; Jessup et al., 1982; Van Reenen, 1982; Andryk et al., 1983; Bates et al., 1985; Krausman et al., 1985; Kock et al., 1987). Increased knowledge has enabled the planning, modification and selection of appropriate capture methods for different wildlife management situations. The effects of capture on various biological parameters in wild animals have been reported (Franzmann and Thorne, 1970; Franzmann and Herbert, 1971; Seal et al., 1972; Franzmann et al., 1975; Harthoorn, 1975, 1977, 1982b; Seal and Hoskinson, 1978; Wesson et al., 1979; McDonald et al., 1981; Bubenik, 1982; Jessup et al., 1982; Foreyt et al., 1983). These reports are limited in sample size, types of analyses, and few report detailed evaluations of interactions among these parameters.

This paper reports on further analyses of data from 634 bighorn sheep captured between 1980 and 1986 in the western United States using four capture methods previously reported (Kock et al., 1987). Specific comparisons are made for selected physiological, biochemical and hematological parameters, and for age/sex interactions between these different capture methods.

## MATERIALS AND METHODS

Bighorn sheep 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 previously (Jessup et al., 1982; Kock et al., 1987).

Bighorn sheep captured by drop-net and drive-net were handled as soon after capture as possible (<1 to 2 min). Initial handling included physical restraint and removal from the net, followed by blindfolding and the application of leg hobbles to individual bighorn sheep. These sheep were then transported by helicopter to a base camp. Occasionally, animals were transported by wildlife personnel and ground vehicles, depending on the location and accessibility of the capture site. Chemical immobilized bighorn sheep were observed from the helicopter following darting and during induction. Recumbent darted sheep were approached on foot, blindfolded, hobbled and processed. Sheep captured by the net-gun were physically restrained quickly (depending on the terrain but generally <1 min following capture), blindfolded and hobbled following removal of the net.

Blood sampling and processing techniques were standardized as much as possible under field conditions. Blood samples and physiological data were collected at base camp in drop-net and drive-net sheep, generally within 10–30 min of capture. With the exception of body temperature which was monitored at the capture site and again at the base camp, temperatures reported here represent values obtained at the capture site. In chemically immobilized and net-gunned sheep, samples and data were collected immediately following capture. Blood was collected with a 60-$cm^3$ syringe and a 16-gauge, 2.54-cm needle by jugular venipuncture or by using the Vacutainer blood collection system (Becton, Dickinson and Comp., Rutherford, New Jersey 07070, USA). Blood samples were immediately transferred to stoppered glass vacuum tubes, then refrigerated until processing. Most blood samples were collected within 0.5 to 1.0 hr of capture, but a few were collected 1 to 2 hr postcapture. Blood samples were centrifuged within 2 to 8 hr postcapture and the serum was harvested.

Analyses of both biochemical and hematological samples were conducted by California Veterinary Diagnostics, Inc. (Sacramento, California 95691, USA). Values for serum enzymes CPK, LDH and SGOT were analyzed using a Chemetric-2 analyzer (Chemetrics Corporation, 197 Airport Boulevard, Burlingame, California 94010, USA). Values for sodium and potassium were determined using an I.L. 143 flame photometer; the remaining chemistries were performed on a 8700 Chemistry Analyzer (Boehringer Mannheim Diagnostics, 7800 West Park, Houston, Texas 77063, USA). Complete blood counts (CBC) were analyzed from whole blood, and a Coulter Model S. Senior blood analyzer (Coulter Electronics, 590 West 12th, Hialeah, Florida 33010, USA) was utilized. Serum cortisol levels were analyzed by radioimmunoassay (RIA) at Colorado State University Veterinary Diagnostic Laboratory (Fort Collins, Colorado 80523, USA) and by the Department of Reproduction, School of Veterinary Medicine (University of California, Davis, California 95616, USA). Whole blood samples were analyzed by the University of California (Davis Extension Service, Davis, California 95616, USA) for absolute selenium (Se) values. Plasma pH and $PCO_2$ measurements were determined within 6 hr of capture. The former was determined by a hand-held Digital Mini pH meter (Cole-Parmer Instrument Company, 7425 North Oak Park Avenue, Chicago, Illinois 60648, USA) (calibrated at pH 7.0), the latter by using a $PCO_2$ apparatus set (Harleco, Dade Diagnostics Inc., Aguada, 00602 Puerto Rico).

Variables were selected for statistical evaluation based on our clinical experience and a literature review (Cardinet et al., 1967; Franzmann and Thorne, 1970; Franzmann and Herbert, 1971; Seal et al., 1972; Gericke and Belonje, 1975; Harthoorn, 1975, 1977, 1982b; Spraker, 1977, 1982; Seal and Hoskinson, 1978; Cardinet and Stephens-Orvis, 1980; McDonald et al., 1981; Bubenik, 1982; Jessup et al., 1982; Van Reenen, 1982; Mohr and Jessup, unpubl. data). These variables included physiological measures (temperature, pulse and respiration), and several biochemical and hematological parameters chosen for their potential value as stress or health indicators (cortisol, CPK, SGOT, LDH, AP, potassium, sodium, chloride, creatinine, BUN, selenium, glucose, total protein, PCV, HB, RBC, WBC, plasma pH and plasma $PCO_2$).

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 capture method and each file included codes for species, season, capture method, state, with county and mountain range, age, sex and outcome determined after capture. The spreadsheet files were modified into subfiles for specific analyses.

Statistical analyses were performed on the physiological, biochemical, and hematological data. They were initially evaluated using a statistical graphics program (StatGraphics, 1985, Statistical Graphics Corporation, Rockville, Maryland 20280, USA). This exploratory data analysis was performed to establish information on data distribution, and to identify possible trends and differences in the data that would require further detailed analyses. Summary statistics were generated for the total data set, biological parameters of interest for capture method, age and sex.

The biological effects due to capture were further analyzed by one-way analysis of variance (ANOVA, BMDP PIV, BMDP Statistical Software, Los Angeles, California 90025, USA) and Tukey's HSD test for factor level means (Daniel, 1983). The distribution of CPK was extremely skewed and required transformation to a log-normal distribution ($\log_e$ transformation) prior to analysis by ANOVA (Fig. 1). Statistical significance was determined at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Table 1 provides a statistical summary for the total data set. Evaluation of biological data between bighorn sheep of different ages (0–2 yr, >2 yr) and sexes (rams and ewes), both within the total data set and within capture methods (Kock et al., 1987) indicated that these two zoographic variables had the potential to confound the results. Values of temperature ($\bar{x}$ = 41.2 C), pulse (132 bpm), respiration (67 bpm) and glucose (138 mg%) in young bighorn sheep of both sexes consistently were higher than in older sheep of both sexes (40.8 C, 128 bpm, 56 bpm and 128 mg%, respectively). Cortisol levels were lower in older (>2 yr) rams (3.3 $\mu$g/dl) compared to young and old ewes, and young rams (overall $\bar{x}$ = 4.1 $\mu$g/dl). SGOT values were higher in older bighorn rams (204 I.U./liter) compared to other age and sex groups (overall $\bar{x}$ = 166 I.U./liter). In the total data set, AP values were higher in young animals of both sexes which confirms findings in domestic animals (Benjamin, 1978), and this trend was found by age within capture method. Creatinine and total protein values were higher in older animals of both sexes when compared to young sheep, but BUN followed the opposite trend. RBC and WBC values appeared to be higher in young animals regardless of sex.

A summary of findings for the above

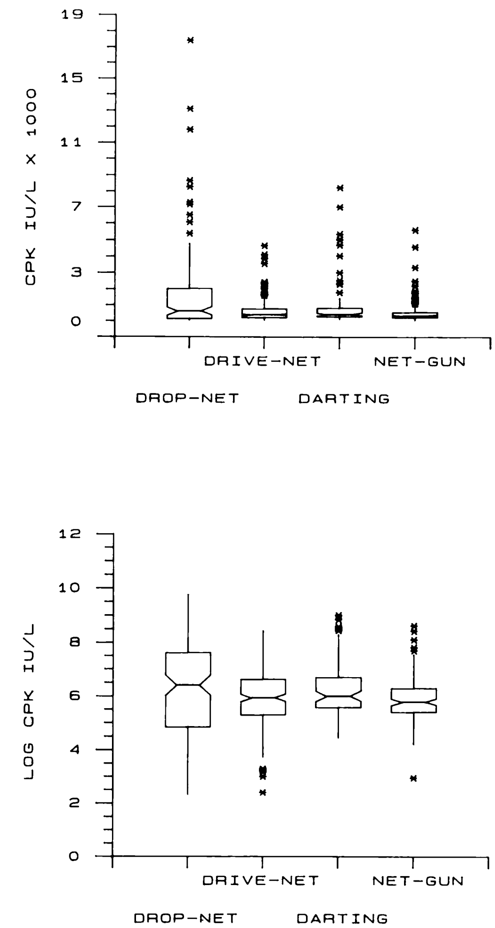


FIGURE 1. Notched box and whisker plots displaying the relative data distribution of CPK (I.U./liter) prior to and following transformation to log-normal. The median is portrayed by the horizontal line segment within the box. The notches provide an approximate 95% test of the null hypothesis that the true medians are equal. The whiskers represent the tails of the distribution and the outside values are considered outliers (Chambers et al., 1983)

parameters across the four capture methods is presented in Tables 2–4. Of special interest are highly significant differences among capture groups ($P$ < 0.05) relative to body temperature, respiration, cortisol, CPK, SGOT, potassium, glucose and WBC. Subsequent testing of the differences between the means in each pair of groups resulted in a number of significant differences. Physiological data are presented

TABLE 1. Statistical summary of combined biological data from bighorn sheep captured using four different capture methods; western United States, 1980–1986.

| Variable (units) | *n* | Mean | Median | SD[a] | Min–Max |
|---|---|---|---|---|---|
| Temp (C) | 427 | 40.9 | 41.0 | 2.0 | 38.2->43.8 |
| Pulse (bpm) | 339 | 129.9 | 120.0 | 35.8 | 30->240 |
| Respiration (bpm) | 358 | 59.8 | 50.0 | 29.7 | 12->200 |
| Cortisol ($\mu$g/dl) | 474 | 4.3 | 3.9 | 2.6 | 0.14->14.08 |
| CPK (I.U./liter) | 589 | 884.0 | 388.0 | 1,548.7 | 10->17,402 |
| SGOT (I.U./liter) | 620 | 176.4 | 144.5 | 105.8 | 42->904 |
| LDH (I.U./liter) | 572 | 619.4 | 580.0 | 272.1 | 237->3,591 |
| AP (I.U./liter) | 405 | 317.5 | 215.0 | 304.0 | 40->2,580 |
| Potassium (meq/liter) | 576 | 5.9 | 5.4 | 2.14 | 1.4->20.6 |
| Sodium (meq/liter) | 584 | 151.0 | 150.0 | 8.4 | 124->187 |
| Chloride (meq/liter) | 507 | 102.2 | 102.0 | 7.3 | 83->125 |
| Creatinine (mg%) | 357 | 1.9 | 1.9 | 0.4 | 1->3.4 |
| BUN (mg%) | 610 | 17.4 | 17.0 | 6.6 | 4->56 |
| Selenium (ppm) | 457 | 0.25 | 0.20 | 0.25 | 0.03->1.60 |
| Glucose (mg%) | 546 | 130.1 | 126.0 | 50.4 | 9->368 |
| Total protein (g%) | 610 | 7.3 | 7.2 | 1.0 | 5->11.2 |
| PCV (%) | 464 | 47.0 | 47.2 | 7.2 | 7->70 |
| Hb (g%) | 465 | 16.6 | 16.6 | 2.5 | 1.2->24.8 |
| RBC ($\times 10^6$/ml) | 466 | 12.1 | 12.3 | 2.1 | 1.3->18.12 |
| WBC ($\times 10^3$/ml) | 464 | 7.3 | 6.8 | 3.8 | 1->27 |
| Plasma pH | 132 | 7.3 | 7.2 | 0.2 | 6.8->7.74 |
| Plasma $PCO_2$ (mmol/liter) | 86 | 12.0 | 8.8 | 8.8 | 1->36.2 |

[a] Standard deviation.

(Table 2, Fig. 2). In particular, average temperature of sheep caught by drop-net was significantly lower than that of sheep in the other capture groups. Also, the temperature of sheep captured by net-gun was significantly lower than that in sheep captured by drive-net and chemical immobilization. The drive-netting sample had much greater number of young rams and ewes compared to the net-gun and this may have influenced the results of statistical comparisons. Despite a similar age distribution in the drop-netting group, temperatures were lower and did not appear to be influenced by age. This may be explained by the lack of pre-exertional

TABLE 2. Statistical summary of physiological data from bighorn sheep sampled by four different capture methods; western United States, 1980–1986.

| Variable (units) | Capture method | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | Drop-net | *n* | Drive-net | *n* | Darting[a] | *n* | Net-gun |
| Temperature (C) | 73 | 40.1[d] | 197 | 41.2[b] | 43 | 41.5[b] | 92 | 40.7[c] |
| | | 1.8[e] | | 1.8 | | 1.6 | | 1.7 |
| Pulse (bpm) | 53 | 124.4 | 139 | 130.0 | 38 | 125.0 | 90 | 139.0 |
| | | 33.7 | | 34.6 | | 34.8 | | 39.5 |
| Respiration (bpm) | 54 | 46.4[c] | 150 | 72.0[b] | 39 | 50.0[c] | 93 | 54.0[c] |
| | | 12.4 | | 35.0 | | 25.0 | | 22.0 |

[a] Darting = chemical immobilization.

[b,c,d] Means with different superscripts are significantly different from each other at $P < 0.05$ significance level (Tukey HSD test); means without superscripts are not significantly different from each other.

[e] Standard deviation.

TABLE 3. Statistical summary of biochemical data for bighorn sheep sampled by four different capture methods; western United States, 1980–1986.

| | Capture method | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable (units) | *n* | Drop-net | *n* | Drive-net | *n* | Darting | *n* | Net-gun |
| Cortisol ($\mu$g/dl) | 119 | 3.8[c]<br>2.6[e] | 168 | 4.5[bc]<br>2.8 | 72 | 4.9[b]<br>2.7 | 115 | 4.3[b,c]<br>1.8 |
| CPK[a] (I.U./liter) | 142 | 1,583[c]<br>2,563 | 229 | 595[b]<br>671 | 83 | 1,015[b]<br>1,566 | 135 | 559[b]<br>751 |
| SGOT (I.U./liter) | 151 | 133[b]<br>69.4 | 246 | 194[c]<br>109.6 | 88 | 207[c]<br>142 | 135 | 173[c]<br>89 |
| LDH (I.U./liter) | 129 | 649<br>351 | 226 | 580<br>187 | 83 | 628<br>419 | 134 | 653<br>166 |
| AP (I.U./liter) | 53 | 199[b]<br>155 | 178 | 338[bc]<br>292 | 41 | 223[bc]<br>170 | 133 | 366[c]<br>372 |
| Potassium (meq/liter) | 133 | 6.3[c]<br>2.5 | 228 | 5.5[b]<br>1.6 | 88 | 7.0[c]<br>3.2 | 127 | 5.6[b]<br>1.1 |
| Sodium (meq/liter) | 133 | 146[d]<br>5.8 | 228 | 153[c]<br>8.7 | 88 | 149[b]<br>6.6 | 135 | 154[c]<br>8.5 |
| Chloride (meq/liter) | 104 | 100[bc]<br>7 | 190 | 103[c]<br>6 | 82 | 98[b]<br>8 | 131 | 106[d]<br>6 |
| Creatinine (mg%) | 44 | 1.5[b]<br>0.3 | 139 | 1.9[c]<br>0.4 | 41 | 2.1[c]<br>0.4 | 133 | 1.9[c]<br>0.4 |
| BUN (mg%) | 141 | 19.8[b]<br>7.7 | 246 | 17.3[c]<br>6.0 | 88 | 15.8[c]<br>6.1 | 135 | 16.4[c]<br>6.0 |
| Glucose (mg%) | 150 | 147[b]<br>59 | 212 | 124[c]<br>44 | 73 | 119[c]<br>56 | 111 | 127[c]<br>39 |
| Total protein (g%) | 142 | 7.0[b]<br>0.9 | 245 | 7.1[b]<br>0.9 | 88 | 7.4[c]<br>1.0 | 135 | 7.7[c]<br>1.2 |

[a] Statistical significance reported for log CPK.

[b,c,d] Means with different superscripts are significantly different from each other at $P < 0.05$ significance level (Tukey HSD test); means without superscripts are not significantly different from each other.

[e] Standard deviation.

stress prior to capture by this method. It is of interest that although pulse rate did not show any significant differences among capture groups, respiration was significantly elevated in drive-netting compared to sheep captured by other capture methods. Again, age must be considered when interpreting these results.

Biochemical data were also evaluated by capture groups (Table 3; Figs. 3, 4). Cortisol levels did not differ significantly except between sheep captured by drop-net and chemical immobilization. The influence of low cortisol levels in older rams within capture methods ($\bar{x}$ = 2.7 to 4.3 $\mu$g/dl), contrasting with high values in young rams and ewes (3.3 to 6.6 $\mu$g/dl), and older ewes (3.24 to 6.08 $\mu$g/dl) in chemical immobilization may partly explain the differences.

CPK (log CPK) values were not significantly different among sheep captured by drive-net, chemical immobilization, or the net-gun, but sheep captured by drop-net had CPK values significantly higher than from sheep captured by drive-net or the net-gun. Evaluation of the CPK data shows that in order to reflect the true mid-range value of the CPK distribution, the median would be more appropriate to use (338 I.U./liter for the combined data) than the mean (884 I.U./liter for the combined data, Table 1). SGOT values were significantly less for those bighorn sheep captured by

TABLE 4. Statistical summary of hematological data in bighorn sheep sampled by four different capture methods; western United States, 1980–1986.

| | Capture method | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable (units) | *n* | Drop-net | *n* | Drive-net | *n* | Darting | *n* | Net-gun |
| PCV (%) | 90 | 50[c] | 163 | 45[a] | 84 | 46[ad] | 127 | 48[bd] |
| | | 7[e] | | 9 | | 6 | | 5 |
| HB (g%) | 90 | 17.4[a] | 164 | 16.1[b] | 85 | 16.4[b] | 126 | 16.5[b] |
| | | 2.1 | | 3 | | 1.7 | | 2.2 |
| RBC ($\times 10^6$/ml) | 90 | 13.1[a] | 164 | 11.6[b] | 85 | 11.7[b] | 127 | 12.0[b] |
| | | 1.6 | | 2.5 | | 1.5 | | 2.0 |
| WBC ($\times 10^3$/ml) | 90 | 9.7[a] | 164 | 6.4[b] | 85 | 5.6[b] | 125 | 8.0[c] |
| | | 3.6 | | 3.0 | | 2.8 | | 4.0 |
| Plasma pH | 49 | 7.2[a] | 76 | 7.3[b] | NC[f] | NC | 13 | 7.1[a] |
| | | 0.1 | | 0.2 | | NC | | 0.2 |
| Plasma $P_{CO_2}$ (mmol/liter) | 49 | 13.8[a] | 23 | 12[b] | NC | NC | 14 | 5.7[b] |
| | | 8.2 | | 10.1 | | NC | | 3.3 |

[a,b,c,d] Means with different superscripts are significantly different from each other at $P < 0.05$ significance level (Tukey HSD test); means without superscripts are not significantly different from each other.

[e] Standard deviation.

[f] Data not collected.

drop-net than were values for the other capture methods. This result is noteworthy because SGOT would be expected to follow CPK values, as the former (although not as specific an indicator of muscle damage as CPK) does increase with muscle necrosis (Benjamin, 1978; Spraker, 1982). This result may be explained by the under representation in the drop-net group ($n = 5$) of older rams compared to the other capture methods ($n = 99$). LDH values were not significantly different between those sheep captured by the drop-net, drive-net, darting and the net-gun.

Potassium levels for sheep captured by either drop-net or chemical immobilization were significantly higher than in sheep captured by other methods (Fig. 3) and this reflects a higher level of capture stress, particularly with the latter capture method. Glucose levels were significantly higher in animals captured by drop-net compared to those animals captured by other methods. Evaluation of the raw data indicates that this difference may have been due to a few animals in a single, particularly stressful capture episode (Kock et al., 1987). Also, comparisons between drop-net, chemical immobilization and the net-gun are probably influenced by the small number of young animals of both sexes in the latter two capture methods ($n = 12$ and 23, respectively) compared to the drop-net ($n = 64$).

Hematological data are presented (Table 4, Fig. 4). PCV, HB and RBC show similar patterns in which sheep captured by drop-net had significantly elevated values compared to sheep captured by other methods. WBC values in bighorn sheep were significantly elevated in animals captured by either drop-net or net-gun compared to other capture methods. Bighorn sheep captured by the net-gun had a significantly lower plasma $P_{CO_2}$ compared to those sheep captured by drop-net, and sheep captured by both the net-gun and drop-net had significantly lower plasma pH than those captured by the drive-net (Fig. 4).

Physiological, biochemical and hematological values have been reported in free-ranging bighorn sheep (Franzmann and Thorne, 1970; Woolf and Kradel, 1970, 1973; Franzmann 1971b; Franzmann and Herbert, 1971; Bunch et al., 1980; McDonald et al., 1981; Jessup et al., 1982; Turner, 1984; Krausman et al., 1985; Clark et al., 1987), captive bighorn (Franzmann and Thorne, 1970; Franzmann, 1971b; Mohr and Jessup, unpubl. data) other wild sheep (Franzmann, 1971a; Foreyt et al., 1983), and domestic sheep (Gericke and Belonje, 1975; Benjamin, 1978). These variables have been investigated to establish baseline values, to evaluate health and nutritional status, and as indicators of stress-related compromise following forced exercise and capture. Findings and generalizations from many of these studies have been restricted by sample size, limited selection of parameters and types of data analyses.

Previous comparisons between capture methods (Kock et al., 1987) demonstrated the usefulness of the net-gun, drive-net and drop-net to capture free-ranging bighorn sheep, with low compromise and mortality rates. None of the four capture methods were without stress, but chemical immobilization had the highest combined risk rate (compromise plus total mortality rates). This stress or compromise in wild animals results in the alteration of certain biological parameters. If the level of stress is sustained, and particularly if it is prolonged, compromise of the animals' ability to adapt occurs and complications such as capture myopathy can develop (Harthoorn, 1975, 1977; Bartsch et al., 1977; Fowler, 1978; Spraker, 1982). Specific biological parameters, including physiological and biochemical values, are affected by capture and can be considered as indicators of how severely an animal's homeostasis has being compromised (Cardinet et al., 1967; Franzmann and Thorne, 1970; Seal et al., 1972; Franzmann et al., 1975; Harthoorn, 1975, 1977, 1982a, b; Seal and Hoskinson, 1978; Jessup et al., 1982; Spraker, 1982; Van Reenen, 1982). For example, changes in physiologic parameters such as temperature and respiration may reflect over-exertion with hyperthermia and acidosis (Harthoorn, 1982a; Spraker, 1982); changes in serum enzymes such as CPK, SGOT and LDH reflect varying degrees of muscle damage (Rose et al., 1970; Gericke and Belonje, 1975; Benjamin, 1978; Cardinet and Stephens-Orvis, 1980) and levels may be significantly elevated with over-exertion and the development of capture myopathy (Bartsch et al., 1977; Harthoorn, 1982a; Spraker 1982). In addition, elevation of potassium results from muscle damage, and this is a major component in the pathogenesis of capture stress or com-

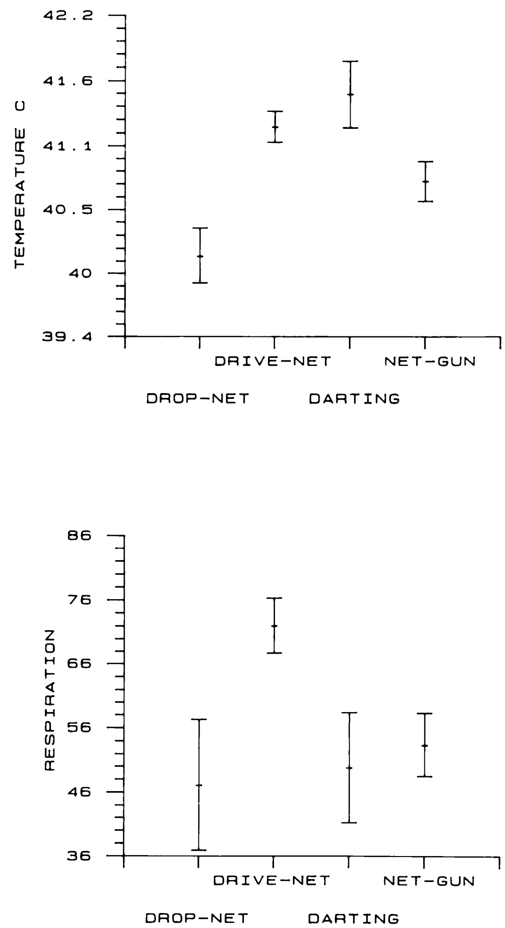


FIGURE 2. Plots of means derived from ANOVA and 95% Tukey HSD intervals for factor means, for significant ($P < 0.05$) physiological parameters compared among four different methods used to capture bighorn sheep.

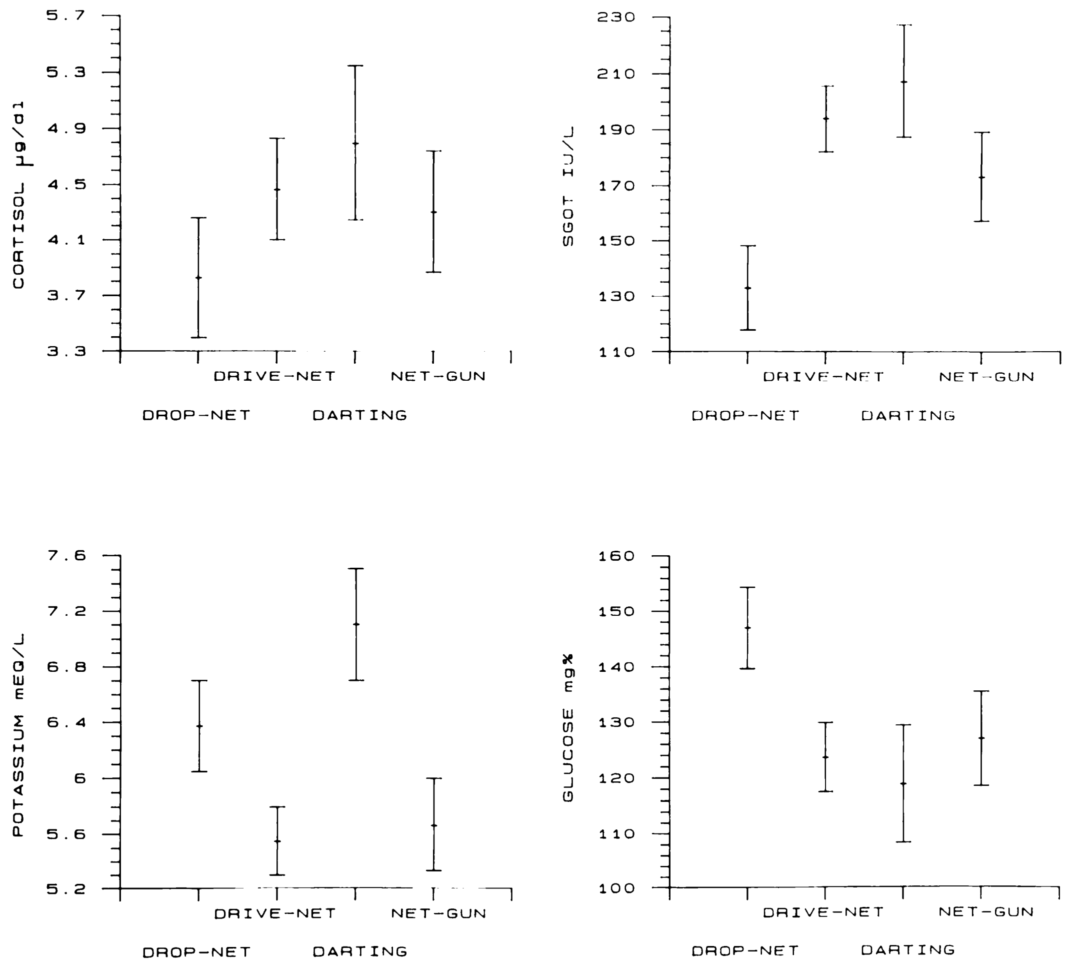


FIGURE 3. Plots of means for significant ($P < 0.05$) biochemical parameters compared among different capture methods.

promise and capture myopathy (Harthoorn, 1982a; Spraker, 1982). Glucose is elevated due to the output of epinephrine from the adrenal gland in response to stress resulting in increased glycogenolysis, and is necessary to provide energy to cells in response to muscle exertion. A metabolic acidosis due to exertional stress is reflected by a blood pH <7.35 and low plasma bicarbonate based on domestic sheep (Gericke and Belonje, 1975; Benjamin, 1978). Therefore, these various biological parameters, due to their significance in the stress response, are useful for comparing the effects of different capture methods used on bighorn sheep.

Other limited comparisons of biological parameters between capture methods have been reported. McDonald et al. (1981) and Bunch et al. (1980) compared physiological and blood parameters in desert bighorn related to two capture methods; drop-net and chemical immobilization, but the sample size was limited ($n = 27$ and $n = 44$, respectively). In comparing data from the current study for sheep captured by drop-net with McDonald's data, we found lower average values of SGOT (133 versus 284 I.U./liter), LDH (649 versus 826 I.U./liter) and glucose (147 versus 226 mg%). Values from sheep captured by chemical immobilization were higher in the current data than those reported by McDonald et al. (1981) (mean body temperature 41.5 C versus 41.0 C, pulse rate 124 versus 115, respiration rate 49 versus 32, glucose 118 versus 98 mg%). These differences may reflect, in part, the difference in sample sizes. A large data base is less influenced by outliers. Alternatively, the differences may be due to other factors such as differences in subspecies, seasonal patterns, variations in assay methods, etc.

Franzmann and Thorne (1970) considered that chemical immobilization minimized the degree of excitement at capture, but they immobilized bighorn sheep from the ground under more controlled conditions than helicopter darting. Our study showed that the latter method adversely affected biological parameters.

The preferential use of nets over chemical immobilization (Kock et al., 1987) to capture free-ranging bighorn sheep is further supported by the present study. Evaluation of biological parameters shows that net capture can cause significant adverse alteration in body homeostasis if a particular capture episode is poorly planned and executed, or if there are no attempts in crucial areas (Kock et al., 1987) to reduce the level of stress related to capture. Because of rapid deployment resulting in short pursuit, capture and processing times, use of the net-gun apparently results in relatively minimal biological compromise. Drop-netting also appears to produce minimal compromise and, if the geographical location of capture is suitable and planning is thorough, it may be the capture method of choice for large groups of bighorn sheep. Our data set was overly influenced by a few poorly planned drop-net capture episodes, further emphasizing the need for adequate planning. Both the drop-net and drive-net have the potential to produce major alterations in several biological parameters, reflecting significant exertional muscle damage and the potential for developing capture stress or compromise and capture myopathy mortality. Animals must

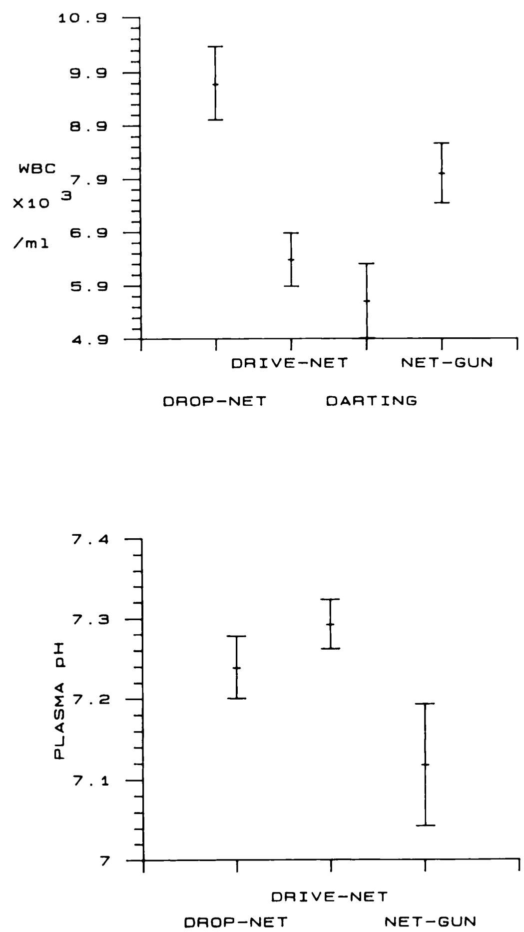


FIGURE 4. Plots of means for significant ($P < 0.05$) biochemical and hematological parameters compared among different capture methods.

be removed from the net(s) efficiently and rapidly and handling times of captured animals should be kept to an absolute minimum. Drop-net, drive-net and the net-gun all appear to produce varying degrees of metabolic acidosis as a result of the stress of capture (Table 4). Harthoorn (1982b) discusses physical aspects of both mechanical and chemical capture and considers physical stress to be a concomitant of capture by drugs. Deaths not due to dart penetration may be induced by acidosis, hyperkalemia and myoglobinemic nephrosis. Based on experiences in Africa, Harthoorn (1982b) recommends that the deleterious effects of chemical capture can be modified or attenuated by prior mechanical herding. In our study of bighorn sheep three methods of mechanical capture were superior to the use of drugs. Therefore, chemical immobilization as a primary means of capture cannot be recommended.

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