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CAPTURE METHODS IN FIVE SUBSPECIES OF FREE-RANGING BIGHORN SHEEP: AN EVALUATION OF DROP-NET, DRIVE-NET, CHEMICAL IMMOBILIZATION AND THE NET-GUN

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ABSTRACT: Six hundred thirty-four bighorn sheep (*Ovis canadensis*) were captured in the western United States between 1980 and 1986, using four different methods: drop-net (n = 158), drive-net (n = 249), chemical immobilization (n = 90) and net-gun (n = 137). The net-gun was found to have considerable advantages over the use of ground nets and chemical immobilization methods for capturing bighorn sheep. Evaluation of specific outcome categories for individual sheep, including normal, compromised (stress-induced), mortality from capture myopathy (CM), and accidental mortality, revealed significant differences in these rates between capture groups ($P < 0.05$). The use of the net-gun resulted in the lowest proportion of compromised sheep at 11% (15/137), had no CM mortality, and resulted in a 2% (2/137) accidental mortality. The use of drop-nets resulted in 15% compromised sheep (24/158), a CM mortality rate of 2% (3/158), and an accidental mortality rate of 1% (2/158). A similar proportion of sheep were compromised with the drive-nets (16%, 39/249). This method also had the highest CM mortality rate at 3% (7/249), and an accidental mortality rate of <1% (2/249). Chemical immobilization resulted in the most compromised sheep at 19% (17/90), had a CM mortality rate of 2% (2/90), and caused the most accidental deaths at 6% (5/90). Drop-nets and drive-nets were comparable when combining total mortality with rates for compromised bighorn sheep, 18% and 19%, respectively (29/158 and 48/249). Chemical immobilization had the highest combined measure of risk at 27% (24/90) and net-gun lowest at 12% (17/137). Advantages of the net-gun, which might account for the lower rates, include rapid and accurate deployment which results in short capture and processing times. The net-gun is highly effective in the capture of individual and occasionally pairs of sheep. Large groups of bighorn sheep can be most effectively captured, with apparently minimal compromise, using ground nets. Chemical immobilization, unless all other alternatives are considered inappropriate, cannot be recommended.

Key words: *Ovis canadensis*, bighorn sheep, capture, drop-net, drive-net, chemical immobilization, net-gun.

INTRODUCTION

Habitat encroachment and reduction has increased the need for active wildlife management techniques such as capture and handling of individual animals. Capture is necessary for relocation, disease investigations, telemetry and biological studies, environmental monitoring and for other research purposes. There have been recent advances in handling methods to minimize the amount of stress imposed on animals and to reduce the risk of mortality at the time of capture. This has been essential because of the expense and logistics of capture, increased public awareness and sensitivity to humane issues and the need to minimize mortality in the management of rare, threatened or endangered species.

There are numerous investigations on wildlife capture and the development of stress-related problems, including capture myopathy (Harthoorn, 1975, 1977, 1982a, b; Bartsch et al., 1977; Barrett et al., 1982; Jessup, 1982; Jessup et al., 1982, 1984; Spraker, 1982; Van Reenen, 1982; Andryk et al., 1983; Bates et al., 1985; Krausman et al., 1985) but few detailed, large scale

studies exist on specific adverse effects of capture methods (Bates et al., 1985; R. Mohr and D. A. Jessup, 1985, unpubl. data).

This paper presents morbidity and mortality rates from four different methods used to capture 634 bighorn sheep, of five subspecies, between 1980 and 1986, in the western United States.

MATERIALS AND METHODS

Four capture methods commonly used on bighorn sheep were evaluated. Three of these methods are described previously (Jessup et al., 1984). The procedure for drop-netting involved the baiting of suitable, flat terrain with either salt, fermented apple pulp and/or alfalfa. This was done initially for a few weeks to months without a net to habituate the animals to the location. Following this, a large standing elevated net was placed and the sheep further habituated prior to dropping the net by remote control. A large group of sheep could be caught at one time by this method.

Drive-netting involved the placement of standing linear nets across either migration routes, small valleys, dry washes or other strategic areas. Usually a total of eight nets was used and the placement of the nets was designed to make escape difficult once the sheep were herded to within 100 m of the net configuration. The herding of individual or groups of sheep towards the nets was performed by a helicopter, and the animals were herded over varying distances.

Chemical immobilization of bighorn sheep involved the pursuit of individual animals by a helicopter, and subsequent darting with a suitable dart projectile fired from a capture rifle. Drugs used included either etorphine (M99, Lemmon Company, Sellersville, Pennsylvania 18960, USA) with xylazine (n = 79) (Rompun, Bayvet Division, Miles Laboratories, Inc., Shawnee, Kansas 66201, USA), or carfentanil (Wildnil, Wildlife Laboratories, Inc., Fort Collins, Colorado 80525, USA) with xylazine (n = 11).

Net-gunning involved the use of a helicopter-mounted (Landells Aviation, Desert Hotsprings, California 94220, USA) or a hand-held four barreled commercial 0.308 cartridge fired net-gun (Coda Enterprises, Inc., Mesa, Arizona 85203, USA). These are described in greater detail in a companion paper (Jessup et al., 1988). These devices were capable of delivering, with great accuracy, a large weighted nylon or cotton blend net, approximately 5 × 5 m in size, from a helicopter over individuals or occasionally pairs of animals.

The effects of the four capture methods were evaluated by placing individual sheep into specific, defined outcome categories within each capture method. These outcome categories were determined by clinical signs, personal observations, and by case record evaluations. Bighorn sheep in Outcome 1 (normal) were those sheep that experienced minimal stress and excitement prior to, during, and after capture. All were released in apparently good health.

Sheep were placed in the compromised category (Outcome 2) when they experienced one or more of the following: body temperature greater than 42.2 C, prolonged pursuit by helicopter, open-mouthed breathing, excessive struggling, clinical evidence of shock and any other evidence of nonfatal capture-related compromise (stress-induced). All these sheep were released following appropriate therapy. Outcome 3 was an infectious disease morbidity category that was not evaluated here. Outcome 4 was a capture myopathy mortality category (CM). These deaths were due to development of peracute, acute or chronic capture myopathy and the cause of mortality was confirmed by gross postmortem signs, blood parameter analyses, and histopathology. Outcome 5, or the accidental mortality category, included bighorn sheep that died from causes other than CM, such as a broken neck.

The data from the 634 bighorn sheep were entered using a microcomputer onto a spreadsheet (SuperCalc 3, 1985, Computer Associates International, San Jose, California 95131, USA). The information was organized by capture method and each file included data coded for subspecies, season, capture method, state (including county and mountain range), age, sex and outcome. Morbidity and mortality rates were tabulated according to outcome (Table 1) and analyzed statistically with a Chi-square test for independence (Daniel, 1983).

RESULTS

Six hundred thirty-four bighorn sheep were captured (Table 1). Evaluation of the age distribution within capture method shows that young sheep were over represented in the drop-net and drive-net groups, and older animals are over represented in the chemical immobilization and net-gun groups. This demonstrates the selectivity of the latter two capture methods. There was no apparent association between gender and capture method. Males and females were represented about equally in each capture group. Five sub-

TABLE 1. Numbers of bighorn sheep captured by four capture methods and the distribution of age and sex within and across capture methods.

	Drop-net	Drive-net	Chemical immobilization	Net-gun	Total numbers captured
Totals	158	249	90	137	634
Sex					
Male	40% (35/158)	42% (78/249)	34% (31/90)	33% (45/137)	189
Female	78% (123/158)	58% (171/249)	66% (59/90)	67% (92/137)	445
Age					
0–2 yr	40% (64/158)	36% (90/249)	13% (12/90)	17% (23/137)	189
>2 yr	60% (94/158)	64% (159/249)	87% (78/90)	83% (114/137)	445

species were captured, with the majority being desert bighorn sheep (*Ovis canadensis nelsoni*) (n = 369). The other four subspecies were California bighorn sheep (*O. canadensis californiana*) (n = 98), Rocky Mountain bighorn sheep (*O. canadensis canadensis*) (n = 60), peninsular bighorn sheep (*O. canadensis cremnobates*) (n = 59), and Mexican bighorn sheep (*O. canadensis mexicana*) (n = 48). The numbers of bighorn sheep were evaluated also according to season of capture and the seasons were based on the accepted calendar dates. One hundred sixty bighorn sheep were captured in the spring, 116 in the summer, 203 in the fall, and 155 in the winter. Of the total number of sheep captured 403 were from California, 15

TABLE 2. Comparison of outcome rates between four different methods of capturing bighorn sheep, number of animals in the normal outcome category, number of compromised animals (C), mortalities related to capture myopathy (CM), mortalities due to causes other than CM, total number of mortalities, CM mortality plus compromised bighorn sheep and total mortalities plus compromised bighorn sheep.

	Capture method				
	Drop-net	Drive-net	Chemical immobilization	Net-gun	Totals
Normal	114 (72%)	191 (77%)	63 (70%)	106 (77%)	474 (75%)
Compromised	24 (15%)	39 (16%)	17 (19%)	15 (11%)	95 (15%)
CM mortality	3 (2%)	7 (3%)	2 (2%)	0 (0%)	12 (2%)
Other mortality	2 (1%)	2 (<1%)	5 (6%)	2 (<2%)	11 (2%)
Total mortality	5 (3%)	9 (4%)	7 (8%)	2 (<2%)	23 (4%)
CM mortality plus C	27 (17%)	46 (19%)	19 (21%)	15 (11%)	107 (17%)
Total mortality plus C	29 (18%)	48 (19%)	24 (27%)	17 (12%)	118 (19%)

from Idaho, 39 from Washington, 37 from New Mexico, 12 from Montana, 19 from Arizona, 50 from Nevada, nine from South Dakota and 50 from Utah.

Outcome data are summarized in Table 2. A Chi-square test for independence indicated normal outcome, compromise rate and total mortality were significantly associated with capture method ($P < 0.05$). The CM mortality rate at <2% and the mortality rate from other causes at <2% for the total data set were low when compared to the total number of sheep captured ($n = 634$), indicating generally acceptable loss rates. The 0% CM mortality in net-gun capture is noteworthy, although there was a <2% accidental mortality rate associated with this capture method. Drive-netting had the highest CM mortality rate at <3%, but the lowest accidental mortality rate at <1%. Chemical immobilization of bighorn sheep from a helicopter produced a 6% accidental mortality rate and a total mortality rate of 8%. Combined total mortality and compromise rate was highest for darting (27%), with drive-net and drop-net next (19% and 18%, respectively). Combined risks for net-gun (12%) capture remained the lowest.

DISCUSSION

Few detailed reports evaluate the effects of different capture methods on bighorn sheep. Jessup et al. (1982) reported preliminary findings on stationary corral trapping, drive-netting, darting, drop-netting and miscellaneous procedures on different subspecies of bighorn, but the sample sizes were too small to reach any definite conclusions. Other reports have been limited similarly by sample size and usually compare only two methods. Andryk et al. (1983) compared the use of the net-gun to darting, reporting no ill effects in 12 sheep captured by the net-gun. Ten sheep darted with etorphine and xylazine recovered without serious problems, but three of these died within 2 mo of capture. It was not clear if these deaths were related to the capture episode. These authors found both techniques suitable for the capture of mountain bighorn sheep, but the conclusions were based on limited data.

Bates et al. (1985) compared the drive-net to darting and reported 23% mortality in 147 desert bighorn sheep chemically immobilized between 1972 and 1980. Because of this excessive mortality, drive-nets were used in the following years, successfully catching 136 sheep with a mortality rate of only 2% (3/136) between 1981 and 1984. Trauma accounted for many of the deaths occurring with drug-containing projectile darts ($n = 16$), while a similar number were considered to be stress induced ($n = 14$). The authors concluded that netting eliminated the physical injuries caused by darting and preferred this method. De Vos and Remington (1981) reported only 3% mortality in 165 darted desert bighorn sheep.

Our study suggests that chemical immobilization of bighorn sheep results in a significantly higher risk of mortality, especially of accidental death, when compared to drop-net, drive-net and the net-gun. Additionally, this method produces a high number of compromised animals (19%).

Comparison of the outcome rates between the four capture methods shows the net-gun results in the lowest percentage of compromised sheep and has a low risk of subsequent capture myopathy. However, it should be noted that since this study was completed a single ewe caught by the net-gun in California has shown signs of chronic capture myopathy, but survives in the free-ranging environment. Barrett et al. (1982) reported two CM mortalities out of three sheep caught with a net-gun, and concluded it may not be suitable for capturing species susceptible to CM. Our study disagrees, because none of the animals caught with the net-gun succumbed to CM mortality. However, accidental mortality may still be a risk with this method.

The use of drop-nets and drive-nets re-

sulted in similar numbers of compromised animals. Mortality rates with both of these capture methods were lower than those captured by chemical immobilization. This finding confirms results reported by others (Bates et al., 1985). The outcome rates for drop-netting may have been biased in our study by one capture episode that was attempted with a capture crew that was too small. This resulted in many drop-netted sheep remaining under the net for extended periods before processing.

The use of nets to capture wild animals remains controversial. Indeed, Harthoorn (1977) considered the mortality rate in animals captured by drive-netting to be unacceptably high based on experiences in Africa. The results of the present study do not support this contention. The drop-net and drive-net appear to be relatively safe for the capture of groups of bighorn sheep and the net-gun appears to be one of the safest capture methods for individual animals. Van Reenen (1982) reported considerable success using the net-gun to capture red deer (*Cervus elaphus*) in New Zealand.

RECOMMENDATIONS

The major concern of wildlife professionals with capture and relocation is to maintain losses and stress related compromise to an absolute minimum, not only at the time of capture but during processing and following release. Based on our study, preventive management procedures for the capture of bighorn sheep can be established. These include adequate initial justification for the capture, training personnel in methods of capture, proper animal handling techniques, personal safety and animal health problems related to stress of capture, and utilizing experienced wildlife professionals. This process should consist of continuing education workshops to train new people and retrain experienced biologists and managers. Organization and preparation before the capture should keep handling times to less than 10 min and therefore the compromise associated with prolonged handling to a minimum.

TABLE 3. Medication recommendations for compromised or potential capture myopathy in bighorn sheep.

Drug	Dose per 27–75 kg
Prednisolone sodium succinate (Solu-Delta-Cortef, 100 mg/ml)[a]	150–800 mg i.v.[d]
Sodium bicarbonate[b]	25–50 mEQ i.v. 100–200 mEQ i.p.[e]
Lactated Ringers Solution[c]	½–2 liters i.v. or i.p.

[a] Rugby Laboratories, Inc., Rockville Centre, New York 11570, USA.
[b] Med-tech, Inc., Elwood, Kansas 66024, USA.
[c] Travenol Laboratories, Inc., Deerfield, Illinois 60015, USA.
[d] Intravenously.
[e] Intraperitoneally.

Routine treatment of all animals should include long-acting antibiotics and vitamin/selenium in areas where soils are lacking in trace elements. Veterinary expertise should be available to evaluate and treat compromised or injured bighorn sheep and assist in the overall planning of capture. Specific treatment of compromised and potential CM animals should involve fluids, sodium bicarbonate and corticosteroids (Table 3), preferably intravenously. Hyperthermia (>41.9 C) should be vigorously treated with cold water, ice or snow externally or with a rectal enema. Rapid processing at the capture site and subsequent helicopter transport to base camp will aid in cooling animals.

More specific management procedures must be related to the method of capture. The total number of sheep from all capture methods in the compromised category (n = 95, 15.0%) caused some concern in the present study, and needed improvement. This reveals that none of the four capture methods are without stress-related problems. Therefore, an understanding of the effects of prolonged pursuit, physiological

compromise and shock is essential. Ultimately, the selection of the most appropriate method of capture will determine whether bighorn sheep are caught successfully and with minimal compromise.

Our results suggested that the net-gun has a potential for the selective capture of bighorn sheep for disease surveys, for biological data collection and individual marking, and as a supplement to drive-netting for relocation purposes. Considerations concerning this capture method include utilizing the most experienced and skillful helicopter pilot and net-gunner and an appropriately powered helicopter (Jessup et al., 1982). As shown by Jessup et al. (1988), net-gun capture is inherently dangerous and there must be absolute adherence to safety procedures. Experience suggests that successful use of the net-gun requires terrain that has some brush and other natural obstacles but not thick cover, otherwise animals may run for considerable distance before becoming entangled or eventually escape. The catching of the net on these obstacles will aid in the firm entanglement of the sheep. There may be considerable difficulty in net-gunning sheep under windy conditions at high altitude in shallow snow due to improper net placement over the animal and failure of the net to catch on surrounding obstacles (D. A. Jessup and R. K. Clark, pers. obs.). Although the net-gun can be used to capture pairs of sheep, this may result in trauma to one or both of the animals. Capture of more than two sheep is not recommended since entanglement often is so severe that handling is prolonged. When firing the net-gun the operator should not attempt capture on steep cliff faces or where rocks may deflect the net weights into the main or tail rotors of the helicopter. Preferably sheep should be herded down to flat terrain or sand washes or up short distances to mountain passes avoiding trees and cactus, and adjacent to terrain where the helicopter can land safely and quickly. The net-gun should only be fired when the animal being pursued is running parallel to the direction of the helicopter into a "window area," avoiding the helicopter skids. The rear weights of the net should contact the ground in the same plane as the animal's rear legs while the front weights deploy the net in a curtain so that the animal runs into it, insuring quick restraint.

Chemical immobilization is not recommended based on our study, except under special circumstances. These include foliage too dense for net-gunning and when very few selected individuals are to be captured. It requires highly trained personnel experienced in the use of a helicopter, knowledgeable in drug pharmacology and safety, with an understanding of animal anatomy and physiological responses to stress, and proficiency in the use of the dart-gun.

Drive-netting and drop-netting are highly effective in the capture of groups of bighorn sheep. General considerations include knowledge that drop-netting requires considerable planning and time and that it is essential to have an adequate number of personnel available (at least 1.5 to 2 people per animal captured). Drive-netting is similar in requirements to the drop-net. The helicopter herding of bighorn sheep must be conducted slowly until the last minute, and prolonged pursuit must be avoided ($\leq$10 min continuous herding). Animals should be closely monitored for signs of stress, rested frequently and herding halted if the animals' survival is threatened. Herding of large groups of sheep ($>$10 to 12) should be avoided. If accomplished efficiently, both the drop-net and drive-net produce relatively low compromise and mortality rates. Presently, the use of nets appears to provide the most satisfactory method for capturing free-ranging bighorn sheep.

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