5-1985

Behavioral Response of Desert Bighorn Sheep to Human Harassment: A Comparison of Disturbed and Undisturbed Populations

Michael M. King
Utah State University

BEHAVIORAL RESPONSE OF DESERT BIGHORN SHEEP TO HUMAN HARASSMENT: A COMPARISON OF DISTURBED AND UNDISTURBED POPULATIONS

by

Michael M King

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Fisheries and Wildlife

Approved:

Major Professor	Committee Member
Committee Member	Committee Member
Committee Member	Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1985

ACKNOWLEDGEMENTS

My sincerest thanks go to the many people and agencies who cooperated to insure the success of this project. The Bureau of Land Management (BLM) provided the major funding for the study. BLM wildlife biologists Joe Cresto and Rich McClure shared their knowledge of the bighorn and the area as well as making sure everything with respect to the administration of the contract to USU went smoothly.

The Utah Division of Wildlife Resources (UDWR) captured and collared desert bighorn monitored during the study. They also donated fixed-wing aircraft flights, a four-wheel drive vehicle, and lodging for myself during the course of the project. UDWR biologists James Bates and Derris Jones were particularly helpful when animals were being captured and collared. Val Judkins, UDWR pilot, flew fixed wing telemetry flights on a monthly basis. His visits were most appeciated and welcomed.

Special thanks go to the members of my doctoral committee at Utah State University. Drs. Gar W. Workman, Barrie K. Gilbert, Phillip J. Urness, Jessop B. Low, and Donald V. Sisson reviewed this dissertation and provided much needed direction throughout the study until its completion. Dr. Sisson along with Dr. David White assisted with the statistical analyses.

My deepest appreciation goes to Dr. Gar W. Workman, my major professor, for having the foresight and determination to get such

a project off the ground. I am especially grateful to him for selecting me to work on the project, thus allowing me the opportunity to work in such a fascinating place with an intriguing animal. Without his encouragement and support, completion of this project would not have been possible.

My friend Carl Mahon introduced me to desert bighorn and their habitat in southeastern Utah as he has done to with so many others. For the education I recieved from him about desert bighorn sheep, I am most indebted.

I thank Bill Hull, fellow sheep biologist, for his most welcomed visits while in the field. His friendship during the course of the study was most appreciated.

I would like to especially thank my family and my wife's family for the continued support they have given to me throughout my graduate program. They were especially helpful to me and my wife and children while I spent extended periods away from home. My mother and father were especially supportive as they have been in all that I have done throughout my life.

I thank my wife and children, Megan, Mikelle, and Tyler, for trying to understand why I had to spend so much time away from home and family. The appreciation I feel for my wife, Jan, cannot be adequately expressed. Her continual support throughout all the difficulties and discouraging times was the driving force behind my efforts. She truly deserves equal credit for the completion of this degree.

Michael M King

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF FIGURES (Cont.)

ABSTRACT

Behavioral Response of Desert Bighorn Sheep to Human Harassment: A Comparison of Disturbed and Undisturbed Populations

by

Michael M King, Doctor of Philosophy

Utah State University, 1985

Major Professor: Dr. Gar W. Workman
Department of Fisheries and Wildlife

Desert bighorn sheep (Ovis canadensis nelsoni) response to human disturbance was evaluated in southeastern Utah from 1981-1983. Bighorn response was compared between the Red Canyon area, an area with relatively high levels of human disturbance, and the White Canyon area, an area with relatively low levels of human disturbance. Bighorn were deliberately harassed by vehicles and hikers and immediate response and distance fled were recorded. When bighorn remained in the presence of the harassing stimuli, actual time spent in and proportion of animals engaged in various behaviors were recorded to determine group wariness and activity budgets under harassed conditions. Bighorn were also observed under unharassed conditions to compare behavior between harassed and unharassed conditions.

Red Canyon bighorn responded more severely to harassment

trials than White Canyon bighorn. Response by Red Canyon bighorn was generally running flight whereas White Canyon bighorn responded most often with non-flight behaviors. Group wariness was greater for Red Canyon bighorn than White Canyon bighorn when bighorn were exposed to continuous harassment. Activity budgets of unharassed bighorn were similar between areas, however, activity budgets of harassed animals differed significantly between areas particularly with respect to attention and feeding behaviors. Red Canyon bighorn were at attention longer and fed less than White Canyon bighorn under harassed conditions.

Energy-nutrient relationships, hunting ramifications, and management implications as they relate to harassment of desert bighorn sheep in southeastern Utah are discussed.

(137 pages)

INTRODUCTION

Major declines in North American wildlife populations have been attributed to the advent of European man (Kimball and Johnson 1978, Wagner 1978). However, the specific effects of human disturbance on the biology of wildlife have received little study until recently. The extent of our knowledge is generally limited to documentation of range abandonment or population decline and speculation about possible causes. Few studies deal with more subtle, but equally interesting and, perhaps, more important areas of how human disturbance affects physiology, bioenergetics, population dynamics, ecology, and behavior of disturbed species. This is, no doubt, a direct result of the difficulty involved in collecting such data in field-oriented studies. However, in light of increasing potential for disturbances associated with an expanding human population, information on the effects of human disturbance will be needed to predict impacts on wildlife populations (Sinclair 1979).

Bighorn sheep (Ovis canadensis spp) have been particularly susceptible to human disturbances. Buechner (1960) concurred with Seton's (1929) estimate of 1.5 to 2 million bighorn sheep in North America prior to the advent of European man. However, Wagner (1978) suggested that those estimates might be somewhat conservative based on the widespread distribution of bighorn depictions in native American rock art and bighorn remains at archaeological sites in western America. Bighorn numbers dropped

radically during the latter half of the nineteenth century to an estimated low of approximately 45,000 in 1978 (Wishart 1978). Biologists agree that expansion of human influence westward into bighorn habitat was most likely responsible for reduced numbers (Trefethen 1975, Lawson and Johnson 1982). Declines occurred in northern bighorn (Cowan 1940, McCann 1956, Buechner 1960, Stelfox 1971) as well as in the southern races of desert bighorn (Russo 1956, Wilson 1968, McQuivey 1978, Wehausen 1980, DeForge 1980). Several varied factors, including habitat destruction, vegetation alteration, unrestriced hunting, and problems associated with the introduction of domestic livestock have been cited as reasons for bighorn losses (Wilson 1968, Galliziolli 1977, McQuivey 1978, Wagner 1978, Wehausen 1980, Bailey 1980, McCutchen 1981, Hansen 1982, Goodson 1982, Foreyt and Jessup 1982).

Several management practices ranging from transplant and reintroduction programs to complete protection have been initiated to check falling bighorn numbers and restore them to former ranges (Trefethen 1975, Wishart 1978, Wehausen 1980 Rowland and Schmidt 1981, Lawson and Johnson 1982). Despite all these efforts, many pertinent questions regarding human disturbance remain unanswered. Little research has been conducted to determine how bighorn are being affected behaviorally or physiologically. Geist (1975a) and Miller and Gunn (1979) have pointed out the deficiency of systematic studies with respect to harassment for virtually all wildlife species, citing inappropriate research design and timing as major drawbacks to the study of harassment. Most information now

available has come tangentially from studies with other primary objectives and is fragmentary at best. Information now available on how human disturbance affects bighorn sheep is no exception.

In light of the lack of knowledge regarding harassment effects on bighorn sheep this study was initiated to systematically compare bighorn sheep behavior in areas where bighorn have been exposed to contrastingly different disturbance regimes. An opportunity to study bighorn sheep under such conditions existed in San Juan County, Utah in the Red Canyon and White Canyon areas.

OBJECTIVES

The purpose of this study was to determine if desert bighorn sheep that occupy an area of southeastern Utah with a relatively high level of human disturbance (Red Canyon area) exhibit behavioral differences compared to desert bighorn sheep that occupy an area with a relatively low level of human disturbance (White Canyon area). The way in which animals respond and budget their time with respect to proximate variables is of particular interest to behavioral ecologists (Bekoff and Wells 1981) . Particularly meaningful are responses and resultant activity patterns as a result of human disturbance. In this light, two specific areas were investigated with the intent of determining how bighorn behavior is affected by human disturbance and evaluating the usefulness of overt behavior as an indicator of levels of harassment. This analysis included immediate response to harassment stimuli and, secondly, alteration of activity patterns under conditions of harassment. The following two major objectives were addressed and their accompanying hypotheses were tested:

1. To study differences in behavioral response by desert bighorn to human harassment in the Red Canyon and White Canyon areas of southeastern Utah with respect to severity of immediate response and distance fled.

Null Hypotheses:

a. Immediate response by desert bighorn to human harassment will not differ for Red Canyon and White Canyon areas.
b. Distance fled by desert bighorn after human harassment will not differ for Red Canyon and White Canyon areas.

2. To evaluate differences in activity budget for desert bighorn for Red Canyon and White Canyon areas under harassed and unharassed conditions with respect to major behavioral categories.

Null Hypotheses:

a. There will be no difference in group wariness between desert bighorn in Red Canyon and White Canyon areas during periods of prolonged human harassment.
b. Activity budgets for desert bighorn sheep will not be different for Red Canyon and White Canyon areas under harassed and unharassed conditions with respect to amount of time spent in each behavior category and number of individuals involved in each behavior category.

LITERATURE REVIEW

Geist (1975a) defined harassment as any stimulus that causes an excited state in an animal. This level of excitement may vary from low levels characterized by slight elevations in heart rate to high levels characterized by panic and severe exertion resulting from flight. Harassment or disturbance to wildlife populations occurs when people and wildlife come together. This is especially important now as demands for construction, mineral exploration and extraction, tourism, and recreation increase and expand into remote areas, thereby increasing the chances of man-animal interaction.

These confrontations between humans and wildlife present new learning experiences to animals. The appearance of human activities causes a change in an animal's environment and the animal will respond in an attempt to adapt to the change (Miller and Gunn 1979). If the change creates a novel stimulus, animals generally undergo an alarm reaction as they ready themselves for flight (Selye 1973). If a negative experience follows, animals form a strong aversion towards the stimulus object or situation. Future exposure to the same stimulus or similar stimuli to which the animal might generalize the negative experience (Fantino and Logan 1979), can result in elevated levels of excitement or avoidance of the area where the disturbance occurred (Geist 1971a, 1975a, Horesji 1976). Besides range abandonment, disturbance can cause neurosis and increased metabolism which

competes for energy at the expense of growth and reproduction (Liddell 1961, Blaxter 1962, Geist 1971a, Geist 1975a). These factors can lead to weight loss, loss of appetite, malfunctioning horn growth, increased susceptibility to predation, reduced reproduction or death. Generally, animals tend to seek predictable environments (Geist 1979) in which to live. Therefore, disturbance is most detrimental if frequent and unpredictable so that the animal cannot escape it (Geist 1975a, DeForge 1980).

If the stimulus is neutral and poses no threat, animals habituate to or ignore the stimulus or similar stimuli (Geist 1975a, 1978, Horesji 1976, Fantino and Logan 1979). Failure to ignore innocuous stimuli wastes valuable time and energy as the animal engages in uneconomical behavior (Klopfer 1973, McCullough 1982). If the stimulus is positively reinforcing, animals can be expected to approach it (Stokes 1970, Geist 1971a). In other words, an animal's behavior toward humans is primarily a consequence of human behavior toward the animal. Animals behave the way humans teach them to behave (Geist 1971a). There is no reason to believe that wildlife cannot live in close proximity to man given that activities of man do not present disturbing stimuli (Parker and Graham 1971, Cowan 1974). This is evidenced by many examples of wild animals becoming habituated to human researchers that pose no threat (Welles and Welles 1961, Holdroyd 1967, Geist 1967) and tameness of wildlife in national parks or other areas where they are protected from hunting and other negative experiences (Geist

1971a, 1975a, Horesji 1976, Thorne et al. (1978), Hicks and Elder 1979). This encourages researchers to determine which stimuli from the wide spectrum of stimuli presented to wildlife by man are the most harmful so they can be averted when man and animals interact.

Geist (1975a) provided significant insight into the field of human disturbance or harassment to wildlife. Along with providing a working definition of harassment, he suggested a framework for future study by synthesizing existing information on the effects of harassment from several different scientific fields. Geist identified three major effects that harassment can cause to wildlife dependent on the level of excitement in the animal. First, metabolism is elevated at the expense of body growth, development, and reproduction. The result of excitation is highly variable, but chronic excitement can increase metabolism by as much as 25 percent above maintenance (Geist 1975a). In addition to excitation, harassment can cause animals to increase energy-inefficient activities such as running and climbing that can exceed basal metabolism by as much as 8 to 20 times (Moen 1973, Brockway and Gessaman 1977, Gates and Hudson 1978). Second, harassment can lead to accidents, death, illness, and reduced reproduction due to secondary effects of exertion. Not only is physical exertion metabolically costly, it can lead to damaged body tissues as well (Chalmers and Barrett 1982). Depressed body condition resulting from harassment can increase susceptibility to bacterial and viral infections (McFarlane 1976, Thorne et al. 1978, Sinclair 1977, DeForge 1981). Third,

harassment can lead to avoidance or abandonment of areas where negative stimuli have been experienced. This may lead to reductions in range, quality habitat, or food resources. Several studies have demonstrated that animals avoid areas where humans disturb them (Ward et al. 1972, Ward 1973, Schultz and Bailey 1978, Miller and Gunn 1979, Morgantini and Hudson 1979, Rost and Bailey 1979, Irwin and Peek 1980).

There is evidence in the scientific literature to suggest all three major effects of harassment discussed by Geist are operational in bighorn sheep populations. Bighorn have abandoned many areas of historic use after human disturbance (Nelson 1966, Geist 1971b, Douglas 1976, Horesji 1976). Activity and habitat use patterns have also been altered in some areas that have been altered by man (Jorgensen 1974, Leslie and Douglas 1980, Campbell and Remington 1981). DeForge (1981) has suggested that poor body condition and small horn size of bighorn in a few areas in southern California was attributable to stress imposed by human disturbance.

Horesji (1976) further categorized harassment into forms he termed active and passive. Active harassment, a result of approach or pursuit, causes an obvious change in activity and results in flight. Passive harassment results from the mere presence of humans within an animal's home range and does not usually cause flight but elevation of excitement levels. As a result the effects of passive harassment are subtle and difficult to ascertain. In both cases energy expenditure is increased and animals are prevented from exploiting their environments as they

normally would had the harassment not occurred.

A few studies have provided some insight into the effects of human disturbance on bighorn behavior. Wehausen et al. (1977) and Wehausen (1980) studied the effects of human approach on bighorn in the Sierra Nevada, California. He found, as might be expected, that closer approach, particularly from above, caused a more extreme response. Ewes with lambs were more reactive than ram groups, particularly in the spring and summer seasons. Based on this information, Wehausen recommended that caution should be used by land management agencies in setting quotas for backcountry recreationists, particularly during the time when lambs are still dependent on their mothers.

Hamilton (1982), Hamilton et al. (1982), and Holl and Bleich (1983) studied the effects of vehicle and human approach on bighorn behavior in the San Gabriel Mountains, California. As Wehausen (1980) found, the closer bighorn were approached by both vehicles and humans the more severely they responded. However, they concluded that heavy trail use by hikers (over 14,000 hikers from June to September) through bighorn habitat did not cause bighorn to abandon areas next to trails. Hicks and Elder (1979) found similar results in areas of high hiker use in the Sierra Nevada. Although bighorn did not abandon areas of heavy hiker use in the San Gabriel Mountains, they did alter their activity patterns, particularly at mineral licks. Licks were not used by bighorn while hikers were in close proximity to the lick area. Bighorn waited until humans left the lick before entering the lick area themselves. Holl and Bleich (1983) also found that

responses were affected by season, sex, habitat type, frequency and type of encounter between bighorn and people.

Bates (1982) found, as Geist (1971b) had, that escape terrain was an important component of bighorn habitat. Bighorn farther from escape terrain reacted more severely than bighorn in close proximity to escape terrain. Bighorn that were close to escape terrain often moved only short distances after being exposed to various types of human disturbance.

Wehausen (1983) also found that habitat played an important role in determining how flight prone bighorn were in the White Mountains, California. He found bighorn that were disturbed in open terrain had longer flight distances (Walther 1969) than those disturbed in or near rocky canyons. He also found, as he had earlier in the Sierra Nevada, that as lambing season approached, ewes became increasingly more wary.

Although Horesji (1976) did not research the effects of harassment specifically, he made several interesting observations based on his experience in the field. He pointed out, as Hansen (1970) and Geist had (1971b), that hunting had a definite effect on bighorn behavior. They suggested that hunted populations of bighorn were more wary than unhunted populations, as tolerant individuals had most likely been culled by hunters. Unhunted animals, such as those in national parks, have shorter flight distances than hunted animals. Geist (1971b) cited an instance where heavy hunting pressure of Rocky Mountain bighorn in Canada had caused rams to abandon their home ranges permanently. Batchelor (1968, in Geist 1975a) noted similar shifts in habitat

use by red deer (Cervus elaphus) and chamois (Rupicapra rupicapra) after they had been hunted heavily as a means of pest control in New Zealand.

Thorne et al. (1978) also suggested that hunting would negatively affect bighorn populations, especially if ewe hunts were initiated. They feared that ewes would abandon critical winter range if hunted, which would in turn restrict ewes to suboptimal range and lead to reduced lamb production.

Geist (1975b) and Horesji (1976) also made the point that in areas where hunting occurred, other humans such as hikers, geologists, miners, livestock operators, etc., could be presenting a stimulus to bighorn that could not be differentiated from hunters. Thus those activities could be presenting a negative experience every time bighorn were exposed to them. They suggested possible consequences of continuous exposure to these activities could result in sheep that are nervous and exhibit increased alertness, pacing, prolonged staring, and more severe flight. They also predicted that sheep exposed to excessive harassment would become more secretive, more inefficient at conversion of food resources into usable energy, and more likely to use areas of less favorable habitat. Geist (1971a, 1975b) suggested that consumptive uses (hunting) and nonconsumptive uses (photography, hiking, etc.) are not compatible in the same areas and encouraged wildlife managers to set aside natural areas where hunting would not be allowed so interpretive programs for nonconsumptive users could be established.

MacArthur et al. (1979, 1982) conducted heart rate telemetry

and behavioral studies on free-ranging Rocky Mountain bighorn sheep (*O. c. canadensis*) in the Sheep River Wildlife Sanctuary, Canada, under various behavioral and environmental conditions. They found that cardiac and behavioral responses were greatest when bighorn were approached by humans accompanied by a dog or from above over a ridge. Reactions to road traffic and aircraft were only significant if distance to disturbance was relatively close (within 400 m, 437 yds). Increased heart rates as a result of disturbance were discovered that were not evident from overt behavior alone. However, mean duration of increased cardiac response was not greater than mean period of behavioral reaction. They concluded that heart rate telemetry and behavioral observation were both valuable tools in assessing impacts of human disturbance on wildife populations, though the expense of heart rate telemetry is often prohibitive.

Despite all the information available about bighorn reaction to human disturbance, there have been no studies that actually compare harassed populations to unharassed populations to determine behavioral differences. However, Berger et al. (1983) did take a novel approach and compared behavior of pronghorn (*Antilocapra americana*) in disturbed and undisturbed areas. They concluded that pronghorn in the disturbed area were more vigilant (spent more time scanning their environment during feeding bouts) and, therefore, foraged less efficiently than conspecifics from undisturbed areas. When deliberately harassed, animals from the disturbed area expended more energy in escape effort (ran farther at a faster rate) than

pronghorn from the undisturbed area. Animals in the disturbed area also displayed heightened alarm responses as indicated by a greater percentage of clumped flights, more piloerection, and greater delay in resumption of feeding when compared to animals from the undisturbed area.

Though all aspects of the effects of human disturbance on wildlife are of value to wildlife managers, ways that disturbances alter normal behavior patterns are particularly meaningful. Behavior exhibited in response to harassment incidents can be observed without sophisticated and expensive equipment and may prove to be useful as an indicator of disturbance levels.

DESCRIPTION OF STUDY AREA

Topography and Geology

The desert canyons and mesas of San Juan County, Utah, provide generally suitable habitat for desert bighorn sheep. Stable populations of desert bighorn live along the Colorado River and Lake Powell and in the rugged canyons that drain into the lake and river. The area between Dark Canyon to the north, Red Canyon to the south, and Lake Powell to the west, and Natural Bridges National Monument to the east was selected specifically for the study (Figure 1). The study area, approximately 310 square km (190 square miles), is administered by the Bureau of Land Management and the National Park Service.

The area is part of the Colorado Plateau and consists of a gently westward dipping plateau that has been deeply cut by Dark, White, and Red Canyons and their tributaries (Thaden et al. 1964). High mesas, steep cliffs, precipitous talus slopes, and valley floors dissected by deep inner canyons are common throughout the area. A high divide nearly 24 km (15 miles) long, the Wingate Mesa, separates White and Red Canyons (Figure 1). Elevations range from 1128 m (3700 feet) on the shores of Lake Powell to over 2134 m (7000 feet) on several of the mesa tops.

Major geologic formations in the area (Figure 2) include the Cutler formation, a light colored sandstone that forms valley floors often cut by narrow inner canyons; the Moenkopi formation, a chocolate colored sandstone that forms cliffs and talus slopes

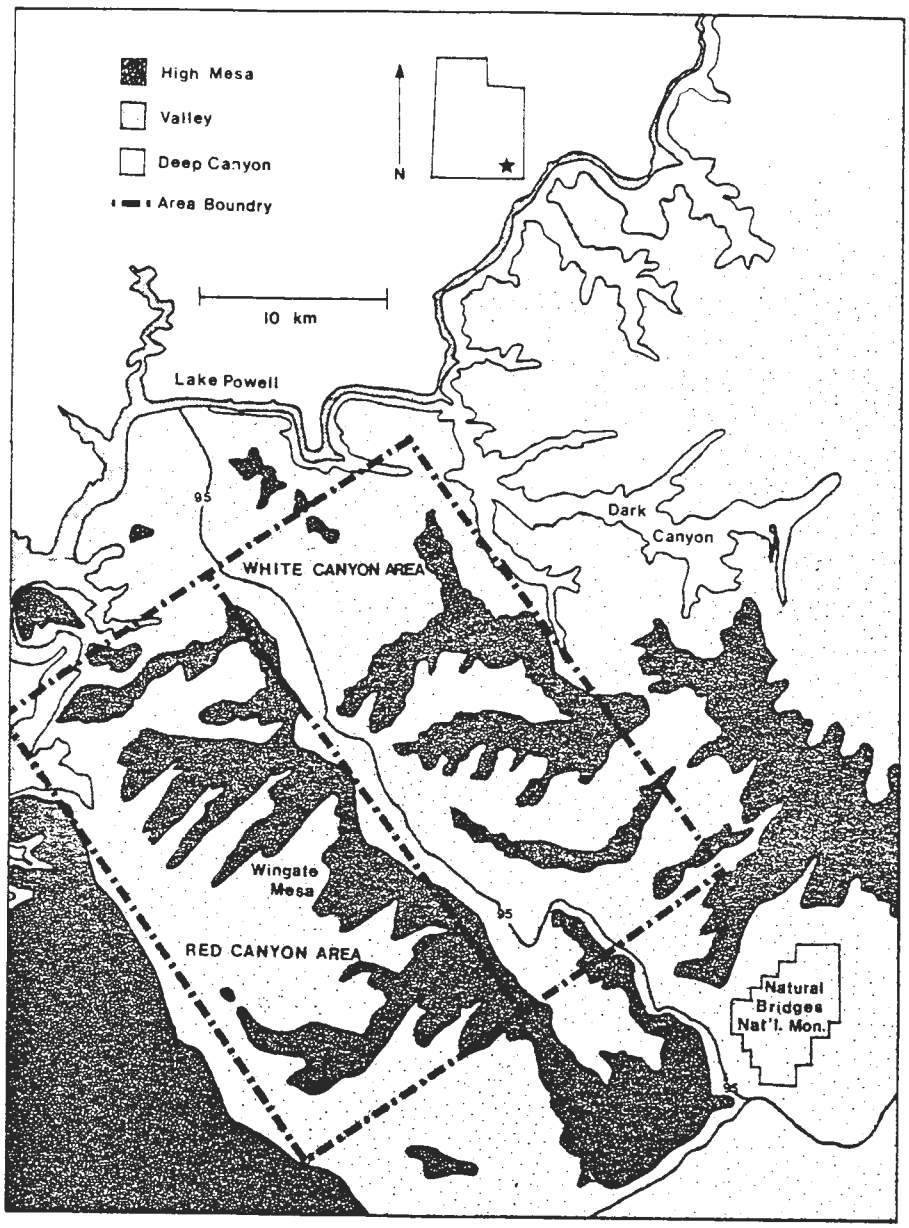

Figure 1. Red and White Canyon study areas in southeastern Utah.

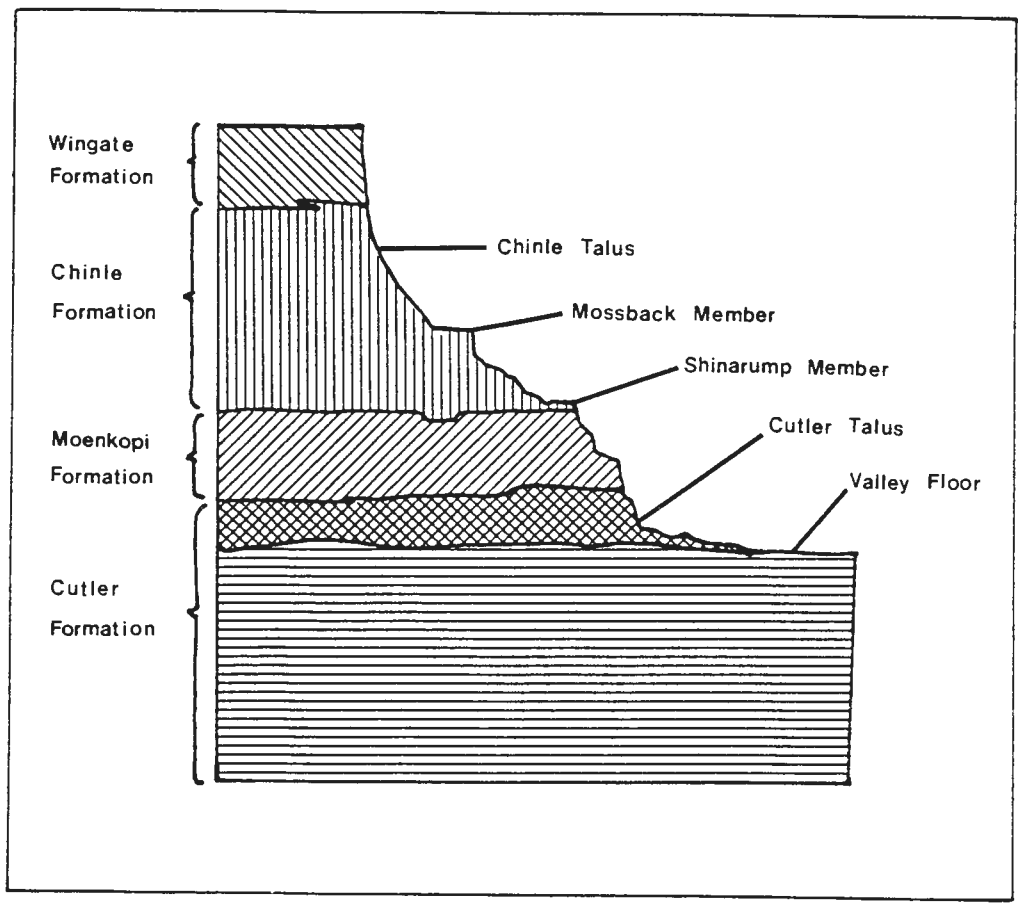

Figure 2. Geologic profile of the Red and White Canyon study areas.

above the Cutler valley floors; the Chinle formation, an easily erodable limestone-sandstone-claystone-siltstone that forms reddish talus slopes above the Moenkopi; the Wingate formation that forms an unscalable cliff approximately 91 m (300 feet) thick above Chinle slopes; and the Navajo and Kayenta formations that form a sandstone caprock on top of the Wingate (Thaden et al. 1964).

Vegetation

Various plant communities are found in the area and are controlled by altitude, topography, water availability, and soil type (Thaden et al. 1964, Loope 1977). Common plant communities found in the area include: (1) blackbrush (Coleogyne ramosissima)-galleta grass (Hilaria jamesii) on many valley floors and lower benches, (2) shadscale (Atriplex confertifolia)-ephedra (Ephedra spp.)-galleta grass common on higher south and east facing slopes and benches, (3) pinyon pine (Pinus edulis)-Utah juniper (Juniperus osteosperma) found on mesa tops, rims, and valley floors, and (4) salina wild rye (Elymus salinus)-galleta grass on higher north and west facing slopes (Wilson 1968).

Climate

Precipitation varies with location. Generally, annual average precipitation increases in eastern locations throughout the area. Natural Bridges National Monument at the eastern boundary of the area receives an annual average precipitation of

about 38 cm (15 inches), while Hite Ranger Station at the western boundary of the study area receives an annual average of only about 23 cm (9 inches). Distribution of precipitation is seasonal, although the monthly rainfall from year to year is highly variable. Generally fall and winter are the wettest seasons, while spring and summer are the dryest. June, July, and August are the hottest months of the year. Maximum temperatures during this period commonly exceed 40°C (104°F). December and January are the coldest months with minimum temperatures commonly reaching -12°C (10°F) at night (National Climatic Data Center 1979-1984).

Comparison of Red and White Canyon Areas

The Red Canyon-White Canyon area provided a suitable place to compare behavioral differences between subpopulations of desert bighorn. The two areas, though not identical, have similar topographic and vegetation characteristics. Both areas are extremely rugged and are characterized by steep broken terrain. Areas of high visibility are available as well as areas of low visibility due to dense vegetation and broken terrain. All previously described topographic and vegetation types are found in both areas, though not in the same proportions. The Red Canyon area (233 km^2) is dominated by steep Chinle talus slopes vegetated predominantly with shadscale-ephedra-galleta grass communities. The White Canyon area (259 km^2) is dominated by Moenkopi, Chinle, and Organ Rock talus slopes covered largely with pinyon pine-Utah juniper communities and to a lesser extent

shadscale-ephedra-galleta grass communities. Flat areas in both canyons are dominated by blackbrush-galleta grass vegetation, and pinyon pine-Utah juniper vegetation increases in importance moving eastward through both areas as well.

Annual average group size in the two areas is virtually the same. Red Canyon average group size of 7.5 (n = 134, range = 1-23) and White Canyon average group size of 7.4 (n = 139, range = 1-20). Reproductive rates, herd composition, and physical characteristics of both herds are also comparable (unpublished data of personal observations).

Several human activities occur in both areas as well. Cattle are grazed in both areas during winter. Grazing privileges in Red Canyon are restricted to every other year, however, trespass animals were in the study area every year during the study. Cattle grazing is permitted in the White Canyon area every year. Helicopter flights are made in essentially equal proportions in both areas. A majority of the helicopter flights in the area are made during bighorn sheep surveys conducted by the Utah Division of Wildlife Resources each fall. All areas of both canyons have been sampled for the past 15 years under this program. Sheep are exposed to boats in both areas, often several hundred each year as rafters float the Colorado River and boaters explore the many side canyons of Lake Powell.

Mining activities have been common in both areas. During the uranium boom of the 1950's and 1960's, extensive mineral exploration and mining took place in both areas. However, due to

the unfavorable market for uranium for the past several years, mining was virtually nonexistent in either area during the course of the study. Small amounts of mineral exploration did occur in both areas, but the disturbance to the area was minimal.

Although Red and White Canyons receive relatively little vehicular traffic, differences between the two areas are apparent. Utah Highway 95 roughly bisects the White Canyon study area, and although many vehicles travel on the highway, areas actually occupied by desert bighorn in Red Canyon are more likely to receive vehicular traffic than in White Canyon. Roads in the White Canyon area through desert bighorn habitat are very rugged and are generally accessible only with 4-wheel drive vehicles, whereas three improved roads in the Red Canyon area are maintained by San Juan County each year to allow better access into the area, specifically to Lake Powell. This is evident by the average number of vehicles encountered by the author per visit into the two areas. Average number of vehicles encountered per visit in the Red Canyon area was 1.7 ($n = 142$, range = 0-30), whereas average number of vehicles encountered per trip in the White Canyon area was 0.3 ($n = 156$, range = 0-4). Most human activity in the area occurs during the spring and fall when weather conditions are favorable for recreational activities.

Hunting pressure in the two areas is considerably different. Red Canyon has been a popular area for bighorn hunters since 1967 with the exception of 1973 and 1974 when no legal hunts were held, whereas White Canyon has received little hunting pressure during that time. This is primarily due to habitat use patterns

by mature rams in both areas. Mature rams are not generally found in the White Canyon area during the hunting season, while they are found in the Red Canyon area during that time. Sexes are spatially segregated throughout the year with the exception of the breeding season similar to several other large ungulates (Geist and Petocz 1977, McCullough 1979, Franklin and Lieb 1980, King and Smith 1980, Morgantini and Hudson 1981, Clutton-Brock et al. 1982, Bowyer 1984). The hunting season takes place immediately prior to the breeding season so ewes and rams are segregated. However, in Red Canyon during the last few days of the general hunting season young, but legal, rams move into ewe groups. As a result several rams have been killed in the company of ewes and lambs in the Red Canyon area during the course of the study. Since the inception of the desert bighorn hunt in Utah in 1967, approximately 46 rams have been killed in the Red Canyon area. In contrast, only eight rams have been killed in the White Canyon area, six of which were killed prior to or during 1970. During the 1981, 1982, and 1983 desert bighorn hunts, an average of 105 hunter days per season (number of hunters and their non-hunting companions times the number of days in the field) was spent by hunters in the Red Canyon area compared to an average of only five hunter days in the White Canyon area.

The observed differences between the two areas with respect to vehicular traffic and hunting pressure are significant enough to make predictions about the behavioral differences between Red and White Canyon bighorn when exposed to harassing stimuli. Red Canyon was designated as the disturbed site based on the

relatively high vehicular traffic and heavy hunting pressure and the White Canyon area was designated as the undisturbed site based on lower levels of vehicular traffic and hunting pressure. Based on these assumptions it was predicted that Red Canyon animals should be more wary and respond more severely than White Canyon bighorn when subjected to harassment stimuli.

METHODS

Data Collection

As part of a long-term study on the ecology of desert bighorn sheep in southeastern Utah by Utah State University, the Bureau of Land Management, and the Utah Division of Wildlife Resources, nine desert bighorn were collared in the Red Canyon area and ten were collared in the White Canyon area from 1981-1983. Desert bighorn were captured by drug immobilization (M99) from a helicopter or by hazing animals into tangle nets with a helicopter (King and Workman 1982, 1983). Once captured, desert bighorn were fitted with radio collars (Telonics Inc., Mesa, Arizona) and released. To facilitate efficient data collection, these animals and their associates were used to evaluate the effects of harassment on bighorn because they could be located quickly and observed for extended periods of time.

Behavioral data were collected over a 19-month period from October 1981 through December 1981 and June 1982 through September 1983. A total of 2480 hours was spent observing desert bighorn behavior during that time. Observations were made during all daylight hours and in all calendar seasons with 10 x 50 binoculars and a 15-60 x spotting scope. Behaviors were monitored utilizing scan and focal animal sampling techniques (Altmann 1974) so that number of individuals participating in and actual time spent in various behaviors could be recorded (see Appendix F for sample data sheet).

Harassment Trials

To compare immediate response and distance fled between disturbed bighorn (Red Canyon animals) and relatively undisturbed bighorn (White Canyon animals), it was necessary to deliberately harass bighorn and monitor their response. Hikers and vehicles, the most likely disturbances to be encountered by desert bighorn, were the only harassment stimuli considered. When possible, desert bighorn were located and observed from great distances so they were not aware of the researcher's presence. Once initial behavior was recorded, bighorn were approached on foot or by vehicle until they became aware of the harassing stimulus at which time the researcher held his position. An attempt was made conduct all harassment trials in a consistent fashion, however, clothes worn by the researcher and vehicles used differed throughout the study. Because there were several occaisions when bighorn and researcher became aware of each other's presence simultaneously, a reaction distance (distance at which bighorn became aware of harassment) was recorded so responses at different distances could be compared between areas. Desert bighorn reaction was recorded as one of the four following response categories based on how the majority of the harassed group reacted:

Slight Interruption: bighorn interrupt their behavior, exhibit attention, but return to original behavior; may exhibit infrequent attention behavior subsequently.

Considerable Interruption: bighorn terminate their behavior, exhibit attention, initiate new behavior; interrupted frequently with attention behavior.

Walking Flight: bighorn terminate their behavior, immediately walk away from harassing stimuli or exhibit attention and then walk away.

Running Flight: bighorn terminate their behavior, immediately run away from harassing stimuli or exhibit attention and then run away.

Two further categories were defined for convenience in analysis and discussion of data:

Flight: includes walking flight and running flight categories.

Non-flight: behavioral responses other than flight, includes slight interruption, and considerable interruption response categories.

Distances fled by harassed bighorn were estimated visually or from 15^{0} quad topographic maps. Flight responses were considered terminated when the majority of group initiated a behavior other than flight (e.g. feeding, lying, social behavior, etc.) or until the group was no longer visible.

For each harassment trial the following independent variables with their respective levels were recorded:

Area: Red Canyon, White Canyon

Disturbance Type: Hiker, Vehicle

Reaction Distance: 0-100 m, 101-200 m, 201-400 m, > 400 m

Approach Position: Above, Level, Below (position of the

harassing stimulus relative to the bighorn)

Season: Winter, Spring, Summer, Fall (calendar seasons)

Habitat Type: Chinle talus, Moenkopi talus (only types considered in analysis)

Group Composition: ewe (ewes + lambs + rams; yearling to three years old), mixed (ewes + rams; > three years old), ram (any age rams)

Group Size: 1, 2-7, > 7

Initial Behavior: Lying, Standing, Feeding (only categories used in analysis; behavior of bighorn at the time of harassment)

Activity Budget and Group Wariness

In order to evaluate changes in activity budgets as a result of human disturbance, bighorn behavior was monitored after the initial harassment while individuals remained in the presence of the harassing stimuli. Desert bighorn in both areas were also observed under unharassed conditions (bighorn not in presence of any human disturbance) so comparisons could also be made between areas under those conditions.

Once a bighorn group was located, a focal animal was selected and observed for a 15-minute period during which actual time engaged in all behavioral categories was recorded. At the end of the 15-minute period, a new focal animal was selected and the process was repeated. At five-minute intervals during the focal-animal-sampling-period all members of the group were scanned and the number of individuals engaged in each activity

was recorded. When bighorn were being observed under harassed conditions, no attempt was made by the researcher to remain motionless.

The same independent variables that were recorded for immediate response analyses were recorded for activity budget analyses with the following exceptions. Approach position was changed to disturbance position (above, level, below) because the harassing stimulus made no approach but remained stationary. Reaction distance was changed to distance to disturbance (0-100 m, 101-200 m, 201-400 m, > 400 m) because the harassing stimulus was fixed but bighorn often moved between distance categories. Disturbance type was modified to include harassed conditions (vehicle and hiker harassment instances were combined) and unharassed conditions (bighorn unaware of any unharassing stimuli. Initial behavior was not considered.

Group wariness was monitored to determine comparitive wariness of Red and White Canyon bighorn by scanning individual group members at five minute intervals after the initial harassment and recording the number of animals at attention or engaged in flight behavior relative to non-flight behaviors.

Description of Behaviors

The following behaviors were monitored through the course of the study:

Attention: a category expanded to include both alarm and attention postures defined by Geist (1971b), characterized by raised head, rigid tense steps, stamping ground, sudden

freezing of movement, ears perked forward, body generally oriented toward line of sight, can occur while standing or lying.

Lying: characterized by sheep lying down with head down or up, rumination may be concurrent.

Standing: standing with head up, looking around, but not at attention.

Walking: movement from one place to another, head up, excluding feeding behavior, includes movement after disturbance.

Running: rapid movement from one place to another, includes flight after disturbance.

Feeding: browsing, chewing, walking between food items with head down searching for food (Berger et al. 1983).

Social Behavior: includes reproductive behavior, dominance and agressive behavior, nuzzling, and other contact behaviors (Geist 1971b).

Group Wariness: number of animals engaged in attention or flight behaviors as result of harassment.

Drinking, body care, play, and mother-young behaviors were also recorded but those behaviors made up such a small fraction of the entire behavioral budget that they were not included in the analyses.

Statistical Comparisons

Data were analyzed with several statistical procedures. Immediate response to harassment and activity budgets with respect to number of individuals participating in various

behaviors were analyzed by simple Chi-square tests and a multivariate categorical data analysis technique based on Goodman's log-linear models (Fienberg 1977). A t-test based on the arcsin transformation (Sokal and Rohlf 1969) was used to test the equality of proportions when significance was found during categorical data analysis.

Distance fled in response to harassment and activity budgets based on actual time spent in various behaviors were analyzed by analysis of variance techniques for unbalanced designs (Bryce 1970) and differences between means were compared by Fisher' LSD procedures (Steel and Torrie 1980). Differences in group wariness between areas and through time were determined using a binomial Chi-square technique (Cochran and Cox 1957). The 0.05 level was selected as the level of statistical significance.

RESULTS

Immediate Behavioral Response

Immediate behavioral response by desert bighorn sheep to human harassment was compared between Red and White Canyon areas. Differences between areas were compared with respect to disturbance type (vehicles, hikers), reaction distance (0-100m, 101-200m, 201-400m, > 400m), approach position of the harassing stimulus (above, level, below), season (winter, spring, summer, fall), habiat type (Chinle talus, Moenkopi talus), group composition (ewes, mixed, rams), group size (1, 2-7,> 7), and initial behavior of bighorn at the time of harassment (lying, standing, feeding). Results of these comparisons are summarized in Table 1 (Appendix A).

Disturbance Type

Response to hiker harassment by desert bighorn was significantly different between Red and White Canyons (X^2=41.9, df=3, P<0.005). Red Canyon bighorn responded most frequently to harassment with running flight (response category 4), whereas the most common response by White Canyon bighorn was remaining in the presence of harassing stimuli with only slight interruption in behavior (response category 1).

There was no significant difference in immediate behavioral response between Red and White Canyon desert bighorn after harassment by vehicles (X^2=7.0, df=3, P<0.10). However the

relatively low probability value is suggestive of more severe reactions by Red Canyon bighorn to vehicular harassment (Figure 3).

Reaction Distance

Significant differences in response by bighorn between Red and White Canyons were found when bighorn first became aware of harassing stimuli in the 0-100m (X^2=18.0, df=3, P<0.005) and 101-200m (X^2=30.5, df=3, P<0.005) categories. No significant differences in behavioral response were found between Red and White Canyon bighorn in the 201-400m (X^2=5.6, df=3, P>0.10) and > 400m (X^2=5.2, df=3, P>0.10) categories. For reaction distances of 0-200m, Red Canyon bighorn responded to harassment most frequently with flight responses whereas non-flight and flight responses were approximately equal by White Canyon bighorn (Figure 4).

Approach Position

Bighorn response to harassment was significantly different between Red and White Canyon areas with respect to all three approach postions (above X^2=8.4, df=3, P<0.05; level X^2=37.0, df=3, P<0.005; below X^2=8.4, df=3, P<0.05). Red Canyon bighorn responded most frequently with flight responses whereas non-flight and flight responses were approximately equal by White Canyon bighorn (Figure 5).

Season

With the exception of winter (X^2=1.0, df=3, P>0.10) when sample sizes were small, Red and White Canyon bighorn responded differently to harassment in all seasons. In spring (X^2=9.6,

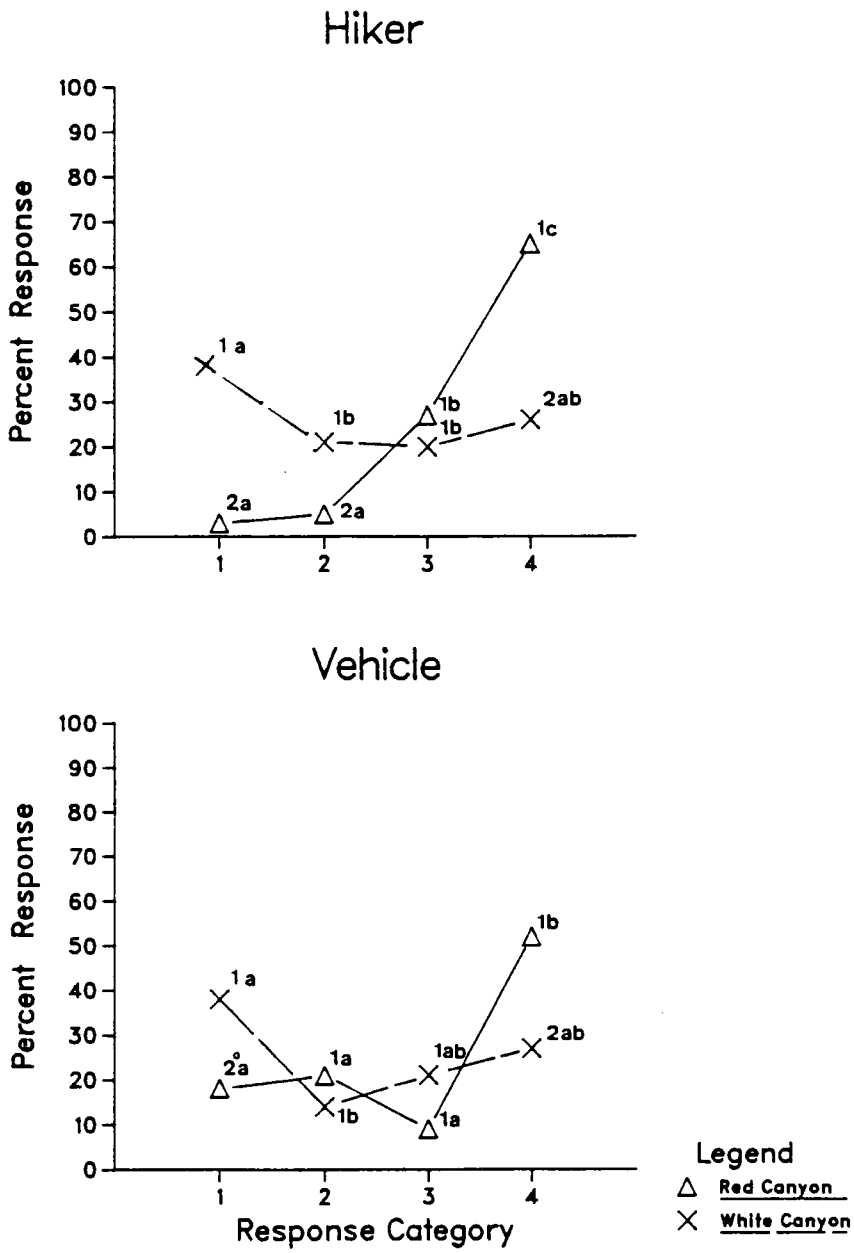

Figure 3. Comparison of immediate response by Red and White Canyon desert bighorn to harassment by vehicles and hikers. Response category: 1=slight interruption, 2=moderate interuption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P < 0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas, 2°=significance at $P=0.10$.

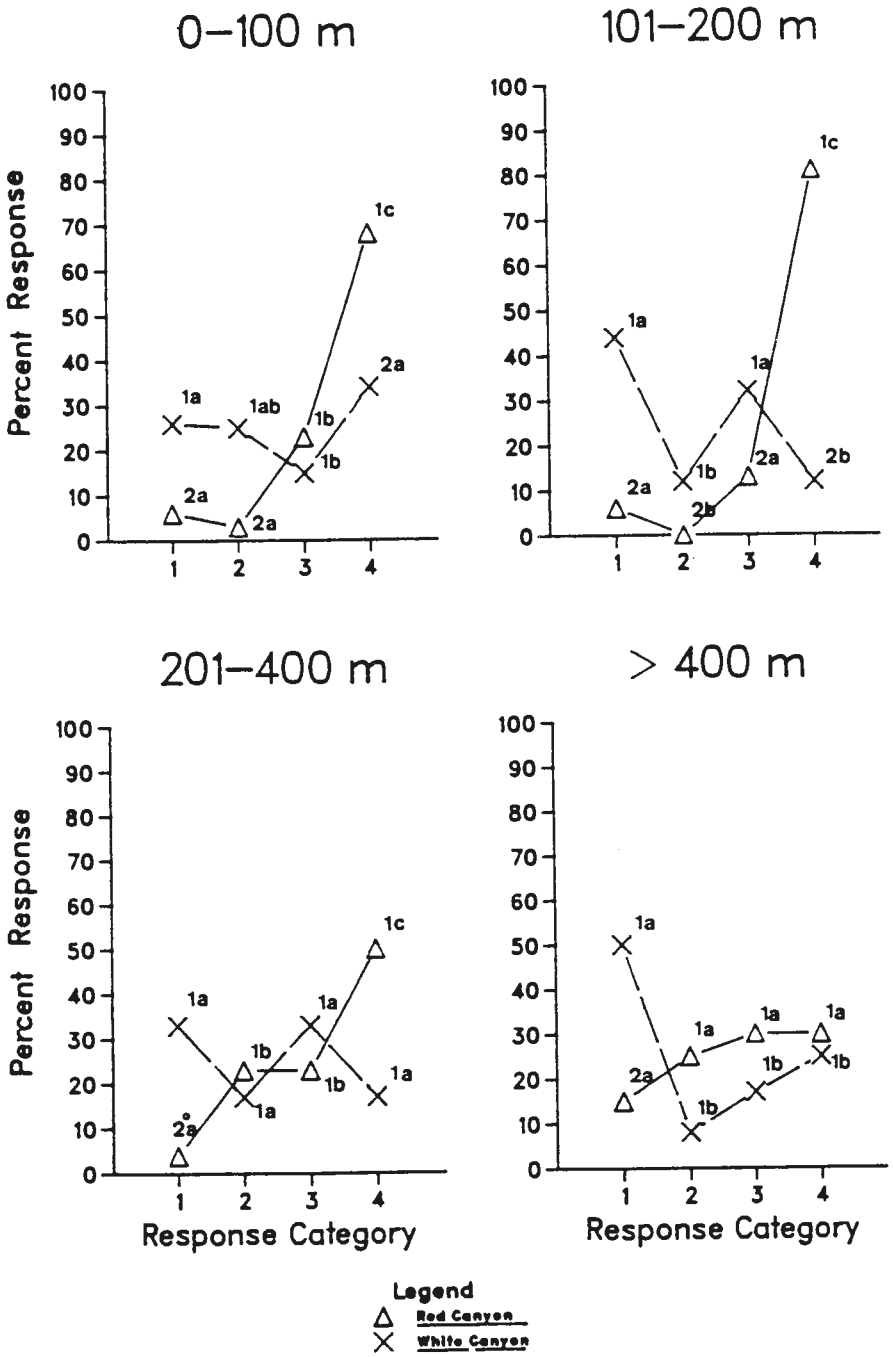

Figure 4. Comparison of immediate response by Red and White Canyon desert bighorn to harassment at various reaction distances. Response category: 1=slight response, 2=moderate response, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P<0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas, 2^{0}=significance at $P=0.10$.

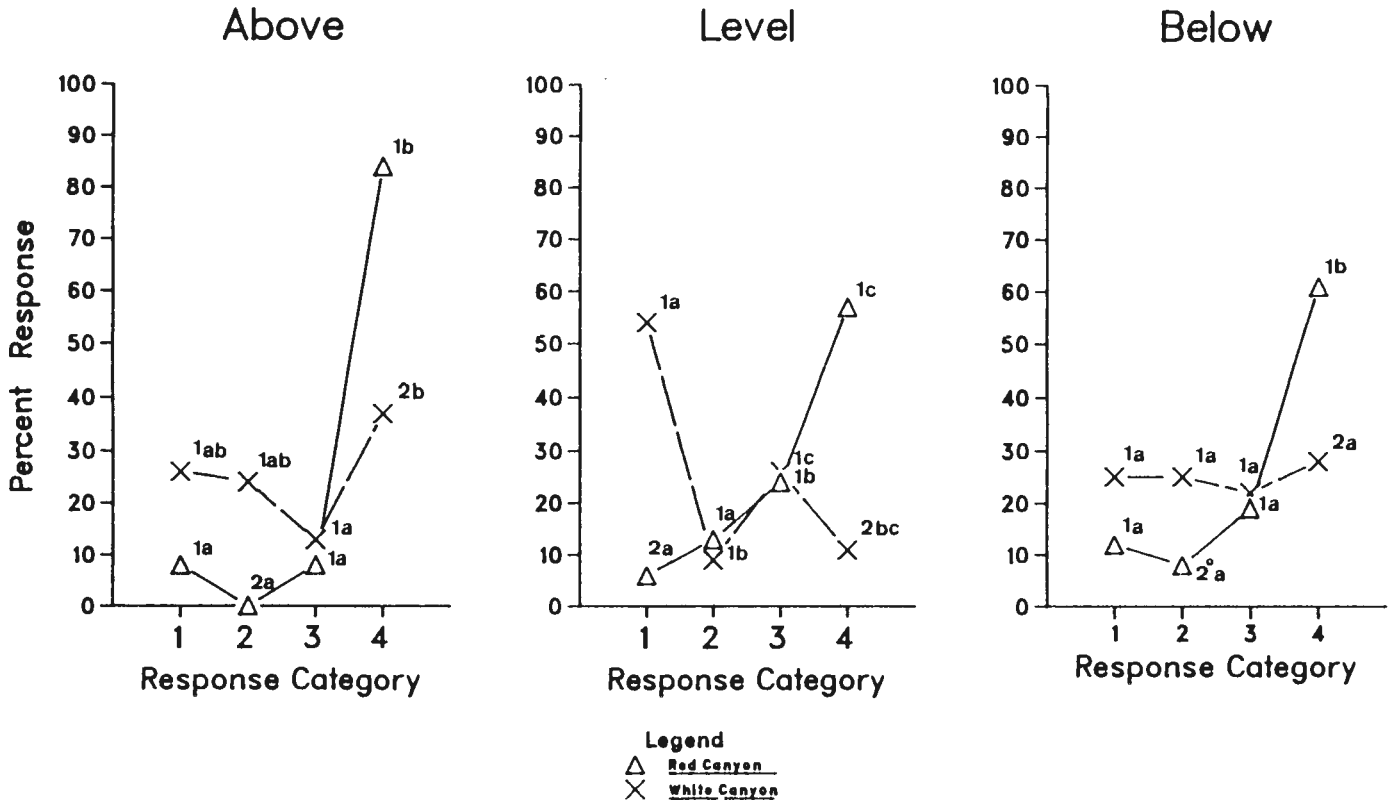

Figure 5. Comparison of immediate response by Red and White Canyon desert bighorn to harassment at various approach positions. Response category: 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P < 0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas, 2^{o}=significance at P=0.10.

df=3, P<0.01), summer (X^2=16.3, df=3, P<0.005), and fall (X^2=18.3, df=3, P<0.005) flight responses were most common by Red Canyon bighorn whereas non-flight responses were approximately equal to or more common than flight responses by White Canyon bighorn (Figure 6).

Habitat Type

Several habitat types are available in both areas, however Chinle talus and Moenkopi talus were the only habitat types that received enough use by bighorn in both areas to make adequate statistical comparisons. Response to harassment by Red and White Canyon bighorn was significantly different in Chinle talus areas (X^2=35.5, df=3, P<0.005). Red Canyon bighorn exhibited flight behavior most often whereas White Canyon bighorn responded most frequently with non-flight behaviors. Sample sizes for Moenkopi talus were small and response by bighorn in Red and White Canyon areas was not statistically different (X^2=5.3, df=3, P>0.10). However, the trend was similar to responses in Chinle talus (Figure 7).

Group Composition

Immediate behavioral response by Red and White Canyon bighorn was significantly different for ewe groups (X^2=20.6, df=3, P<0.005), mixed groups (X^2=8.8, df=3, P<0.05), and ram groups (X^2=14.8, df=3, P<0.005). With the exception of ram groups, White Canyon group types responded most frequently with non-flight behaviors. White Canyon ram groups responded more frequently with flight behaviors due to the large number of instances

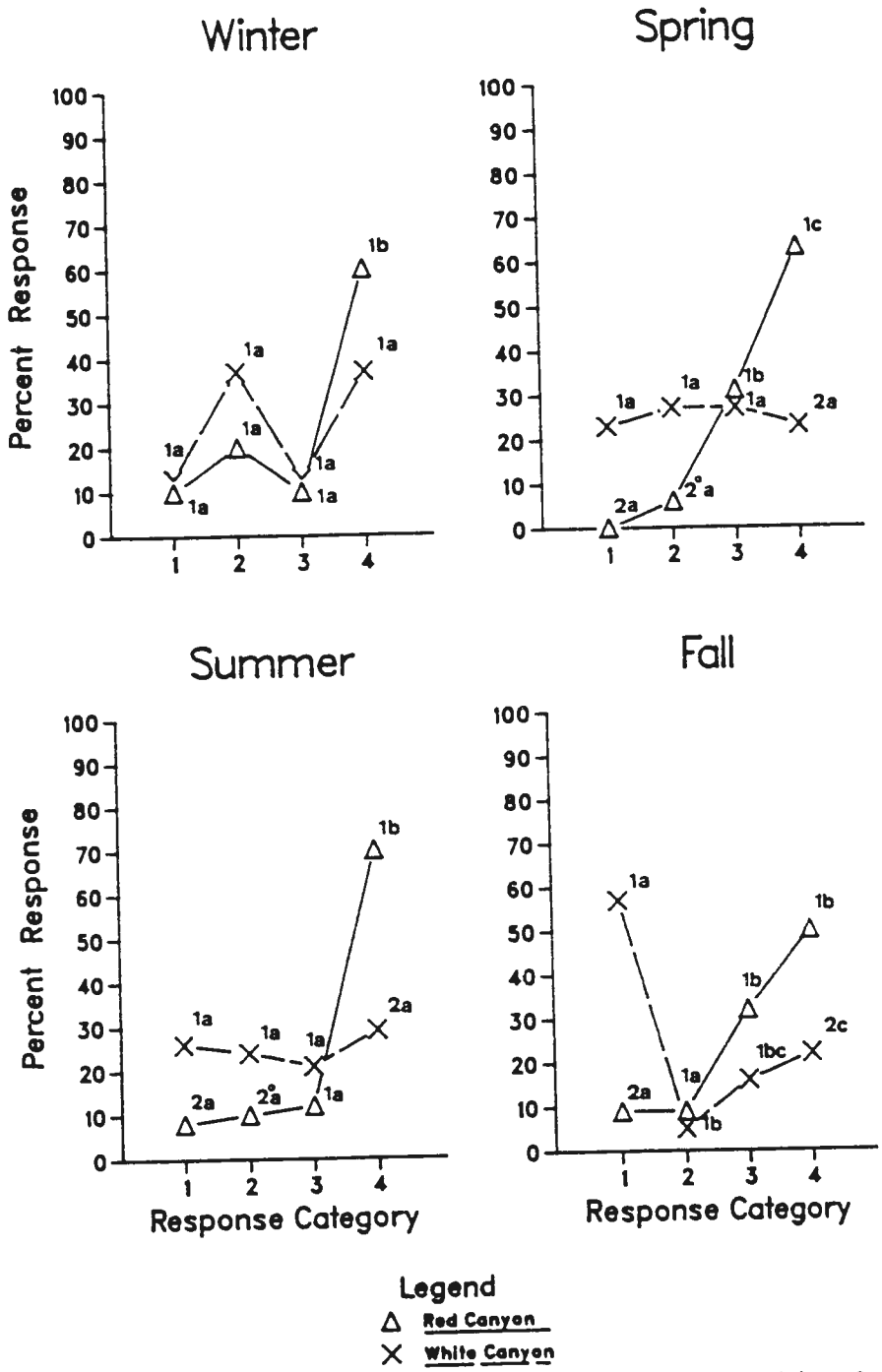

Figure 6. Comparison of immediate response by Red and White Canyon desert bighorn to harassment with respect to season. Response category: 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P<0.05$) between areas within response categories, different letters indicate significiant differences among response categories within areas, 2^{0}=significance at P=0.10.

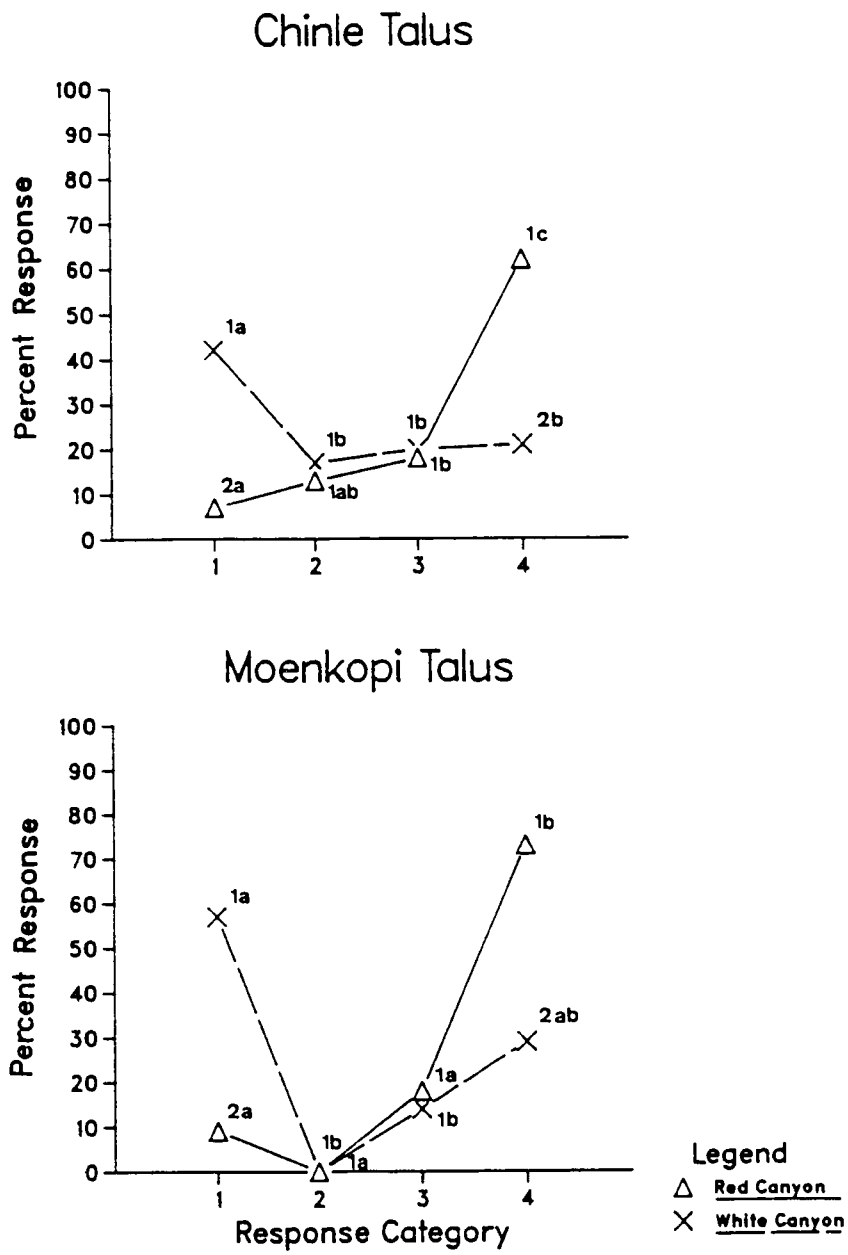

Figure 7. Comparison of immediate response by Red and White Canyon desert bighorn to harassment with respect to habitat type. Response category: 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P<0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas.

of walking flight (response category 3). Running flight (response category 4) occurred significantly more often in Red Canyon than White Canyon ($P<0.05$). Flight responses were most common for all Red Canyon group types (Figure 8).

Group Size

Solitary individuals in Red and White Canyon areas did not respond differently as a result of harassment ($X^2=5.6$, df=3, $P>0.10$). Solitary animals from both areas exhibited flight responses most often when harassed. Groups of two to seven animals ($X^2=30.7$, df=3, $P<0.005$) and groups of more than seven animals ($X^2=9.7$, df=3, $P<0.025$) responded differently between areas. Flight responses were most common in Red Canyon whereas in White Canyon non-flight responses were approximately equal to or more common than flight responses (Figure 9).

Initial Behavior

Sample size for response when standing was the initial behavior at the time of harassment was small and the difference between Red and White Canyons was not significant ($X^2=1.7$, df=3, $P>0.10$). However, differences between Red Canyon and White Canyon bighorn when lying ($X^2=11.7$, df=3, $P<0.01$) and feeding ($X^2=22.2$, df=3, $P<0.005$) were the initial behaviors were significantly different. Flight responses were most common for both areas when lying was the initial behavior, however, frequency of running flight (response category 4) was significantly greater for Red Canyon bighorn than White Canyon bighorn ($P<0.05$). Remaining in the presence of disturbance with only slight

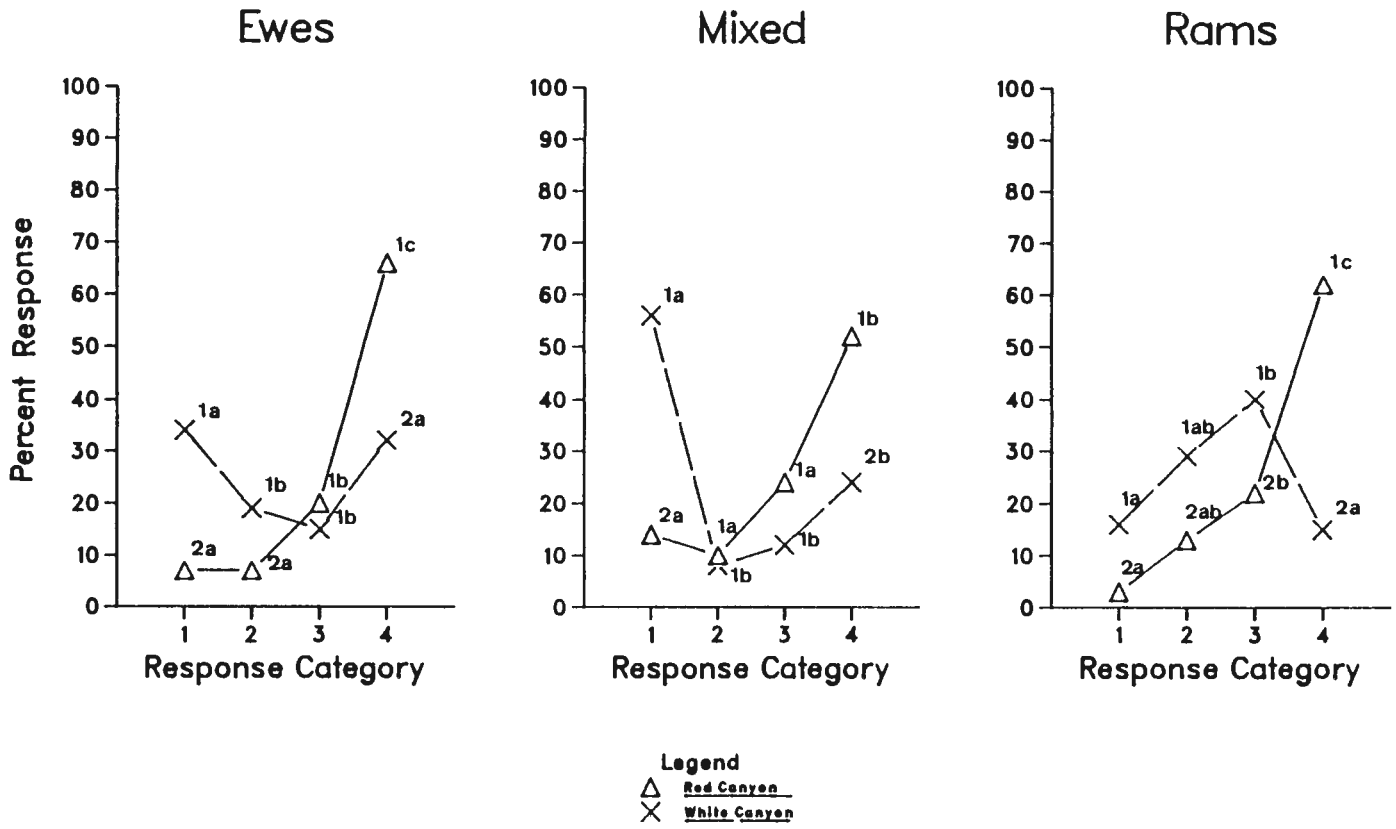

Figure 8. Comparison of immediate response by Red and White Canyon desert bighorn with respect to group type. Response category: 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P < 0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas.

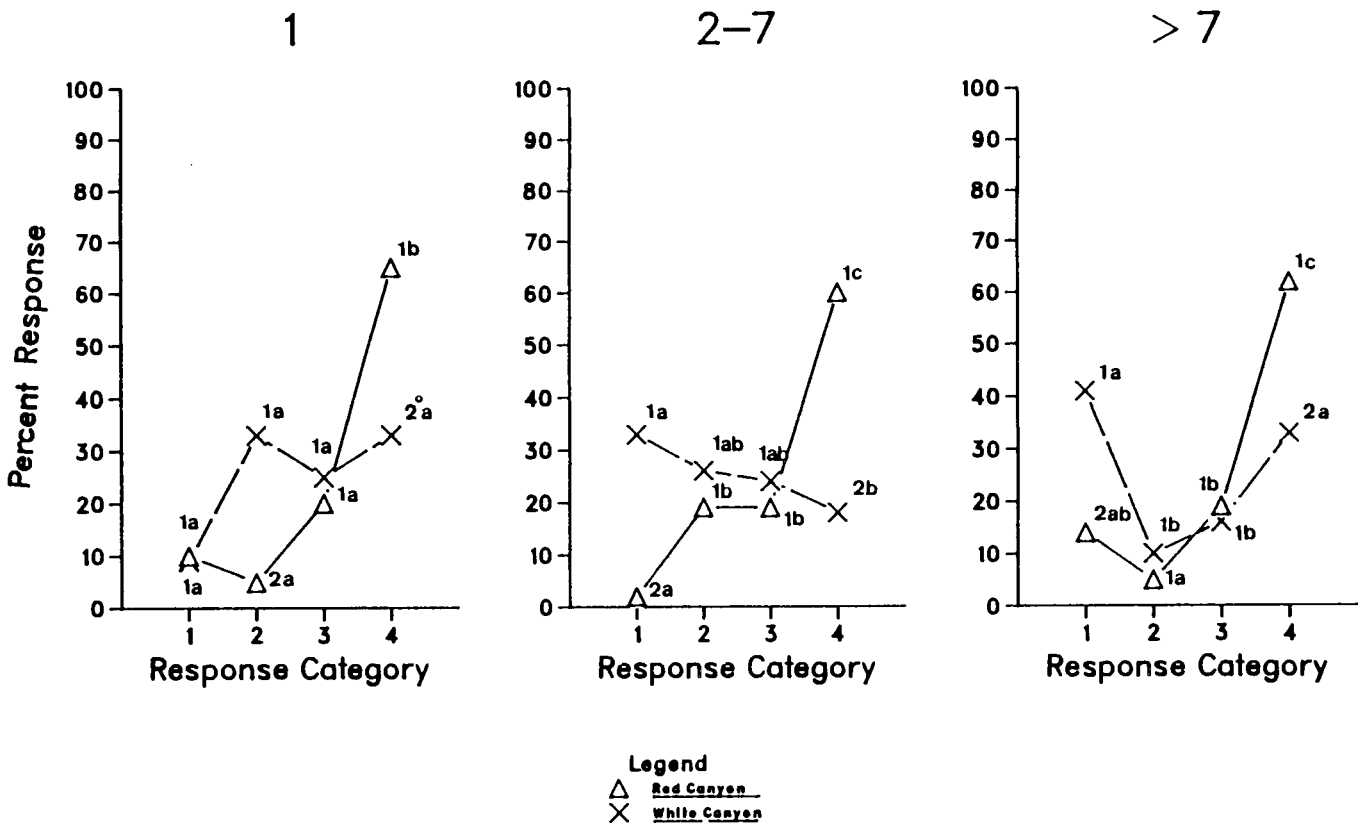

Figure 9. Comparison of immediate response by Red and White Canyon desert bighorn with respect to group size. Response category: 1=slight interruption, 2=moderate interruption, 3= walking flight, 4=running flight. Different numerals indicate significant differences ($P<0.05$) between areas within response categories, different letters indicate significant differences among response categories, 2^{o}=significance at P=0.10.

interruption in behavior (response category 1) occurred significantly more often for White Canyon bighorn than Red Canyon bighorn ($P<0.05$). When feeding was the initial behavior, flight responses occurred most frequently in Red Canyon, whereas in White Canyon non-flight responses occurred most often (Figure 10).

Distance Fled

Average distance fled by harassed desert bighorn was compared between Red and White Canyon areas. Red Canyon bighorn fled significantly farther than White Canyon bighorn after harassment with respect to disturbance type, approach position, reaction distance, season, habitat type, group composition, group size, and initial behavior. Results of analysis of variance for these relationships are summarized in Table 2 (Appendix B). In all cases, average distance fled by Red Canyon bighorn was significantly greater than average distance fled by White Canyon bighorn (Table 3, Appendix B). There were no significant interactions between area and any of the other independent variables indicating Red Canyon bighorn fled consistently farther than White Canyon bighorn regardless of independent variable levels.

The above analysis of average distance fled considered all response categories including non-flight categories. This gave an estimate of distance moved for every bighorn-human interaction. However, averages therefore included distances of zero if animals did not walk or run away from the harassment. To determine real differences in average distance fled, only

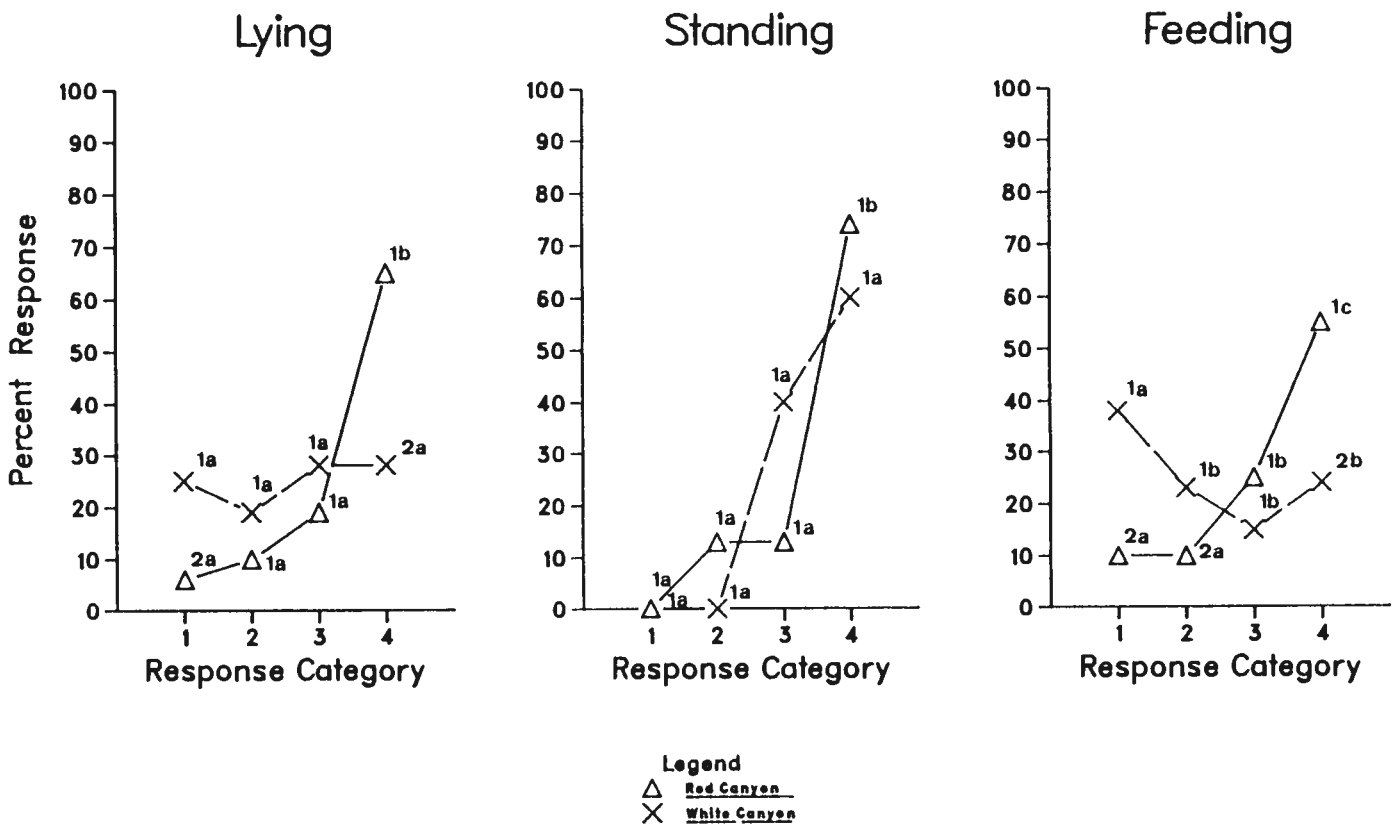

Figure 10. Comparison of immediate response by Red and White Canyon desert bighorn with respect to initial behavior. Response category: 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight. Different numerals indicate significant differences ($P<0.05$) between areas within response categories, different letters indicate significant differences among response categories within areas.

harassment trials that resulted in flight (response categories 3 and 4) were considered separately. This analysis indicated the same trend as when all response categories were considered (Tables 2-3).

Disturbance Type

Average distance fled with respect to disturbance type was significantly different between Red and White Canyon bighorn. Red Canyon bighorn fled farther than White Canyon bighorn for hiker and vehicle harassment trials when all response categories as well as when only flight categories were evaluated.

When all response categories were considered, Red Canyon bighorn fled farther when harassed by hikers than by vehicles but distance fled by White Canyon bighorn was not different with respect to hikers or vehicles. When only flight responses were considered, there were no significant differences in average distance fled when harassment was by hikers or vehicles in either area (Figure 11).

Reaction Distance

Bighorn were harassed from various reaction distances in both Red and White Canyon areas. When all response categories were considered Red Canyon bighorn fled significantly farther than White Canyon bighorn except when reaction of bighorn to harassment occurred at distances > 400 m. When only flight responses were considered, Red Canyon bighorn fled significantly farther than White Canyon bighorn only at reaction distances of < 200 m. Sample sizes for reaction distances > 200 m were small, particularly for White Canyon.

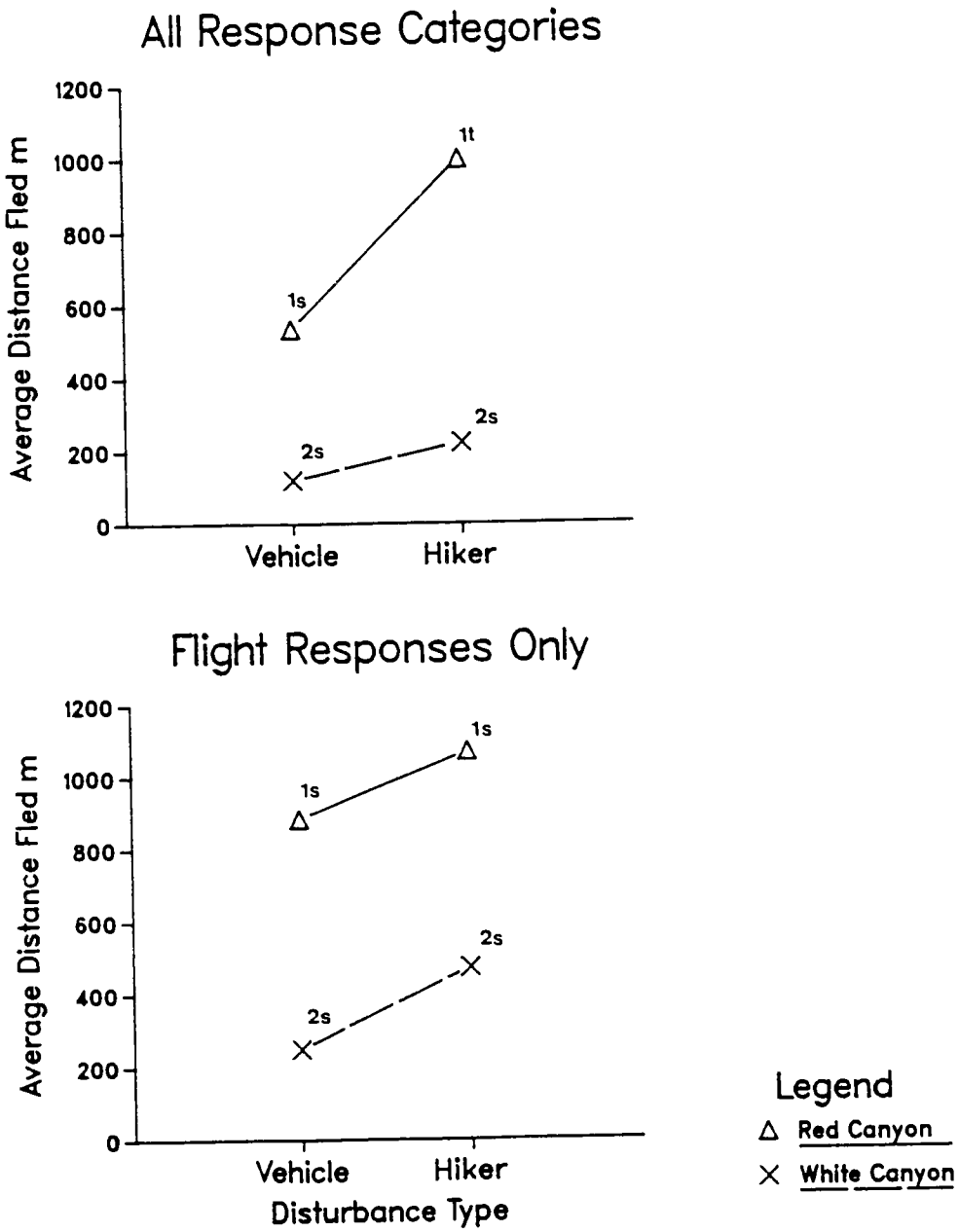

Figure 11. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to disturbance type. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P > 0.05$) between areas within disturbance types, different letters indicate significant differences among disturbance types within areas.

When all response categories were considered, mean distance fled was not significantly different for Red Canyon bighorn among reaction distances except that average distance fled when animals were harassed at distances greater than 400 m was less than distance fled when animals were harassed at distances less than 200 m. When flight responses only were considered there was no difference in distance fled among reaction distances. There were no differences in average distance fled for White Canyon bighorn at any reaction distance when all response categories or flight responses only were considered (Figure 12).

Approach Position

Average distance fled by Red and White Canyon bighorn differed significantly with respect to approach position of harassing stimuli. For all approach positions (above, level, below) Red Canyon bighorn fled significantly farther than White Canyon bighorn when all response categories were considered as well as when only flight responses were considered. There were no differences in average distance fled among approach postions for either area when all response categories or flight responses only were considered (Figure 13).

Season

When all response categories as well as only flight categories were evaluated, Red Canyon bighorn fled farther than White Canyon bighorn in all seasons except winter when no differences could be detected between areas. There were no differences in average distance fled by White Canyon in any

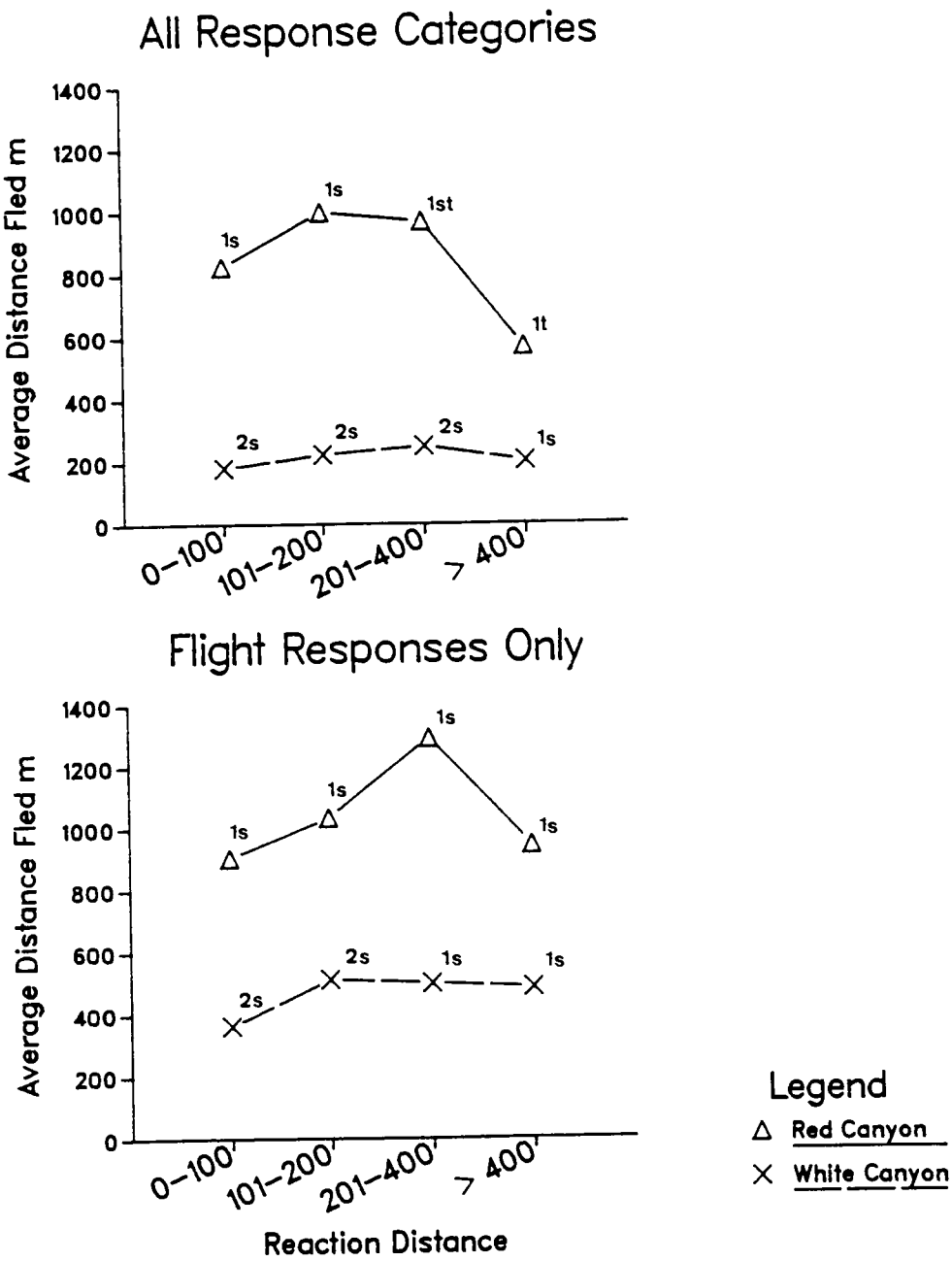

Figure 12. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to reaction distance. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P>0.05$) between areas within reaction distances, different letters indicate significant differences among reaction distances within areas.

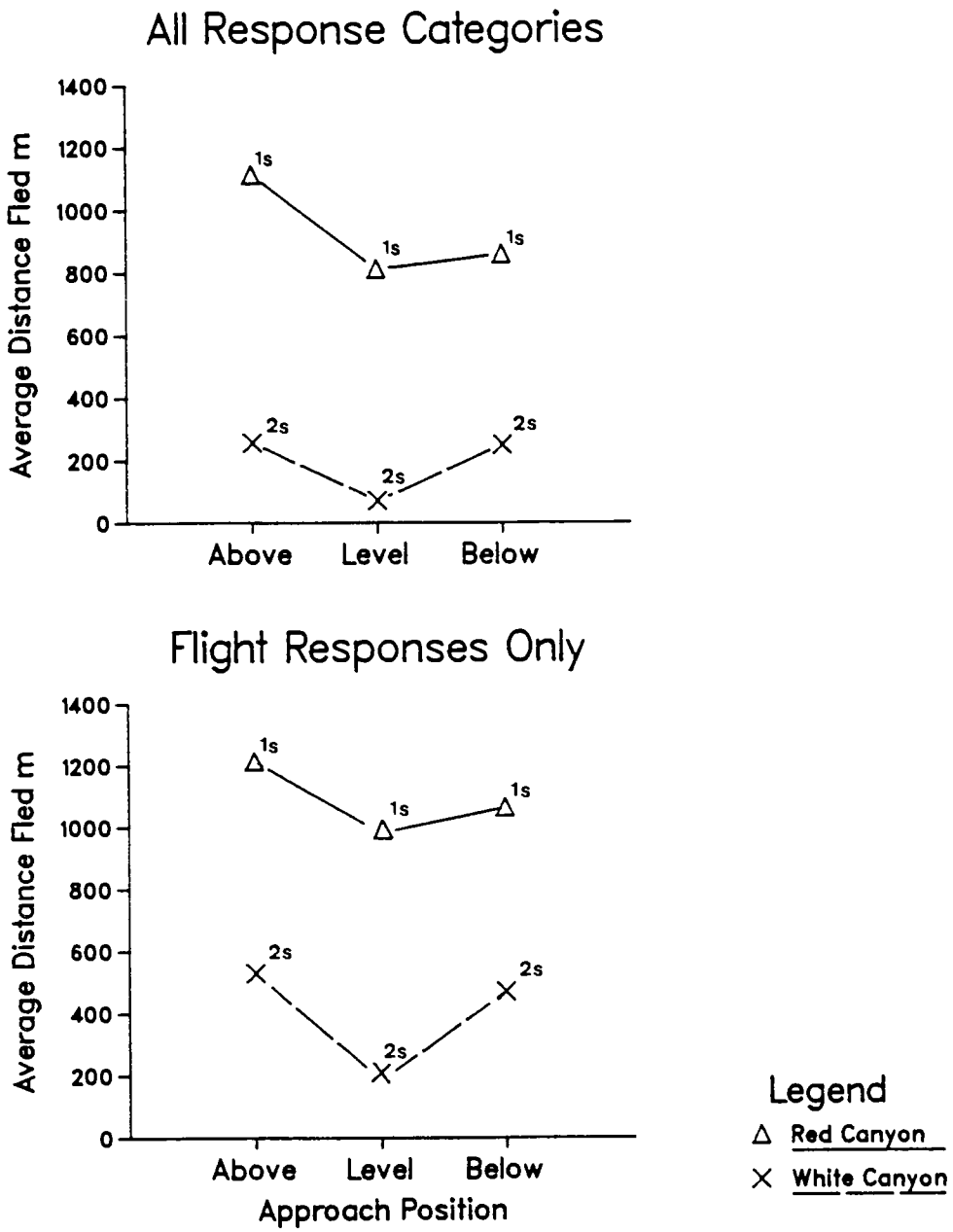

Figure 13. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to approach position. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P > 0.05$) between areas within approach positions, different letters indicate significant differences among approach positions within areas.

season, whereas Red Canyon bighorn fled farther during spring than in winter but summer and fall were not different than were not different than winter or spring when all response categories were considered. When only flight responses were analyzed there were no differences in distance fled among seasons in either area (Figure 14).

Habitat Type

Average distance fled by Red and White Canyon bighorn was compared for Chinle talus and Moenkopi talus habitat types. Common use of other types was not extensive enough for comparison. When all response categories were considered, Red Canyon bighorn harassed in the Chinle talus fled farther relative to White Canyon bighorn harassed in Chinle talus. Only small sample sizes were available for the Moenkopi talus type and mean distances fled by Red and White Canyon bighorn were not different.

When only flight responses were treated, there were no significant differences between Red Canyon and White Canyon bighorn in Moenkopi talus but average distance fled was greater for Red Canyon bighorn in Chinle talus than for White Canyon bighorn (Figure 15).

There were no differences in distance fled among habitat types for either area when all response categories or flight responses only were considered.

Group Composition

Red Canyon ram, ewe, and mixed groups fled significantly farther than White Canyon groups when all response categories as

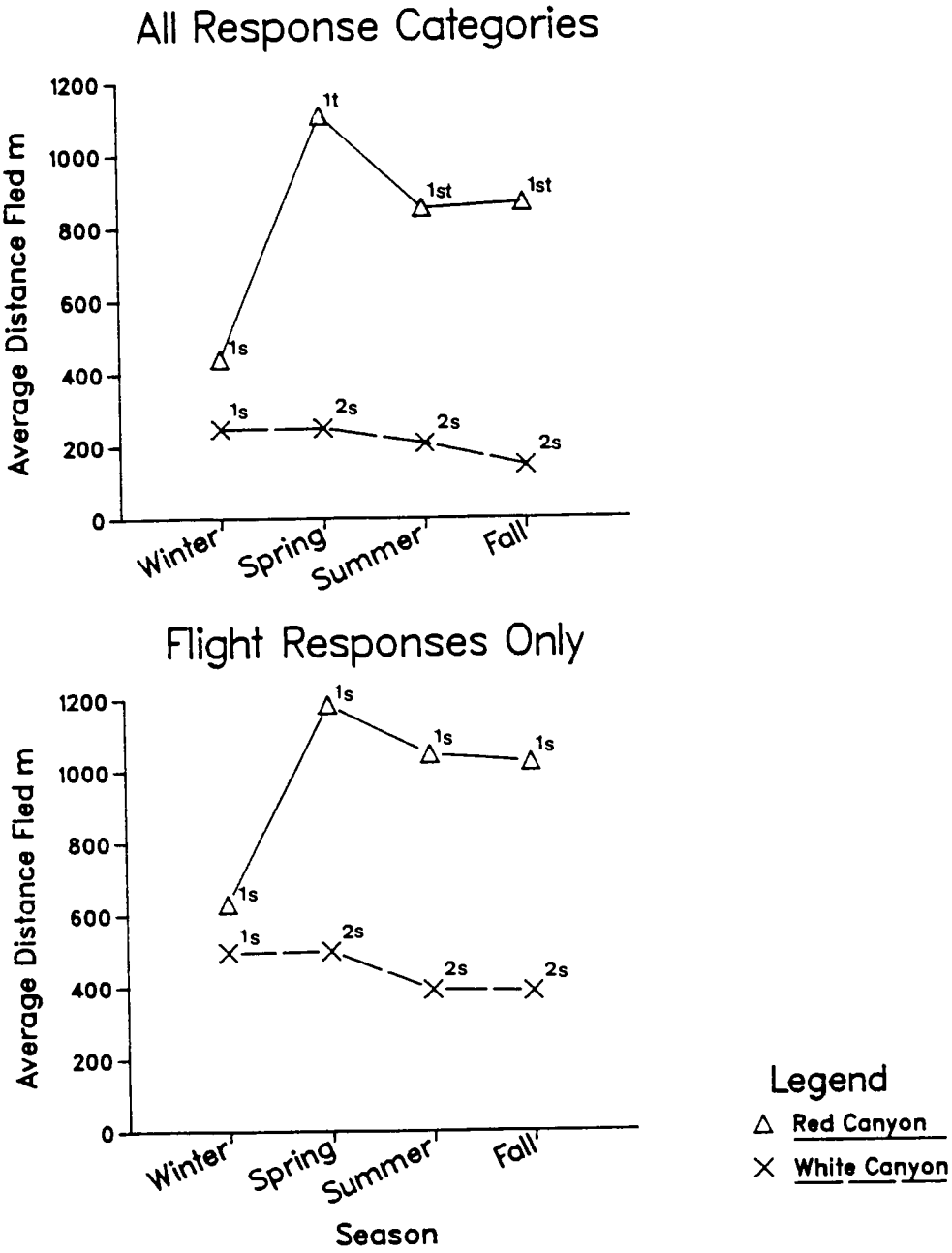

Figure 14. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to season. All response categories as well as flight categories only considered. Different numerals indicate significant differences ($P>0.05$) between areas within seasons, different letters indicate significant differences among seasons within areas.

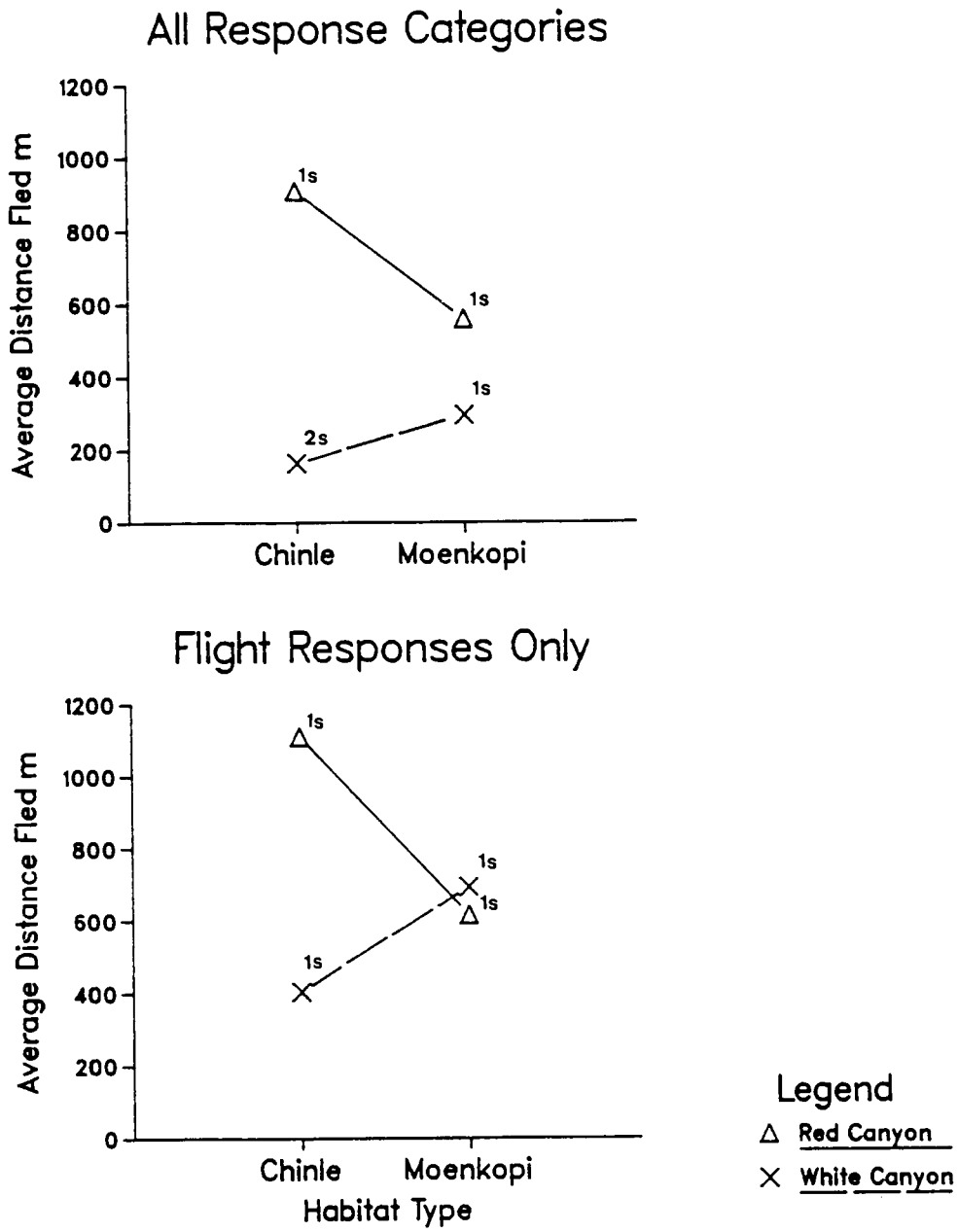

Figure 15. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to habitat type. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P>0.05$) between areas within habitat types, different letters indicate significant differences among habitat types within areas.

well as when only flight responses were analyzed. There were no differences in distance fled among groups within areas in either case (Figure 16).

Group Size

All size categories of Red Canyon groups fled significantly farther than White Canyon groups of corresponding size when all response categories were considered and there were no differences among groups within areas. When only flight responses were evaluated, average distance fled by medium and large groups was greater for Red Canyon bighorn than White Canyon bighorn but average distance fled by solitary animals in Red and White Canyons was not different. However, sample sizes were small for solitary animals and the trend is similar to the comparison of all response categories. There were no differences in distance fled among groups within areas in either case (Figure 17).

Initial Behavior

When all response categories were considered Red Canyon bighorn fled farther than White Canyon bighorn when initial behavior was standing, lying, or feeding. Red Canyon animals fled farther when they were harassed while engaged in lying or standing than if harassed when feeding. Average distances fled by White Canyon bighorn were not different regardless whether harassment trials occurred while animals were lying, standing, or feeding (Figure 18).

When only flight responses were considered, Red Canyon bighorn fled farther than White Canyon animals only when lying

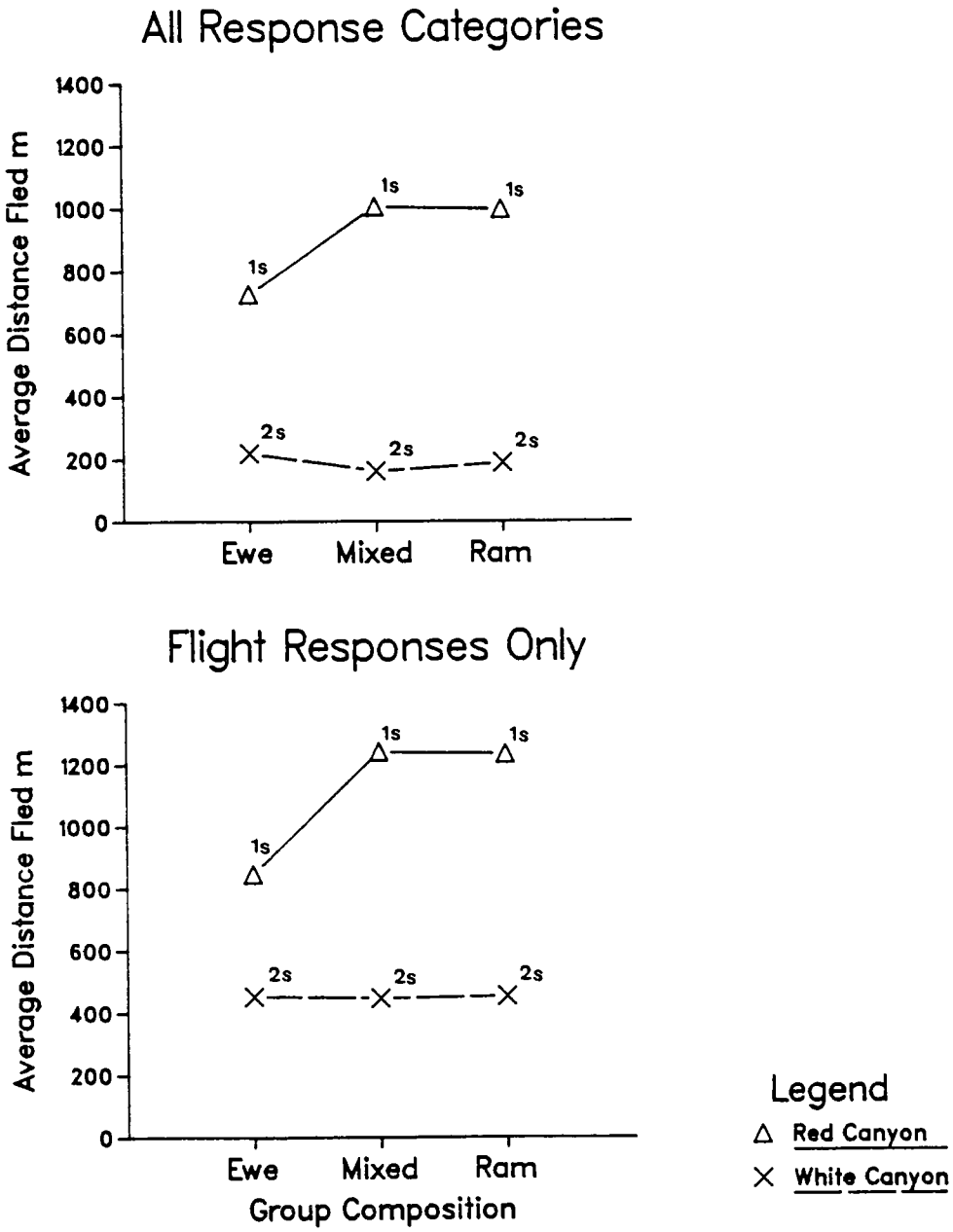

Figure 16. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to group composition. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P>0.05$) between areas within group compositions, different letters indicate significant differences among group compositions within areas.

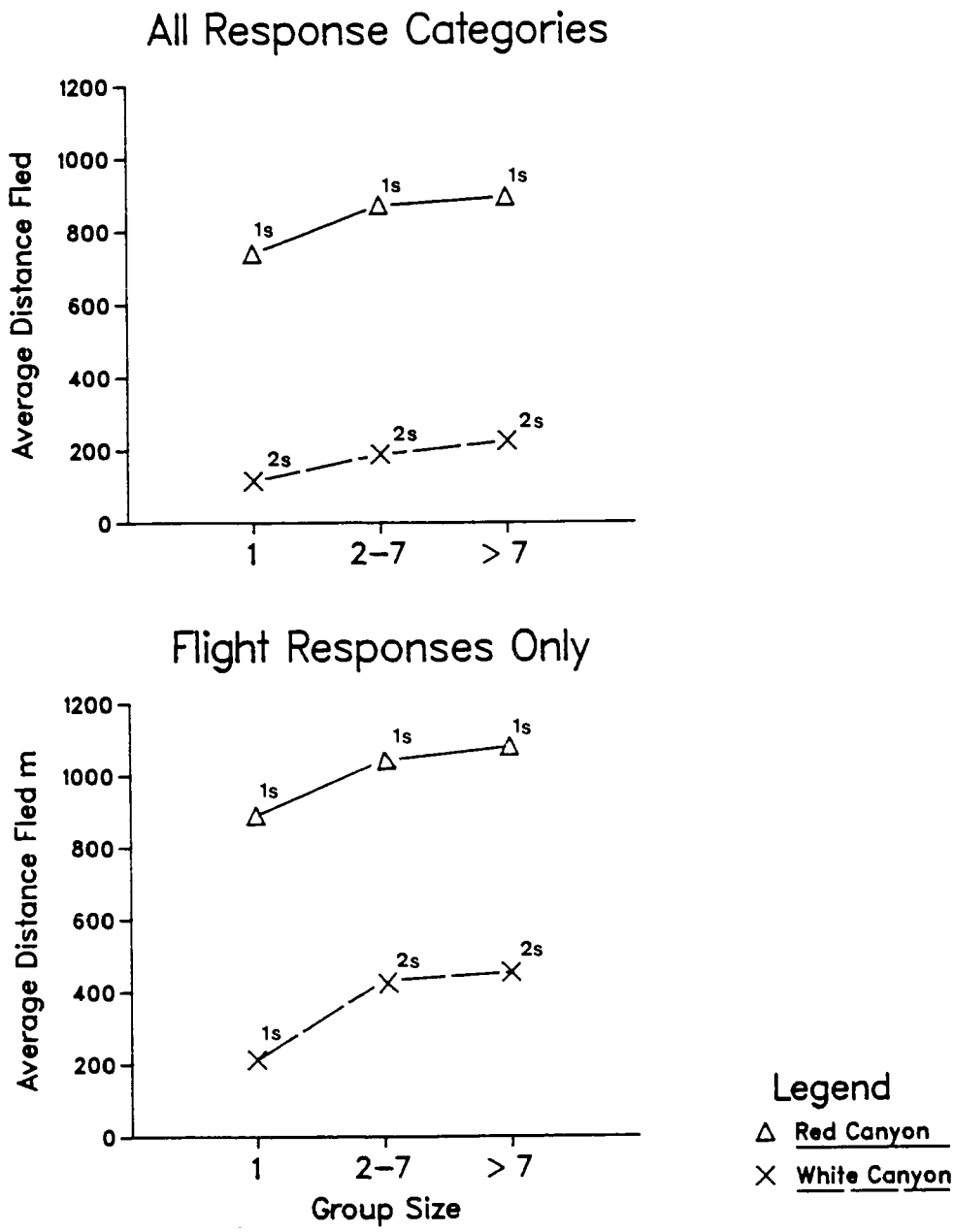

Figure 17. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to group size. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P > 0.05$) between areas within group sizes, different letters indicate significant differences among group sizes within areas.

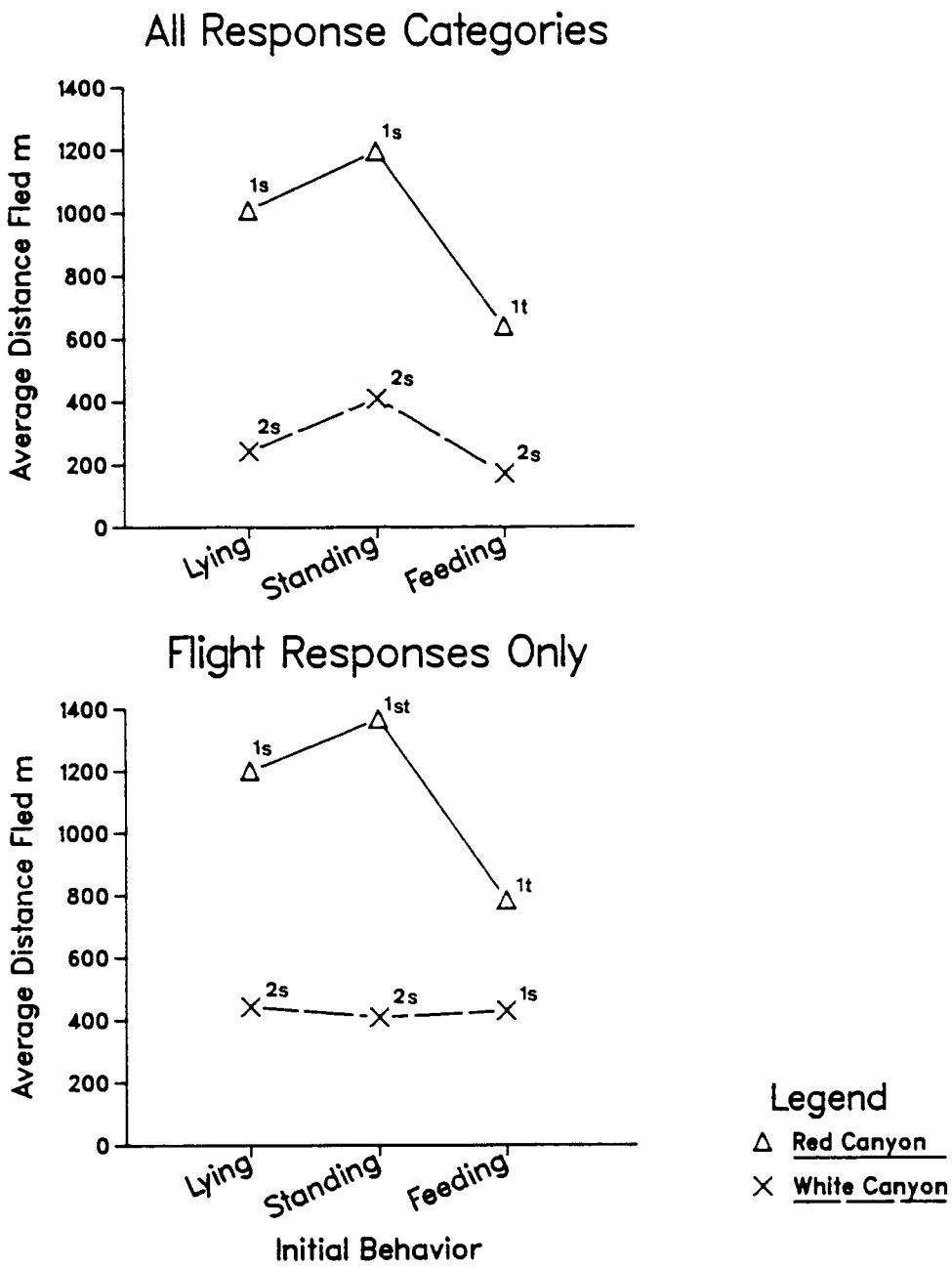

Figure 18. Average distance fled (m) by harassed Red and White Canyon bighorn with respect to initial behavior. All response categories as well as flight responses only considered. Different numerals indicate significant differences ($P > 0.05$) between areas within initial behaviors, different letters indicate significant differences among initial behaviors within areas.

and standing were initial behaviors at the time of harassment. Differences in average distance fled when feeding was the initial behavior were not significant between areas. Red Canyon bighorn fled farther when harassed while lying than when feeding but differences for lying and standing as well as standing and feeding were not significant. No differences were detected in average distance fled when harassment took place during any initial behavior categories for White Canyon bighorn (Figure 18).

Group Wariness

Group wariness (proportion of animals per group engaged in attention and/or flight behaviors at five-minute intervals after harassment) was evaluated with a binomial X^2 analysis. Results of this test are summarized in Tables 4-5 (Appendix C). Ram groups (area X^2=91.5, df=1, P<0.005; time X^2=101.0, df=12, P<0.005; area X time X^2=23.1, df=12, P<0.05) and ewe groups (area X^2=569.5, df=1, P<0.005; time X^2=593.0, df=12, P<0.005; area X time X^2=143.4, df=12, P<0.005) were significantly different with respect to area and time and there was a significant two-way interaction between area and time for both group types indicating that the relationship between area and group wariness changed through time. For both ram and ewe group types, Red Canyon animals were more wary than White Canyon animals and the proportion of animals exhibiting wariness behavior decreased through time in both areas. Initially a greater proportion of Red Canyon ewes were either fleeing or at attention than White Canyon ewes and through time a higher proportion of Red Canyon

ewes remained at attention than White Canyon ewes (Figure 19). The proportion of Red and White Canyon rams at attention or fleeing was high immediately after harassment, however, through time the percentage of White Canyon rams at attention declined more rapidly relative to Red Canyon rams (Figure 20).

Differences in group wariness for Red and White Canyon mixed groups (area X^2=178.1, df=1, P<0.005; time X^2=509.4, df=12, P<0.005; area X time X^2=14.9, df=12, P>0.10) were significant between areas and through time. A greater percentage of Red Canyon bighorn were engaged in attention or flight behaviors than White Canyon bighorn. Significantly more bighorn were engaged in wariness activities immediately after harassment compared to several minutes after the disturbance occurred in both Red and White Canyon areas. However, there was no significant interaction between area and time for mixed groups indicating that group wariness is consistently greater in Red Canyon groups than in White Canyon groups at all five-minute intervals after harassment (Figure 21).

Activity Budget

Actual Time

Activity budget of desert bighorn sheep based on actual time engaged in each behavior was compared between Red and White Canyon areas in winter, spring, and summer under harassed (combination of hiker and vehicle disturbances) and unharassed conditions (Figures 22-25). No comparisons were made for fall because io observations of White Canyon bighorn were made under unharassed

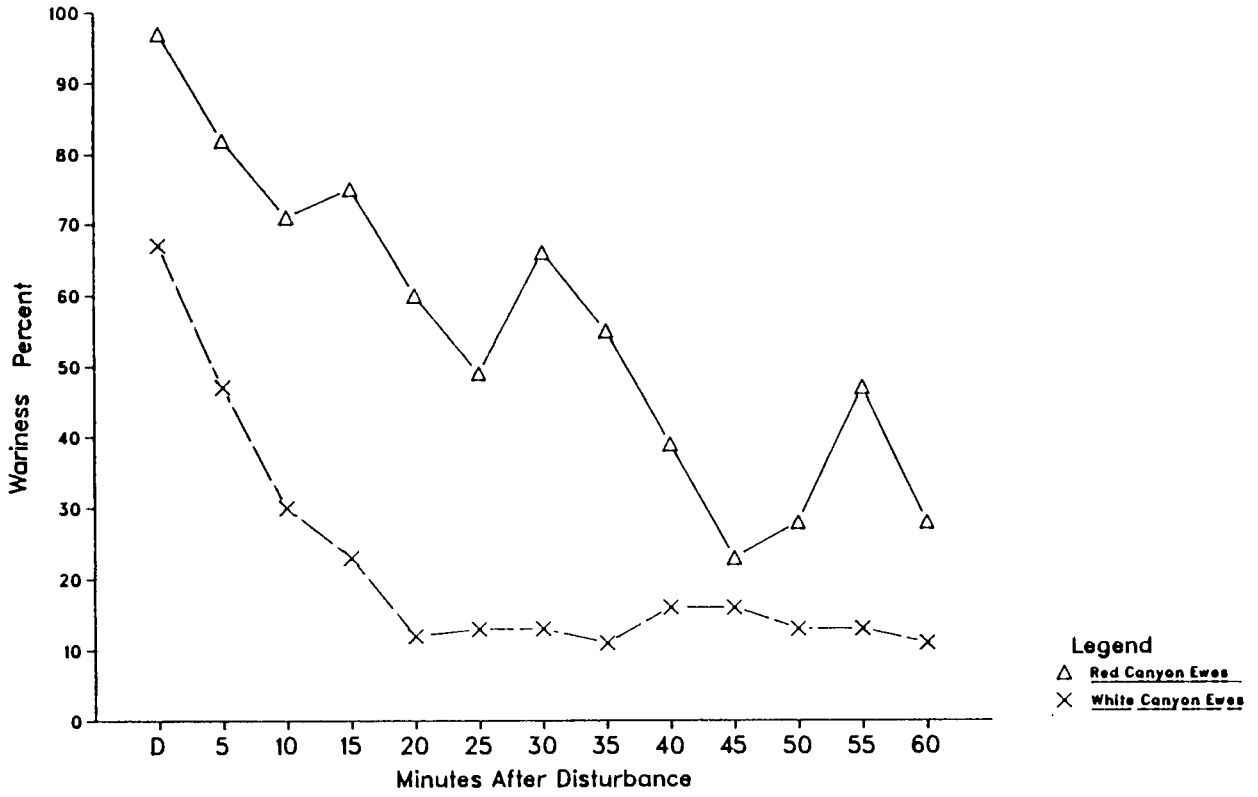

Figure 19. Group wariness of harassed Red and White Canyon ewe groups.

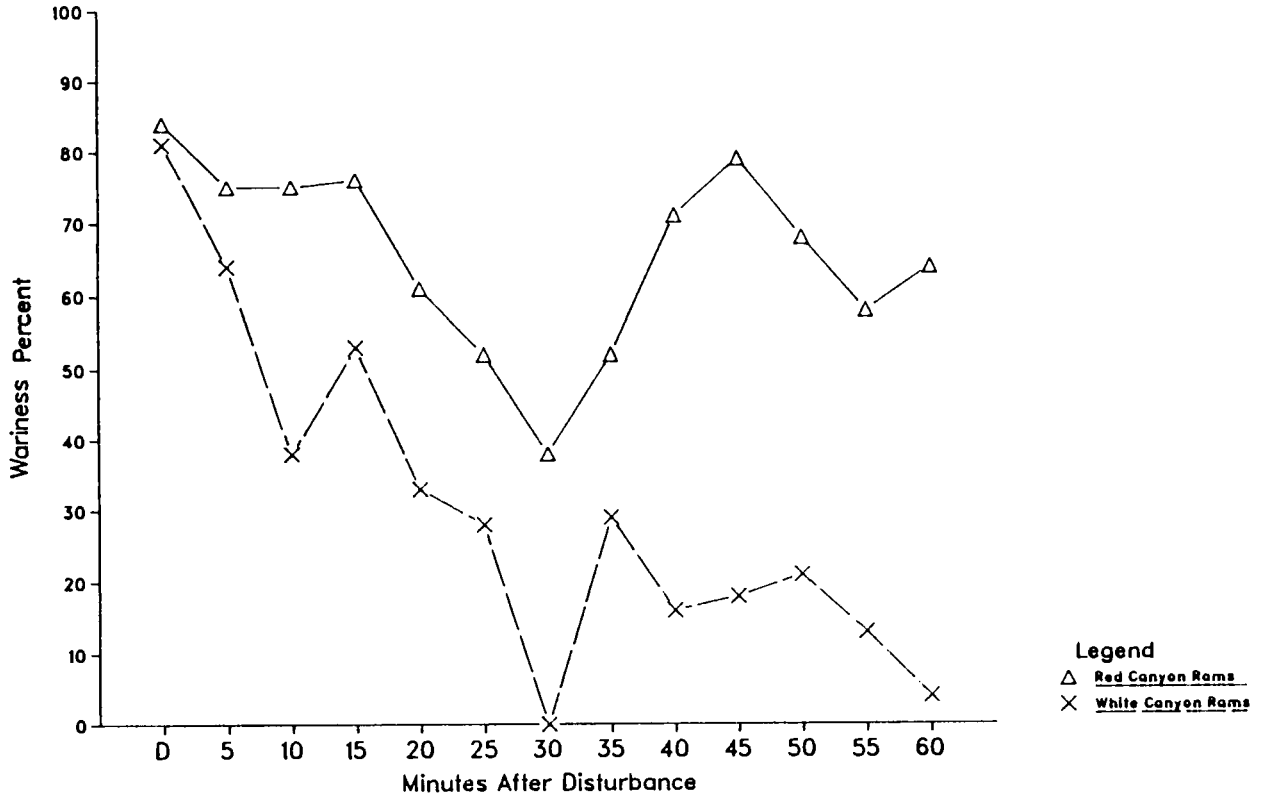

Figure 20. Group wariness of harassed Red and White Canyon ram groups.

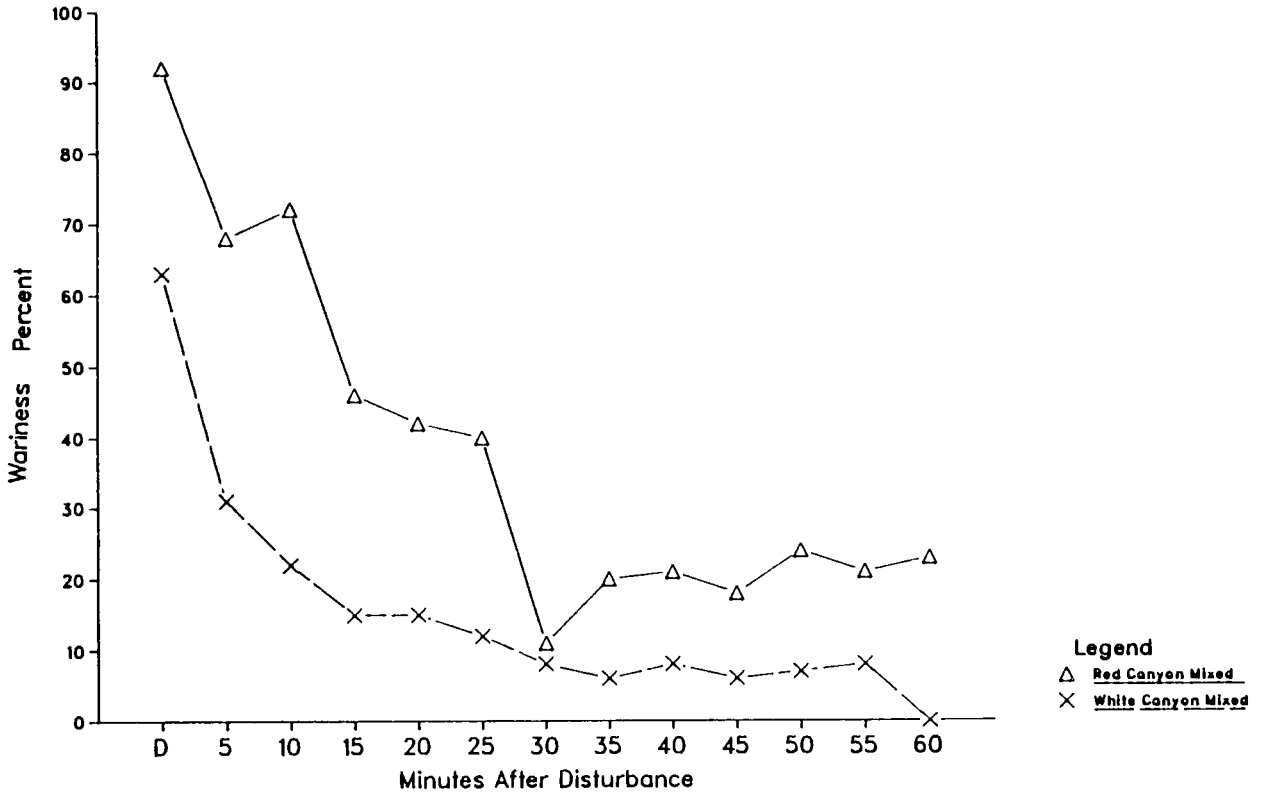

Figure 21. Group wariness of harassed Red and White Canyon mixed groups.

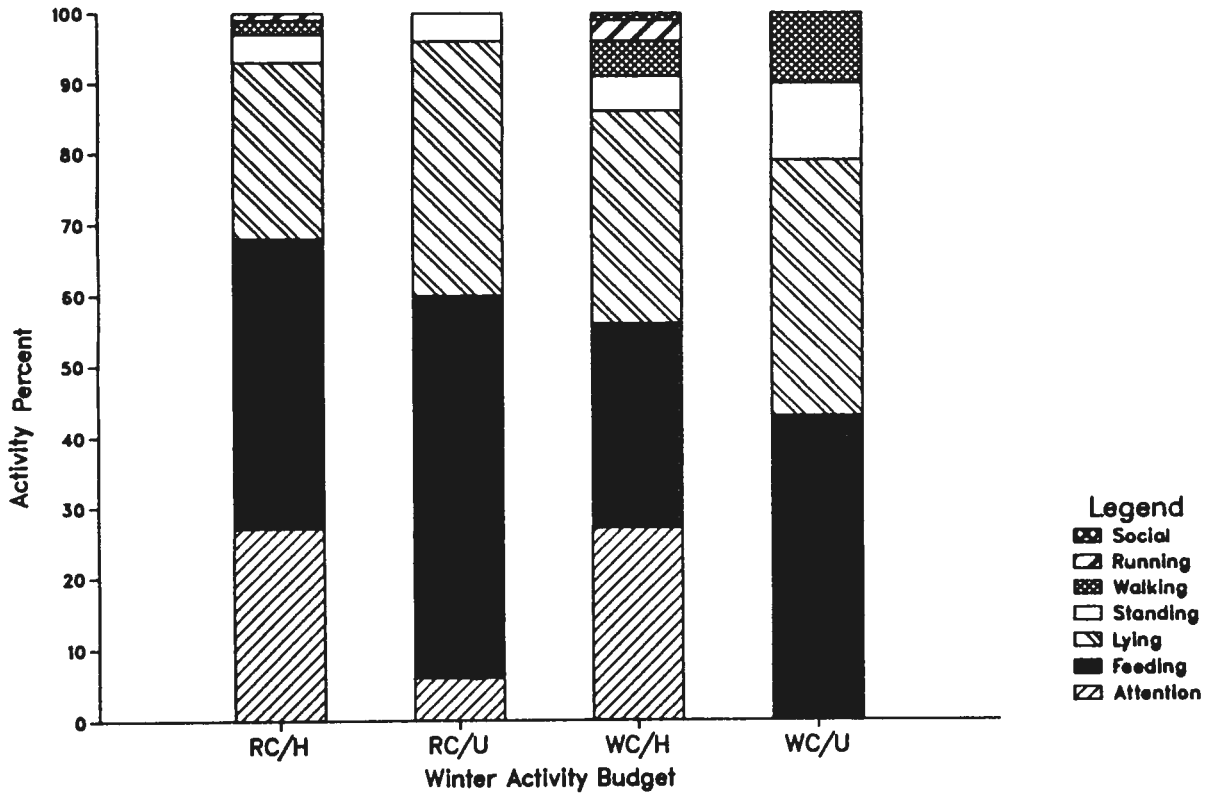

Figure 22. Winter activity budget of Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on mean time per 15 minute observation period each behavior contributed.

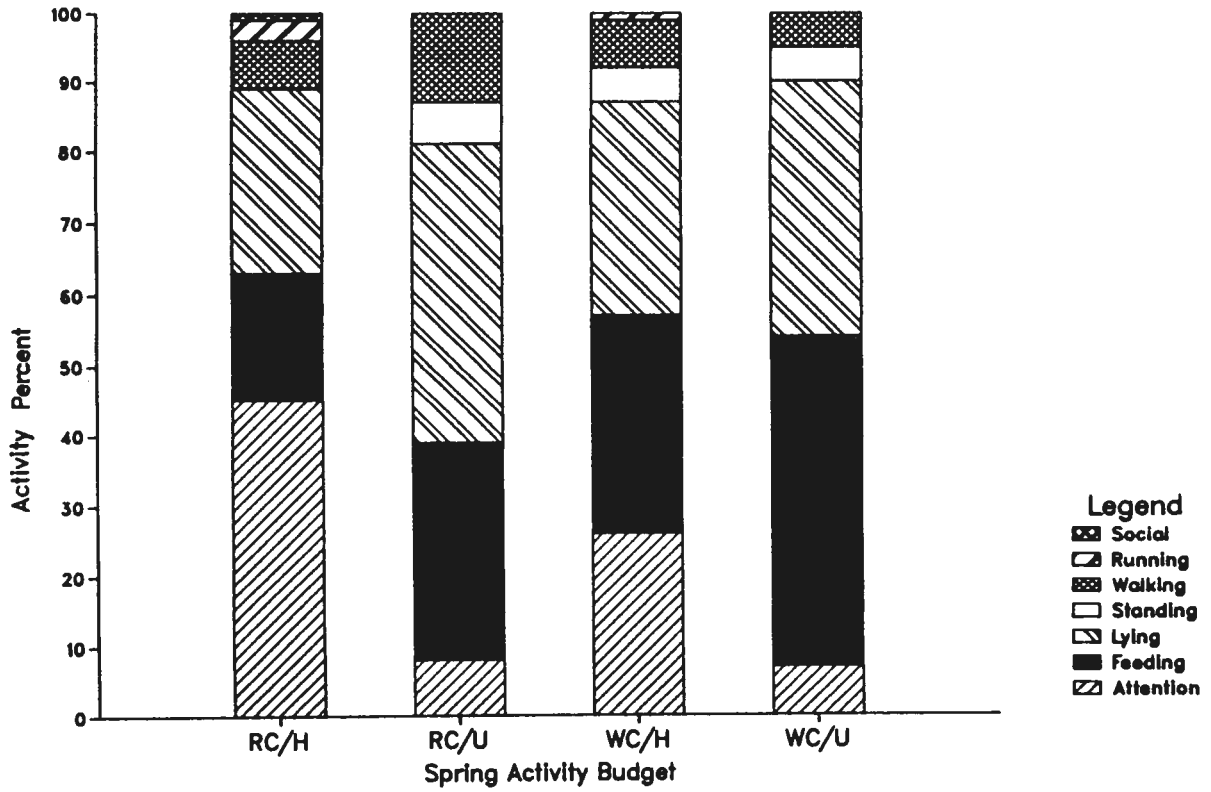

Figure 23. Spring activity budget of Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on mean time per 15 minute observation period each behavior contributed.

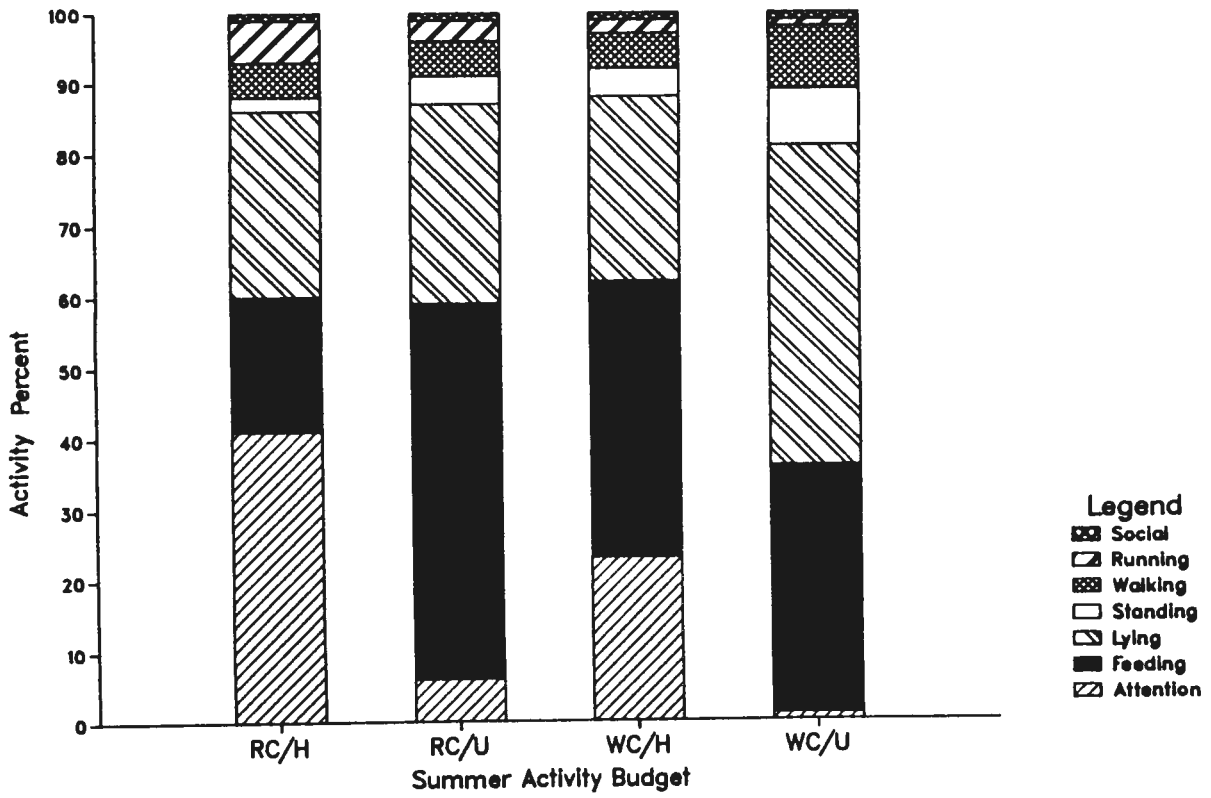

Figure 24. Summer activity budget of Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on mean time per 15 minute observation period each behavior contributed.

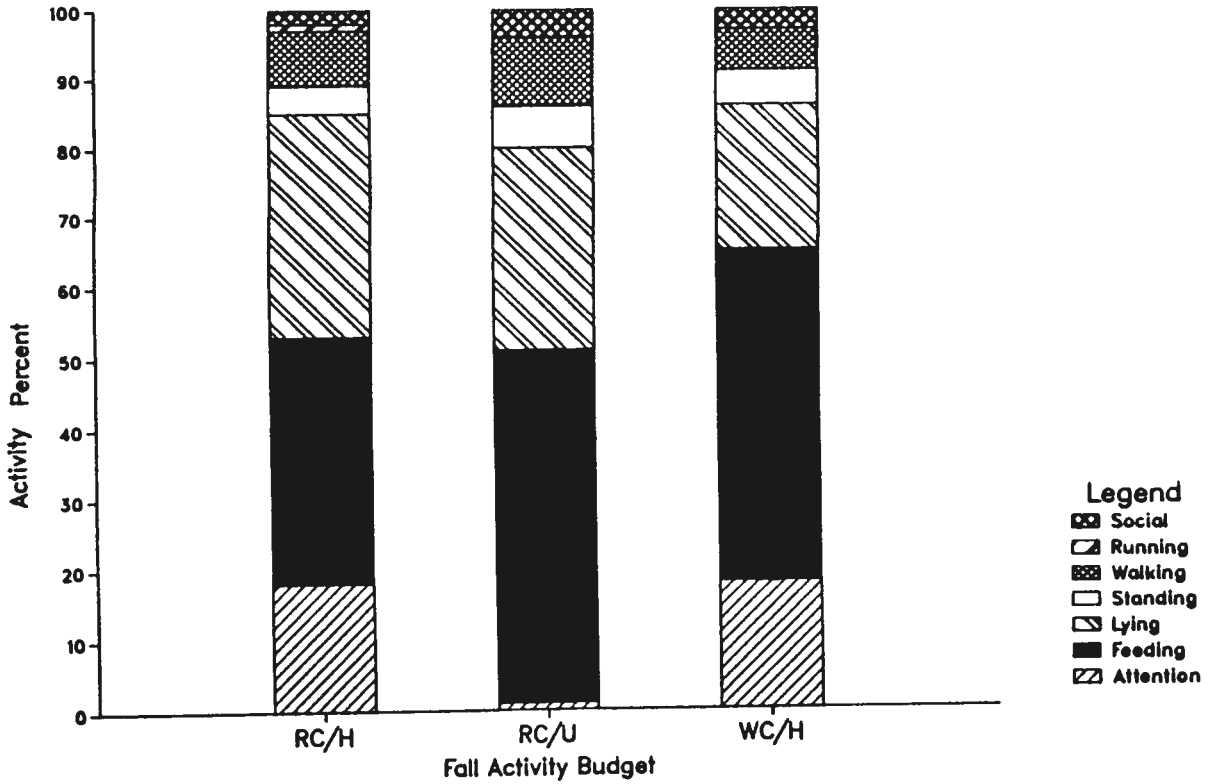

Figure 25. Fall activity budget of Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on mean time per 15 minute observation period each behavior contributed.

conditions. Because of the interest in comparing behavior in response to harassment between areas and among seasons the 3-way interaction between area, season, and disturbance level, was particularly meaningful. Only attention, feeding, and standing behaviors had significant 3-way interaction#. The results of analysis of variance of the main effects of area, disturbance level, and season on attention, feeding, and standing are summarized in Table 6 (Appendix D). Data for all behaviors are summarized in Table 7 (Appendix D).

When attention behavior was evaluated there was a significant 3-way interaction between area, disturbance, and season ($F=3.39$, $df=1,591$, $P<0.05$) indicating that seasonal effects of harassment on amount of time spent in attention behavior was dependent on area (Figure 26). During winter both Red and White Canyon bighorn spent more time in attention behavior under harassed conditions than under unharassed conditions, however diffenences in amount of time spent at attention between Red and White Canyon bighorn for harassed and unharassed conditions were not significant.

During spring, bighorn from both areas spent more time in attention behavior when harassed than when unharassed. However, Red Canyon bighorn spent significantly more time at attention than White Canyon bighorn under harassed conditions. Differences between areas under unharassed conditions were not significant.

During summer, Red Canyon bighorn spent more time engaged in attention behavior when harassed than when unharassed. White Canyon bighorn did not spend significantly more time at attention

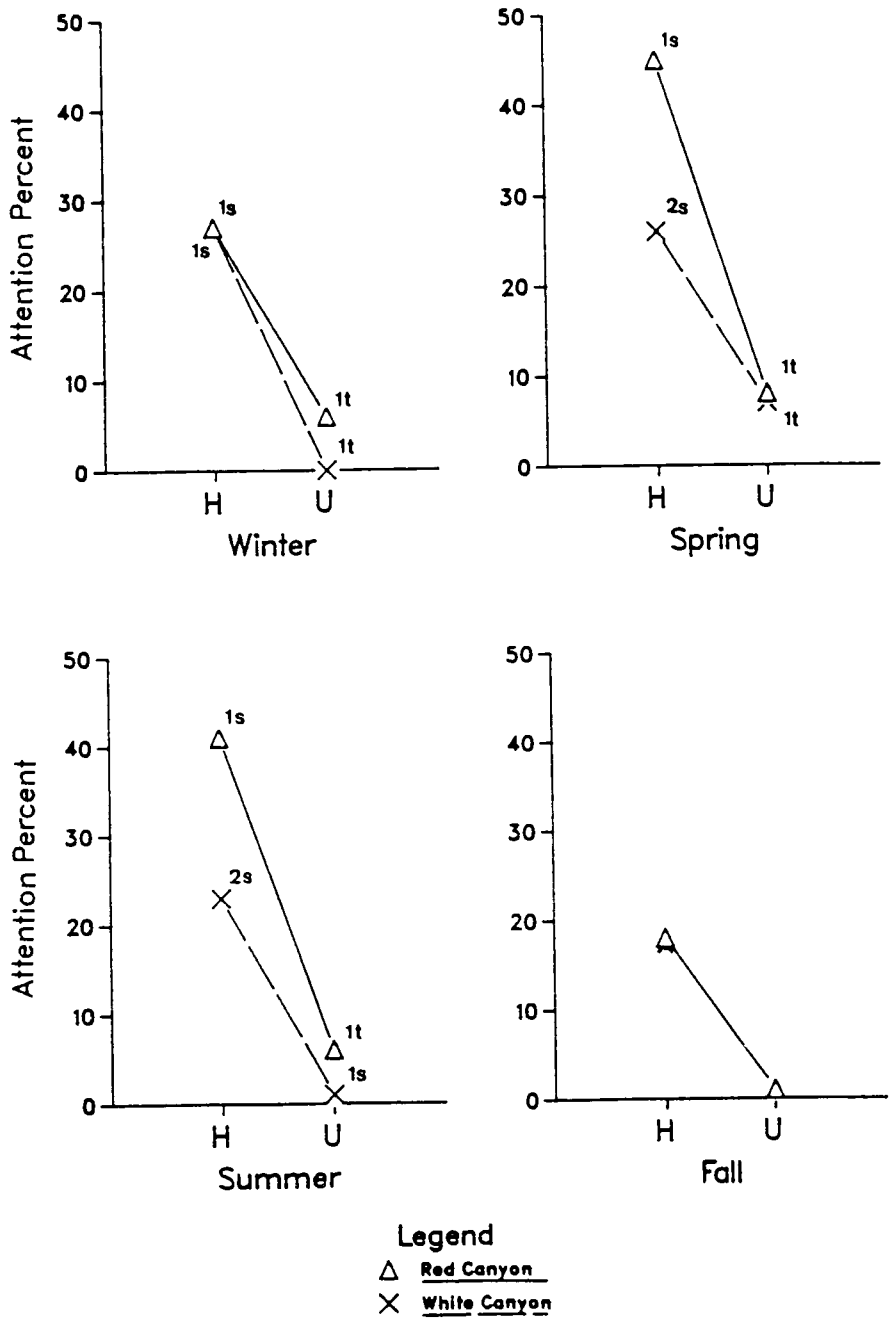

Figure 26. Seasonal comparison of attention behavior by Red and White Canyon bighorn under harassed and unharassed conditions. Different numerals indicate significant differences ($P<0.05$) between areas within harassment levels (H= harassed, U=unharassed), different letters indicate significant differences among harassment levels within areas.

when harassed compared to when they were unharassed. Red Canyon bighorn spent significantly more time engaged in attention behavior than White Canyon bighorn under harassed conditions, but there was no significant difference between the two areas under unharassed conditions.

No statistical comparisons were made for fall because no observations were made in White Canyon under unharassed conditions. However, average time spent at attention under harassed conditions was identical in the two areas. Average time spent at attention by harassed bighorn was lowest during fall for both areas.

No significant differences in time spent at attention between seasons under harassed or unharassed conditions were detected for White Canyon bighorn. Red Canyon bighorn spent significantly more time at attention in spring and summer than for winter and apparently fall under harassed conditions, but there were no differences between seasons under unharassed conditions.

When feeding behavior was considered, there was a significant 3-way interaction between area, disturbance level, and season ($F=4.1$, $df=3,591$, $P<0.05$) indicating that seasonal effects of harassment on amount of time spent feeding by bighorn was dependent on area. During winter and spring, there were no differences between Red and White Canyon bighorn in amount of time spent feeding under harassed or unharassed conditions. In winter and spring in both Red and White Canyons, harassed animals fed significantly less than unharassed animals.

During summer, harassed Red Canyon bighorn spent significantly

less time feeding than harassed White Canyon animals, but Red Canyon bighorn fed significantly more than White Canyon bighorn under unharassed conditions. Harassed Red Canyon bighorn fed significantly less than unharassed animals, however, in White Canyon there was no difference in average feeding time between harassed and unharassed animals.

No statistical comparisons were made for fall because White Canyon bighorn were not observed under unharassed conditions, but a trend similar to summer was apparent. Red Canyon bighorn fed less when harassed than when unharassed and apparently fed less than harassed White Canyon bighorn.

Amount of time spent feeding by harassed Red Canyon bighorn was significantly less in spring and summer than winter. Unharassed Red Canyon animals spent less time feeding in spring than either winter or summer. Amount of time spent feeding by harassed White Canyon bighorn was not different in any season, nor was amount of time spent feeding by unharassed White Canyon bighorn different in any season (Figure 27).

When standing was considered, a 3-way interaction was found between area, disturbance level, and season ($F=3.32$, $df=2$, $P<0.05$) indicating that seasonal effects of harassment on amount of time spent standing was dependent on area. The general trend is reduced amount of time spent standing when animals are harassed relative to when they are unharassed (Table 7). This is not surprising since attention may occur while bighorn are standing or lying. Reduction in time spent standing is no doubt absorbed by the number of animals standing at attention. Though not

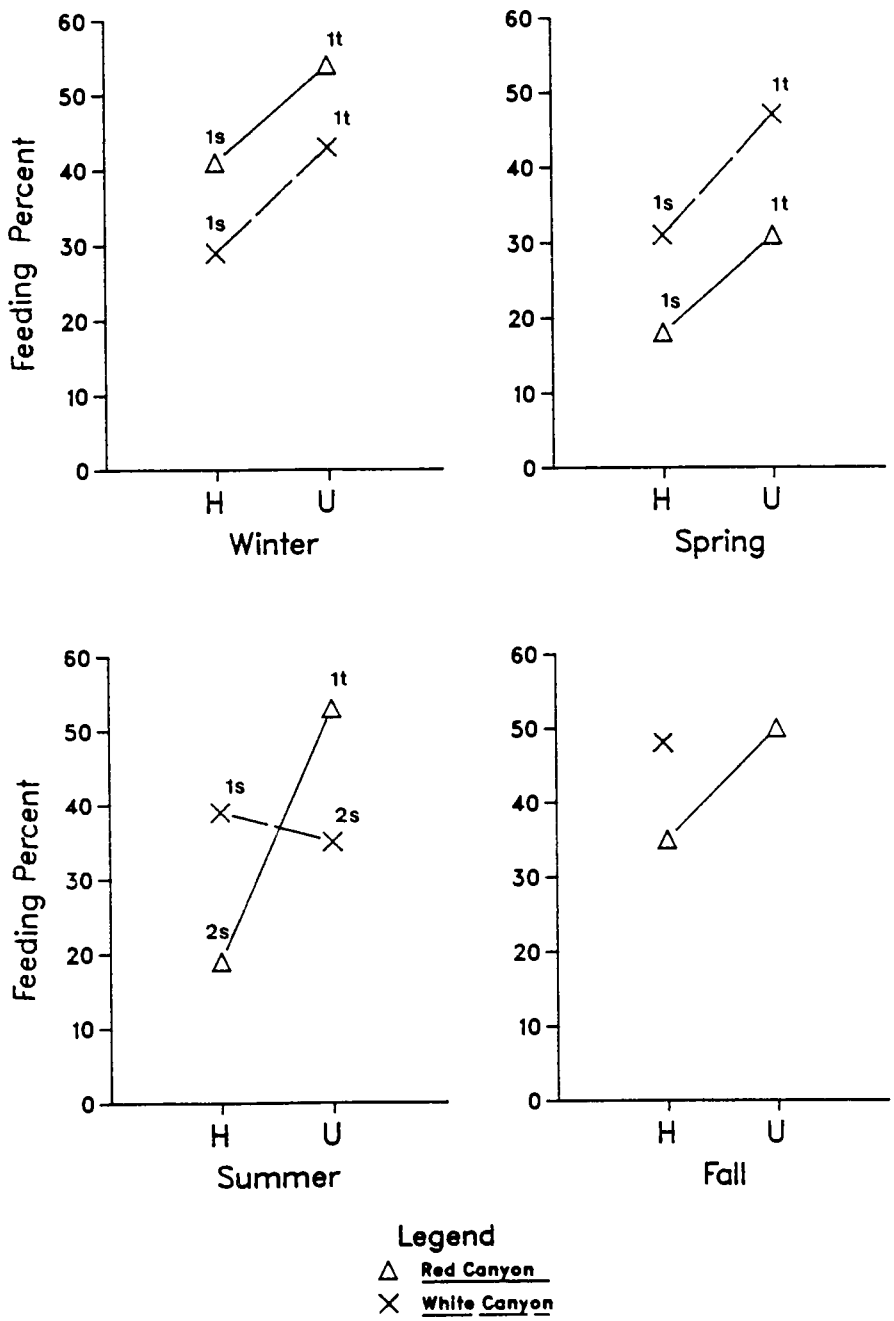

Figure 27. Seasonal comparison of feeding behavior by Red and White Canyon bighorn under harassed and unharassed conditions. Different numerals indicate significant differences ($P<0.05$) between areas within harassment levels (H= harassed, U=unharassed), different letters indicate significant differences among harassment levels within areas.

significant, a similar trend exists for lying behavior as well.

Number of Animals

Differences in activity budget between areas were also evaluated by determining number of desert bighorn engaged in each of the seven previously described behaviors in all seasons under harassed and unharassed conditions (Figures 28-31). Categorical data analysis for each season revealed a significant 3-way interaction between area, disturbance level, and behavior suggesting that the effect of harassment on behavior was dependent on area (winter X^2=118.3, df=6, P<0.005; spring X^2=29.9, df=6, P<0.005; summer X^2=186.5, df=6, P<0.005; fall X^2=152.7, df=6, P<0.005). Data are summarized in Table 8 (Appendix D).

Because sample sizes were extremely large, statistical significance was apparent in comparisons where often only a one to two percent difference between areas was observed. Although statistically significant, these differences may not be of much biological significance. Trends are similar to those suggested by analysis of actual time spent in various behaviors. Attention, feeding, and lying behaviors showed greatest deviations when comparing Red and White Canyon bighorn under harassed and unharassed conditions.

During winter there was little difference in percentage of individuals engaged in attention behavior in Red and White Canyons regardless of disturbance level. In both areas harassment caused a significant increase in the proportion of bighorn at attention compared to when they were unharassed.

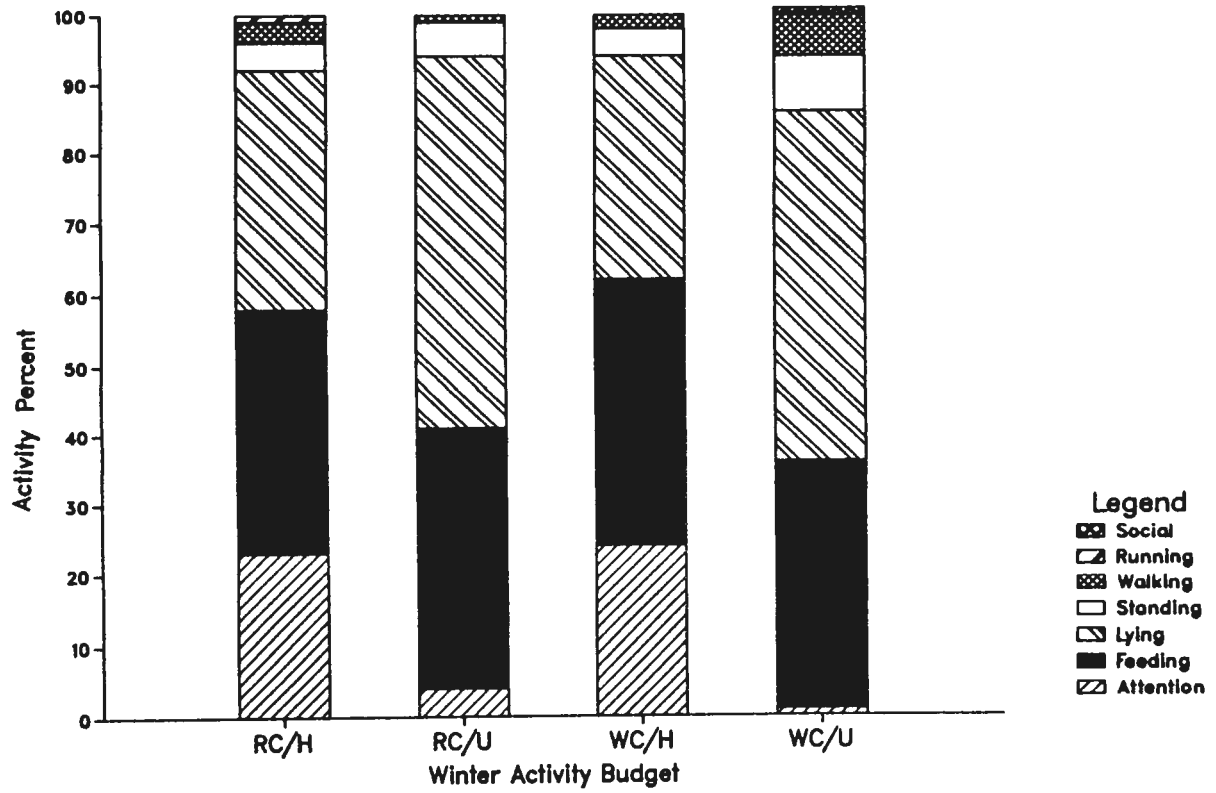

Figure 28. Winter activity budget for Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on number of animals engaged in each behavior at five minute scan intervals.

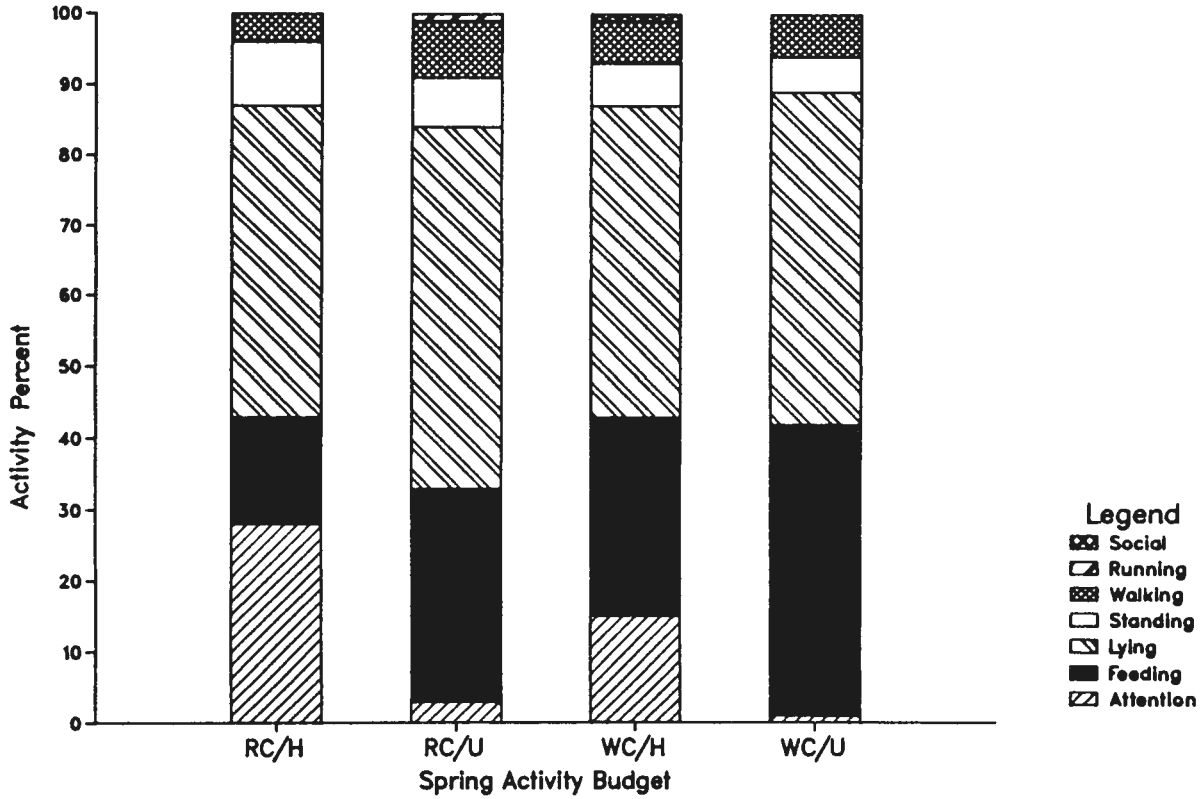

Figure 29. Spring activity budget for Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on number of animals engaged in each behavior at five minute scan intervals.

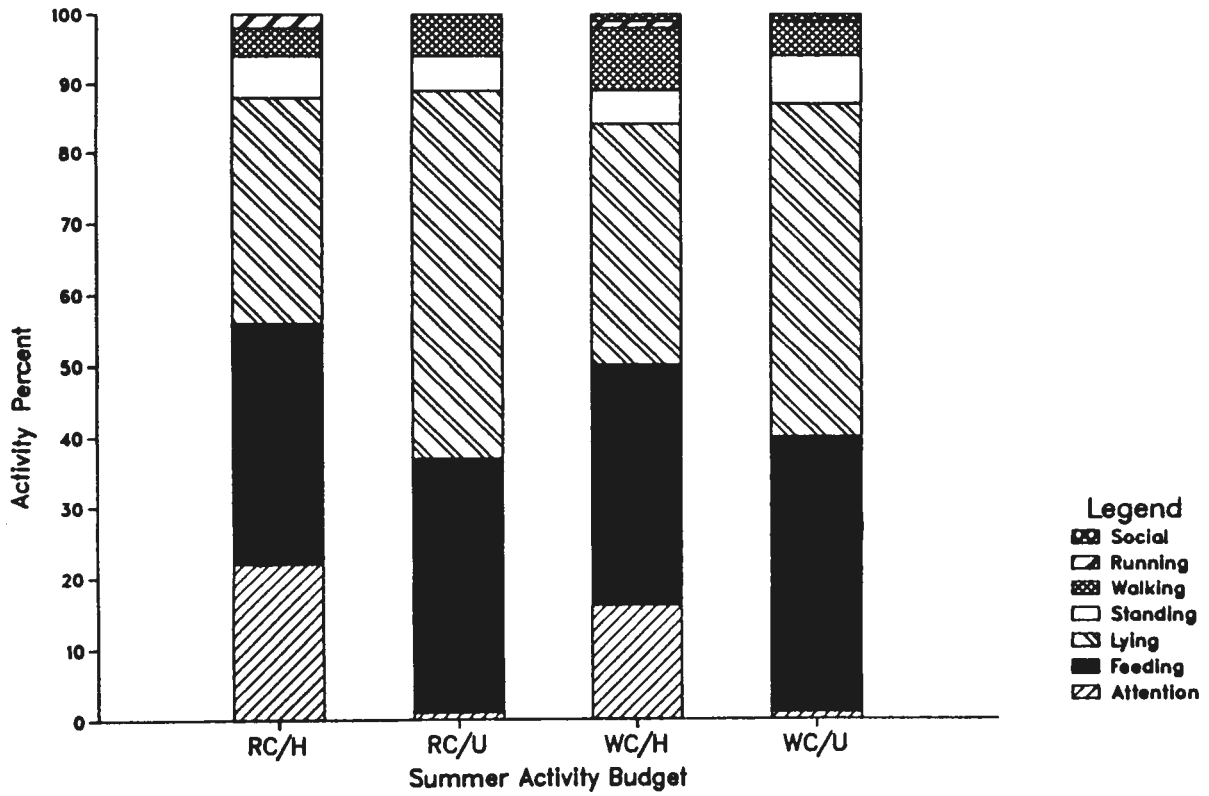

Figure 30. Summer activity budget for Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on number of animals engaged in each behavior at five minute scan intervals.

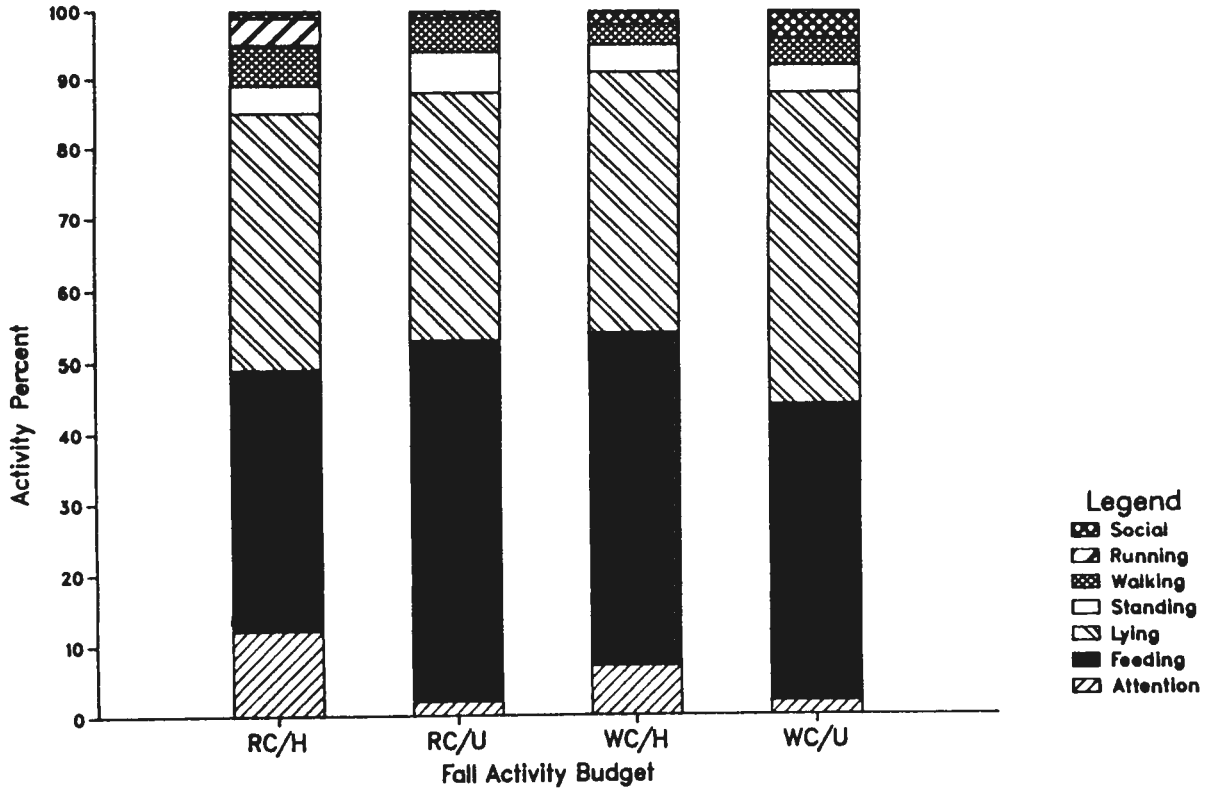

Figure 31. Fall activity budget for Red and White Canyon bighorn under harassed and unharassed conditions. Percentages based on number of animals engaged in each behavior at five minute scan intervals.

During spring, summer, and fall a greater proportion of Red Canyon bighorn exhibit attention behavior when harassed than White Canyon bighorn under harassed conditions. Differences between the two areas when animals were unharassed were minimal. Bighorn in both areas appeared to be least sensitive to human harassment in fall as reflected by the relatively low proportion of bighorn engaged in attention behavior during harassment (Figure 32).

Generally, a greater proportion of bighorn fed when unharrassed than when harassed in both areas. However, in White Canyon during winter and fall the proportion of animals feeding increased under conditions of harassment relative to when they were unharassed. In spring and fall, the proportion of White Canyon animals feeding under harassment was greater than proportion of Red Canyon animals under the same conditions, however, for winter and summer differences between areas were not significant (Figure 33).

In all seasons, lying behavior occurred most often under unharassed conditions in both Red and White Canyon areas (Table 8). Under harassed conditions, the proportion of animals lying dropped considerably. Since attention can occur while animals are either lying or standing, it can be expected that the proportion of animals lying will drop as those animals lying at attention are absorbed into the attention category.

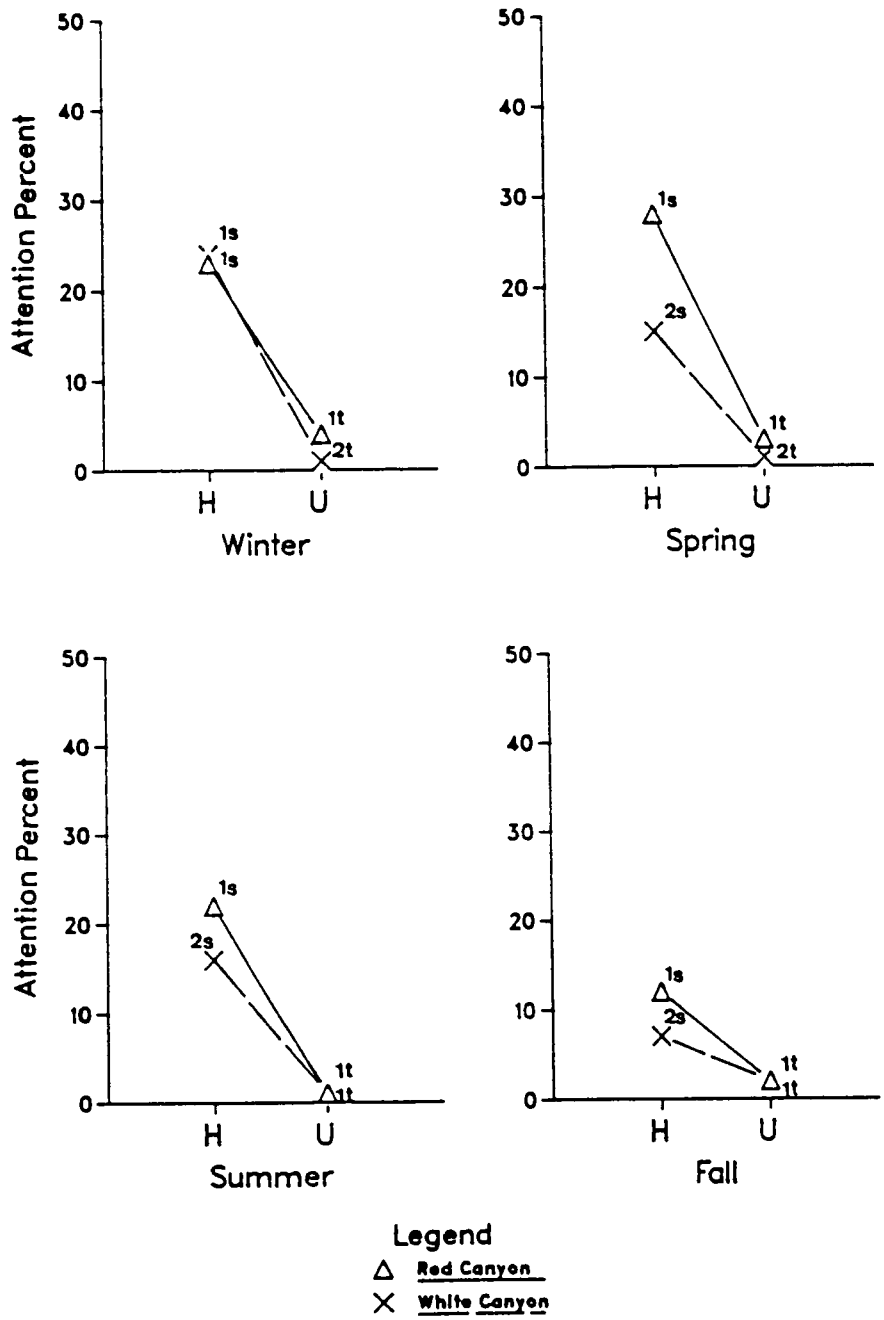

Figure 32. Seasonal comparison of attention behavior by Red and White bighorn under harassed and unharassed conditions. Different numerals indicate significant differences ($P<0.05$) between areas within harassment levels (H= harassed, U=unharassed), different letters indicate significant differences among harassment levels within areas.

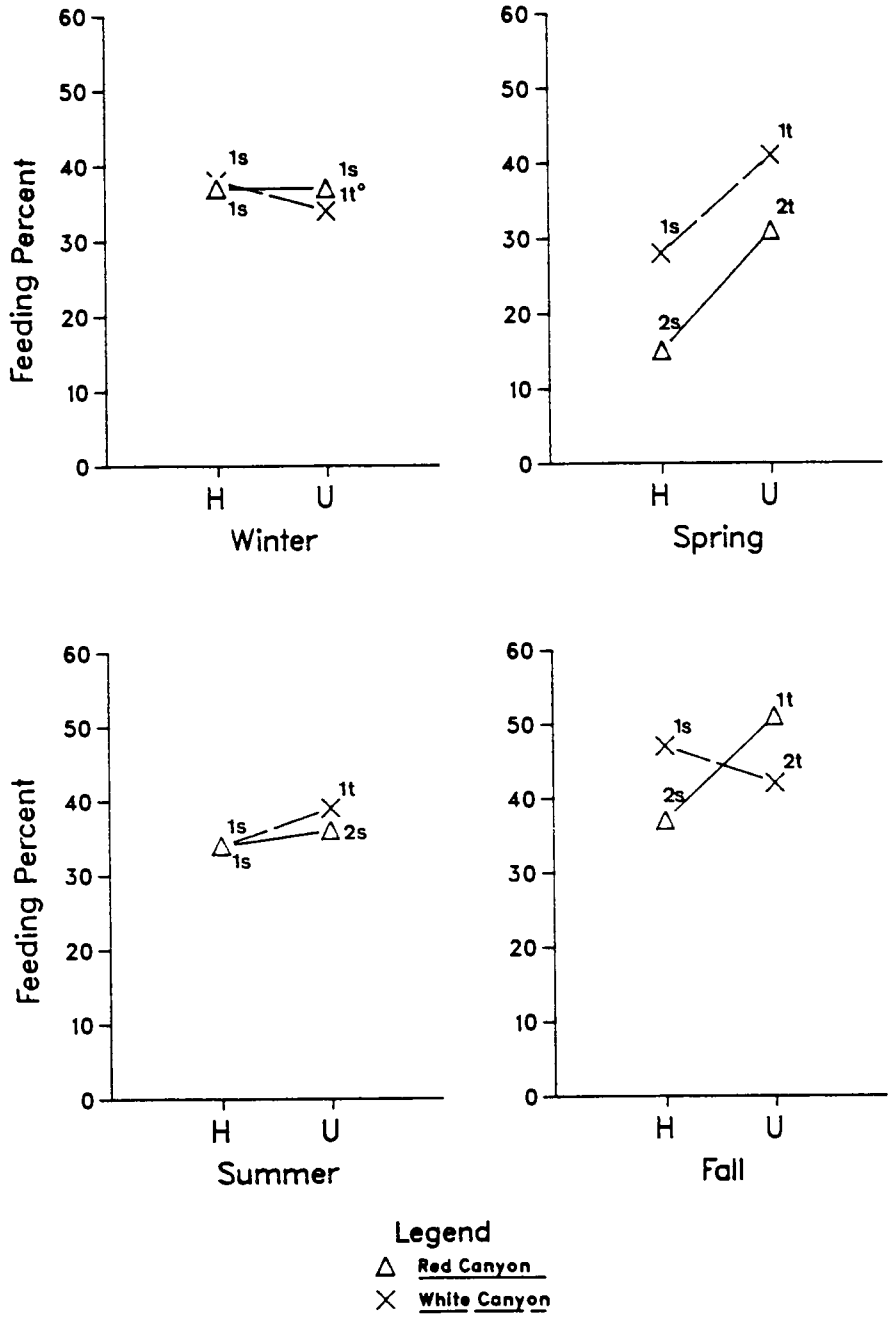

Figure 33. Seasonal comparison of feeding behavior by Red and White Canyon bighorn under harassed and unharassed conditions. Different numerals indicate significant differences ($P<0.05$) between areas within harassment levels (H=harassed, U=unharassed), different letters indicate significant differences among harassment levels within areas, t^{0} = significance at $P \leq 0.10$.

DISCUSSION

Wildlife and land management agencies have only recently taken an active role in assessing impacts humans have on wildlife populations. Recent research has addressed the issue of human impacts on bighorn sheep at several levels. Researchers have attempted to answer the question of how various human disturbances affect bighorn by field as well as laboratory experimentation. Most field studies have examined human impacts on bighorn as they affect behavior. Severity of behavioral response for various disturbance distances, approach positions, seasons, disturbance types, etc., has been determined in several areas. Heart rate telemetry studies have been conducted to determine what types of harassment stimuli illicit increases in cardiac response and presumably energy expenditure. Despite these advances there are many areas in which our knowledge is deficient regarding the influence of human disturbance on bighorn. This study adds information in two of those deficient areas.

Prior to this study, no systematic investigation had been conducted to compare impacts of harassment in areas with contrasting disturbance histories and no attempt had been made to determine effects of harassment on activity budgets. This study incorporated the aspects of behavioral response as well as activity budgets in assessing the effects of harassment.

Review of Hypotheses

Effects of human harassment on desert bighorn sheep were evaluated with respect to four null hypotheses that suggested there would be no significant behavioral differences between Red and White Canyon bighorn. Based on the results, all four are rejected. Bighorn behavior as a result of human harassment was different between Red and White Canyon areas. Red Canyon bighorn were more severely impacted by human harassment than White Canyon animals. This difference is attributable to contrasting patterns of human use in the two areas.

Hypothesis one stated that immediate response by Red and White Canyon bighorn would not be different during harassment trials. However, when deliberately harassed, immediate response by desert bighorn differed significantly between Red and White Canyon bighorn. Red Canyon bighorn were more reactive than White Canyon bighorn when harassed and animals responded to harassment most often with flight responses. Contrastingly, White Canyon bighorn reacted most often with non-flight responses. This difference applied when immediate response was compared between areas with respect to disturbance type, reaction distance, approach position, season, habitat type, group composition, group size, and initial behavior.

The second hypothesis stated that average distance fled by harassed bighorn would not differ between areas. However, average distance fled by Red Canyon bighorn was significantly greater than average distance fled by White Canyon bighorn as a result of harassment trials. Similar to the trend

for immediate response, average distance fled by Red and White Canyon bighorn differed significantly with respect to the same independent variables.

Hypothesis three suggested that group wariness of harassed bighorn would not be different between areas. However, a greater proportion of Red Canyon bighorn exhibited wariness for longer periods of time than White Canyon animals while in the presence of harassing stimuli.

The last hypothesis suggested that activity budget as determined by actual time spent by bighorn as well as number of animals engaged in various behaviors would not differ between Red and White Canyon areas. Significant differences in activity budgets were discovered between areas, particularly under harassed conditions. Feeding and attention behaviors were particularly affected when bighorn were subjected to harassment. Attention behavior occurred significantly more often and feeding occurred significantly less often in Red Canyon than in White Canyon under harassed conditions.

Both methods used to determine activity budgets (actual time and number of animals) indicated significant differences in behavior of Red and White Canyon bighorn when subjected to harassment. Both methods provide useful information to wildlife and land managers. Although actual time data are more difficult to obtain, actual time spent by bighorn in each behavior category can be used to calculate energy budgets when adequate estimates of energy expended in corresponding behaviors are determined. Number of animals cannot be used in calculating time-energy

budgets, but because of the ease of data collection they can be used readily to obtain relative estimates of disturbance levels in given populations.

Energy-Nutrient Relationships

The well-being of an animal in its environment is subject to energetic constraints (Moen 1973). Optimal use of habitat requires a high degree of awareness by animals. They are finely tuned to stimuli indicating the presence of food, conspecifics, predators, etc. However, if an animal is continually aroused, as from human disturbance, the added costs of excitement and escape may interfere with health, growth, reproductive fitness, and emotional welfare (Thompson 1957, Liddell 1961, Geist 1979). Therefore, it is necessary to understand the nature of energy requirements and energy expenditure patterns of animals so that harassment effects on energy balance can be predicted.

Energy costs realized by wildlife as a result of human harassment are associated with increased excitement, avoidance or withdrawal response, and duration of response as measured by distance traveled or time engaged in an energy costly-response. Higher-than-natural excitement levels are contrary to long-term energy conservation adaptations that wildlife possess (Moen 1976). Expenditure of energy due to excitement is costly because metabolism is increased, thus competing for energy otherwise available for maintenance, reproduction, and growth (Blaxter 1962, Geist 1971b). MacArthur et al. (1979,1982) demonstrated that heart rate of bighorn sheep increased as a result of various

harassment stimuli including approach by man, approach by man with dog, approach by man from over ridgetop, and approach by vehicle. They suggested that elevated heart rates were indicative of increased energy costs. Several studies show relatively strong correlation between heart rate and energy expenditure (Webster 1967, Brockway and McEwan 1969, Adams et al. 1971, Holter et al. 1976, Moen 1978). However, caution must be used when assigning energy expenses based on heart rate telemetry studies as suggested by Robbins et al. (1979) and Mautz and Fair (1980) who found unreliable correlations between heart rate and energy expense.

Costs of withdrawal from harassing stimuli are not well studied, but energy expense of various forms of locomotion have been documented for several ungulates. Energy costs increase linearly with speed (Gates and Hudson 1978, Robbins et al. 1979, Mautz and Fair 1980, Kautz et al. 1982, Parker et al. 1984). Walking away from disturbance is therefore less expensive than trotting, or running in more panicked flight.

Costs of running increase with decreasing body size (Schmidt-Nielsen 1979). This relationship is particularly meaningful for young animals as they have higher energy costs per unit body weight than adults (Chassin et al. 1976).

Uphill or vertical locomotion is more energy consuming than movement on the level (Brockway and Gessaman 1977, Parker et al. 1984). Depending on the incline, uphill movement can increase energy costs as much as 21% over horizontal movements (Robbins et al. 1979).

Summing the costs of movement type, distance moved, and excitement can give a relative estimate of energy expense for individual harassment situations. It is intuitive that the more excited, the faster the flight, and the longer the duration of the flight response, the more energy will be expended.

Given these relationships, and knowing what the response patterns of desert bighorn sheep in Red and White Canyons are, relative costs of harassment trials for each area can be estimated. Red Canyon bighorn responded most frequently in harassment trials by running away from the disturbance (61%). Average distance fled by Red Canyon bighorn when flight response was running was 1228 m. By comparison, running away from harassing stimuli by White Canyon bighorn occurred in only 26% of the harassment trials and the average distance fled was only 484 m (Table 9, Appendix E). No energy costs of excitement can be added at this point because cardiac response was not monitored. However, based on response and distance fled it can be concluded that on the average, Red Canyon bighorn spend more energy during instances of harassment than White Canyon bighorn.

This is particularly meaningful in light of the delicate energy balance that exists for most wildlife species. Animals must meet daily and seasonal needs for maintenance, growth, and reproduction through efficient exploitation of available foods (Robbins 1983). Generally animals optimze diet selection within energy, time, and bulk constraints (Schoener 1971, Westoby 1974, 1978, Hainsworth and Wolf 1979). Disturbance that alters normal foraging and food processing patterns hinders the

efficiency with which animals assimilate energy. Therefore, it is important that animals maximize energy intake while minimizing energy expenditures.

Such an optimization process is evident for many large ungulates especially in winter when they reduce foraging to presumably decrease activity and metabolism to live within a restricted energy budget (Chappel and Hudson 1978, Moen 1976, 1978). Rocky Mountain bighorn and Stone's sheep (O. dalli stonei) follow such a pattern as resting and feeding combined make up over 80% of the total activity budget (Geist 1971b).

Ruminants are faced with a unique problem with respect to energy balance in that rumen capacity represents a finite limit to the amount of nutrients available in a given time (Moen 1973). The digestive process of rumenation proceeds slowly to completion, particularly if high-fiber containing plants are consumed (Robbins 1983). If forage quality is poor, individuals must consume more to get adequate nutrients, but rumen capacity and processing time limit how much can be ingested and processed (Montgomery and Baumgardt 1965). In this regard larger individuals with correspondingly larger rumens are in a more favorable energetic state because more lower-quality forage can be successfully processed (Bell 1971, Van Soest 1981). Short (1964) suggested high winter mortality rates of deer fawns may be related to their relatively small stomach capacity and inability to metabolize energy rapidly enough to maintain necessary body heat.

Energy-nutrient relationships for desert bighorn sheep are

subject to the same constraints as other wildlife species. Commonly they are forced to maximize energy intake and minimize energy expenditure on frequently marginal quality ranges. However, human disturbance causes significant alterations in activity budgets that may not allow maintenance energy requirements to be met.

Harassed bighorn in both Red and White Canyon areas spend significantly more time engaged in attention behaviors and significantly less time feeding. With the exception of winter when amount of time spent at attention for Red and White Canyon bighorn was identical, Red Canyon bighorn under harassed conditions spent nearly twice as much time at attention as White Canyon bighorn (Table 6). During winter and spring, differences in amount of time spent feeding between Red and White Canyon bighorn under harassed conditions were not significant. However, during summer harassed Red Canyon bighorn spent significantly less time feeding than harassed White Canyon bighorn (Table 6). Reduction in feeding during summer appears particularly significant since summer is possibly the most nutritionally critical period for desert bigorn in southeastern Utah (Hull 1984). During summer, protein and phosphorus levels are particularly low relative to requirements for lactating ewes and their young lambs. Ewes that are harassed will be forced to expend energy in avoidance behavior and divert energy away from lactation, itself an energy costly process (Moen 1981). Aside from increased energy lambs will be forced to expend in avoidance behavior, they may not be able to consume adequate nutrients given

their small rumen size and high energy requirements. Nutrients not received as a result of poor lactation will necessarily have to be gained through forage. However, they may not be able to process the relatively poor quality forage fast enough to compensate for energy and nutrient losses. This may lead to poor growth and development. Domestic sheep that were fed restricted diets failed to recover body condition compared to lambs that were fed unrestricted diets (National Research Council 1981). Poor body condition resulting from inadequate nutrition will likely contribute to increased susceptibility to the several diseases that affect bighorn populations and eventually lead to death from pneumonia (DeForge et al. 1982).

Some caution must be used in assuming that uptake of adequate nutrients and energy is being prevented by human harassment. Observations of Red and White Canyon bighorn were only made during daylight hours so no estimate of how much time is spent foraging at night. Early observers of bighorn felt that night activity of desert bighorn was very limited (Hansen 1964, Wilson 1968), but more recent studies (Simmons 1969, Miller 1984) indicated that nighttime activity and feeding might be more extensive than previously thought. There is also no information available on diet selection after or during harassment that might indicate possible changes in feeding rates or diet quality that may be compensatory to incurred energy costs. Both of these areas should prove to be promising areas for future research.

What can be said is that the ways in which desert bighorn

sheep in southeastern Utah, particularly those in Red Canyon, exploit their environment are significantly altered by human harassment. Efforts should be made to determine how much energy is expended in the face of harassment and whether the available forage possesses enough nutritive value to make up for energy costs. Attempts should also be made to determine the degree to which animals can compensate for energetic costs by behavioral adjustment.

Hunting Ramifications

As suggested earlier, the annual desert bighorn sheep hunt has had considerable impact on bighorn behavior in the study area. No other single activity brings as many people directly into bighorn habitat with the potential of encountering bighorn sheep. Although the number of permits issued each year is small (five or six/year), the hunting season is long (30 days) and the probability that hunters will encounter several bighorn is high. Because the nature of the hunt is extremely difficult, generally several non-hunting companions accompany the permit holder to assist his efforts. Non-hunting companions and their vehicles add considerably to disturbance in the area during the hunting season.

Alterations in bighorn behavior as a result of hunting have been observed by Geist (1971b), and DeForge (1980) who suggested that hunting in some areas had caused rams to abandon traditional home ranges even though hunting levels were low. Horesji (1976) noted behavioral differences between hunted and unhunted bighorn

populations that were only separated by a short distance. Hunted bighorn had long flight distances (distance to which animals would allow humans to approach before fleeing, see Walther 1969) even though hunting groups were as few as one per year, whereas unhunted bighorn were tolerant and often approached Horesji to within close range. Differences in behavior between hunted and unhunted animals have been noted for a variety of ungulate species (Geist 1971a, Dorrance et al. 1975, Horesji 1976, Schultz and Bailey 1978, Berger et al. 1983). These differences are particularly evident when comparing relatively tame behavior exhibited by protected wildlife in National Parks to wild behavior of nearby animals that are regularly hunted. Morgantini and Hudson (1985) demonstrated that normal feeding patterns of elk changed during a hunting season in Canada. Elk moved to different habitat types and switched from a grazing habit to browsing. After the hunt was over, elk returned to areas they had occupied prior to the hunt and again chose grass over browse. Batchelor (1968, in Geist 1975a) showed that calf production in red deer dropped in New Zealand when hinds were forced to use suboptimal habitats as a result of hunting for damage control purposes.

Geist (1971a, 1975b) suggested that hunting, a consumptive use, was not compatible with non-consumptive uses such as photography and wildlife observation. Ungulates are not capable of differentiating between hunters and non-hunters and thus the reaction by animals is the same towards both groups (Horesji 1976). Therefore, bighorn in hunted areas generalize the stimuli

presented by all humans to the negative experience with hunters and wariness of animals increases.

In most areas bighorn are hunted as trophy animals and only mature rams are harvested. Hunts are conducted during late summer when the sexes are spatially segregated prior to breeding seasons. In those cases it can be expected that rams will be more wary than ewes because ewe groups absorb relatively little impact from hunters. However, in some areas ewe hunts have been conducted as a means of population regulation (Nichols 1976, Wishart 1976, Smith and Wishart 1978). Ewes and lambs in these areas are most likely more wary and respond to humans more severely than ewes that are not subjected to hunting pressure.

Thorne et al. (1978) observed that ewe hunts as a means of population regulation in Wyoming may be detrimental to bighorn by causing ewes and lambs to become more ram-like in their responses to humans, particularly on winter range where encounter rate with humans is high. They felt that high-quality winter ranges would be avoided for perhaps poorer but more secluded areas.

The desert bighorn hunt in Utah is a trophy hunt with only mature rams being legal trophies. However a unique situation exists in that the hunt begins in early fall while rams and ewes are still segregated but continues for a 30 day period by which time younger but legal rams have moved in with ewe groups, particularly in the Red Canyon area. Many of the rams harvested are killed during the last few days of the hunt in or in close proximity to ewe groups. In essence ewes and lambs are being hunted as well. The situation is further complicated by a

special high-bid desert bighorn hunt that has been conducted during the rut in each of the last five years (1980-1984). All five permit holders have been successful and again rams have been killed in groups containing ewes and lambs.

Given this situation, it might be expected that Red Canyon ewe groups would be more exciteable by human disturbances than nearby White Canyon ewe groups that are rarely disturbed by humans. It might also be expected that Red Canyon ewes and rams would exhibit similiar more reactive response patterns to human harassment than less disturbed White Canyon animals. It could also be predicted that White Canyon sexes should show similar behavior patterns only less reactive than Red Canyon bighorn.

Data collected in this study indicate that Red Canyon groups have been taught by hunters that humans are a negative stimulus and thus they are more reactive than White Canyon groups to any human disturbance. Behavior in response to interactions with humans is similar among group types within areas, particularly in immediate response (Figure 8), distance fled (Figure 16), and group wariness (Figures 34-35, Appendix C).

Although hunting has caused Red Canyon animals to be more wary than White Canyon animals when they interact with humans, this does not necessarily mean that the impacts are all negative. Increased wariness may, in fact, make Red Canyon animals less susceptible to poaching because they are less tolerant and less approachable than White Canyon animals.

Management Implications

Sound management of desert bighorn sheep populations is an important goal of wildlife and land management agencies in the western United States. Agency managers want and need to know what the effects of human disturbance are so those impacts can be incorporated in planning efforts. Effects of various types of disturbance, critical seasons, and harassment threshold levels that, when exceeded, will lead to population declines are areas of concern often raised by managers. Answers to these and related questions are difficult to obtain and require research in a number of scientific disciplines. This study cannot answer all questions regarding harassment of bighorn sheep, but does provide new information that will be of use in formulation of management plans for desert bighorn.

Although Red Canyon bighorn are more disturbed by interaction with humans than White Canyon bighorn, present levels of human activity in desert bighorn habitat in the Red and White Canyon areas are relatively low. Encounters between desert bighorn and humans are generally infrequent and occur primarily during spring and fall seasons. The level of disturbance in the area is probably not severe enough to impact bighorn at the population level, but differences in behavior between the two areas as a result of human activities are identifiable.

Results of the study indicate that desert bighorn in Red Canyon, those exposed to heavier hunting pressure and relatively higher traffic levels, react more severely and flee farther thus expending more energy than White Canyon animals. In the face of

continuous harassment, the proportion of Red Canyon animals exhibiting wariness behavior is significantly greater relative to White Canyon animals for a longer period of time. Activity budgets of harassed Red Canyon bighorn are more severely altered than those of harassed White Canyon bighorn. More time is spent by harassed Red Canyon animals in attention behavior and less time in feeding behavior compared to harassed White Canyon animals. Activity budgets of unharassed animals are similar for both areas. Subsequently, harassment alters the normal behavior patterns of desert bighorn and prevents them from spending as much time as they normally would in a variety of behaviors. These differences allow identification of areas of consideration during management planning efforts. Some specific areas are discussed below.

Red Canyon bighorn that have experienced considerably more negative interactions with people than White Canyon bighorn are more sensitive to human activities. It can be expected that if hunting patterns continue status quo, Red Canyon bighorn will continue to react severely to human presence. This reaction will occur when hikers, miners, geologists, and ranchers as well as hunters interact with bighorn since bighorn are not capable of differentiating between classes of humans. White Canyon bighorn can be expected to continue to be tolerant of people as long as they are not actively hunted. If hunting pressure increases in the White Canyon area, bighorn behavior will likely begin to resemble that of Red Canyon animals. The chance of increased hunting in White Canyon is a likely possiblity as hunters become

more aware of ram habitat use patterns in the area.

Harassment in any season can have negative impacts on desert bighorn depending on the intensity of the disturbance. However, there are times when the effects of harassment will be more severe. Results of this study indicate that bighorn are most sensitive to human disturbance in spring and summer and least sensitive during fall and winter. Spring harassment can be particularly harmful to pregnant or lactating ewes in terms of energy costs. Rapid growth by lambs and lactation by ewes demand high amounts of energy (Moen 1981). Energy spent in excitement or flight would subtract from the total needed to maintain adequate milk production and growth. During the course of the study desert bighorn ewes with lambs were harassed on several occasions. Response was generally greater than in other seasons in both areas, though the response by Red Canyon animals was greater than for White Canyon bighorn. Extreme response characterized by running flight by ewes with lambs was noted several times. On three occasions distance fled by ewes with one to two week old lambs exceeded 4 miles with only brief pauses (in one instance the distance was over seven miles). Extreme exertion like these cases cannot be beneficial for small lambs.

Summer can also be a critical season for desert bighorn in southeastern Utah as well. Response to harassment and distances fled are comparable to those for spring, but unlike spring when forage is relatively nutritious, forage is at its lowest nutrient levels (Hull 1984). Flights from harassing stimuli can be particularly severe if energy expended cannot be recoverd from

nutrients available in their diet. Bighorn may also suffer from excessive heat loading if forced to flee during extremely high temperatures common to desert habitats. Efforts to cool body temperatures to tolerable levels add further energetic costs (National Research Council 1981). Measures should be taken to minimize major disturbances during spring and summer that would cause lactating ewes and young lambs to expend large amounts of energy due to excitement or flight.

Although bighorn response to human disturbances in fall and winter is less pronounced than during spring or summer, it does not mean that interactions between man and bighorn in those seasons will not be harmful. Because bighorn are more tolerant of people at those times of the year, they are more susceptible to poaching. Bighorn rams in the rut are relatively unconcerned by human approach during late fall and early winter. On several occasions during the breeding season the researcher was able to observe mature rams at close distances in Red Canyon as well as White Canyon. Rams were preoccupied with courtship and dominance behaviors as they courted ewes and contested other rams for breeding priviledges. This loss of wariness during the breeding season is the main reason that rut season hunts are successful. The first year that desert bighorn were hunted in Utah (1967) the hunt was conducted during the rut and all permittees were successful. Since the special high bid hunt was initiated in Utah five years ago, all hunters have hunted during the rut and all have killed rams. Though the removal of the few rams that are harvested is of little harm to the bighorn population as a

whole, behavior of ewes, lambs, and young rams is affected when animals are killed within short distances of or directly from mixed groups. Ewes and lambs sensitized to human encounters by exposure to hunters will respond more severely to encounters with other but harmless humans in the future. If possible, hunts should be planned so they can be conducted while rams and ewes are sexually segregated to minimize the impact on ewes and lambs.

Bighorn were more sensitive to hikers than vehicles, more sensitive when interactions with humans occurred at distances < 400 m, and generally more sensitive to approach from above than from below or on the level. Although it is difficult to regulate human activities on public lands especially on existing roads and trails, people should be urged to minimize the negative effects of bighorn-human encounters by remaining in vehicles and close to roads if possible. If bighorn are encountered by vehicles, people should be encouraged not to approach the animals closer on foot. Hikers should be cautioned against approaching closer when bighorn are encountered, especially from above.

Major developments in bighorn habitat should be discouraged, but when necessary they should be planned to avoid spring and early summer when young lambs are present. Activities during the breeding season should also be limited when possible as disturbance may have the tendency of limiting normal rutting behavior. If new roads and building complexes are planned, they should be built as far away from critical bighorn areas as possible to maximize distance of bighorn-human encounters. New roads and developments should be constructed a minimum of 400 m

away from talus slopes commonly used by bighorn.

Construction crews, miners, surveyors, etc. working in bighorn habitat should be encouraged by managemnt officials to follow a predictable routine when possible to give bighorn an opportunity to habituate to their activities, thus minimizing negative effects. Crews working in the area should not be discouraged from observing bighorn, but should be encouraged not to sensitize them further to human encounters by approaching the animals or harassing them in any way.

Disturbance to bighorn populations by people will undoubtedly continue as the demand for recreation in remote areas increases. The potential for human interaction with desert bighorn in southeastern Utah is also on the rise as the area's popularity with recreationists increases. Should the now depressed uraninum market improve and should discussed plans for tar sands development in the area come about, more people will have the opportunity to encounter bighorn in their native habitat. The negative impacts of these encounters can be buffered to some extent if the above precautions are followed.

Because of the differences in behavior of bighorn in areas of contrasting disturbance levels, behavior can be used by wildlife and land managers as a tool to indicate levels of harassment of given bighorn populations. If major developments are planned for certain areas behavioral baseline data can be readily collected prior to the disturbance. Attention and feeding behaviors could be monitored and later compared with the same behavior patterns during and after the disturbance to

determine sensitivity levels and how lasting the effects of the disturbance were.

SUMMARY

Response of desert bighorn sheep to human disturbance has been evaluated in several areas of the western United States. However, disturbance objectives have been secondary to other areas of emphasis. Behavioral responses by bighorn to human encounters have been documented but generally little information other than broad response category has been recorded. Most of these evaluations have been conducted in areas where bighorn are exposed to large numbers of people, but are not hunted. No systematic studies have been made that compare unhunted areas to hunted areas to determine if behavioral differences occur.

This study was the first to investigate behavioral response of desert bighorn in two areas with contrasting disturbance levels. Response to human harassment was evaluated in terms of immediate response to harassment, distance fled as a result of harassment, group wariness during harassment, and activity budgets to determine if differences in behavior existed between Red Canyon (high disturbance level) and White Canyon (low disturbance level) bighorn.

It was predicted that Red Canyon animals would be more reactive, flee farther, exhibit more group wariness, and have more significant alterations in normal activity budgets because they had been subjected to high hunting pressure and high vehicular traffic relative to White Canyon bighorn. Red Canyon animals were in fact more sensitive to harassment trials than

White Canyon bighorn. Red Canyon bighorn reacted most frequently to human harassment trials by fleeing, whereas White Canyon bighorn responded most commonly with non-flight behaviors. Distance fled by Red Canyon bighorn was approximately 1.6 times farther than for White Canyon bighorn when walking flight was the observed response and 2.5 times farther when running flight was the observed response.

Red Canyon bighorn showed a higher degree of group wariness for longer periods of time than White Canyon bighorn when faced with constant presence of harassing stimuli. Activity budgets of Red Canyon bighorn were significantly different than those of White Canyon bighorn when animals were harassed. Red Canyon animals spent more time at attention and less time feeding than White Canyon animals when they were harassed. Behavior was similar for both areas when bighorn were observed under unharassed conditions.

Based on these evident behavioral differences between Red and White Canyon bighorn it can be concluded that overt behavior can be used as an effective indicator of relative disturbance levels in a given population of bighorn.

Hunting has had a considerable impact on behavior of bighorn in response to human encounters. Regularly hunted Red Canyon bighorn are more wary than White Canyon animals. High wariness is consistent for all Red Canyon group types including ewes and lambs. This is attributed to the relative high frequency ewes and lambs in the Red Canyon area have been exposed to hunting pressures. Late season hunters often kill trophy rams in

close proximity to ewe groups, thus sensitizing ewes and lambs to future encounters with humans.

Although relative expenditure of energy in response to human disturbance is greater for Red Canyon bighorn than for White Canyon bighorn, exact energy costs incurred by animals in both areas is not known. Future research to determine energy and nutrient requirements and actual energy expenditure for activities related to normal behavior and behavior in response to harassment would provide the additional information necessary to determine differences in energy expenditures as a result of harassment. With this information wildlife biologists could predict harassment threshold levels so sought after by wildlife and land managers.

LITERATURE CITED

Adams, D. B., G. Baccelli, G. Mancia, and A. Zanchetti. 1971. Reaction of cardiovascular changes in fighting to emotion and exercise. J. Physiol. 212:321-335.

Altmann, J. 1974. Observational study of behaviour: sampling methods. Behaviour 49:227-267.

Bailey, J. A. 1980. Desert bighorn, forage competition, and zoogeography. Wildl. Soc. Bull. 8(3):208-216.

Batchelor, C. L. 1968. Compensatory responses of artificially controlled mammal populations. Proc. N.Z. Ecol. Soc. 15:25-30.

Bates, J. W., Jr. 1982. Desert bighorn sheep habitat utilization in Canyonlands National Park. M.S. Thesis. Utah State Univ., Logan, UT. 118 pp.

Bekoff, M., and M.C. Wells. 1981. Behavioral budgeting by wild coyotes: the influence of food resources and social organization . Anim. Behav. 29:794-801.

Bell, R. H. V. 1971. A grazing system in the Serengeti. Sci. Am. 225:86-93.

Berger, J., D. Daenke, J. Johnson, and S. H. Berwick. 1983. Pronghorn foraging economy and predator avoidance in a desert ecosystem: implications for the conservation of large mammalian herbivores. Biol. Conserv. 25:193-208.

Blaxter, K. L. 1962. The fasting mechanism of adult wether sheep. Brit. J. Natr. 16:615-626.

Brockway, J. M., and J. A. Gessaman. 1977. The energy costs of locomotion on the level and on gradients for the red deer (Cervus elaphus). Quart. J. Exp. Physiol. 62:333-339.

Brockway, J. M. and E. H. McEwen. 1969. Oxygen uptake and cardiac performance in the sheep. J. Physiol. 202:661-669.

Bryce, G. R. 1970. A unified method for the analysis of unbalanced designs. M. S. Thesis, Brigham Young University, Provo, UT. 90 pp.

Bowyer, R. T. 1984. Sexual segregation in southern mule deer. J. Mammal. 65:410-417.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. No. 4. 147 pp.

Campbell, B., and R. Remington. 1981. Influence of construction activities on water-use patterns of desert bighorn sheep. Wildl. Soc. Bull. 9(1):63-65.

Chalmers, G. A., and M. W. Barrett. 1982. Capture myopathy. Pages 84-94 in Noninfectious diseases of wildlife. G. L. Hoff and J. W. Davis (eds.). Iowa State Univ. Press, Ames, IA.

Chappel, R. W., and R. J. Hudson. 1978. Winter bioenergetics of Rocky Mountain bighorn. Can. J. Zool. 56:2388-2393.

Chassin, P. S., C. R. Taylor, N. C. Heglund, and H. J. Seeherman. 1976. Locomotion in lions: energetic costs and maximum aerobic capacity. Physiol. Zool. 49:1-10.

Clutton-Brock, T. H., F. E. Guiness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. Univ. Chicago Press, Chicago, IL. 378 pp.

Cochran, W. G., and G. M. Cox. 1957. Experimental design. 2nd ed. Wiley, New York, NY. 616 pp.

Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. Amer. Mid. Natur. 24(3):505-580.

Cowan, I. McT. 1974. Management implications of behavior in the large herbivorous mammals. Pages 921-934 in The behavior of ungulates and its relation to management. V. Geist and F. Walther (eds.). Vol. 2. IUCN Publ. New Series 24. Morges, Switzerland.

DeForge, J. R. 1980. Ecology, behavior, and population dynamics of desert bighorn sheep, Ovis canadensis nelsoni, in the San Gabriel Mountains of California. M.S. Thesis. Calif. State Poly. Univ., Pomona, CA. 133 pp.

DeForge, J. R. 1981. Stress: environments and their effects on bighorn sheep. Desert Bighorn Council Trans. 25:15-16.

DeForge, J.R., D. A. Jessup, C. W. Jenner, and J. C. Scott. 1982. Disease investigations into high lamb mortality of desert bighorn in the Santa Rosa Mountains, California. Desert Bighorn Council Trans. 26:76-81.

Dorrance, M. F., P. T. Savage, and D. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. J. Wildl. Manage. 39:563-569.

Douglas, C. L. 1976. Coordination of bighorn research and management in Joshua Tree National Monument. Trans. North American Wild Sheep Conf. 2:1-15.

Fantino, E., and C. A. Logan. 1979. The experimental analysis of behavior. W. H. Freeman and Co. San Francisco, CA. 559 pp.

Fienberg, S. E. 1977. The analysis of cross-classified categorical data. MIT Press, Cambridge, MA.

Foreyt, W. J., and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Diseases 18:163-168.

Franklin, W. L., and J. W. Lieb. 1980. The social organization of a sedentary population of North American elk: a model for understanding other populations. Pages 185-198 in M. S. Boyce and L. D. Hayden-Wing (eds.). North American elk: ecology, behavior, and mangement. Univ. Wyoming Press, Laramie, WY.

Galliziolli, S. 1977. Overgrazing on desert bighorn ranges. Desert Bighorn Council Trans. 21:21-23.

Gates, C., and R. J. Hudson. 1978. Energy costs of locomotion in Wapiti. Acta Theriol. 22:365-370.

Geist, V. 1967. A consequence of togetherness. Nat. Hist. 76:24-31.

Geist, V. 1971a. A behavioral approach to the management of wild ungulates. Pages 413-424 in The scientific management of animal and plant communities for conservation. E. Duffey and A. S. Watt (eds.). Blackwell Aca. Publ., Oxford.

Geist, V. 1971b. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Chicago, IL. 383 pp.

Geist, V. 1975a. Harassment of large mammals and birds. Report to the Berger Commission, Univ. Calgary, Calgary, Alberta. 62 pp.

Geist, V. 1975b. On the management of mountain sheep: theoretical considerations. Pages 77-105 in The wild sheep in modern North America. J. B. Trefethen (ed.). The Winchester Press, New York, NY.

Geist, V. 1978. Behavior. Pages 283-295 in Big game of North America. J. L. Schmidt and D. L. Gilbert (eds.). Stackpole Books, Harrisburg, PA.

Geist, V. 1979. Life strategies, human evolution, environmental design. Springer-Verlag, New York, NY. 495 pp.

Geist, V., and R. G. Petocz. 1977. Bighorn sheep in winter: do rams maximize reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Proc. Bienn. Symp. North. Wild Sheep and Goat Conf. 3:287-313.

Hainsworth, F. R., and L. L. Wolf. 1979. Feeding: an ecological approach. Adv. Study Behav. 9:53-96.

Hamilton, K. M. 1982. Effects of people on bighorn sheep in the San Gabriel Mountains, Calif. Coop. Nat. Park Studies Unit Report No. CPSU/UNLV 020/06. Univ. Nevada, Las Vegas. 69 pp.

Hamilton, K. M., S. A. Holl and C. L. Douglas. 1982. An evaluation of effects of recreational activities on bighorn sheep in the San Gabriel Mountains, Calif. Desert Bighorn Council Trans. 26:50-55.

Hansen, C. G. 1964. Progress report from the Desert Game Range, Nevada. Desert Bighorn Council Trans. 8:69-76.

Hansen, C. G. 1970. Tongue color in desert bighorn. Desert Bighorn Council Trans. 26:50-55.

Hansen, M. C. 1982. Desert bighorn sheep: another view. Wildl. Soc. Bull. 10:133-140.

Hicks, L. L., and J. M. Elder. 1979. Human disturbance of Sierra Nevada bighorn sheep. J. Wildl. Manage. 43:909-915.

Holdroyd, J. C. 1967. Observations of Rocky Mountain goats on Mount Wardle, Kootenay National Park, B.C. Can. Field Nat. 81:1-22.

Holl, S. A., and V. C. Bleich. 1983. San Gabriel Mountain sheep: biological and management considerations. U.S.D.A., San Bernadino Nat. Forest, San Bernadino, Calif. 136 pp.

Holter, J. B., W. E. Urban, H. H. Hayes, and H. Silver. 1976. Predicting metabolic rate from telemetered heart rates in white-tailed deer. J. Wildl. Manage. 40:626-629.

Horesji, B. 1976. Some thoughts and observations on harassment and bighorn sheep. Proc. North. Wild Sheep Coun. 1976:1-14.

Hull, W. B. 1984. Seasonal nutrition of desert bighorn sheep in Canyonlands National Park, Utah. M. S. Thesis, Utah State University, Logan, UT. 88 pp.

Irwin, L. L., and J. M. Peek. 1980. Relationship between road closure and elk behavior in northern Idaho. Pages 199-204 in North American elk: ecology, behavior, and management. M. S. Boyce and L. Hayden-Wing (eds.). Univ. Wyoming Press, Laramie, WY.

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering area. Desert Bighorn Council Trans. 18:18-24.

Kautz, M. A., G. M. Van Dyne, and L. H. Carpenter. 1982. Energy cost for activities of mule deer fawns. J. Wildl. Manage. 46:704-710.

Kimball, T. L., and R. E. Johnson. 1978. The richness of American wildlife. Pages 3-17 in Wildlife and America. H. P. Brokaw (ed.). U.S. Govt. Printing Office, Washington, D.C.

King, M. M., and H. D. Smith. 1980. Differential habitat utilization by the sexes of mule deer. Great Basin Nat. 40:273-281.

King, M. M., and G. W. Workman. 1982. Ecology of the desert bighorn sheep in southeastern Utah. Second Annual Report to BLM, contract no. YA-533-CTO-1068. 115 pp.

King, M. M., and G. W. Workman. 1983. Ecology of the desert bighorn sheep in southeastern Utah. Third Annual Report to BLM, contract no. YA-533-CTO-1068. 120 pp.

Klopfer, P. 1973. Behavioral aspects of ecology. 2nd ed. Prentice-Hall, Englewood Cliffs, NJ.

Lawson, B., and R. Johnson. 1982. Mountain sheep. Pages 1036-1054 in Wild mammals of North America. J. A. Chapman and G. A. Feldhamer (eds.). The Johns Hopkins Univ. Press, Baltimore, MD.

Leslie, D. M., and C. L. Douglas. 1980. Human disturbance at water sources of desert bighorn sheep. Wildl. Soc. Bull. 8(4):284-290.

Liddell, H. S. 1961. Contributions of conditioning in the sheep and goat to an understanding of stress, anxiety and illness. Pages 227-255 in Western Psychiatric Institute and Clinic lectures on experimental psychiatry. Univ. of Pitt. Press, Pittsburgh, PA.

Loope, W. L. 1977. Relationships of vegetation to environment in Canyonlands National Park. Ph. D. Disseration. Utah State University, Logan, UT. 142 pp.

MacArthur, R. A., V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manage. 46(2):351-358.

MacArthur, R. A., R. H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Can. J. Zool. 57:2010-2021.

Mautz, W. W., and J. Fair. 1980. Energy expenditure and heart rate for activities of white-tailed deer. J. Wildl. Manage. 44:333-342.

McCann, L. J. 1956. Ecology of the mountain sheep. Amer. Mid. Natur. 56:297-324.

McCullough, D. R. 1979. The George Reserve deer herd. Univ. Michigan Press, Ann Arbor, MI. 271 pp.

McCullough, D. R. 1982. Benavior, bears, and humans. Wildl. Soc. Bull. 10:27-33.

McCutchen, H. E. 1981. Desert bighorn zoogeography and adaptation in relation to historic land use. Wildl. Soc. Bull. 9:171-179.

McFarlane, H. 1976. Malnutrition and impared immune response to infection. Proc. Nutr. Soc. 35:263-272.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nev. Fish and Game Biol. Bull. 6. 81 pp.

Miller, F. L., and A. Gunn. 1979. Responses of Peary caribou and musk oxen to helicopter harassment. Can. Wildl. Serv. Occas. Paper No. 40. Edmonton, Alberta. 60 pp.

Miller, G. F. 1984. Nighttime activity of desert bighorn sheep. Desert Bighorn Council Trans. 28:23-25.

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman, San Francisco, CA. 458 pp.

Moen, A. N. 1976. Energy conservation by white-tailed deer in winter. Ecology 57:192-198.

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. J. Wildl. Manage. 42:715-738.

Moen, A. N. 1981. The biology and management of wild ruminants. Part III. Cornerbrook Press, Lansing, NY.

Montgomery, M. J., and B. R. Baumgardt. 1965. Regulation of food intake in ruminants. J. Dairy Sci. 48:569-574.

Morgantini, L. E., and R. J. Hudson. 1979. Human disturbance and habitat selection in elk. Pages 132-139 in North American elk: ecology, behavior, and management. M. S. Boyce and L. D. Hayden-Wing (eds.). Univ. Wyoming Press, Laramie, WY.

Morgantini, L. E., and R. J. Hudson. 1981. Sex difference in use of the physical environment by bighorn sheep. Can. Field Nat. 95:69-74.

Morgantini, L. E., and R. J. Hudson. 1985. Changes in diets of wapiti during a hunting season. J. Range Manage. 38:77-79.

National Climatic Data Center. 1979-1984. Climatological data: Utah. National Oceanic and Atmospheric Administration, Asheville, NC.

National Research Council. 1981. Effect of environment on nutrient requirements of domestic animals. National Academy Press, Washington, DC. 152 pp.

Nelson, M. 1966. Problems of recreational use of game ranges. Desert Bighorn Council Trans. 10:13-20.

Nichols, L. 1976. An experiment in Dall sheep management: progress report. Trans. N. Am. Wild Sheep Conf. 2:16-34.

Parker, J. S. C. and A. D. Graham. 1971. The ecological and economic basis for game ranching in Africa. Pages 393-404 in The scientific management of animal and plant communities for conservation. E. Duffey and A. S. Watt (eds.). Blackwell Aca. Publ., Oxford.

Parker, K. L., C. T. Robbins, and T. H. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. J. Wildl. Manage. 48:474-488.

Robbins, C. T. 1983. Wildlife nutrition. Academic Press, New York, NY. 343 pp.

Robbins, C. T., Y. Cohen, and B. B. Davitt. 1979. Energy expenditure by elk calves. J. Wildl. Manage. 43:445-453.

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. J. Wildl. Manage. 43(3):634-641.

Rowland, M. M., and J. L. Schmidt. 1981. Transplanting desert bighorn: a review. Desert Bighorn Council Trans. 25:25-28.

Russo, J. P. 1956. The desert bighorn sheep in Arizona. Arizona Game and Fish Dept. Wildlife Bull. No. 1. 153 pp.

Schmidt-Nielsen, K. 1979. Animal physiology: adaptation and environment. Cambridge Univ. Press, London. 550 pp.

Schoener, T. W. 1971. Theory of feeding strategies. Ann. Rev. Ecol. Syst. 2:369-404.

Schultz, R. D., and J. A. Bailey. 1978. Responses of national park elk to human activity. J. Wildl. Manage. 42:91-100.

Selye, H. 1973. The evolution of the stress concept. Am. Sci. 61:692-699.

Seton, E. T. 1929. Lives of game animals. Doubleday Page and Co. New York, NY. 780 pp.

Short H. L. 1964. Post natal stomach development of white-tailed deer. J. Wildl. Manage. 28:445-458.

Simmons, N. M. 1969. The social organization, behavior, and environment of the desert bighorn sheep on the Cabeza Prieta Game Range, Arizona. Ph. D. Dissertation, Univ. Arizona, Tucson. 145 pp.

Sinclair, A. R. E. 1977. The African buffalo. A study of resource limited populations. Univ. Chicago Press, Chicago, IL. 335 pp.

Sinclair, A. R. E. 1979. Dynamics of the Serengeti ecosystem. Pages 1-30 in Serengeti; dynamics of an ecosystem. A. R. E. Sinclair and N. N. Griffiths (eds.). Univ. Chicago Press, Chicago, IL.

Smith, K. G., and W. Wishart. 1978. Further observations of bighorn sheep non-trophy seasons in Alberta and their management implications. Proc. North. Wild Sheep and Goat Conf. 1:42-51.

Sokal, R. R., and R. E. Rohlf. 1969. Biometry; the principles and practice of statistics in biological research. W. H. Freeman, San Francisco, CA. 776 pp.

Steel, R. D. G., and J. H. Torrie. 1980. Principles and procedures of statistics. 2nd ed. McGraw-Hill Book Co., New York, NY.

Stelfox, J. G. 1971. Bighorn sheep in the Canadian Rockies: a history, 1800-1970. Can. Field Nat. 85:101-122.

Stokes, A. W. 1970. An ethologist's views on managing grizzly bears. Bio Science 20:1154-1157.

Thaden, R. E., A. F. Trites, and T. L. Finnel. 1964. Geology and ore deposits of the White Canyon area of San Juan and Garfield Counties, Utah. U. S. G. S. Bull. 1125. U. S. Govt. Printing Office, Washington, DC. 166 pp.

Thompson, W. R. 1957. Influence of prenatal maternal anxiety on emotionality in rats. Science 125:698-699.

Thorne, E. T., T. Varcalli, K. Becker, and G. B. Butler. 1978. Some thoughts on the consequences of non-trophy sheep hunting in the Wind River Mountains of Wyoming. Proc. North. Wild Sheep and Goat Conf. 1:42-51.

Trefethen, J. B. 1975. The wild sheep in modern North America. The Winchester Press, New York, NY. 302 pp.

Van Soest, P. 1981. Nutritional ecology of the ruminant. O and B Books, Corvallis, OR. 374pp.

Wagner, F. W. 1978. Livestock and the livestock industry. Pages 121-145 in Wildlife and America. H. P. Brokaw (ed.). U.S. Govt. Printing Office, Washington, D. C.

Walther, F. R. 1969. Flight behavior and avoidance of predators in Thomson's gazelle. Behavior 34:184-221.

Ward, L. A. 1973. Elk behavior in relation to multiple uses on the Medicine Bow National Forest. Proc. West. Assoc. State Game and Fish Comm. 53:125-139.

Ward, L. A., J. J. Cupal, A. L. Lea, C. A. Oakley, and R. W. Weeks. 1972. Elk behavior in relation to cattle grazing, forest recreation, and traffic. Trans. North Am. Wildl. Conf. 38:327-337.

Webster, A. J. F. 1967. Continuous measurement of heart rate as an indicator of energy expenditure of sheep. Br. J. Nutr. 21:769-785.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. Dissertation. Univ. Michigan, Ann Arbor. 240 pp.

Wehausen, J. D. 1983. White Mountain bighorn sheep: an analysis of of current knowledge and management alternatives. Administrative report, Inyou National Forest, Contract No. 53-9JC9-0-32. 93 pp.

Wehausen, J. D., L. L . Hicks, D. P. Garber, and J. Elder. 1977. Bighorn sheep management in the Sierra Nevada. Desert Bighorn Council Trans. 21:30-32.

Welles, R. E., and F. B. Welles. 1961. The bighorn of Death Valley. U. S. National Park Fauna Series No. 6, U. S. Govt. Printing Office, Washington, DC. 242 pp.

Westoby, M. 1974. An analysis of diet selection by large generalist herbivores. Am. Nat. 108:290-304.

Westoby, M. 1978. What are biological bases for varied diets? Am. Nat. 112:627-631.

Wilson, L. O. 1968. Distribution and ecology of the desert bighorn sheep in southeastern Utah. M. S. Thesis, Utah State Univ., Logan, UT. 220 pp.

Wishart, W. 1976. The Ram Mountain orphan lamb experiment. Proc. N. Wild Sheep Council 1976:70-80.

Wishart, W. 1978. Bighorn sheep. Pages 161-171 in Big game in North America. J. L. Schmidt and D. L. Gilbert (eds.). Stackpole Books, Harrisburg, PA.

APPENDICES

Appendix A

Summary of Immediate Responses of Harassed Desert Bighorn Sheep in Southeastern Utah

Table 1. Immediate behavioral response of Red and White Canyon desert bighorn during harassment trials. Response category 1=slight interruption, 2=moderate interruption, 3=walking flight, 4=running flight; *=significance (P<0.05) between Red and White Canyon areas, a,b,c=significance (P<0.05) between response categories, y,z=signicicance (P<0.05) between flight and non-flight categories, ⊙=significance (P<0.10).

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Disturbance type						
Vehicle (X^2=7.0, df=3, P<0.10)						
Non-flight						
	1	6	18a	11	38a	⊙
	2	7	21a	4	14b	
	sub total	13	39y	15	52y	
Flight						
	3	3	9a	6	21ab	
	4	18	52b	8	27ab	*
	sub total	21	61z⊙	14	48y	
	Total	34	100	29	100	
Hiker (X^2=41.9, df=3, P<0.005)						
Non-flight						
	1	2	3a	29	33a	*
	2	4	5a	19	21b	*
	sub total	6	8y	48	54y	*
Flight						
	3	20	27b	18	20b	
	4	49	65c	23	26ab	*
	sub total	69	92z	41	46y	*
	Total	75	100	89	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Reaction distance						
0-100m (χ^2=18.0, df=3, P<0.005)						
	Non-flight					
	1	2	6a	18	26a	*
	2	1	3a	17	25ab	*
	sub total	3	9y	35	51y	*
	Flight					
	3	8	23b	10	15b	
	4	23	68c	23	34a	*
	sub total	31	91z	33	49y	*
	Total	34	100	68	100	
101-200m (χ^2=30.5, df=3, P<0.005)						
	Non-flight					
	1	2	6a	14	44a	*
	2	0	0b	4	12b	*
	sub total	2	6y	18	56y	*
	Flight					
	3	4	13a	10	32a	⊙
	4	25	81c	4	12b	*
	sub total	29	94z	14	44y	*
	Total	31	100	32	100	
201-400m (χ^2=5.6, df=3, P>0.10)						
	Non-flight					
	1	1	4a	2	33a	⊙
	2	5	23b	1	17a	
	sub total	6	27y	3	50y	
	Flight					
	3	5	23b	2	33a	
	4	11	50c	1	17a	
	sub total	16	73z	3	50y	
	Total	22	100	6	100	
>400m (χ^2=5.2, df=3, P>0.10)						
	Non-flight					
	1	3	15a	6	50a	*
	2	5	25a	1	8b	
	sub total	8	40y	7	58y	
	Flight					
	3	6	30a	2	17b	
	4	6	30a	3	25b	
	sub total	12	60y	5	42y	
	Total	20	100	12	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Approach position						
Above	(X^2=8.4, df=3, P<0.05)					
	Non-flight					
	1	1	8a	10	26ab	
	2	0	0a	9	24ab	*
	sub total	1	8y	19	50y	*
	Flight					
	3	1	8a	5	13a	
	4	10	84b	14	37b	*
	sub total	11	92z	19	50y	*
	Total	12	100	38	100	
Level	(X^2=37.0, df=3, P<0.005)					
	Non-flight					
	1	4	6a	19	54a	*
	2	9	13a	3	9b	
	sub total	13	19y	22	63y	*
	Flight					
	3	17	24b	9	26c	
	4	40	57c	4	11bc	*
	sub total	57	81z	13	37z	*
	Total	70	100	35	100	
Below	(X^2=8.4, df=3, P<0.005)					
	Non-flight					
	1	3	12a	11	25a	
	2	2	8a	11	25a	*
	sub total	5	20y	22	50y	*
	Flight					
	3	5	19a	10	22a	
	4	16	61b	13	28a	*
	sub total	21	80z	23	50y	*
	Total	26	100	45	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Season						
Winter	(X^2=1.0, df=3, P>0.10)					
	Non-flight					
	1	1	10a	1	13a	
	2	2	20a	3	37a	
	sub total	3	30y	4	50y	
	Flight					
	3	1	10a	1	13a	
	4	6	60b	3	37a	
	sub total	7	70z	4	50y	
	Total	10	100	8	100	
Spring	(X^2=9.6, df=3, P<0.01)					
	Non-flight					
	1	0	0a	5	23a	*
	2	1	6a	6	27a	
	sub total	1	6y	11	50y	*
	Flight					
	3	5	31b	6	27a	
	4	10	63c	5	23a	*
	sub total	15	94z	11	50y	*
	Total	16	100	22	100	
Summer	(X^2=16.3, df=3, P<0.005)					
	Non-flight					
	1	4	8a	13	26a	*
	2	5	10a	12	24a	
	sub total	9	18y	25	50y	*
	Flight					
	3	6	12a	11	21a	
	4	34	70b	15	29a	*
	sub total	40	82z	26	50y	*
	Total	49	100	51	100	
Fall	(X^2=18.3, df=3, P<0.005)					
	Non-flight					
	1	3	9a	21	57a	*
	2	3	9a	2	5b	
	sub total	6	18y	23	62y	*
	Flight					
	3	11	32b	6	16bc	
	4	17	50b	8	22c	*
	sub total	28	82z	14	38z	*
	Total	34	100	37	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Habitat type						
Chinle talus	(χ^2=35.5, df=3, P<0.005)					
	Non-flight					
	1	6	7a	17	42a	*
	2	12	13ab	7	17b	
	sub total	18	20y	24	59y	*
	Flight					
	3	17	18b	8	20b	
	4	58	62c	9	21b	*
	sub total	75	80z	17	41z	*
	Total	93	100	41	100	
Moenkopi talus	(χ^2=5.3, df=3, P>0.10)					
	Non-flight					
	1	1	9a	4	57a	*
	2	0	0a	0	0b	
	sub total	1	9y	4	57y	*
	Flight					
	3	2	18a	1	14b	
	4	8	73b	2	29ab	○
	sub total	10	91z	3	43y	*
	Total	11	100	7	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Group composition						
Ewes	(X^2=20.6, df=3, P<0.005)					
	Non-flight					
	1	4	7a	21	34a	*
	2	4	7a	12	19b	*
	sub total	8	14y	33	53y	*
	Flight					
	3	11	20b	9	15b	
	4	37	66c	20	32a	*
	sub total	48	86z	29	47z	*
	Total	56	100	62	100	
Mixed	(X^2=8.8, df=3, P<0.05)					
	Non-flight					
	1	3	14a	14	56a	*
	2	2	10a	2	8b	
	sub total	5	24y	16	64y	*
	Flight					
	3	5	24a	3	12b	
	4	11	52b	6	24b	*
	sub total	16	76z	9	36z	*
	Total	21	100	25	100	
Rams	(X^2=14.8, df=3, P<0.005)					
	Non-flight					
	1	1	3a	5	16a	*
	2	4	13ab	9	29ab	*
	sub total	5	16y	14	45y	*
	Flight					
	3	7	22b	12	40b	*
	4	20	62c	5	15a	*
	sub total	27	84z	17	55z	*
	Total	32	100	31	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Group size						
1	(χ^2=5.6, df=3, P>0.10)					
	Non-flight					
	1	2	10a	1	9a	
	2	1	5a	4	33a	*
	sub total	3	15y	5	42y	⊙
	Flight					
	3	4	20a	3	25a	
	4	13	65b	4	33a	⊙
	sub total	17	85z	7	58y	⊙
	Total	20	100	12	100	
2-7	(χ^2=30.7, df=3, P<0.005)					
	Non-flight					
	1	1	2a	18	33a	*
	2	12	19b	14	26ab	
	sub total	13	21y	32	58y	*
	Flight					
	3	12	19b	13	24ab	
	4	37	60c	10	18b	*
	sub total	49	79z	23	42z⊙	*
	Total	62	100	55	100	
> 7	(χ^2=9.7, df=3, P<0.025)					
	Non-flight					
	1	5	14ab	21	41a	*
	2	2	5a	5	10b	
	sub total	7	19y	26	51y	*
	Flight					
	3	7	19b	8	16b	
	4	22	62c	17	33a	*
	sub total	29	81z	25	49y	*
	Total	36	100	51	100	

Table 1. Continued.

Main effect	Response category	Area: Red Canyon n	Red Canyon %	White Canyon n	White Canyon %	
Initial behavior						
Lying	(X^2=1.7, df=3, P>0.10)					
	Non-flight					
	1	3	6a	8	25a	*
	2	5	10a	6	19a	
	sub total	8	16y	14	44y	*
	Flight					
	3	9	19a	9	28a	
	4	31	65b	9	28a	*
	sub total	40	84z	18	56z	*
	Total	48	100	32	100	
Standing	(X^2=11.7, df=3, P<0.01)					
	Non-flight					
	1	0	0a	0	0a	
	2	1	13a	0	0a	
	sub total	1	13y	0	0y	
	Flight					
	3	1	13a	2	40a	
	4	6	74b	3	60a	
	sub total	7	87z	5	100z	
	Total	8	100	5	100	
Feeding	(X^2=22.2, df=3, P<0.005)					
	Non-flight					
	1	5	10a	28	38a	*
	2	5	10a	18	23b	*
	sub total	10	20y	46	61y	*
	Flight					
	3	13	25b	11	15b	
	4	28	55c	18	24b	*
	sub total	41	80z	29	39z	*
	Total	51	100	75	100	

Appendix B

Summary of Distances Fled by Harassed Desert Bighorn Sheep in Southeastern Utah

Table 2. Analysis of variance table for distance fled examining the effect of area with disturbance type, reaction distance, approach position, season, habitat type, group composition, group size, and initial behavior for flight categories and for all response categories combined.

	All response categories			Flight categories only		
Source	df	F-ratio	P	df	F-ratio	P
Area	1	33.84	0.000	1	15.46	0.000
Disturbance	1	7.66	0.006	1	1.72	0.192
A X D	1	3.12	0.079	1	0.01	0.908
Error	222			142		
Area	1	28.47	0.000	1	10.24	0.002
React dist	3	0.84	0.474	3	0.47	0.702
A X RD	3	0.59	0.620	3	0.10	0.960
Error	218			138		
Area	1	46.72	0.000	1	21.47	0.000
Approach pos	2	1.68	0.189	2	1.28	0.282
A X AP	2	0.39	0.677	2	0.19	0.827
Error	220			140		
Area	1	27.98	0.000	1	9.89	0.002
Season	3	1.01	0.389	3	0.34	0.800
A X S	3	0.96	0.411	3	0.34	0.793
Error	213			138		
Area	1	5.71	0.013	1	1.02	0.316
Habitat type	1	0.27	0.607	1	0.11	0.740
A X HT	1	1.31	0.254	1	1.57	0.213
Error	150			103		
Area	1	51.44	0.000	1	22.20	0.000
Group comp	2	0.78	0.460	2	0.76	0.467
A X GC	2	1.45	0.237	2	1.53	0.219
Error	220			140		
Area	1	34.21	0.000	1	15.86	0.000
Group size	2	0.37	0.694	2	0.50	0.607
A X GS	2	0.02	0.981	2	0.01	0.988
Error	220			140		
Area	1	20.53	0.000	1	14.54	0.000
Initial behav	2	3.48	0.032	2	1.41	0.248
A X IB	2	1.21	0.300	2	1.37	0.258
Error	214			136		

Table 3. Average distances fled by Red and White Canyon desert bighorn during harassment trials.

Effect	Red Canyon n	Red Canyon Average distance ± st. dev.	White Canyon n	White Canyon Average distance ± st. dev.
All response categories				
Disturbance type				
Vehicle	33	535 ± 119	29	121 ± 127
Hiker	75	999 ± 79	89	223 ± 73
Reaction distance (m)				
0-100	34	825 ± 120	68	181 ± 85
101-200	30	999 ± 128	32	224 ± 124
201-400	24	969 ± 143	6	250 ± 285
> 400	20	568 ± 156	12	202 ± 202
Approach position				
Above	12	1113 ± 202	37	257 ± 114
Level	70	813 ± 84	36	71 ± 116
Below	26	860 ± 137	45	251 ± 104
Season				
Winter	10	440 ± 221	8	247 ± 247
Spring	16	1109 ± 175	22	249 ± 149
Summer	49	853 ± 100	51	207 ± 104
Fall	33	868 ± 122	37	146 ± 115
Habitat type				
Chinle	94	909 ± 84	42	164 ± 126
Moenkopi	11	559 ± 245	7	296 ± 308
Group composition				
Ewe	56	726 ± 93	62	218 ± 89
Mixed	21	1005 ± 152	25	161 ± 140
Ram	31	996 ± 125	31	188 ± 125
Group size				
1	18	740 ± 166	11	116 ± 212
2-7	55	872 ± 95	57	189 ± 93
> 7	35	895 ± 119	50	226 ± 99
Initial behavior				
Lying	50	1009 ± 99	33	242 ± 122
Standing	8	1197 ± 247	5	410 ± 312
Feeding	49	640 ± 100	75	172 ± 81

Table 3. Continued.

Effect	Red Canyon n	Red Canyon Average distance ± st. dev.	White Canyon n	White Canyon Average distance ± st. dev.
Flight response only				
Disturbance type				
Vehicle	20	884 ± 175	14	250 ± 209
Hiker	70	1071 ± 94	42	474 ± 121
Reaction distance (m)				
0-100	31	905 ± 142	34	362 ± 135
101-200	29	1033 ± 147	14	512 ± 211
201-400	18	1292 ± 186	3	500 ± 456
> 400	12	945 ± 228	5	485 ± 353
Approach position				
Above	11	1214 ± 237	18	529 ± 185
Level	58	981 ± 104	14	184 ± 210
Below	21	1064 ± 172	24	470 ± 161
Season				
Winter	7	629 ± 299	4	494 ± 396
Spring	15	1183 ± 205	11	498 ± 239
Summer	40	1045 ± 125	27	391 ± 152
Fall	28	1023 ± 150	14	386 ± 212
Habitat type				
Chinle	77	1110 ± 100	17	404 ± 213
Moenkopi	10	615 ± 278	3	692 ± 507
Group composition				
Ewe	48	847 ± 112	30	452 ± 142
Mixed	17	1241 ± 189	9	447 ± 259
Ram	25	1235 ± 156	17	343 ± 189
Group size				
1	15	888 ± 204	6	213 ± 323
2-7	46	1042 ± 117	25	432 ± 158
> 7	29	1080 ± 147	25	453 ± 158
Initial behavior				
Lying	42	1201 ± 121	18	443 ± 185
Standing	7	1368 ± 296	5	410 ± 350
Feeding	40	784 ± 124	30	430 ± 143

Appendix C

Summary of Group Wariness for Harassed Desert Bighorn Sheep in Southeastern Utah

Table 4. Group wariness of Red Canyon and White Canyon desert bighorn sheep at five minute intervals after harassment.

Group composition	Minutes after disturbance	Area: White Canyon a	White Canyon n	White Canyon %	Red Canyon n	Red Canyon a	Red Canyon %
Ram							
	D	34	42	81	27	32	84
	5	27	42	64	24	32	75
	10	16	42	38	24	32	75
	15	21	40	53	22	29	76
	20	13	40	33	17	28	61
	25	11	40	29	12	23	52
	30	0	38	0	8	21	38
	35	11	38	29	11	21	52
	40	6	37	16	15	21	71
	45	6	33	18	15	19	79
	50	7	33	18	13	19	68
	55	4	30	13	11	19	58
	60	1	24	4	14	22	64
Ewe							
	D	178	266	67	181	193	97
	5	122	259	47	158	193	82
	10	73	243	30	134	189	71
	15	54	234	23	131	175	75
	20	27	222	12	100	166	60
	25	25	191	13	71	144	49
	30	24	183	13	84	127	66
	35	20	183	11	67	121	55
	40	29	183	16	47	121	39
	45	27	168	16	28	121	23
	50	21	151	13	31	109	28
	55	21	151	13	52	110	47
	60	17	159	11	34	122	28
Mixed							
	D	54	86	63	113	123	92
	5	27	86	31	84	123	68
	10	19	86	22	89	123	72
	15	13	86	15	50	109	46
	20	13	86	15	43	102	42
	25	10	86	12	35	88	40
	30	7	86	8	10	87	11
	35	5	86	6	17	87	20
	40	7	86	8	18	87	21
	45	5	86	6	16	87	18
	50	6	86	7	19	78	24
	55	7	86	8	16	78	21
	60	0	86	0	18	78	23

a=total number of bighorn at attention or in flight

n=total number of bighorn in view

%=a/n

D=initial disturbance

Table 5. Binomial Chi-square analysis of group wariness for Red and White Canyon groups through time.

Group composition	Source	df	X^2	Significance
Ram				
	area	1	91.5	P<0.005
	time	12	101.0	P<0.005
	area X time	12	23.1	P< 0.05
	total	25	215.6	
Ewe				
	area	1	569.5	P<0.005
	time	12	593.0	P<0.005
	area X time	12	143.4	P<0.005
	total	25	1305.9	
Mixed				
	area	1	178.1	P<0.005
	time	12	509.4	P<0.005
	area X time	12	14.9	P> 0.10
	total	25	702.4	

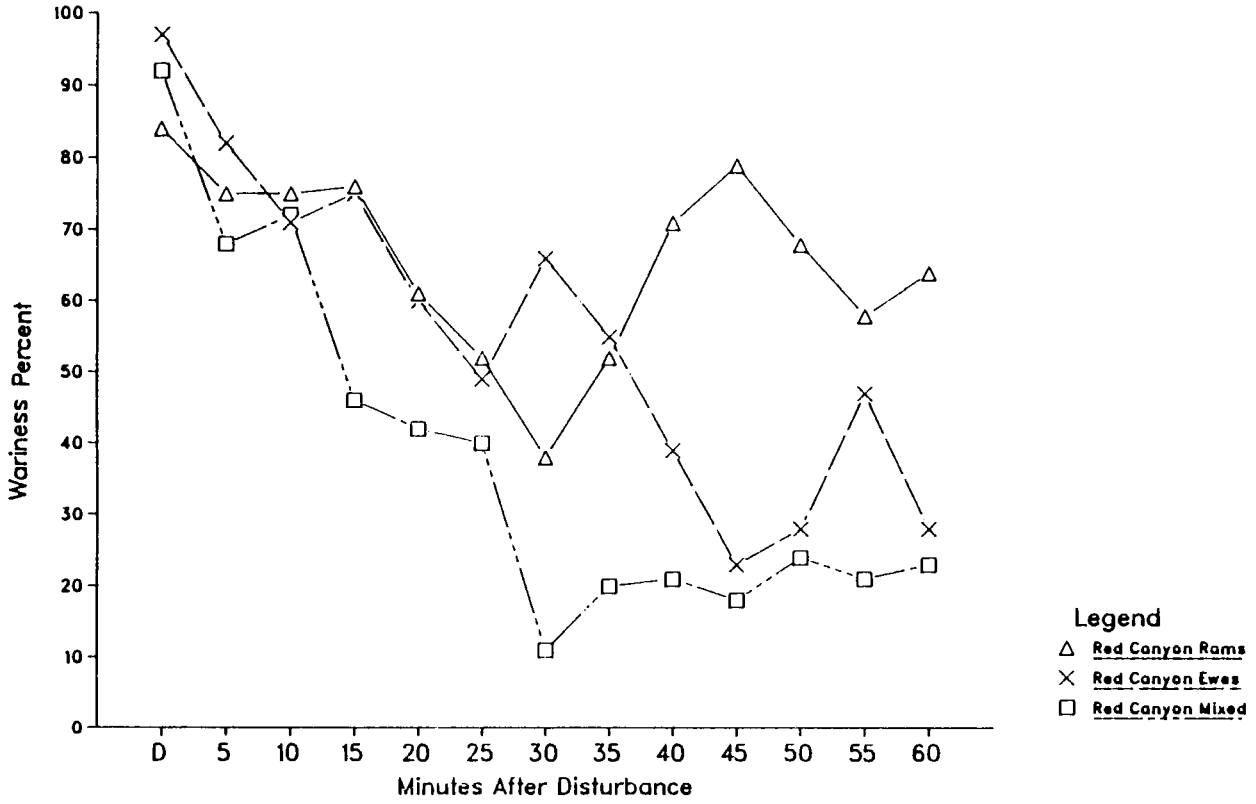

Figure 34. Group wariness for harassed Red Canyon desert bighorn groups.

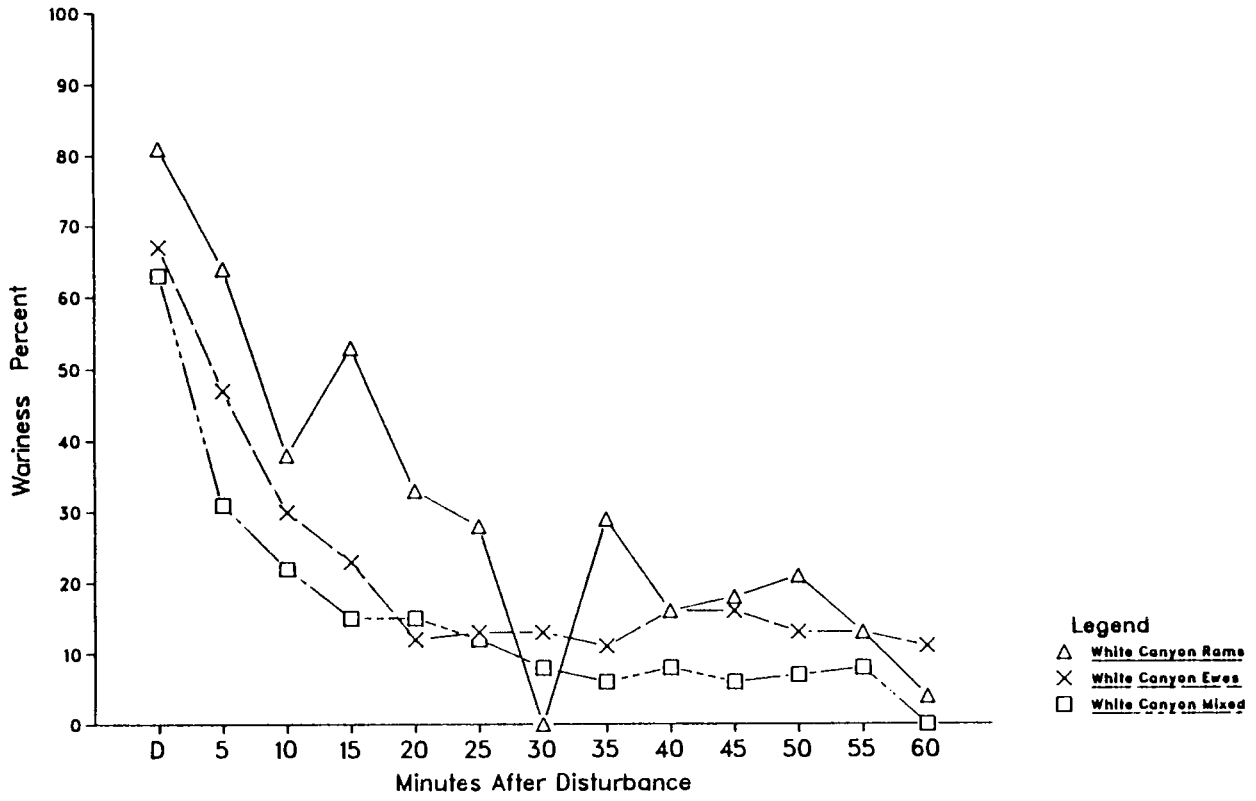

Figure 35. Group wariness for harassed White Canyon desert bighorn groups.

Appendix D

Summary of Activity Budgets for Desert Bighorn Sheep in Southeastern Utah

Table 6. Analysis of variance table for activity budget examining the effects of area, season, and disturbance level on attention, feeding, and standing.

Source	df	F-ratio	Significance level
Attention			
Area	1	12.36	0.000
Season	2	3.08	0.047
Disturbance	1	99.94	0.000
A X S	2	0.23	0.796
A X D	1	1.56	0.213
A X S X D	2	3.39	0.034
Error	507		
Feeding			
Area	1	0.22	0.640
Season	2	3.41	0.047
Disturbance	1	17.92	0.000
A X S	2	3.90	0.021
A X D	1	1.81	0.179
A X S X D	2	4.06	0.018
Error	507		
Standing			
Area	1	9.04	0.003
Season	2	1.53	0.217
Disturbance	1	7.79	0.005
A X S	2	0.32	0.727
A X D	1	0.48	0.490
A X S X D	2	3.32	0.037
Error	507		

Table 7. Seasonal activity budgets of Red and White Canyon desert bighorn based on average time in each behavior category per 15 minute observation period.

Season	Behavior	Red Canyon Harassed min.	%	Red Canyon Unharassed min.	%	White Canyon Harassed min.	%	White Canyon Unharassed min.	%
Winter		n=54		n=40		n=41		n=17	
	Attention	4.05	27	0.87	6	4.05	27	0.01	0
	Feeding	6.15	41	8.10	54	4.37	29	6.45	43
	Lying	3.75	25	5.40	36	4.50	30	5.40	36
	Standing	0.60	4	0.60	4	0.75	5	1.65	11
	Walking	0.30	2	0.07	0	0.75	5	1.50	10
	Running	0.08	1	0.02	0	0.45	3	0.01	0
	Social	0.02	0	0.02	0	0.15	1	0.05	0
Spring		n=42		n=43		n=55		n=21	
	Attention	6.75	45	1.20	8	3.90	26	1.05	7
	Feeding	2.70	18	4.65	31	4.50	31	6.90	47
	Lying	4.05	26	6.30	42	4.50	30	5.40	36
	Standing	0.01	0	0.90	6	0.75	5	0.75	5
	Walking	1.05	7	1.95	13	1.05	7	0.75	5
	Running	0.45	3	0.01	0	0.15	1	0.02	0
	Social	0.15	1	0.02	0	0.04	0	0.05	0
Summer		n=54		n=16		n=62		n=72	
	Attention	6.30	41	0.90	6	3.50	23	0.18	1
	Feeding	3.00	19	7.95	53	5.70	39	5.25	35
	Lying	3.90	26	4.05	28	3.90	26	6.74	45
	Standing	0.34	2	0.60	4	0.60	4	1.24	8
	Walking	0.90	5	0.76	5	0.79	5	1.43	9
	Running	0.90	6	0.46	3	0.36	2	0.14	1
	Social	0.15	1	0.16	1	0.16	1	0.14	1
Fall		n=30		n=15		n=42			
	Attention	2.60	18	0.15	1	2.65	18	---	
	Feeding	5.25	35	7.49	50	7.07	47	---	
	Lying	4.81	32	4.33	29	3.21	21	---	
	Standing	0.60	4	0.90	6	0.68	5	---	
	Walking	1.21	8	1.47	10	0.87	6	---	
	Running	0.19	1	0.00	0	0.02	0	---	
	Social	0.30	2	0.60	4	0.47	3	---	

Table 8. Seasonal activity budgets for Red and White Canyon desert bighorn based on the number of individuals engaged in each activity under harassed and unharassed conditions.

		Area							
		White Canyon				Red Canyon			
		Harassed		Unharassed		Harassed		Unharassed	
Season	Behavior	n	%	n	%	n	%	n	%
Winter	(X^2=118.3, df=6, P<0.005)								
	Attention	348	24	8	1	300	23	26	4b
	Feeding	550	38	286	34y⊙	454	35	257	37
	Lying	464	32	420	50y	443	34z	366	53
	Standing	58	4	67	8y	52	4	32	5b
	Walking	29	2	51	6y	39	3z	4	1b
	Running	1	0a	2	0	13	1z	0	0
	Social	10	0	8	1y	4	0	0	0b
	Total	1460		842		1305		685	
Spring	(X^2=29.9, df=6, P<0.005)								
	Attention	147	15a	19	1y	244	28z	99	3b
	Feeding	272	28a	756	41y	131	15z	2450	31b
	Lying	425	44	863	47	382	44z	1656	50b
	Standing	59	6a	93	5	79	9	232	7b
	Walking	57	6a	111	6	35	4z	264	8b
	Running	7	0	3	0	2	0z	33	1b
	Social	10	1a	7	0y	1	0	6	0
	Total	977		1852		874		3318	
Summer	(X^2=186.5, df=6, P<0.005)								
	Attention	482	16a	38	1y	610	22z	27	1
	Feeding	1036	34	1492	39y	942	34	2440	36b
	Lying	1011	34	1796	47y	888	32z	1404	52b
	Standing	151	5	269	7y	166	6z	135	5b
	Walking	271	9a	192	5y	111	4z	161	6
	Running	33	1a	17	0y	55	2z	0	0
	Social	26	1a	40	1	8	0	8	0b
	Total	3010		3844		2780		2705	
Fall	(X^2=152.7, df=6, P<0.005)								
	Attention	197	7a	23	2y	136	12z	19	2
	Feeding	1318	47a	498	42y	420	37z	492	51b
	Lying	1039	37	520	44y	409	36	338	35
	Standing	112	4	47	4	45	4z	58	6b
	Walking	84	3a	44	4	68	6	48	5
	Running	1	0	10	0	45	4z	0	0
	Social	56	2a	46	4y	12	1	12	1b
	Total	2807		1188		1135		967	

a=significant difference (P<0.05) between areas; harassed conditions

b=significant difference (P<0.05) between areas; unharassed conditions

y=significant difference (P<0.05) between harassed and unharassed conditions; White Canyon

z=signficant difference (P<0.05) between harassed and unharassed conditions; Red Canyon

⊙=significance at P=0.10

Appendix E

Flight Effort of Harassed Desert Bighorn Sheep in Southeastern Utah

Table 9. Relative flight effort of Red and White Canyon desert bighorn sheep based on immediate response and distance fled.

Area	Response	n	%	Distance moved (m) ± st. dev.
Red Canyon				
	walk	23	21	499 ± 421
	run	66	66	1228 ± 995
White Canyon				
	walk	24	20	315 ± 321
	run	31	26	484 ± 490

Appendix F

Sample Data Sheet

Location_____ Date_____ Collar #_____

Area_____ Time of Day_____ Slope Aspect_____

Habitat Type_____ Weather_____ Group Size_____

Group Comp_____ Init Behav_____ Reac Dist_____

Approach Pos_____ Immed Response_____ Dist Fled_____

Disturb Type_____ Terrain_____ Vegetation_____

Focal Animal			Behavior										
			Lying	Stand	Walk	Run	Feed	Drink	Body Care	Atten.	Nursing	Play	Social
Time	Sex	Age											
Scan													

Area: 1=Red Canyon, 2=White Canyon

Dist Type: 1=vehicle, 2=hiker, 3=none

Approach Pos: 1=above, 2=level, 3=below

Slope Aspect: 1=E, 2=W, 3=S, 4=N,
5=SE, 6=SW, 7=NE, 8=NW

Terr in: 1=valley floor, 2=bench, 3=Moenkopi talus
4=Chinle talus, 5=mesa top

Vegetation: 1=blackbrush, 2=shadscale-ephedra
3=pinyon-juniper, 4=other

Initial Behav: 1=lying, 2=standing, 3=walking
4=running, 5=feeding

Immediate Response: 1=none, 2=slight interrupt
3=moderate interrupt, 4= walk away
5=run away

Comments:

VITA

Michael M King

Candidate for the Degree of

Doctor of Philosophy

Dissertation: Behavioral response of desert bighorn sheep to human harassment: a comparison of disturbed and undisturbed populations.

Major Field: Fisheries and Wildlife

Biographical Information:

Personal Data: Born in Salt Lake City, Utah, 30 August 1952, son of A. LaVell and Mayzell M. King; married Jan Christensen 14 May, 1977. Three children; Megan (7), Mikelle (5), Tyler (2).

Education: Attended elementry school in Orem and Price, Utah; junior high school in Price and Salt Lake City, Utah; graduated from Carbon County High School in Price, Utah, 1970; received Associate of Science degree from College of Eastern Utah, 1974; received Bachelor of Science degree in Zoology from Brigham Young University, 1977; received Master of Science Degree in Zoology from Brigham Young University,1979.

Professional Experience: 1980 to present Research Assistant, Department of Fisheries and Wildlife, Utah State University; 1977-1979 Teaching Assistant, Zoology Department, Brigham Young University; 1978, Research Assistant, Department of Zoology, Brigham Young University; 1977, 1979 Biological Aid, Utah Division of Wildlife Resources.